Detection of Radio Emission from Fireballs

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DETECTION OF RADIO EMISSION FROM FIREBALLS

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ABSTRACT

We present the findings from the Prototype All-Sky Imager, a back-end correlator of the first station of the Long Wavelength Array, which has recorded over 11,000 hr of all-sky images at frequencies between 25 and 75 MHz. In a search of this data for radio transients, we have found 49 long-duration (10 s of seconds) transients. Ten of these transients correlate both spatially and temporally with large meteors (fireballs), and their signatures suggest that fireballs emit a previously undiscovered low frequency, non-thermal pulse. This emission provides a new probe into the physics of meteors and identifies a new form of naturally occurring radio transient foreground.

Key words: meteorites – meteors – meteoroids

Online-only material: color figures

1. INTRODUCTION

In recent years, the field of radiotransients has seen much interest, most of which has been focused on >1 GHz radio emission (Frail et al. 2012; Lorimer et al. 2007; Keane et al. 2012; Thornton et al. 2013; Wayth et al. 2012). Only a handful

for 5 s with 75 kHz bandwidth tunable to a center frequency anywhere within the 78 MHz over which the LWA1 operates. PASI also produces dirty images of the entire $\sim 2\pi$ sr sky above the LWA1 (Obenberger et al. 2014), and in 2012 April began saving the images to a permanent archive.[8] This archive now contains 11,000 hr of all-sky images at various center

P r

- Co
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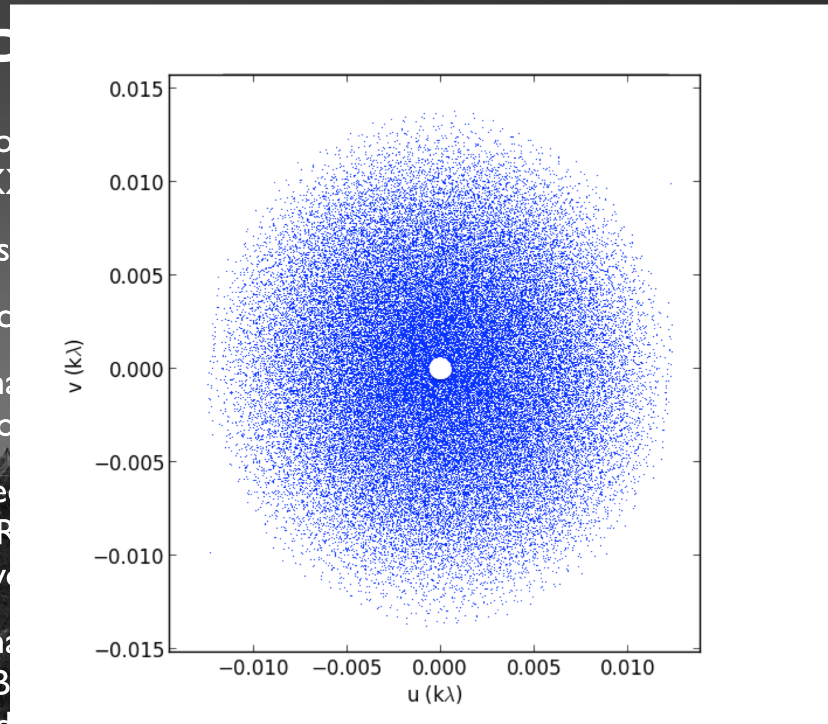
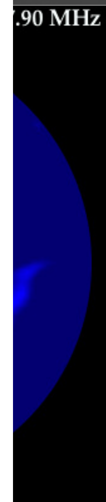
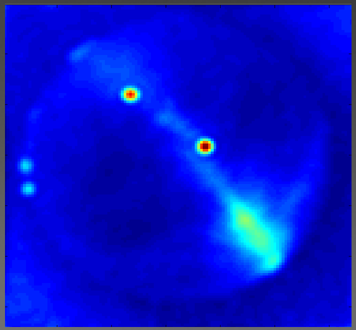
- Ima
TB
indefinitely. 15,000 hours so far!





Search for Transients



- We use image subtraction to allow images to be searched for transients
- From every image a running average of the previous 4 images is subtracted
- Image noise ~ 45 Jy
- Pixels above 6 sigma of the image noise are considered to be transient candidates

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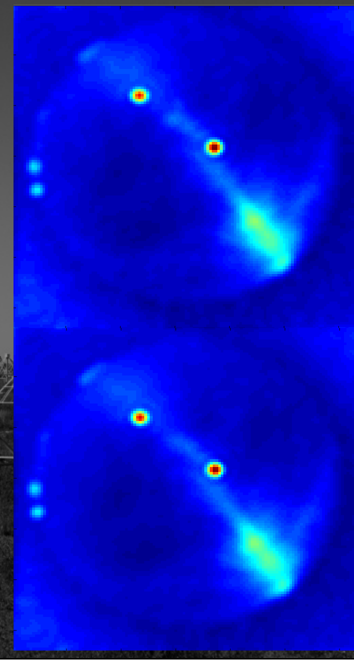

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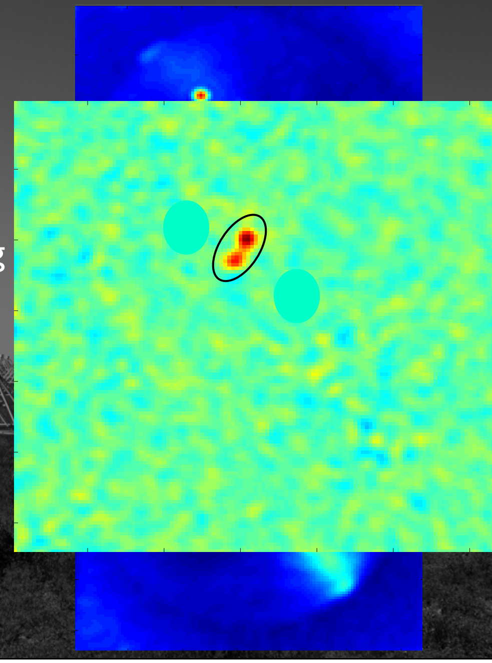
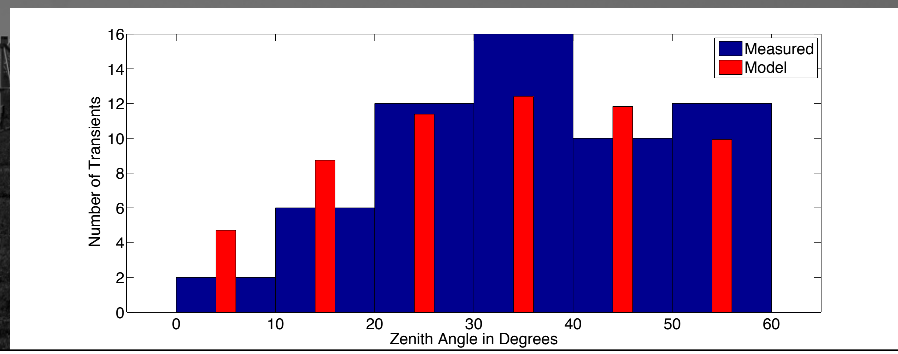


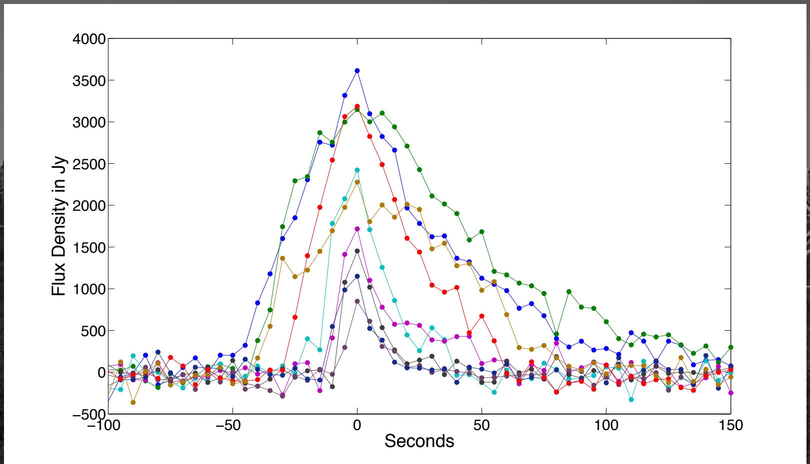
Analyzing the full 13,000 hours

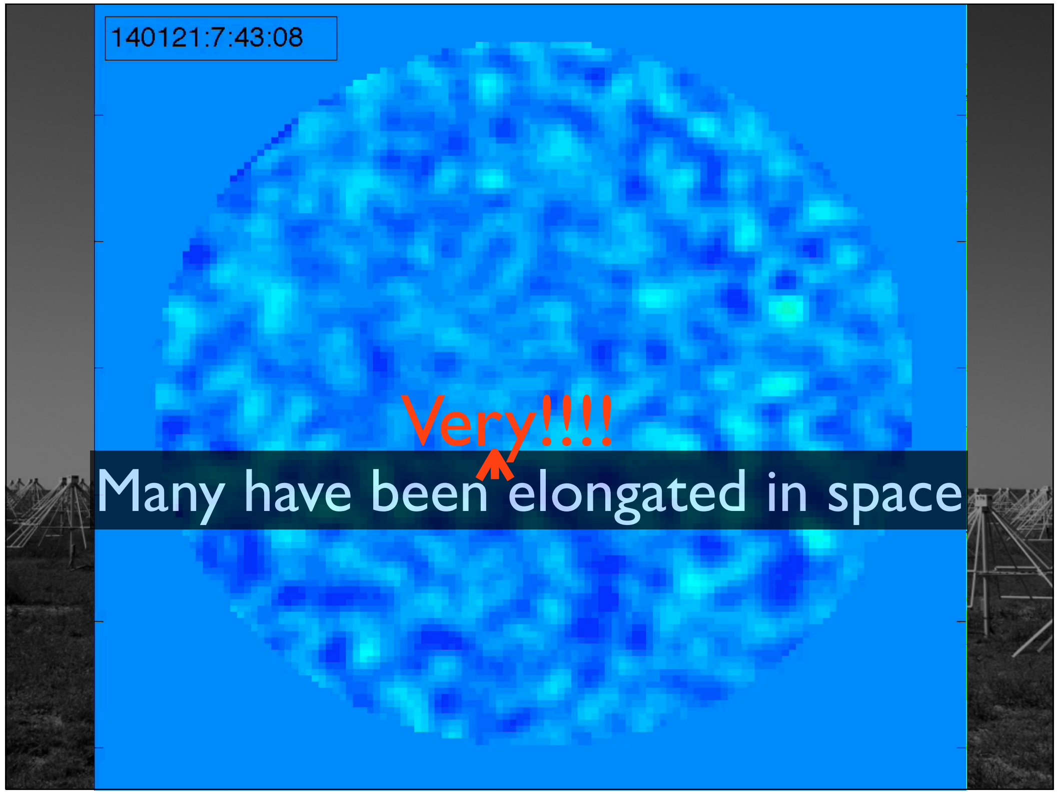
- Used image subtraction on the entire 13,000 hours
- Have found 65 transients between 25 and 38 MHz
- Observed rate density at 38 MHz: $6.3 \times 10^{-3}\ yr^{-1} deg^{-2}$
- Distributed randomly on the sky, consistent with a uniform distribution convolved with power pattern



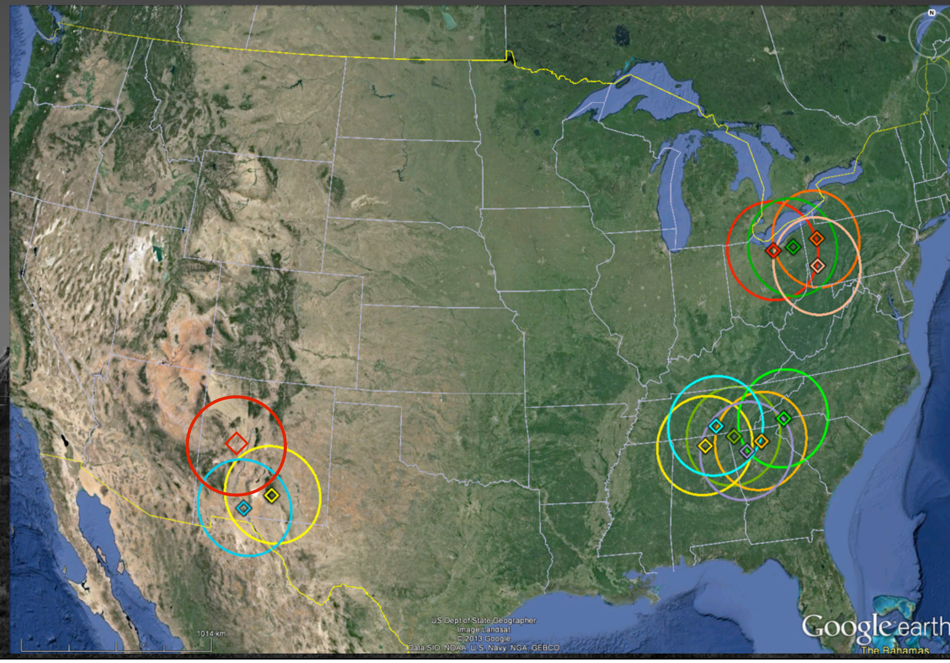
Transients

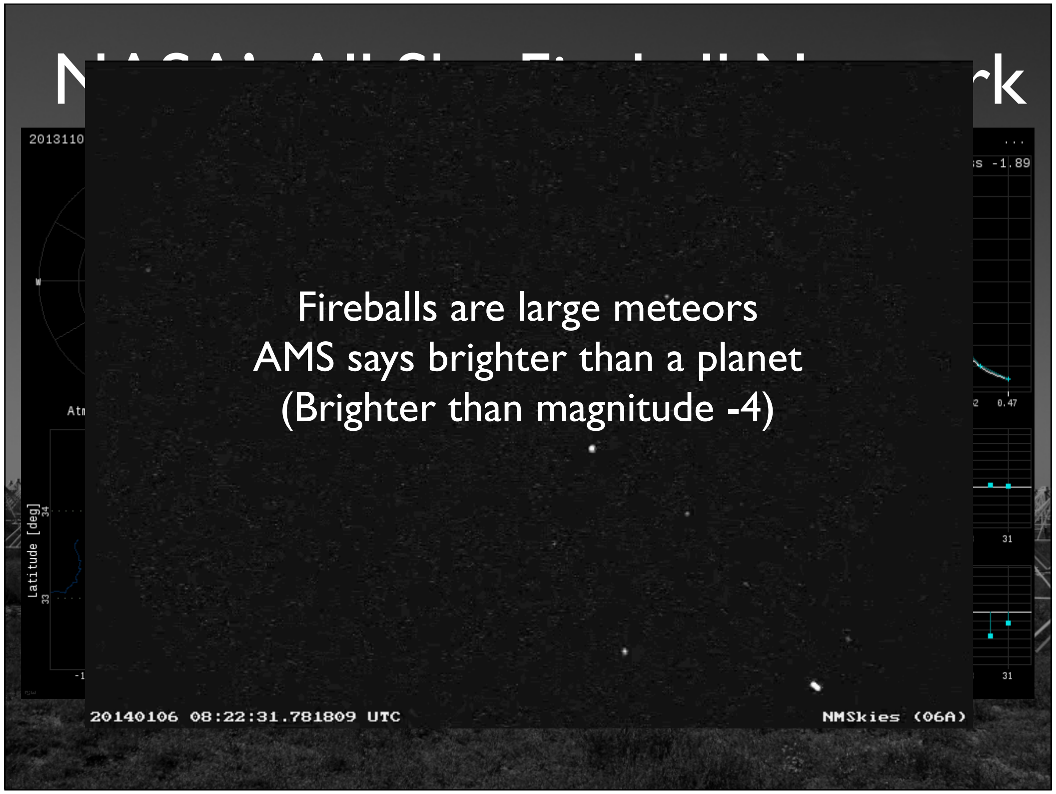
- Light Curves are all very similar, fast rise with exponential decay, and they're spectra is constant across the 75 kHz
- They all show no signs of polarization beyond what is expected from leakage




140121:7:43:08
Very!!!!
Many have been elongated in space

NASA's All Sky Fireball Network



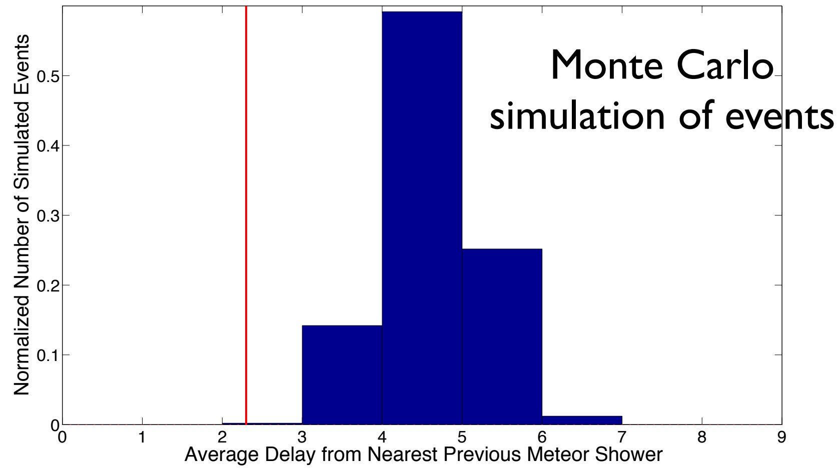

Fireballs are large meteors
AMS says brighter than a planet
(Brighter than magnitude -4)
20140106 08:22:31.781809 UTC
NMSkies (06A)
Latitude [deg]

Fireball Correlation?

- We found 12 of our 65 Transients to correlate in both space and time all were brighter than visual magnitude -4
- Given the fact that one should expect to see a fireball that bright once every 20 hours or so, the probability of coincidence is about one in 10^{28}

	vel.	M	ht. 1	ht. 2
av	65 km/s	-4.9	111 km	91 km
σ	11 km/s	1.5	9 km	9 km

Distribution of the events in Time



Ok they're meteors...

- Meteors plasma trails have long been known to reflect man made RFI (Helmboldt et al. 2014)
- They satisfy specular (Snell's Law) requirements and usually only a small portion of the trail satisfies this
- Signals are almost always strongly linearly polarized
- Almost always narrow band, and most PASI RFI is narrow band
- The number of reflections increases dramatically as you get closer to the horizon

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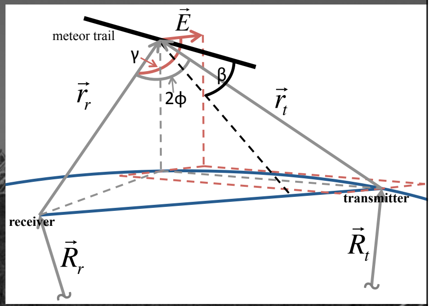

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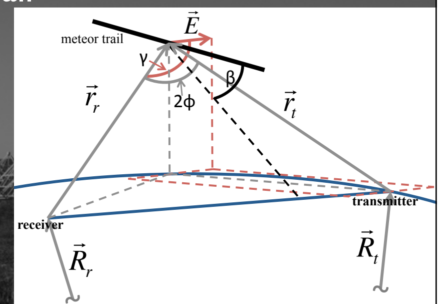

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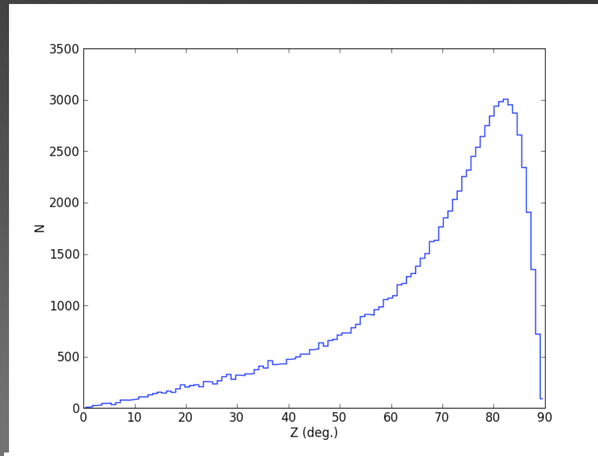

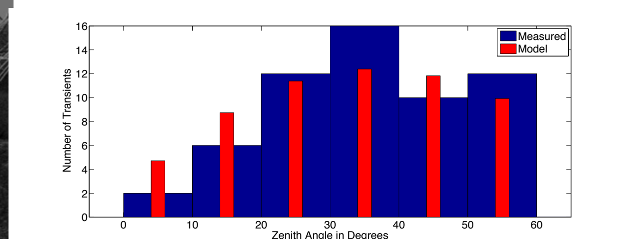

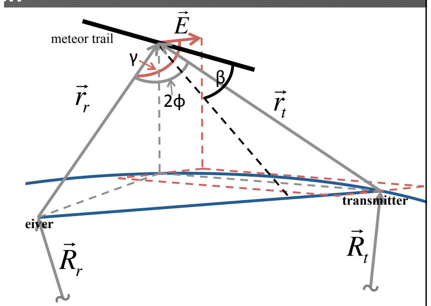

horizon

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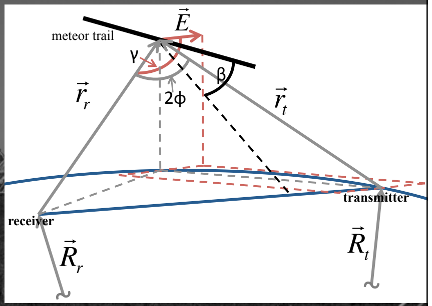

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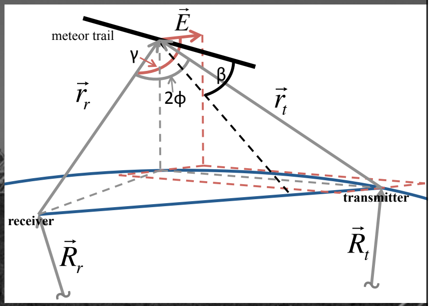

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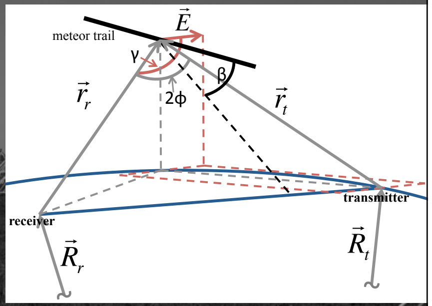
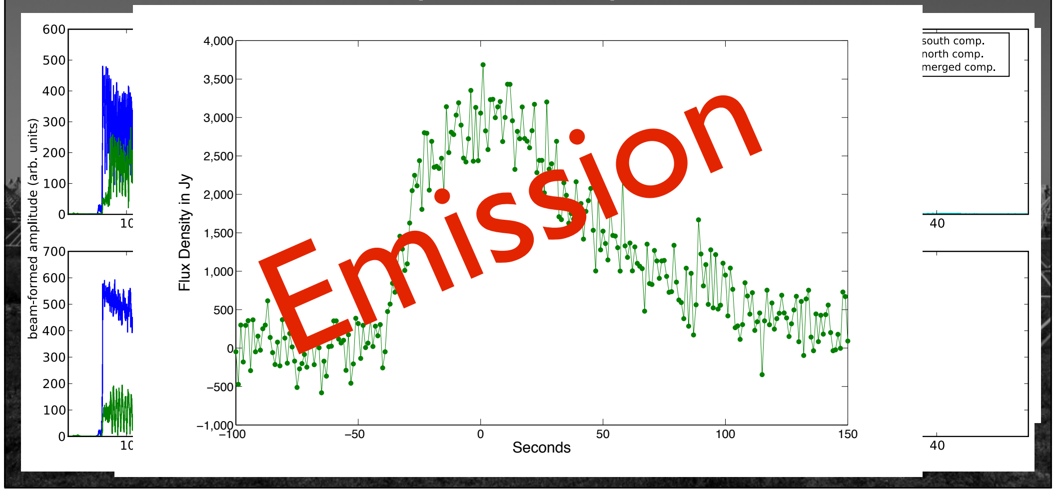


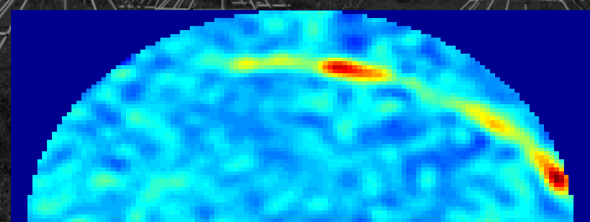
How about the light curves

- The light curves of our transients are all consistent FREDs
- Long Duration Meteor Trail reflections usually have erratic trails, and almost always have a very sudden onset < 1s



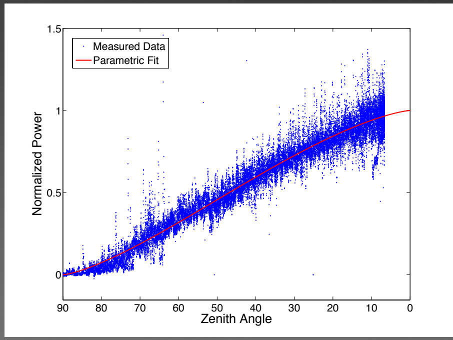
Conclusions

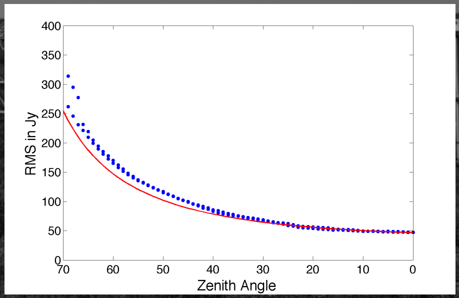
- We discovered a new type of emission from fireballs, which were previously unknown to emit in the HF and VHF bands
- The fact that we do not see them at 52.0 and 74.0 MHz and they appear brighter at 25.6 than at 38 leads us to believe the emission is non-thermal
- Radio Energy ~ 10^{-3} J, which is 10^{-11} of the total kinetic energy
- Brightness temperatures of 10^5 K also supports this idea
- Appeared in the June 20 issue of ApJ Letters (788 L26)



Power Calibration

- Power from Cygnus A measured on ten separate days throughout the year and fit with with a parametric model
- Used this to calibrate the off-source noise
- Computed standard deviation every degree of movement to estimate the zenith dependent RMS noise

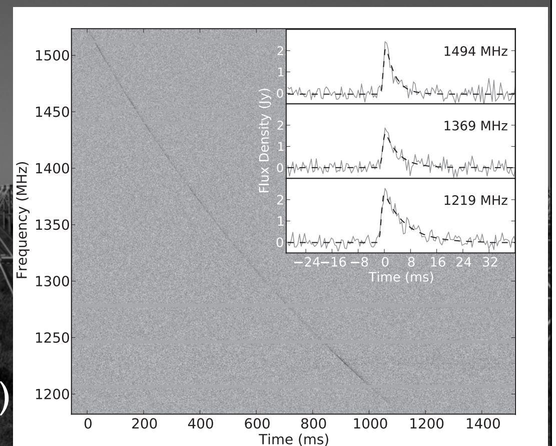





Backup Slides

FRBs

- Fast Radio Bursts (FRBs) have recently been discovered (Lorimer et al. 2007; Thornton et al. 2013; Spilter et al. 2014)
  - High dispersion measures >300 pc cm^{-3}
  - Pulse widths ~ 3 ms
  - Flux Density ~ 1-5 Jy
  - ~ 10^4/day
- A large spectral index may make FRBs extremely bright at low frequencies
- But large amounts of scattering (Pulse Broadening) may prevent detection



FRBs

- We should be able to constrain different parts of parameter space with both PASI and beam observations
- They might be related to another class of recently discovered transient at higher frequencies, Perytons, which are thought to occur in the atmosphere, and perhaps even FRBs (Kulkarni et al. 2014; Katz 2014; Burke- Spoloar et al. 2011; Thornton et al. 2013; Lorimer et al. 2007)
  - We just discovered a source of radio emission in the atmosphere, fireballs. Given the large range in energies, size scales, and time scales of meteors, they could be responsible for Perytons

Time of Day of Transients