SAND2022-14379C

WOOTTON CAPP

Laboratory Observations of Hydrogen Balmer Line Profiles

Bart Dunlap, UT Austin

APS Division of Plasma Physics

October 18, 2022

Collaborators: Mike Montgomery (UT), Patty Cho (UT), Jackson White (UT), Bryce Hobbs (UT), Don Winget (UT), Marc Schaeuble (SNL), Thomas Gomez (SNL), Tai Nagayama (SNL), Jim Bailey (SNL), Sonal Patel (SNL), Georges Jaar (UNR), Patrick Dufour (U Montreal), Ivan Hubeny (UA)

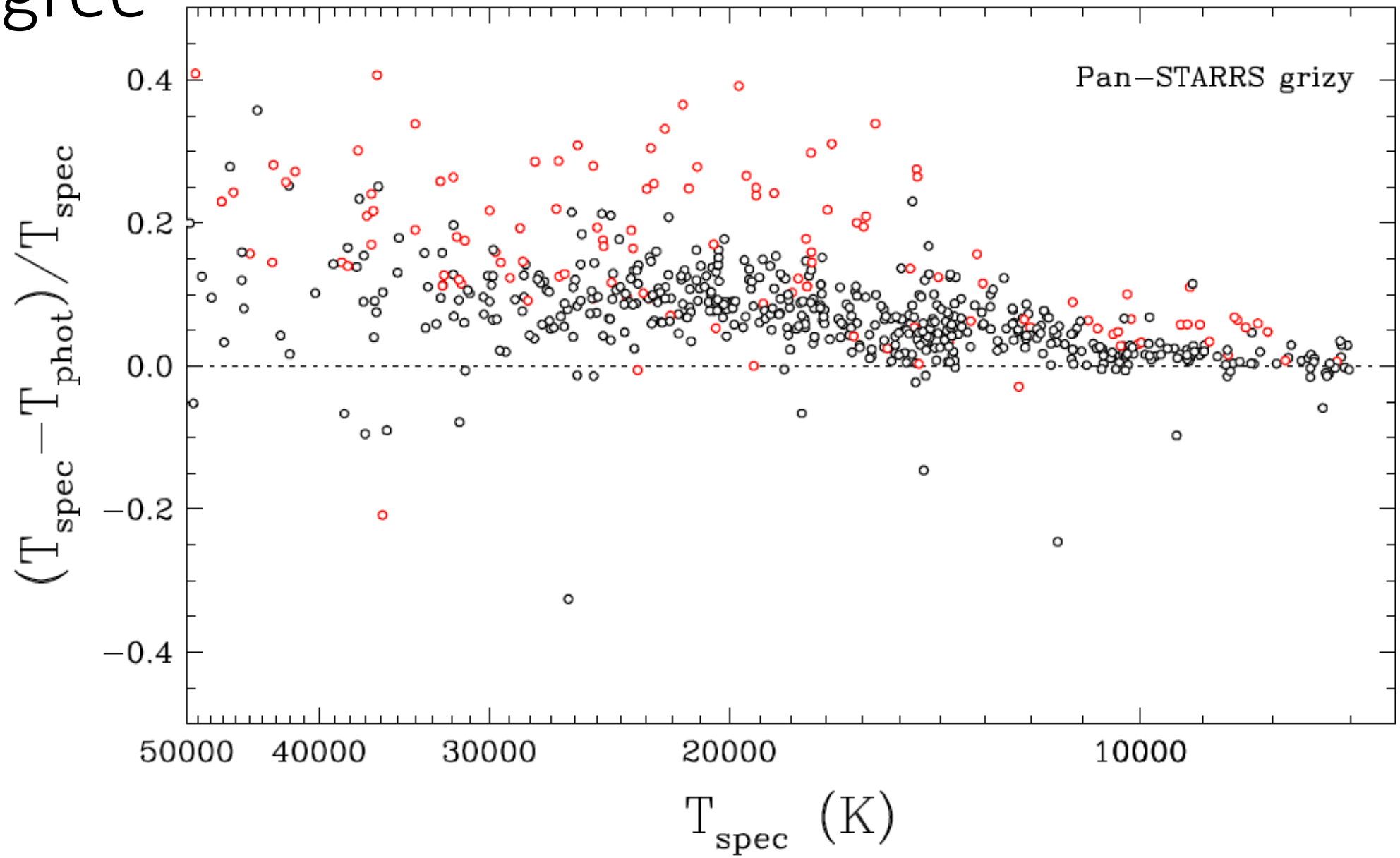
TEXAS
The University of Texas at Austin

Funded by NNSA through SSAAP DE-NA0003843

U.S. DEPARTMENT OF ENERGY | Office of Science

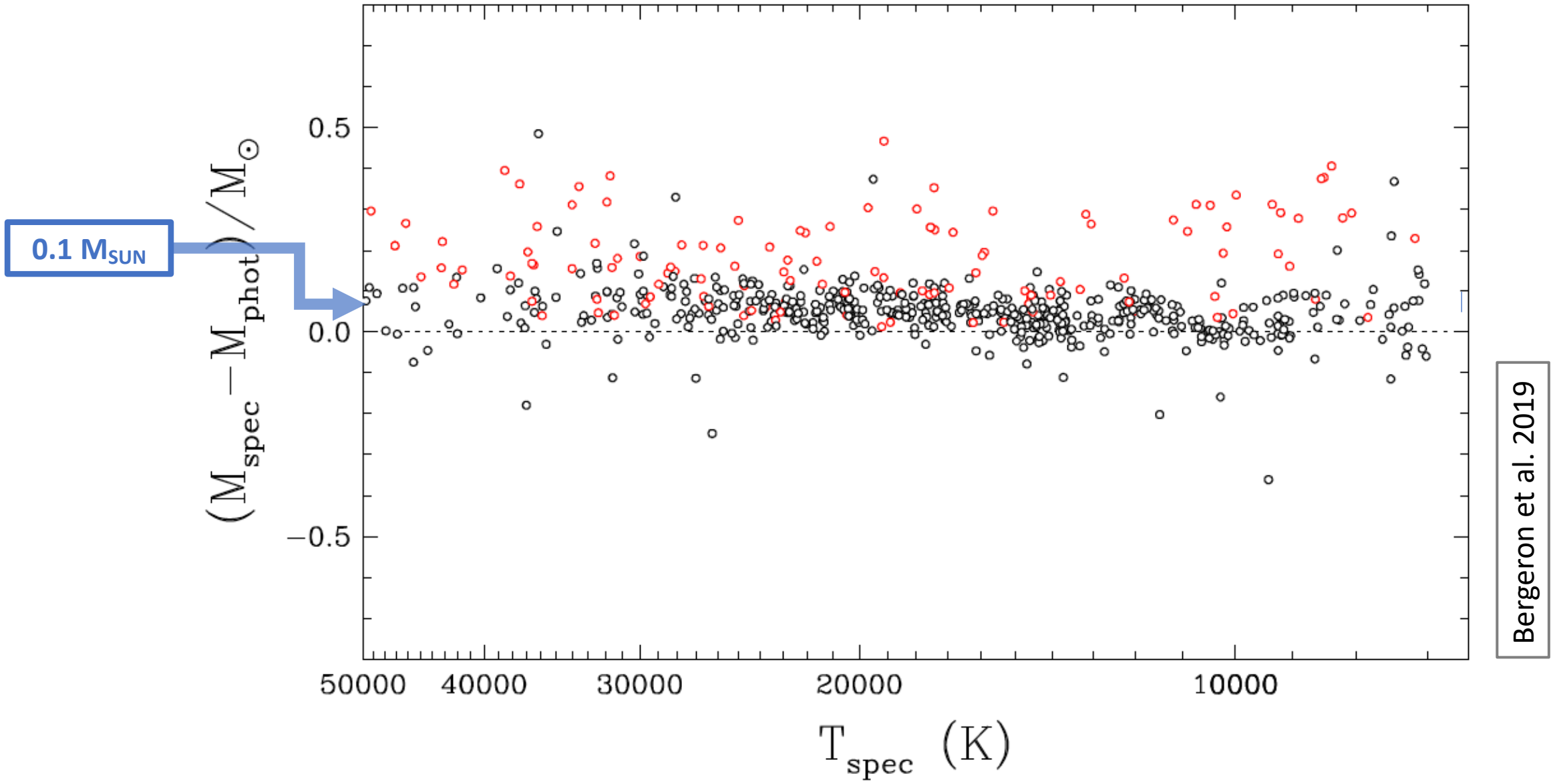
NSF

Photometric and Spectroscopic Temperatures Disagree

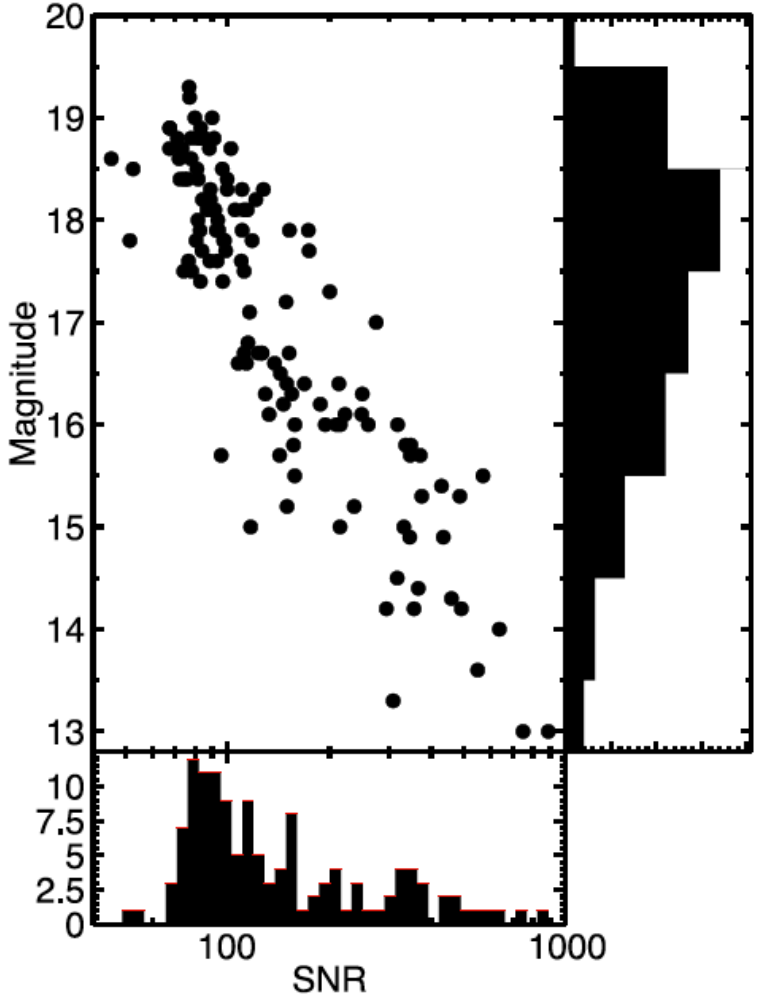


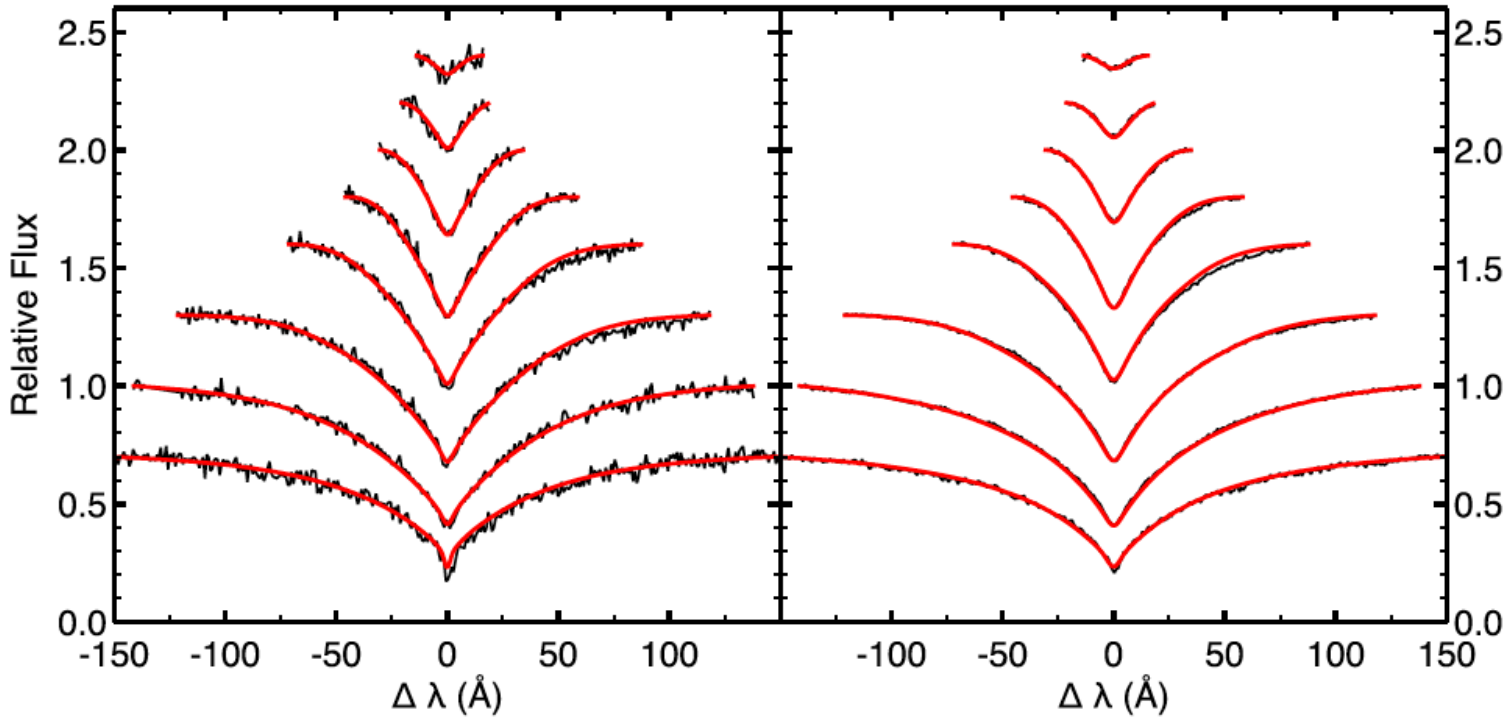
Bergeron et al. 2019

Photometric and Spectroscopic Masses Disagree



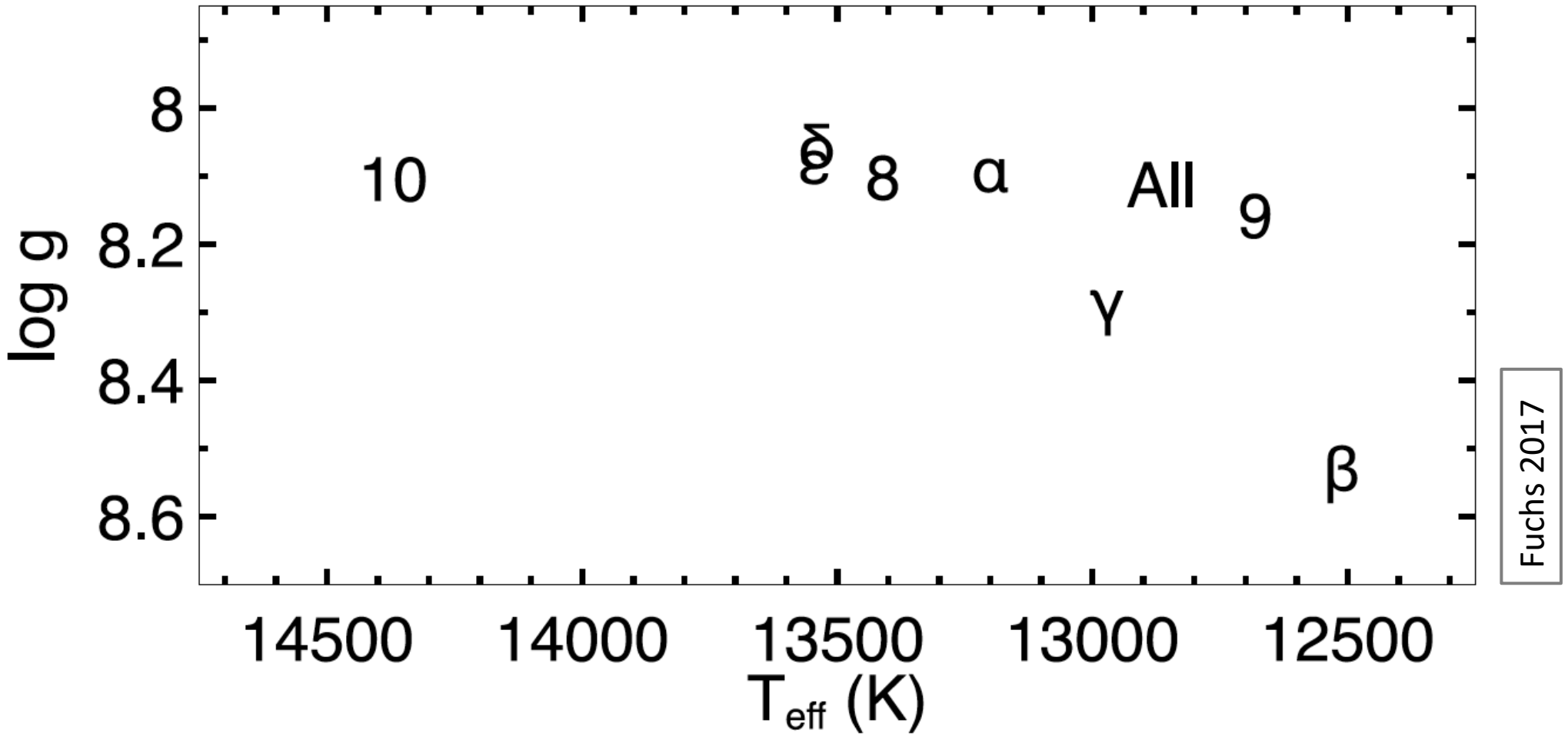
Fits to white dwarf spectral lines look pretty good, but…





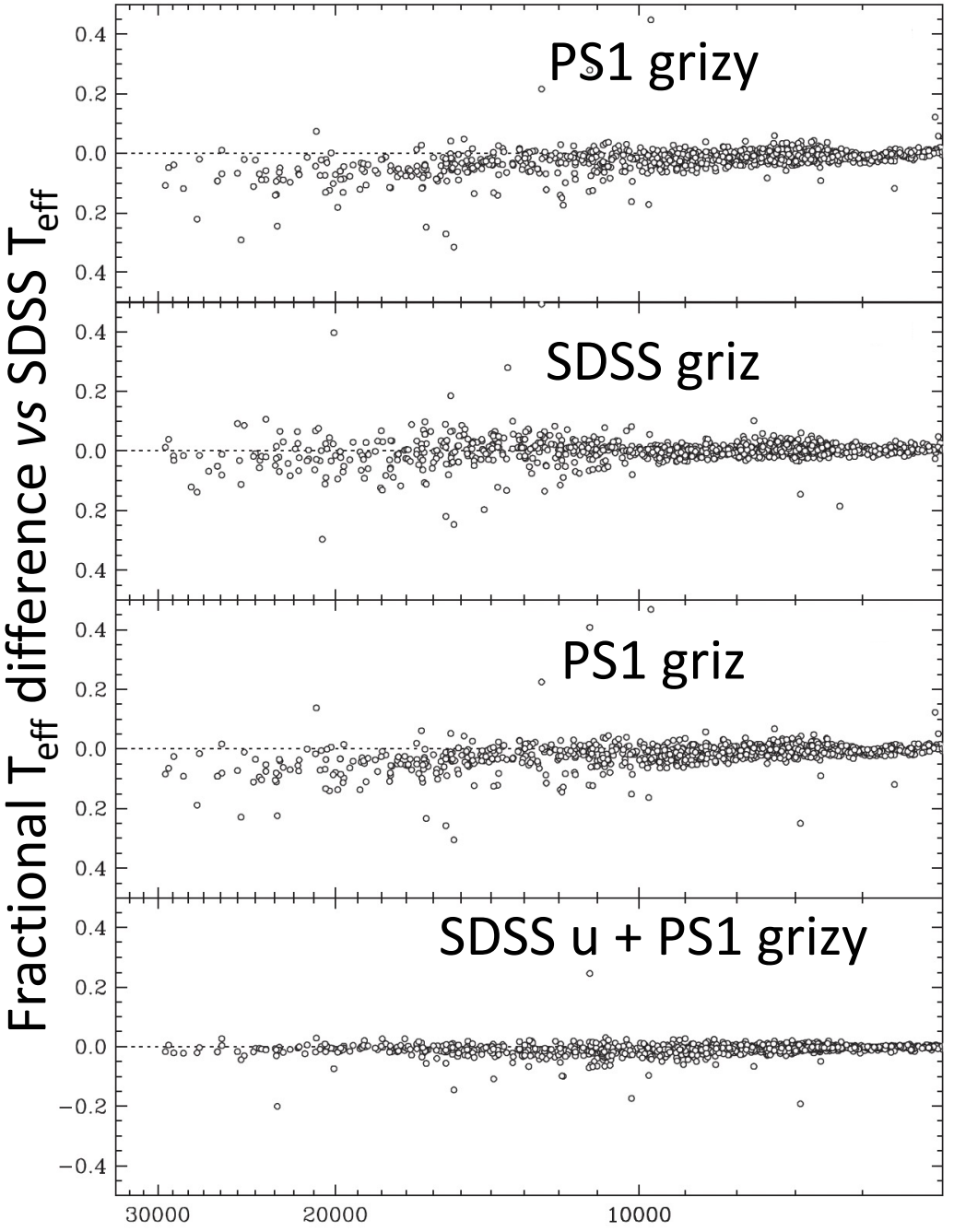
High S/N spectroscopy of 129 DAs in and around the DAV pulsational instability strip (Fuchs 2017)

Individual Balmer lines give different results



Mass and Temperature Estimates Using Different Photometric Bands Disagree

Derived T_{eff} and Mass depend on choice of SDSS & PanSTARRS (PS1) bands.



Bergeron et al. 2019

The Calibration of Photometric Systems Depends on Fits to White Dwarf Balmer Lines

The absolute flux scale is tied to the flux of Vega at 5556 Å.

But relative flux of all other wavelengths depends on the 3 well observed WD flux standards.

See lots of papers by Bohlin et al.

The Calibration of Photometric Systems Depends on Fits to White Dwarf Balmer Lines

The absolute flux scale is tied to the flux of Vega at 5556 Å.

But relative flux of all other wavelengths depends on the 3 well observed WD flux standards.

And how do we know the flux of these WDs relative to their flux at 5556 Å?

The Calibration of Photometric Systems Depends on Fits to White Dwarf Balmer Lines

The absolute flux scale is tied to the flux of Vega at 5556 Å.

But relative flux of all other wavelengths depends on the 3 well observed WD flux standards.

And how do we know the flux of these WDs relative to their flux at 5556 Å?

By using model WD spectra.

The Calibration of Photometric Systems Depends on Fits to White Dwarf Balmer Lines

The absolute flux scale is tied to the flux of Vega at 5556 Å.

But relative flux of all other wavelengths depends on the 3 well observed WD flux standards.

And how do we know the flux of these WDs relative to their flux at 5556 Å?

By using model WD spectra.

Which models do we use to set the relative flux of the 3 WD standards?

The Calibration of Photometric Systems Depends on Fits to White Dwarf Balmer Lines

The absolute flux scale is tied to the flux of Vega at 5556 Å.

But relative flux of all other wavelengths depends on the 3 well observed WD flux standards.

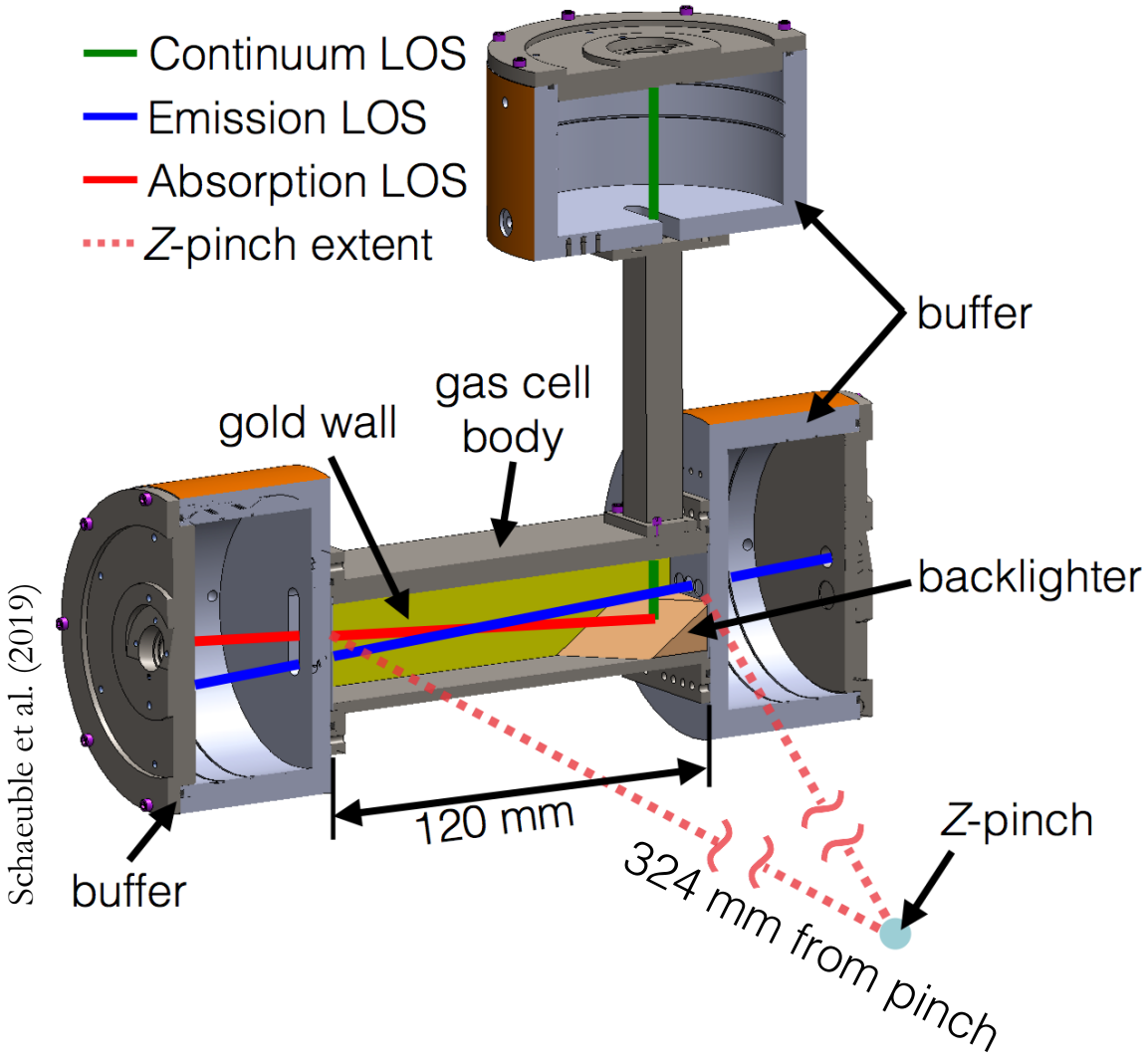
And how do we know the flux of these WDs relative to their flux at 5556 Å?

By using model WD spectra.

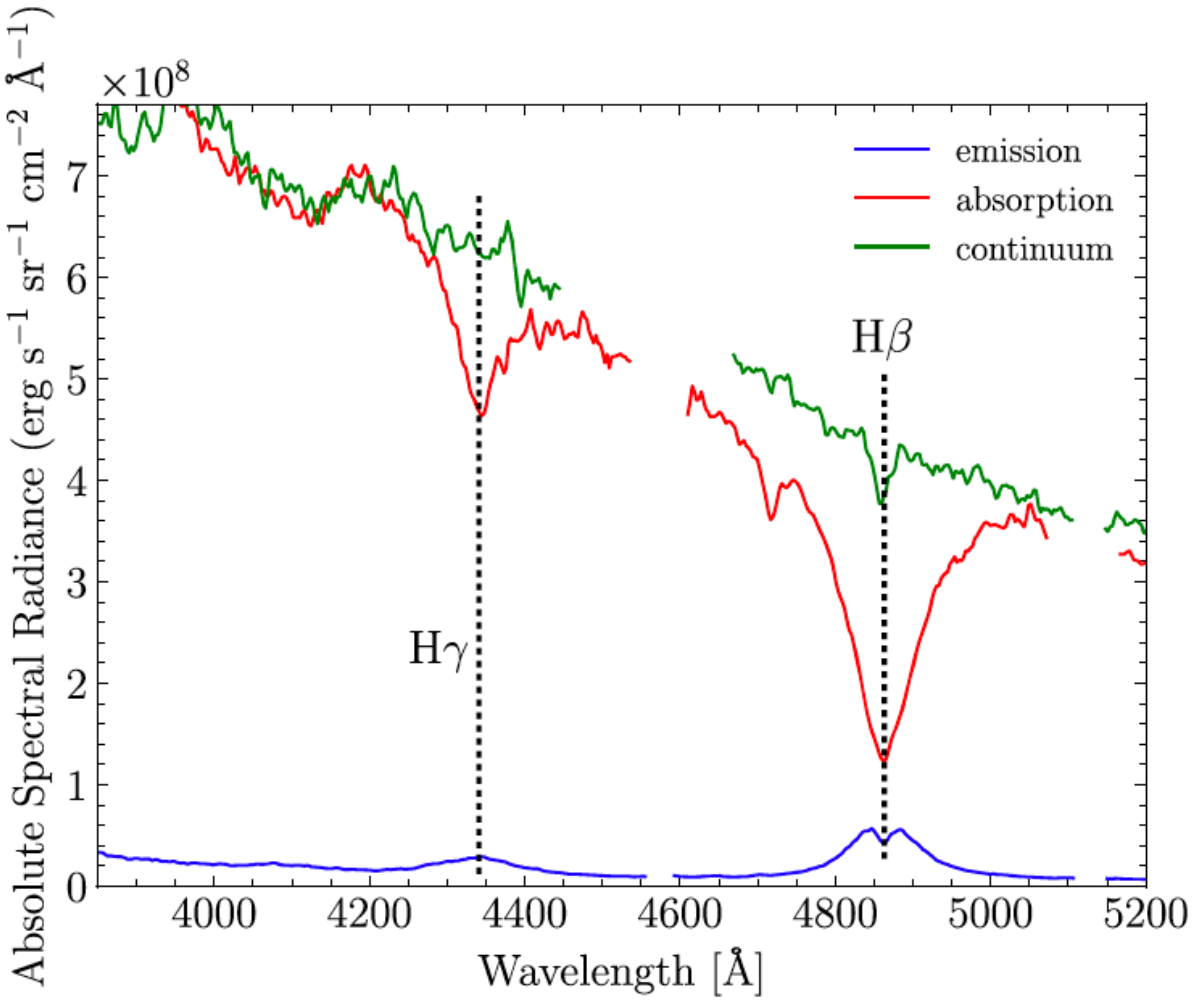
Which models do we use to set the relative flux of the 3 WD standards?

The ones determined by fits to their Balmer lines.

The White Dwarf Photosphere Experiment Measures



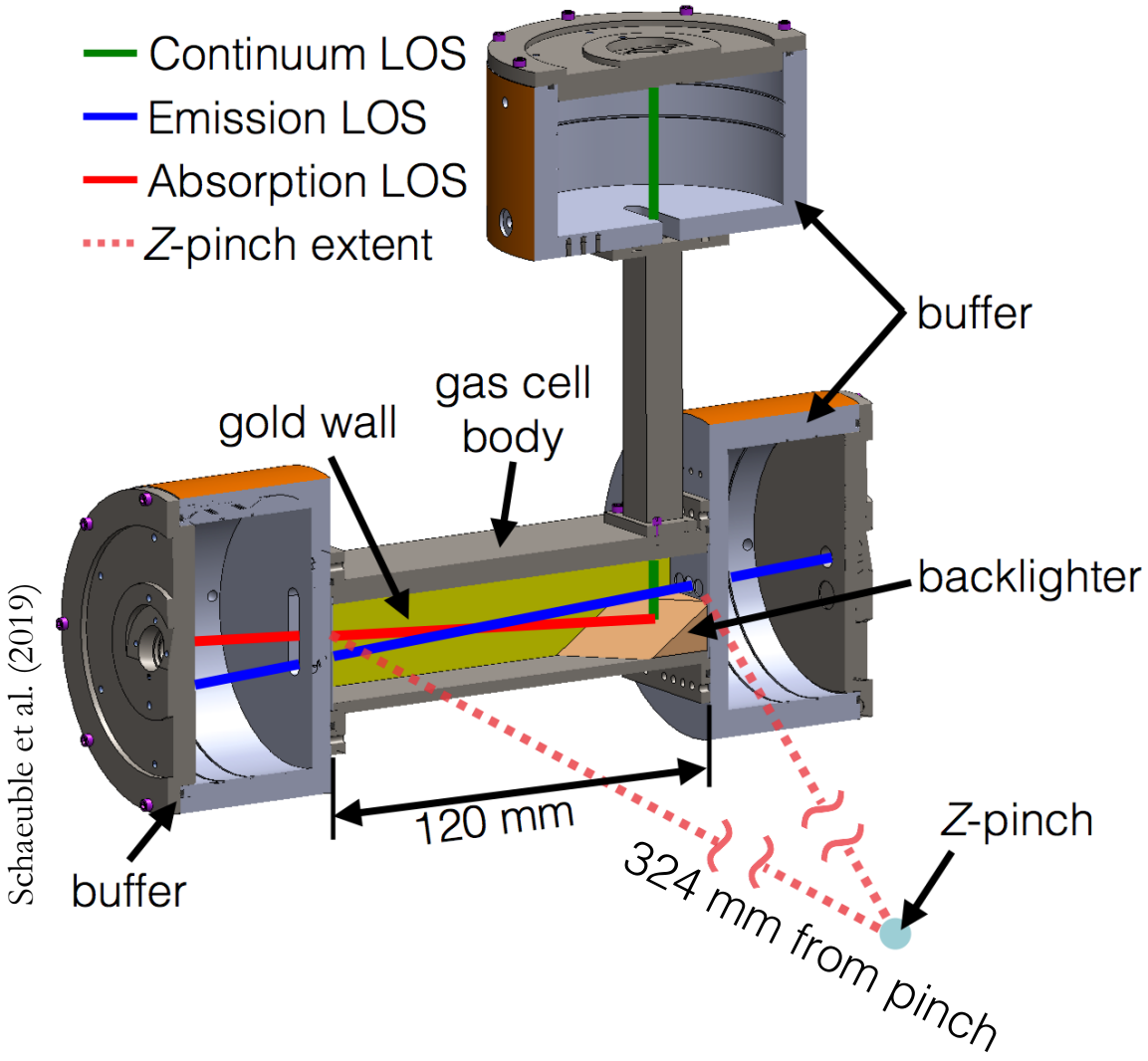
Schaeuble et al. (2019)



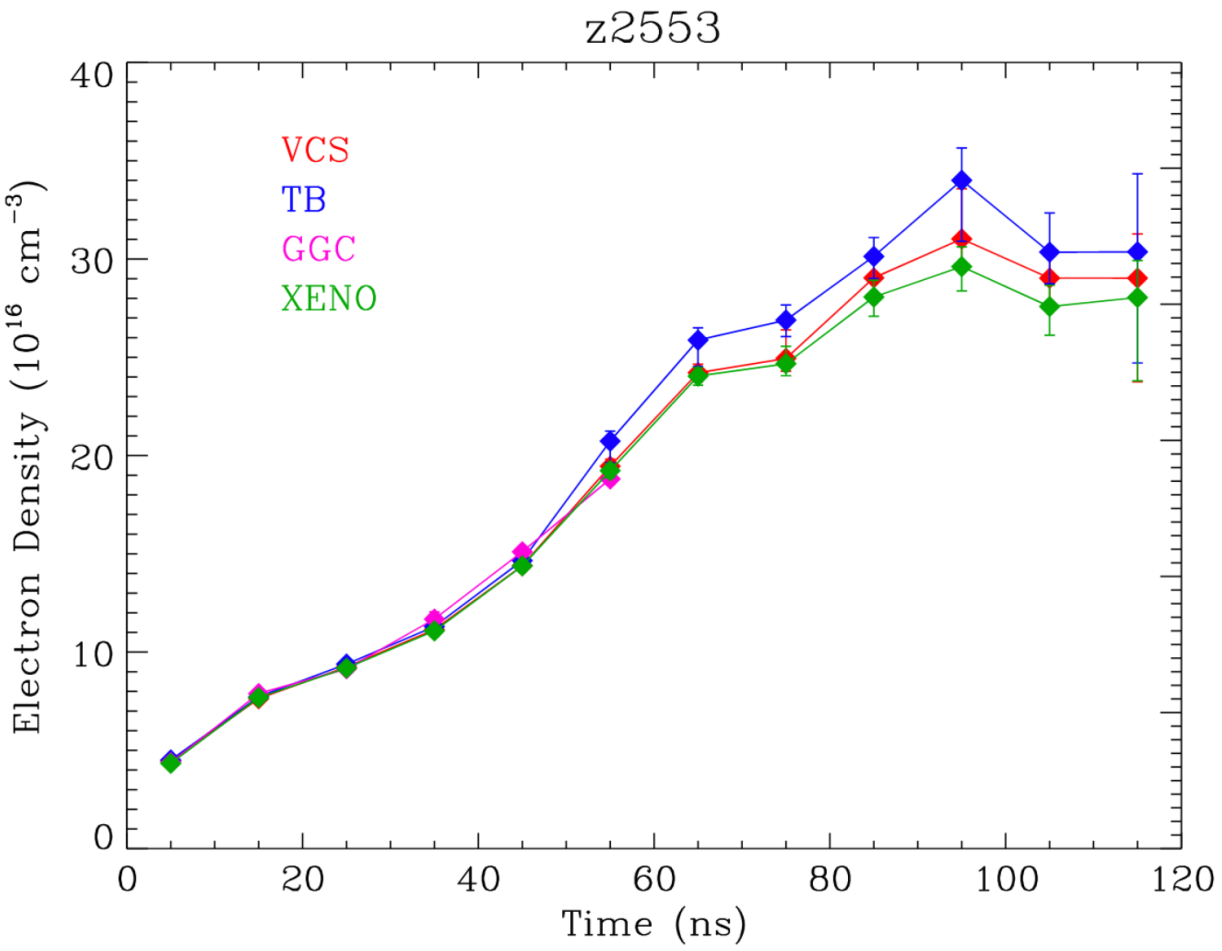
Schaeuble et al. (2019)

The White Dwarf Photosphere Experiment Measures

Across a range of n_e during each experiment.

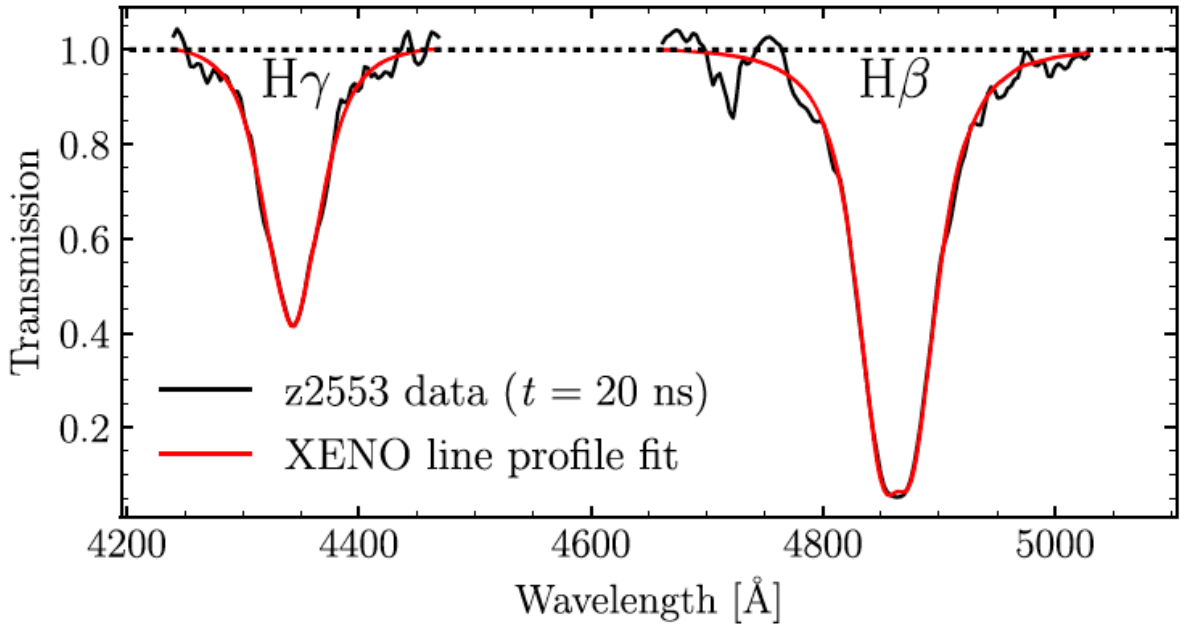


Schaeuble et al. (2019)

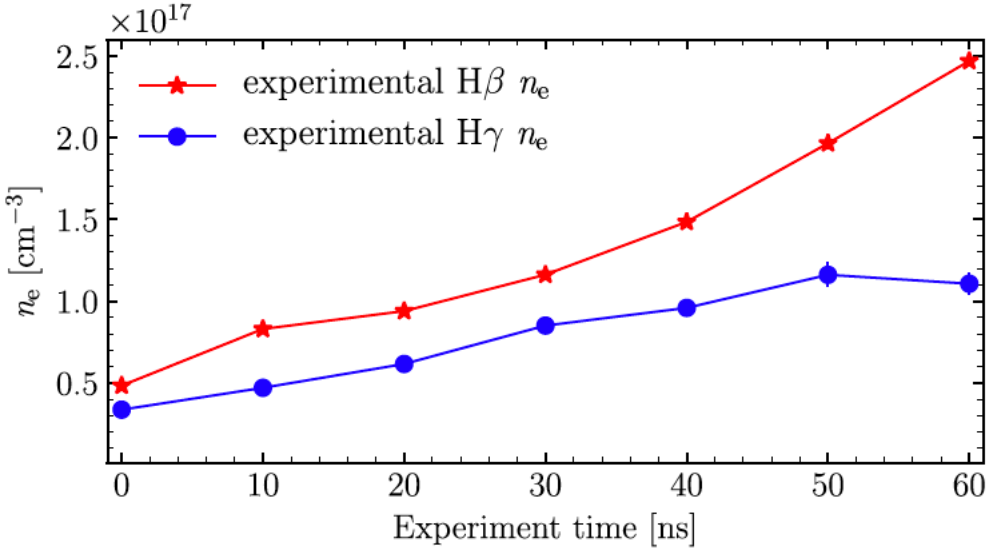


Falcon et al. ApJ (2015)

Analysis of the WDPE absorption spectra reveals trends similar to those observed in stellar spectra



Line fits to absorption spectra.
These are used to extract n_e values.



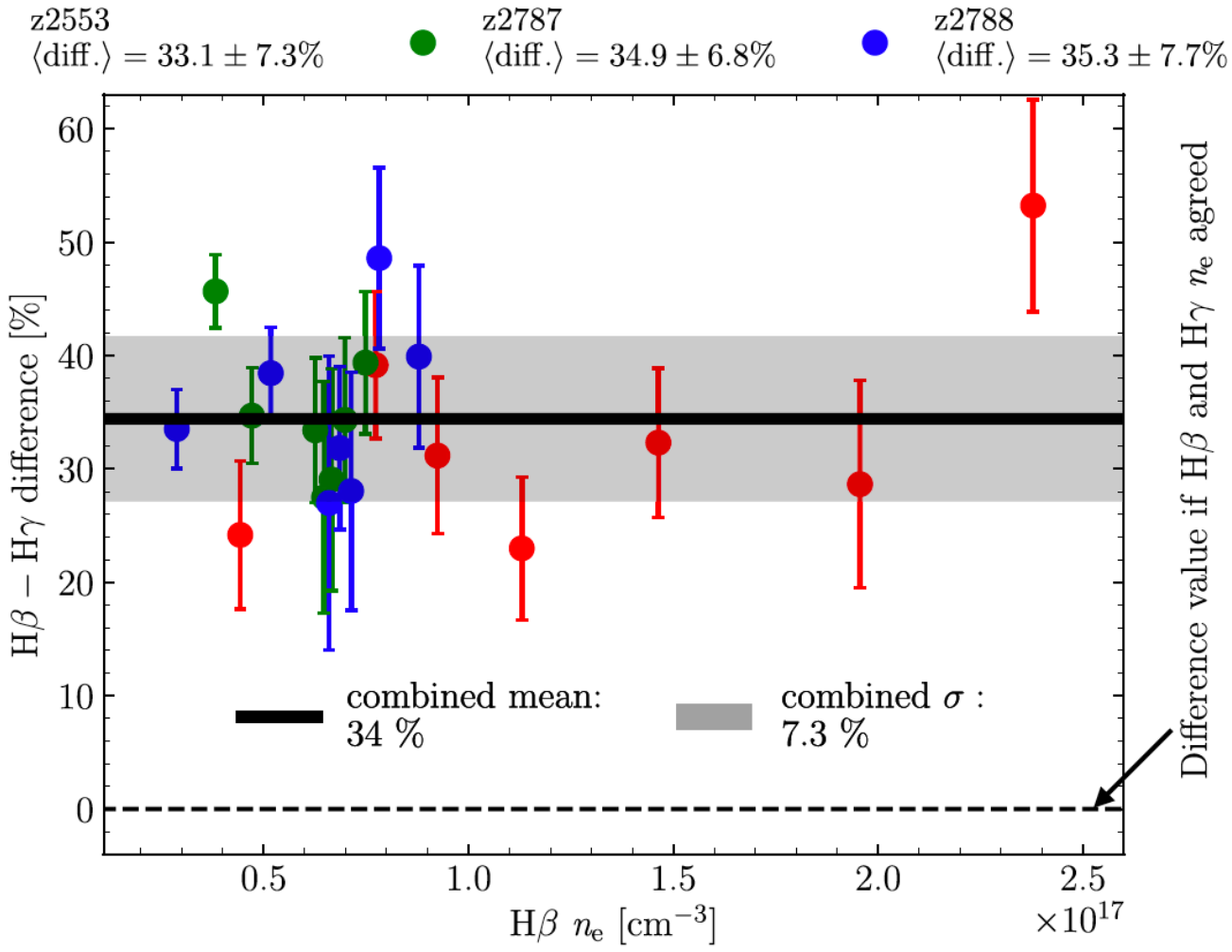
Schaeuble et al. (2019)

Hβ and Hγ n_e values differ by ~30%.

Analysis of the WDPE absorption spectra reveals trends similar to those observed in stellar spectra

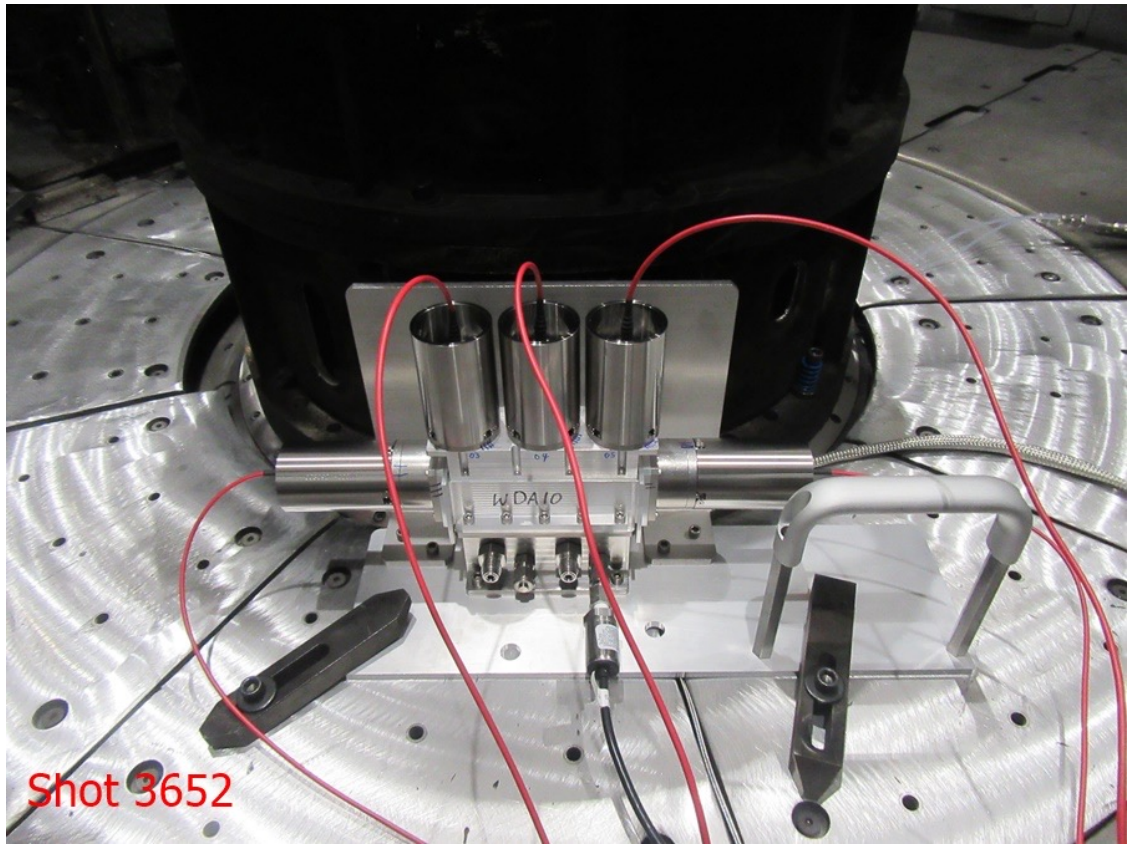
Hβ and Hγ n_e values differ by ~30%.

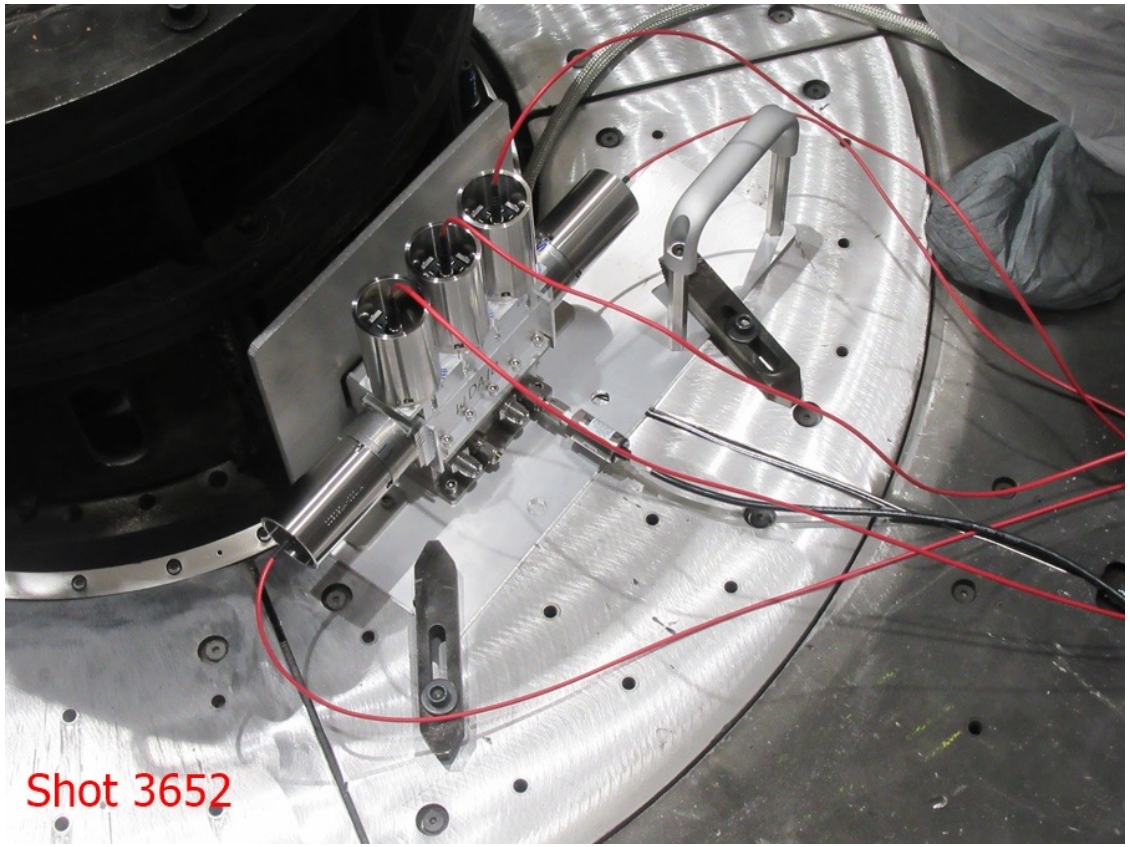
This difference is consistent across multiple shots.

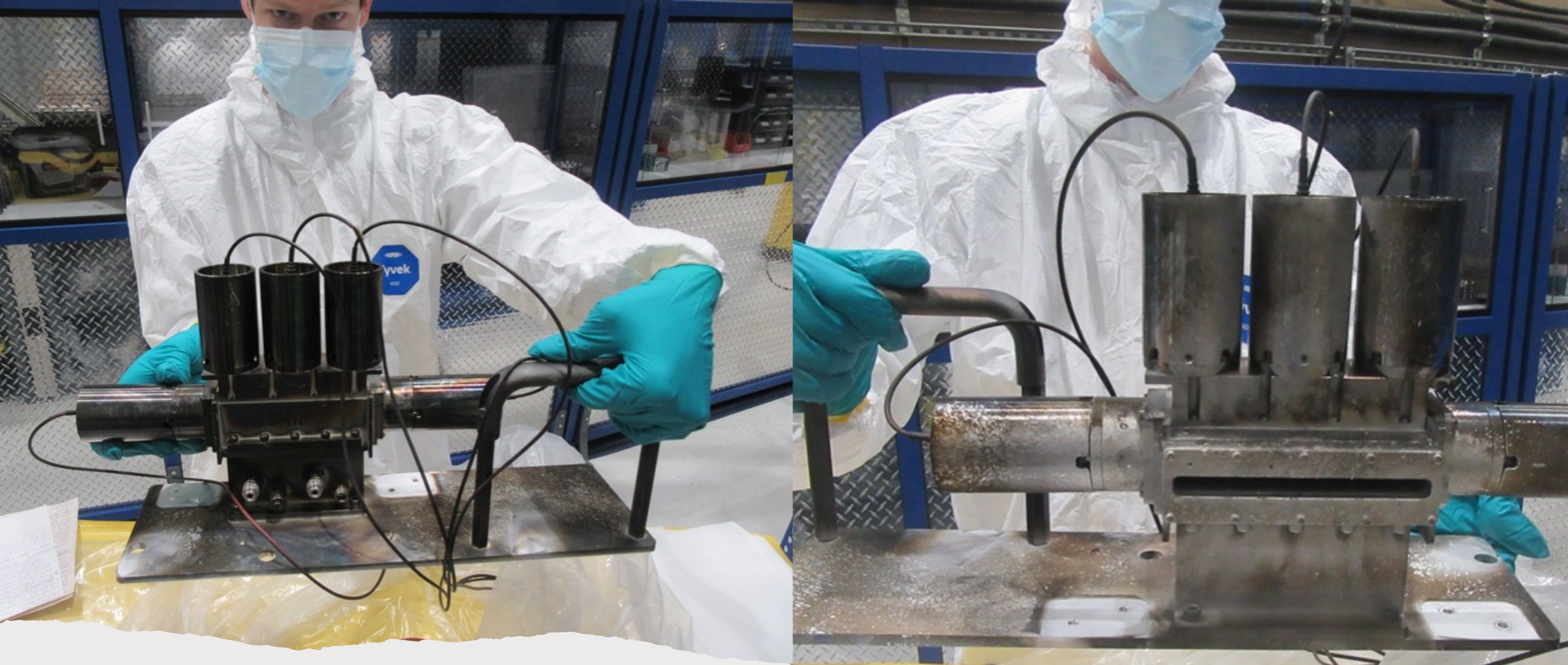


Schaeuble et al. (2019)

The White Dwarf Gas Cell in Chamber



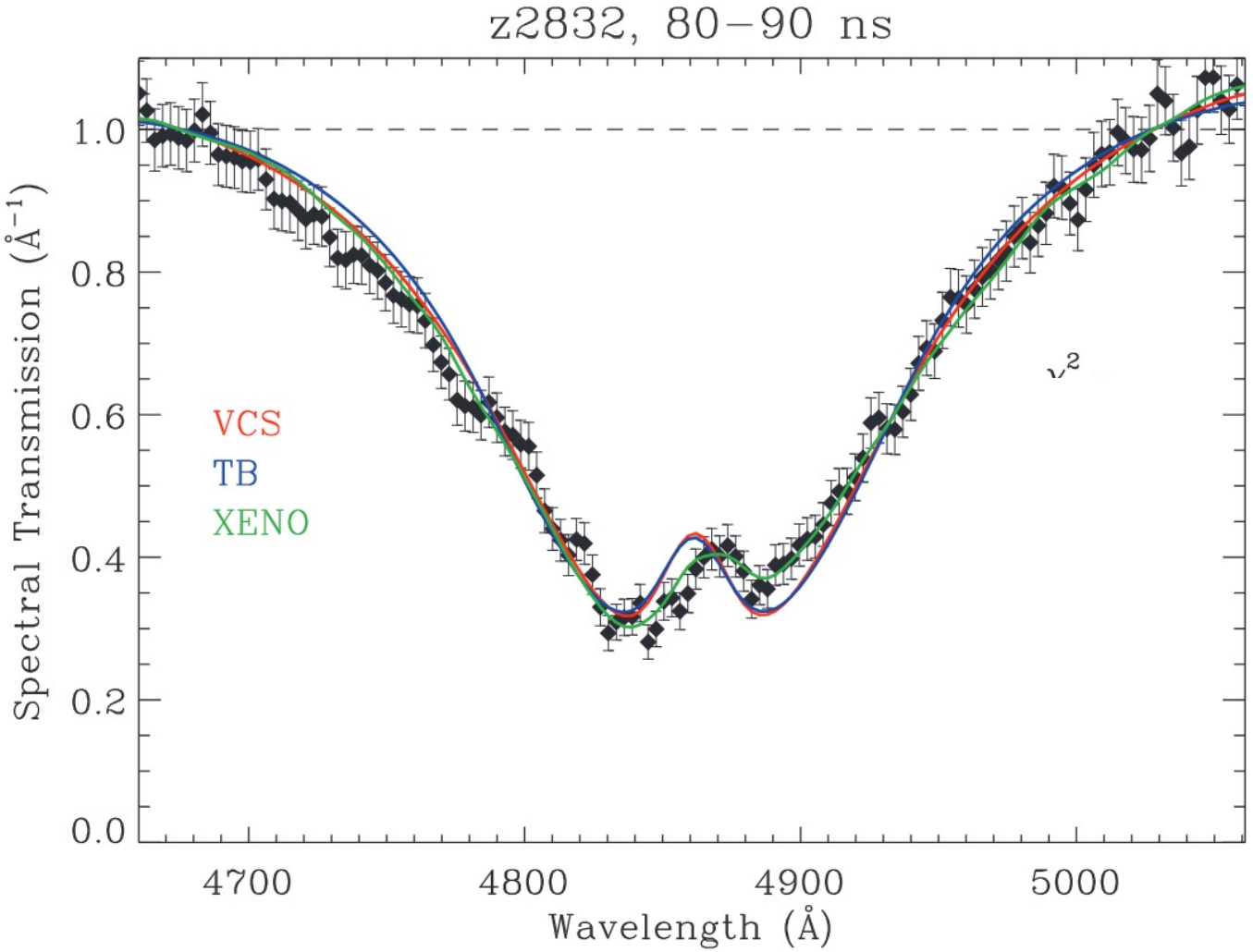




The White Dwarf Gas Cell Post Shot

Hydrogen data at higher densities can more easily test theories of line shapes and occupation probability

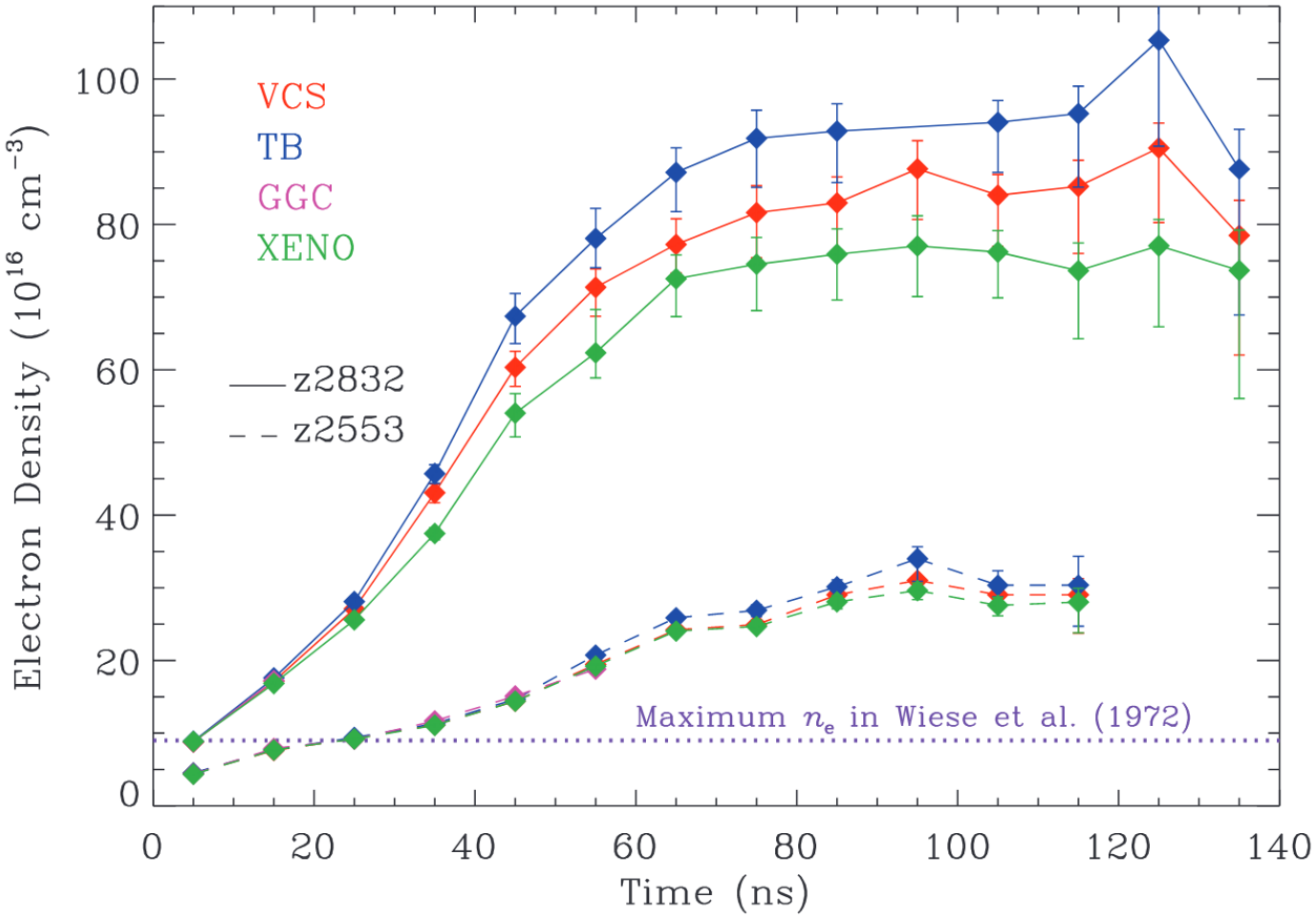
Previous data at higher densities showed larger disagreement among theories.



Falcon et al. 2017

Hydrogen data at higher densities can more easily test theories of line shapes and occupation probability

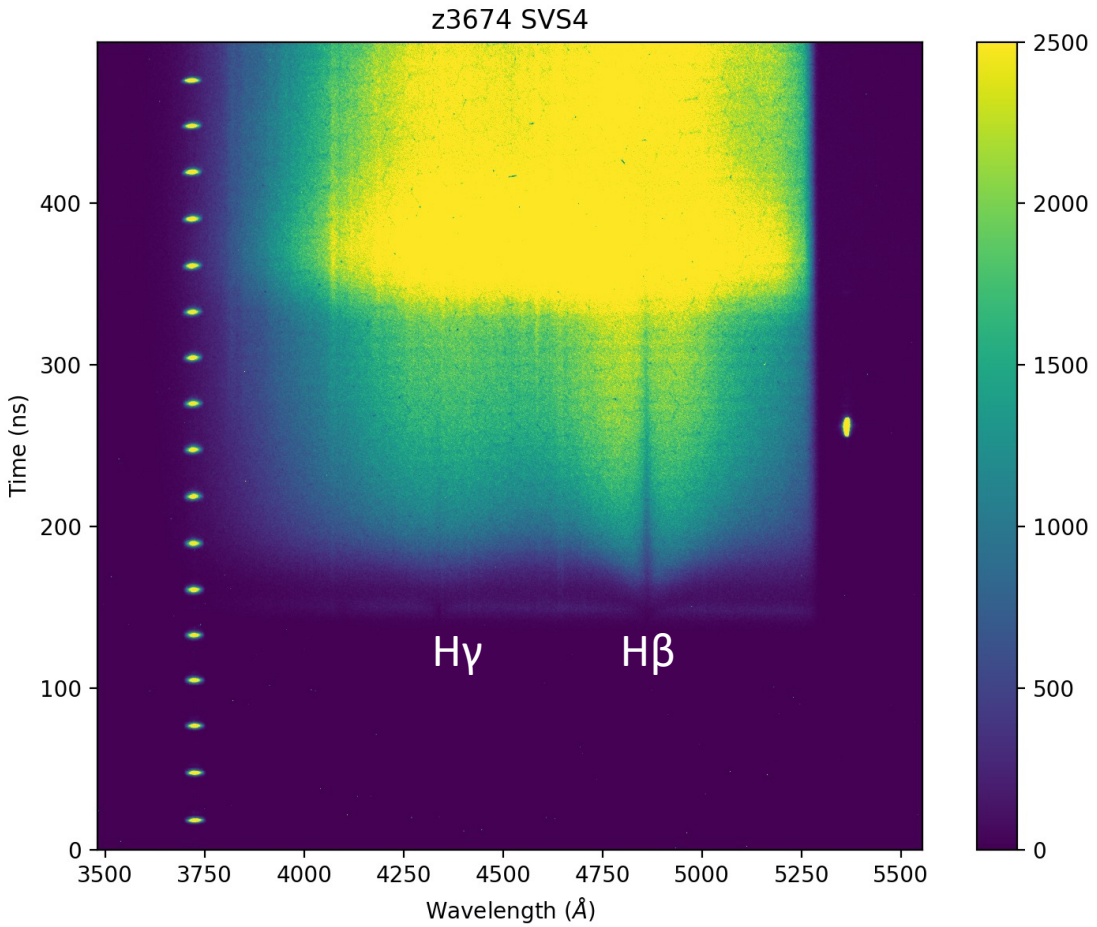
Previous data at higher densities showed larger disagreement among theories.

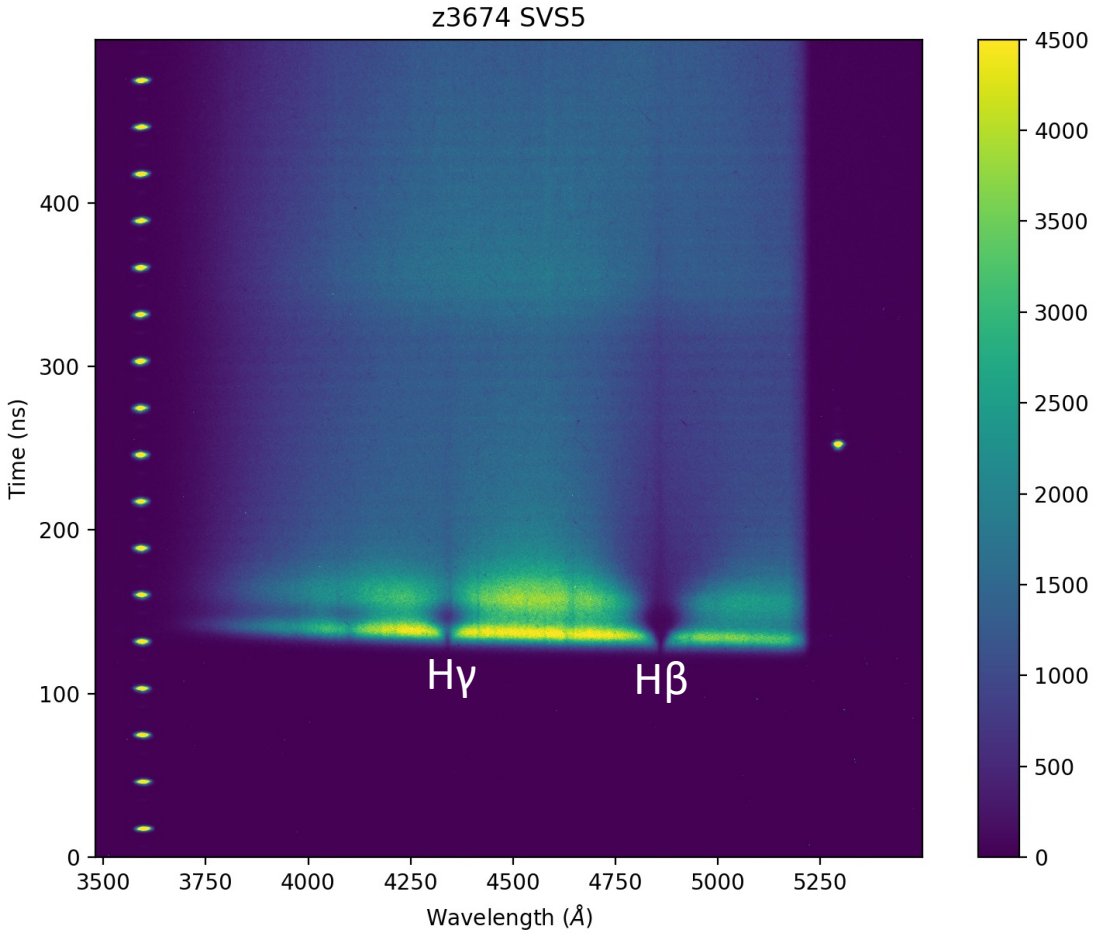


Falcon et al. 2017

Achieved higher n_e in H at 10 mm line of sight

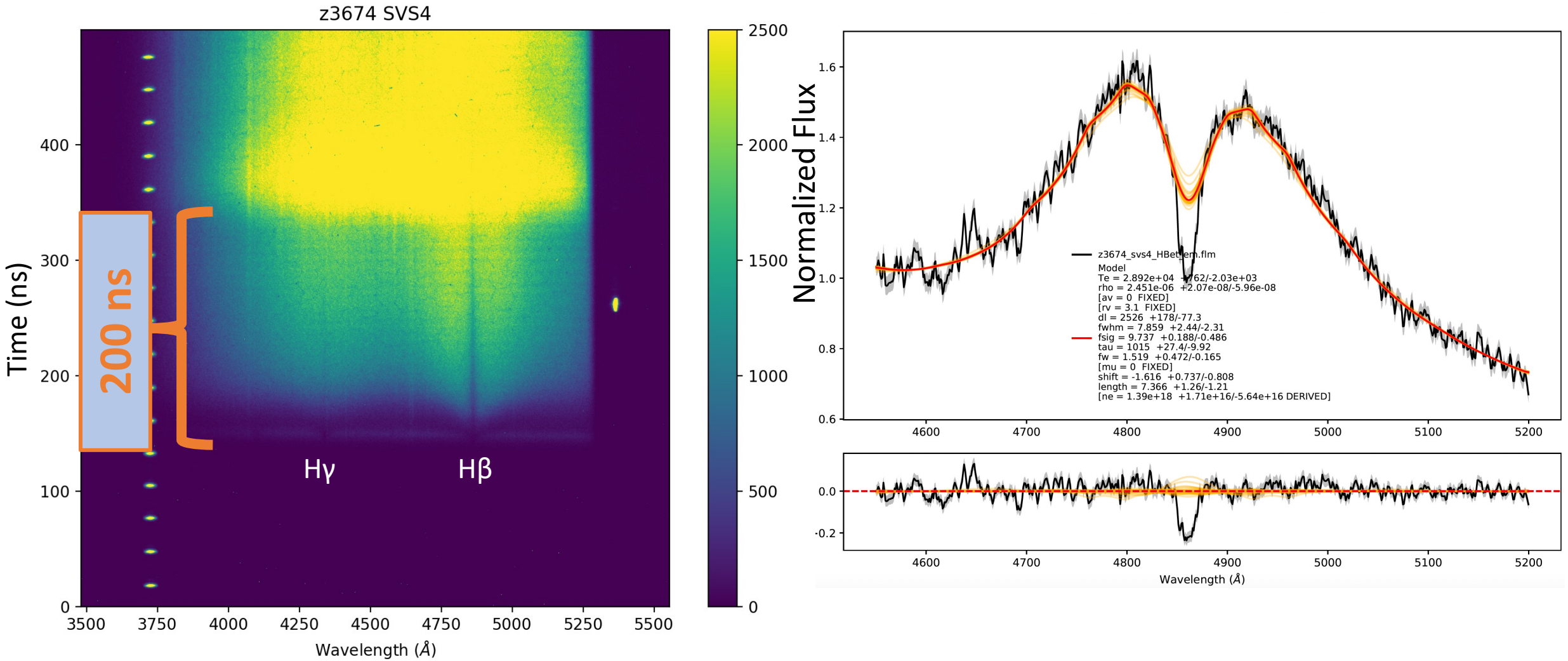
Increased pressure (from 10 Torr to 25 Torr) **and**
Decreased window thickness (from 1.4 µm to 0.7 µm)



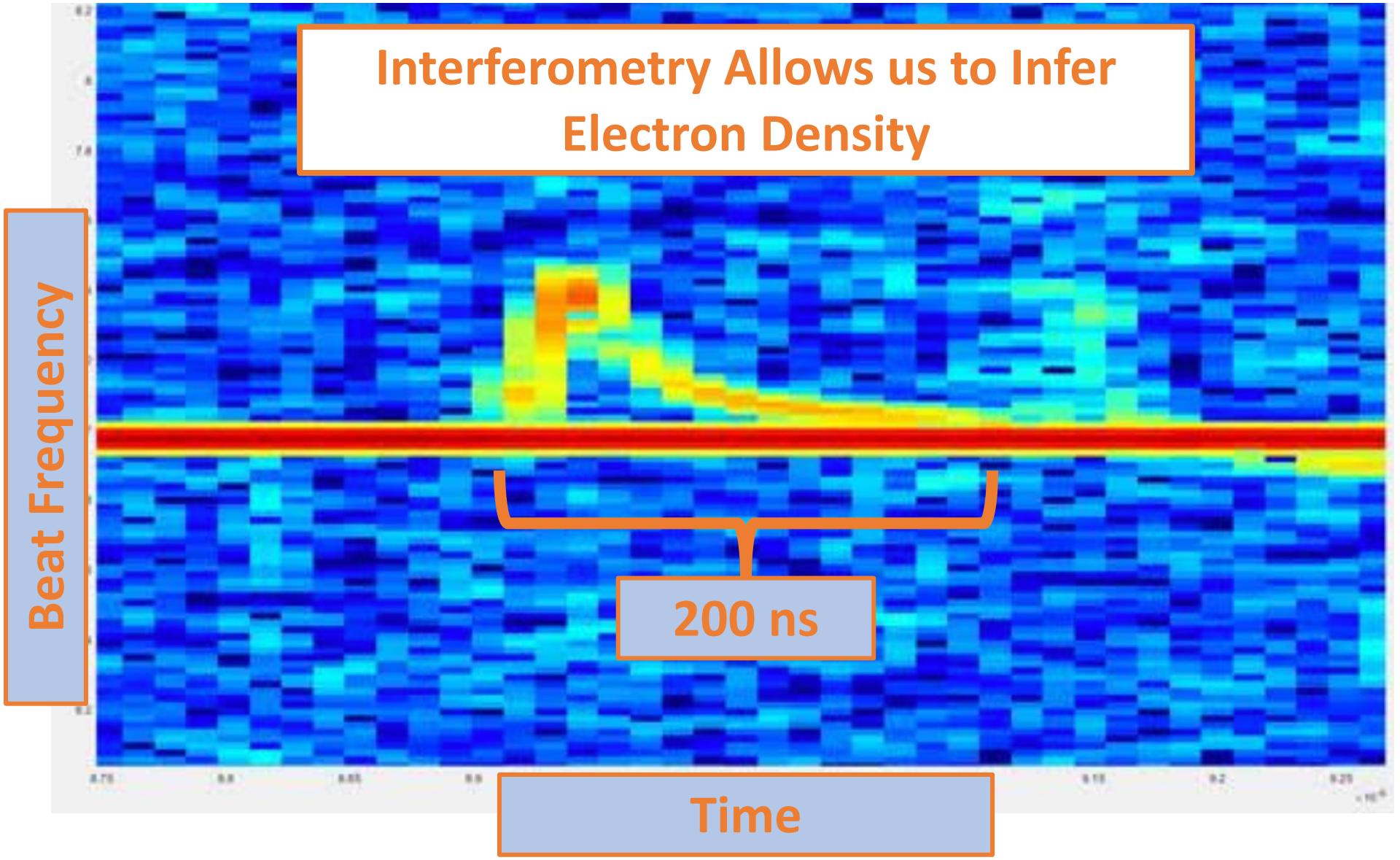


Fits to Hβ suggest $n_e > 10^{18}$ cm^{-3}

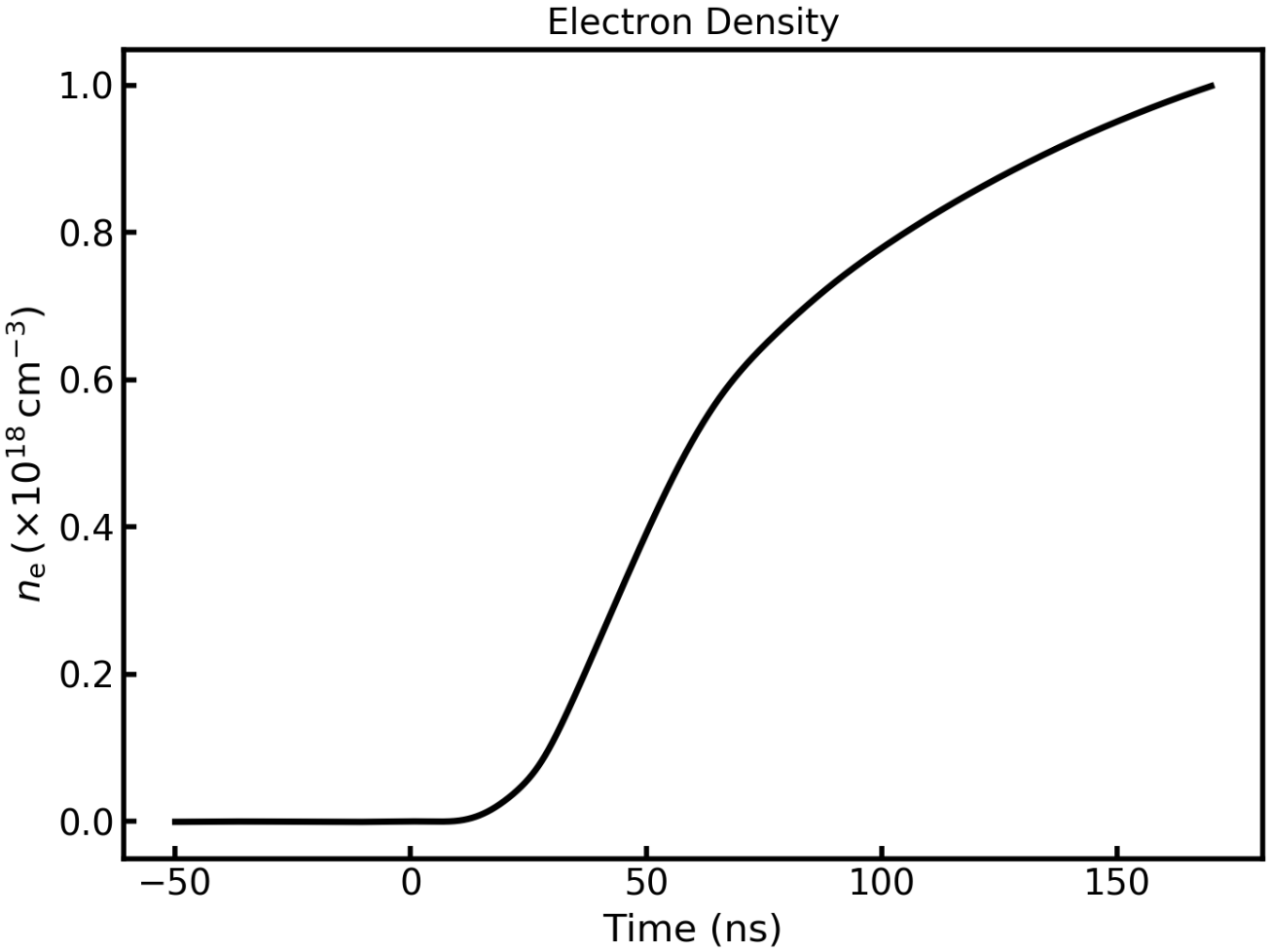
Hitting upper bounds of our current model grid.
Cf. our typical n_e ~ 5 x 10^{16} – 3 x 10^{17}.



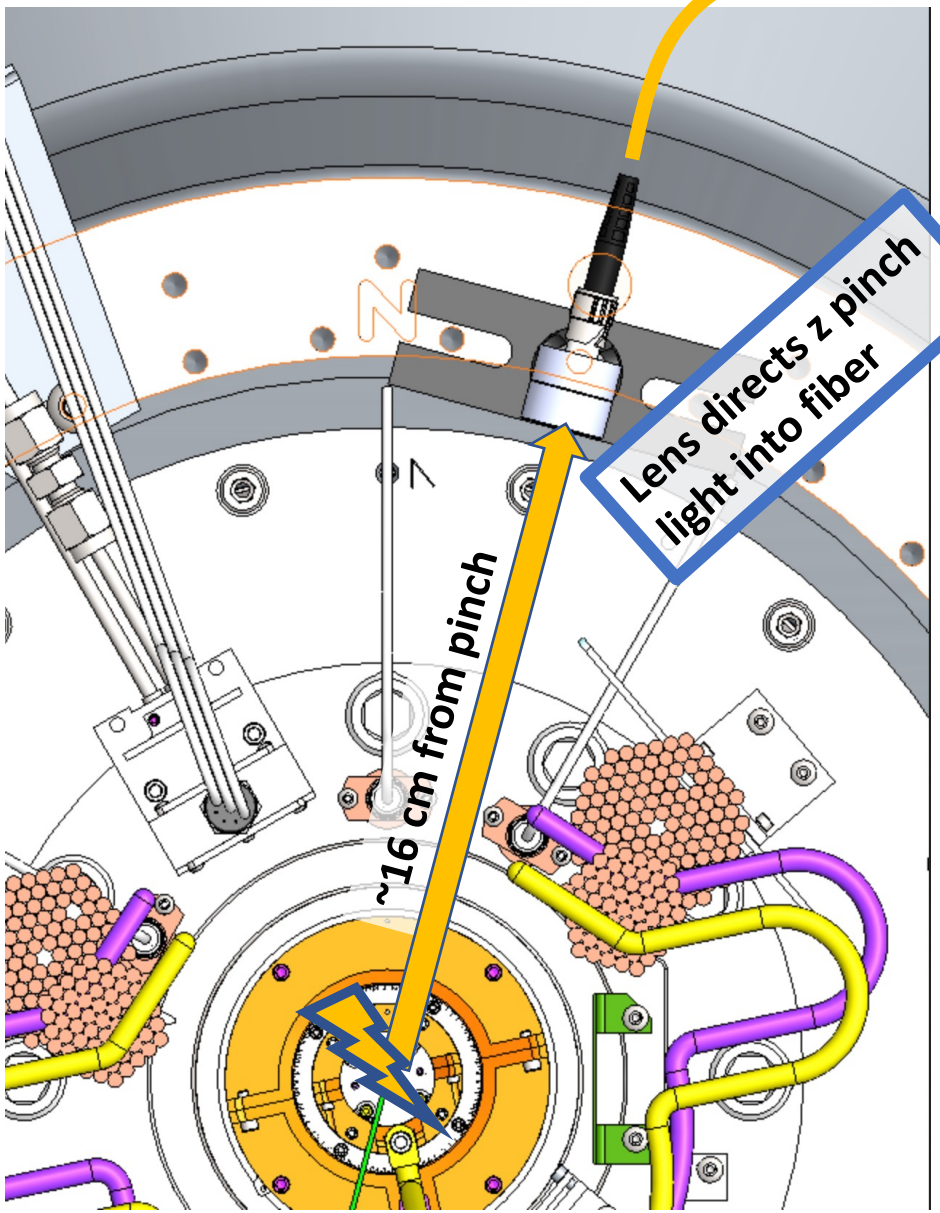
Acquired first PDV results 2.5 weeks ago



Results indicate n_e near 10^{18} cm^{-3}



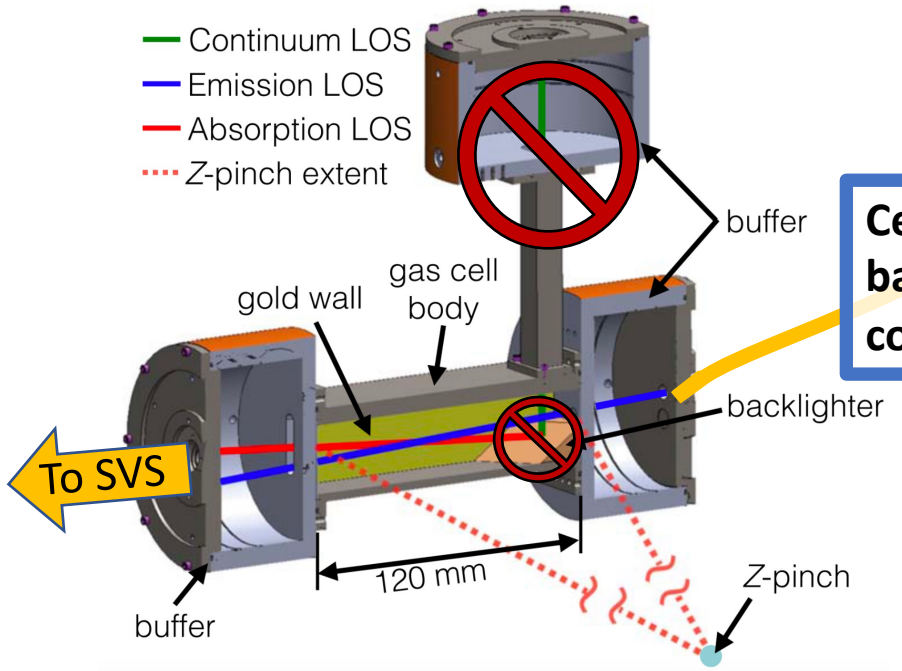
Light from pinch is used to backlight plasma in cell



Long fiber delays light and directs it into cell

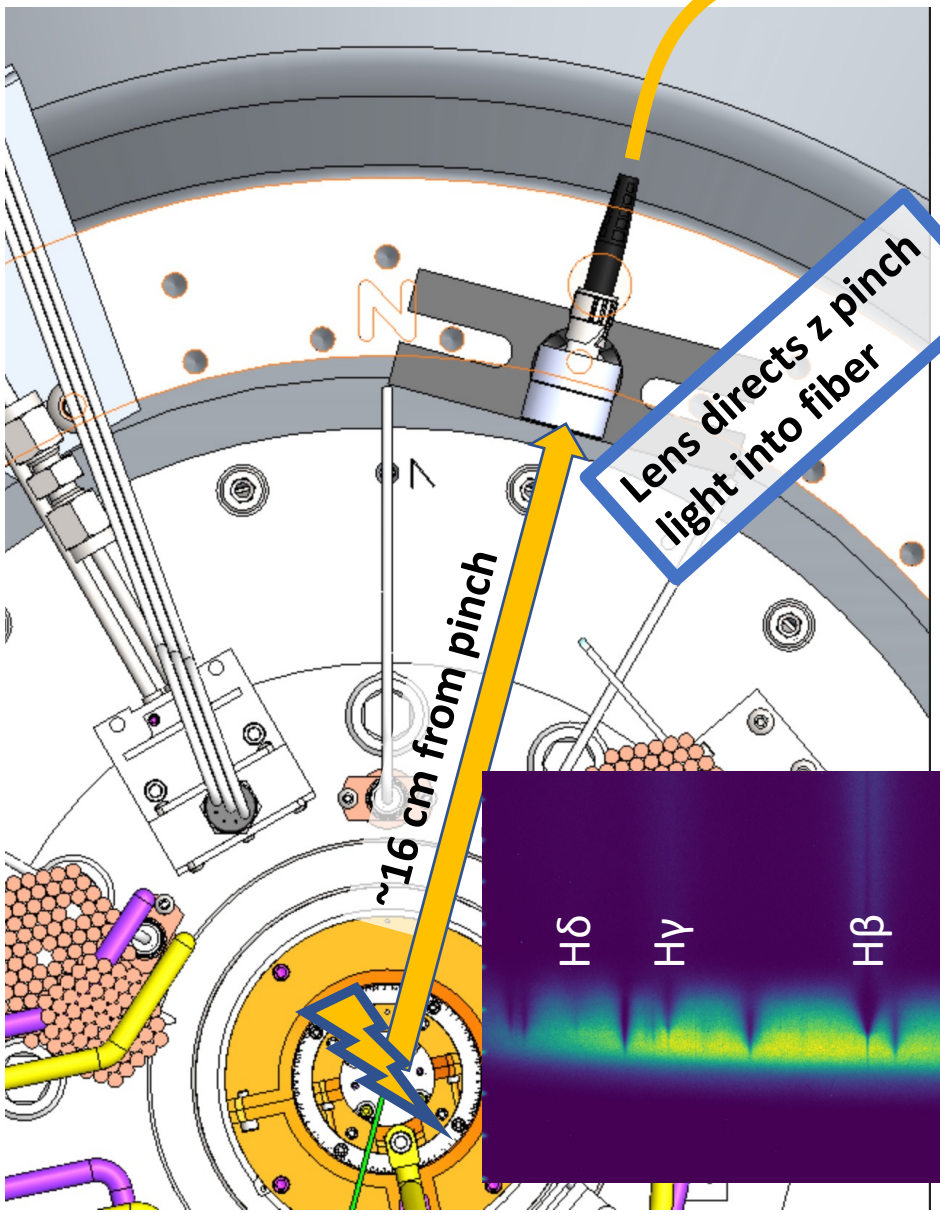
To SVS

Dual core fiber allows direct measurement of backlighting signal



Cell no longer needs backlighting wedge or continuum line of sight

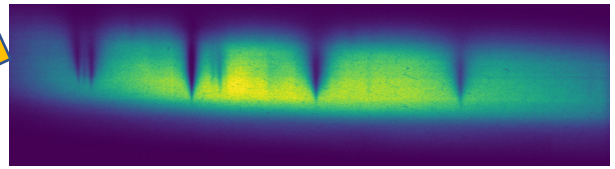
Light from pinch is used to backlight plasma in cell



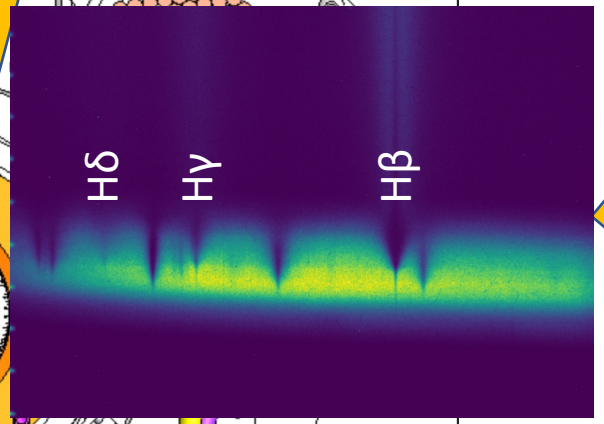
Lens directs z pinch light into fiber

Long fiber delays light and directs it into cell

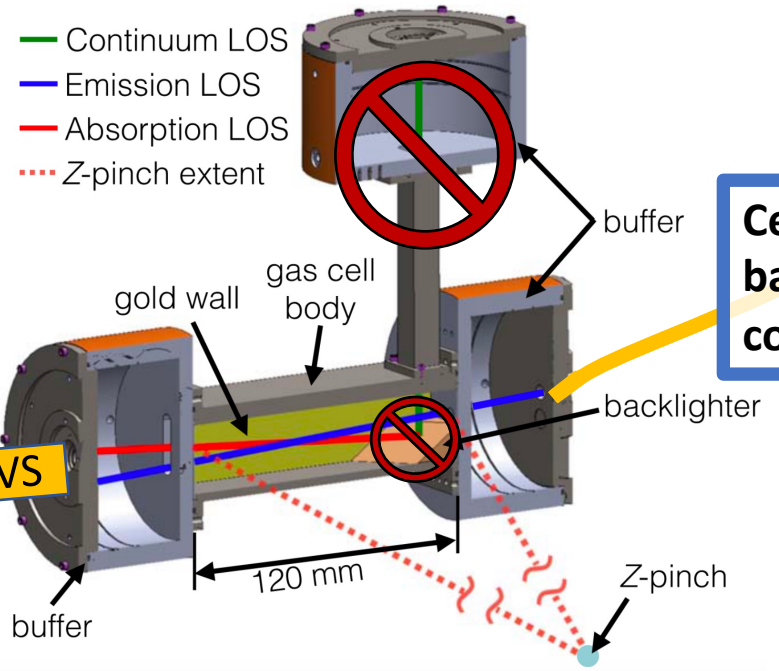
To SVS



Dual core fiber allows direct measurement of backlighting signal



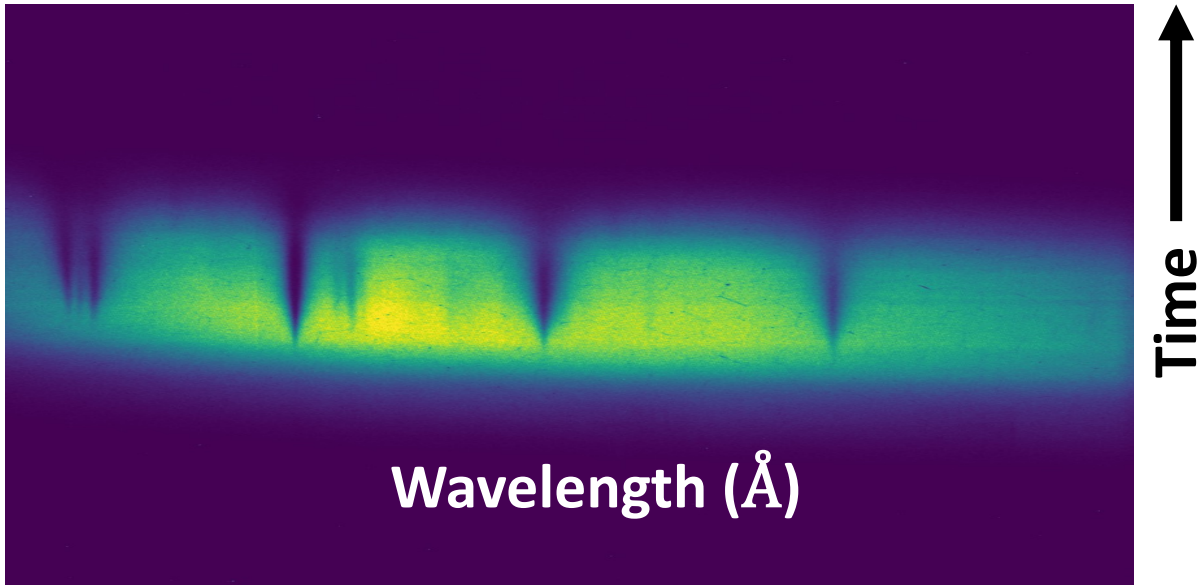
To SVS

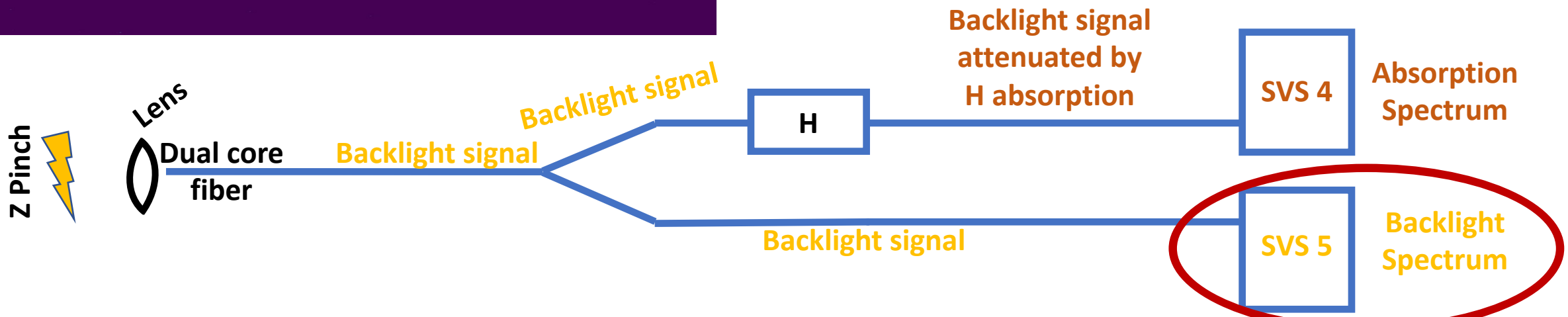


Cell no longer needs backlighting wedge or continuum line of sight

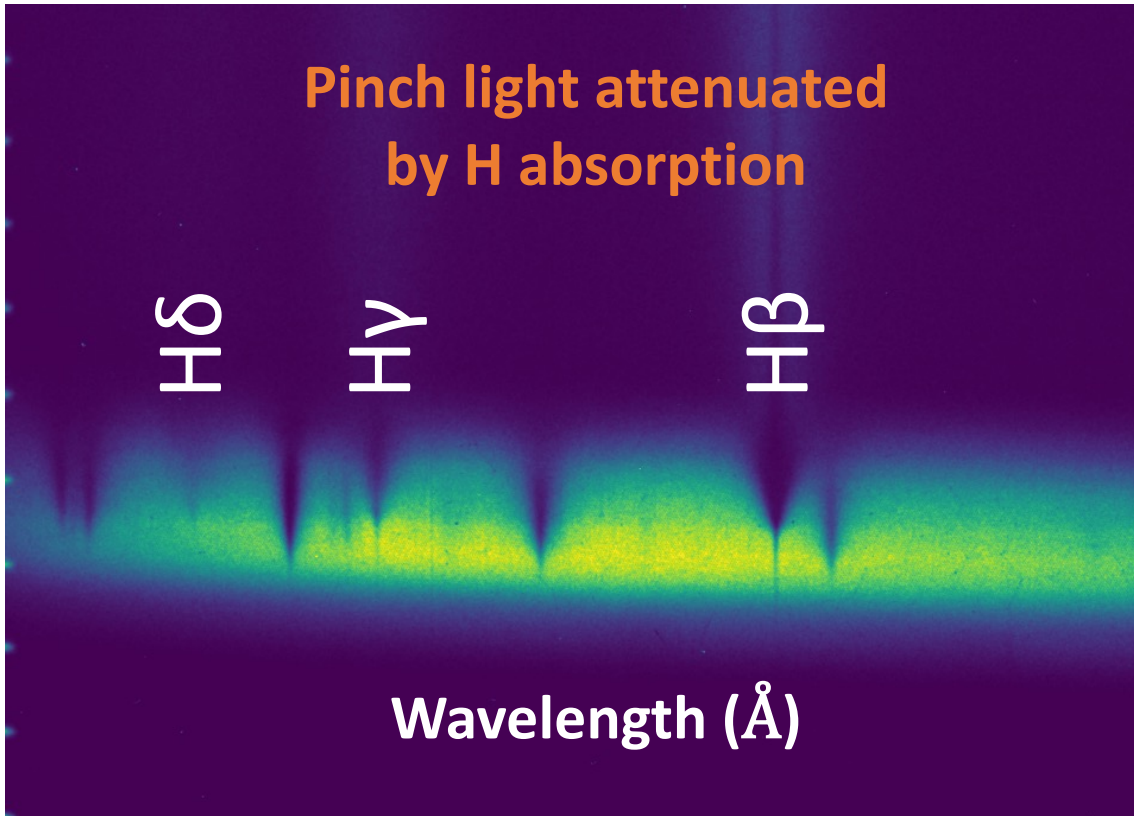
Pinch light successfully fielded as backlight for absorption spectrum

Pinch light direct to SVS

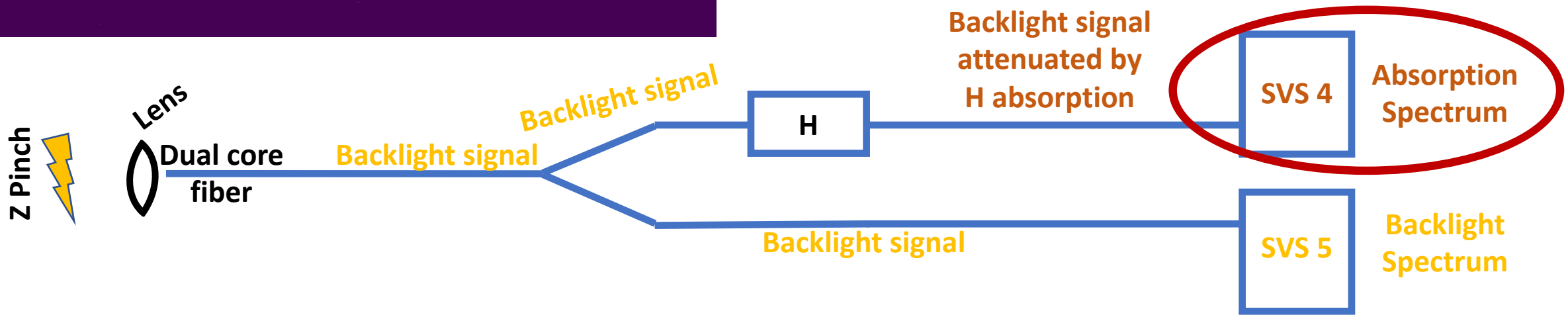




Pinch light successfully fielded as backlight for absorption spectrum

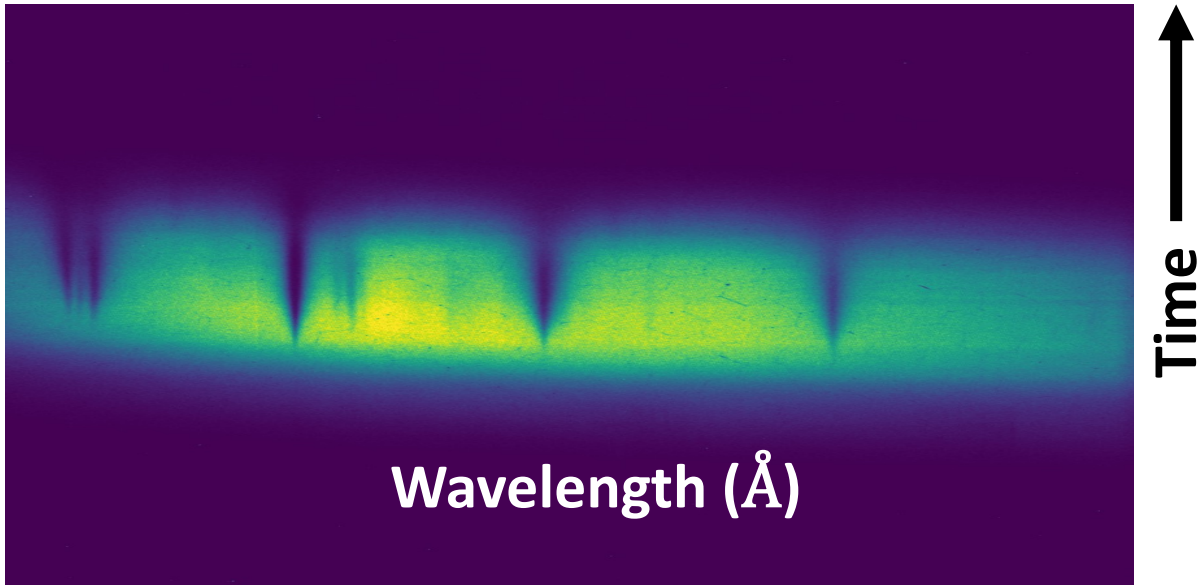


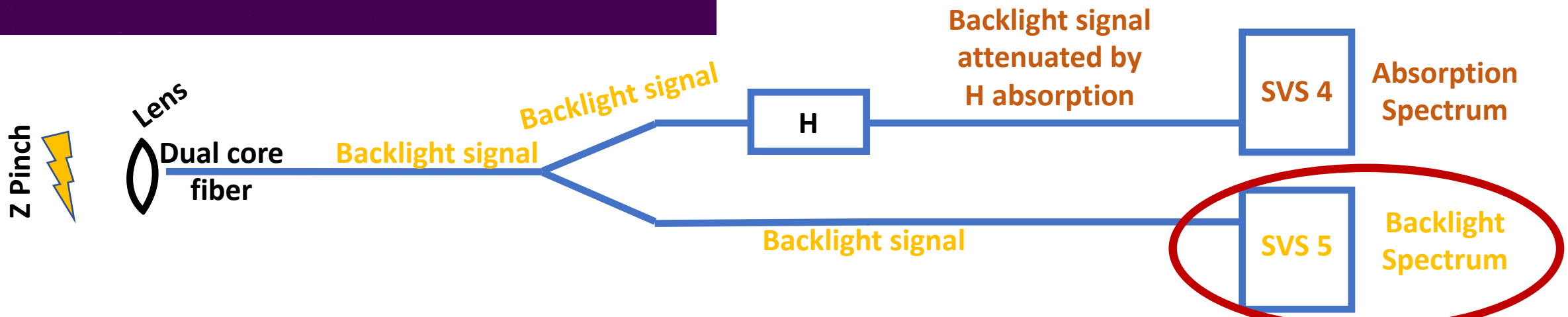
Time



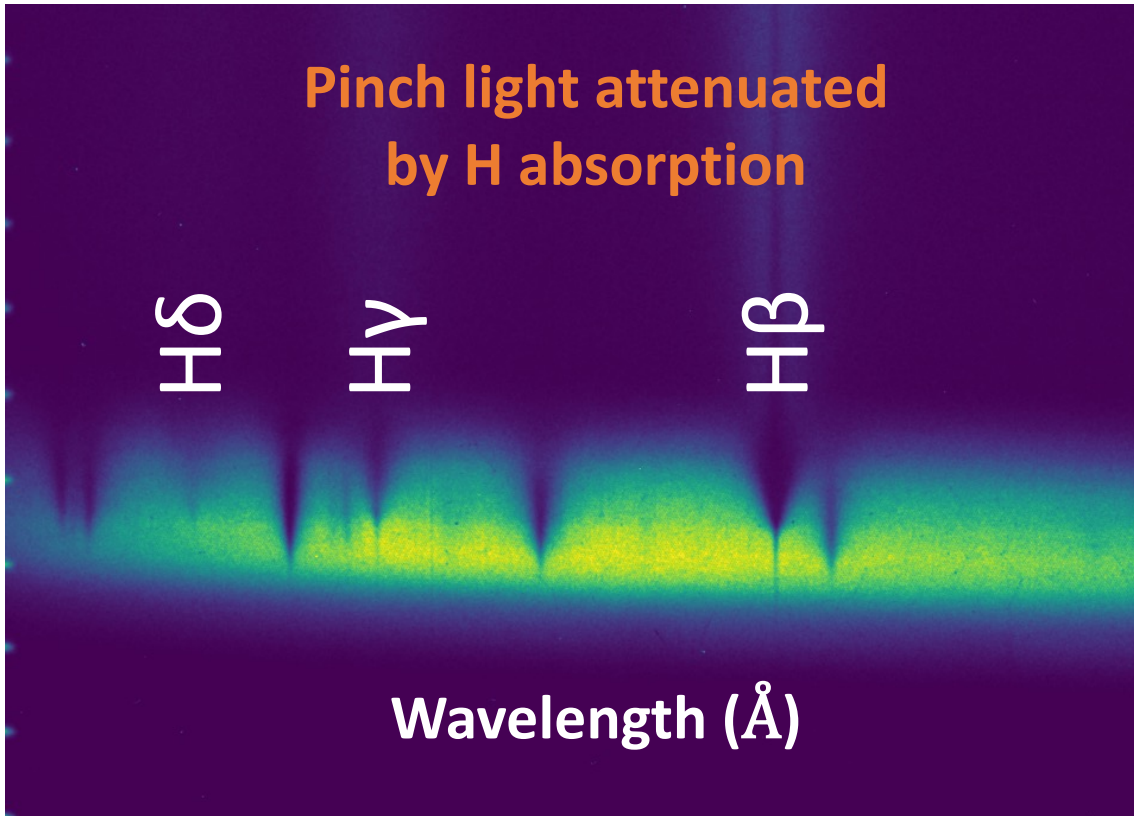
Pinch light successfully fielded as backlight for absorption spectrum

Pinch light direct to SVS

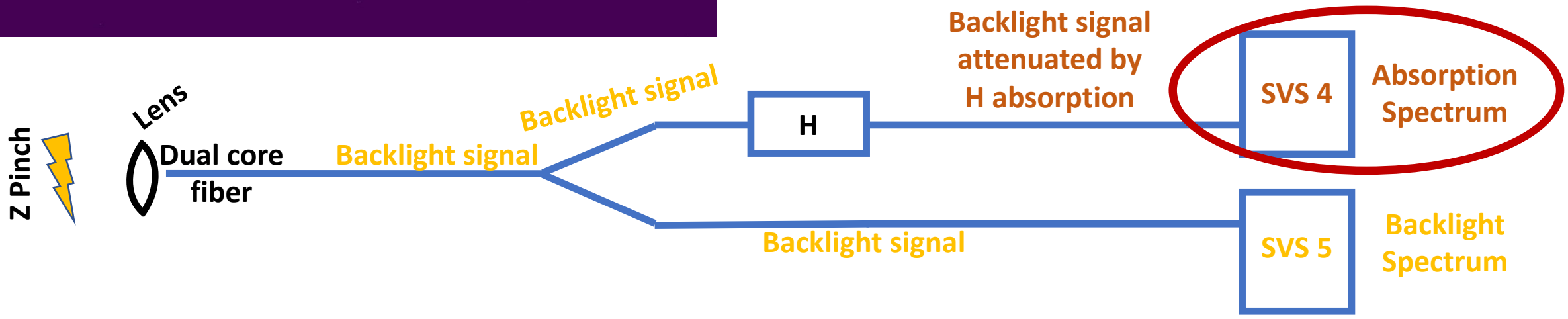




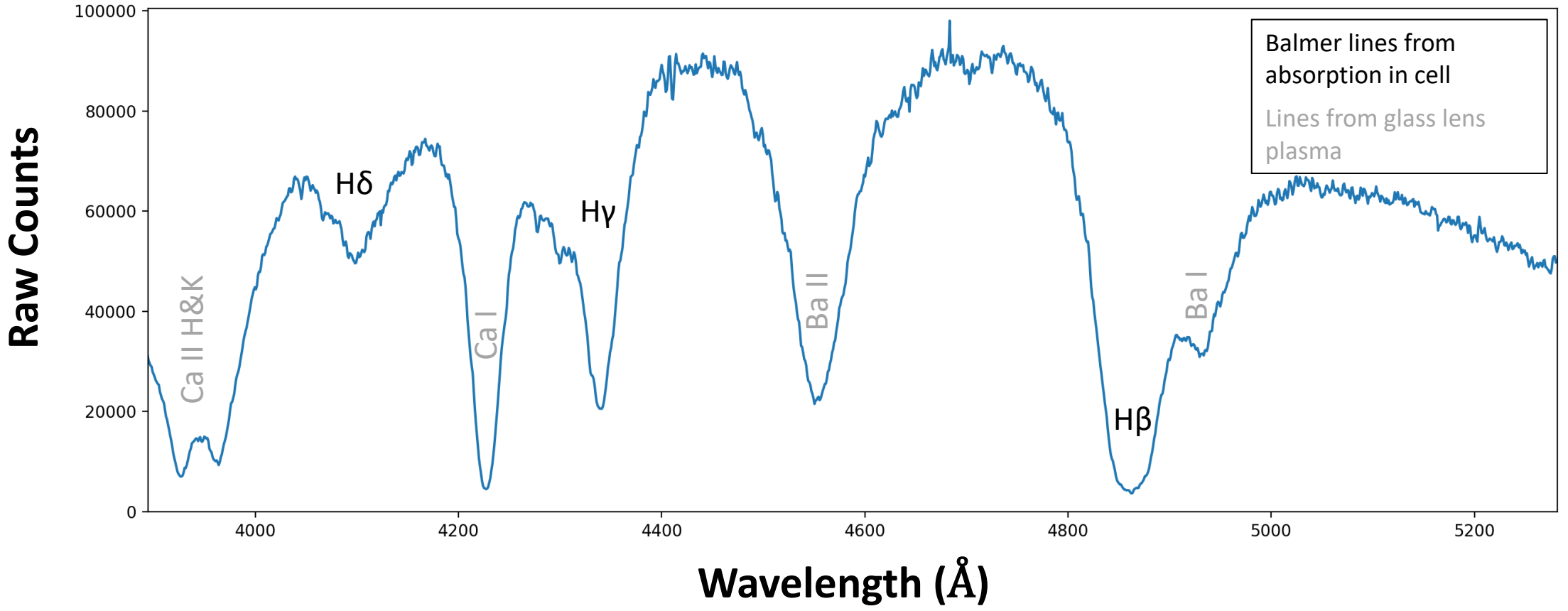
Pinch light successfully fielded as backlight for absorption spectrum



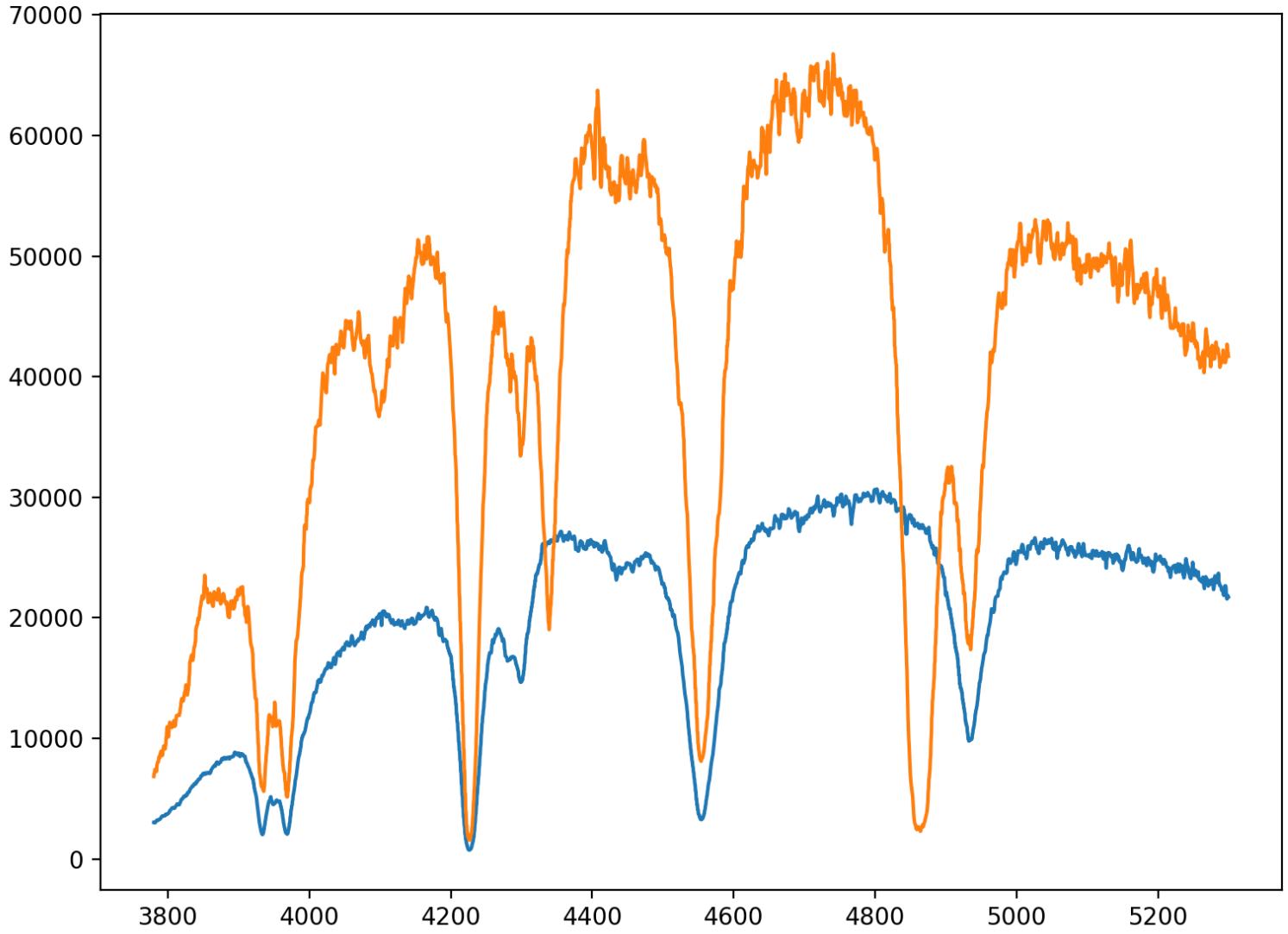
Time



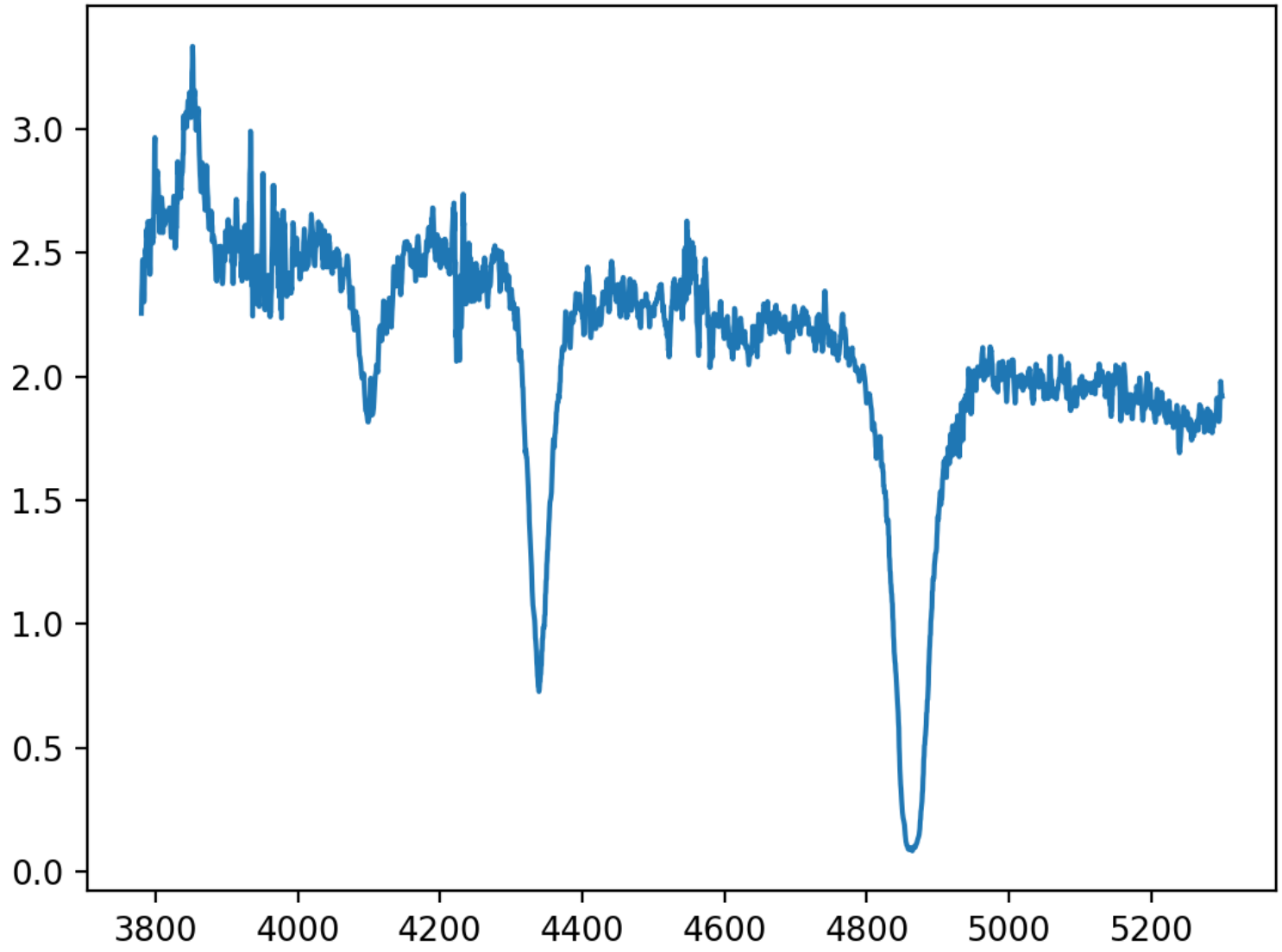
Hydrogen absorption measured with backlight from z pinch



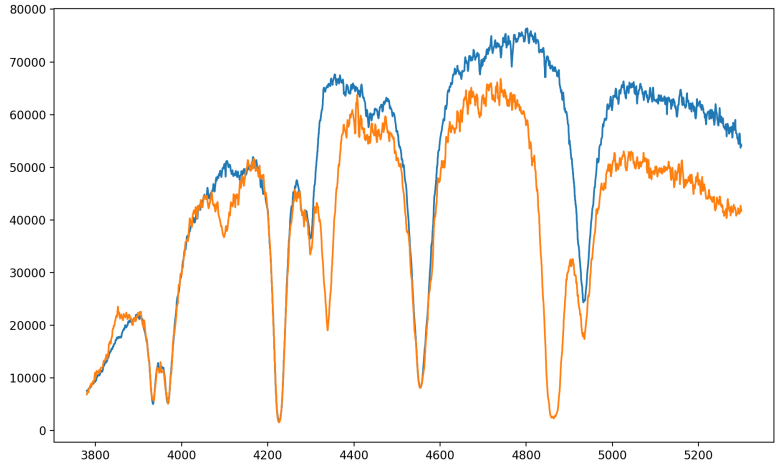
Naïve application shows attenuated spectrum brighter than backlight spectrum

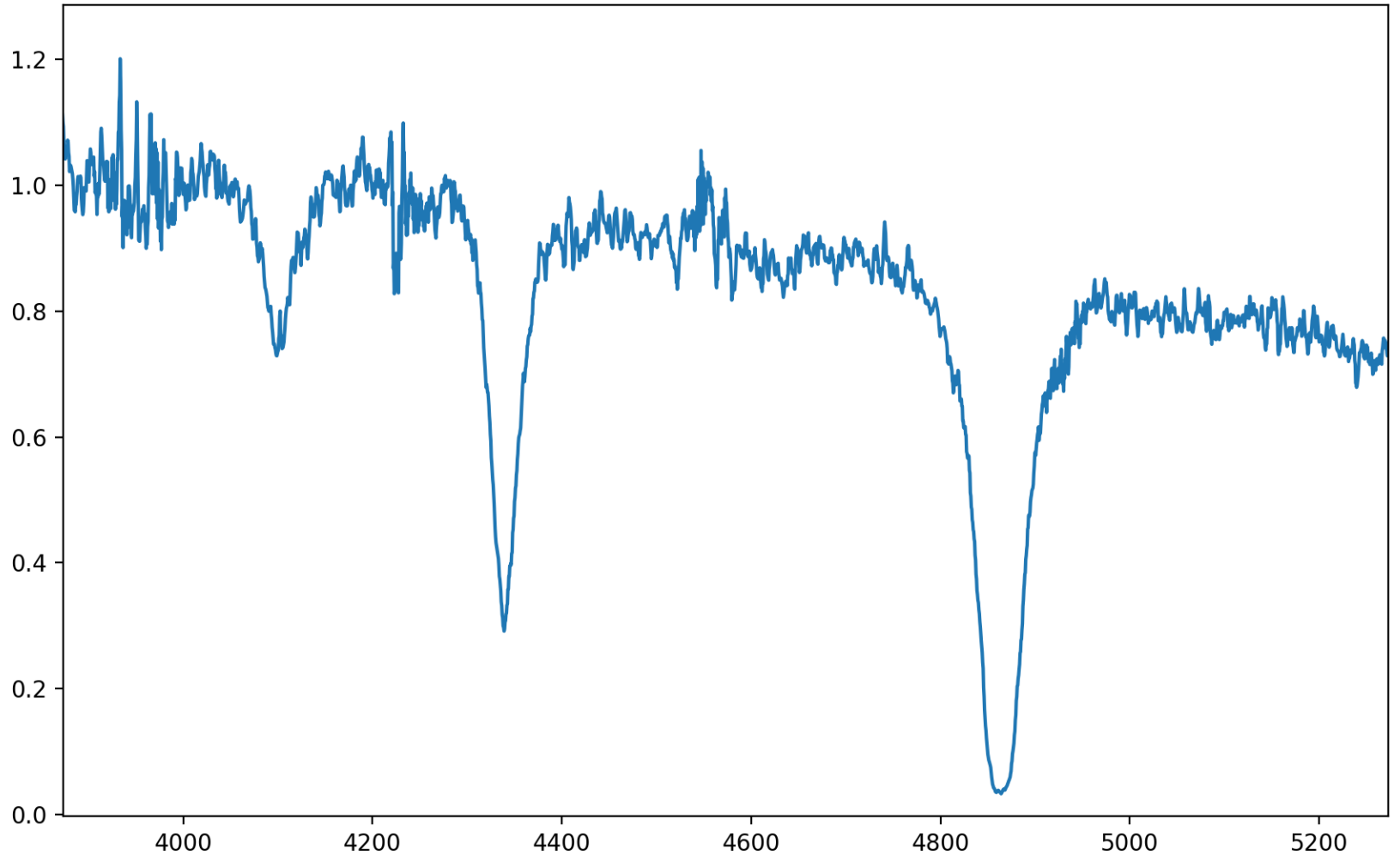


Spectral lines from lens are removed ~ well in resulting transmission spectrum



Spectra can be scaled based on early-time data

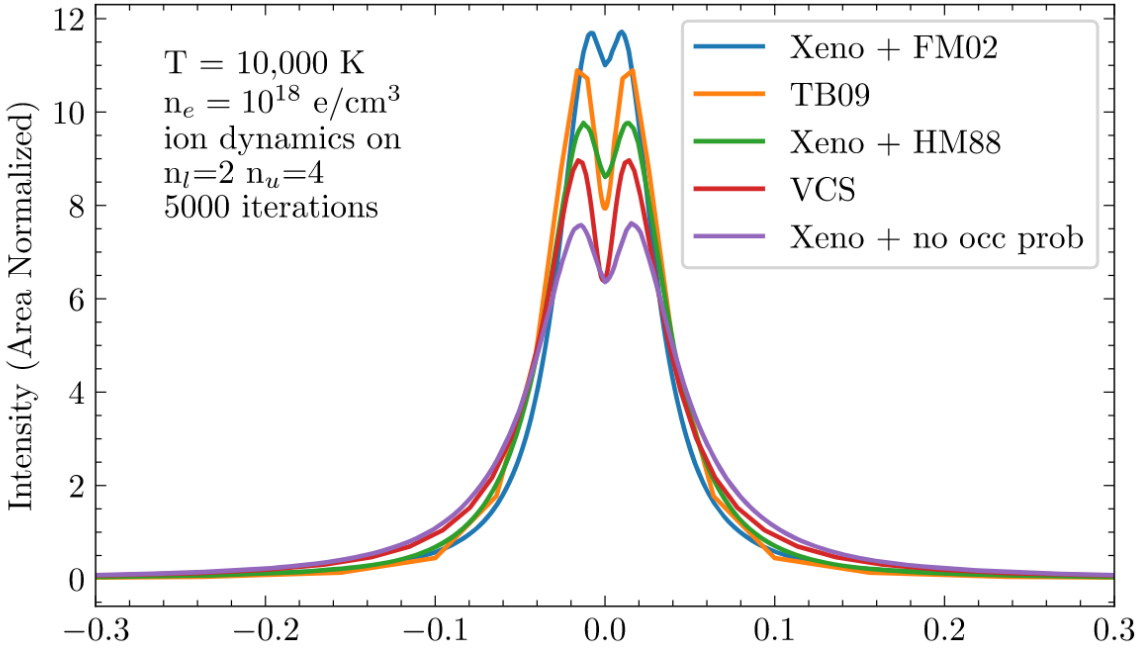


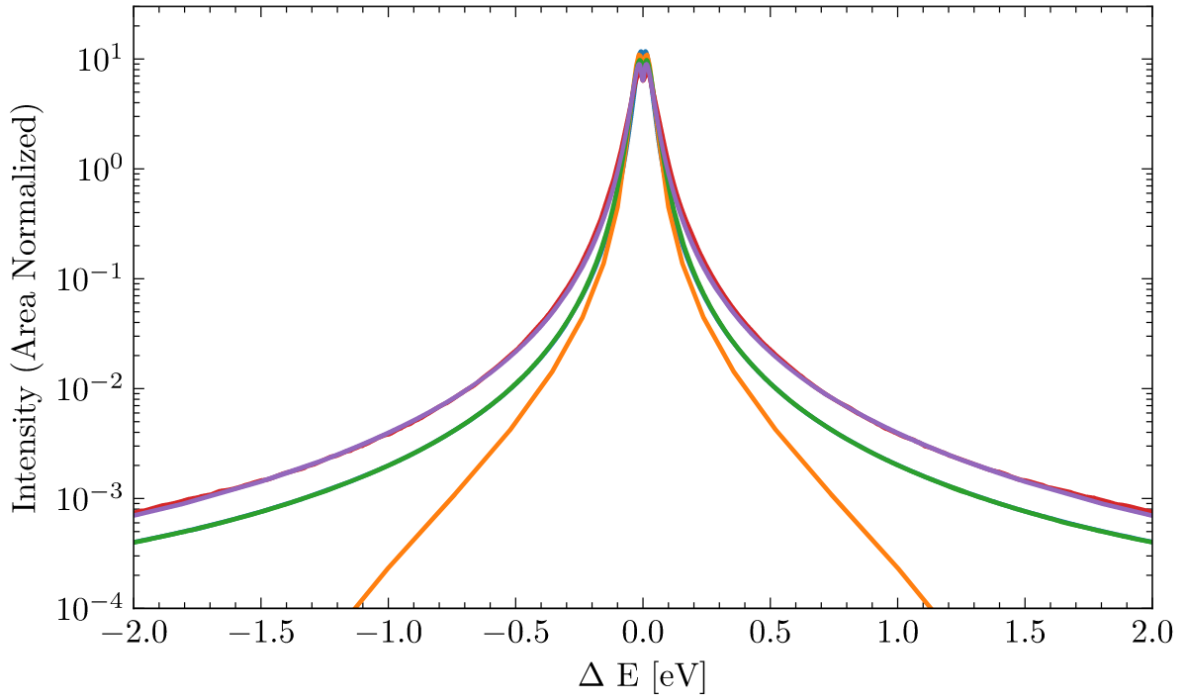


Occupation probability prescription matters

THE ASTROPHYSICAL JOURNAL, 927:70 (20pp), 2022 March 1 https://doi.org/10.3847/1538-4357/ac4df3

Simulation of Stark-broadened Hydrogen Balmer-line Shapes for DA White Dwarf Synthetic Spectra





What happens to E levels when an ion gets close: