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GLOBAL INFRASOUND DETECTIONS OF ENERGETIC BOLIDES

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Thursday, March 14, 2024, 14:20 – 14:30

Planetary Defense Session, Abstract # 1017

LDRD LABORATORY DIRECTED RESEARCH & DEVELOPMENT
WHERE INNOVATION BEGINS

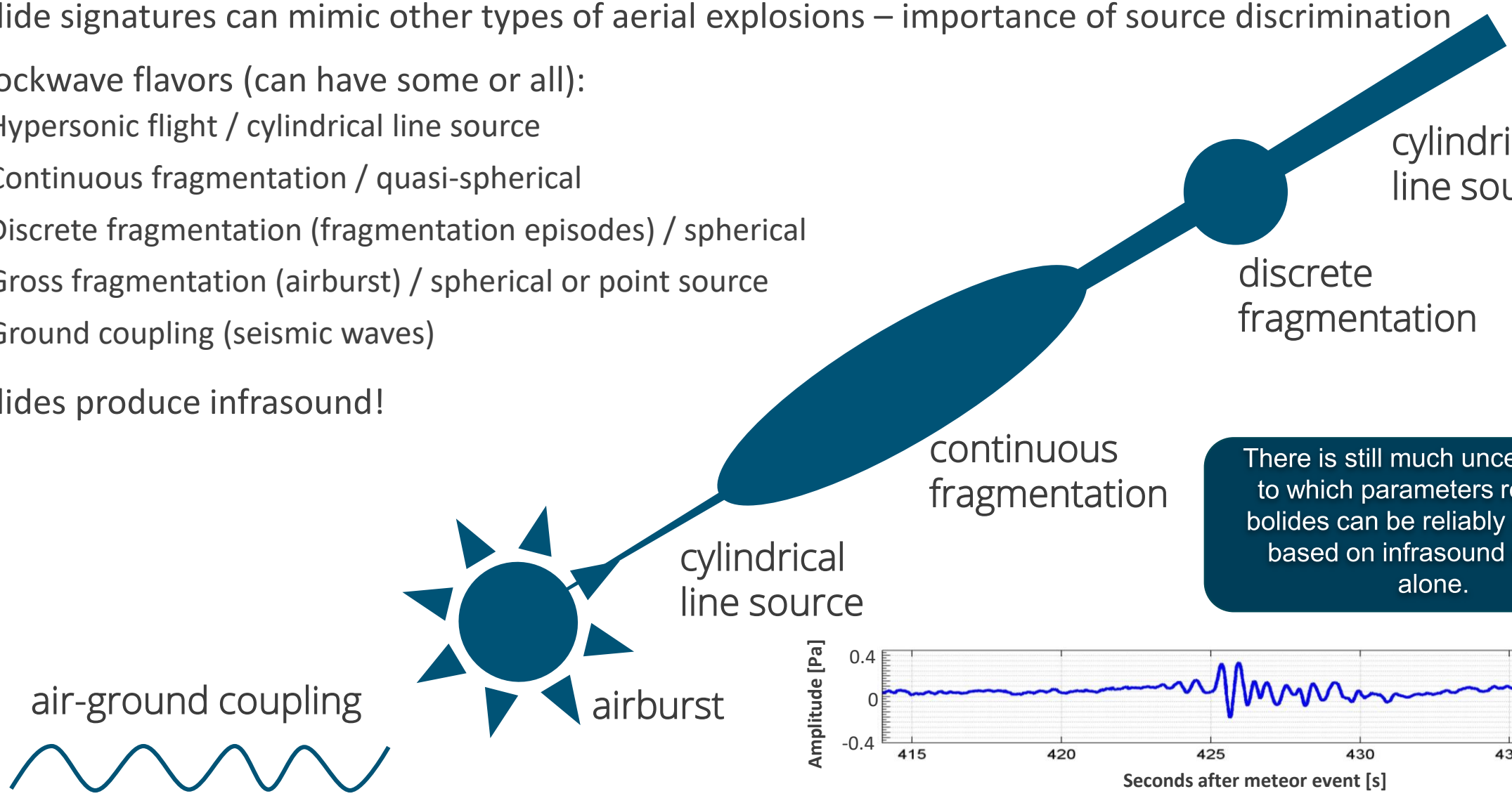
OBSERVATIONS OF LARGE BOLIDES

Image credit: Peter Meadows (April 1 , 2022, at 22:18 UTC), Chelmsford, England

- In addition to producing a spectacular display in the sky, fireballs and bolides generate ***shockwaves***
- Ongoing effort to better characterize large bolides
- Events recorded and documented through various means of observation
  - US Government sensors
  - GLM
  - All-sky cameras (still and video)
  - Radar
  - Casual witnesses
  - Other less conventional methods – ***infrasound & seismic***
- There is no perfect approach that would provide all answers we seek; therefore it is imperative to leverage all approaches

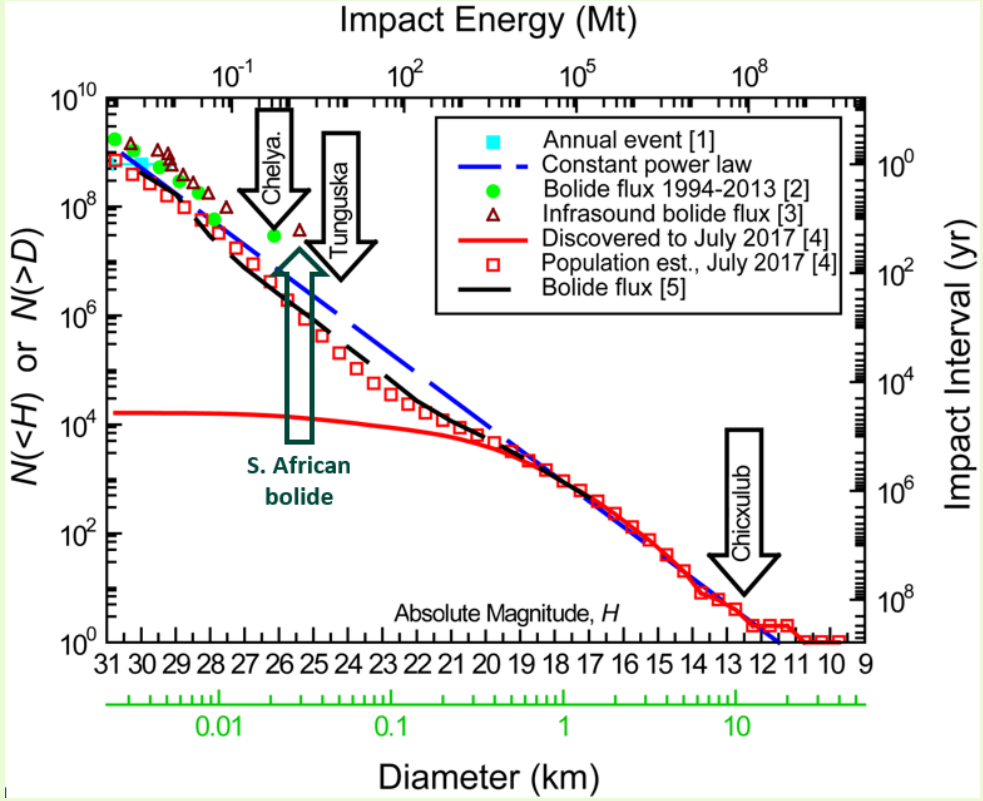
BOLIDES PRODUCE SHOCKWAVES

- Bolide signatures can mimic other types of aerial explosions – importance of source discrimination
- Shockwave flavors (can have some or all):
  - Hypersonic flight / cylindrical line source
  - Continuous fragmentation / quasi-spherical
  - Discrete fragmentation (fragmentation episodes) / spherical
  - Gross fragmentation (airburst) / spherical or point source
  - Ground coupling (seismic waves)
- Bolides produce infrasound!



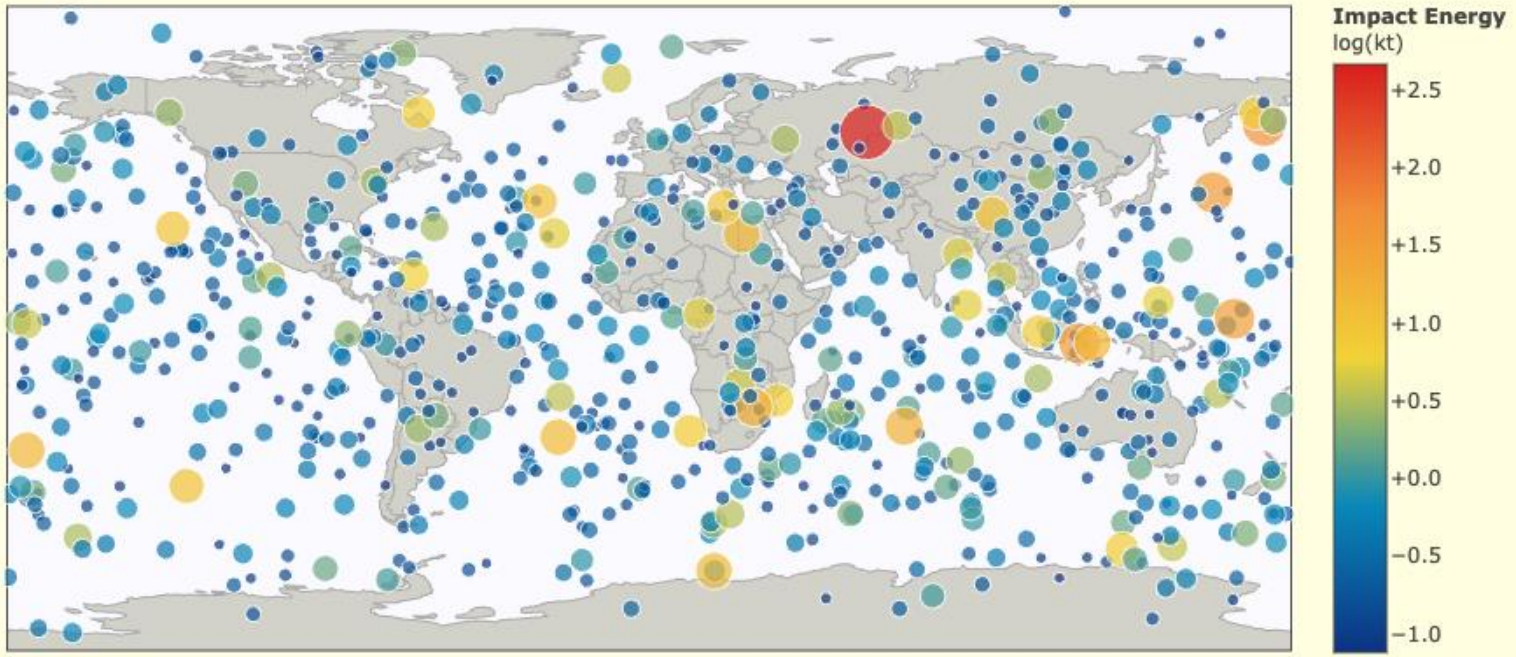
There is still much uncertainty as to which parameters related to bolides can be reliably extracted based on infrasound records alone.

APPROACH



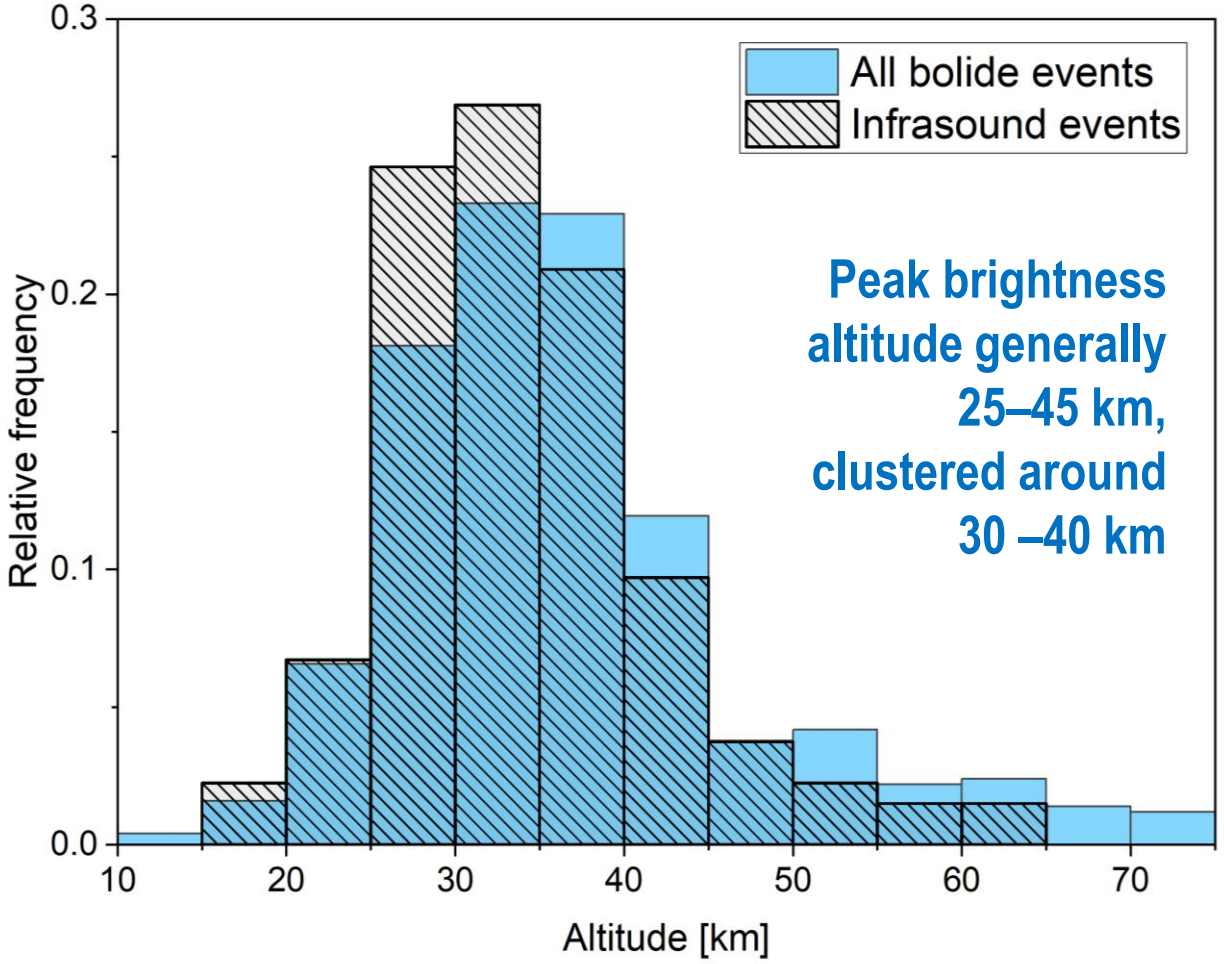
References:
[1] Brown et al. (2002)
[2] Boslough et al. (2015)
[3] Silber et al. (2009)
[4] Stokes et al. (2017)
[5] Tricarico (2017)

Figure from: Silber et al. (2018) Physics of Meteor Generated Shock Waves in the Earth's Atmosphere – A Review, *ASR*

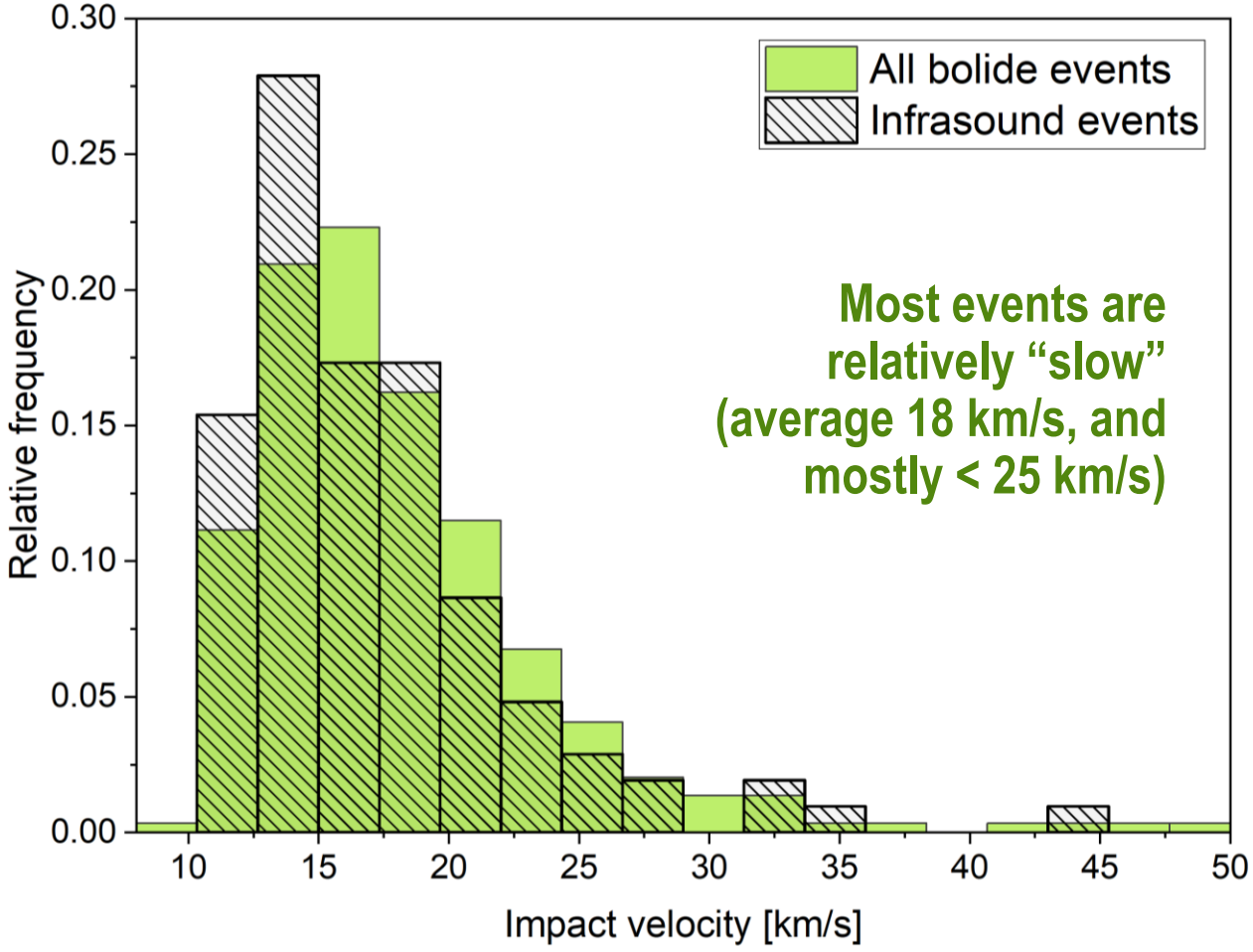


- Leverage the JPL CNEOS global fireballs database (960 events as of Aug 2023) and search for infrasound signals for each event
- Known location, time; in most cases altitude, and in some cases velocity vector
- Thus far, 162 confirmed bolide events generated infrasound since 1998
- 297 have a velocity vector and 502 have altitude of peak brightness (296 overlap)

PRELIMINARY RESULTS

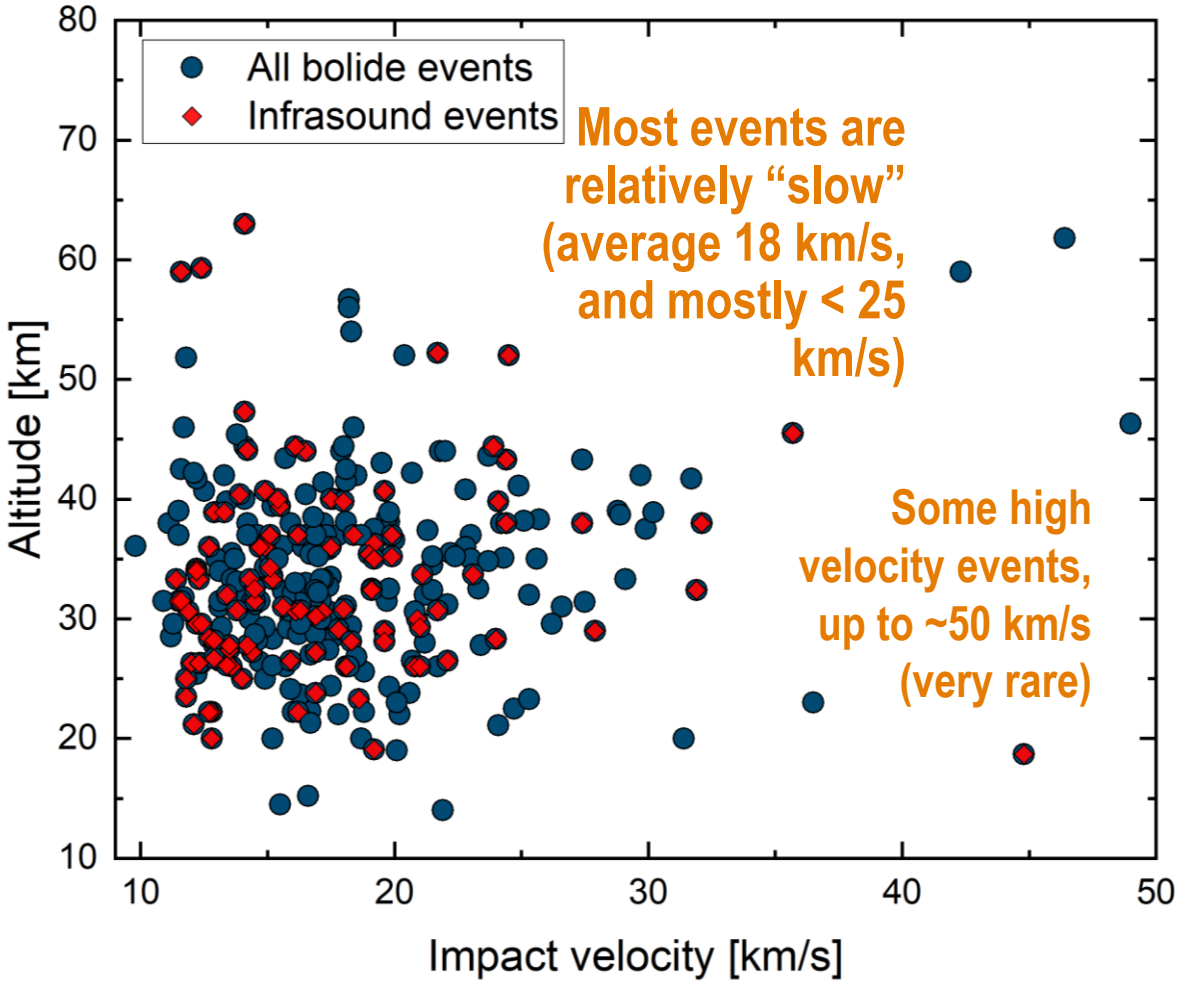


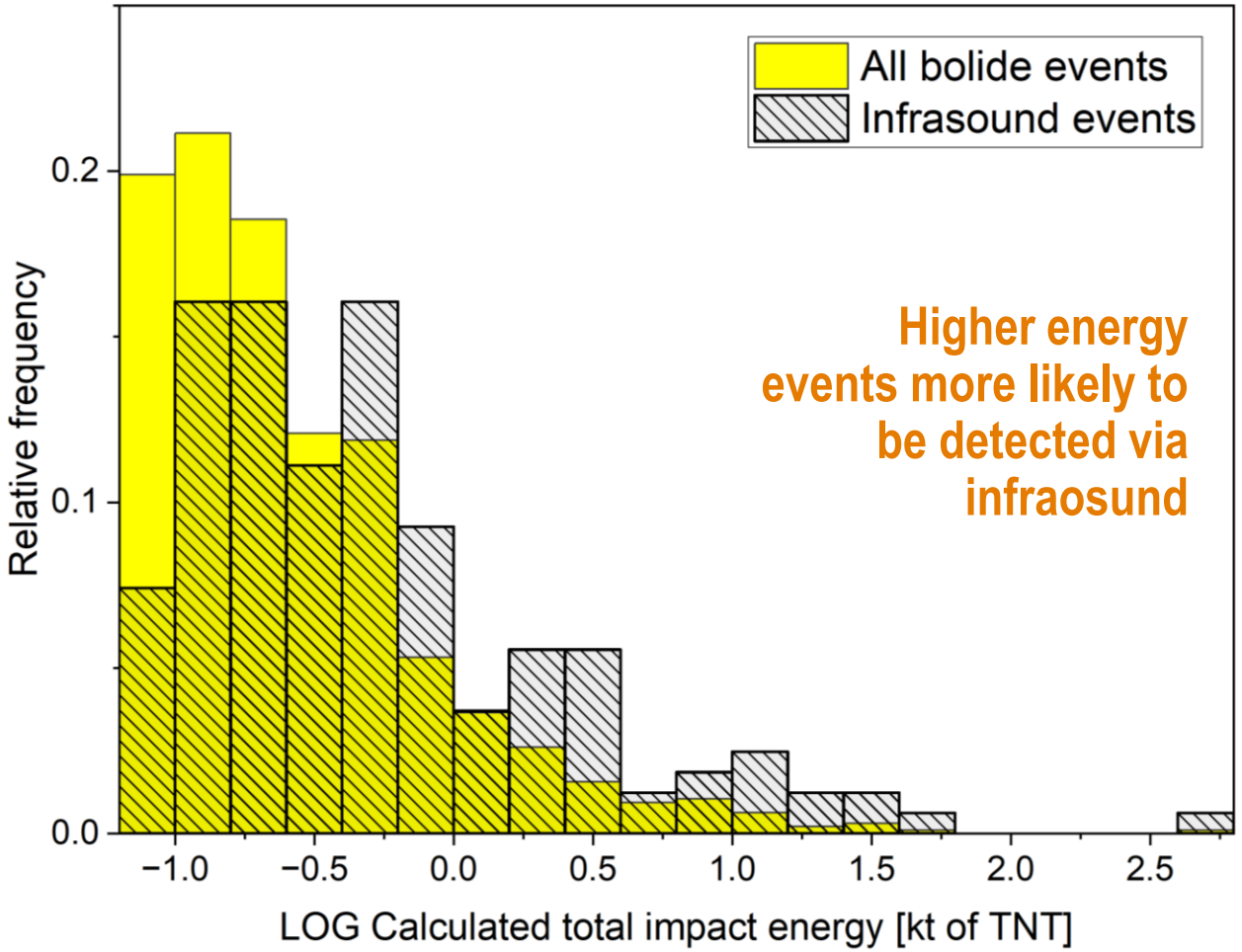
Peak brightness altitude generally 25–45 km, clustered around 30 –40 km



Most events are relatively "slow" (average 18 km/s, and mostly < 25 km/s)

PRELIMINARY RESULTS





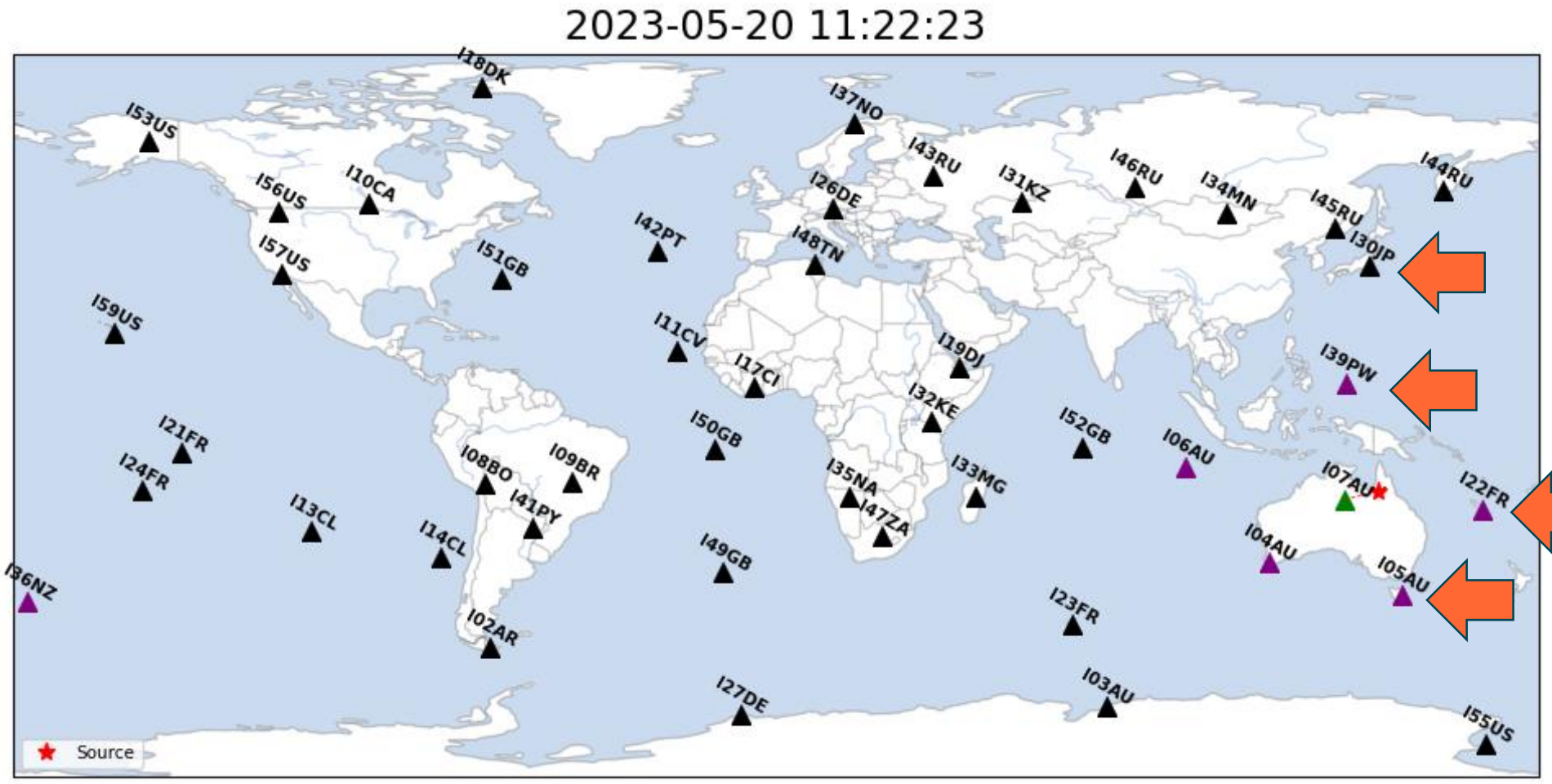
AUSTRALIAN BOLIDE (MAY 20, 2023)

- Bolide over Queensland, at 9:22 pm local time (May 20, 2023)
- Was visible 600 km away
- Blackbull, a small rural locality between the Gulf communities of Normanton and Croydon, in north-west Queensland
- Altitude = 29 km, v = 28 km/s
- Size ~ 3.5 m
- Produced a sonic boom
- E = 7.2 kt of TNT equivalent (top 20 in the entire JPL CNEOS database)

Image credit: Cairns Airport

AUSTRALIAN BOLIDE (INFRASOUND DETECTIONS)

- Detected on 4 stations of the IMS network, predominantly east from the bolide (effect of winds)



I22FR – 2650 km

I05AU – 2800 km

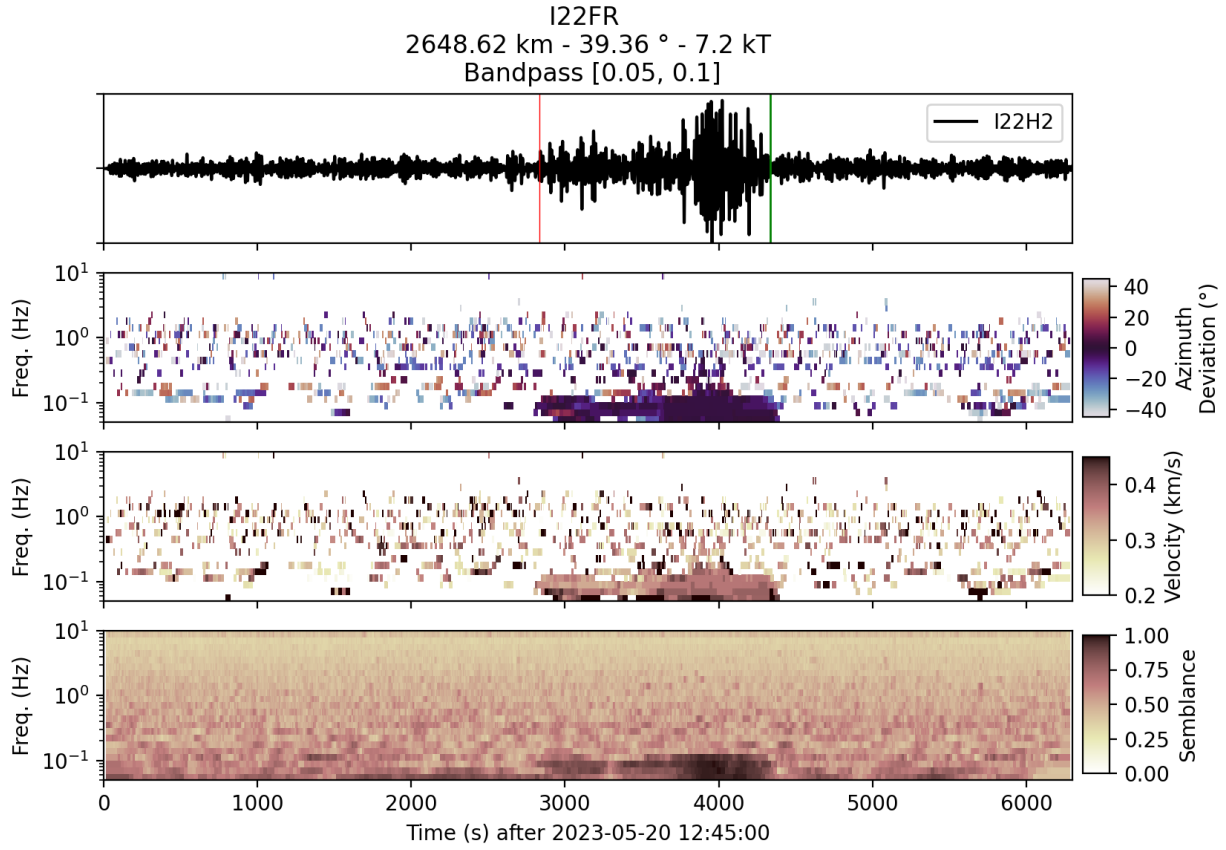
I39PW – 2930 km

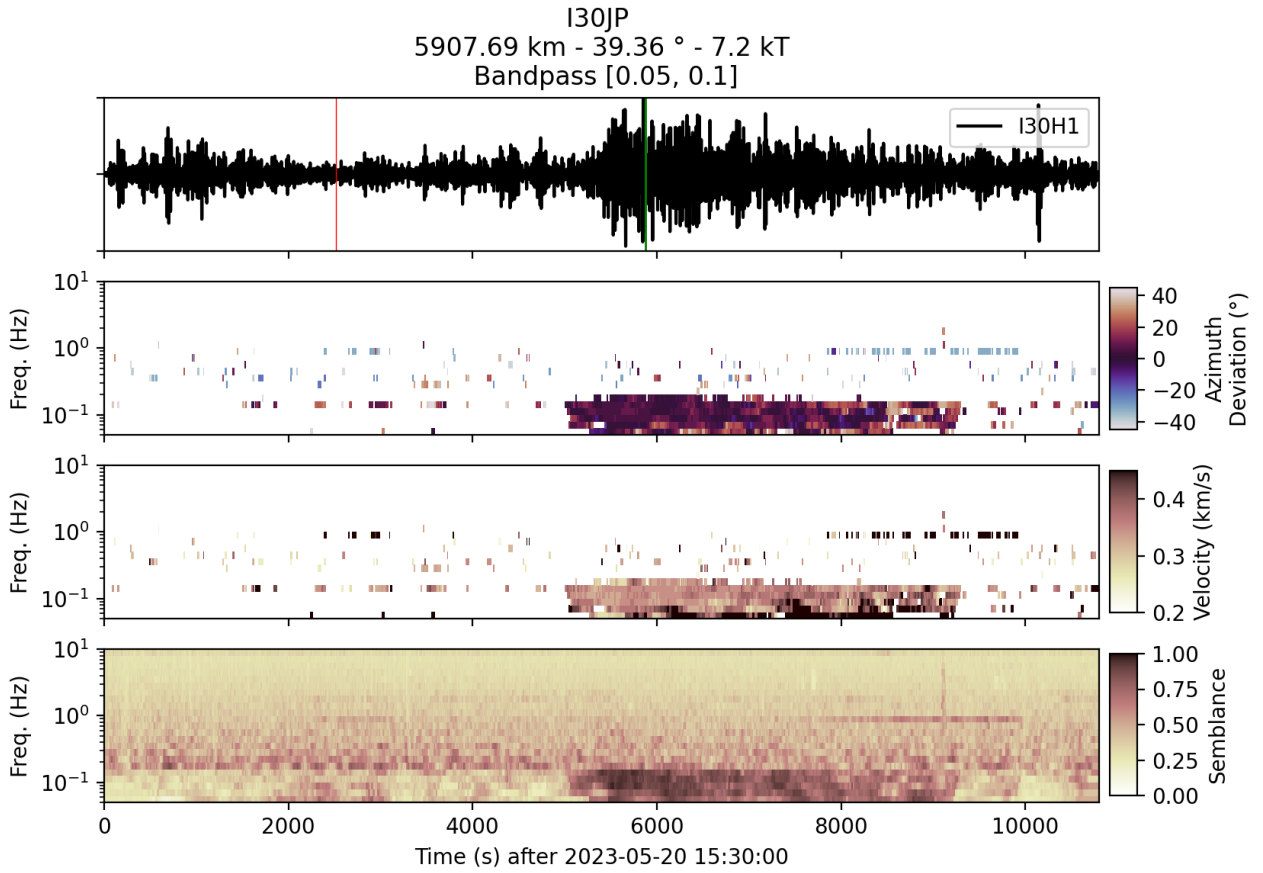
I30JP – 5907 km

I07AU – 830 km (no detection)

I04AU – 3140 km (no detetion)

AUSTRALIAN BOLIDE





Energy estimate (ReVelle, 1997)

$\log (E/2) = 3.34 \log(T) - 2.58$

7 kt of TNT

US government sensors

7.2 kt of TNT

SUMMARY

- Infrasound can be leveraged towards global monitoring and detection of large bolides
- Useful when ground truth is not well documented
- Can provide yield estimate and other information that might not be readily available through other means
- Synergetic with other sensing modalities

Image credit: Marko Korosec/Solent News/Shutterstock

THANK YOU!