Radio Afterglows From Large Meteors

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Fifteenth Synthesis Imaging Workshop

1-8 June 2016

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New Mexico Tech
SCIENCE · ENGINEERING · RESEARCH · UNIVERSITY

The University of New Mexico

New Mexico CONSORTIUM

13th Synthesis Imaging Workshop (2012)

The First Station of the Long Wavelength Array (LWA1)

The LWA1 consists of 256 dual polarization dipoles, 100 x 110 m ellipse, 10 - 88 MHz, located adjacent to the VLA

Beamforming

The dipoles can be phased and summed to mimic a 100 m dish.

This is done digitally so up to 4 beams can be formed at any one time

Each beam covers ~32 MHz bandwidth

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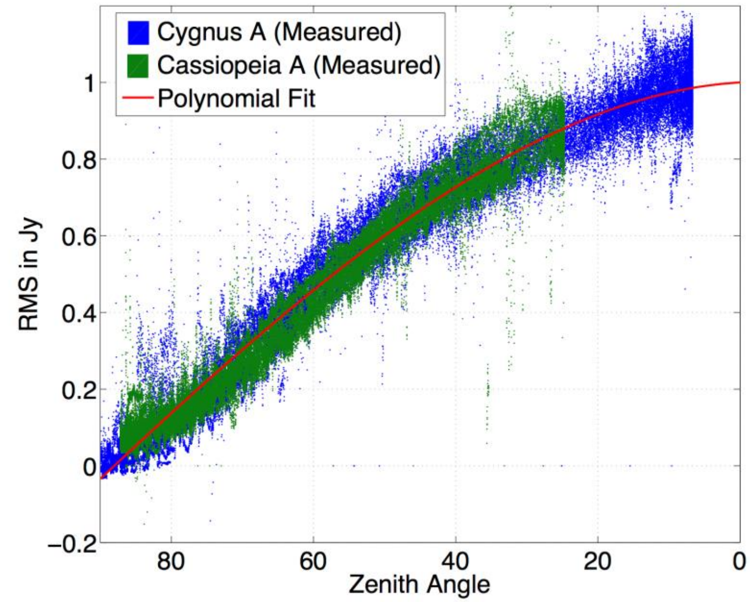
The First Station of the Long Wavelength Array (LWA1)

The LWA1 consists of 256 dual
100 x 110 m ellipse, 10 - 88 MH
the VLA

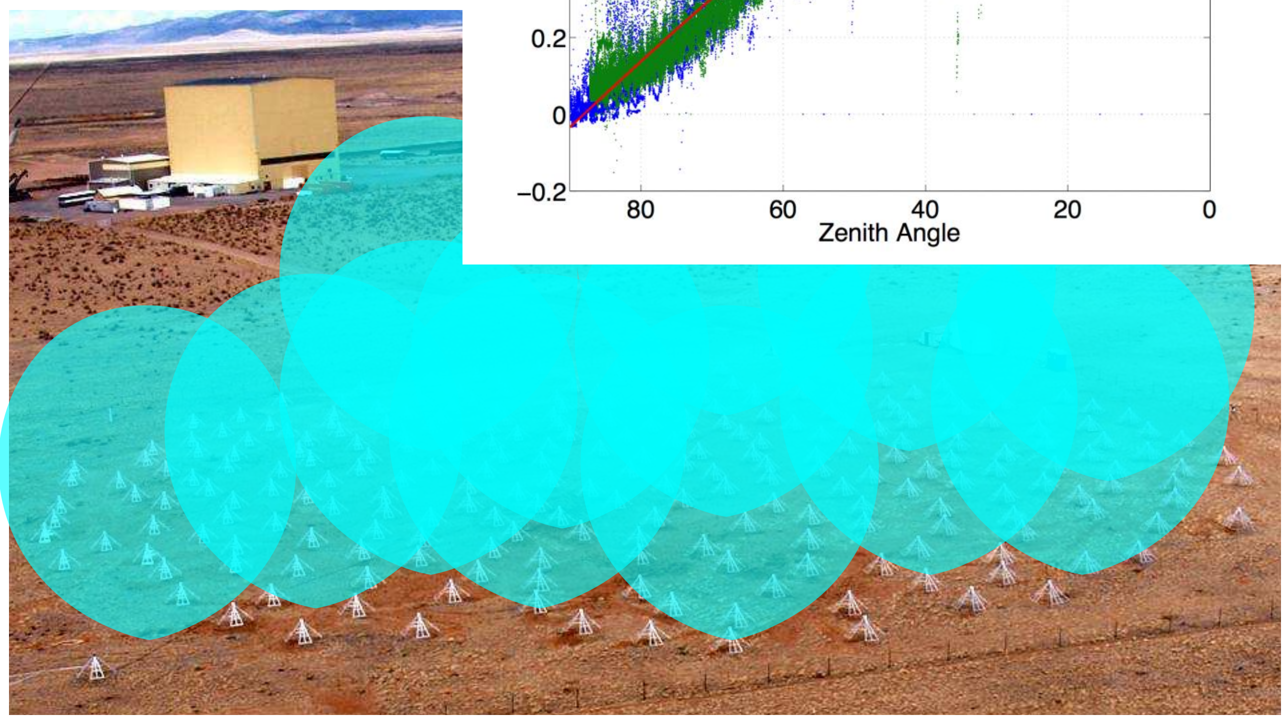
All-Sky Mode



The raw voltage from each antenna can be recorded or sent to a correlator

Due to computational constraints only 75 kHz can be used

Each dipole is sensitive to nearly the entire sky



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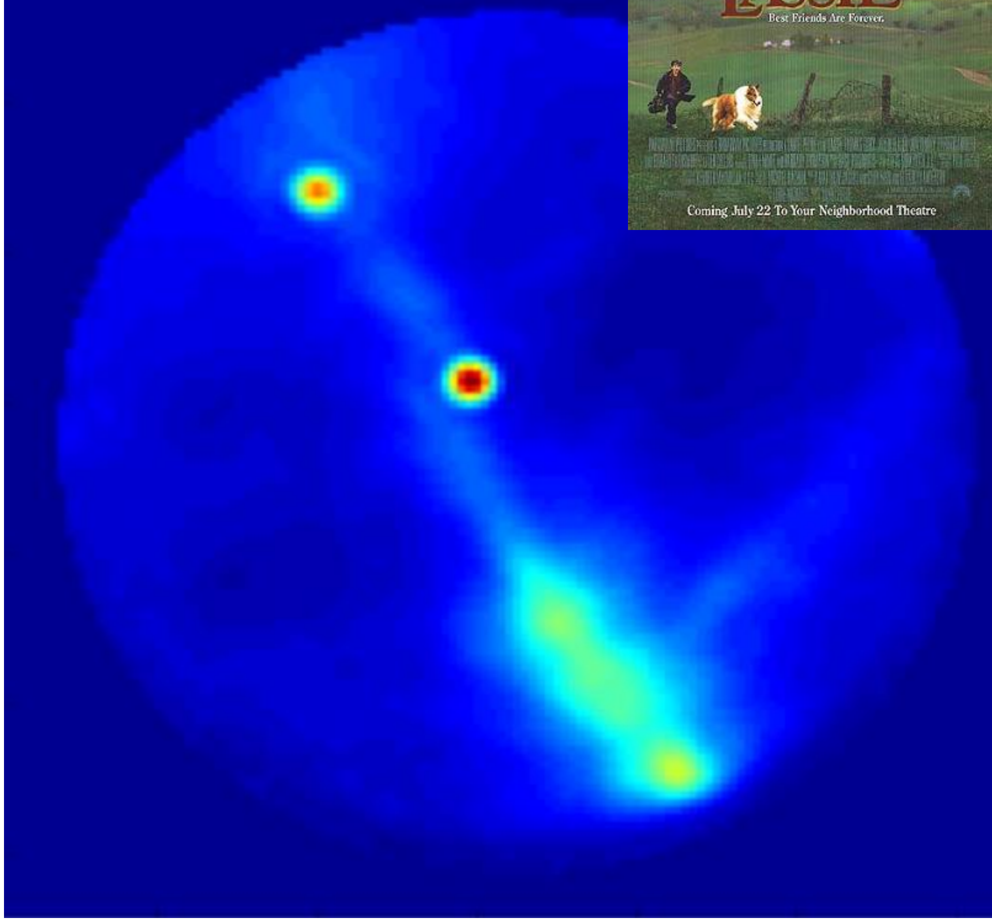
LWA All-Sky Imager (LASI)

- Correlates live stream of raw voltages
- Creates all-sky images
- Keeps all 4 Stokes polarizations
- 5 second integrations
- 6 channels covering 75 kHz
- Images are saved to an archive ~ 20,000 hours so far!



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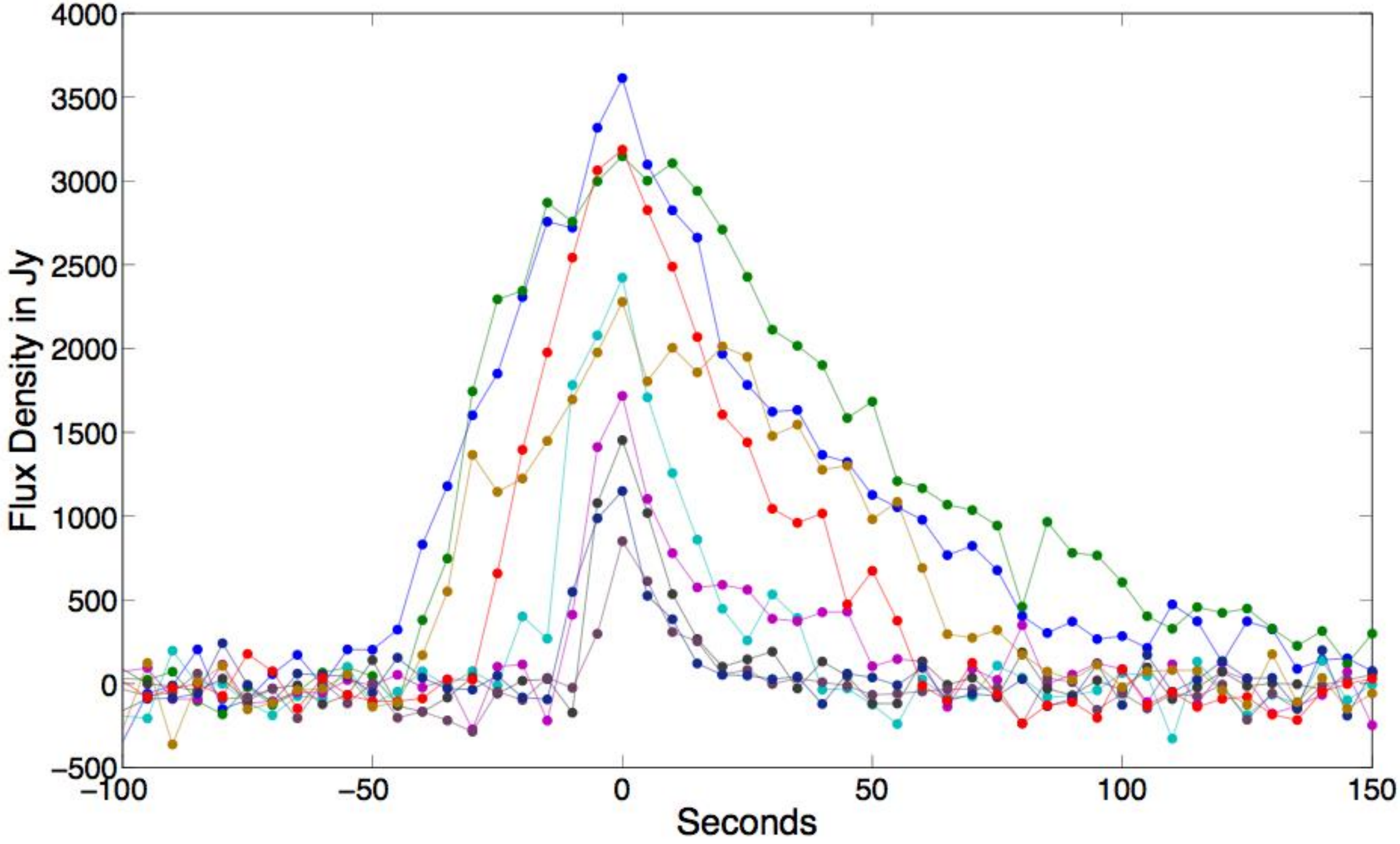
Transients Found



Transients Found

- In ~20,000 hours (14 million images) of observation we have found 154 events, using image subtraction
- Light Curves are all similar, typically a fast rise with slow decay, and lasting up to a few minutes
- Flux densities range from 250 – 10,000 Jy
- ~ 40 events/year brighter than 540 Jy at 38 MHz
- The occurrence of the events correlate with meteor showers
- Many are elongated across the sky

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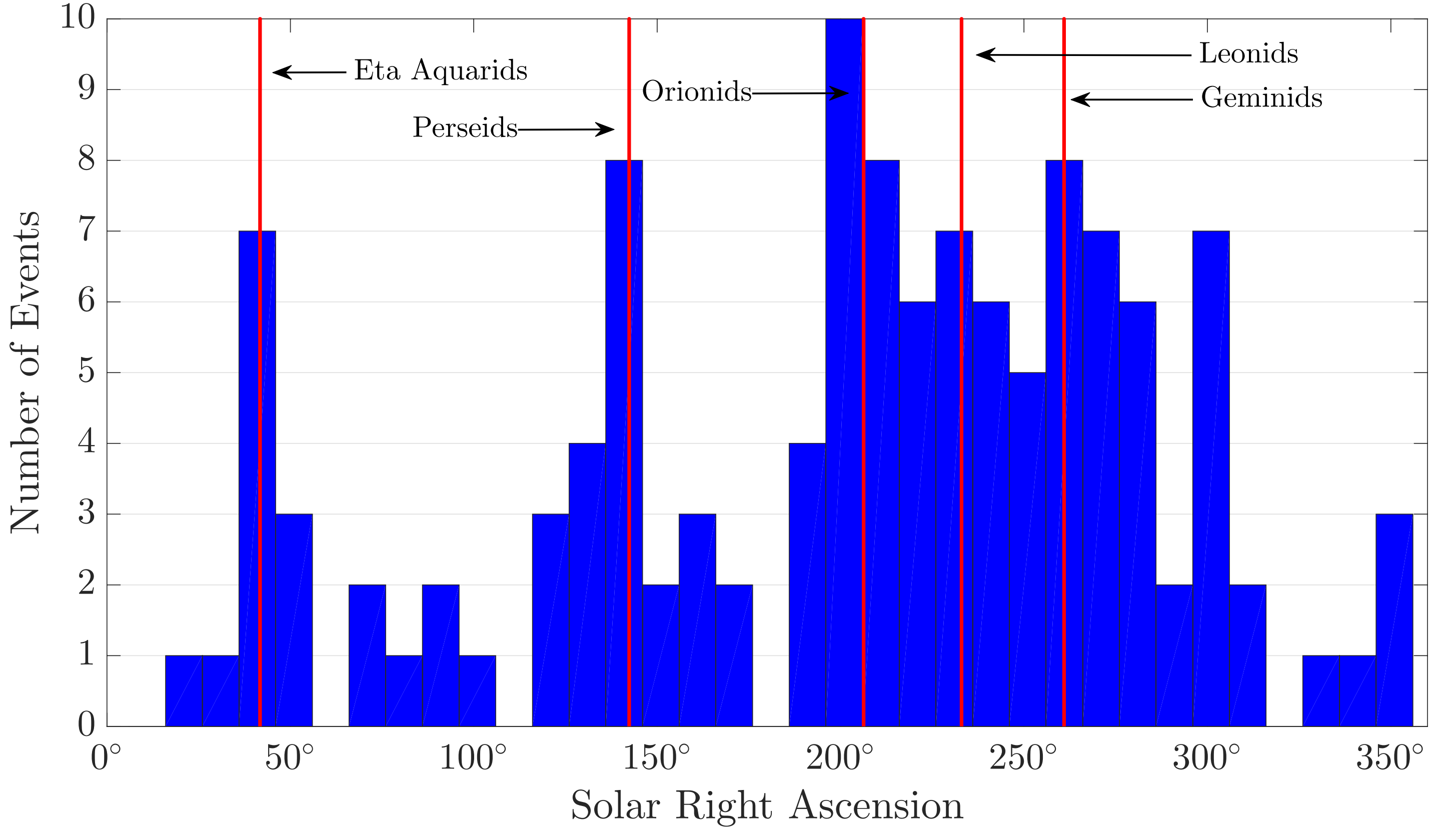
Transient Found

Correlation with Meteor Showers



Transients Found

- In ~20,000 hours (14 million images) of observation we have found 154 events
- Light Curves are all similar, linear rise with exponential decay, and lasting up to a few minutes
- Flux densities range from 250 – 10,000 Jy
- The occurrence of the events correlate with meteor showers
- Many are elongated over 10° across the sky

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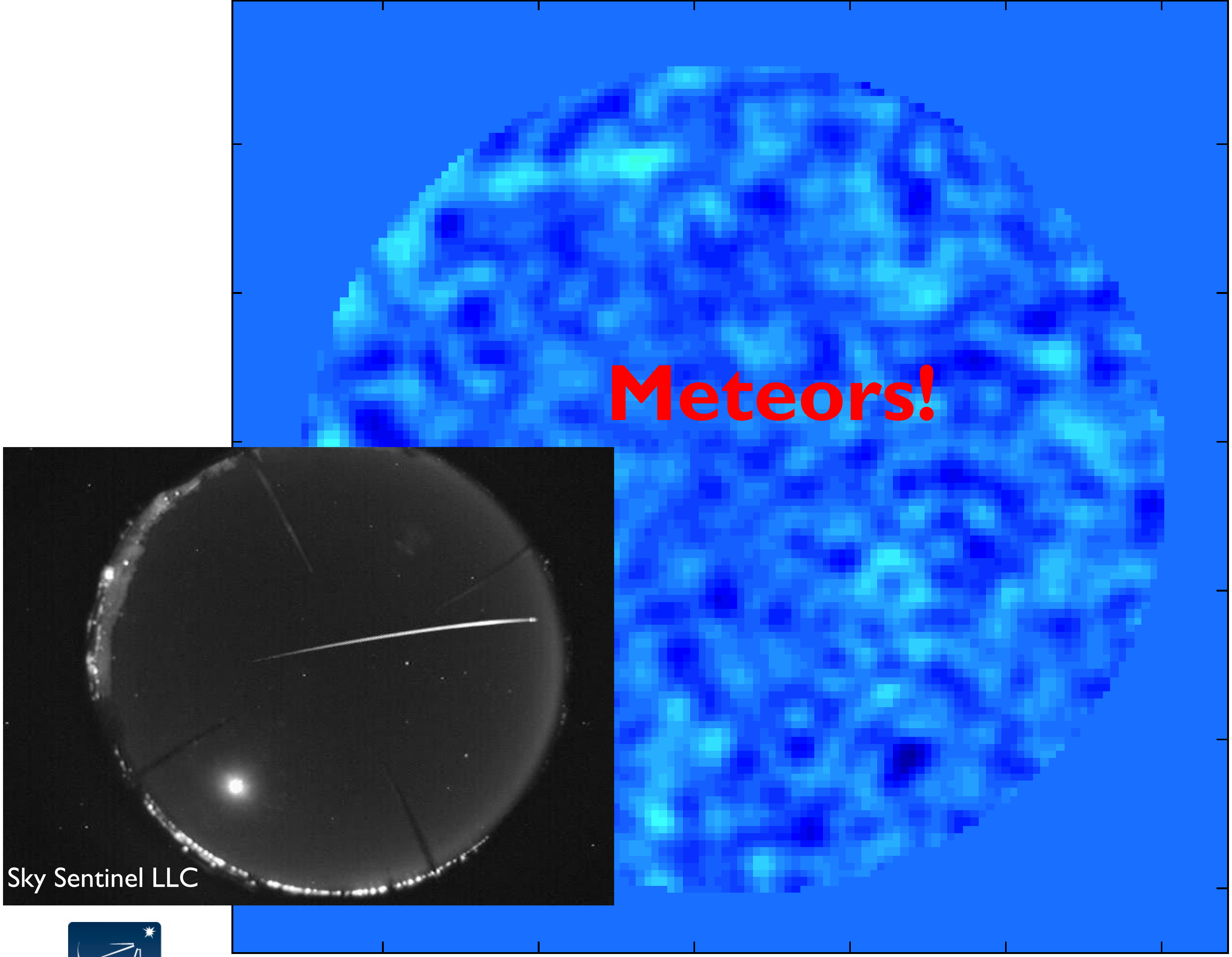

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What are Meteors?

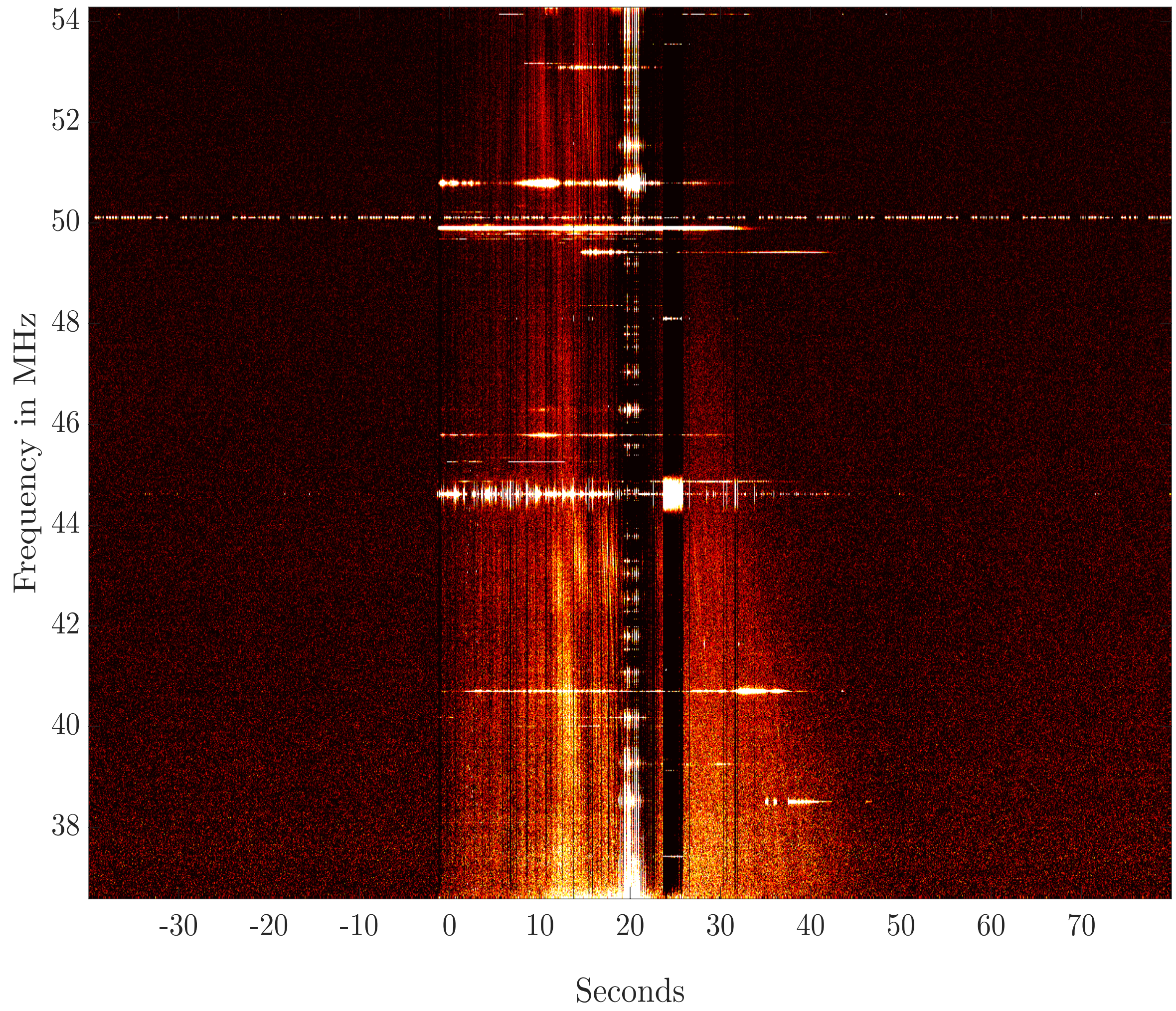
- Meteors are the short lived burning phase of meteoroids colliding with earths atmosphere
- Meteoroids traveling 10 to 80 km/s heat up due to friction in Earth's atmosphere (up to 10,000 K)
- This heating results in ablation and ionization of the meteoroid material and air between 120 and 60 km
- A dense plasma trail is left behind, which then quickly cools and diffuses into the mesosphere
- These trails can reflect man-made RFI

ESO/C. Malin

Meteor Radio Afterglows

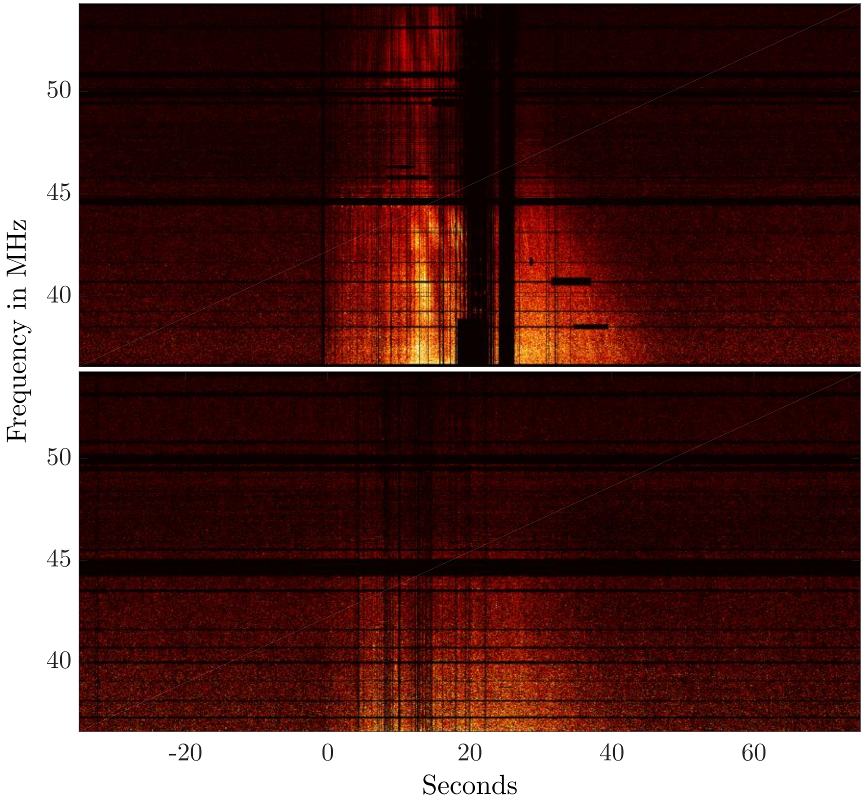
Spectra

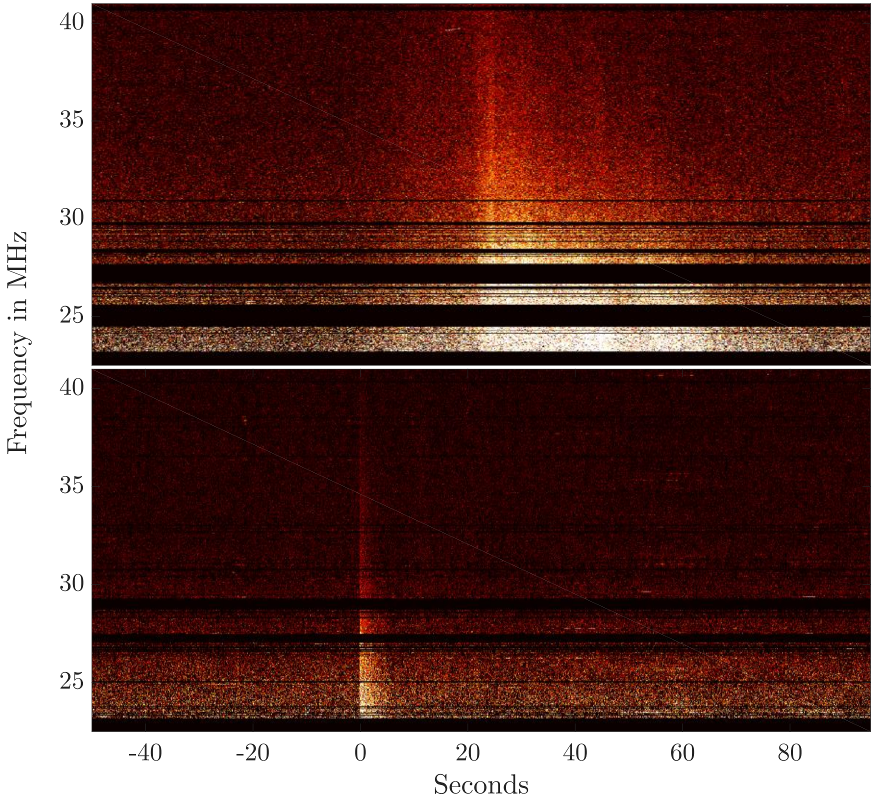
- During night-time LASI operation, we also point three beams around zenith
- Currently 4 fireballs have passed through at least one beam
- The beams allow us to capture ~32 MHz of bandwidth (425x that of LASI)



Meteor Radio Afterglows

Spectra

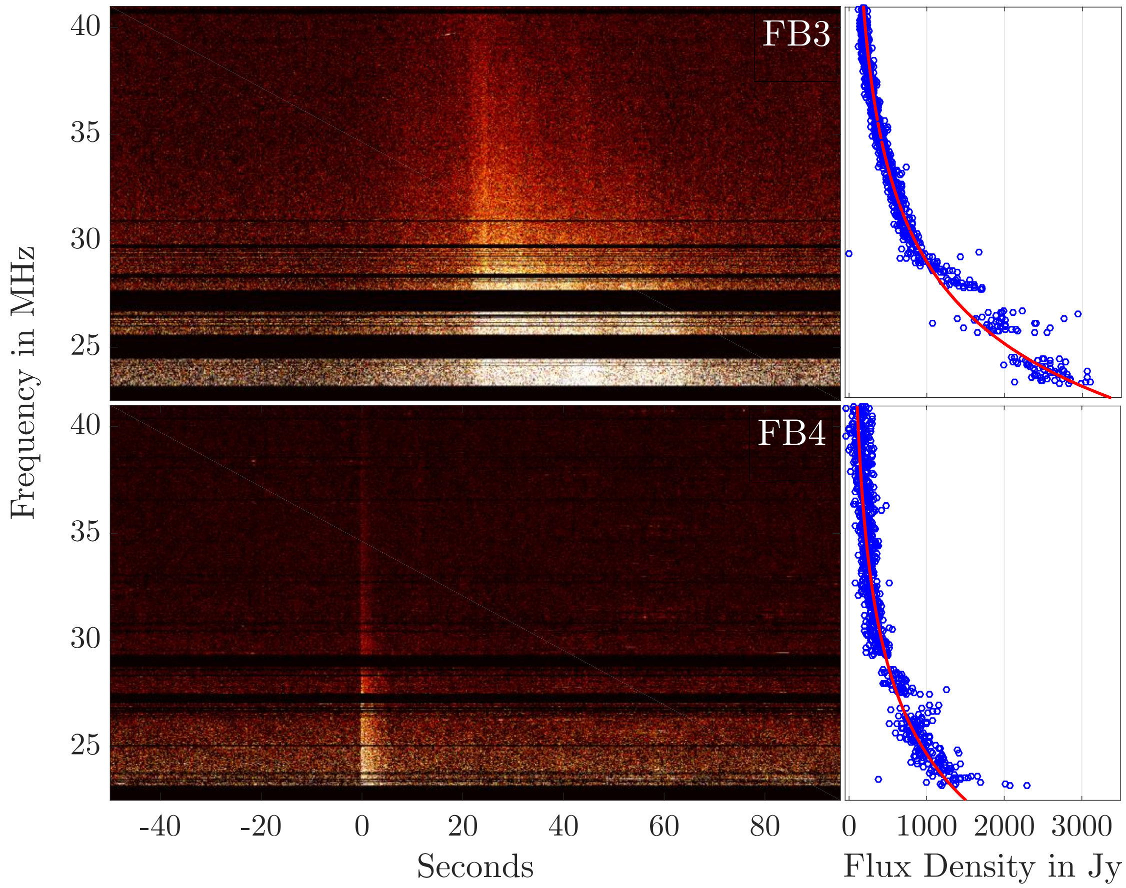




Meteor Radio Afterglows

Spectra

- All four fireballs follow a power law spectra
- $S \propto \nu^{-\alpha}$
- We find that α evolves from ~ 3 to 8 over the duration of the afterglow
- Definitely non-thermal
- We can use the spectral indices and rates at 38 MHz to predict the rate of detectable fireballs seen from other low frequency telescopes



Meteor Radio Afterglows

Emission

- The emission is occurring at the range of plasma frequencies ($\nu_p \propto \sqrt{n_e}$) found in meteor trails, which suggests plasma wave (Langmuir) emission
- Steep density gradients in the turbulent trail would allow Langmuir (electrostatic) waves to be converted into electromagnetic waves
- However electron collisions with neutrals and ions would suppress wave formation at lower altitudes
- Collisions would also quickly thermalize the electrons, meaning that they should quickly stabilize and not produce waves
- Therefore, a continuous source of energy may be needed to drive the waves, and chemical reactions may be enough to do so

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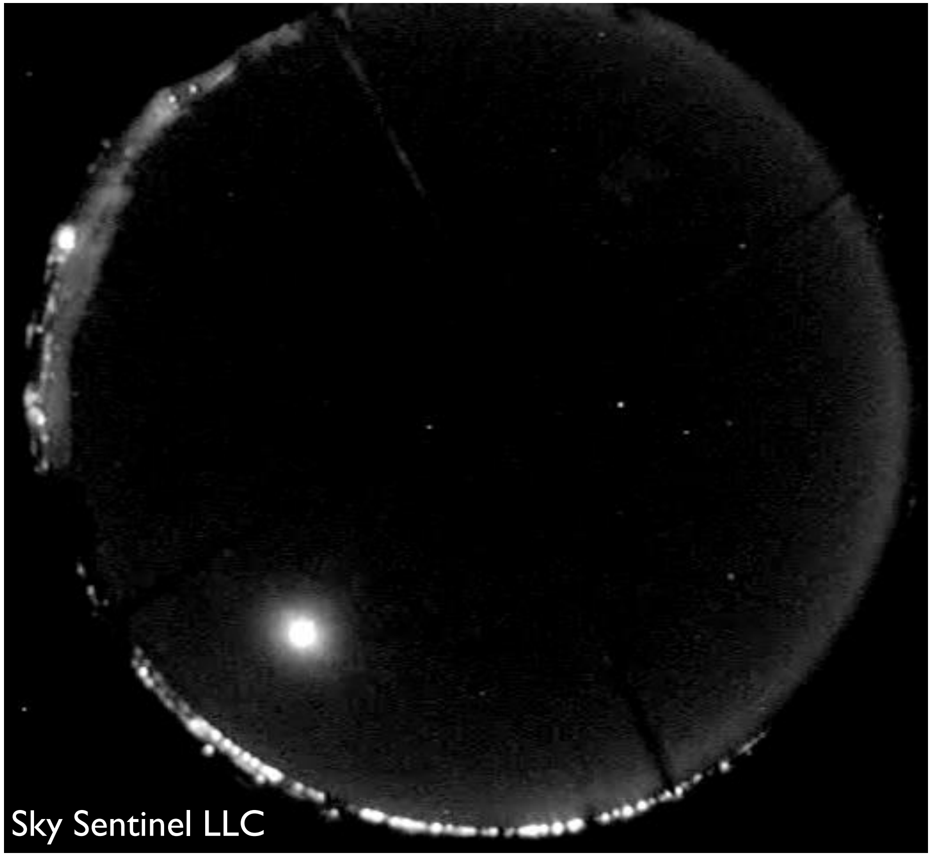
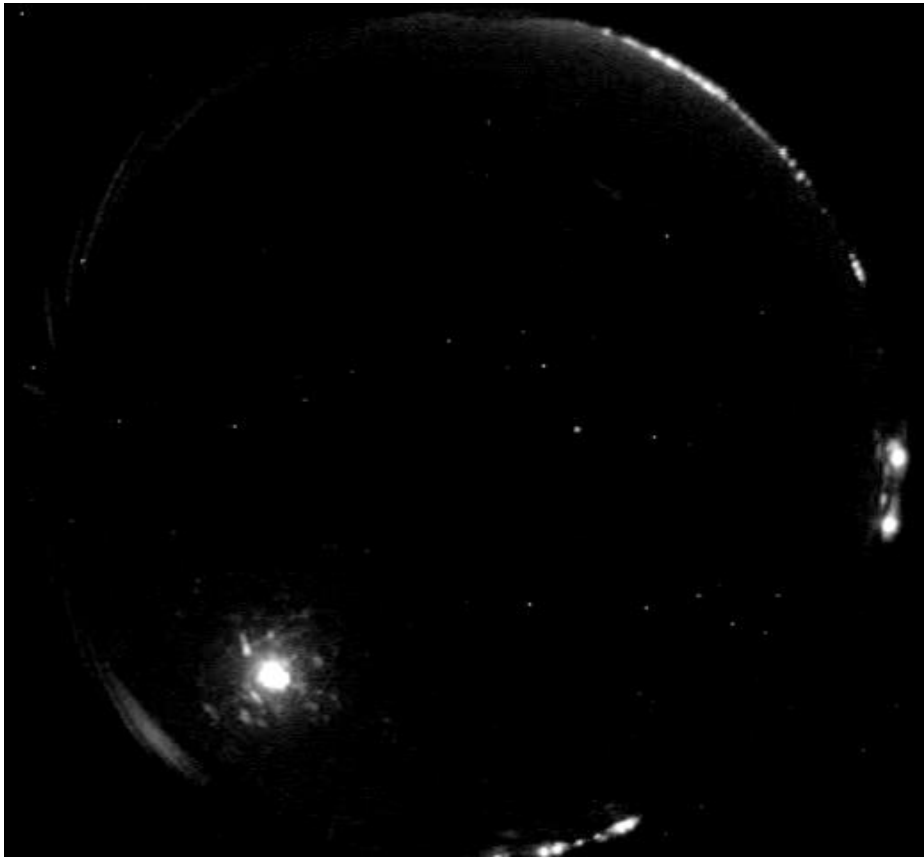
Meteor Radio Afterglows
Optical Triangulation



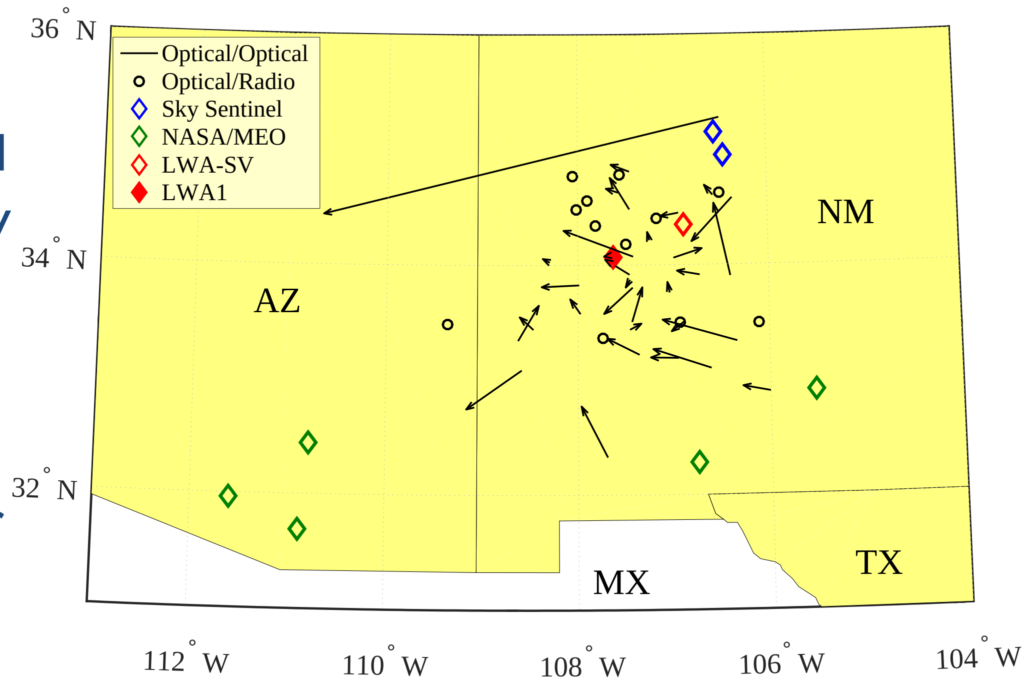
Albuquerque, NM



Kirtland AFB, NM

Meteor Radio Afterglows
Optical Counterparts

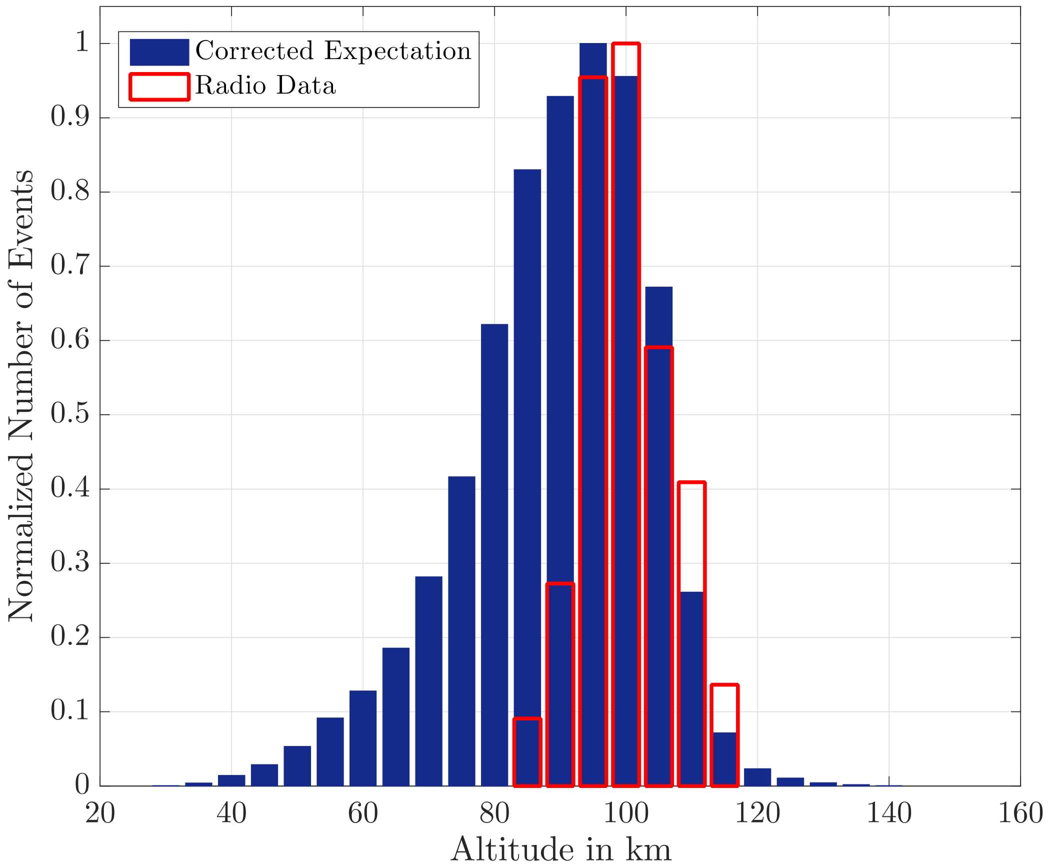
- There are 8 all-sky fireball (bright meteor) searching cameras located in NM and AZ with overlapping sky with LWA1
- Using any pair of cameras or a camera plus the LWA1 we can triangulate the positions of meteor radio afterglows
- We have found 44 counterparts, providing a good sample of altitudes to analyze



Meteor Radio Afterglows

Altitude Dependence

- Above 90 km radio afterglows occur with similar distribution as meteors
- Below 90 km there is a strong cutoff where radio afterglows do not occur, despite large numbers of meteors passing through these altitudes
- This finding suggests that air density effects the emission mechanism (collisions)



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OBSERVED

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Meteor Radio Afterglows

LWA-SV

- Optical data is limited to night, is subject to cloud cover and moonlight, all of which lower the detection rate
- Radio telescopes don't have these problems
- With a new LWA station we could better our statistics, and even try long baseline, near field interferometry!
- Plus there may be some astrophysical transients hidden in our meteor population

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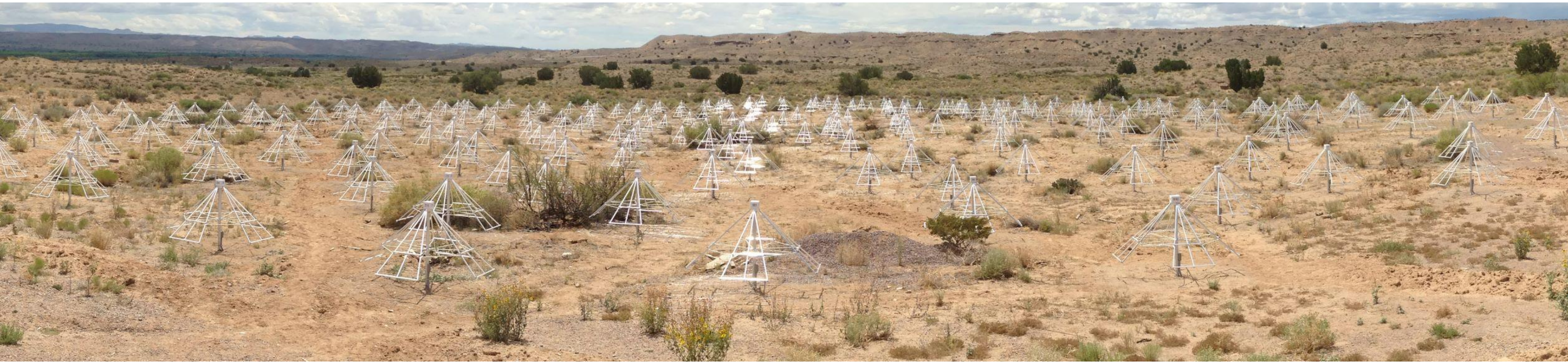
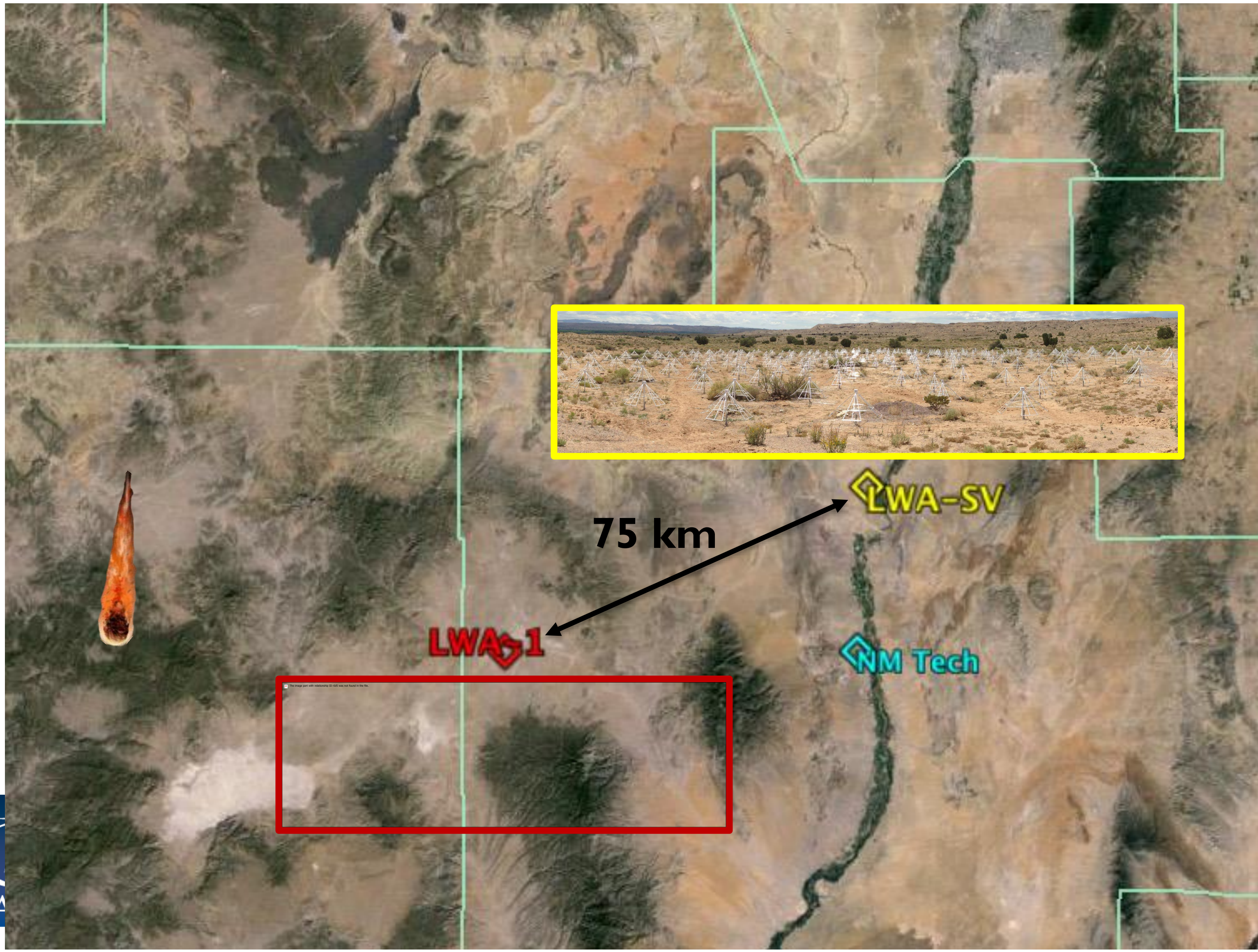
Meteor Radio Afterglows
LWA-SV

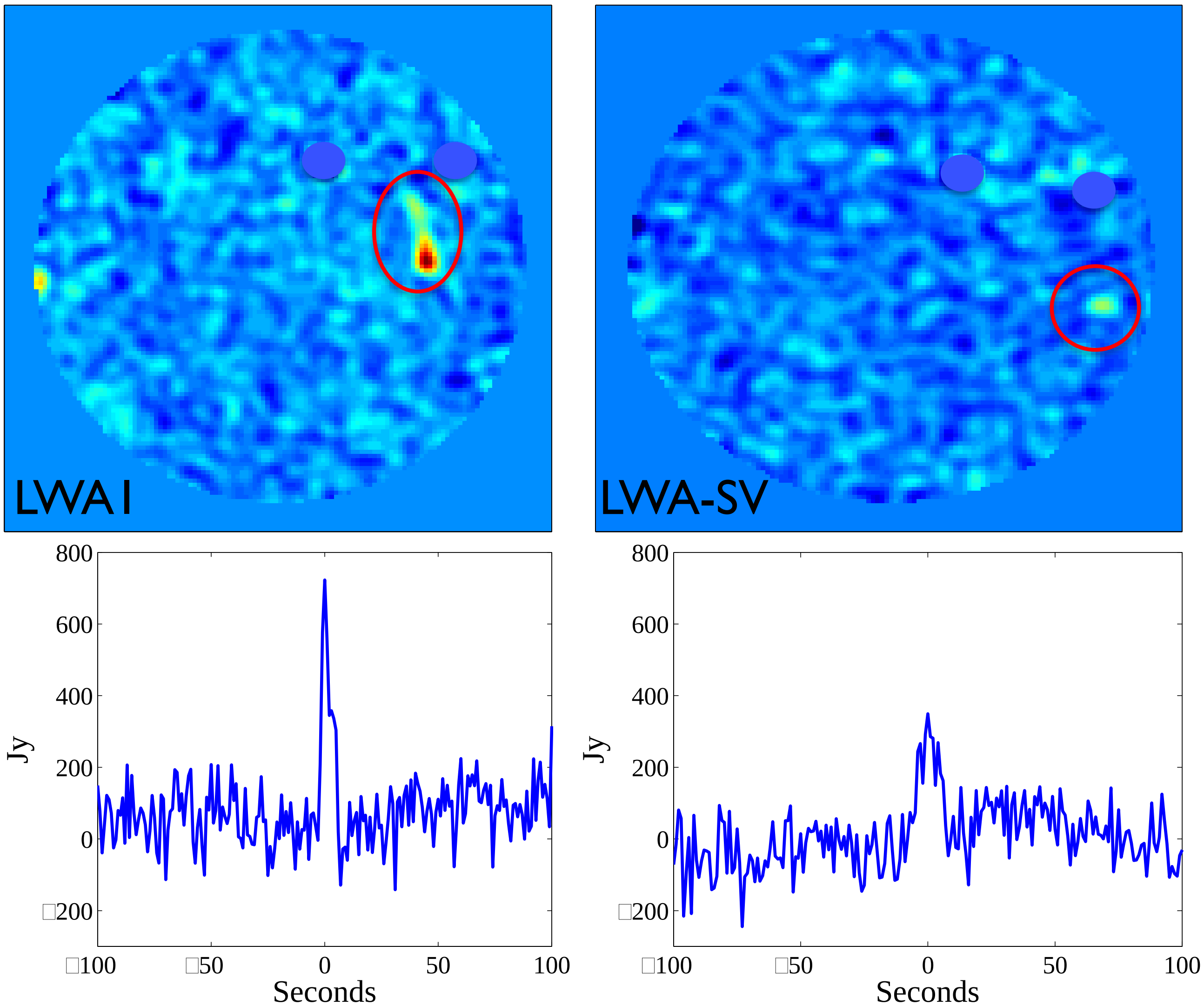


Sevilleta National Wildlife Refuge

Meteor Radio Afterglows
LWA1 to LWA-SV



Meteor Radio Afterglows



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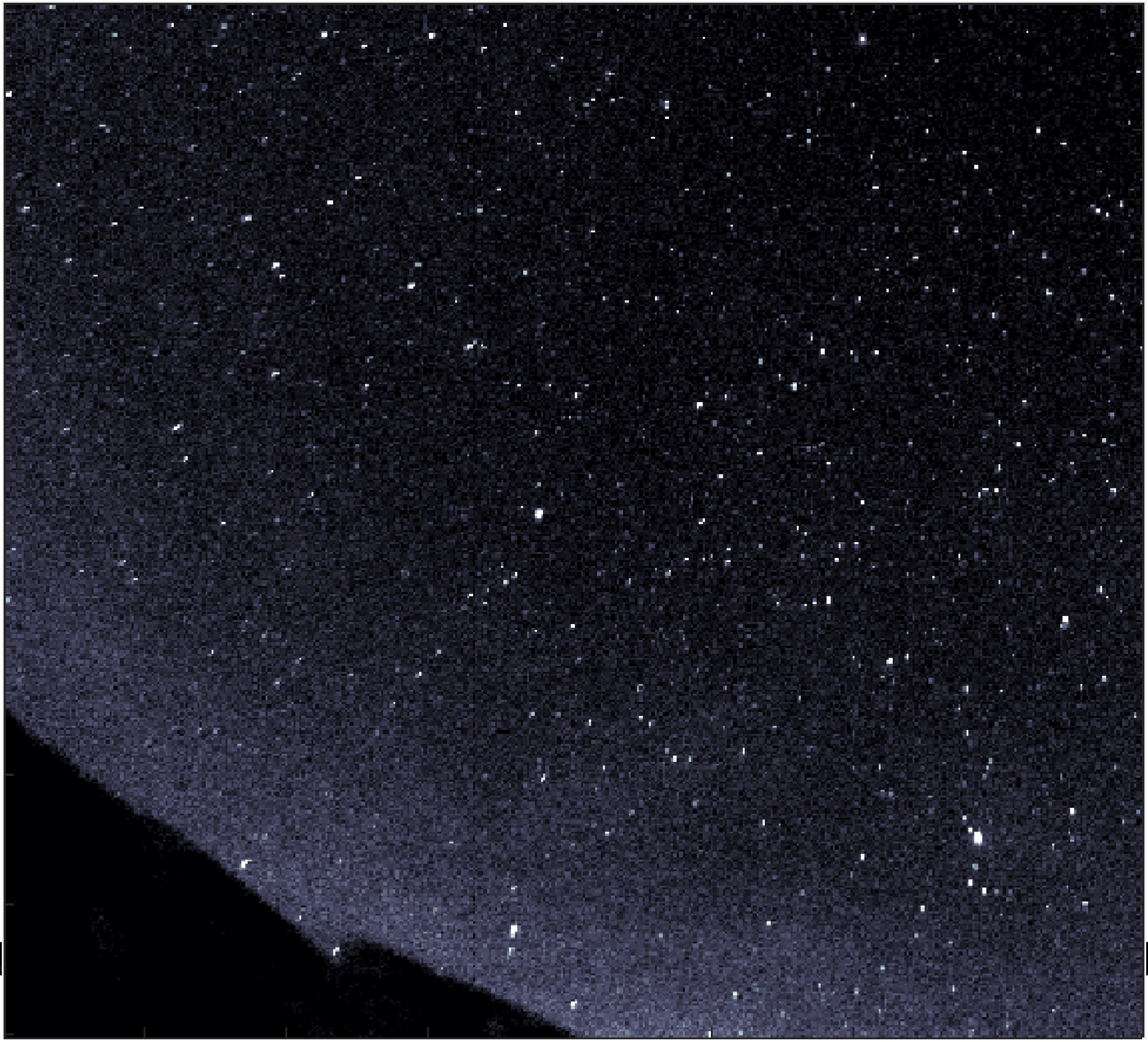
Meteor Radio Afterglows

Chemically Driven Persistent Trains

Meteor Radio Afterglows

Chemically Driven Persistent Trains



Meteor Radio Afterglows

Conclusion

- Meteoroids can produce a radio afterglow observable using new low-frequency wide-field radio telescopes (LWA, LOFAR, MWA)
- The afterglow spectra occurs near the plasma frequency, and is very steep, getting brighter at lower frequencies
- The emission seems to be exclusive to altitudes above ~90 km
- Our current hypothesis: Radiation of Langmuir waves
- The LW hypothesis suggests that there is an unidentified continuous driving mechanism
- Meteors provide a probe of the mesosphere, and high resolution imaging would show the turbulent and magnetized diffusion of plasma into the windy surroundings

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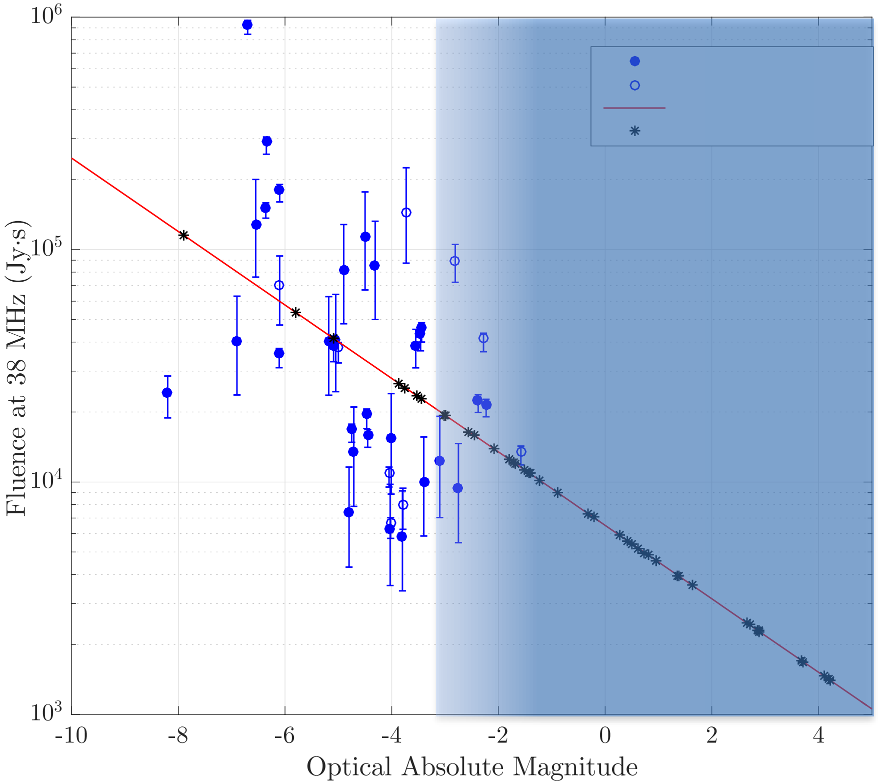
Backup Slides

Meteor Radio Afterglows

Optical Brightness – Radio Energy

- There is a slight trend where higher radio energy events correspond to brighter optical events
- Most of the 45 optically unseen events were radio dim, implying that they were optically dim
- Optical camera detection rate drops for events dimmer than -3
- Also 20 of the events occurred on overcast nights



Transient Search

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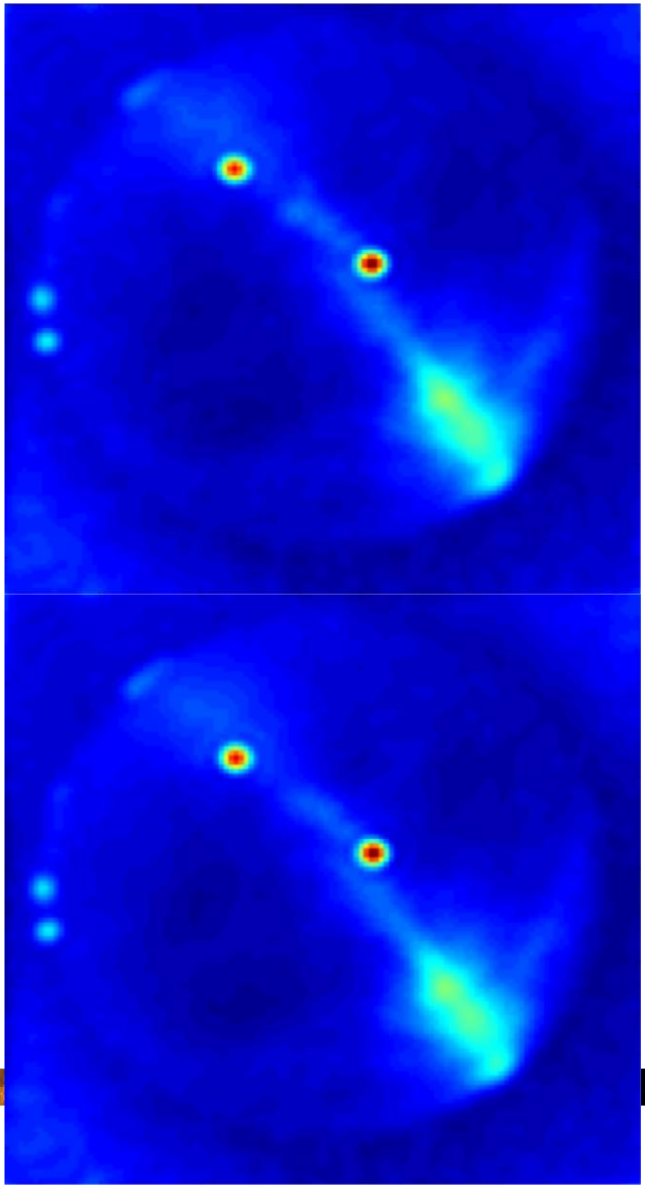
- Pixels above 6 sigma of the image noise are considered to be transient candidates



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