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Millimeter-wave observations of Euclid Deep Field South using the South Pole Telescope

A data release of temperature maps and catalogs

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ABSTRACT

Context. The South Pole Telescope third-generation camera (SPT-3G) has observed over 10 000 square degrees of sky at 95, 150, and 220 GHz (3.3, 2.0, 1.4 mm, respectively) overlapping the ongoing 14 000 square-degree *Euclid* Wide Survey. The *Euclid* collaboration recently released *Euclid* Deep Field observations in the first quick data release (Q1).

Aims. With the goal of releasing complementary millimeter-wave data and encouraging legacy science, we performed dedicated observations of a 57-square-degree field overlapping the Euclid Deep Field South (EDF-S).

Methods. The observing time totaled 20 days and we reached noise depths of 4.3, 3.8, and 13.2 $\mu\text{K}\text{-arcmin}$ at 95, 150, and 220 GHz, respectively.

Results. In this work we present the temperature maps and two catalogs constructed from these data. The emissive source catalog contains 601 objects (334 inside EDF-S) with 54% synchrotron-dominated sources and 46% thermal dust emission-dominated sources. The 5σ detection thresholds are 1.7, 2.0, and 6.5 mJy in the three bands. The cluster catalog contains 217 cluster candidates (121 inside EDF-S) with median mass $M_{500c} = 2.12 \times 10^{14} M_{\odot}/h_{70}$ and median redshift $z = 0.70$, corresponding to an order-of-magnitude improvement in cluster density over previous tSZ-selected catalogs in this region (3.81 clusters per square degree).

Conclusions. The overlap between SPT and *Euclid* data will enable a range of multiwavelength studies of the aforementioned source populations. This work serves as the first step towards joint projects between SPT and *Euclid* and provides a rich dataset containing information on galaxies, clusters, and their environments.

Key words. catalogs – surveys – galaxies: clusters: general – galaxies: high-redshift – cosmology: observations – submillimeter: galaxies

1. Introduction

Many future astronomical discoveries are expected to come from leveraging multiwavelength datasets to improve the reach and impact of next-generation surveys. Two projects contributing to such multiwavelength insights are the South Pole Telescope (SPT; Carlstrom et al. 2011) and *Euclid* (Euclid Collaboration et al. 2024) at millimeter and optical/infrared wavelengths, respectively.

The SPT began observations in 2007 and the current camera, SPT-3G (Benson et al. 2014; Sobrin et al. 2022), began operating in 2017. The SPT and its cameras were designed for low-

noise, high-resolution (~ 1 arcmin) observations of the cosmic microwave background (CMB), and the total sky area observed with the SPT-3G camera through 2024 is over 10 000 square degrees (Prabhu et al. 2024). The deep, arcminute-resolution millimeter-wave data enables precision cosmology with primary and secondary CMB anisotropies (e.g., Dutcher et al. 2021; Reichardt et al. 2021; Balkenhol et al. 2021, 2023), CMB lensing (e.g., Pan et al. 2023; Ge et al. 2024), galaxy clusters selected through the thermal Sunyaev-Zel'dovich (tSZ) effect (e.g., Bocquet et al. 2024), as well as astrophysical studies using the kinematic SZ effect (kSZ; e.g., Raghunathan et al. 2024), the tSZ effect (e.g., Bleem et al. 2022), galactic and extragalactic tran-

sients (Whitehorn et al. 2016; Guns et al. 2021; Tandoi et al. 2024), and high-redshift star-burst galaxies, which inform studies of galaxy evolution in the early Universe (e.g., Vieira et al. 2013; Reuter et al. 2020).

Euclid launched in 2023. Over its six-year mission it will observe 14 000 square degrees in the “Wide Survey” (Euclid Collaboration et al. 2022b, 2024). The *Euclid* VISual instrument (VIS) observes from 500-900 nm and the Near-Infrared Spectrometer and Photometer (NISP) observes 900-2 000 nm in the Y, J, and H passbands. In addition to the Wide Survey, 12% of the total *Euclid* observing time is dedicated to observing three deep fields with goals of calibrating the wide-field data and enabling legacy science. The three deep fields have four-band *Spitzer*/IRAC coverage (Euclid Collaboration et al. 2022a) and the *Euclid* Deep Field South (EDF-S) in particular overlaps with two Legacy Survey of Space and Time (LSST) deep-drilling fields, Rubin-a and Rubin-b (Euclid Collaboration et al. 2024). *Euclid* catalog parameter estimates such as photometric redshifts and stellar masses will be informed by joint efforts between LSST (Rhodes et al. 2017; Mitra et al. 2024) and other multiwavelength observatories. In March 2025 the first of numerous scheduled Quick Data Releases, Q1, was released and included deep field data at the depths of the planned *Euclid* Wide Survey (Pettorino & Laureijs 2024).

The data release described in this work includes SPT data products derived from or supporting observations overlapping the EDF-S including maps at 95, 150, and 220 GHz and source catalogs that complement the optical/infrared EDF-S data taken by *Euclid*. The map data products described in this work are similar to those in Schaffer et al. (2011), which detailed products for a previous-generation SPT camera. Two of the three main populations of objects presented in this work, high-redshift dusty galaxies and galaxy clusters, have properties that make them detectable with a particularly clean selection by the SPT. As both of these samples are drawn from observations at depths approximating that of their larger area surveys (i.e., the *Euclid* Wide Field and the SPT-3G 1 500-square-degree main survey), analyses of data products from this first joint survey field will provide important milestones to the exploitation of the full combined dataset. The products are made publicly available online.¹

The typical millimeter-wave emissive source population at the flux levels probed in this work is composed primarily of synchrotron-emitting active galactic nuclei (AGN) and dust-enshrouded star-forming galaxies emitting quasi-thermally (Everett et al. 2020). The two populations can be distinguished by SPT spectral index. The AGN population probed at millimeter wavelengths (compared to typical radio-selected samples) is dominated by flat spectrum radio quasars (FSRQs; Condon 1992; Padovani et al. 2017). The dusty SPT sources are a combination of low-redshift luminous/ultraluminous infrared galaxies (LIRGs/ULIRGs) and distant dusty star-forming galaxies (DSFGs;² Everett et al. 2020), including some galaxy protoclusters containing numerous DSFGs in a single SPT beam (e.g., Overzier 2016; Casey 2016; Miller et al. 2018; Wang et al. 2021). Thought to be progenitors of present-day elliptical galaxies (Blain et al. 2004; Casey et al. 2014), DSFGs are of broad interest and relevance to the community, as the number density of such sources are not yet well understood (see e.g., Hayward et al. 2021) and they are integral to our picture of the cosmic star

formation history of the Universe (Madau & Dickinson 2014; Koprowski et al. 2017). These sources are efficiently detectable in the millimeter and submillimeter bands, as they are dust-enshrouded to the point of being obscured at optical wavelengths (Blain & Longair 1993; Hughes & Birkinshaw 1998; Blain et al. 2002; Casey et al. 2014), but a strong negative K -correction enables their detection in millimeter wavelengths almost independent of redshift ($1 \lesssim z \lesssim 10$; Blain & Longair 1993; Blain et al. 2002).

The millimeter regime is similarly well-suited for detecting clusters of galaxies. The hot dense gas in galaxy clusters interacts with CMB photons via the tSZ effect (Sunyaev & Zel'dovich 1972). The tSZ surface brightness is redshift-independent, meaning that for a CMB instrument with angular resolution well-matched to the arcminute-scale signal, galaxy clusters can be detected to arbitrarily high redshift, in contrast to methods that rely on cluster emission (such as optical/infrared and X-ray), which suffer from cosmological dimming. The tSZ surface brightness is also a probe of the total cluster thermal energy, providing a low-scatter mass proxy. These properties lead to clean, approximately mass-limited cluster samples that are of great value for both cosmological and astrophysical studies (e.g., Carlstrom et al. 2002; Allen et al. 2011; Kravtsov & Borgani 2012; Bleem et al. 2015; Bocquet et al. 2024). This new joint dataset offers the possibility of impactful studies in understanding the role of environment in the formation and evolution of galaxies, especially in the high-redshift universe at a crucial era ($1 < z < 2$) where there is evidence for strong changes in quenching efficiency and AGN activity in dense environments (see e.g., the recent review by Alberts & Noble 2022, and references therein).

This paper is organized as follows: in Section 2, we describe the SPT, SPT-3G camera, and SPT-3G EDF-S observations. Section 3 describes how we process the telescope data into maps. In Section 4, we outline the pipelines used for generating the emissive source and cluster catalogs. Section 5 describes the data products included in the release, such as maps, masks, and filter components. Section 6 describes the contents of the emissive source catalog, including the nature of the objects and associations with external datasets, and Section 7 describes the results for the cluster catalog. We summarize our work in Section 8.

Conventions: Cluster masses are reported in M_{500c} , defined as the mass enclosed in a radius, r_{500c} , at which the average enclosed density is 500 \times the critical density at the cluster redshift. In determining cluster masses we use the fiducial Λ CDM cosmology assumed in Bleem et al. (2015) with $\sigma_8 = 0.80$, $\Omega_b = 0.046$, $\Omega_m = 0.30$, $h = 0.70$, $n_s(k_s = 0.002) = 0.97$, and $\Sigma m_\nu = 0.06$ eV. In accordance with the convention of CMB experiments, we report map noise depth in units of $\mu\text{K-arcmin}$, which expresses sky intensity as the equivalent CMB temperature fluctuation while referring to the typical noise level of a 1 square arcmin patch of map. This convention allows for a standardized noise comparison regardless of choice of map pixel size when the noise is uncorrelated between pixels.

2. Instrument and observations

In this section we describe the characteristics of the telescope and camera. We also present the field observations and discuss them in the broader context of the SPT-3G surveys.

2.1. The SPT and SPT-3G instrument

The capabilities of the SPT and SPT-3G camera are described at length in Carlstrom et al. (2011) and Sobrin et al. (2022),

¹ <https://pole.uchicago.edu/public/data/edfs25/>

² DSFGs may also be referred to as “submillimeter galaxies” or SMGs due to typical strong submillimeter emission as described in e.g., Smail et al. 2002; Casey et al. 2014; Hodge & da Cunha 2020.

respectively, though we highlight relevant specifications in this section. The SPT has a 10-meter primary mirror and is located at the Amundsen-Scott South Pole Station. The site has the lowest annual median precipitable water vapor of any developed observatory on Earth, making it particularly suitable for ground-based millimeter observations. The SPT is sensitive to the arcminute angular scales required for tSZ surveys and has produced the deepest millimeter-wave wide surveys of the high-redshift galaxy population.

The SPT-3G camera has improved detector count, field of view, and mapping speed than previous cameras on the SPT, resulting in significantly deeper maps over its predecessors. Though we do not include polarization data in the data release, the detectors are also sensitive to linear polarization in all three bands (95, 150, and 220 GHz) enabling studies of CMB polarization (Dutcher et al. 2021; Balkenhol et al. 2021, 2023; Ge et al. 2024), polarized atmosphere (Coerver et al. 2024), and polarized transients (e.g., Guns et al. 2021).

2.2. Euclid Deep Field South observations

Since 2019, the SPT-3G camera has been used to observe the “SPT-3G Main” field during most austral winters, “SPT-3G Summer” fields during most austral summers, and the “SPT-3G Wide” field during the 2024 observing season. These fields and the 57-square-degree “SPT-3G EDF-S” overlapping the 30-square-degree EDF-S³ are shown in Figure 1.

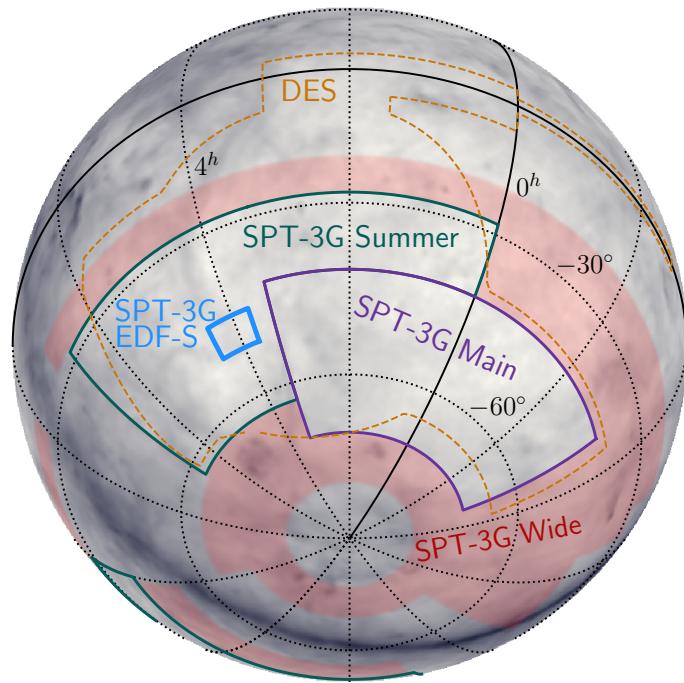


Fig. 1. Dedicated SPT-3G observations of the EDF-S (blue outline) were taken from October to December 2024. SPT-3G observations of the Main (purple outline), Summer (green outline), and Wide (red shade) fields total approximately 10 000 square degrees of sky coverage. The background image is a dust map from *Planck* (Planck Collaboration et al. 2016a) and the Dark Energy Survey (DES) footprint is also shown (orange dotted outline).

³ Though the Q1 area reported in Euclid Collaboration et al. (2025a) is 28.1 square degrees, the version of the mask we use is equivalent to 30 square degrees.

We observed the EDF-S from 6 October 2024 to 3 December 2024 in 197 non-consecutive individual observations (we observed the SPT-3G Main field when we were not observing the EDF-S). The SPT’s sky scanning strategy is a result of its location on Earth at the geographic South Pole and a requirement for constant-declination-scans. The telescope scans at constant declination across the field, reverses direction to scan back across the field, then takes a 12.5 arcmin step in declination, and this sequence repeats until the full declination range of the field has been scanned. Therefore, to observe the 30-square-degree EDF-S region, the SPT observed a 69-square-degree box centered at right ascension (R.A.)=61.25 deg (04h04m) and declination (Dec.)=−48.75 deg. The 69-square-degree area is reduced to 57 square degrees in the analysis due to necessary edge apodization. At approximately 2.5 hours per observation and 197 individual observations, we observed the SPT-3G EDF-S for approximately 20 days. Though we previously observed the EDF-S during SPT-3G Summer observations, the dedicated EDF-S observations dominate the map depth over that region, therefore we opt not to include the observations from previous years in this analysis.

The field characteristics are summarized in Table 1. The EDF-S boundary overlaid onto the SPT 150 GHz map made from the inverse-variance-weighted average of all individual observations (also called a “coadd”) is shown in Figure 2.

Quantity	Value
SPT field name	RA4h04DEC-48
R.A. center	61.25 deg (04h04m)
Dec. center	−48.75 deg
Δ R.A.	11.5 deg
Δ Dec.	6 deg
Effective area	57 square degrees
Observing dates	6 October 2024–3 December 2024
Time on field	20 days

Table 1. Information about the observing footprint used in this work. We calculate an apodization mask (see Section 5.1.1) based on the weights of the map pixels that down-weights the noisy edge regions of the map. The effective area of the field is determined by the mask and is the region over which we search for point sources and clusters.

3. Map making

The first step in our analysis is to process the camera data into maps (“map making”), which are used by both the point-source and cluster-finding algorithms. The SPT-3G map-making procedure is detailed in Dutcher et al. (2021), with changes and choices specific to our analysis described here.

3.1. Timestream processing

SPT-3G observations are recorded as time-ordered data (TOD), or timestreams.⁴ We filter the TOD and bin data into pixels to create temperature maps. Different science analyses in the SPT collaboration necessitate different TOD filtering and map binning choices, such as the angular scales to high- and low-pass filter, treatment of bright sources, map resolution and projection, and whether to use flat- or curved-sky maps. In this work, we optimize the TOD processing for small-angular-scale science, namely detections of point sources and galaxy clusters.

⁴ The SPT-3G public software repository is available on Github (CMB-S4/SPT-3G Collaboration 2024).

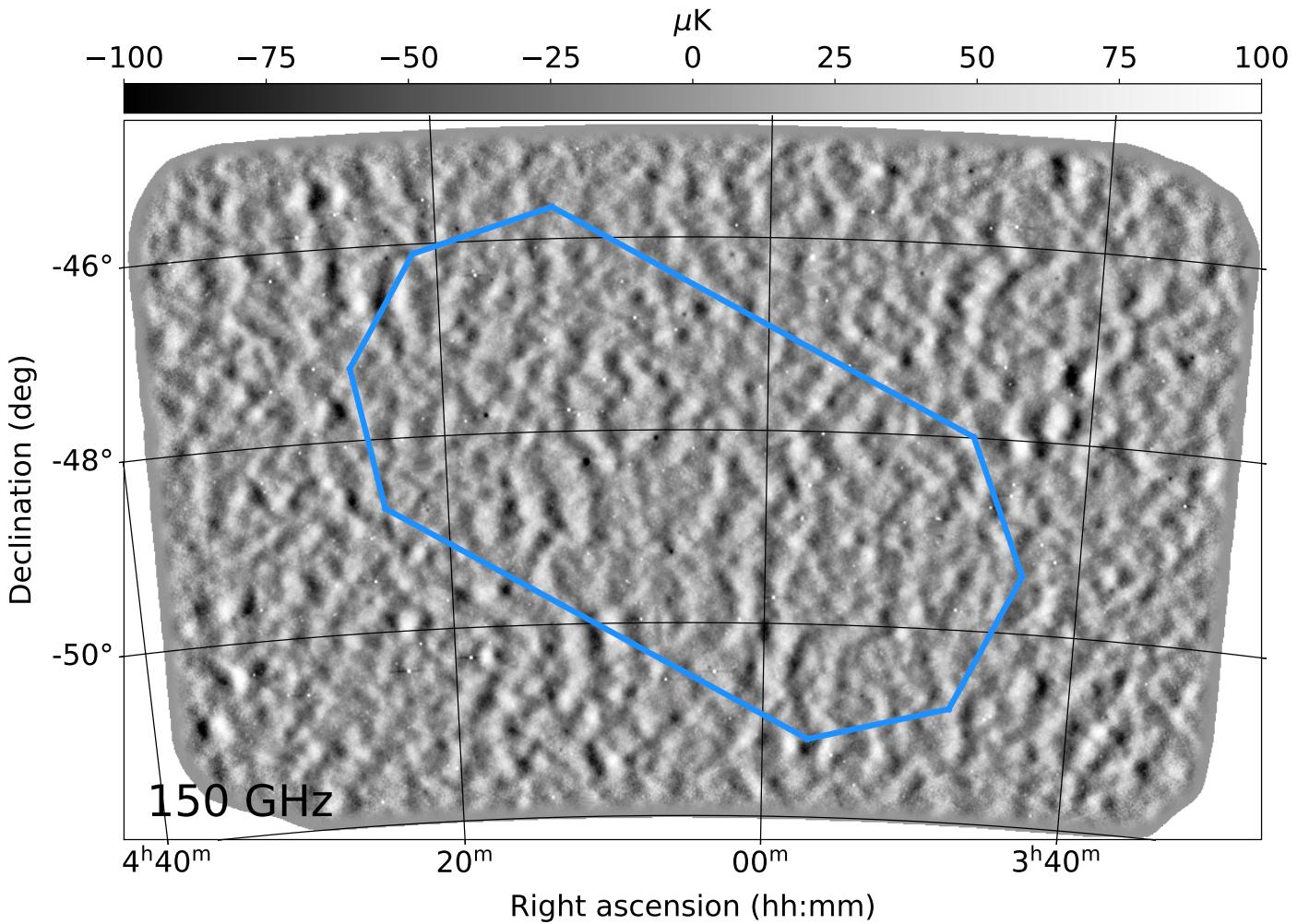


Fig. 2. The approximate full-depth EDF-S sky footprint (shown in a blue outline) overlaid on top of the 57-square-degree SPT-3G 150 GHz coadded temperature map in the ZEA projection. Notable features of the map include the small-angular-scale CMB temperature fluctuations, emissive point sources which appear as bright dots, and tSZ decrements from galaxy clusters which appear as compact dark spots. Artifacts from interpolated bright sources appear as discs of which a close-up is shown in Figure 3. The grey border is the apodized edge (apodization is described in Section 5.1.1). The 95 and 220 GHz coadded map images are shown in Appendix A.

The timestreams are high-pass filtered along the scan direction below $\ell_{\text{HP}}=500$ (using the relation $\theta = \pi/\ell$, this corresponds to 21.6 arcmin in angular units; the high-pass cutoff is chosen to remove as much atmospheric signal as possible without significantly impacting science signal of interest) and low-pass filtered above $\ell_{\text{LP}}=20\,000$ (corresponding to 0.54 arcmin) to reduce aliasing when the data are binned into map pixels. We apply a polynomial filter by fitting and subtracting a 9th-order Legendre polynomial from the timestreams, which has a similar effect as the Fourier-space high-pass filter. Finally, a “common-mode” filter is applied, which averages signals in each SPT-3G camera wafer and band and subtracts the common signal (typically caused by the atmosphere) from the TOD.

The filters are represented by a series of linear operations on the TOD (Dutcher et al. 2021) and are well approximated by analytic expressions in the Fourier domain. The effects of the TOD filtering can be modeled in map space in the Fourier domain by Equations 1 and 2. The functional forms for our low-pass, H_{LP} , and high-pass, H_{HP} , filters as scan-synchronous exponentials are shown in Equation 1:

$$H_{\text{LP}} = e^{-\left(\frac{\ell_x}{\ell_{\text{LP}}}\right)^6}$$

$$H_{\text{HP}} = e^{-\left(\frac{\ell_{\text{HP}}}{\ell_x}\right)^6} \quad (1)$$

and the common-mode filter, H_{CM} , is:

$$H_{\text{CM}} = \begin{cases} e^{-\frac{(\ell-\ell_0)^2}{2\sigma^2}} & \ell \leq \ell_0 \\ 1 & \ell > \ell_0 \end{cases} \quad (2)$$

where the cutoff scale (ℓ_0) is 745 and the width (σ) is 240. Taken together, we analytically describe the TOD filtering using the transfer function H , which is used to extract point sources and clusters (see Section 4).

The maps have 0.25 arcmin pixels, which is sufficient to Nyquist sample our smallest beam at 220 GHz. We present temperature maps in both the oblique Lambert zenithal equal-area (ZEA; Calabretta & Greisen 2002) and Sanson-Flamsteed projections (SFL; Calabretta & Greisen 2002), which are used in

the point-source-finding and galaxy-cluster-finding pipelines, respectively. We further note that since the high- and low-pass filtering is along the scan direction, i.e., along lines of constant declination, the analytic forms presented in Equations 1 and 2 can only be applied to maps in which the x -direction of the map is also at constant declination. This is satisfied by the SFL maps at the expense of shape distortions at the map edges but not the ZEA maps.

The SFL projection was used in previous SPT cluster analyses (e.g., Bleem et al. 2015; Kornelje et al. 2025) because of the ability to conveniently filter the map. The ZEA projection was used in the most recent SPT point source analysis (Everett et al. 2020). The pipelines were independently developed and optimized according to the SPT-3G data landscape, taking into account all of the sky areas shown in Figure 1.

3.2. Deconvolving detector time constants

Unlike previous SPT-3G analyses, we measure, then correct for, two independent timing effects of our system: detector time constants, τ , and a constant timing offset between detector and telescope pointing data. A detector time constant measures how long it takes for a detector to respond to a changing input signal. The value of τ is affected by the atmospheric loading on the detectors and is therefore different for every observation and individual bolometer.

The time constants are measured and calculated using methods presented in Pan et al. (2018). First, we record timestreams while the detectors are illuminated by a chopped thermal calibration source, acquiring data at several different frequencies of the chopper. We then fit the amplitude of each detector's fundamental mode response, as a function of frequency, to the Fourier transform of an exponential decay model in which the detector time constant, τ , is the free parameter. We deconvolve the measured time constants from the timestreams in Fourier space before binning them into map pixels, multiplying by the deconvolution expression in Equation 3:

$$G(\nu) = 1 + 2\pi i\nu\tau \quad (3)$$

We deconvolve the median τ value per detector across all measurements, because an individual detector's behavior is not likely to change significantly between observations. Furthermore, the time constants depend on the telescope's elevation and season of observing, so we restricted the τ measurements to calibrator frequency sweeps performed between observations of the EDF-S.

The median τ for all time constants for all detectors per band is 5.6, 5.5, and 3.3 ms for 95, 150, and 220 GHz, respectively. The distributions of τ are skewed, with a tail extending to large values of τ . We therefore report the median absolute deviation, which is more robust to outliers than standard deviation, as 1.9, 1.9, and 1.4 ms for the bands.

The time offset is understood as a disagreement between the recorded detector time stamps and telescope pointing time stamps. We use scan-direction differenced observations of the high signal-to-noise H α region MAT 5A to measure the offset. In each observation, the telescope slews in a right-going and a left-going direction over the same sky and the data are all added together in the final maps. For this measurement, we create two separate maps consisting of data from either all left-going or all right-going scans with the detector time constants deconvolved. We then subtract the two maps and the resulting difference map contains a dipole structure due to the difference in apparent position of MAT 5A between the two maps. We measure the width

of the dipole in the difference map and convert the width to time using the telescope's scan speed. The time offset is constant in time and measured to be -4.6 ± 0.4 ms for all frequencies. We similarly deconvolve this global time offset from the timestreams before map making.

3.3. Calibration and astrometry

For the EDF-S observations, we follow the same field calibration procedures as described in Sobrin et al. (2022). Regular observations of the galactic H α region RCW 38, which has a precisely known location in the sky and reference flux that was calibrated to *Planck* in Mocanu et al. (2019), were taken throughout the EDF-S observation period. The primary purpose of observing RCW 38 is to calibrate each SPT-3G bolometer based on the measured temperature and the known value.

We improve the telescope's pointing accuracy by comparing source positions in the single observation maps to The Australia Telescope 20 GHz Survey (AT20G, Murphy et al. 2010), which has positional uncertainties of less than an arcsecond, and remaking the single observation maps with the pointing corrections applied (Chichura et al. 2024). To quantify the accuracy of the final positions, we again compare the catalog positions of 18 sources from the coadded map to those in AT20G and find rms positional offsets between sources of 3.8 and 1.8 arcsec and mean offsets of -0.8 and -0.8 arcsec in R.A. and Dec., respectively.

3.4. Bright source treatment

As a result of the TOD processing, especially bright point sources in the maps will have significant "ringing" features around them that extend along R.A. if not addressed at the timestream processing stage. Because our maps are low-noise, the ringing features can be significant and difficult to remove or ignore after maps are made. Other unwanted effects include hiding point sources and clusters beneath the ringing artifacts and slowing down the source-finding pipelines.

To resolve these issues at the timestream level, we interpolate over 14 point sources that have approximate flux > 30 mJy at 95 GHz using a 3 arcmin radius circle. To make the bright source list, we create preliminary maps and a preliminary source catalog from which we identify sources above the threshold. We then create a final set of maps, interpolating over the sources that are above the threshold. A total of 0.2 square degrees of map area is lost to interpolation (which is 0.4% of the 57-square-degree SPT-3G EDF-S footprint). The source-finding pipelines do not search these regions for point sources or clusters and a single point source is assumed to lie in each bright source disc. The interpolated regions appear as discs in the coadded maps shown in Figures 2, A.1, and A.2, with a close-up in Figure 3.

Because we remove the sources from the maps, but include them in the emissive source catalog, we provide separate files of the bright source maps as 30×30 arcmin thumbnails in the data release. The thumbnail maps have the same filtering settings described throughout this section as the larger field maps. We also provide a mask (described in Section 5.1.1) with the interpolation regions zeroed out.

In the emissive source catalog, bright source thumbnails are indicated by a string with the source name (if *True*) in the *thumb* column and all other sources are 0 (for *False*); see Tables B.2 and B.4 for an example and more details.

3.5. Beam convolution

Characterizing the point spread function, or telescope “beam,” is necessary to recover as much sky signal as possible and calculate accurate fluxes of astrophysical sources. Releasing the complete SPT-3G beam is outside the scope of this work, therefore, we simplify the beam and map products (the empirical beam is the focus of a forthcoming publication by the SPT-3G collaboration).

To simplify the maps, we first deconvolve the best-fit empirical beam model from them, then convolve them with two-dimensional Gaussians (see Section 5.1.2) that are not significantly wider than the empirical beams. There is <2% impact on the number of point sources found with the Gaussian beam maps and filters when compared to using our empirical beam measurement.

3.6. Data quality

The 197 individual observations of the EDF-S are combined using a weighted average to produce a coadded map. Every map pixel in every individual observation has an associated weight; individual-observation pixels that are especially noisy (for example, due to poor weather or unusual bolometer behavior) are down-weighted in the final coadd (Dutcher et al. 2021).

As long as the weights accurately describe the pixel variance, coadding maps in the manner previously described will produce map pixel values that are unbiased with minimum variance, even if some individual observations are especially noisy. We compute some basic statistics on each map, such as pixel mean and variance, to confirm that we only include maps whose weights accurately describe the noise. The map statistics are uniform enough that no cuts are warranted, therefore the final coadd includes all individual observations that the SPT took of the EDF-S.

The maps included in our release are not intended for CMB power spectrum or lensing analyses, mainly owing to the band-pass filtering choices which remove large angular scale features, where the relevant cosmological signals are most significant, while preserving small angular scale features that would contaminate power spectra. Maps and data products optimized for analyzing CMB lensing and cross-correlations with *Euclid* data are intended for a future study and data release.

To compute the white noise levels reported in Table 2, we subtract one half of the individual maps from the other in 25 different random groups of maps, then compute the power spectrum of the difference maps in the range $5\,500 < \ell < 6\,500$ and calculate the median noise value. The final map depths are 4.3, 3.8, and $13.2 \mu\text{K}\text{-arcmin}$ at 95, 150, and 220 GHz; for comparison, the field depths for four observing seasons of the SPT-3G Main field, which covers $\sim 1\,500$ square degrees, are 3.2, 2.6, and $9.0 \mu\text{K}\text{-arcmin}$ at 95, 150, and 220 GHz (Kornoelje et al. 2025). The 5σ detection threshold flux values for the emissive source catalog are also reported in Table 2. The process to compute flux from CMB temperature, and the relevant conversion factors for the point source-processed maps, are described in Section 4.1.

Nominal band (GHz)	95	150	220
Nominal band (mm)	3.3	2.0	1.4
Map noise ($\mu\text{K}_{\text{CMB}}\text{-arcmin}$)	4.3	3.8	13.2
5σ point source (mJy)	1.7	2.0	6.5

Table 2. Map noise levels of the coadded maps provided in CMB units of $\mu\text{K}_{\text{CMB}}\text{-arcmin}$ and flux thresholds of a 5σ point source.

4. Signal extraction and catalog generation

Both the point-source and galaxy-cluster-detection pipelines use the coadded maps described in Section 3 and have significant similarities in the methods used to detect and characterize signals of interest. We describe these commonalities in this section and expand upon the specific choices for point-source and cluster-detection in Sections 4.1 and 4.2, respectively.

The SPT maps contain significant scale-dependent contributions from primary CMB, tSZ, kSZ, spatially-clustered DSFGs, Poisson-distributed DSFGs, and radio galaxies. We model the temperature fluctuations in the maps as a function of spatial position (θ) and frequency (ν_i) by:

$$T(\theta, \nu_i) = B(\theta, \nu_i) * [\Delta T(\theta, \nu_i) + N_{\text{astro}}(\theta, \nu_i)] + N_{\text{instr}}(\theta, \nu_i) \quad (4)$$

where the sky signals are convolved ($*$) with the telescope beam and transfer function (which encodes the impact of our timestream filtering—see Section 3.1), with ΔT representing the sky signal of interest (e.g., tSZ), B representing the beam and transfer function, N_{instr} representing the instrumental and residual atmospheric noise, and N_{astro} representing all undesired astrophysical signals (in both the point source and cluster case, this includes CMB).

Following common practice in millimeter-wave surveys (e.g., Tegmark & de Oliveira-Costa 1998; Melin et al. 2006), we use matched filtering techniques to optimize sensitivity to desired signals in the presence of these contaminants. The optimal filter applied to the maps takes the form for frequency ν_i :

$$\psi(\ell, \nu_i) = \sigma_{\psi}^2 \sum_j N_{ij}^{-1}(\ell) f(\nu_j) S_{\text{filt}}(\ell, \nu_j) \quad (5)$$

where $N_{ij}(\ell)$ is the noise covariance matrix, $S_{\text{filt}}(\ell, \nu_j)$ is the spatial profile of the targeted signal, and $f(\nu_j)$ is its spectral dependence. The noise covariance matrix combines the measured instrumental and atmospheric noise residuals (Section 5.1.3) with the models of astrophysical noise from Reichardt et al. (2021). The summation, j , occurs over either a single or all SPT frequencies for point sources and clusters, respectively. Finally, the variance in the optimal filter is given by

$$\sigma_{\psi}^{-2} = \int d^2\ell \sum_{i,j} f(\nu_i) S_{\text{filt}}(\ell, \nu_i) N_{ij}^{-1}(\ell) f(\nu_j) S_{\text{filt}}(\ell, \nu_j) \quad (6)$$

which is used to normalize the filter such that the response to our desired signal is unity. We make a number of different choices for the modeling of these components in the point source and cluster analyses.

Point source filtering

- *Spatial template*: The source profile adopted for the point source analysis is a δ function. Emissive extended sources are flagged according to Section 6.3.
- *Spectral template*: In this analysis we do not assume a frequency dependence for the point source emission *a priori*. As such, each frequency map is filtered independently and the single-band source lists are combined.
- *Instrumental noise*: For instrumental noise, we use the map white noise levels in Table 2. At low- ℓ the CMB signal dominates over the instrument noise, so approximating the instrument noise as white in the construction of the point source filter is a reasonable approximation.

- *Map projection:* We decompose the filter components and apply the beam and noise components of the filter to the map in the ZEA projection and the transfer function in one dimension in the Plate Carrée map projection, where strips of declination are also strips of x .

Galaxy cluster filtering

- *Spatial template:* Galaxy clusters are extended structures in the SPT maps. As the physical scale of the tSZ signal depends on a cluster’s mass and redshift, we make use of a range of spatial templates in our blind cluster search by modeling the spatial profile of the tSZ decrement signal assuming an isothermal projected β -model as in Cavaliere & Fusco-Femiano (1976):

$$S = \Delta T_0 \left(1 + \frac{\theta^2}{\theta_c^2}\right)^{-\frac{3}{2}\beta + \frac{1}{2}} \quad (7)$$

with normalization ΔT_0 , core radii (θ_c) ranging from 0.25 to 3 arcmin in increments of 0.25 arcmin, and with a fixed $\beta = 1$. The choice of β -model as a spatial template is consistent with previous SPT analyses and has negligible impact when compared to other common profiles (Vanderlinde et al. 2010). For the cases of common candidate detections between filter scales, the core size that maximizes the significance is included in the final catalog.

- *Spectral template:* The tSZ signature is a spectral distortion caused by the inverse Compton scattering of CMB photons off of high-energy electrons within the intracluster medium (ICM). The spectral distortion can be represented as temperature fluctuations dependent on the electron number density n_e , temperature T_e , and Thomson scattering cross-section σ_T :

$$\begin{aligned} \Delta T_{\text{SZ}} &= T_{\text{CMB}} f_{\text{SZ}}(x) \int n_e \frac{k_B T_e}{m_e c^2} \sigma_T d\ell \\ &= T_{\text{CMB}} f_{\text{SZ}}(x) y_{\text{SZ}} \end{aligned} \quad (8)$$

where we take the Compton- y parameter y_{SZ} to be the total thermal energy of the electron gas integrated along the line of sight (LOS; Sunyaev & Zel’dovich 1972). Here, $f_{\text{SZ}}(x)$ is the frequency dependence of the tSZ effect,

$$f_{\text{SZ}}(x) = \left(x \frac{e^x + 1}{e^x - 1}\right) (1 + \delta_{\text{rc}}) \quad (9)$$

where $x \equiv h\nu/k_B T_{\text{CMB}}$, h is Planck’s constant, and k_B is the Boltzmann constant. We use the effective frequencies for the tSZ signal in each band, where ν is 95.7, 148.9, and 220.2 GHz for nominal bands 95, 150, and 220 GHz. The term “effective frequency” refers to the frequency at which the instrument response to a δ function would be equivalent to that of a source of a specified spectrum after integrating over the real bandpass and taking into account the beam dependence on frequency. δ_{rc} represents the relativistic correction to the electron gas’s energy spectrum (Erler et al. 2018) which is assumed to be negligible for this analysis.

- *Instrumental noise:* We empirically estimate the instrumental and residual atmospheric noise by creating “signal-free” coadded maps by randomly multiplying half of the observations by -1 to remove sky signals. The average of the Fourier transform of 25 such realizations is used to estimate the N_{inst} term in the noise covariance matrix used in constructing the optimal filters.

- *Map projection:* We use the SFL projection in the entire cluster-finding procedure, which aligns the rows of map pixels with the telescope’s scan direction. This projection makes it convenient to correct for effects from our constant-declination-scan filtering using the transfer function described in Section 3.1 at the expense of small shape distortions at the field edges.

4.1. Point source catalog generation

The point-source-finding procedure can be described in three coarse steps: optimally filtering the raw coadd, processing the filtered map, and pixel-grouping the processed map. Once the pixels are grouped into sources, the CMB brightness temperature fluctuations from the sources are converted to flux density. The specific details of these steps will be described in a forthcoming publication by the SPT-3G collaboration, though an overview is provided in this section. A zoomed-in portion of the 150 GHz map undergoing the point-source-finding procedure is shown in Figure 3 as a reference for the following steps.

CLEAN: We first apply the point source filter described in the previous section to the individual frequency maps. The filter is applied in Fourier space and normalized such that the resulting map is in CMB temperature units (top right panel of Figure 3).

Next, an implementation of the CLEAN algorithm (Högbom 1974) is applied to the optimally filtered map to remove filtering artifacts present around sources. In Section 3.4, we discuss the 14 sources >30 mJy at 95 GHz that are interpolated over as the solution to ringing features from particularly bright sources so that we do not have to CLEAN them; one of these is visible in Figure 3. In Figure 3’s top right panel, the emissive sources are the white dots and the filtering artifacts are the dark features encircling the white dots. The inverse of these colors towards the middle of the panel is a galaxy cluster (which is a decrement at 150 GHz).

As in Everett et al. (2020), CLEAN is implemented where the brightest pixel in the map is found and a fraction of a source template (called the “loop gain,” which we set at 0.1) is removed from that location, gradually decreasing the maximum map amplitude. The iterations proceed until a 5σ signal-to-noise threshold is reached. The map left over after the first part of CLEAN is called the “residual map” (lower left panel of Figure 3) – the reason one can still see the remnants of the sources, and the galaxy cluster in particular, is because these features are just below the threshold at which CLEAN stopped.

During the CLEAN iterations, the source locations and pixel amplitudes are recorded, then a new source template—the “clean beam” or point source template without the filtering artifacts—is iteratively returned to the map with the appropriate amplitude. The final result is a “clean beam map” (lower right panel of Figure 3) which has the following key characteristics: large-scale modes such as CMB and atmosphere have been suppressed and unresolved point sources appear as simple telescope beams. To generate the catalog from this map, a simple pixel grouping algorithm (`photutils`, Bradley et al. 2023) is applied to the clean beam map, which extracts groups of pixels above 5σ most likely to be distinct sources and deblends sources near each other. The peak temperature map value of a source is recorded from the centroid location found by `photutils`.

The aforementioned map processing steps are applied to each frequency map individually to create three separate source catalogs. The three catalogs are unified using a simple radial as-

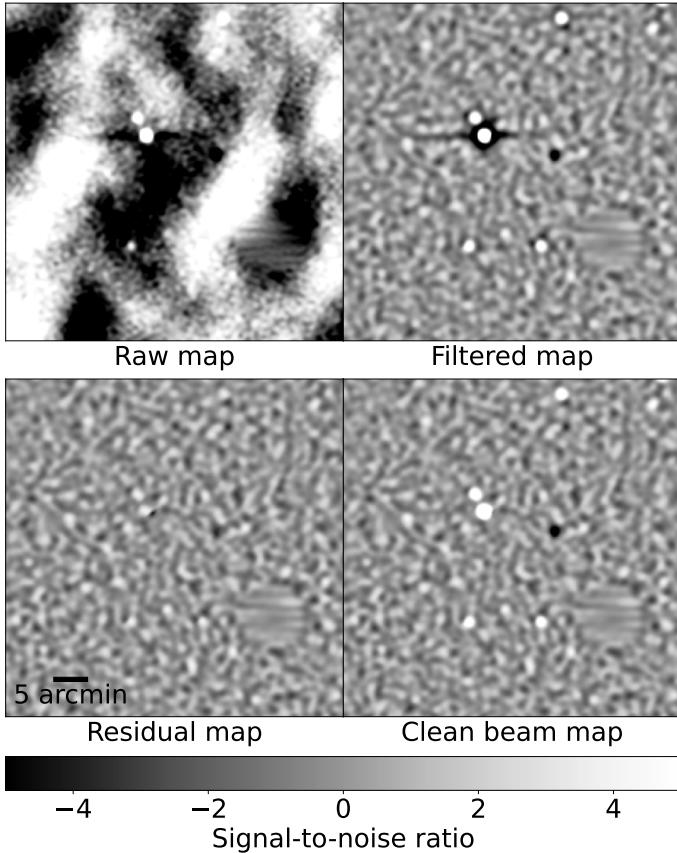


Fig. 3. Each panel shows a major map processing step in the point-source-finding procedure. For demonstration purposes, the 150 GHz map is shown, however each band’s coadd undergoes source finding independently. *Top left:* the coadded temperature map before any processing. On the same color scale as all other panels, we observe the large CMB fluctuations dominating the emissive sources and the galaxy cluster. The first step is to remove the CMB. *Top right:* the map after an optimal filter has been applied and suppressed most of the CMB modes. The emissive galaxies are positive points with negative filtering wings around them. The galaxy cluster is a decrement. The second step is to remove the filtering effects around sources. *Bottom left:* the residual map leftover after applying a CLEAN algorithm which iteratively removes “dirty beams” at the location of sources. The pixels left over in their place are just below the 5σ threshold. *Bottom right:* the third step is to put back in the “clean beam” at source locations without the filtering artifacts. This clean beam map is the image to which a simple pixel grouping algorithm is applied to generate the emissive source catalog. Note that while the cluster in this example is affected by the procedure, it is not optimal to find and characterize clusters using these methods, therefore a separate pipeline is used. The disc feature in the lower right of all panels is an interpolated bright source (see Section 3.4).

sociation radius of 43.2 arcsec between bands. This value comes from 3×1.2 arcmin/ 5σ (Ivison et al. 2007), where 1.2 arcmin is the 150 GHz Gaussian beam FWHM, 5σ is the lowest possible detection significance for a source, and $3 \times$ is a discretionary choice that minimizes adverse affects when using the emissive source catalog for source subtraction during cluster finding (see Section 4.2). We opt to use the 150 GHz beam size rather than the other bands because it is between the other sizes, and sources are more likely to be detected at 150 GHz plus another band than any other combination of bands. The location of the highest signal-to-noise detection in any map is recorded as the source’s R.A. and Dec. in the catalog. If a source is not detected above 5σ in a band’s map, we use forced photometry in the map where

the source is below the threshold and record the signal-to-noise and forced-photometry temperature value in the catalog.

The raw coadded temperature maps and the final clean beam maps in the ZEA map projection are included in the released products. One could construct the intermediate maps using the ancillary data products described in Section 5.

Flux calculation: The conversion between CMB temperature and flux density is computed from the derivative of the Planck blackbody function and evaluated at a fiducial frequency and temperature,

$$S(\text{Jy}) = T_{\text{peak}} \cdot \Delta\Omega_f \cdot 10^{26} \cdot \frac{2k_B}{c^2} \cdot \left(\frac{k_B T_{\text{CMB}}}{h} \right)^2 \frac{x^4 e^x}{(e^x - 1)^2} \quad (10)$$

where $x \equiv h\nu/(k_B T_{\text{CMB}})$ and $\Delta\Omega_f$ is the solid angle of the optimal filter ψ (Everett et al. 2020),

$$\Delta\Omega_f = \left[\int d^2\ell \psi(\ell) B(\ell) \right]^{-1} \quad (11)$$

and B is the transfer function combined with the beam. Though we could make any choice of fiducial frequency at which to calculate and report source fluxes, we choose 94.2, 147.8, and 220.7 GHz for the nominal 95, 150, and 220 GHz bands, which correspond to the effective band centers for a flat spectrum, point-like source. The fiducial frequencies depend on the real SPT-3G bandpasses (Sobrin et al. 2022), taking into account how the telescope beam behaves with frequency. At this choice of fiducial frequencies, the conversion factors between CMB temperature and flux are 0.07513, 0.05856, and 0.05068 mJy/ μK for nominal bands 95, 150, and 220 GHz, respectively.

Unlike previous SPT point source analyses (Vieira et al. 2010; Mocanu et al. 2013; Everett et al. 2020), we do not account for certain biases in the flux calculation that are caused by selecting peaks in a Gaussian noise field; this accounting is known as “flux de-boosting” (Coppin et al. 2005). On average, the boosting results in fluxes that are overestimated by $11 \pm 3\%$, $15 \pm 9\%$, and $23 \pm 10\%$ at 95, 150, and 220 GHz, respectively, for sources detected between 5 and 5.5σ . Above 5.5σ , the effect from boosting is smaller than the uncertainty on the flux measurement. It should also be noted that the bias only affects sources detected above 5σ —for sources with forced photometry measurements in non-detection bands, we do not expect the flux to be overestimated. One should take this potential bias into account if using the reported fluxes to construct spectral energy distributions (SEDs) based on photometry.

We make this choice because the main goal of the emissive catalog release is to study the individual sources themselves and not number counts for the types of millimeter sources represented, which have already been well characterized in previous analyses in other parts of the sky (e.g., Everett et al. 2020; Vargas et al. 2023). The practical effect on source classification of not accounting for flux boosting is to shift the classification of $\sim 3\%$ of sources (based on preliminary measurements) from “dusty” to “synchrotron” or vice-versa (source classification is discussed in detail in Section 6.1). However, the affected sources have other indications of synchrotron emission, such as radio counterparts and dipping or peaking spectral behavior, so not knowing their de-boosted flux values does not significantly hinder one’s ability to understand the source’s nature.

4.2. Galaxy cluster catalog generation

Galaxy clusters are identified as peaks in the frequency-combined minimum variance tSZ maps filtered by the optimal β -model filters discussed in the beginning of Section 4. Before applying these filters we first remove signals from emissive sources to mitigate spurious contamination from these sources in our cluster candidate list.

Emissive source subtraction and masking: Like emissive source detection, cluster detection is sensitive to the ringing wings caused by the timestamp filtering procedure. The wings have an opposite sign to the central source and can hold a significant portion of the source's amplitude, which can lead to spurious false detections that impact the purity of the final cluster sample (see e.g., discussion in Kornoelje et al. 2025). Bleem et al. (2024) introduced a treatment of these sources through “source subtraction.” Similar to the previous subsection, we adopt a model of the beam convolved with the transfer function as our model for the spatial profile of emissive sources. We subtract templates scaled by measured source amplitudes from emissive source locations in the coadded temperature maps for all three frequencies for sources detected at 95 GHz at a signal-to-noise greater than 5—essentially acting as a CLEAN iteration with a loop gain of 1 (see Section 4.1).

We additionally adopt a masking procedure similar to Reichardt et al. (2013) and SPT cluster analyses thereafter by masking a 4 arcmin radius region around bright source locations interpolated over during the map-making procedure. Following an initial cluster detection run we visually inspected⁵ all tSZ cluster candidates and flagged an additional 10 regions for masking in the construction of the final sample owing to poor source subtraction. The problematic regions are at the locations of bright (signal-to-noise > 50 at 95 GHz) or extended sources (such as NGC 1493 and NGC 1494; Sulentic & Tifft 1999).

Cluster detection observable, ξ : We define the cluster significance, ξ , as the signal-to-noise ratio maximized over 12 spatial filter scales. The numerator for ξ is directly returned by the matched filter at every location in the map. We form the basis for the denominator by estimating the noise in our minimum-variance matched-filtered maps.

We estimate the noise by fitting a Gaussian to the distribution, in a series of declination-dependent strips, of pixel values that fall within 5σ of the mean of that strip. The averaging of pixel values occurs in strips that are 1.5 deg tall to capture declination-dependent noise that stems from unequal area coverage and variations in atmospheric loading. We set the minimum significance threshold for detection at $\xi_{\min} = 4$, balancing purity with the size of the sample. The purity of the sample degrades as ξ decreases due to the noise fluctuations, the implications of which are discussed further in Section 7.1.

Once tSZ candidates are identified by the preceding filtering scheme, we estimate redshifts and masses for the sample, and we compare to optical and infrared data. The methods are described in the following subsections and the results are discussed further in Section 7.

⁵ Using a new inspection tool, ImageMarker, see <https://github.com/andikisare/imgmarker>.

4.2.1. Photometric redshift estimation

As the tSZ effect is redshift-independent, we require external survey data to confirm our tSZ candidates as galaxy clusters and to provide redshift estimates. We provide a brief summary of the multi-component matched filter method (MCMF; Klein et al. 2018, 2019, 2024a) that we use to probabilistically assign optical and infrared galaxy cluster counterparts to the tSZ detections and estimate their redshifts. In this work we use data from the DR10 release of the DECam Legacy Survey (DECALS; Dey et al. 2019), which combines data from the DES (Flaugher et al. 2015) and the Wide-field Infrared Survey Explorer (WISE; Wright et al. 2010) in the SPT-3G EDF-S region. Readers are referred to preceding publications for further details on the implementation and performance of MCMF for tSZ galaxy cluster redshifts. In total we estimate redshifts for 188 clusters.

MCMF identifies counterparts by identifying excesses of bright red-sequence (shown to be excellent tracers of optical galaxy clusters, see e.g., Gladders & Yee 2000; Rykoff et al. 2014) or infrared galaxies along the LOS at SPT candidate locations. Similar estimates along random sight lines are used to assess the probability of falsely associating tSZ candidates with optical overdensities as a function of redshift, z , and cluster galaxy richness, λ (the latter being a weighted form of cluster galaxy count, see Klein et al. 2018). We quantify the false association probability through the statistic f_{cont} given by:

$$f_{\text{cont}}(\lambda_i, z_i) = \frac{\int_{\lambda_i}^{\infty} f_{\text{rand}}(\lambda, z_i) d\lambda}{\int_{\lambda_i}^{\infty} f_{\text{SZ}}(\lambda, z_i) d\lambda} \quad (12)$$

where f_{rand} traces the galaxy richness distributions along random lines of sight and f_{SZ} is the richness distribution along lines of sight from tSZ candidates. We consider a candidate confirmed as a galaxy cluster if $f_{\text{cont}} < 0.2$. For candidates in which multiple optical or infrared overdensities along the line of sight have $f_{\text{cont}} < 0.2$, we adopt the association with the smallest contamination fraction as the primary association (and assign the cluster this redshift and richness) but also provide optical properties for these additional structures.

When combined with the intrinsic purity $p(\xi > \xi_{\min})$ of the tSZ candidate sample (see Section 7.1), the overall contamination for the optically confirmed sample is

$$\text{contamination} = f_{\text{cont}}^{\max} \times [1 - p(\xi > \xi_{\min})] \quad (13)$$

or approximately 3% at $\xi > 4$ for $f_{\text{cont}}^{\max} = 0.2$ given the high purity, 87%, of the tSZ candidate list. In the catalog, we provide redshifts, galaxy richnesses, and contamination fractions for confirmed clusters. The exact column labels and details are provided in Table B.4.

4.2.2. Spectroscopic redshift assignment

We follow our previous work on optical follow-up (Klein et al. 2023, 2024b) and obtain spectroscopic redshifts for clusters using three methods. The first method involves cross-matching confirmed clusters with previously published clusters that have known spectroscopic redshifts, using a maximum separation of 2 arcmin from the cluster center. In the second method, we use public spectroscopic surveys to search for multiple galaxies with consistent redshifts within a 2 Mpc radius around the cluster center. In the third method, we search for spectroscopic redshifts of the brightest cluster galaxy (BCG) in the literature.

In total, we assign spectroscopic redshifts to nine clusters. Eight of these are obtained by matching to clusters with existing spectroscopic measurements (De Propris et al. 2002; Williamson et al. 2011; Bayliss et al. 2016; Tempel et al. 2016; Hilton et al. 2021; Xu et al. 2022). For the remaining cluster, SPT-CL J0357–4935, we adopt the spectroscopic redshift of the BCG identified in the 2dF Galaxy Redshift Survey (2dFGRS; Colless et al. 2001).

4.2.3. Mass estimation

Since the magnitude of the tSZ effect is dependent on the electron pressure in the ICM, the significance of the cluster has been shown to have a strong correlation to the integrated mass of the system (de Haan et al. 2016; Bocquet et al. 2024). We estimate the masses of clusters using the significance-mass relation from Benson et al. (2013):

$$\langle \ln \zeta \rangle = \ln \left[A_{\text{SZ}} \left(\frac{M_{500}}{3 \times 10^{14} M_{\odot} h^{-1}} \right)^{B_{\text{SZ}}} \left(\frac{E(z)}{E(0.6)} \right)^{C_{\text{SZ}}} \right] \quad (14)$$

where the parameters A_{SZ} , B_{SZ} , and C_{SZ} characterize the normalization, mass slope, and redshift evolution of the significance-mass relation, respectively, and $E(z) \equiv H(z)/H_0$. As ξ is a biased tracer of detection significance due to its maximization over preferred position and filter scale, we introduce the unbiased estimator of our detection significance, ζ . Following Vanderlinde et al. (2010), ζ is related to ξ by:

$$\zeta \equiv \sqrt{\langle \xi \rangle^2 - 3} \quad (15)$$

which holds for $\xi > 2$. We assume a unit-width Gaussian scatter on ξ and a log-normal scatter on ζ of 0.2.

The significance-mass relationship is dependent on the level of noise in the map. To remove this field-level noise dependence, as in previous SPT publications, A_{SZ} is rescaled as γA_{SZ} , where γ parametrizes the noise level of the field. Given the SPT-3G EDF-S field only spans 57 square degrees, fitting for the parameters of Equation 14 by using cluster abundances of the EDF-S at our fixed fiducial cosmology (as was done in e.g., Bleem et al. 2015, 2024, for the SPT-SZ and SPTpol surveys) leads to poor constraints on the scaling relation parameters. Thus we elect to adopt the best-fit A_{SZ} , B_{SZ} , and C_{SZ} from Bleem et al. (2024) and to estimate γ by comparing the masses of cross-matched clusters between the EDF-S and the SPT-SZ survey, allowing γ to vary until the median ratio of the masses of these clusters is unity. We find a value of $\gamma = 3.8$ for the SPT-3G EDF-S; this is approximately 3× the γ value for the SPT-SZ survey in this region, meaning that the average significance of clusters in common between the SPT-SZ and SPT-3G EDF-S fields is roughly a factor of 3× greater in the new SPT-3G EDF-S data.

5. Temperature maps and data products

We provide the coadded temperature maps at 95, 150, and 220 GHz in both the ZEA and SFL projections in the data release. Figure 2 shows the 150 GHz map which features the large spatial scale CMB fluctuations, bright individual galaxies, and tSZ decrements. The 95 and 220 GHz maps are shown in the appendix in Figures A.1 and A.2. The data products released with this paper include the entire 57 square degrees, though it is noted in the catalogs whether or not the object is strictly inside the EDF-S boundaries. We do not include polarization or lensing maps in this release.

5.1. Ancillary data products

In this section, we describe the data products we provide that are necessary components to reproduce the main analysis results. The specific details of how the data products are used are described in Section 4.

5.1.1. Masks

The maps are saved with an apodized edge for ease of use in Fourier transform operations. The edge apodization masks were created to gently roll off the map edges based on the values of the pixel weights; specifically, to roll off the pixels whose weights are < 0.5 of the median weight value. We decrease the threshold to < 0.1 of the median weight value for the top and bottom of the field to fully encompass the EDF-S field. The apodization mask data products are map-shaped arrays where the values at the edges slowly transition from 0 to 1 in the valid portions of the map. We provide these edge apodization masks in both map projections.

Both the point-source and cluster-finding pipelines use an additional binary “pixel mask” that is used to discard objects found in problematic areas of the map: without modifying the map itself, if a source is found in a 0 region of the pixel mask, it is removed from the catalog. We set the edges of the pixel mask equal to 1 where the apodization masks are > 0.999 , ensuring that source-finding is restricted to the uniform coverage region of the maps. In the pixel masks, we also zero out the discs that are left over from the bright source interpolation procedure (Section 3.4). We provide the pixel masks used to generate the catalogs.

To flag detections as “inside EDF-S,” we used a mask provided by the *Euclid* collaboration (private communication). The binary mask encompasses 30 square degrees. We include the pixel mask we created from the *Euclid*-provided mask in our data release.

5.1.2. Telescope beams

As described in Section 3.5, our maps are convolved with two-dimensional Gaussians rather than the best-fit empirical SPT-3G beams. We supply the B_{ℓ} file for the Gaussian beams, which were generated using `healpy` (Zonca et al. 2019). The FWHMs are 1.8, 1.2, and 1.0 arcmin for 95, 150, and 220 GHz, respectively. Though these beam FWHMs are similar to the published values in Sobrin et al. (2022), they differ slightly and were chosen to ensure the Gaussian beams have 0 power at the same angular scales as the empirical beams. The Gaussian beams have nonzero values to arbitrarily high multipoles, therefore we set the values of B_{ℓ} to 0 when the amplitudes reach 0.005. When using the beams to create the Fourier-space matched filters for finding point sources and clusters (Section 4), we assume azimuthal symmetry to create two-dimensional versions.

5.1.3. Noise amplitude spectral densities

As detailed in Section 4, we construct empirical noise estimates from our observations by constructing many coadded difference maps of our field. We use the Fourier transform of these noise maps to create noise amplitude spectral densities (ASDs). We provide the ASDs used in the cluster-detection procedure in the SFL projection.

5.1.4. Transfer function

We aggressively filter the TOD to make temperature maps (see Section 3). For this analysis, we apply low-pass, high-pass, polynomial, and common mode filters to the TOD and analytically describe the resulting transfer function using Equations 1 and 2. We use the analytic transfer function to create the matched filters in Section 4, as well as to create “source templates” for removing sources from the data during cluster source subtraction and point source CLEAN. Therefore, we provide the analytic transfer function in the two-dimensional Fourier domain as part of the set of data products. It should be noted that our map making filters along the scan-direction of the telescope, and so this analytic form for the transfer function only applies to maps in the SFL projection. We use a one-dimensional, scan-direction only version of the same transfer function in the ZEA projection for point source finding.

6. Results: emissive point source catalog

We present two catalogs of astrophysical objects: emissive point sources in this section and galaxy cluster candidates from tSZ decrements in Section 7. Detections from both catalogs are shown on the 150 GHz clean beam map in Figure 4, where the dominant signals are from individual point sources (bright dots) and galaxy clusters (dark spots). Comparing the clean beam map in Figure 4 to the raw temperature map in Figure 2, we see how the source-finding procedure suppresses CMB signal to leave only point-like features. The census of detections and source designations in the emissive source catalog are provided in Table 3.

Point sources detected at millimeter wavelengths can broadly be categorized into groups of synchrotron-emitting, typically radio-loud AGN and thermally-emitting dusty galaxies at low and high redshift (Everett et al. 2020; Vargas et al. 2023).⁶ Synchrotron emission is associated with a falling or flat source spectrum as frequency increases while thermal emission is associated with a rising spectrum (we do not consider the case of optically thick synchrotron emission, which may appear similar to a thermal source spectrum). The point source catalog comprises 601 (334) total sources (inside EDF-S), 324 (182) of which are synchrotron-dominated and 277 (152) of which are dust-dominated. The multiwavelength counterparts, classifications as synchrotron or dusty, and characterizations of objects in the emissive source catalog are described in the following subsections.

6.1. Type classification

The catalog contains fluxes measured in three bands and signal-to-noise ratios for each source. Fluxes are shown in Figure 5 and marked by external catalog associations, which are discussed in Section 6.4. Two populations of sources, synchrotron and dusty, become obvious in the flux vs. flux plots.

We use the logarithm of the ratio of fluxes between our bands, otherwise known as the spectral index, to classify sources as synchrotron-dominated or dust-dominated. The spectral index, α , is calculated in Equation 16:

$$\alpha_2^1 = \frac{\log(\frac{S_1}{S_2})}{\log(\frac{\nu_1}{\nu_2})} \quad (16)$$

where the subscripts 1 and 2 refer to the frequency bands, such as 95 and 150 GHz or 150 and 220 GHz. We use the fiducial frequencies given in Section 4.1, though the effect of choice of ν on the resulting α and flux values is small.

The turnover point between the source populations is not a strictly flat spectrum ($\alpha = 0$) because the distributions overlap somewhat; we use the Everett et al. (2020) value $\alpha_{220}^{150} < 1.5$ to classify sources as synchrotron-dominated and > 1.5 as dust-dominated. Synchrotron sources make up most of the 95 GHz detections, and to a lesser extent the 150 GHz detections, while dusty sources make up most of the 220 GHz detections.

The median spectral index between 150 and 220 GHz fluxes is -0.5 and 3.5 for synchrotron-dominated and dust-dominated sources, respectively. We highlight that the synchrotron sources in Figure 5 consistently share a spectral index of about -0.5 from both 95 to 150 GHz and from 150 to 220 GHz, however the dusty population has far less emission at 95 GHz overall. For this reason, we use the prescription adopted in Everett et al. (2020) for source classification, where the α_{220}^{150} quantity determines the classification because the forced photometry in the 95 GHz band for dusty sources is often not significant. The distribution of α_{220}^{150} vs. α_{150}^{95} is shown in Figure 6, where the separation between the two populations are most distinct.

Synchrotron-dominated sources: Blazars are AGN with relativistic jets pointed towards the observer. They are further broken into the subclasses FSRQs and BL Lac objects, where FSRQs tend to be brighter and may exhibit emission lines that BL Lac objects lack (Urry & Padovani 1995). The sample of SPT-detected synchrotron-dominated sources are primarily FSRQs. These 324 sources (53.9% of the catalog) are located in the lower left quadrant of Figure 6, where the brightest sources in the catalog have fairly flat spectral indices (both α_{220}^{150} and α_{150}^{95} are close to 0).

Because blazars are typically bright across a wide range of wavelengths, it is expected that the majority of synchrotron sources the SPT detects will have multiwavelength, and particularly radio, counterparts. Indeed, $\sim 95\%$ of the SPT-3G sources classified as synchrotron-dominated have counterparts in the radio catalog with which we compare (there are more details on cross-matching with external datasets in Section 6.4). In the SED of an AGN, synchrotron radiation, which is caused by the acceleration of relativistic charged particles, is observed from radio to ultraviolet wavelengths (Dutka et al. 2017), therefore it is likely that the SPT is probing the same mechanism as the radio regime.

Dust-dominated sources: The other 46.1% of the catalog consists of 277 dust-dominated sources, in which the millimeter emission is primarily reprocessed starlight emitted quasi-thermally by dust grains. A subset of this population of particular astrophysical and cosmological interest are high-redshift DSFGs, some of which are expected to be strongly gravitationally lensed (Vieira et al. 2013; Giulietti et al. 2024). We select high-redshift DSFG candidates by removing from the dust-dominated sample any source that is detected strongly in The AllWISE Data Release catalog (Cutri et al. 2021), which are predominantly at

⁶ We searched for stars in the point source catalog using methods described in Everett et al. (2020) and Tandoi et al. (2024) and determined there are no star candidates.

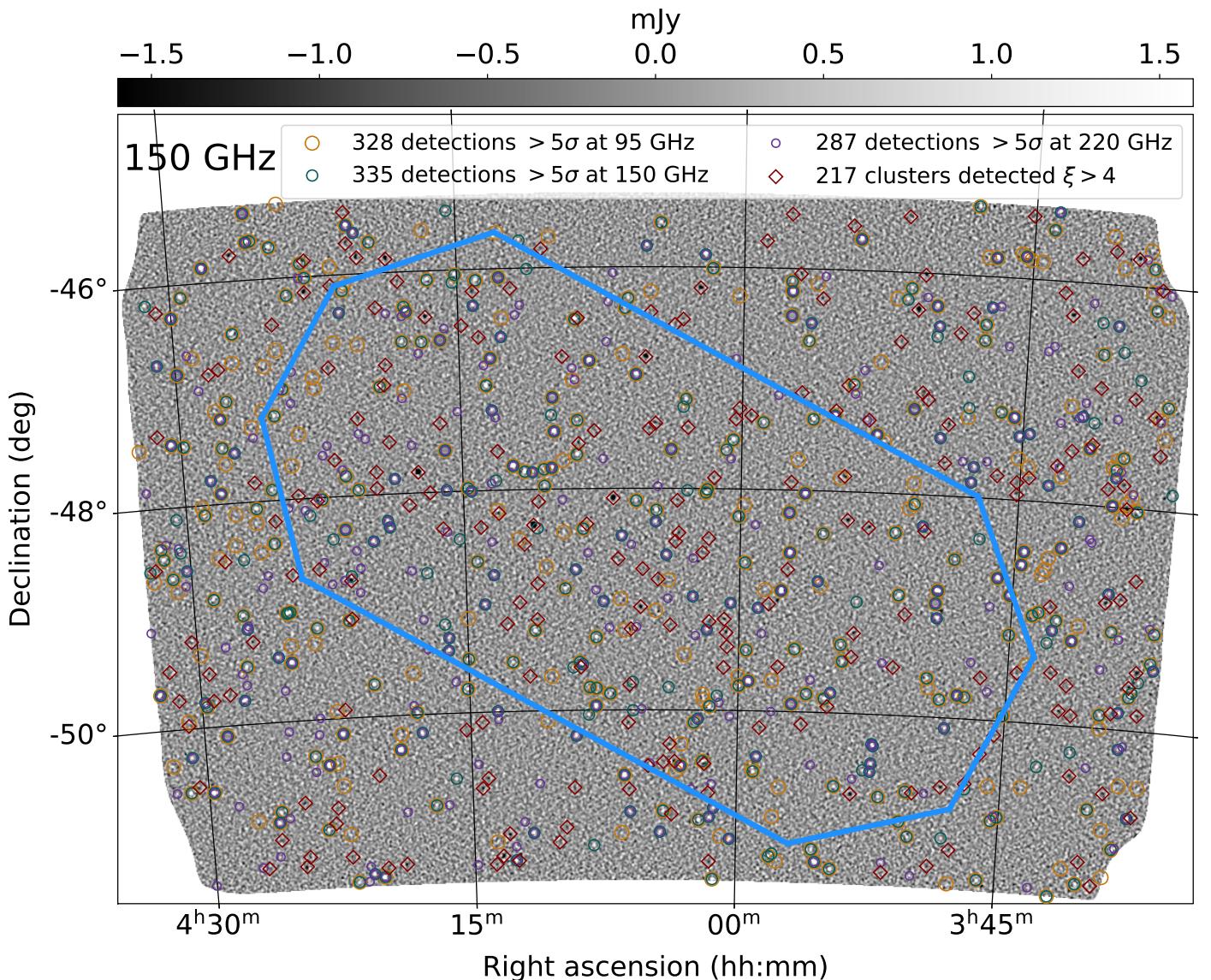


Fig. 4. The SPT-3G 57-square-degree 150 GHz clean beam map with emissive source locations indicated by colored circles (95, 150, and 220 GHz detections in orange, green, and purple, respectively) and 217 galaxy clusters indicated by red diamonds. Bright spots are individual galaxies in the emissive source catalog and dark spots are tSZ galaxy clusters in the cluster catalog. The blue border indicates the EDF-S sky area observed by *Euclid*.

low redshift ($z \lesssim 0.1$), and any source that exhibits unusual or flat spectral behavior not indicative of a high-redshift DSFG. Quantitative details of the DSFG flagging procedure are described in Section 6.3. By these criteria, almost three in four dusty sources in the SPT-3G sample are high-redshift DSFG candidates and do not have counterparts at other wavelengths (emphasized in the right panel of Figure 6).

SPT-selected DSFGs have been measured to have a median redshift of $z \approx 4$ (Reuter et al. 2020) and are important laboratories for studying the extreme end of galaxy formation and evolution. Some objects in the DSFG count may also be galaxy protoclusters (Miller et al. 2018). While protoclusters can be discovered in millimeter-wavelength surveys and selected by searching for DSFG characteristics, high-resolution imaging is needed to confirm them and differentiate the two populations (Wang et al. 2021). According to dusty source models (such as Negrello et al. 2007) that are able to reproduce the strongly lensed DSFG sample discovered with the first-generation SPT camera, SPT-SZ (Vieira et al. 2013; Everett et al. 2020), we would expect ap-

proximately 25 strongly lensed and 23 unlensed DSFGs in the EDF-S (blue outline in Figure 4). Total source counts in this field are $\sim 1\sigma$ higher than those in Everett et al. (2020); that we find 114 DSFG candidates (i.e., and not 48) is under investigation. While some of the discrepancy can be attributed to flux boosting (see Section 4.1), it does not account for the entirety of the difference, and thus we attribute this mostly to random statistical fluctuation.

Extended sources: We find 23 extended sources in the catalog (17 inside EDF-S) based on the procedure described in Section 6.3. These sources span emission type—nine of 13 synchrotron-dominated extended sources have a radio association, indicating that these may be AGN with resolved radio lobes (e.g., AMI Consortium et al. 2011; Mahony et al. 2011) (one of the remaining four has a millimeter association and the other three have no counterparts flagged by our methods; upon visual inspection, two of the three may have radio counterparts just beyond the

Criterion	Number of sources (inside EDF-S)	% of sources (inside EDF-S)
Sources detected only at 95 GHz	120 (63)	20.0 (18.9)
Sources detected only at 150 GHz	48 (26)	8.0 (7.8)
Sources detected only at 220 GHz	146 (79)	24.3 (23.7)
Sources detected only at 95, 150 GHz	146 (85)	24.3 (25.4)
Sources detected only at 150, 220 GHz	79 (45)	13.1 (13.5)
Sources detected only at 95, 220 GHz	0 (0)	0.0 (0.0)
Sources detected in all three bands	62 (36)	10.3 (10.8)
Total number of sources	601 (334)	100 (55.6)
Synchrotron-dominated	324 (182)	53.9 (54.5)
Dust-dominated	277 (152)	46.1 (45.5)
DSFG (radio + infrared)	210 (114)	35.0 (34.1)

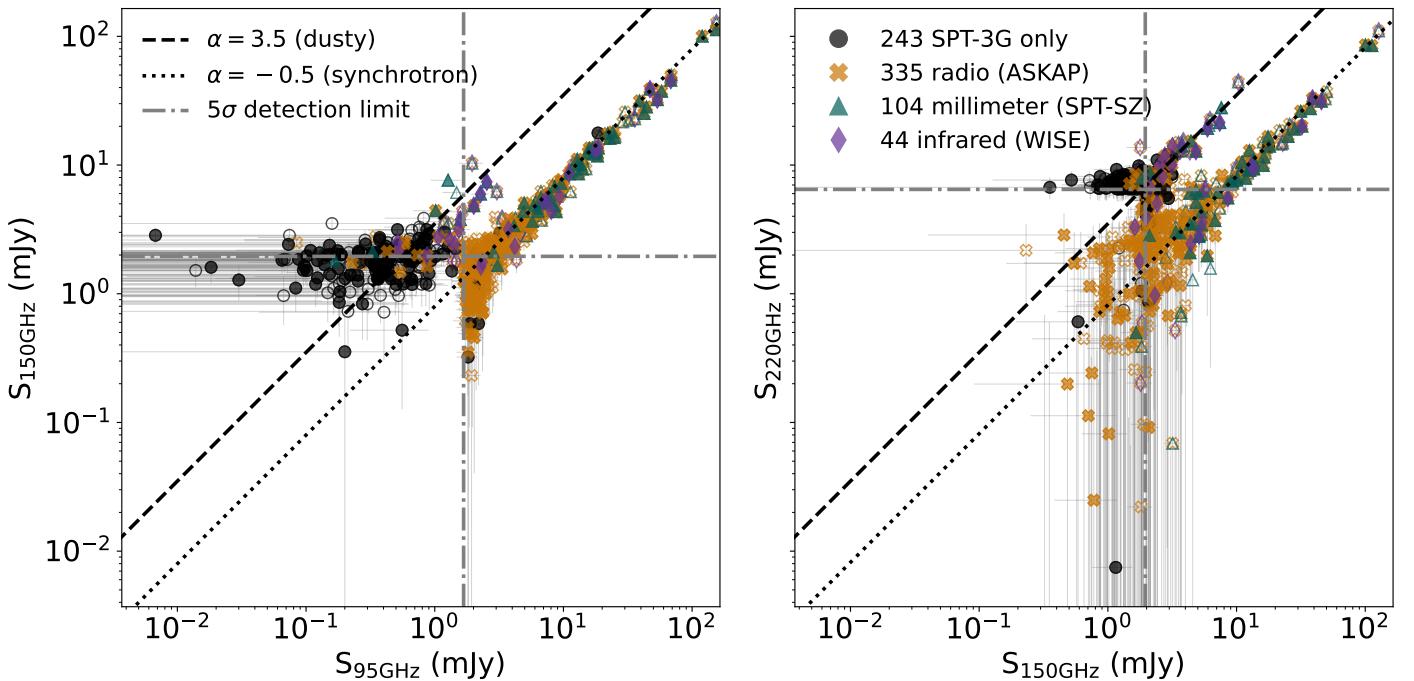


Fig. 5. The 150 GHz vs. 95 GHz fluxes (left panel) and 220 GHz vs. 150 GHz fluxes (right panel) of entries in the emissive source catalog. The sources' external counterparts are marked in black, orange, purple, and green to indicate no association, radio (ASKAP), infrared (WISE), and millimeter (SPT-SZ) associations, respectively. Sources inside the EDF-S footprint are indicated with filled-in symbols and sources outside the footprint are left unfilled. We note that 37 sources are omitted from the left panel and 43 from the right because their flux values are negative in one of the bands and thus cannot be log-scaled. The negative fluxes are a result of noise fluctuations from forced photometry in a source's non-detection band. Of the 80 omitted sources, 37 have no associations, 42 have radio counterparts, and one has an infrared counterpart. We also indicate typical spectral indices for synchrotron ($\alpha = -0.5$) and dusty ($\alpha = 3.5$) sources as dotted and dashed lines, respectively. Finally, we show the 5σ detection thresholds for catalog admission as dot-dash lines. In general, the brightest objects are synchrotron-dominated AGN and the dimmest objects are dust-dominated DSFGs.

threshold we use for association). One dust-dominated extended object is a local galaxy with an infrared counterpart, and seven of the 10 dust-dominated extended sources are flagged as DSFGs with few external counterparts; these sources will be studied further for galaxy protocluster candidacy. The last two non-DSFG, dusty, extended sources with no counterparts have slightly negative 95 GHz forced photometry.

6.2. Purity of emissive detections

We evaluate the purity of the 220 GHz detections by applying the source-finding procedure to the negative 220 GHz map, assuming that no peak in the negative map at 220 GHz is a genuine astrophysical source. This assessment is most important for the DSFG candidates which are most strongly detected at 220 GHz. We are unable to do the same test at 95 and 150 GHz because of the true tSZ decrements in these maps that are detected by the point-source-finding pipeline. There are no 220 GHz decrements above 5σ and just three detections above 4.5σ . The emissive source catalog we provide has a 5σ threshold, so the lack

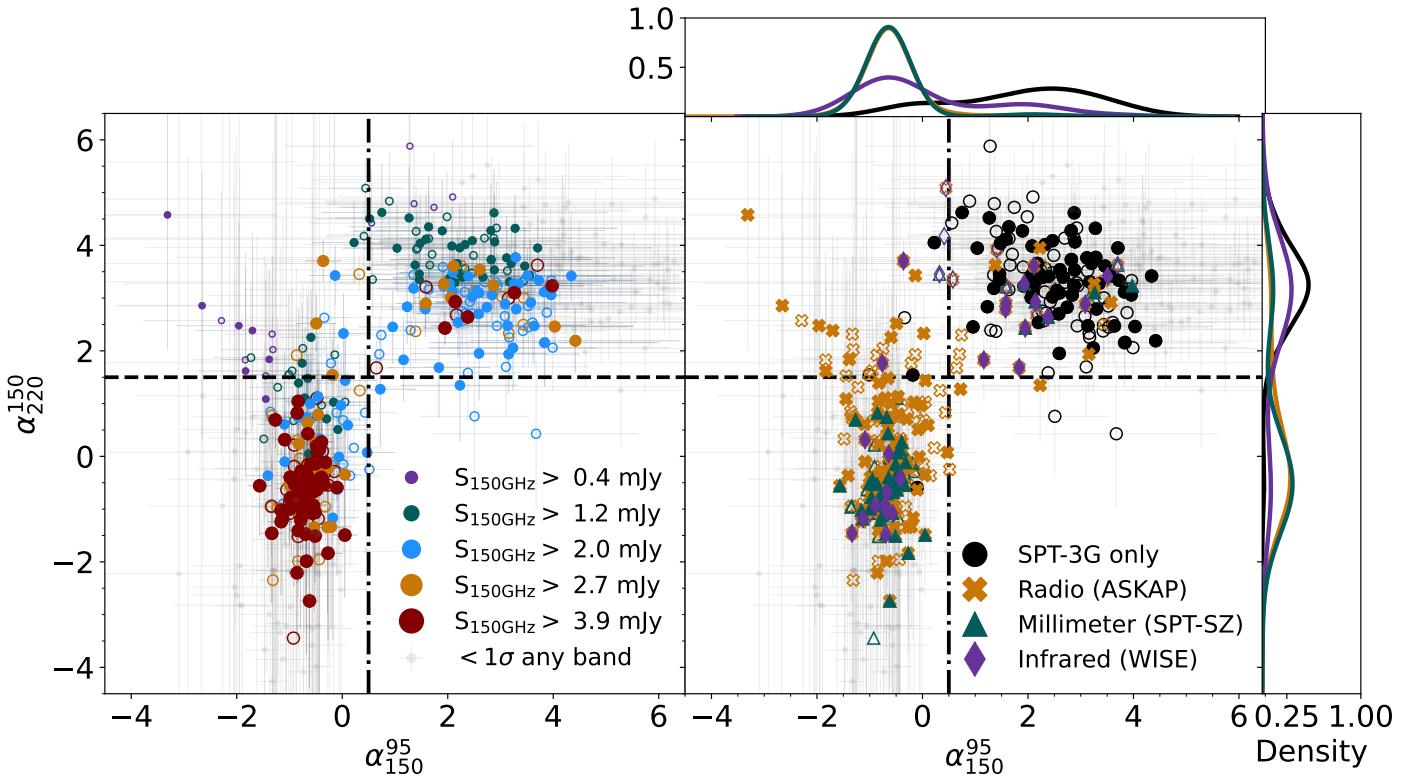


Fig. 6. Source spectral indices between 150 and 220 GHz vs. the spectral indices between 95 and 150 GHz. Note that 80 sources are omitted from the plots because their fluxes are below 0 and filled-in symbols indicate sources inside the EDF-S. *Left panel:* The sources are color-coded according to their 150 GHz flux values: 0.4, 1.2, 2.0, 2.7, and 3.9 mJy are roughly equivalent to 1, 3, 5, 7, and 10 σ detections. This view highlights the population separation between high signal-to-noise sources, which typically have synchrotron-dominated spectra, and dim sources which comprise the dusty population. *Right panel:* The sources are represented by colors and symbols according to their external catalog associations (see caption of Figure 5). In this view, we emphasize that sources with dust-dominated spectra are uniquely discovered by low-noise millimeter-wavelength surveys such as those conducted by the SPT. The top and right panels are the kernel density estimations of each α axis, showing the bimodal distributions in both α_{150}^{95} and α_{220}^{150} but especially how α_{220}^{150} can be used to assign a spectral type of synchrotron or dusty; in this analysis, we adopt the cut-off value of $\alpha_{220}^{150} = 1.5$ (marked by dotted lines).

of 220 GHz decrements indicates high purity of the catalog. A full completeness and purity assessment of the SPT-3G emissive source-finding procedure is the subject of a forthcoming work.

6.3. Flags in the emissive source catalog

We provide a few useful binary flags (1=True and 0=False) for each entry in the emissive source catalog: `edfs_flag`, which indicates whether the object lies in the footprint observed by *Euclid*; `extended`, which indicates whether the source is resolved in the SPT maps; and `dsfg_flag`, which indicates whether the source is a high-redshift DSFG candidate. The criteria for the flags are described in this section.

edfs_flag: We use a mask provided by the *Euclid* collaboration to assess whether objects in the SPT-3G catalog lie in *Euclid*'s EDF-S observational area. 55.6% of the total sources in the sample lie in the EDF-S footprint. Throughout this work, we provide numbers on both the EDF-S-only sources as well as the total sample.

extended: To determine source extension, we make a small cutout of the clean beam map (Figure 4) around every source, fit a two dimensional Gaussian to the cutout, and calculate the major and minor axis FWHM values. We then separate the single

band catalogs into bins of signal-to-noise and create a histogram of the FWHMs associated with each source in that bin. For all point-like sources, we expect a normal distribution of FWHMs when compared to sources at a similar detection level. The extended sources, then, have FWHMs that are outside this distribution. We set the extended threshold to be 3 σ from the median FWHM value in the signal-to-noise bin.

A source is flagged as extended in the catalog if one of its axes has a FWHM that is a $>3\sigma$ outlier and if this occurs for its highest detection significance band. If this occurs in a band other than the highest detection band, the extendedness is indeterminate. It may be an accurate representation of the data for a source to be extended in one band but not another, however we structure the information in this way so that we do not make a strong determination on extendedness based on information from lower-significance detection bands. Using these criteria, 23 (17) sources are flagged as extended, 29 (12) sources are indeterminate, and 549 (305) are not extended (inside EDF-S).

dsfg_flag: We further scrutinize the dust-dominated group to select DSFG candidates that we then flag in the catalog. Following the selection criteria in Everett et al. (2020), we restrict the DSFG candidate sample to sources with strictly rising spectra ($\alpha_{150}^{95} > 0.5$ in addition to $\alpha_{220}^{150} > 1.5$, which includes forced photometry values for sources below the detection threshold) and no infrared counterpart. When applied to the SPT-SZ cat-

alog, these criteria yielded 506 DSFG candidates (out of 4,845 total for $\sim 10\%$ of the sample). We find 210 sources out of 601 (34.9% of the sample) in this catalog are DSFG candidates by the same standards and 114 of these objects lie in the EDF-S region observed by *Euclid*. The reason for the drastic increase in the fraction of DSFG candidates is the improved map depths of the SPT-3G EDF-S observations that reveal more sources along the steep luminosity function of dusty sources. These cuts are agnostic towards lensed and unlensed DSFGs because the differentiation between them cannot be constrained with the arcminute-resolution SPT data alone.

6.4. Cross-matching with external catalogs

To assist in characterizing the properties of the objects, we associate the emissive source catalog with multiwavelength datasets using external radio, millimeter, and infrared catalogs. For cross-matching to the millimeter catalog, we associate sources inside radial distances calculated using Equation 17:

$$r_{\text{assoc}} = \sqrt{2 \left[(\Delta SPT)^2 + \left(\frac{\Gamma_{\text{SPT}}}{5} \right)^2 \right]} \quad (17)$$

where ΔSPT is the positional uncertainty for SPT (rounded up to 5 arcsec), Γ_{SPT} is the beam FWHM for SPT at 150 GHz (1.2 arcmin), and the denominator 5 is the signal-to-noise of the detection (set at 5 for all sources, which is the lowest possible detection value); the result is 43.2 arcsec. For the radio and infrared catalogs which have significantly greater source densities and smaller beam sizes, we use a 30 arcsec association radius. These choices result in probabilities of random association, $P(\text{random}) = \Sigma \cdot \pi \cdot r_{\text{assoc}}^2$, where Σ is catalog source density, that are $\leq 2\%$ for all catalogs.

Though we experimented with varying the distance threshold depending on the SPT signal-to-noise of the detection, we found that it did not significantly improve or affect the results. We cross-match the following external datasets whose relevant characteristics are outlined in Table 4.

ASKAP: The Rapid ASKAP Continuum Survey (RACS) from the Australian Square Kilometre Array Pathfinder (ASKAP; RACS-low at 887.5 MHz, Hale et al. 2021; RACS-mid at 1367.5 MHz, Duchesne et al. 2024; and RACS-high at 1655.5 MHz, Duchesne et al. 2025) has 343 total matches. We separately cross-match the emissive source catalog to each of the ASKAP bands because the catalogs were treated as independent entities in their release. In the SPT-3G catalog file, we indicate only if the SPT detection was associated with a source in any of the ASKAP bands (see the “Counterparts” column of Table B.2). As previously mentioned, $\sim 95\%$ of the synchrotron sources have a radio counterpart in ASKAP, which is consistent with our understanding of the AGN emission mechanism from radio to millimeter wavelengths. Future and ongoing radio surveys in the southern hemisphere with the Square Kilometre Array mid-frequency array and its precursors, MeerKAT (Jonas & MeerKAT Team 2016) and ASKAP, will provide further constraints and discriminatory power for the SPT-3G emissive sources.

SPT-SZ: The SPT-SZ survey at 95, 150, and 220 GHz (Everett et al. 2020) has 104 matches. The SPT-SZ 4.5σ detection limits

are 9.8, 5.8, and 20.4 mJy in 95, 150, and 220 GHz, respectively (or factors of 7, 3.6, and 3.9 higher than the 5σ thresholds presented here). The first-generation SPT survey completely covers the EDF-S, enabling some direct comparisons: one strongly-lensed DSFG, SPT-S J041839-4751.9, is in the EDF-S, and has a spectroscopic redshift of 4.2 from the Atacama Large Millimeter/submillimeter Array (ALMA, Reuter et al. 2020) and characterization from *James Webb Space Telescope (JWST)* observations (Rigby et al. 2025). As a comparison, we also checked the Atacama Cosmology Telescope Southern Surveys point source catalog at 150, 220, and 280 GHz (ACT, Vargas et al. 2023) and confirmed all SPT-3G matches in ACT were also matched to SPT-SZ. Only $\sim 5\%$ of sources classified as dusty in SPT-3G are associated with SPT-SZ sources, meaning that the vast majority of dusty sources in this work are new discoveries.

WISE: WISE at 22 μm (band 4) only (Cutri et al. 2021) has 44 matches. We use counterparts from WISE to flag low-redshift infrared galaxies. In Everett et al. (2020), the Faint Source Survey (FSS) from the Infrared Astronomical Satellite at 12, 25, 60, and 100 μm (IRAS, Moshir & et al. 1990) was used for this purpose. We do not expect the WISE maps to be sensitive to the (largely obscured) stellar emission of DSFGs, whereas low-redshift infrared galaxies are bright at 22 μm . We emphasize that we only associate with sources brighter than 8.05 magnitudes (5.0 mJy) in WISE band 4, which is approximately 5σ , rather than the entire WISE catalog, which would result in numerous false associations. Less than 10% of dusty SPT-3G sources have a WISE counterpart, indicating that a small fraction of SPT-3G dusty sources are at low redshift or are rare, mid-infrared-bright strongly lensed galaxies at $z \sim 1.5 - 2$ (Díaz-Sánchez et al. 2017, 2021). As a check, we also cross-matched with IRAS and confirmed that SPT-3G matches in IRAS are all included in the WISE matches.

There are 243 sources in the emissive sample with no multiwavelength counterparts. We show the fluxes and spectral indices for sources in the catalog indicated by their external associations in Figures 5 and 6; in general, synchrotron sources have a radio counterpart while dusty sources are more likely to be unassociated. Both synchrotron and dusty sources have infrared and millimeter counterparts. Over 90% of the sources without counterparts are classified as dust-dominated, highlighting the distinctive ability of millimeter surveys to discover sources unable to be detected at other wavelengths.

6.4.1. Cross-matching with *Euclid* Q1 catalogs

As discussed in the previous sections, millimeter-selected DSFGs have been found to also be members of rare subpopulations: strongly gravitationally lensed systems and galaxy protoclusters. We would like to investigate the comparative strengths and weaknesses of the SPT and *Euclid* for the discovery and characterization of such sources. It is known from the previous SPT emissive source catalog (Vieira et al. 2013) that a significant fraction of SPT-selected sources are strongly gravitationally lensed. Though the background sources are expected to be obscured in the optical bands, using *Euclid* data to characterize some of the lensing systems would increase efficiency over individual-source follow-up of SPT DSFGs. SPT-selected protoclusters may also be constrained by characteristics in the *Euclid* data that the SPT cannot observe. The *Euclid* Q1 release included a strong lens catalog (Euclid Collaboration et al. 2025d) and the *Euclid* view of *Planck* protoclusters (Euclid Collaboration et al. 2025e).

Survey	Band	Beam FWHM	Σ (deg $^{-2}$)	r_{assoc} (arcsec)	$P(\text{random})$ (%)	N. sources
ASKAP low	887.5 MHz	25 arcsec	87.0	30.0	1.9	328
ASKAP mid	1367.5 MHz	25 arcsec	83.3	30.0	1.8	327
ASKAP high	1655.5 MHz	25 arcsec	86.2	30.0	1.9	326
AT20G	20 GHz (1.5 cm)	4.6 arcsec	0.3	30.0	0.01	18
SPT-SZ	95, 150, 220 GHz	1.7, 1.2, 1.0 arcmin	2.2	43.2	0.1	104
WISE	22 μ m	12 arcsec	32.6	30.0	0.7	44
SPT-3G	95, 150, 220 GHz	1.8, 1.2, 1.0 arcmin	10.6	43.2	0.5	243 [†]

Table 4. Characteristics of the external catalogs with which the emissive point source catalog is cross-matched and results of the cross-matching. We took into consideration the relative beam sizes and source densities when determining the association radii, ensuring $P(\text{random})$ is $\leq 2\%$. The single-band SPT-3G source densities are 5.8, 5.9, and 5.0 sources per square degree for 95, 150, and 220 GHz, respectively. [†]This number reflects sources without counterparts in any of the listed surveys.

tion et al. 2025c) with which we compare the SPT sample. These comparisons are not meant to be exhaustive, but rather provide a first look at SPT-selected DSFGs in *Euclid* with some deeper insight on the classifications of the sources as strong lens and protocluster candidates.

We use a 43.2 arcsec radial association threshold to match to the strong lens catalog and a 5 arcmin threshold to match to the protoclusters, as was used in Euclid Collaboration et al. (2025c). The results of the cross-matching are in Tables B.1 and B.2, showing seven matches to strong lenses (out of over 1 000 in the EDF-S) and five matches to *Planck* protoclusters (out of seven in the EDF-S). There are no matches to grade A strong lenses, one match to grade B, and six matches to grade C lenses. Just two of the lens matches are flagged as DSFG candidates; this low number may indicate that the types of strong lens systems that SPT and *Euclid* respectively probe are different.

Euclid Collaboration et al. (2025c) presents seven *Planck* protoclusters in the EDF-S for comparison and recovers two *Euclid* counterparts. We associate five SPT sources from the list of seven, including the two that Euclid Collaboration et al. (2025c) recovers (SPT-S J040259-4711.6 and SPT-S J041604-4926.0); of the five, four are flagged as DSFGs. While further study is required to fully design a joint protocluster search using SPT and *Euclid* data, it appears promising that millimeter-wave surveys can flag possible candidates while *Euclid* can help distinguish them from DSFGs.

In Figure 7, we show two DSFG-flagged sources from the emissive source catalog (lower panels) as seen in *Euclid* data (H, Y, and VIS as rgb colors). Here, we highlight a SPT strong lens candidate in the lower right panel that is not associated with an object in the Euclid Collaboration et al. (2025d) strong lens catalog. We show a protocluster candidate in *Euclid* data in the lower left panel of Figure 7. It is not one of the *Planck* protocluster matches—its protocluster candidacy is based on its SPT characteristics and visual identification of an apparent overdensity of red galaxies at the SPT location.

7. Results: galaxy cluster catalog

We present a tSZ-selected galaxy cluster catalog over the 57-square-degree SPT-3G EDF-S patch. The catalog contains 217 candidates detected at $\xi > 4$, with 121 located in the 30-square-degree EDF-S patch. This is a cluster density of 3.81 clusters per square degree which is an order of magnitude improvement over previous tSZ-selected cluster catalogs in this region. We provide the equatorial coordinates, detection significance, core size, and estimates of the redshift and mass for each optically confirmed (see Section 4.2.1) candidate in the catalog, which is accessible online with catalog quantities described in Table B.4. In the top

panels of Figure 7 we show two examples of high-redshift clusters found by the SPT in this sample; the tSZ detection contours are overlaid onto imaging data from the *Euclid* Q1 release.

In this section, we analyze the purity and completeness of the cluster sample and draw comparisons to other ICM-selected cluster samples in the SPT-3G EDF-S region. Drawing comparison statistics to other tSZ-selected ICM catalogs shows the advances that have been made in the past several years in obtaining higher cluster counts. Comparing to X-ray catalogs, on the other hand, shows the power of the redshift independent tSZ selection and the different mass regimes that these two methods probe.

Using the optical confirmation criterion described in Section 4.2.1, we report 188 clusters with redshifts (87% of the catalog). We find the median redshift of the cluster sample to be $z = 0.70$ and the total redshift range spanned is $0.07 < z \lesssim 1.6+$ with 49 clusters found above $z > 1$. We are conservative with our high-redshift estimates as there are many uncertainties at $z > 1.6$. We refer the reader to the discussion of these uncertainties in Kornoelje et al. (2025); Bleem et al. (2024) and report all redshifts $z > 1.6$ in a lower bound $z = 1.6+$ bin. The median mass of the sample is $M_{500c} = 2.12 \times 10^{14} M_{\odot}/h_{70}$ with a minimum of $M_{500c} = 1.43 \times 10^{14} M_{\odot}/h_{70}$. MCMF (described in Section 4.2.1) provides excellent redshift precision ($\sigma_z/(1+z)=0.005$) at $z < 1.1$, with degraded precision and confirmation power at higher redshifts ($\sigma_z/(1+z)=0.03$), owing to the limitations of the WISE data. Data from *Euclid* is expected to significantly improve both cluster confirmation and redshift precision for systems at higher redshift. In Figure 8 we show the mass-redshift distribution of the SPT-3G EDF-S sample as compared to wide field samples from *Planck* (Planck Collaboration et al. 2016b), eROSITA (Bulbul et al. 2024), ACT (Hilton et al. 2021), and SPT (Bleem et al. 2020; Klein et al. 2024a; Bleem et al. 2024; Kornoelje et al. 2025, combined), marking in bold those clusters in the SPT-3G EDF-S footprint. As can be seen here and in Figure 10, the SPT sample greatly expands the population of high-redshift ICM-selected clusters in the EDF-S region.

7.1. Completeness and purity of the cluster sample

We estimate the purity and completeness of the SPT-3G EDF-S cluster catalog. Both quantities are a function of significance that worsen near the detection threshold ($\xi = 4.0$).

We model the completeness as the probability that a cluster of a given mass and redshift is detected in the SPT-3G EDF-S field. The completeness is modeled in significance as a Heaviside function of the form $\Theta(\xi-4.0)$, which is translated into completeness in mass and redshift using Equation 14. The conversion considers both the intrinsic scatter from the ζ -mass relationship and the observational scatter on ξ , as discussed in Section 4.2.3.

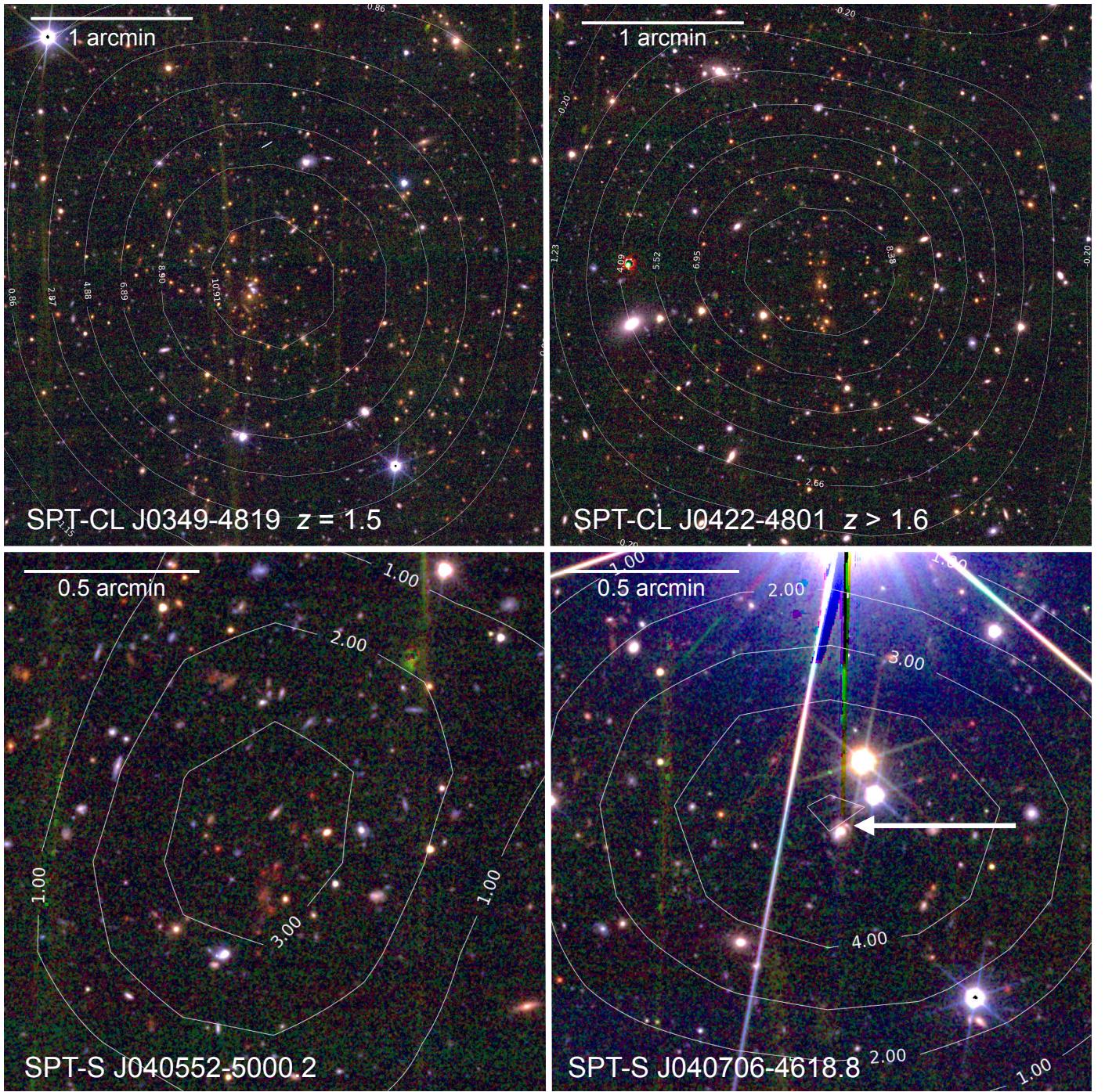


Fig. 7. We show SPT detection contours overlaid on *Euclid* (rgb) H, Y, and VIS imaging from the Q1 data release for four detections in our catalogs. *Top row*: Two tSZ identified clusters from the SPT-3G EDF-S survey (Section 7). These images highlight the sensitivity of both SPT and *Euclid* to high-redshift galaxy clusters. *Bottom row*: Two examples of DSFGs in the emissive SPT-3G source catalog (Section 6). In the bottom left we show a protocluster candidate characterized as a DSFG and associated with the approximately dozen red dots centered at the SPT location. In the bottom right, we show a strongly lensed DSFG candidate, identified by the “halo” feature at the SPT location indicated by an arrow. The visible arc may be an unobsured component of the background DSFG. This strong lens candidate is not identified in the *Euclid* Q1 strong lens catalog, possibly pointing to differences in strong lens selections between *Euclid* and SPT.

We find that the SPT-3G EDF-S cluster catalog is $> 90\%$ complete at masses above $2.5 \times 10^{14} M_\odot/h_{70}$ at $z > 0.25$, shown in the left panel of Figure 9.

We define the purity as the percent of candidate detections that are true galaxy clusters at a given detection significance. We quantify the purity of the cluster sample by detecting clusters in a set of 20 simulated SPT-3G EDF-S-like maps. The construction of the simulated temperature maps follows methods in Korpel et al. (2020) and noelje et al. (2025). We summarize the process as follows: first, we construct a set of Gaussian realizations of the CMB from the best-fit lensed *Planck* 2018 Λ CDM primary CMB parameters (Planck Collaboration et al. 2016b). We do the same for the kSZ and a background of faint dusty sources, which are constructed from the best-fit spatial and spectral values from Reichardt et al. (2021).

We do the same for the kSZ and a background of faint dusty sources, which are constructed from the best-fit spatial and spectral values from Reichardt et al. (2021).

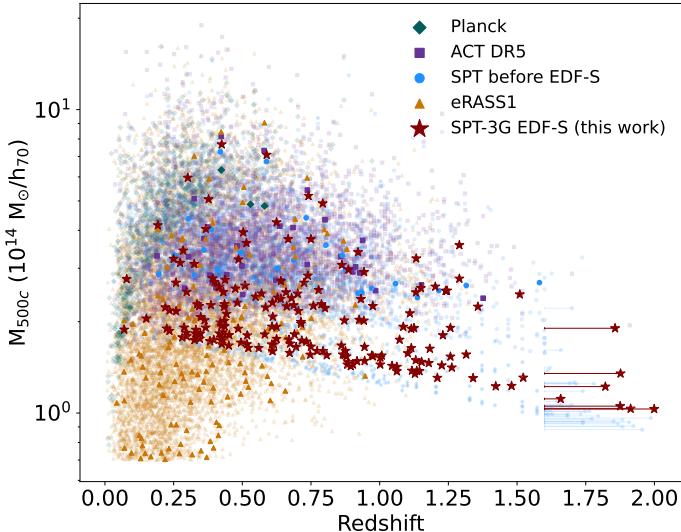


Fig. 8. Mass vs. redshift for the SPT-3G EDF-S cluster catalog compared to samples from other ICM-based wide field cluster surveys. In pale shading we include all clusters from published catalogs and, in bold, clusters in the SPT-3G EDF-S footprint. We plot sources from this work (red stars), *Planck* (green diamonds, Planck Collaboration et al. 2016b), ACT (purple squares, Hilton et al. 2021), eROSITA (orange triangles, Bulbul et al. 2024), and prior SPT samples (blue circles, Bleem et al. 2020; Klein et al. 2024a; Bleem et al. 2024; Kornoelje et al. 2025). The SPT-3G sample extends to significantly lower masses at high redshift than previously published works in the EDF-S region. Finally, note that as we only have lower redshift limits for SPT clusters at $z > 1.6$ (see Section 4.2.1), clusters at higher redshifts are plotted with redshifts drawn from a mass function for our fiducial Λ CDM cosmology.

The remaining simulated map components—the tSZ signal, radio galaxies, and instrumental noise—are not Gaussian realizations of an input power spectrum. The simulated tSZ maps are made by pasting tSZ profiles at the locations of massive halos in a lightcone from the Outer Rim simulation (Heitmann et al. 2019); the maps produced from this process are rescaled such that the amplitude of the tSZ power spectrum matches that measured in Reichardt et al. (2021) at $\ell = 3000$. Radio galaxies are populated in the simulated maps using the point source flux distribution from Lagache et al. (2020). We assume a spectral index of -0.7 and -0.9 with a scatter of 0.3 to rescale the point source maps made at 150 GHz to 95 GHz and 220 GHz, respectively. We finally use instrumental noise maps described in Section 4.

We apply the cluster-finding procedure described in Section 4.2 to the simulated maps to best mimic the detection and catalog generation pipeline. Following Bleem et al. (2024), we associate candidate tSZ detections with halos from the Outer Rim simulation to probabilistically estimate the number of false detections in the maps. The final purity estimates are shown in the right panel of Figure 9 as a function of detection significance. We find that the SPT-3G EDF-S cluster sample is 87% pure above the detection threshold $\xi = 4$, which correspondingly predicts about 30 false detections, consistent with the number of candidates without optical confirmations. When considering the subsample of clusters that have optical confirmations, the purity is 97%.

7.2. Comparisons to other ICM-selected cluster catalogs

We compare the cluster sample to subsamples of other ICM-selected galaxy cluster catalogs. In general, the SPT-3G EDF-S cluster sample spans a wider redshift range and significantly

increases the number of confirmed clusters when compared to other samples over the same sky area. We show the redshift distribution of multiple samples overlapping the SPT-3G EDF-S footprint in Figure 10. We also cross-match our catalog with these external catalogs with a 1.5 arcmin matching radius. We calculate the median angular separation and mass ratios for the matches with uncertainties on the medians estimated by bootstrapping the respective data vectors for angular separation and mass ratio. More details are provided on the cross-comparisons between SPT and other surveys in this section.

eRASS1 The SRG/eROSITA All-Sky Survey (eRASS1) cataloged 12 000 galaxy clusters over 13 116 square degrees of the western galactic hemisphere by identifying hot overdensities in the ICM from X-ray emission over the energy range 0.2 – 10 keV, with the majority of the sensitivity to hot gas in the ICM coming from the “soft X-ray” energy range (0.2 – 2.3 keV, Bulbul et al. 2024). In the SPT-3G EDF-S patch of sky, the eRASS1 catalog contains the largest subsample of galaxy clusters with 167 X-ray-selected candidates, which have a median redshift of $z = 0.32$ and span the redshift range $0.04 < z < 0.99$. The eRASS1 subsample has a median mass of $M_{500c} = 1.3 \times 10^{14} M_\odot/h_{70}$ with a minimum of $M_{500c} = 0.083 \times 10^{14} M_\odot/h_{70}$, which is over an order of magnitude lower than the SPT-3G minimum mass.

The eRASS1 catalog is complementary to our work as it has comparable cluster counts, but has a lower median redshift. Of the 167 eRASS1 clusters, we cross-match 61 to the SPT-3G EDF-S cluster catalog. The median angular separation between the SPT-3G (millimeter) and eRASS1 (X-ray) is 0.31 ± 0.11 arcmin and the samples have a median mass ratio, $M_{\text{eRASS1}}/M_{\text{SPT}}$, of 1.20 ± 0.10 . Kornoelje et al. (2025) found a similar mass discrepancy between the cluster sample from the SPT-3G+SPTpol deep field and eRASS1 which shows that there is future work to be done to explain this discrepancy; such work is outside the scope of this paper. We recover 73% of the eRASS1 clusters that are located within the SPT-3G EDF-S patch with mass $> 2 \times 10^{14} M_\odot/h_{70}$. We recover 90% of the clusters with masses greater than $3 \times 10^{14} M_\odot/h_{70}$. Three of the 12 unmatched X-ray clusters with mass $> 2 \times 10^{14} M_\odot/h_{70}$ fall inside the bright point source mask holes described in Section 3.4. We do not expect to detect the majority of X-ray clusters with mass less than $2 \times 10^{14} M_\odot/h_{70}$ and at low redshift ($z < 0.25$) due to our atmospheric filtering suppressing an already weak tSZ signal (see Figure 9, left panel).

ACT DR5 The fifth data release of the Atacama Cosmology Telescope (ACT DR5, Hilton et al. 2021) included a tSZ-selected galaxy cluster catalog using the 98 and 150 GHz channels over 13 211 square degrees of sky. From this sample, 4 200 clusters at significance > 4 were optically confirmed. We find a subsample of 29 ACT clusters in the SPT-3G EDF-S footprint with a median redshift of $z = 0.58$ that span the redshift range $0.19 < z < 1.38$. The subsample has a median mass of $M_{500c} = 3.05 \times 10^{14} M_\odot/h_{70}$ with a minimum of $M_{500c} = 2.39 \times 10^{14} M_\odot/h_{70}$.

We match 25 ACT DR5 clusters in the SPT-3G EDF-S field. Of the remaining four unmatched clusters, two line up with bright source mask holes. The median angular separation between the matched clusters from SPT-3G and ACT is 0.31 ± 0.14 arcmin, which is similar to the matching to eRASS1. The median mass ratio is 0.99 ± 0.14 , showing the mass estimation between these two tSZ-selected catalogs is in agreement.

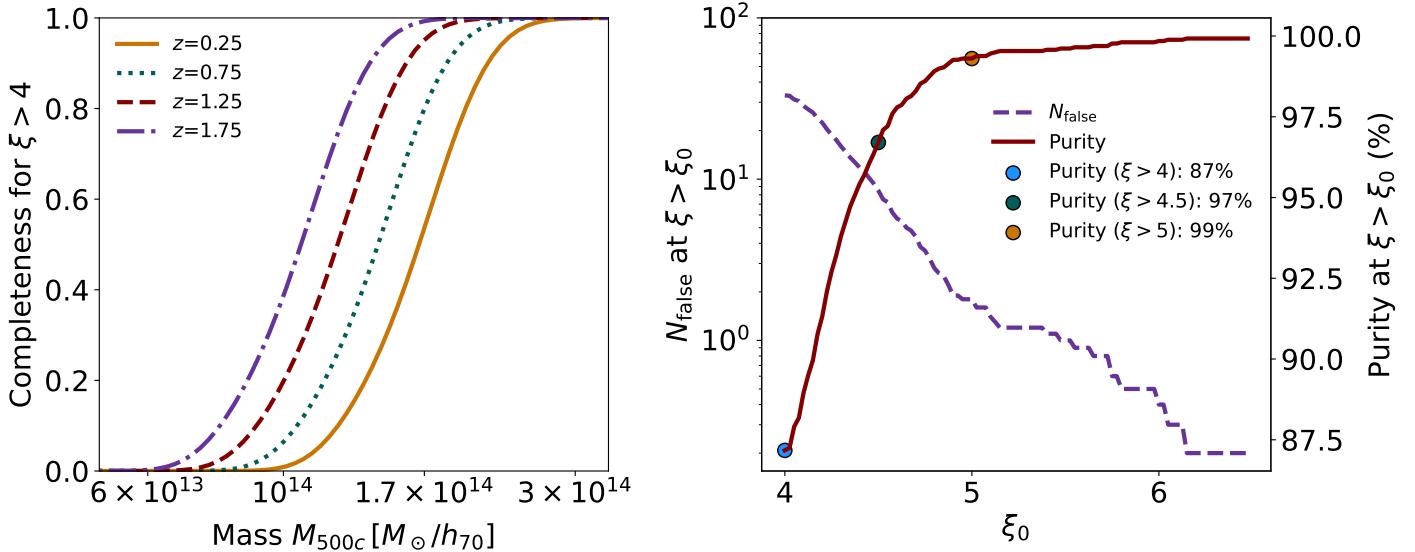


Fig. 9. *Left:* The completeness of the SPT-3G EDF-S cluster catalog as a function of mass at four different slices in redshift, $z = 0.25, 0.75, 1.25$, and 1.75 . The sample is expected to be $> 90\%$ complete above $2.5 \times 10^{14} M_\odot/h_{70}$ at $z > 0.25$. *Right:* The number of false detections and purity of the cluster catalog as a function of minimum detection significance. We find a similar purity of 99% at $\xi > 5$ as was found in previous SPT publications and a purity of 87% above the minimum significance threshold of $\xi = 4$, corresponding to about 30 predicted false detections in the catalog.

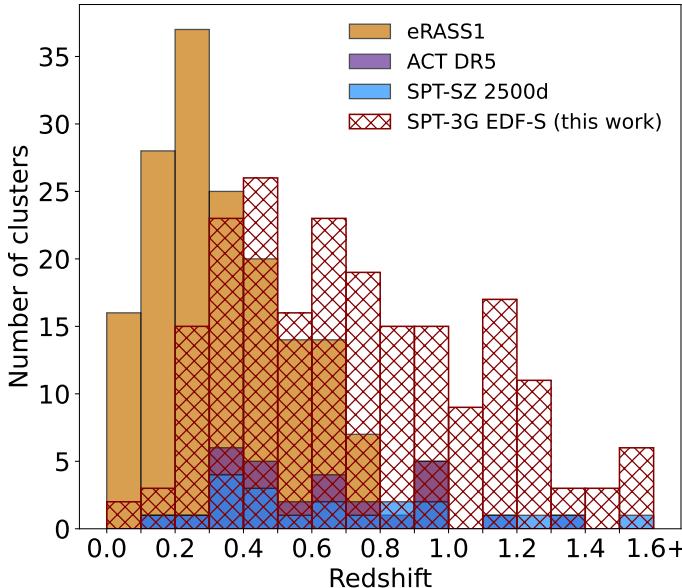


Fig. 10. The redshift distribution of the SPT-3G EDF-S clusters and other ICM-selected clusters in the SPT-3G EDF-S footprint. The SPT-3G EDF-S cluster sample (red hatch pattern) has a median redshift of $z = 0.70$ and spans the range $0.07 < z \leq 1.6 +$. The eRASS1 (X-ray, yellow) subsample has 167 clusters, a median redshift of $z = 0.32$, and spans the range $0.04 < z < 0.99$ (Kluge et al. 2024). The 29 ACT DR5 clusters have median redshift $z = 0.58$ and their redshifts span the range $0.19 < z < 1.38$ (purple, Hilton et al. 2021). We also compare to the SPT-SZ subsample of 24 clusters (blue, Bleem et al. 2015; Klein et al. 2024a). This subsample has a median redshift of $z = 0.58$ and spans the range $0.24 < z < 1.38$. The SPT-3G EDF-S cluster sample significantly increases the number of ICM-selected clusters in this patch, especially at high redshift ($z > 1$).

SPT-SZ 2500d The SPT-SZ cluster catalog over 2500 square degrees contains 343 tSZ-selected clusters with $\xi > 4.5$ (Bleem et al. 2015; Klein et al. 2024a). We find 20 of these clusters in the SPT-3G EDF-S footprint with a median redshift of $z = 0.38$.

and spanning the redshift range $0.24 < z < 1.38$. The subsample has a median mass of $M_{500c} = 3.65 \times 10^{14} M_\odot/h_{70}$ and a minimum mass of $M_{500c} = 3.15 \times 10^{14} M_\odot/h_{70}$. We match 16 SPT-SZ clusters in the SPT-3G EDF-S sample with a median angular separation of 0.23 ± 0.09 arcmin and a median mass ratio of 0.97 ± 0.10 , showing these catalogs are also in agreement as expected.

This work shows an increase in cluster counts of nearly an order of magnitude over previous tSZ-selected cluster catalogs in the same region. Our catalog also offers a complementary higher median redshift sample to eRASS1. 59 of the SPT-3G EDF-S clusters are found at high redshift ($z > 1$), which is more than 10 and 30 times more high-redshift clusters than SPT-SZ and ACT DR5, respectively. Our catalog maintains the tSZ-selected cluster paradigm of a sample with high median redshift ($z=0.70$) which will be matched or improved upon by future SPT-3G catalogs.

7.3. Comparisons to Euclid Q1 data

The photometric redshifts we report in this work are derived from a combination of DES and WISE data. As a consistency check, we also used an early adaptation of MCMF that uses *Euclid* Q1 data and find strong photometric redshift agreement: the median $\Delta_z/(1+z) = 0.0002$ based on 107 clusters.

As a second point of comparison, Euclid Collaboration et al. (2025b) presented an optical and infrared-selected cluster sample of 426 galaxy clusters detected at high signal-to-noise using both the AMICO (Maturi et al. 2019) and PZWav (Thongkham et al. 2024) algorithms in the full 63-square-degree Q1 data. The primary sample spanned redshift $0.2 \leq z \leq 1.5$ and an additional 15 systems at $z > 1.5$ were also identified. Of this 426 member sample, 35 of the highest signal-to-noise detections in the Q1 fields are publicly released as of this publication.

We first compare the SPT-3G EDF-S cluster candidate list to the 18 clusters released so far in the EDF-S Q1 field at $z < 1.5$; this *Euclid* subsample has a median redshift of $z = 0.56$. For

these 18 systems, we find matches for 13 clusters within a 1.5 arcmin matching radius. The median spatial separation is 0.39 arcmin and maximum 0.75 arcmin. The median difference in redshift (adopting the AMICO redshifts for reference) is $0.018/(1+z)$ with a maximum absolute difference of $0.04/(1+z)$, showing excellent agreement between our DES and WISE estimated redshifts and the *Euclid* derived redshifts.

Investigating the five systems without a match in the SPT catalog, we do not find any with tSZ signal in the SPT maps higher than 2.6σ at a 0.25 arcmin spatial filter scale. We also do not find any of these unmatched clusters aligned with bright source mask holes. Euclid Collaboration et al. (2025b) report cluster richesses which gives an indication of cluster mass; of the five unmatched clusters, four of them have low richesses, therefore not detecting them in SPT is consistent with our expectations of completeness at low mass (see the left panel of Figure 9).

Comparing the five $z > 1.5$ clusters released in EDF-S, we find a spatial match between our full candidate list with one system (EUCL-Q1-CL J034533.23–500806.7) at 0.3 arcmin separation, but at highly discrepant redshifts ($z_{\text{AMICO}} = 1.78$ versus $z_{\text{SPT}} = 1.18$, we note however the MCMF run on *Euclid* data does identify a counterpart at $z = 1.7$, so the DES and WISE data might be too shallow in this case). While this is just a single cluster, exploration of such discrepancies on larger joint samples using upcoming data from the respective experiments' wide field surveys will be valuable for understanding the construction of well-characterized cluster samples.

The analysis of *Euclid* data will be informed by tSZ cluster catalogs sampled over a large redshift range, while SPT-3G cluster science will benefit from deriving redshift information from *Euclid*'s state-of-the-art photometric data. The collaboration between SPT-3G and *Euclid* will produce galaxy cluster samples with significant power for constraining cosmology and has implications for studying the formation history of clusters through targeted follow-up observations. These advancements in analysis of galaxy clusters would not be possible with either SPT-3G or *Euclid* data alone.

8. Conclusion

In this work, we presented millimeter-wave maps and source catalogs from SPT-3G observations of the *Euclid* Deep Field South. Though the EDF-S is 30 square degrees, we include all the data from our 57-square-degree observations. The data correspond to 20 days of on-source observation time with SPT-3G where we reached map noise depths of 4.6, 3.8, and $13.2 \mu\text{K}\text{-arcmin}$ at 95, 150, and 220 GHz, respectively. We processed the data to optimize source detection by retaining the small-angular-scale features of the maps. We used two separate, but related, pipelines to generate an emissive source catalog and a galaxy cluster catalog, and we showed how millimeter selection of the various source populations, especially DSFGs and galaxy clusters, has unique benefits over selections at other wavelengths.

The emissive source catalog comprises 601 objects in total (334 inside EDF-S). 53.9% of the emissive sources are synchrotron-dominated AGN, the majority of which have radio counterparts. The other 46.1% are dust-dominated galaxies where approximately one in three lacks a counterpart in external datasets and has spectral behavior characteristic of high-redshift DSFGs. The population of high-redshift DSFGs is of current interest in studies of galaxy evolution, as their observed physical properties are not fully understood with current models of mass assembly in the early Universe.

The galaxy cluster catalog includes 217 total clusters (121 inside EDF-S) with an expected purity of 87%. We used previously-demonstrated methods to obtain redshifts for 188 clusters; the median redshift of the sample is 0.70 with 49 clusters above $z > 1$. The purity of the optically confirmed subsample rises to 97%. The masses for the EDF-S catalog span $M_{500c} = 1.43 \times 10^{14} M_{\odot}/h_{70}$ to $M_{500c} = 7.85 \times 10^{14} M_{\odot}/h_{70}$ with median $M_{500c} = 2.12 \times 10^{14} M_{\odot}/h_{70}$. The sample presented in this work increases the number of tSZ-selected clusters in the SPT-3G EDF-S patch by nearly an order of magnitude with a high median redshift that is complementary to X-ray-selected clusters, such as those detected by eROSITA.

The SPT-3G data and catalogs described in this work, when combined with the deep *Euclid* optical and infrared data in EDF-S, are designed to enable joint projects on a range of topics in astrophysics and cosmology. These topics include: studies of strongly lensed galaxies and protoclusters, the physical properties of the most luminous unlensed DSFGs, redshift and weak lensing mass estimations of galaxy clusters, as well as cluster galaxy populations. Looking further ahead, the SPT-3G collaboration intends to perform cosmological studies on CMB lensing maps constructed from the EDF-S observations discussed in this work, as well as cross-correlation studies of galaxy counts with CMB lensing and galaxy-shape derived weak lensing with the tSZ effect. The observations and data products presented here provide a framework for future collaborative efforts of multi-wavelength astrophysical and cosmological analyses from the *Euclid* and SPT-3G wide field surveys.

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2015), which is supported by the National Science Foundation awards #2030508 and #2323298.

Some of the results in this paper have been derived using the `healpy` and `HEALPix` packages.

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This scientific work uses data obtained from Inyarrimanha Ilgari Bundara, the CSIRO Murchison Radio-astronomy Observatory. We acknowledge the Wajarri Yamaji People as the Traditional Owners and native title holders of the Observatory site. CSIRO's ASKAP radio telescope is part of the Australia Telescope National Facility (<https://ror.org/05qajvd42>). Operation of ASKAP is funded by the Australian Government with support from the National Collaborative Research Infrastructure Strategy. ASKAP uses the resources of the Pawsey Supercomputing Research Centre. Establishment of ASKAP, Inyarrimanha Ilgari Bundara, the CSIRO Murchison Radio-astronomy Observatory and the Pawsey Supercomputing Research Centre are initiatives of the Australian Government, with support from the Government of Western Australia and the Science and Industry Endowment Fund. This work includes archived data obtained through the CSIRO ASKAP Science Data Archive, CASDA (<http://data.csiro.au>).

The Legacy Surveys consist of three individual and complementary projects: the Dark Energy Camera Legacy Survey (DECaLS; Proposal ID #2014B-0404; PIs: David Schlegel and Arjun Dey), the Beijing-Arizona Sky Survey (BASS; NOAO Prop. ID #2015A-0801; PIs: Zhou Xu and Xiaohui Fan), and the Mayall z-band Legacy Survey (MzLS; Prop. ID #2016A-0453; PI: Arjun Dey). DECaLS, BASS and MzLS together include data obtained, respectively, at the Blanco telescope, Cerro Tololo Inter-American Observatory, NSF's NOIRLab; the Bok telescope, Steward Observatory, University of Arizona; and the Mayall telescope, Kitt Peak National Observatory, NOIRLab. Pipeline processing and analyses of the data were supported by NOIRLab and the Lawrence Berkeley National Laboratory (LBNL). The Legacy Surveys project is honored to be permitted to conduct astronomical research on Iolkam Du'ag (Kitt Peak), a mountain with particular significance to the Tohono O'odham Nation.

NOIRLab is operated by the Association of Universities for Research in Astronomy (AURA) under a cooperative agreement with the National Science Foundation. LBNL is managed by the Regents of the University of California under contract to the U.S. Department of Energy.

This project used data obtained with the Dark Energy Camera (DECam), which was constructed by the Dark Energy Survey (DES) collaboration. Funding for the DES Projects has been provided by the U.S. Department of Energy, the U.S. National Science Foundation, the Ministry of Science and Education of Spain, the Science and Technology Facilities Council of the United Kingdom, the Higher Education Funding Council for England, the National Center for Supercomputing Applications at the University of Illinois, Urbana-Champaign, the Kavli Institute of Cosmological Physics at the University of Chicago, Center for Cosmology and Astro-Particle Physics at the Ohio State University, the Mitchell Institute for Fundamental Physics and Astronomy at Texas A&M University, Financiadora de Estudos e Projetos, Fundacao Carlos Chagas Filho

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Appendix A: 95 and 220 GHz temperature map images

For completeness, the images of the 95 and 220 GHz maps are shown in Figures A.1 and A.2.

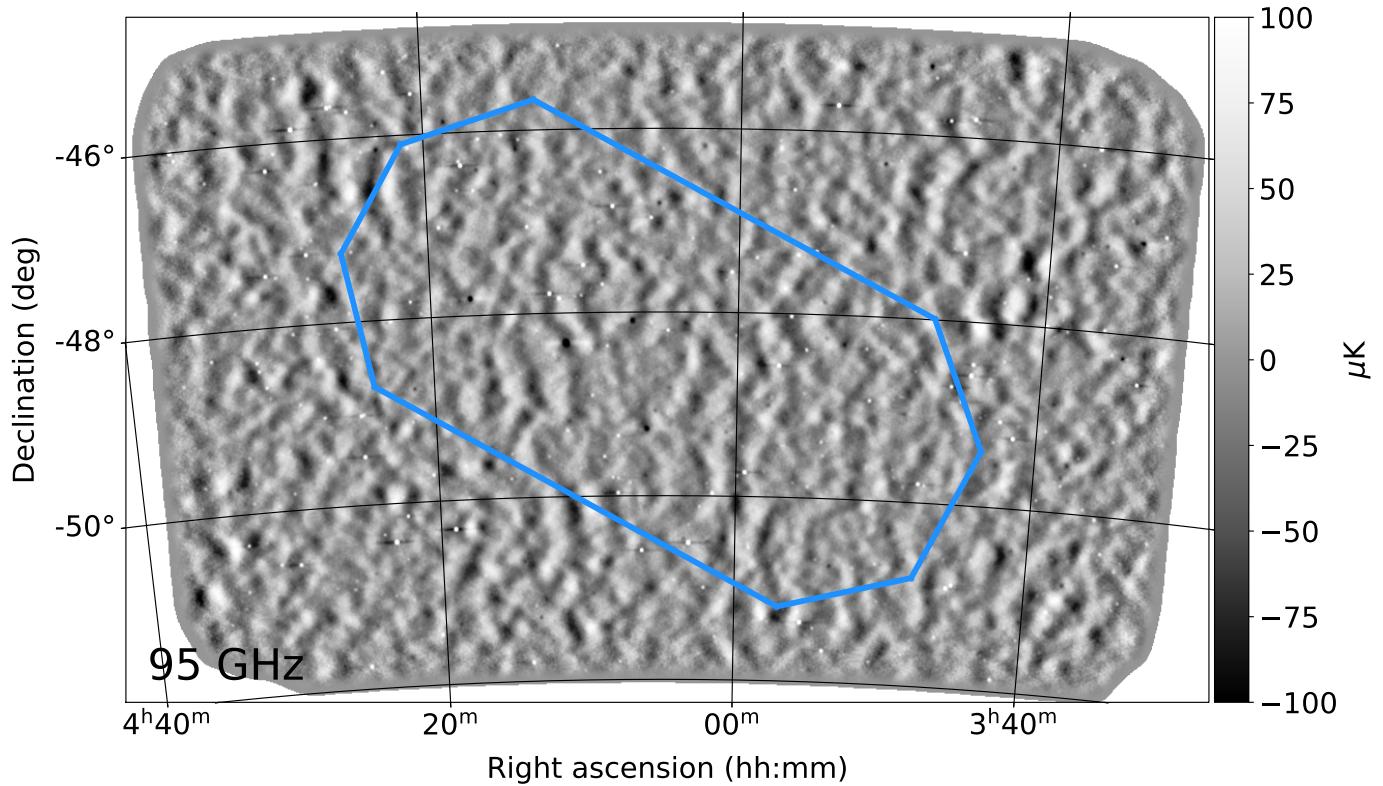


Fig. A.1. 95 GHz coadded temperature map. See Figure 2 caption.

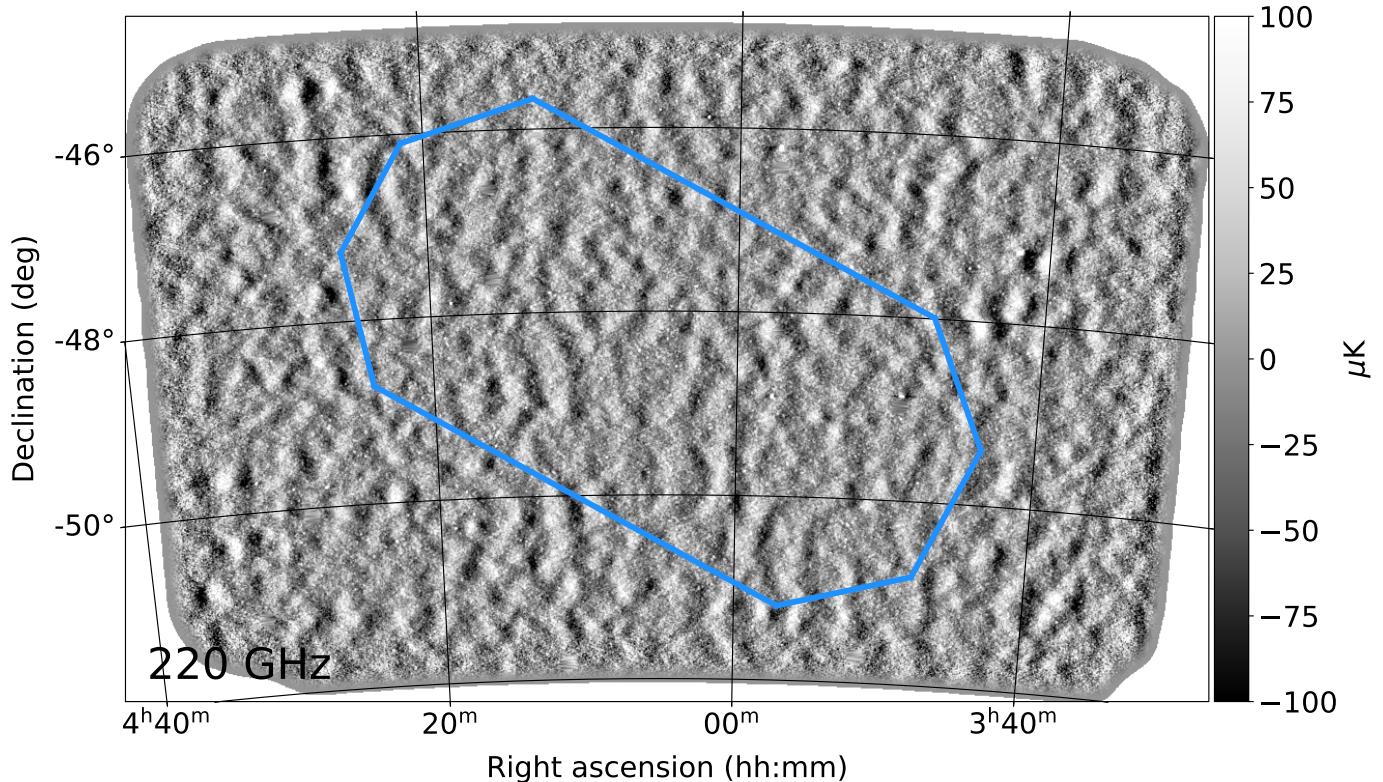


Fig. A.2. 220 GHz coadded temperature map. See Figure 2 caption. The tSZ signal is null at 220 GHz, therefore the dark spots indicating galaxy clusters are not present in this map.

Appendix B: Catalog sample using *Euclid* Q1 data and detailed column descriptions

Tables B.1 and B.2 include 12 catalog entries from the emissive source catalog, where the sample data are sources matched to *Euclid* Q1 strong lenses (Euclid Collaboration et al. 2025d) and *Planck* protoclusters (Euclid Collaboration et al. 2025c). Table B.4 shows the exact name and format of the columns in the emissive and cluster catalog online files as well as detailed explanations of each quantity.

Index	Name and coordinates			95 GHz data		150 GHz data		220 GHz data	
	SPT IAU name	R.A. (deg)	Dec. (deg)	S/N	S (mJy)	S/N	S (mJy)	S/N	S (mJy)
21	SPT-S J040311-5030.2	60.800	-50.504	73.62	24.79	40.3	16.35	8.83	11.53
36	SPT-S J034745-4947.5	56.938	-49.792	37.75	12.81	28.09	11.09	8.13	10.57
131	SPT-S J040259-4711.6	60.749	-47.194	11.26	3.76	8.63	3.33	2.35	3.04
150	SPT-S J041604-4926.0	64.020	-49.435	3.52	1.19	7.62	3.01	7.7	10.07
199	SPT-S J035538-5114.2	58.911	-51.237	7.17	2.58	6.15	2.56	2.76	3.77
244	SPT-S J040308-4715.7	60.784	-47.263	1.57	0.53	5.6	2.16	4.53	5.84
323	SPT-S J041614-4911.8	64.060	-49.197	2.16	0.73	5.06	2.0	2.63	3.43
359	SPT-S J040539-4914.9	61.416	-49.250	2.04	0.69	4.72	1.86	5.75	7.51
372	SPT-S J035223-4839.2	58.098	-48.655	0.19	0.07	4.62	1.82	5.2	6.79
380	SPT-S J042029-4726.6	65.125	-47.445	2.03	0.68	4.58	1.78	5.16	6.66
388	SPT-S J035326-5035.4	58.362	-50.590	-0.32	-0.11	4.51	1.8	5.2	6.79
463	SPT-S J035845-4918.0	59.688	-49.301	2.66	0.9	3.64	1.44	5.37	7.01

Table B.1. SPT-3G EDF-S emissive source catalog preview featuring matches to *Planck* protoclusters and *Euclid* Q1 strong lenses. The catalog file is sorted in descending order of 150 GHz signal-to-noise ratio.

Index	Spectral indices		Thumbnail	Extended	Flags			Notes	
	α_{150}^{95}	α_{220}^{150}			Inside EDF-S	DSFG	Counterparts	Angular separation	
21	-0.92 ± 0.06	-0.87 ± 0.29	0	0	1	0	1,3	3"	C grade SL
36	-0.32 ± 0.1	-0.12 ± 0.32	0	0	1	0	1,3	2"	B grade SL
131	-0.27 ± 0.32	-0.23 ± 1.1	0	0	1	0	1	281"	PC
150	2.06 ± 0.7	3.01 ± 0.46	0	0	1	1	-	68"	PC
199	-0.02 ± 0.48	0.97 ± 0.99	0	0	1	0	1	25"	C grade SL
244	3.14 ± 1.47	2.48 ± 0.71	0	0	1	1	-	117"	PC
323	2.23 ± 1.12	1.35 ± 1.07	0	0	1	0	1	25"	C grade SL
359	2.2 ± 1.19	3.47 ± 0.68	0	0	1	1	-	22"	C grade SL
372	7.4 ± 11.55	3.28 ± 0.72	0	0	1	1	-	68"	PC
380	2.13 ± 1.2	3.29 ± 0.73	0	0	1	1	-	40"	C grade SL
388	-	3.31 ± 0.73	0	0	1	0	-	15"	C grade SL
463	1.04 ± 1.03	3.95 ± 0.83	0	0	1	1	-	113"	PC

Table B.2. SPT-3G EDF-S emissive source catalog preview continued. The external counterparts correspond to the following wavelengths: 1 = radio (ASKAP low, mid, or high), 2 = infrared (WISE), and 3 = millimeter (SPT-SZ). The notes column indicates angular separations from *Planck* protoclusters (PC) and *Euclid* Q1 strong lenses (SL), including the grade of strong lens.

Name and coordinates			Best			Cluster attributes		
SPT IAU name	R.A. (deg)	Dec. (deg)	ξ	θ_{core} (arcmin)	z	$M_{500c} \times 10^{-14} (M_{\odot}/h_{70})$	λ	
SPT-CL J0339-4800	54.786	-48.011	10.8	1	0.49 ± 0.008	$3.39^{+0.39}_{-0.46}$	103 ± 10.6	
SPT-CL J0350-4620	57.717	-46.334	25.7	0.75	0.79 ± 0.02	$5.17^{+0.34}_{-0.64}$	194 ± 17.6	
SPT-CL J0357-4530	59.387	-45.51	4.52	0.25	0.88 ± 0.04	$1.7^{+0.26}_{-0.33}$	80.2 ± 10.7	
SPT-CL J0401-4911	60.415	-49.200	5.18	0.5	0.94 ± 0.06	$1.83^{+0.29}_{-0.34}$	46.7 ± 10.4	
SPT-CL J0403-4828	60.882	-48.479	5.94	1.75	0.34 ± 0.008	$2.44^{+0.36}_{-0.41}$	92.1 ± 10.6	
SPT-CL J0411-4819	62.812	-48.322	45.2	1.25	0.42 ± 0.007	$8.11^{+0.31}_{-0.97}$	313 ± 19.5	
SPT-CL J0418-5120	64.734	-51.345	10.1	0.25	1.1 ± 0.09	$2.66^{+0.29}_{-0.35}$	26.9 ± 10.9	
SPT-CL J0421-4740	65.461	-47.671	4.41	0.25	1.5 ± 0.07	$1.39^{+0.22}_{-0.27}$	47.8 ± 7.97	
SPT-CL J0426-4749	66.55	-47.83	5.67	0.75	1.3 ± 0.07	$1.74^{+0.26}_{-0.32}$	59 ± 8.71	
SPT-CL J0431-4928	67.912	-49.475	4.61	1	0.45 ± 0.01	$1.98^{+0.32}_{-0.39}$	54.2 ± 8.43	

Table B.3. SPT-3G EDF-S cluster catalog preview featuring ten cluster candidates chosen at random. The catalog file is sorted by ascending R.A. value. A description of the column headers can be found in Table B.4.

Emissive catalog column label	Emissive source catalog description
index	Integer index where the catalog is sorted in descending order of 150 GHz signal-to-noise.
iau_name	IAU name follows convention of a catalog prefix (“SPT-S”), R.A., and Dec. in sexagesimal format.
ra (deg)	Right ascension (J2000) of the source in the highest detection band in degrees.
dec (deg)	Declination (J2000) of the source in the highest detection band in degrees.
sn95	95 GHz signal-to-noise ratio of the detection. Values below 5σ are pulled from the signal-to-noise map when the source was detected above 5σ in another band.
sn150	150 GHz signal-to-noise ratio of the detection.
sn220	220 GHz signal-to-noise ratio of the detection.
s95 (mJy)	Flux at 95 GHz in mJy converted from CMB temperature. Fluxes are from forced-photometry in bands where the source was not detected $> 5\sigma$.
s150 (mJy)	Flux at 150 GHz in mJy.
s220 (mJy)	Flux at 220 GHz in mJy.
alpha95	Spectral index between 95 and 150 GHz (α_{150}^{95} , Equation 16).
erroralpha95	The error on α_{150}^{95} propagated from the flux errors.
alpha220	Spectral index between 150 and 220 GHz (α_{220}^{150} , Equation 16).
erroralpha220	The error on α_{220}^{150} propagated from the flux errors.
thumb	“Coadd[frame name]” if the source is one of the specially treated bright source thumbnails (Section 3.4), 0 (for <code>False</code>) otherwise. ¹
extended	1 for <code>True</code> if flagged according to the methods described in Section 6.3, 0 for <code>False</code> if point-like, and <code>nan</code> (not a number) if the extended check was indeterminate.
edfs_flag	1 for <code>True</code> if inside the EDF-S, 0 for <code>False</code> if outside the EDF-S.
dsfg_flag	1 for <code>True</code> if flagged as a DSFG candidate (see Section 6.3), 0 for <code>False</code> otherwise.
counterparts	External catalog counterparts according to Section 6.4 where 1 = radio (ASKAP low, mid, or high), 2 = infrared (WISE), and 3 = millimeter (SPT-SZ).

Cluster catalog column label	Cluster catalog description
iau_name	Name of the SPT cluster candidate. The IAU name follows the convention of a catalog prefix (“SPT-CL”), R.A., and Dec. in sexagesimal format.
ra (deg)	Right ascension (J2000) of the tSZ detection in degrees.
dec (deg)	Declination (J2000) of the tSZ detection in degrees.
xi	SPT cluster detection significance (see Section 4.2).
theta_core	β -profile core radii used in the matched filter corresponding to <code>xi</code> .
redshift	Redshift of associated optical/infrared galaxy overdensity. If no associated redshift is available, column value is -1 .
redshift_unc	Redshift uncertainty if available, -1 otherwise.
specz	Equals 1 if <code>redshift</code> is spectroscopic.
m500	Mass M_{500c} in units of $10^{14} M_{\odot}/h_{70}$.
m500_uerr	1 sigma upper uncertainty on mass.
m500_lerr	1 sigma lower uncertainty on mass.
lambda	Richness of associated optical/infrared galaxy overdensity.
lambda_unc	Richness uncertainty.
fcont	Integrated optical/infrared contamination for richness $> 1\text{ambda}$ (f_{cont} , see Section 4.2.1).
edfs_flag	1 for <code>True</code> if inside the EDF-S, 0 for <code>False</code> if outside the EDF-S.
los	Equals 1 if there is a secondary structure along the LOS with $f_{\text{cont}} < 0.2$.
redshift2	Redshift secondary structure.
redshift2_unc	Redshift uncertainty secondary structure.
lambda2	Richness secondary structure.
lambda2_unc	Richness uncertainty secondary structure.
fcont2	Integrated optical/infrared contamination for richness $> 1\text{ambda2}$ for secondary structure.
unconfirmed_redshift	Redshift for LOS overdensity below confirmation threshold (only provided when candidate is not confirmed).
unconfirmed_redshift_unc	Redshift uncertainty for LOS overdensity below confirmation threshold.
unconfirmed_lambda	Richness of most significant galaxy overdensity along the LOS when candidate is not confirmed.
unconfirmed_lambda_unc	Richness uncertainty for LOS overdensity below confirmation threshold.
unconfirmed_fcont	Integrated optical/infrared contamination for LOS overdensity below confirmation threshold. ²

Table B.4. Exact column labels and their descriptions for the catalogs. Note the following: ¹The bright source’s label in the `thumb` column comes from the center of the thumbnail and is therefore not guaranteed to equate to the IAU name of the source, in the event of the source’s recorded location shifting from the precise center of the thumbnail. ²For unconfirmed cluster candidates ($f_{\text{cont}} > 0.2$), we provide properties of the most significant galaxy overdensity detected along the LOS, but do not report masses for these structures.

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