HF and VHF Radio Emission from Meteor Trails

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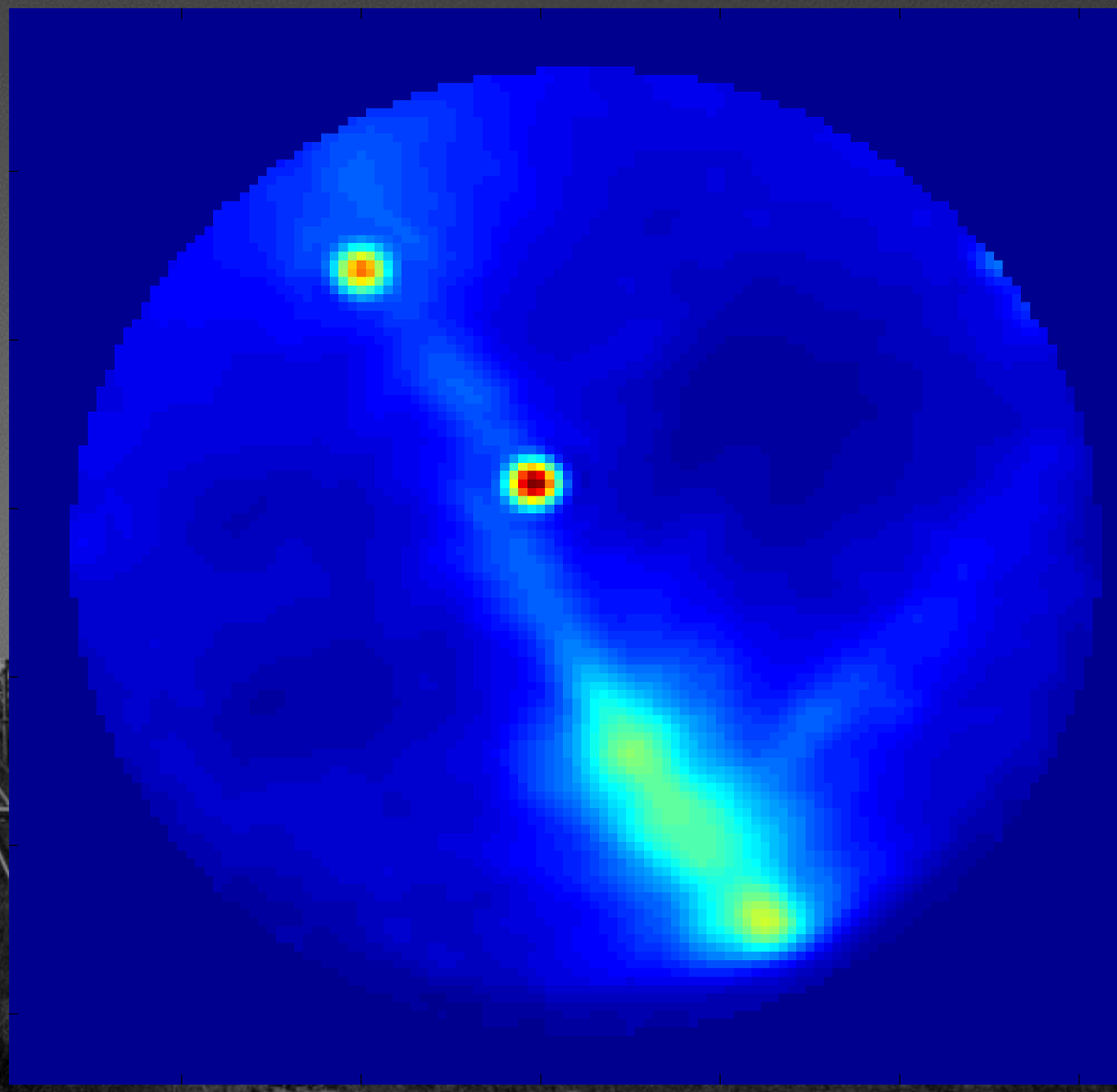
LWA1 & Prototype All Sky Imager

- Operates between 10 - 88 MHz (HF-VHF)
- Correlates live stream from all antennas
- Create all-sky images
- 5 second integrations
- 6 channels covering 75 kHz
- Images are recorded onto a 4 TB hard drive and stored indefinitely. ~ 20,000 hours so far!



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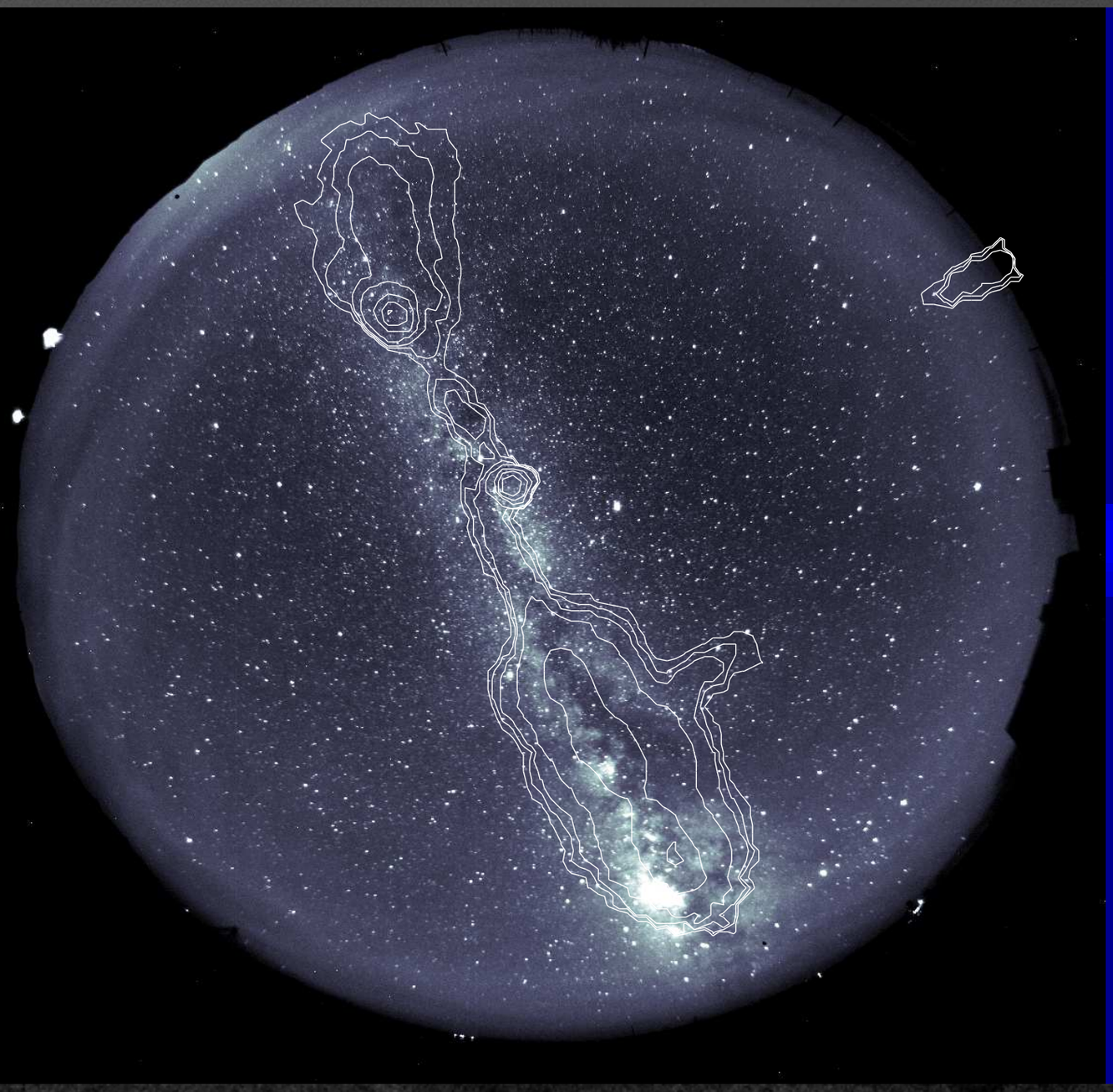
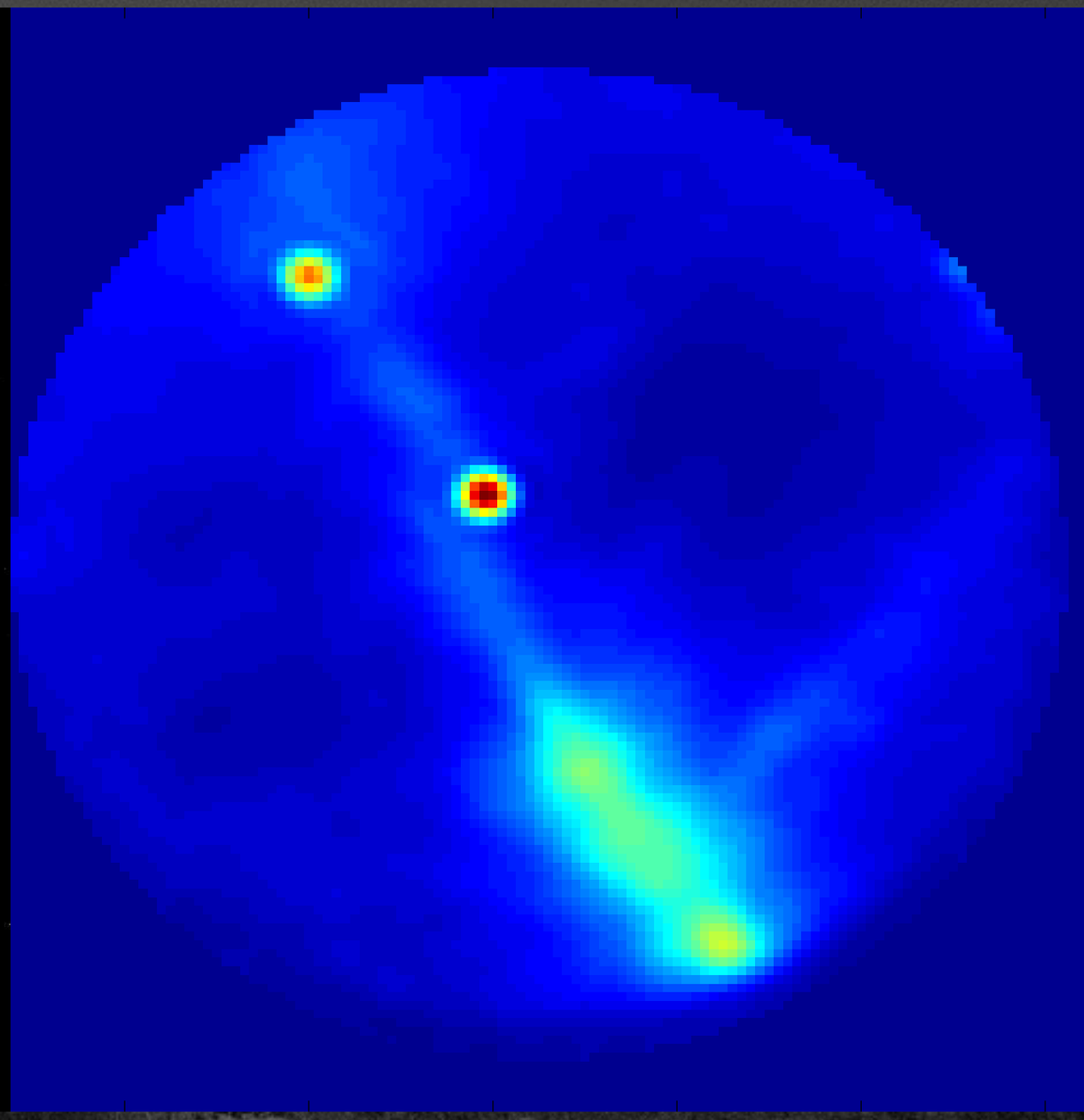
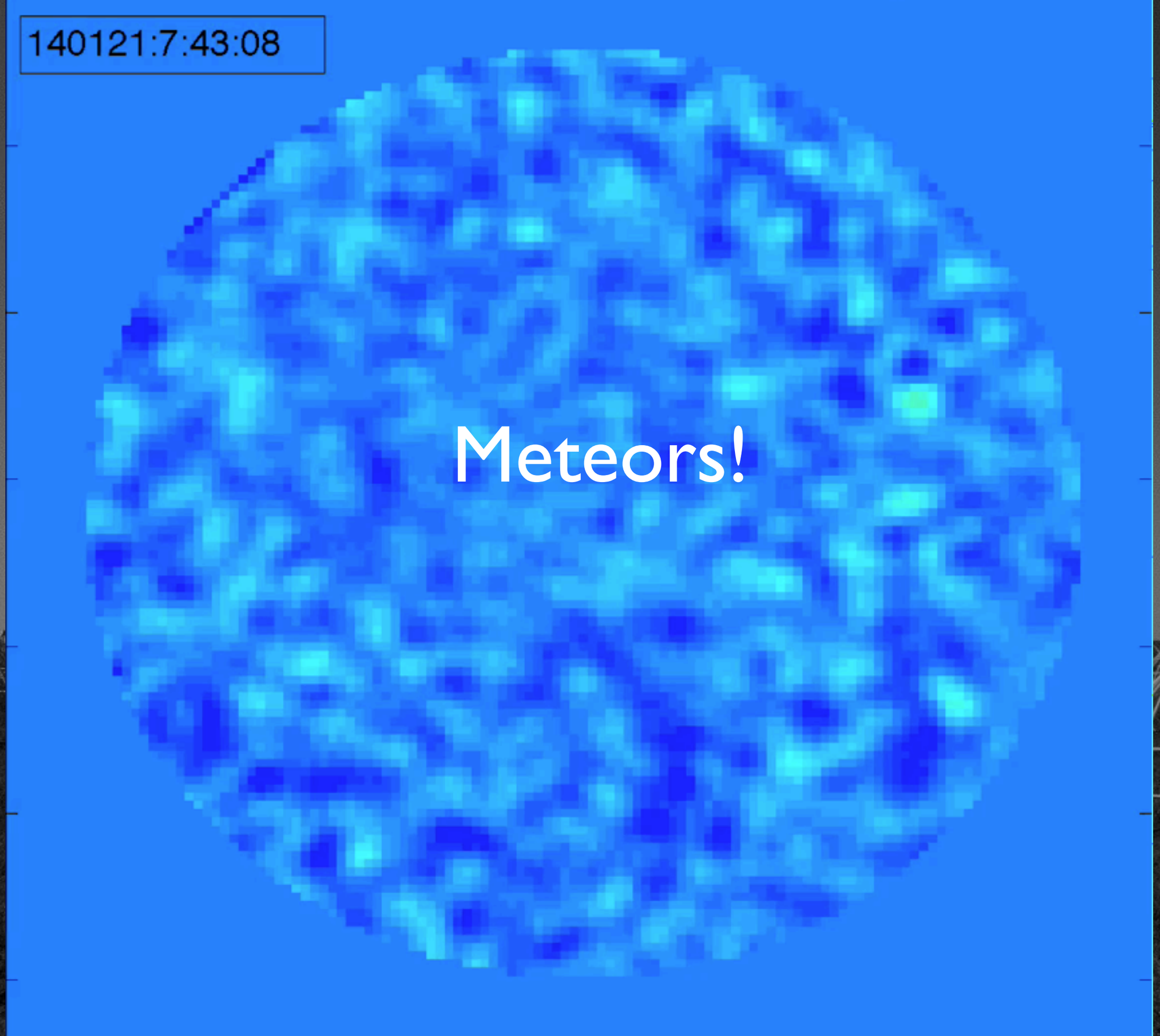






Meteors!

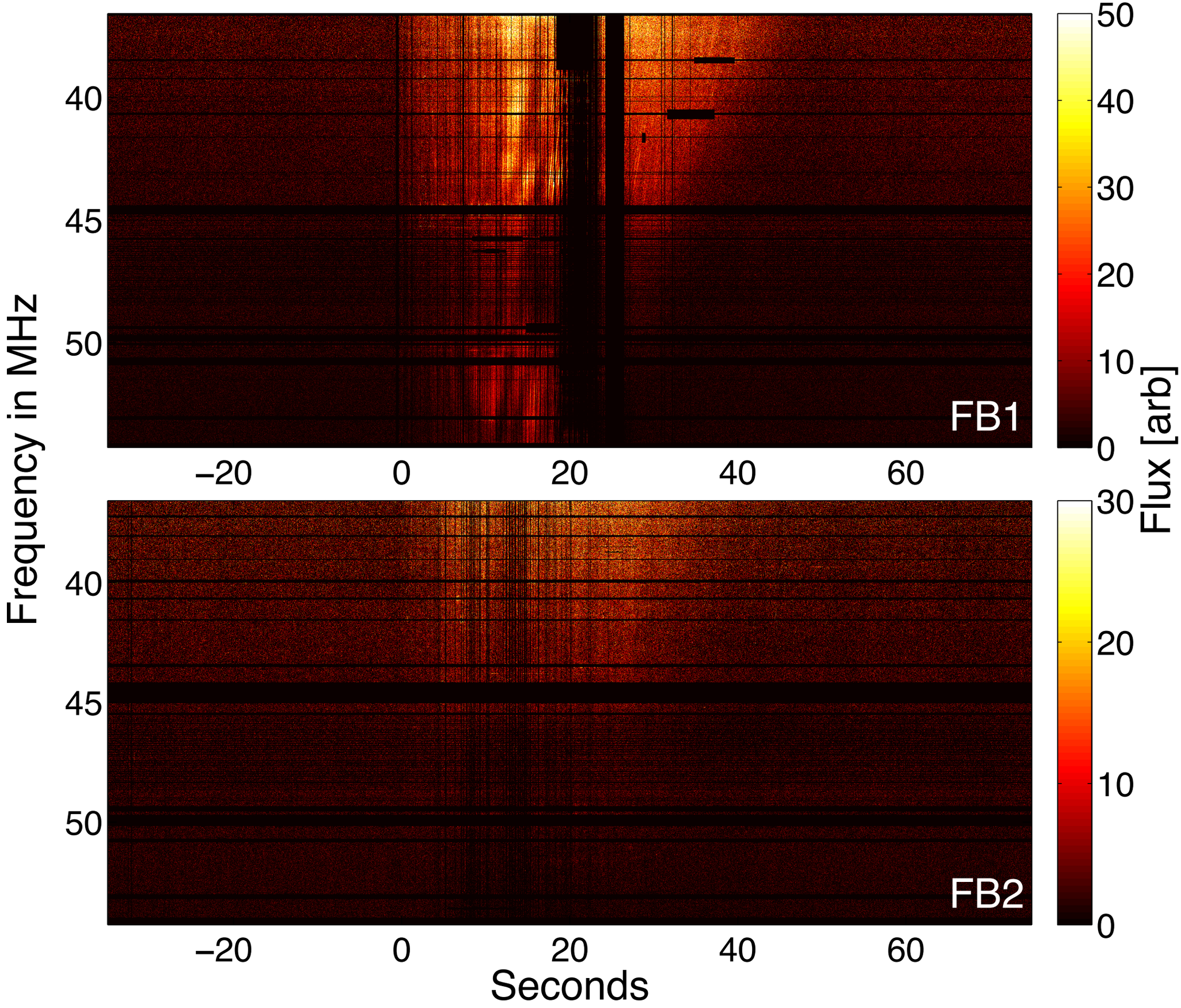
Meteors and their Trails

- Icy/Rocky/Metallic objects ranging in size from dust to boulders
- Traveling 10 - 80 km/s
- Friction with atmosphere causes surface of object to ablate and ionize
- Initial temperature of trail 4,000 - 10,000 K, and quickly cools
- Trails are several km long by several meters wide and are deposited between 30 and 120 km altitude, depending on velocity and mass.
- Initial electron densities are typically 10^8 - 10^9 cm^{-3}
- Plasma frequencies ~ 10^2 MHz
- Really bright events are called fireballs

Okie-Tex Star Party
September 30, 2008
Howard Edin

Fireballs

- Detected 125 transients, the majority (if not all) of which are fireballs
- 18 have been confirmed with optical and there is strong correlation with showers
- We are almost certain the transients are not reflections!
- Most likely self emission
- With broad & steep spectra < 60 MHz
- Average peak absolute magnitude -5.2 (Brightest -8!)
- Mass of ~ 100 g (~ 1 baseball)
- Average velocity of 64 km/s (150,000 MPH fastball)
- This is much faster than typical meteors
- Faster meteors burn up at higher altitudes where the air thiner.


Frequency in MHz
40
45
50
FB1
FB2
−20
0
20
40
60
Seconds
50
40
30
20
10
0
Flux [arb]

Plasma Waves

- Electron Plasma waves (Langmuir) are electron oscillations within a plasma, they occur at the plasma frequency, which is proportional to the square root of the electron density
- Meteor Trails co quencies
- The emission is Langmuir waves analogous to typ

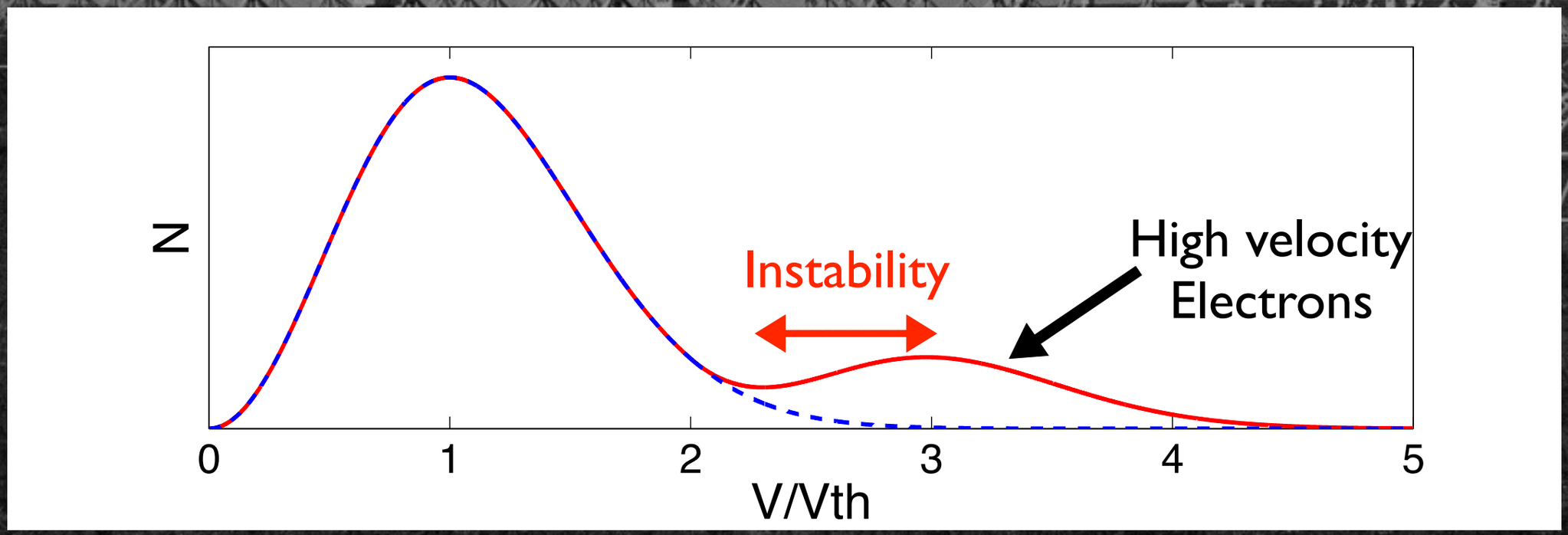
$$f_p \equiv \sqrt{\frac{n_e e^2}{\pi m_e}},$$

- Langmuir waves ion mechanism is mysterious. Steep density gradients most likely aid this emission process
- Perhaps antenna mechanism? Size scales are similar to wavelength scales (~10 m)

Wave Growth

- The electron/neutral collision frequency is very high (10^5 Hz)
- These collision rate removes energy from electrons.
- For Plasma waves to exist both the plasma frequency and growth rate need to be greater than the collision frequency, so they can be driven
- Plasma frequency is over 100 times greater
- So we only need a driving mechanism with a large growth rate

- A bump-on-tail instability can be created by excess suprathermal electrons or an electron beam and drive waves.



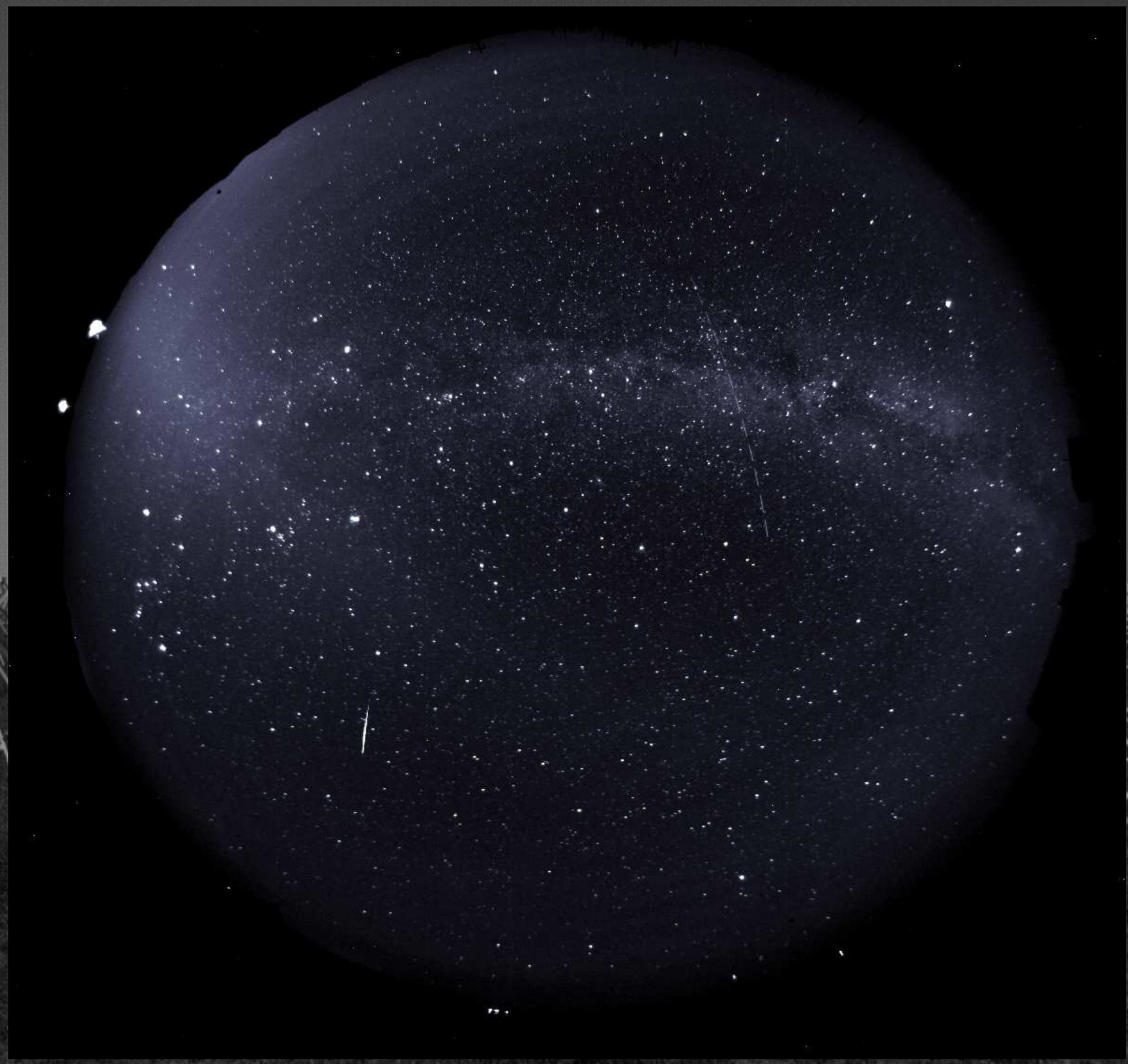
Future Work

- Search for optical persistent train counterparts.
  - These events have the same tendency for high velocity meteors
  - Long duration of ionization is not fully understood
  - Perhaps this energy source could drive an instability by creating suprathermal electrons
- Near Field interferometry with LWA1 and LWA-SV
- Eventually use many stations to make high resolution images
- Install Fireball Network Cameras near LWA1 and LWA-SV to get better statistics for understanding what parameters are required for radio emission.

Persistent Trains

Persistent Trains

- Using an all-sky lens attached to a cooled CCD
- takes 5 s integrations every ~ 7 seconds
- Using a Hough Transform I've written a detection pipeline
- Found ~100 Perseid meteors
- No persistent trains and no radio emission



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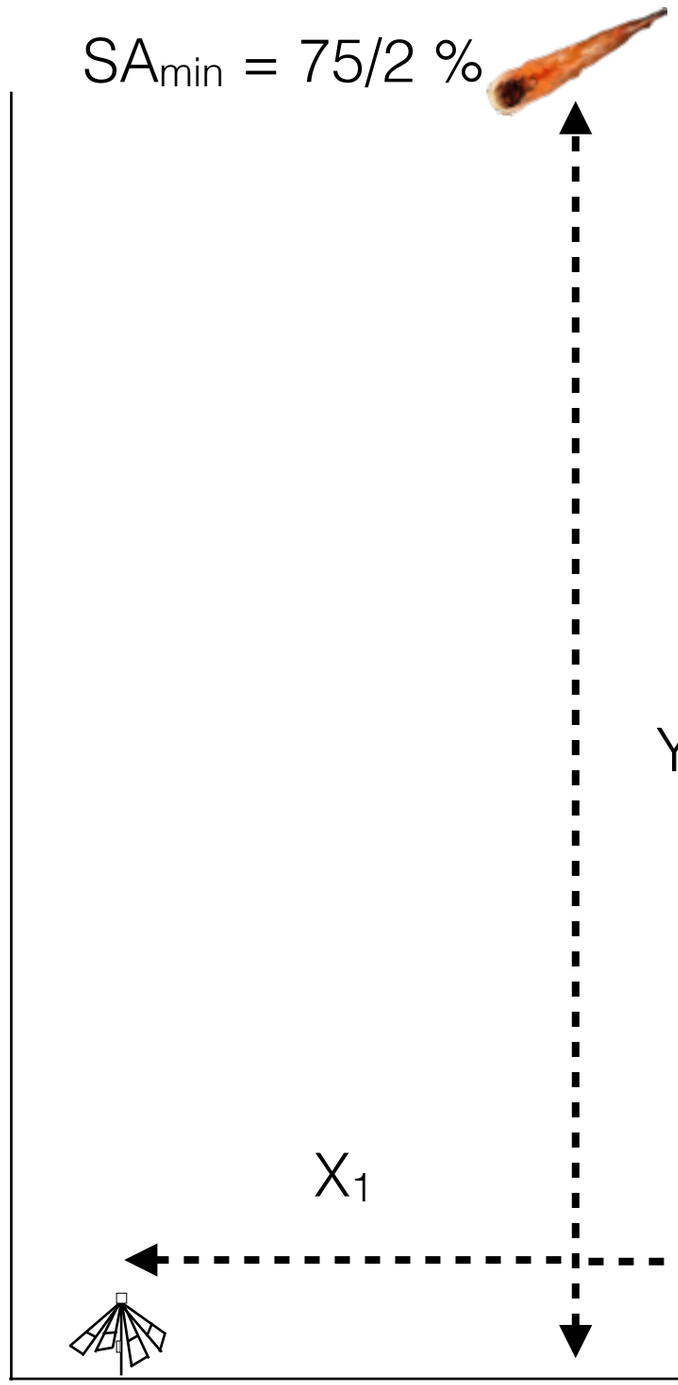
LWA1 to LWA-SV

$$\Theta = 180 + (\text{atan}(X_1/Y) - \text{atan}(X_2/Y))$$

$Y_{min} \sim 80$ km $\qquad\qquad$ $\Theta_{min} = 130^{\circ}$

$SA_{min} = 75/2$ %



Summary

- We discovered a new emissive phenomenon from fireballs, which were previously unknown to emit in the HF and VHF band
- This emission is non-thermal, has a steep broad spectra, and traces the plasma frequency of the meteor trail
- It also contains fine structure, providing clues of it's origin
- The emission is most likely due to the radiation of Langmuir waves
- Combining this with optical observations could yield a broader picture of long living plasmas (persistent trains), and would increase the statistics on the parameters for radio emission
- High resolution images could be used to study long term evolution of the electron densities, turbulence, the neutral wind in the lower ionosphere.