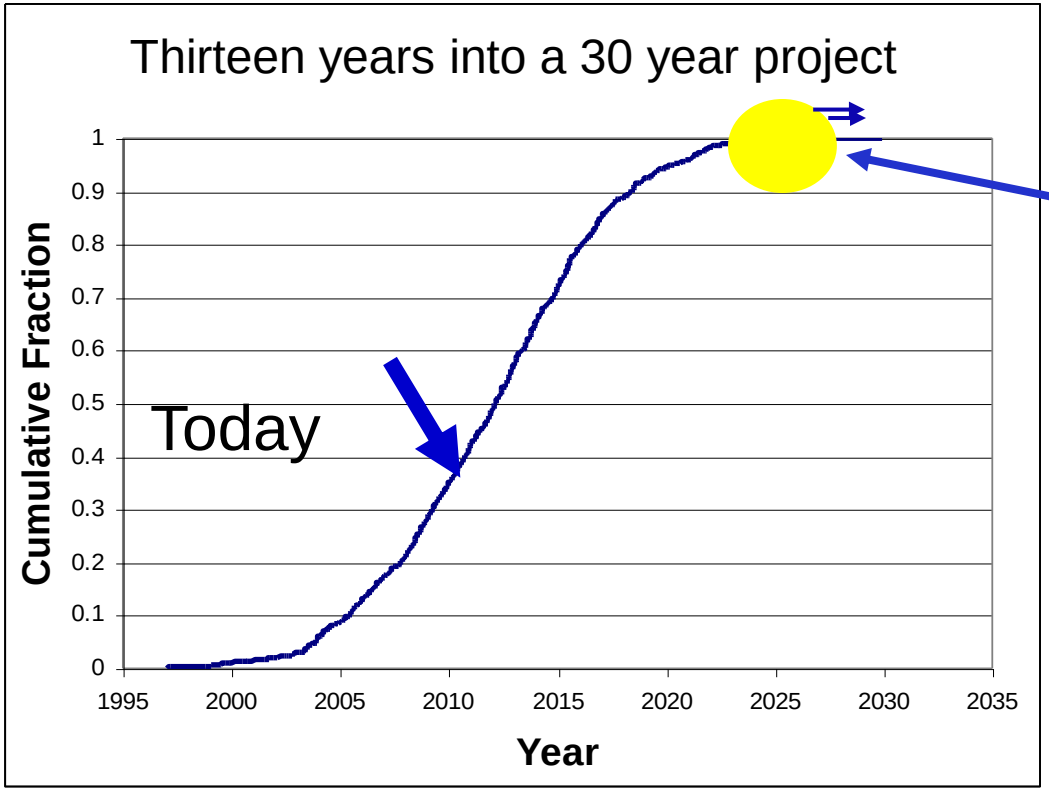
SAND2011-3757C

Extreme Ball Lightning: New Physics, New Energy Source, or Just Great Fun



Scientifically understood, technologically robust, economically advantageous, environmentally sustainable, and socially acceptable energy source

New Physics

Ball Lightning

Pace VanDevender

June 17, 2011

Earliest recording of ball lightning was arguably in Galesteo, NM ca. 1500 CE.

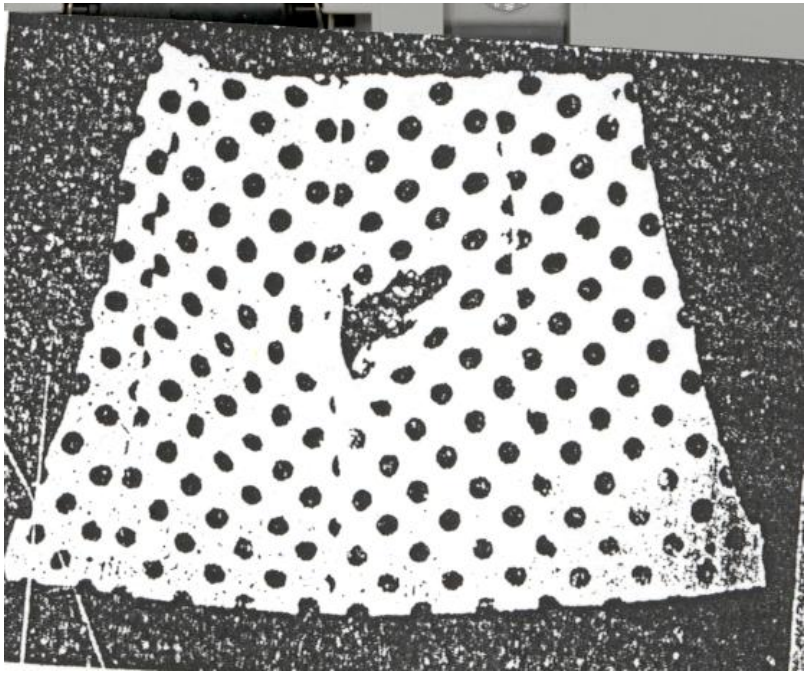
International databases contain over 10,000 reports of ball lightning.

- **Some ball lightning has a subatomic core**
  - On sunny and windy day, grapefruit-sized fireball came from clump of bamboo and passed straight through wall of house, through living room, and through rear wall without any holes.
  - "A six-inch yellow fireball appeared at the window and passed through the glass, moved across the room and out another glass window without any holes, in one minute."
- **Some ball lightning interacts by magnetic induction.**
  - In 1976, a 12 inch diameter fireball materialized right in front of an engineer-attorney inside his house while there were clouds outside over 3/4 s of the sky but no rain or lightning occurred that day. It hovered at 1 m from floor, then moved at walking speed, made one left and three right angle turns, hit a water faucet, and exploded.
  - Fireball follows buried water pipe under a road and through right angle turn into a house.

Paul Sagan (**Ball Lightning—Paradox of Physics)** and Jim McNally (ORNL)

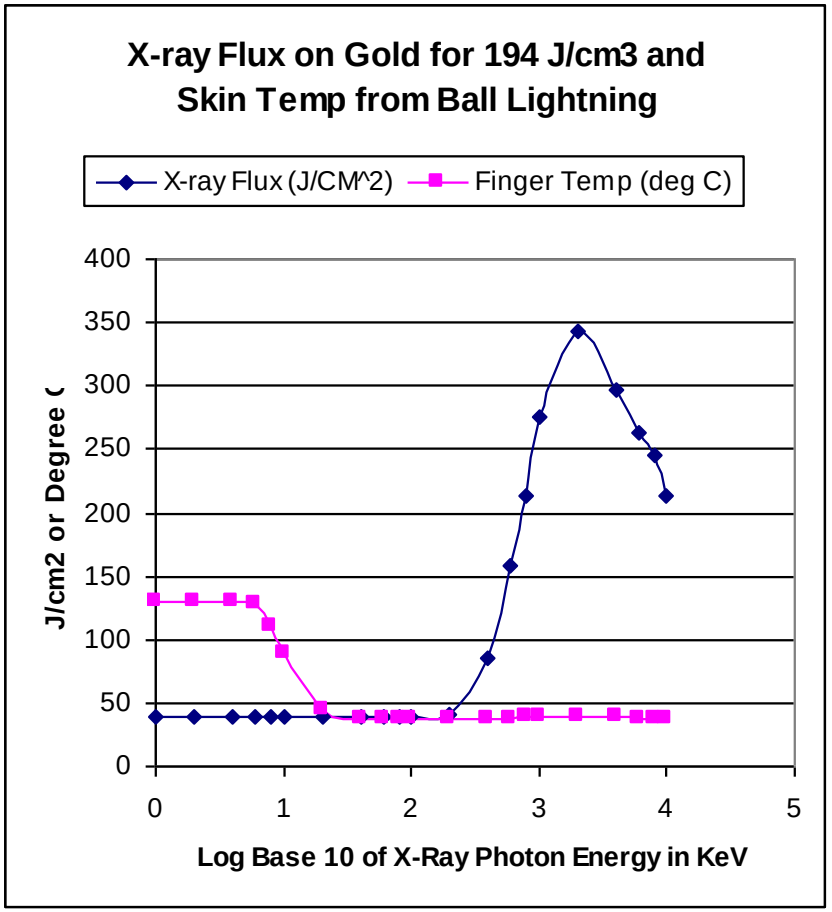
Some ball lightning emits a lot of electromagnetic energy in the MHz range.

- **M. Stenhoff, *Nature* 260,** 596 (1976)
- **Bleached fabric**
- **Decomposed polyester skirt without melting or charring**
- **Red and numbed skin**
- **Heated gold ring to nearly scalding**
- **Felt warmed all over**



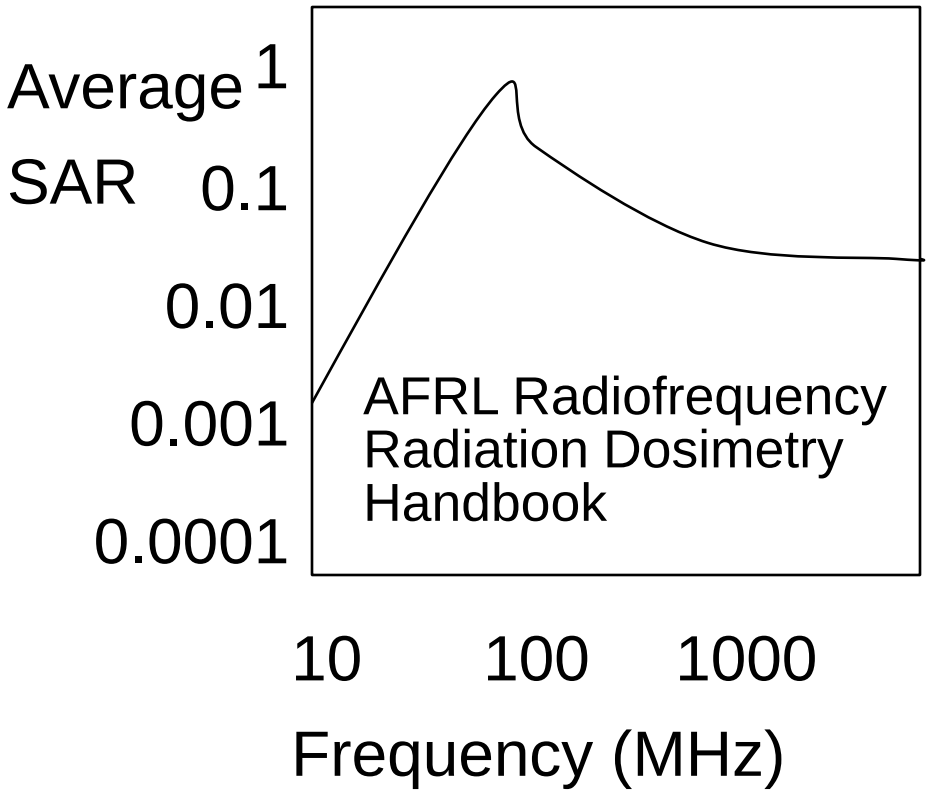
No radiation sickness indicates ball lightning does not emit ionizing radiation.

- M. Stenhoff**,** ***Nature*** **260,** 596 (1976)
- Not < 20KeV photons
- >440 Joules
- If 500 KeV x-rays, then integration of dose over likely path indicates >10^5 rads of dose to the witness.
- No radiation sickness indicates <100 rads.



Electromagnetic emissions would have heated the gold preferentially.

- **Strong enough to heat the gold**
  - **$\delta T = 22\ ^oK$**
  - **Gold**
  - **Time=1 second**
  - **R=0.1 m**
  - **I=900 Amps**
  - **B=0.05 T**
  - **$P = 2\pi R^2 \varepsilon_o E^2 c = 750$ MW**
- **Low enough frequency to not heat the woman**
  - **f < ~1 MHz for delta T <1^{o}C**



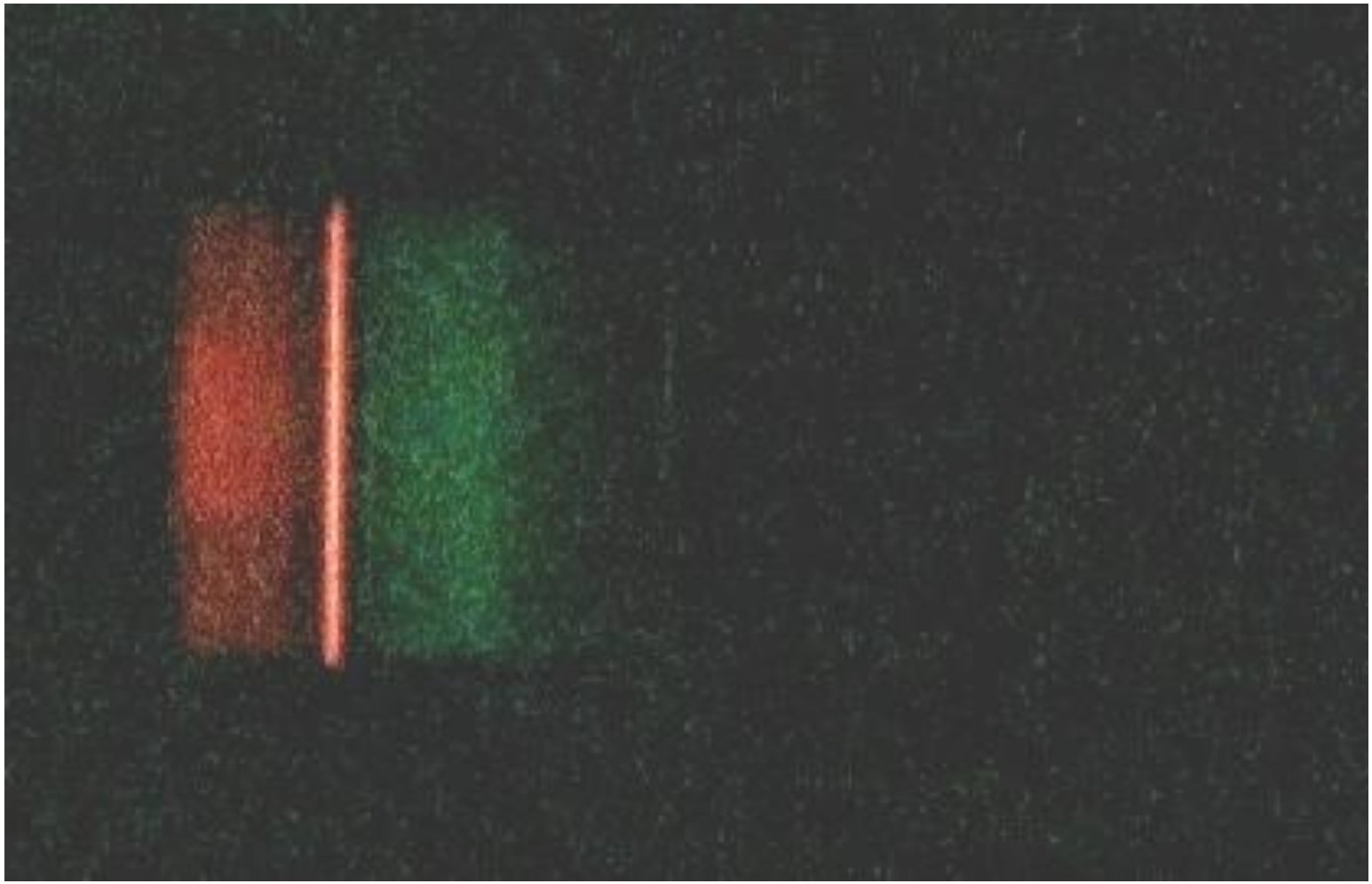
Radiating Electric Dipole Model implies >100 MW emitted RF power at ~1 MHz.

Luminosity does not mean high temperature but glow persists for only ~1 sec without power input.

- Bolometer indicates ~100^{o}C radiation temperature.
- Lifetime scales ~r^2
- Persistent luminosity is an artifact of a powerful source of energy.

Experiments by Alexef, Parameswaran, Thiayagrajan, Grace, and Predeep at University of Tennessee and University of Wisconsin.

Alexeff measured a broad band excitation spectrum plus the lines from the electrode.



RF source makes air glow like ball lightning.

Microwave drill heats Si, SiO_2, Ge, or Al_2O_3 to molten-vapor state and excites it as long as 600 W of 2.45 GHz microwaves sustain it.

Eli Jerby and Vladimir Dikhtyar of Tel Aviv

Burning silicon mimics many characteristics of some ball lightning.

- Melted and vaporized elemental silicon burns and flutters about the lab with dimensions of 1 to 4 cm diameter from droplets of much smaller size.
- Partially supports theory of Abrahamson and Dinniss:
- Nature (London) **403**, 519 (2000)

Paiva, Pavao, de Vasconcelos, Mendes, and da Silva from Brazil:
PRL **98**, 048501 (2007)

There may be different types of ball lightning.

Majority

- **During a storm**
- **< 10 seconds**
- **Benign**
- **No artifacts**
- **<10^5 Joules**
- **Floats through air**
- **Extinguishes in ground or air**

Finkelstein & Rubin, Phys Rev. 134, 2A, pA390-A396.

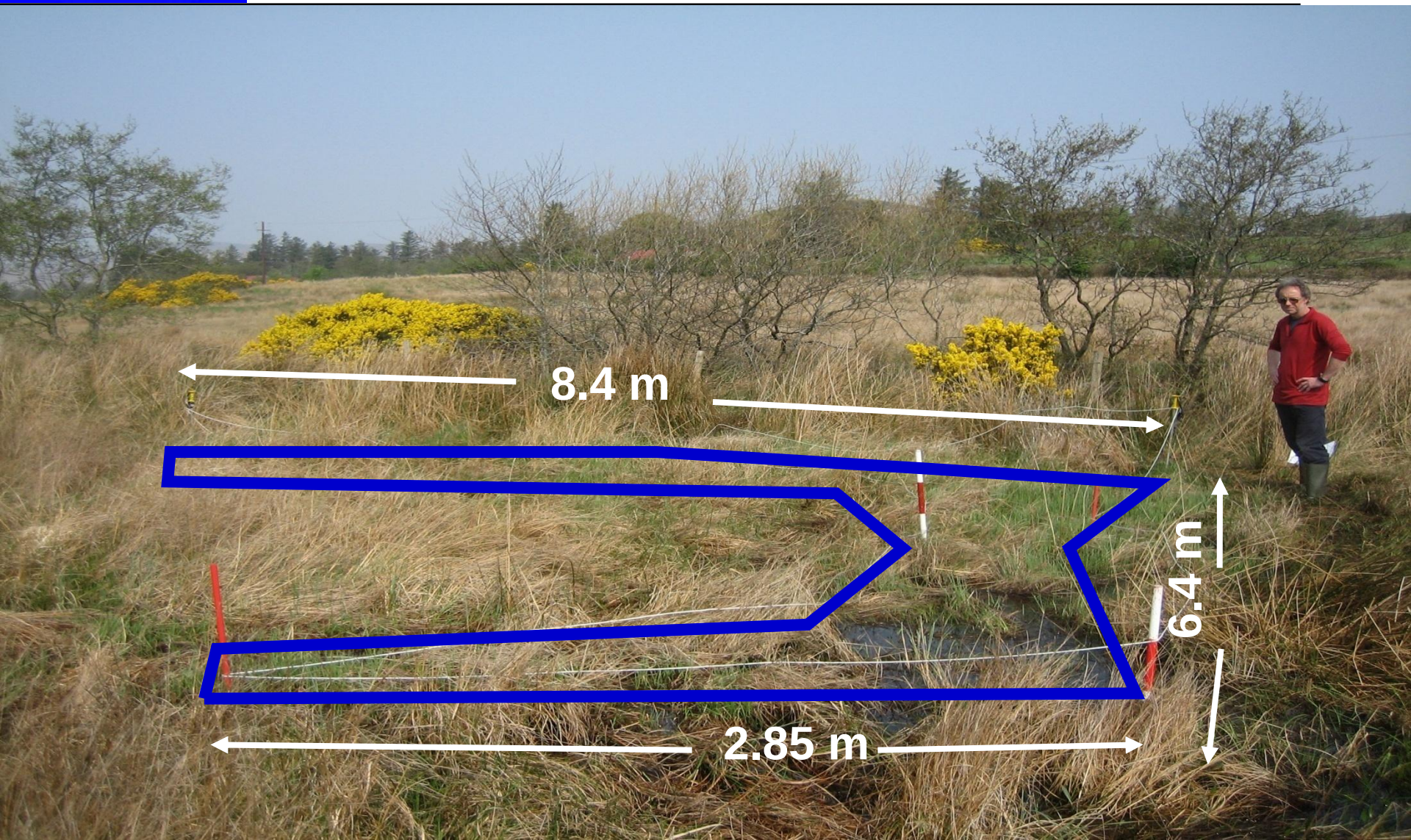
Extreme

- **During high E-field**
- **10 to >1200 seconds**
- **Lethal or potentially lethal**
- **Significant damage**
- **10^5 to >10^9 Joules**
- **Penetrates walls, glass, metal**
- **Moves tons of earth**

Michael Fitzgerald reported the most extreme ball lightning event.

August 6, 1868, County Donegal, Ireland

Probing the depth of the water revealed Fitzgerald's reported "20 ft-square" hole--submerged.

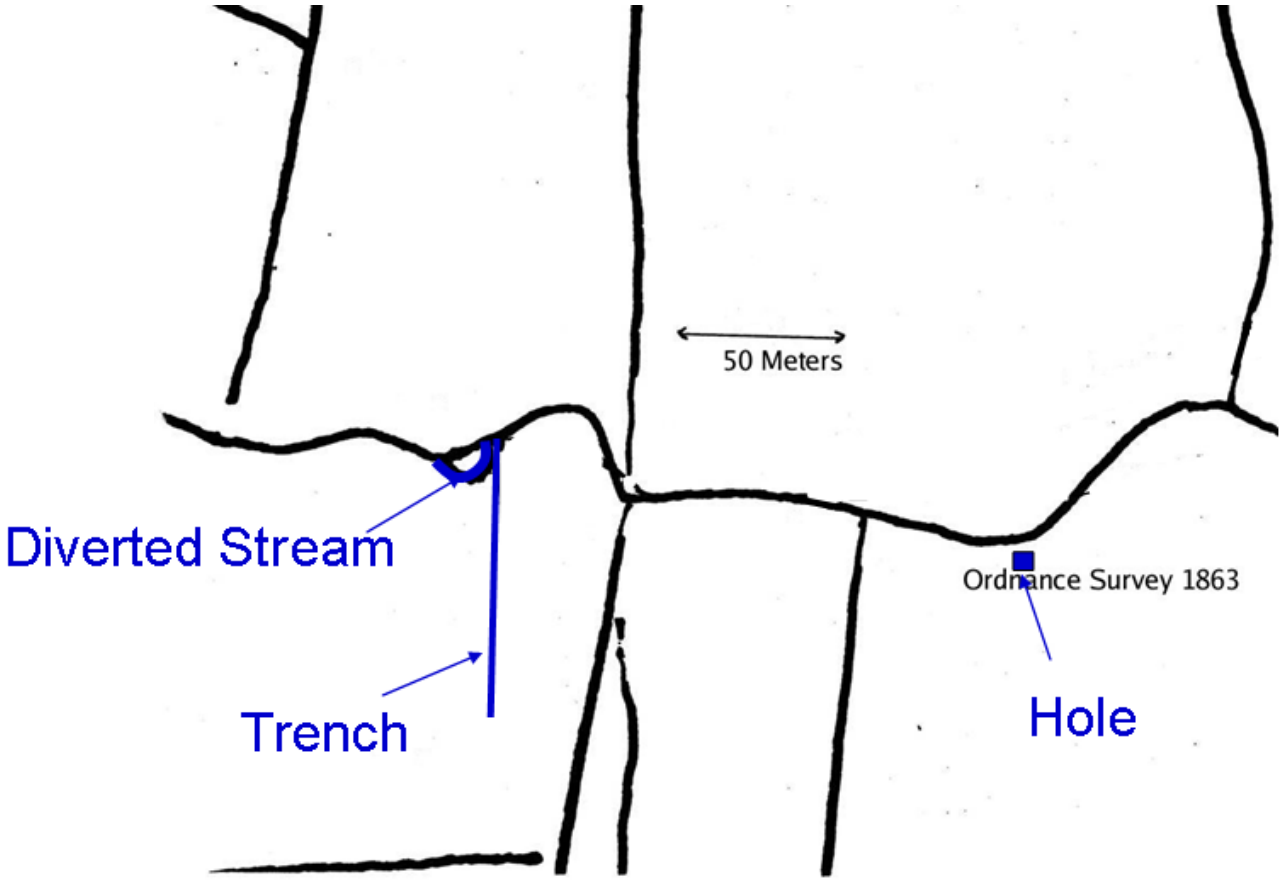


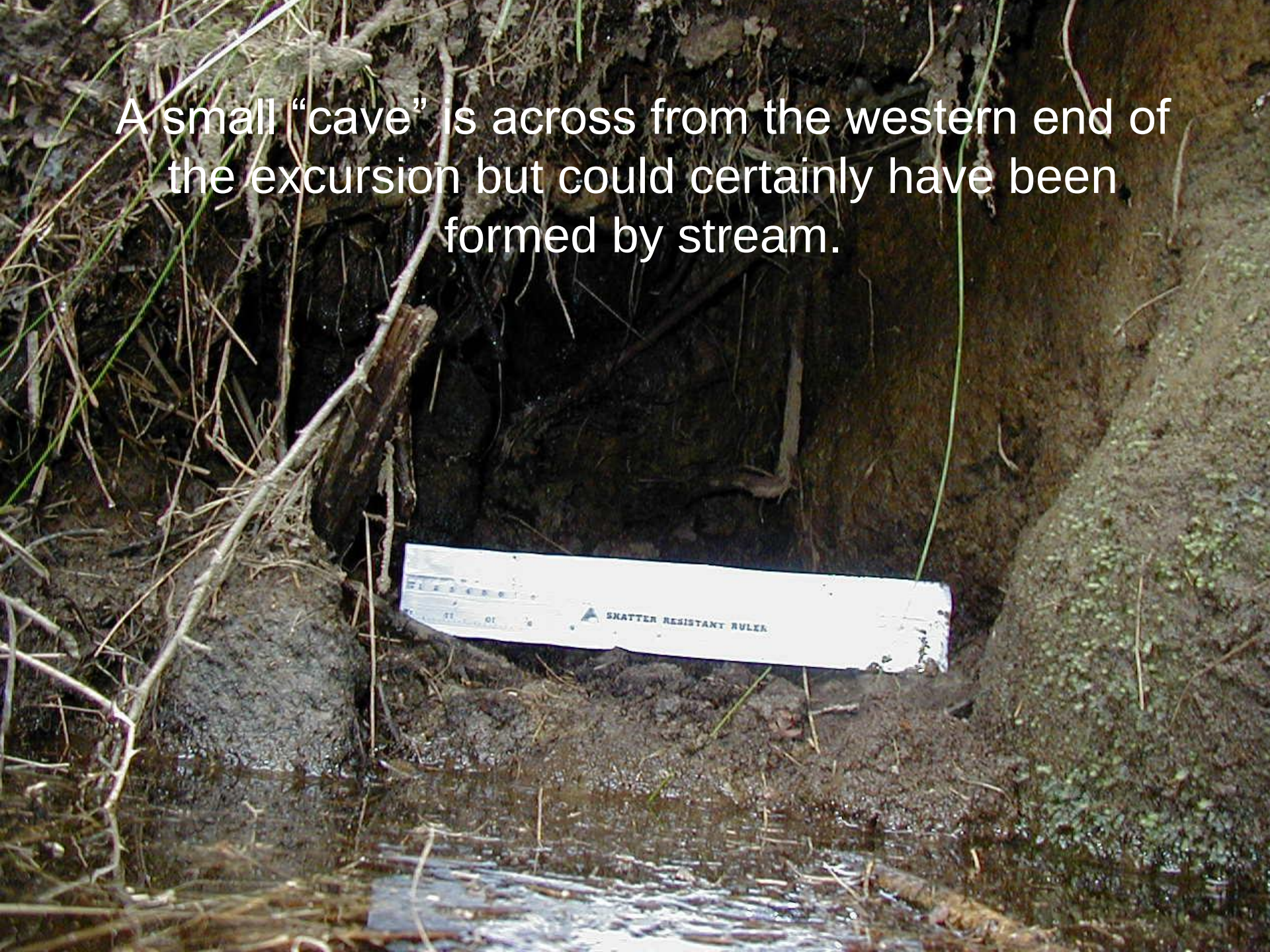
This 63 meter long, 1 meter wide depression is consistent with Fitzgerald's reported "trench".

Carbon-14 dating of the peat in this trench and the adjacent area is consistent with Fitzgerald's report.

Remnants of post 1863 diversion of the stream is consistent with Fitzgerald's report.

Survey map of 1863 shows none of Fitzgerald's reported events of 1868.




A small “cave” is across from the western end of the excursion but could certainly have been formed by stream.
SHATTER RESISTANT RULER

We have no reason to doubt Fitzgerald saw what he reported to the Royal Society.

- **6 m square hole of the right size and location**
- **90 m long trench of right size and location and carbon dated consistent with report**
- **25 m long diversion of stream bank not recorded on survey map of 1863**
- **Cave across from stream diversion may have been formed by water in 1868 and now.**

The 1868 events lets us weigh this ball lightning.

- **Fitzgerald reported that the edges were turned up about 0.3 m.**
- **He does not report any smoke, steam, or explosion.**
- **It floated above peat until it came to soft spots.**
- **Analysis rules out chemical, nuclear, and electrostatic expulsion of the >100 tons of water saturated peat.**

  => A heavy downward force displaced the peat.
- **Uncompressed Yield Strength of the peat = 530 +/- 130 kN/m^2**
  - **Minimum Yield Strength = 270 kN/m^2 at 2 sigma point**
  - **Width of 0.9 m implies 0.7 m^2 footprint**
- **Weight of this ball lightning is 2x10^4 kg to 10^6 kg.**

=> A gravitational singularity emitting a magnetic induction field

We ran across another depression while looking for the Fitzgerald event.

- **1982 event at night**
- **Shook windows 2 km away**
- **Viewed the next day by two rangers and one policeman**
- **Unusually smooth sides and no ejecta**

=>Need to check consistency with magnetic image current deceleration of massive body

Two sites in 100 km^2 area and 100 years apart imply ~10^5 impacts per year.

Ball lightning event of 18 January 1994 in Spain reportedly made this hole—but didn't.

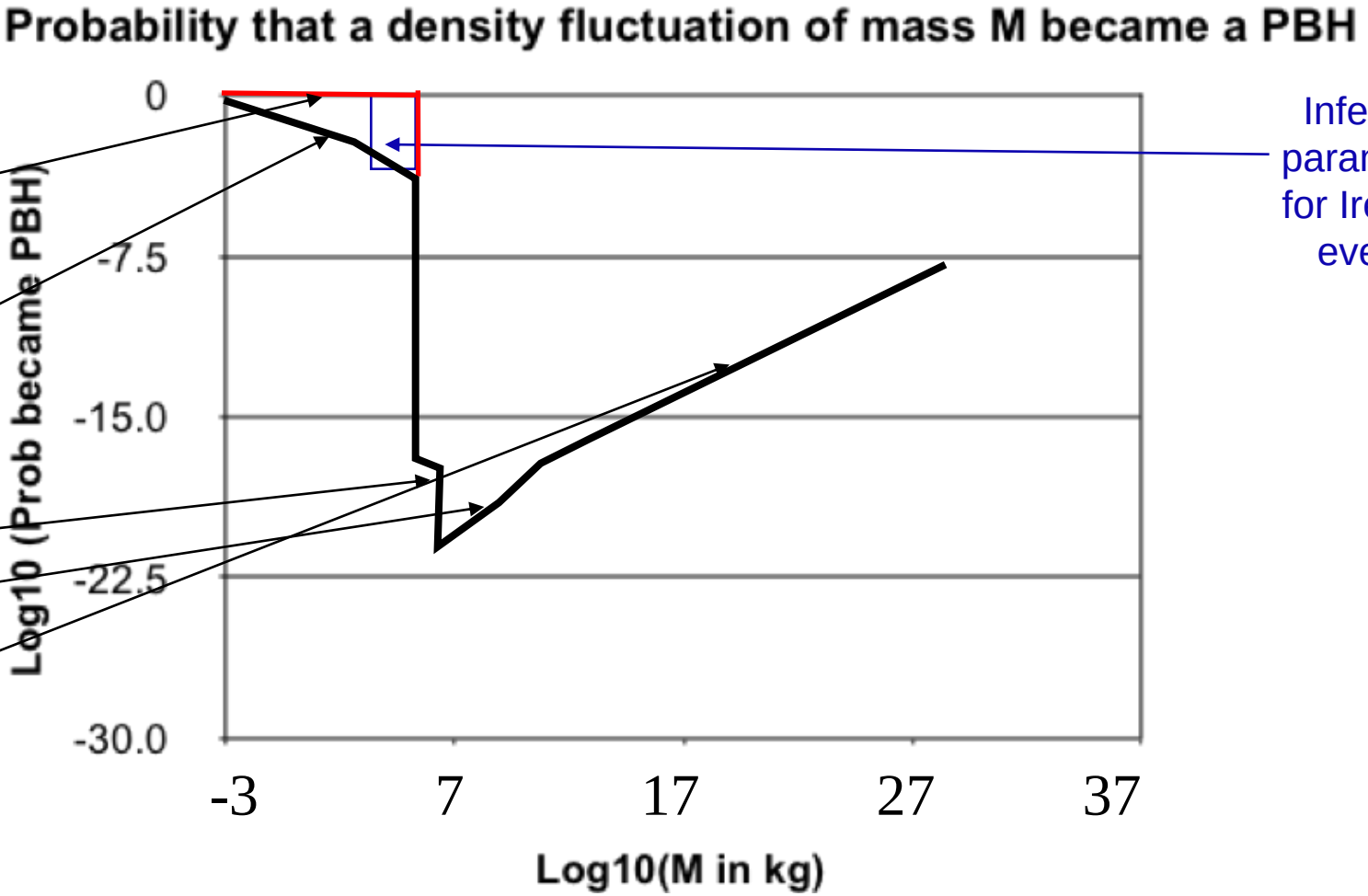
- Glowing ball
- 2 km/s velocity at 18º inclination
- 29m x 13m x 1.5m excavation
- Tossed 75 m down 24º slope over a road
- ➢Minimum impactor mass of 30,000 kg from momentum conservation
- ➢Stopped by magnetic induction

Expedition to this site in April of 2009 found that this scar was from a soil slide—not high pressure release under root-integrated forest floor or magnetically decelerated black hole.

The Big Bang favored formation of Mini Black Holes--MBHs.

Limit:

- No Quantum Evaporation
- Photon/ Baryon Ratio if Quantum Evaporation Occurs
- He
- D
- Density



Inferred parameter for Ireland event.

B. J. Carr, J. H. Gilbert, J. E. Lidsey, Phys Rev. D, V. 50, 4853-4867 (1994)
B. J. Carr, J. E. Lidsey, Phys Rev. D, V. 48, 543 (1993)

MBHs should have evaporated by now but quantum evaporation has become highly controversial.

- **Unruh W. G. and Schützhold R. "Universality of the Hawking Effect." Phys. Rev. D. 2005. V. 71. P. 024028.**
- **Adam Helfer, "Do Black Holes Radiate" Reports on Progress in Physics, v. 66, 943-1008 (2003)**
- **Diverse opinions**
- **Conclusion**
  - **Open question**
  - **Existence of MBHs today should be taken seriously**
  - **MBHs could contribute to Dark Matter**

~400 to 4000 impacts a year at ~10^5 to 10^4 kg is consistent with density of dark matter.

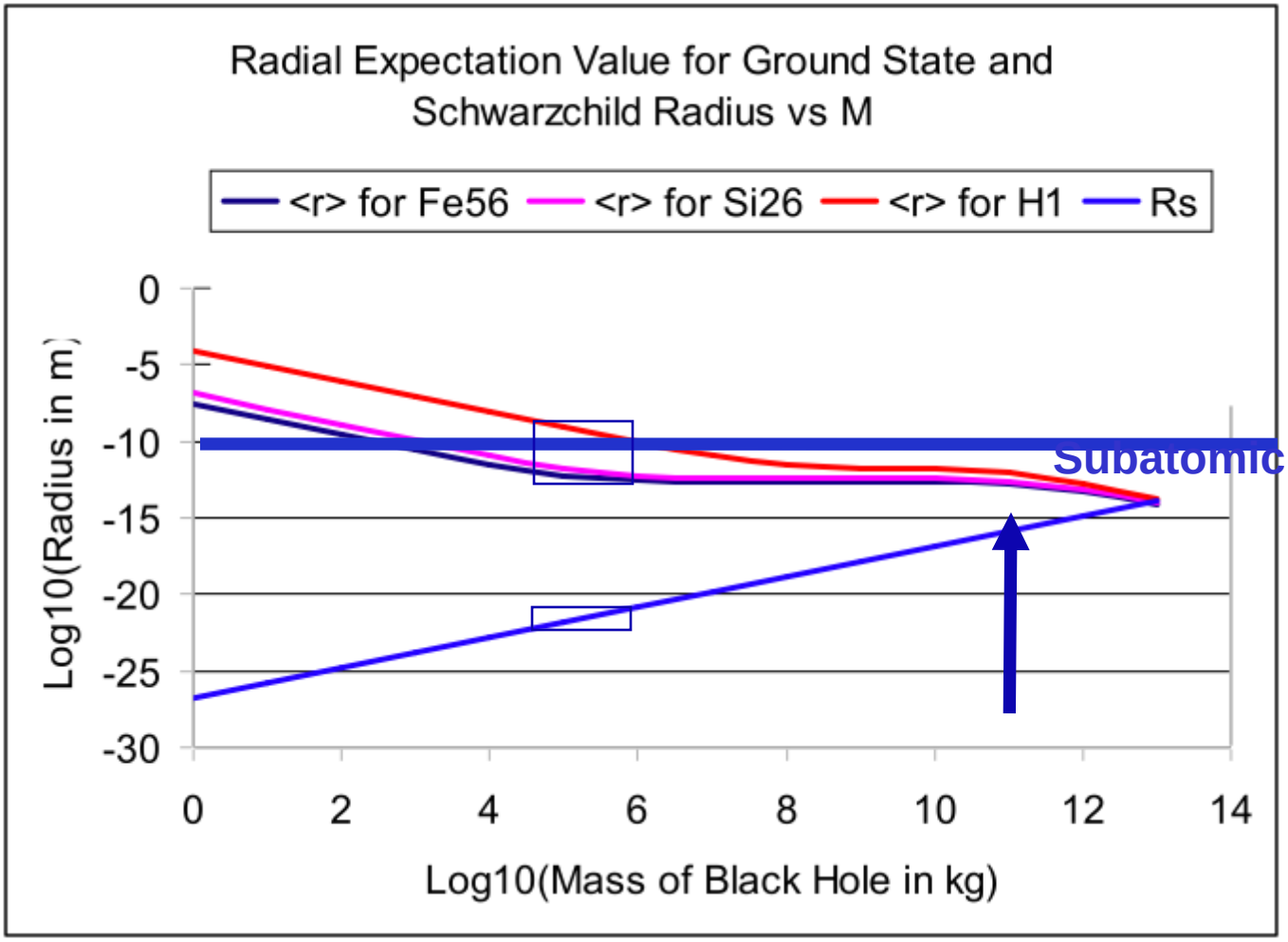
Why don't Mini Black Holes consume the earth?

- **Non-rotating and uncharged PBH has an event horizon at the Schwarzschild radius**
  - **$R_s = 2\,GM/c^2 \sim 1.48 \times 10^{-27}\,M$**

    $\sim 10^{-27}$ m to 10^{-21} m for 1 kg to 10^6 kg
- **Much smaller than a nucleus**
- **Surrounding matter should obey quantum mechanics as electrons around a nucleus do—inhibiting absorption of normal matter.**

⇨ **Gravitational Equivalent of Atom (GEA)**

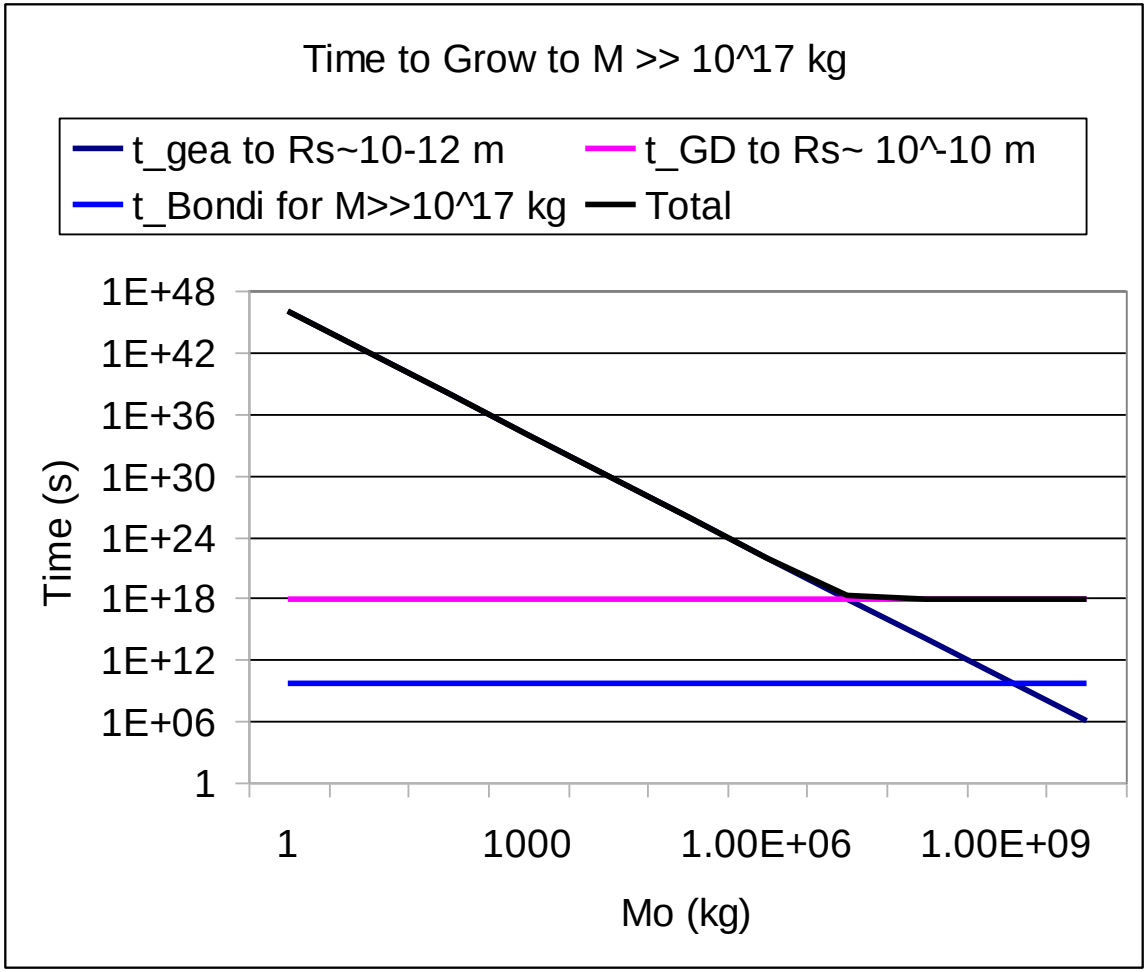
The ground state radius is > the radius of the event horizon for M $<10^{12}$ kg.



Therefore, the black hole in a GEA is inhibited from absorbing the earth.

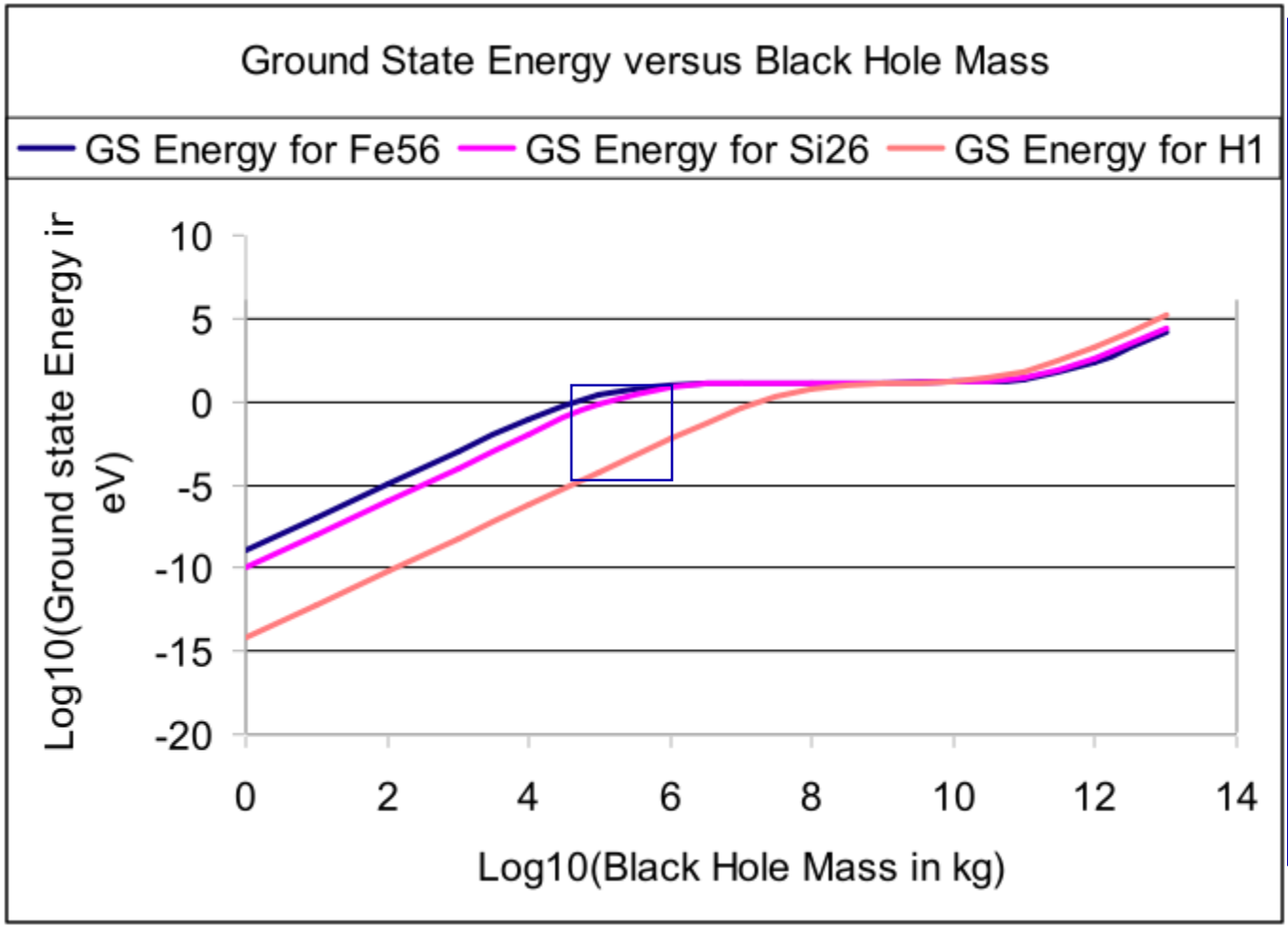
We have extended the analysis of Giddings and Mangano[1] on the mass absorption rate.

- Dirac equation modified to accommodate the combined gravitational potential of the central mass
- Computed the absorption of from the ground state as a function of central mass.
- The earth is safe.



1. S. B. Giddings and M. L. Mangano, Phys Rev D 78, 035009 (2008)

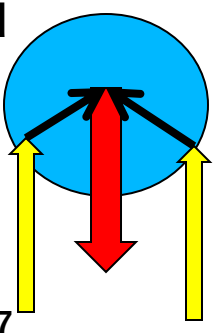
Matter is tightly bound to black hole for greater than ~30,000 kg black hole.



Thomas-Fermi stopping power implies that about 3% of the incident MBHs from dark matter would be captured by the earth--
~12 per year at 10^5 kg each.

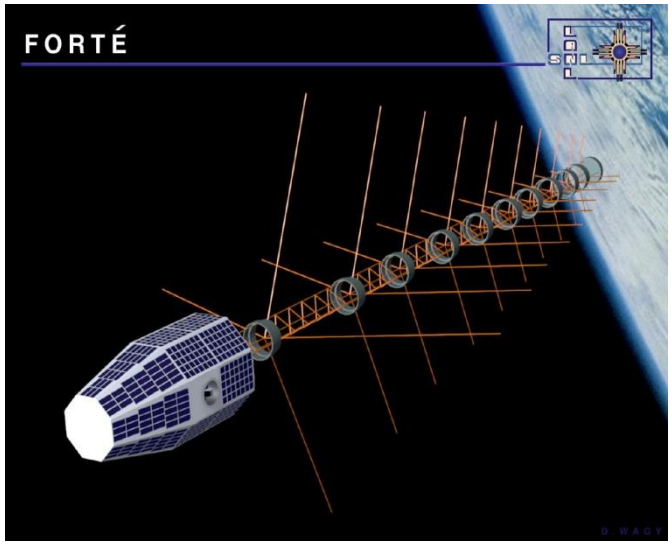
The GEA binding energy is too small to levitate the singularity.

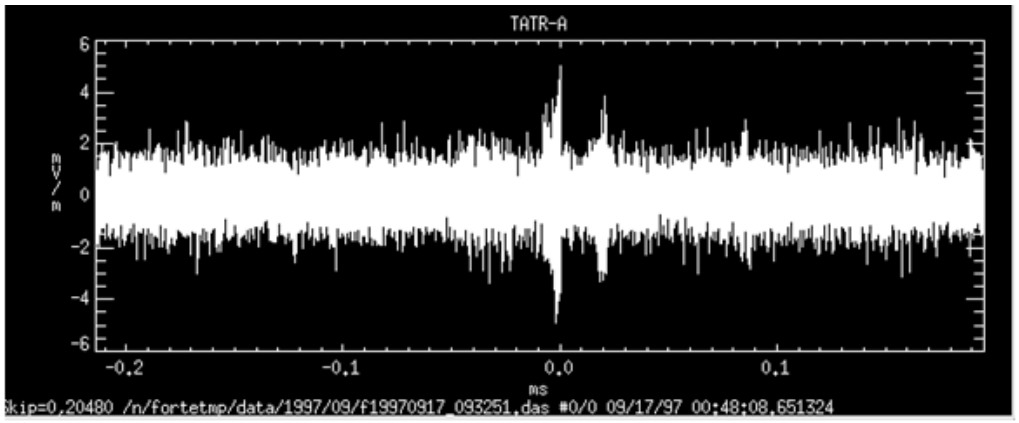
- **If N bound particles are source of magnetic field levitating the GEA, each must transmit F_L=Mg/N force without being stripped from black hole.**
- **M=10^6 kg, g=9.8 m/s^2, F_L=10^7/N**
- **GEA Gravitational force = F_g= GMm/r^2~2.8x10^{-8} Newtons**
  - **G = 6.67x10^{-11}, Ground State radius r ~ 10^{-11}, m= 26*1.6x10^{-27}**
- **F_L<<F_g, N>>Mg/F_g~4x10^{14}**
- **At solid densities of ~(5x10^3 kg/m^3)/(26*1.6x10^{-27} kg/nucleus) ~$10^{29}$$m^{-3}$ so volume ~4x10^{-15} m^3.**
- **δ r~10^{-5} m >> r, so enough normal density matter cannot fit in the GEA**

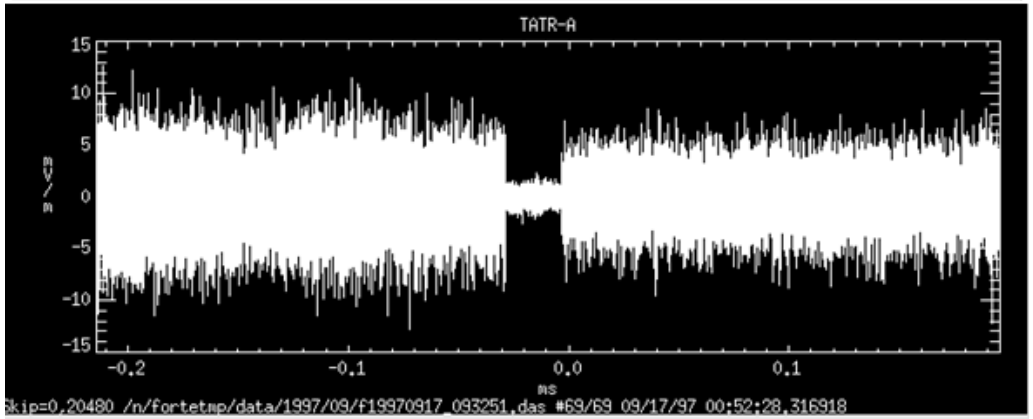


Perhaps the core is a naked singularity instead of a black hole. If so, it might support an oscillating magnetic field, which would have to be included in the analysis.

If ball lightning is magnetically levitated, RF emissions should be observable by FORTE.



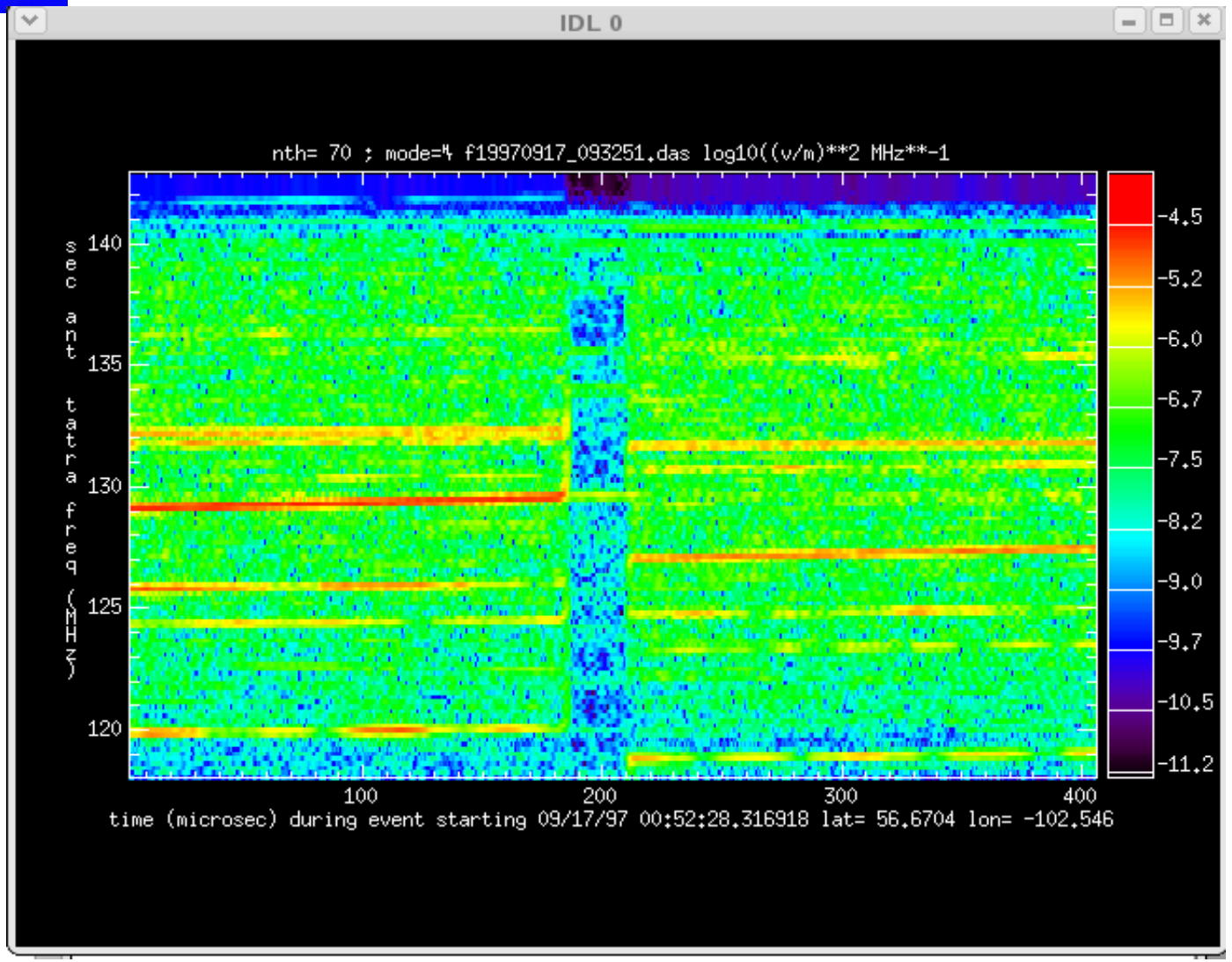




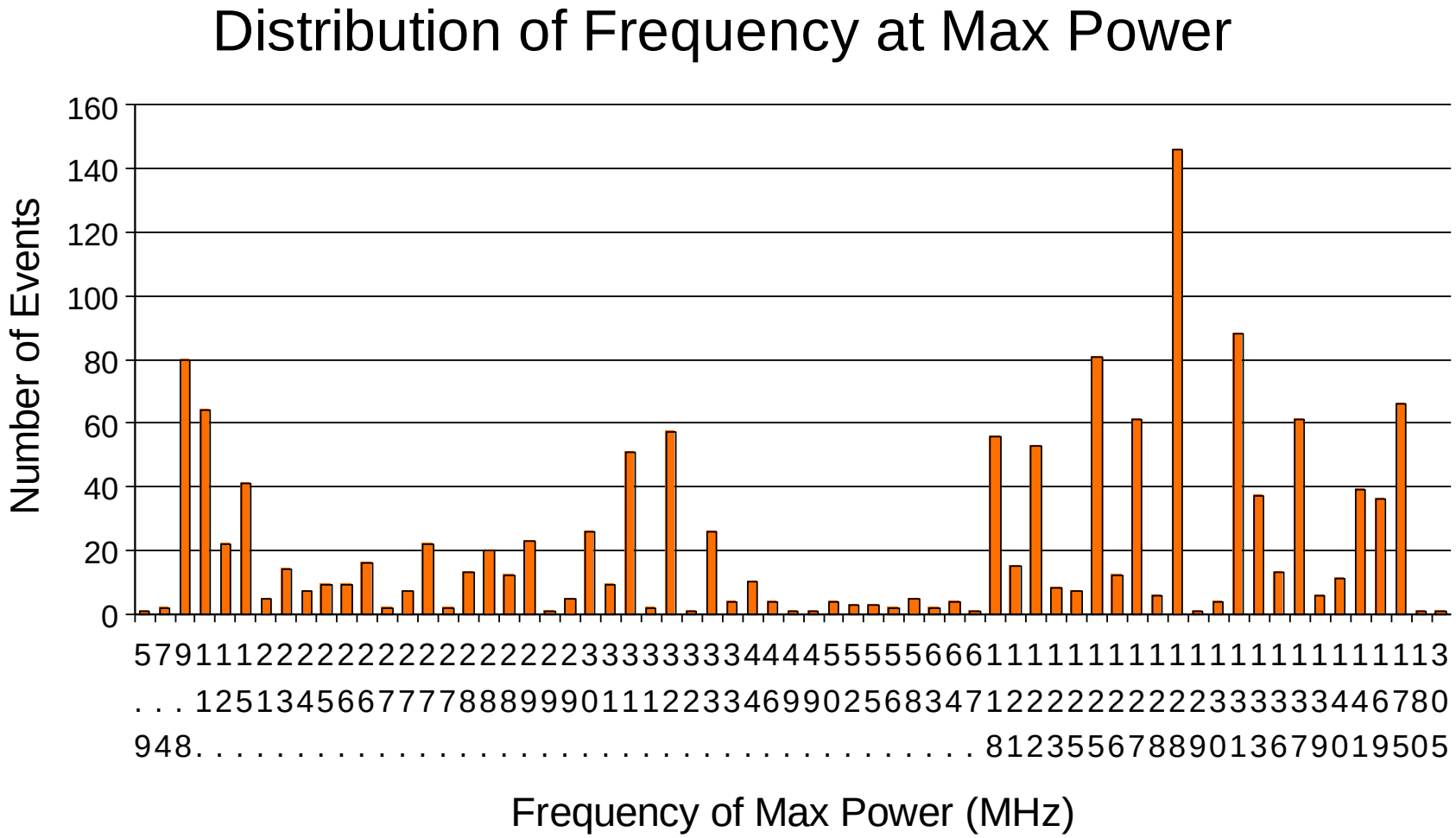
- **5.9 MHz to 300 MHz**
- **400 microsecond windows**
- **Two months of narrow band data for 10 % of the time in September and October 1997**
- **FORTE recorded 5000 unexplained bursts in about 50 pulse trains.**

$10^{4+/-1}$ events per year.

Time resolved spectrum shows an end and a beginning of RF bursts and frequency variability.



The anomalous signals cover many frequencies.



Plasma instabilities are too low frequency to explain observations.

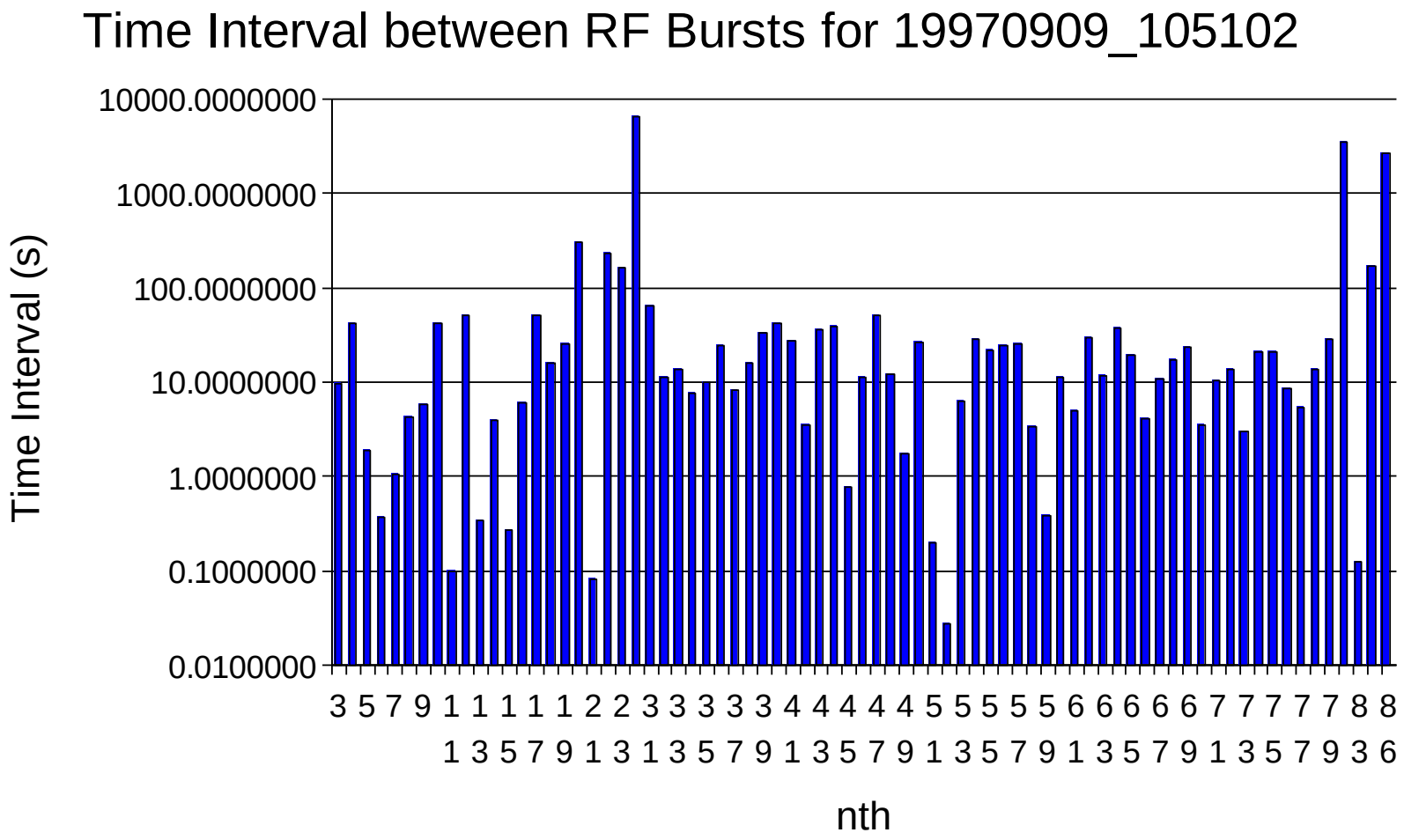
Propagation perpendicular to B

- **Ordinary Mode: 45n Hz, 0.8n MHz, 3 MHz**
- **Extraordinary Mode: Bernstein Modes not supported for $\omega_{ce} < \omega_{pe}$ and upper hybrid mode is at 1.6 MHz.**

Propagation parallel to B

- **Alfven waves: <<45 Hz**
- **Whistler waves: < 1 MHz**
- **Cyclotron waves: 1 MHz and strongly damped**
- **Drift waves: <<45 Hz**

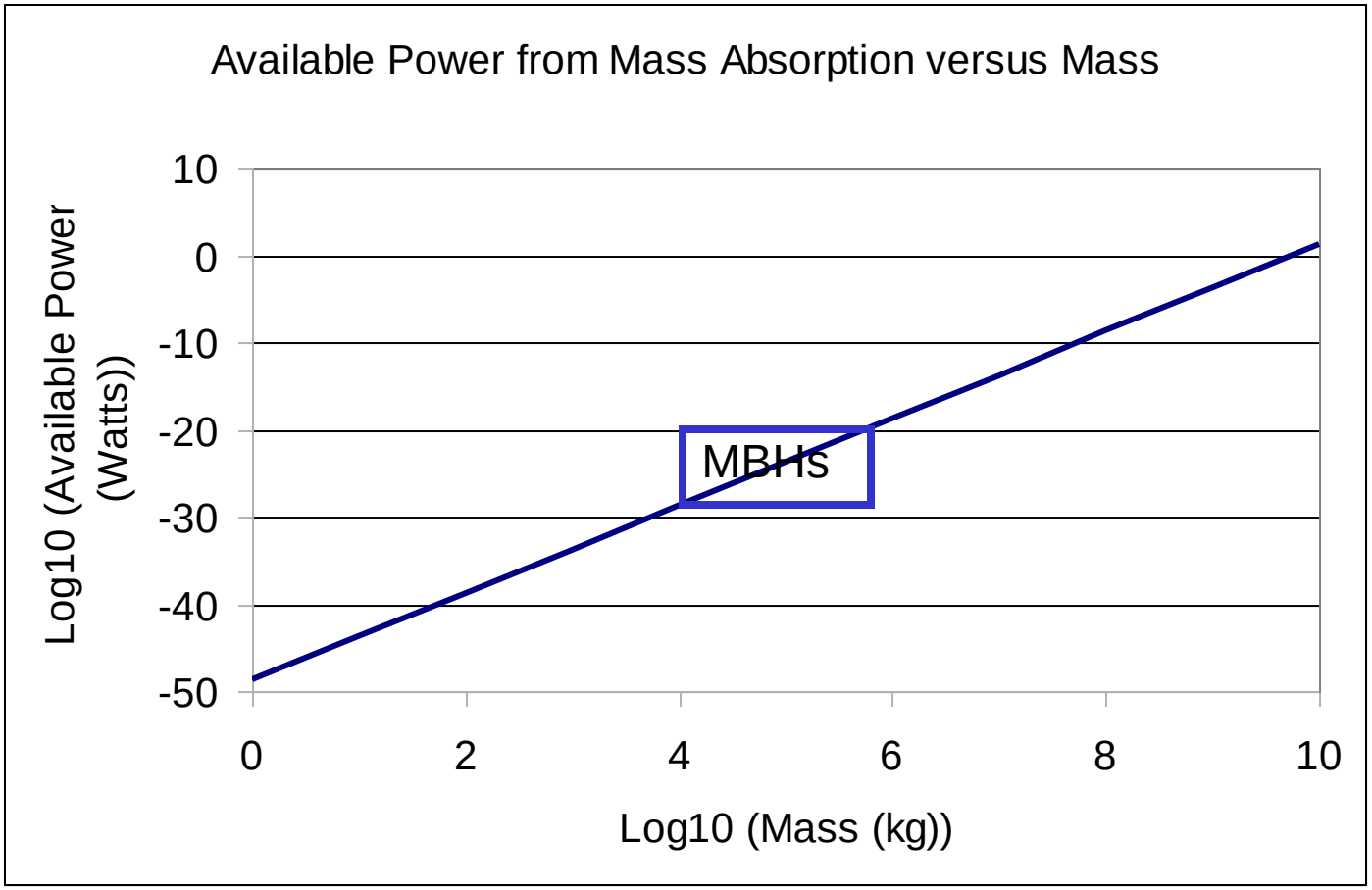
Time between bursts within a pulse train varies considerably.



Time integrated photograph of ball lightning shows starting and stopping.

- **M. T. Dmitriev, V. M. Deryugin, and G. A. Kalindevich**
- **“Optical Emission from Ball Lightning” Soviet Physics-Technical Physics, 17, No. 10, 1724-1725 (April 1973)**
- **Radial profile is most consistent with a central source—not a hollow shell.**

The mass absorption model for a GEA let us calculate the power available for emissions.



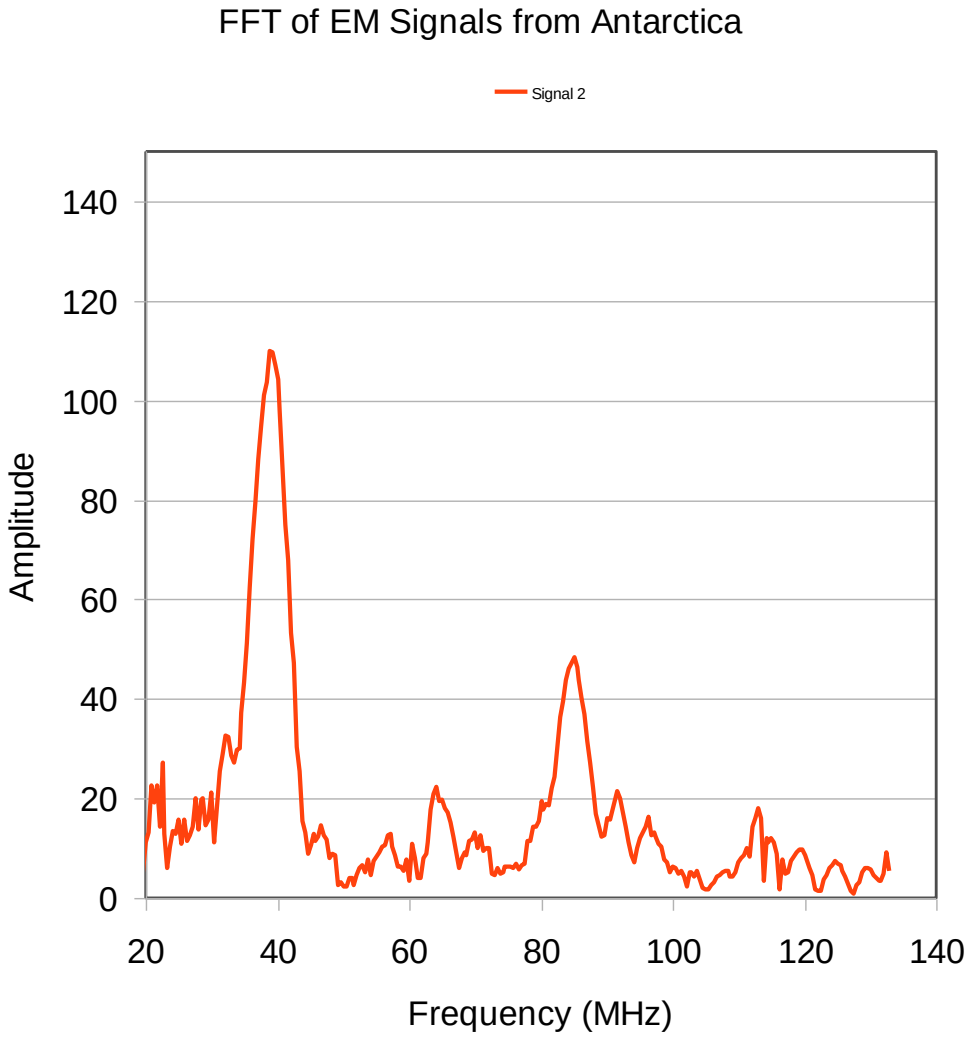
This is too small to be detected.
Central core must be a Mini Naked Singularity (MNS).

Albuquerque RF background foiled efforts to detect the signal FORTE observed.

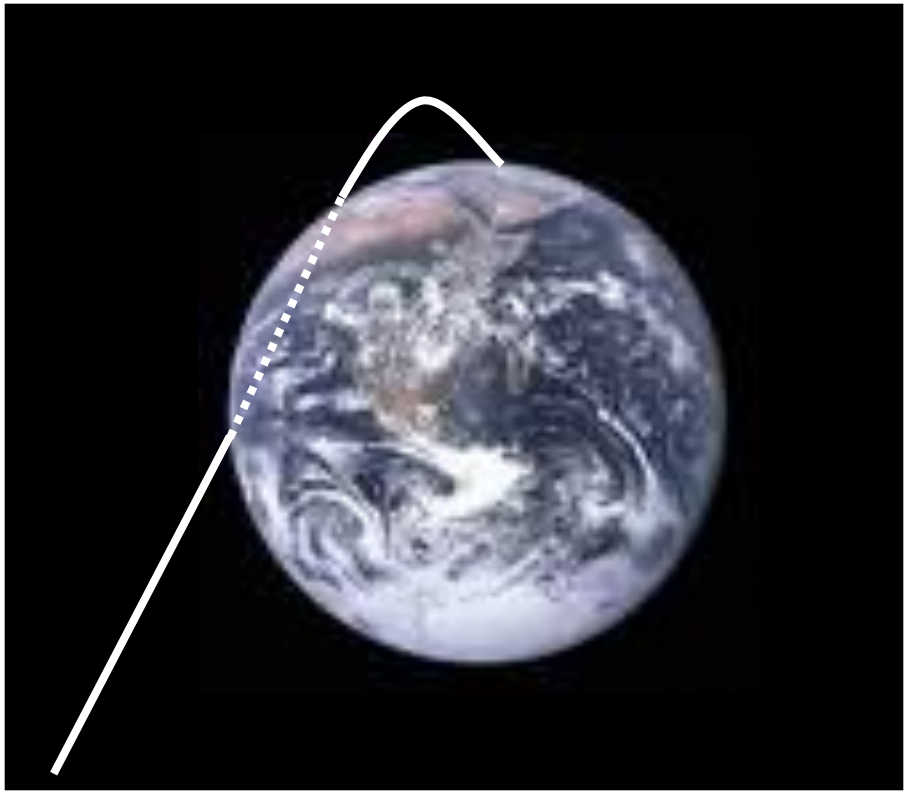
So we went to Antarctica and found the RF background was 40 dB less than that in Albuquerque.

We found RF signals in Antarctica that are consistent with those detected by FORTE.

- The FORTE recorded signal sources are still there and consistent with ~10^6 watt pulsed emitter.
- Motivates development of the hardware and software to record the signals in the RF noisy environment of the USA or set up observations in Antarctica.



Next Step: Ground based network of four stations should track the RF sources.

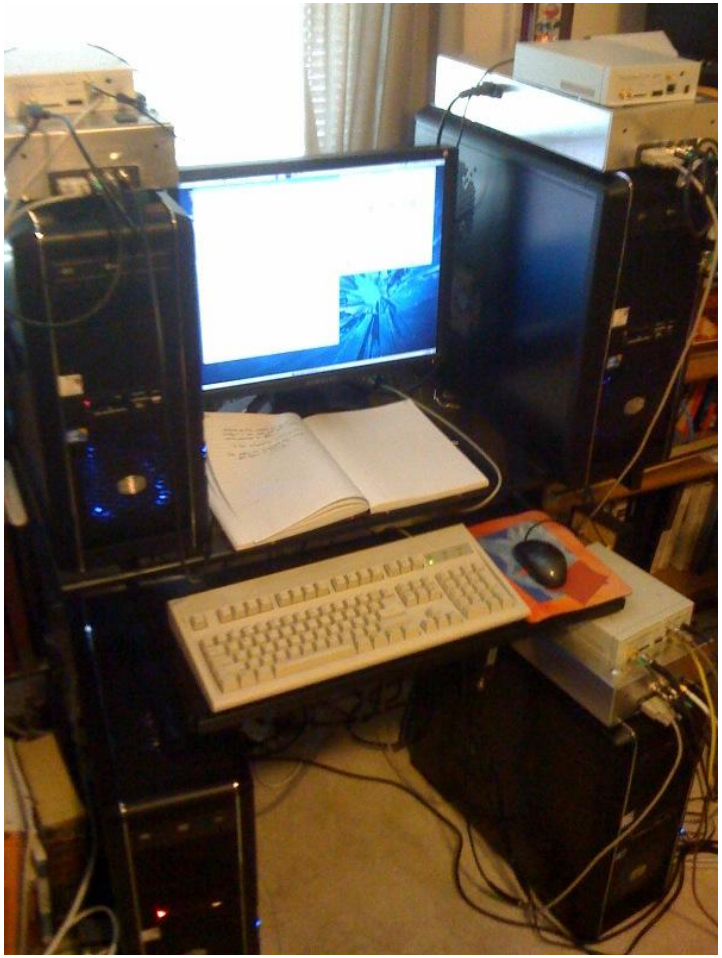


- **LINUX GNU Radio**
- **GPS timing**
- **Universal Software Radio Peripheral**

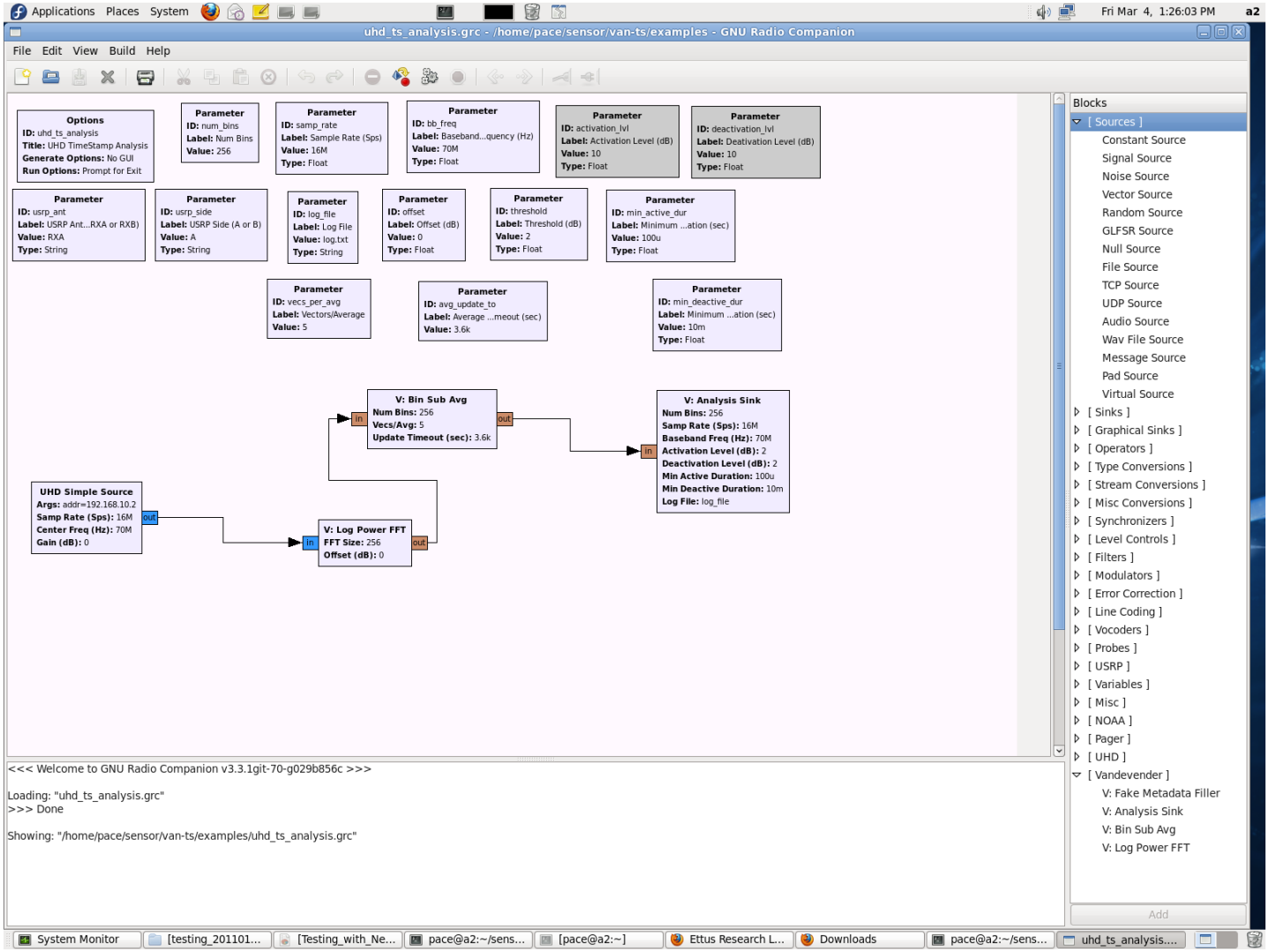
Extra terrestrial tracks with predicted RF signatures and masses from seismic signals would be significant evidence for Mini Naked Singularities (MNSs).

If we can find one in orbit, send an automated laboratory to capture and investigate it. If it is well behaved and interesting, bring it back for laboratory study and application.

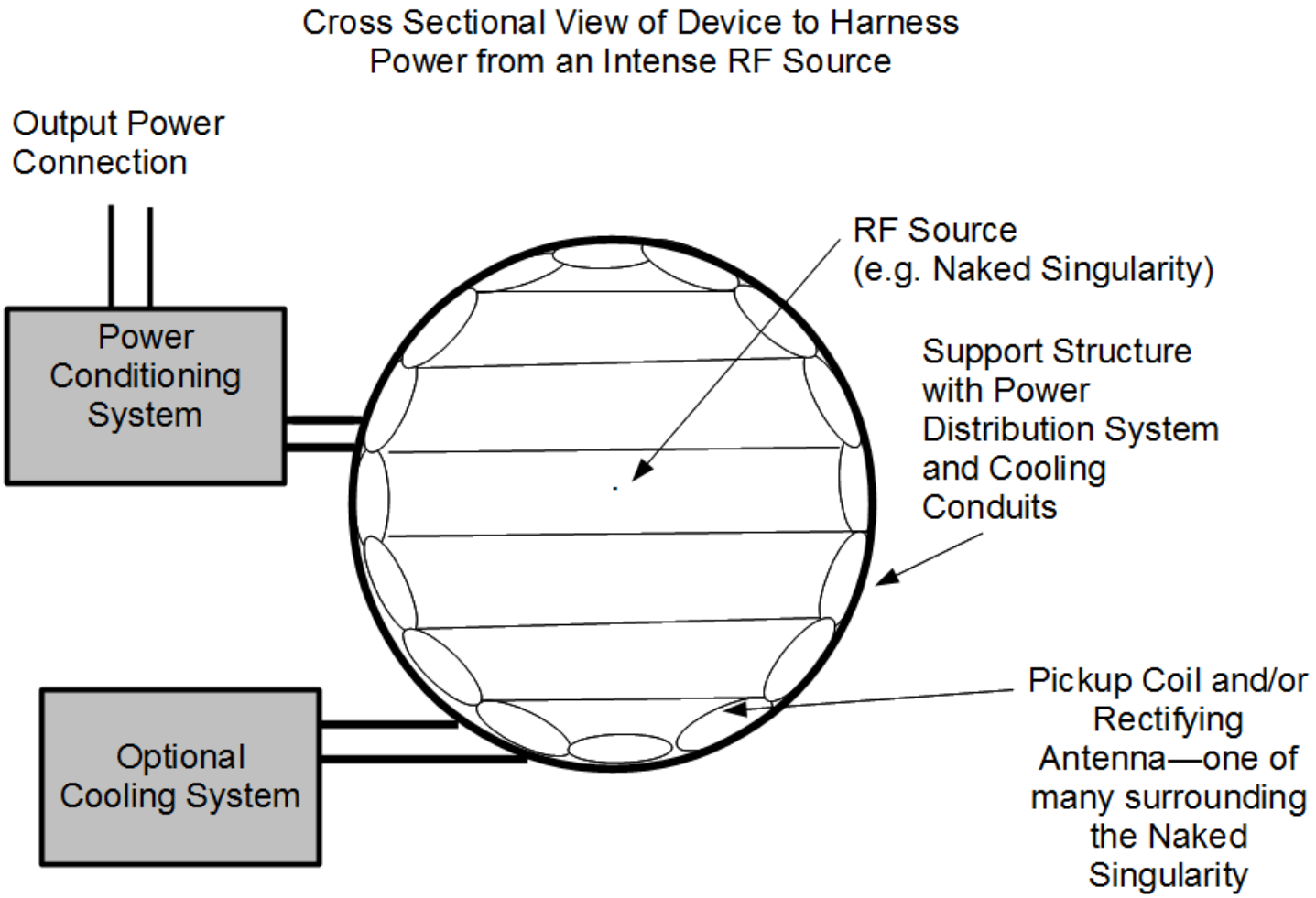
We have built four sensor stations with GPS timing, Ettus Research USRP2 processors, and gnuradio software.



The custom application software is built around the gnuradio-companion and is being debugged.



Whatever is emitting intense RF power could be harnessed for an energy source.



Questions and Suggestions

The research has led to one conclusion and thirteen inferences.

- Conclusion: Ball Lightning event of 1868 happened as Fitzgerald reported it.
- The ball of light weighed >20,000 kg.
- The core was a Primordial Gravitational Singularity supported by magnetic induction.
- The source of the magnetic field must be internal to the core: Mini Naked Singularity (MNS).
- The ensemble is described by a GEA for Gravitational Equivalent of an Atom.
- Quantum effects inhibit the GEA black hole from assimilating the earth and from being detected.
- Although bare PBHs would freely pass through the earth, the earth captures MNSs.
- Peat bogs make excellent witness plates for MNS impacts.
- We discovered a crater consistent one such impact.
- The two sites together imply ~10^{5} impacts or ~10^{9} kg per year of black holes hit earth.
- MNSs might strongly emit bursts of electromagnetic energy.
- The anomalous signals from the FORTE satellite are consistent with ~ $10^{4+/1}$ MNSs per year.
- If dark matter is composed of MNSs, we should expect 10 $^{4+/-3}$ to hit earth per year.

We will look for the electromagnetic signatures with a 4-station array to plot the trajectory and look for the impact signature with seismic array.

We are addressing seven major issues.

- Not having one to study really hinders progress. Have to go get one.
- The ball lightning events might not be related to the sources detected by FORTE.
- Detecting the RF emissions in civilization may be impossible. If so, set up detectors in Antarctica.
- Binding energy of GEA is insufficient to levitate >20 tons and to provide adequate stopping power to capture MBHs, so the central mass has to be a naked singularity.
- The current required to levitate >20 tons at a meter is ~ 1 MA, which must be carried by an air plasma since the peat resistivity ~10^3 Ω-cm.
- Stopping power has to be collective. Use the Spanish and Irish events to see if effects are consistent with a central magnetic field inducing currents for sufficient reaction force.
- The mass absorption rate and corresponding power production rate for a 10^6 kg black hole is too small for a power plant. Need 10^7 kg.

A special thanks to these people:

- **Michael Cai**, Los Alamos National Laboratories, provided access to the FORTE Data
- **Richard Spaulding**, Sandia National Laboratories, for stimulating talks on luminous atmospheric phenomena
- **Mike Vahle**, Sandia National Laboratories, for many useful discussions about General Relativity and the strategy for GEA
- **Steve Slutz**, Sandia National Laboratories, for raising question of how earth captures the GEA
- **David Holcomb**, Sandia National Laboratories, for advice on how to measure yield strength of peat
- **Willie Gallagher**, owner of the land on which this event occurred, for access and encouragement
- **Dan Finley,** UNM, for very useful discussion on General Relativity and the need for demonstrating that matter cannot just fall into PBH
- **Igor Alexef**, University of Tennessee, suggested the negative mass instability around a black hole would provide coherent electromagnetic radiation.
- **Jerald V. Parker**, SAIC, suggested rotating magnetic dipole would provide alternative to radiator
- **Josey Duddy**, who showed us the 1982 event.

Ball lightning can be dangerous.

Curious Phenomenon In Venezuela
Cowgill, Warner; Scientific American, 55:389, December 18, 1886

During the night of the 24th of October last, which was rainy and tempestuous, a family of nine persons, sleeping in a hut a few leagues from Maracaibo, were awakened by a loud humming noise and a vivid, dazzling light, which brilliantly illuminated the interior of the house. The occupants, completely terror stricken, and believing, as they relate, that the end of the world had come, threw themselves on their knees and commenced to pray, but their devotions were almost immediately interrupted by violent vomitings, and extensive swellings commenced to appear in the upper part of their bodies, this being particularly noticeable about the face and lips. It is to be noted that the brilliant light was not accompanied by a sensation of heat, although there was a smoky appearance and a peculiar smell.

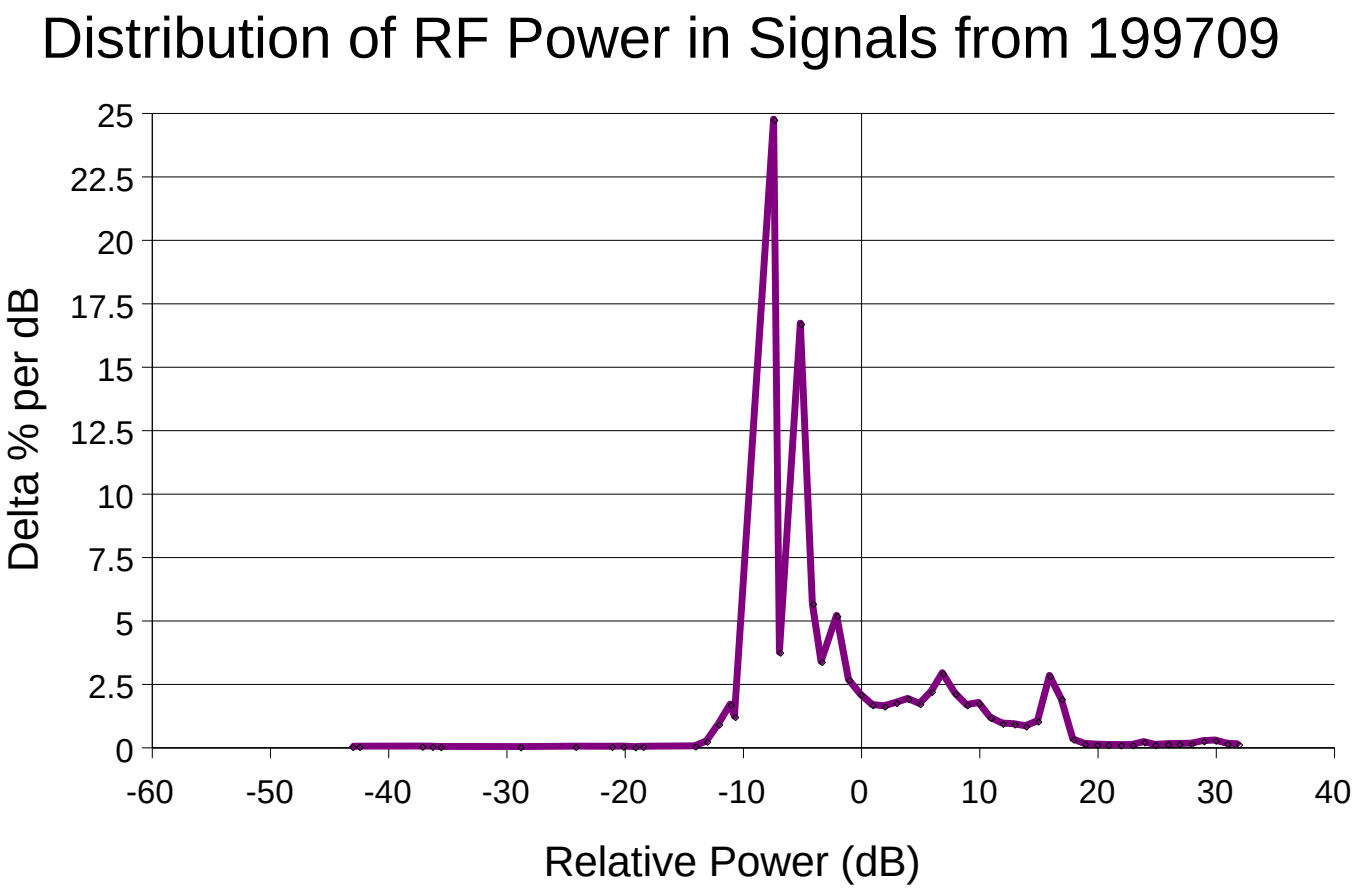
The next morning the swellings had subsided, leaving upon the face and body large black blotches. No special pain was felt until the ninth day, when the skin peeled off, and these blotches were transformed into virulent raw sores. The hairs of the head fell off upon the side which happened to be underneath when the phenomenon occurred, the same side of the body being, in all nine cases, the more seriously injured.

The remarkable part of the occurrence is that the house was uninjured, all doors and windows being closed at the time. No trace of lightning could afterward be observed in any part of the building, and all the sufferers unite in saying that there was no detonation, but only the loud humming already mentioned.

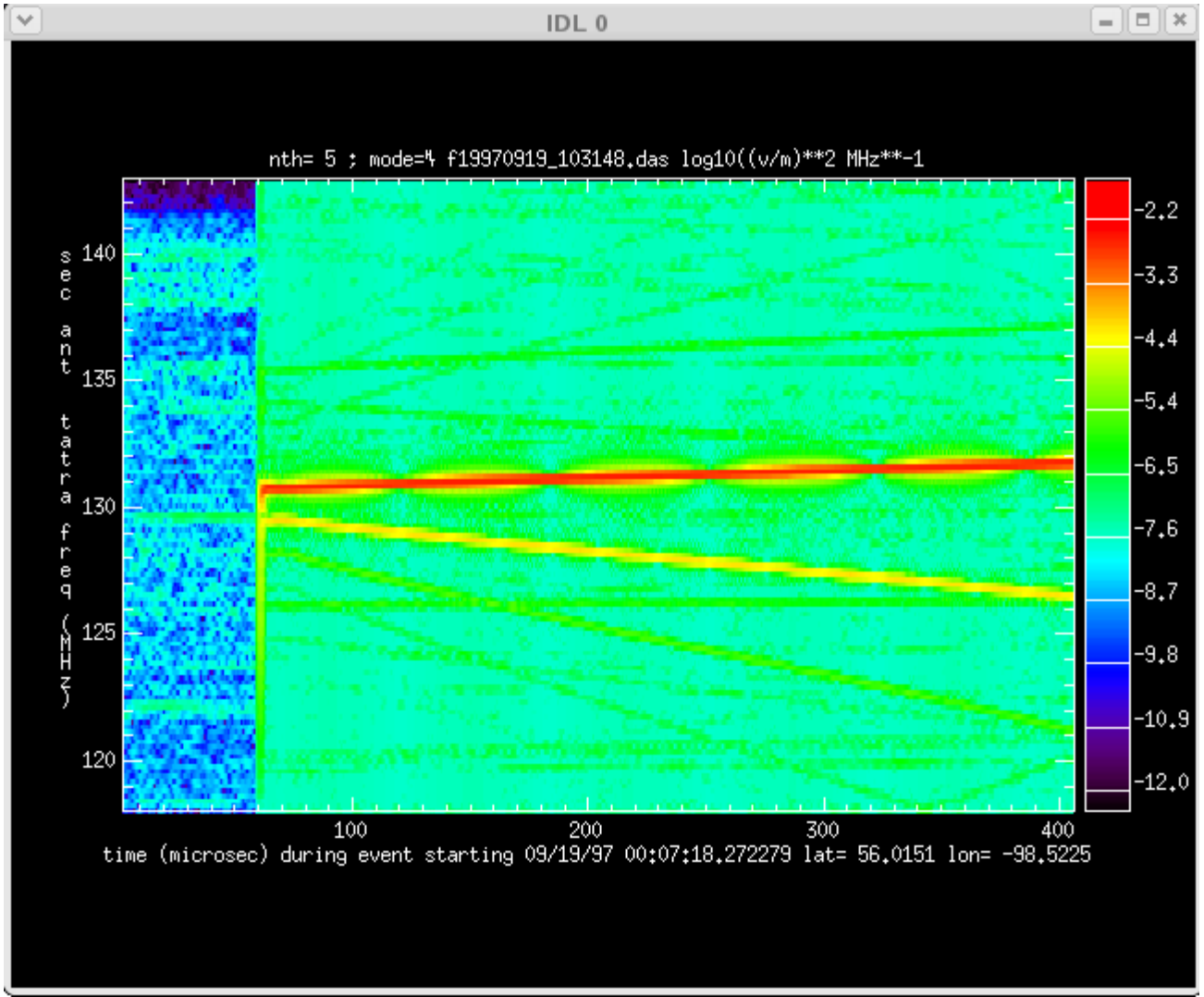
Another curious attendant circumstance is that the trees around the house showed no signs of injury until the ninth day, when they suddenly withered, almost simultaneously with the development of the sores upon the bodies of the occupants of the house. This is perhaps a mere coincidence, but it is remarkable that the same susceptibility to electrical effects, with the same lapse of time, should be observed in both animal and vegetable organisms.

I have visited the sufferers, who are now in one of the hospitals of this city; and although their appearance is truly horrible, yet it is hoped that in no case will the injuries prove fatal.<End of Sci. Amer. article>

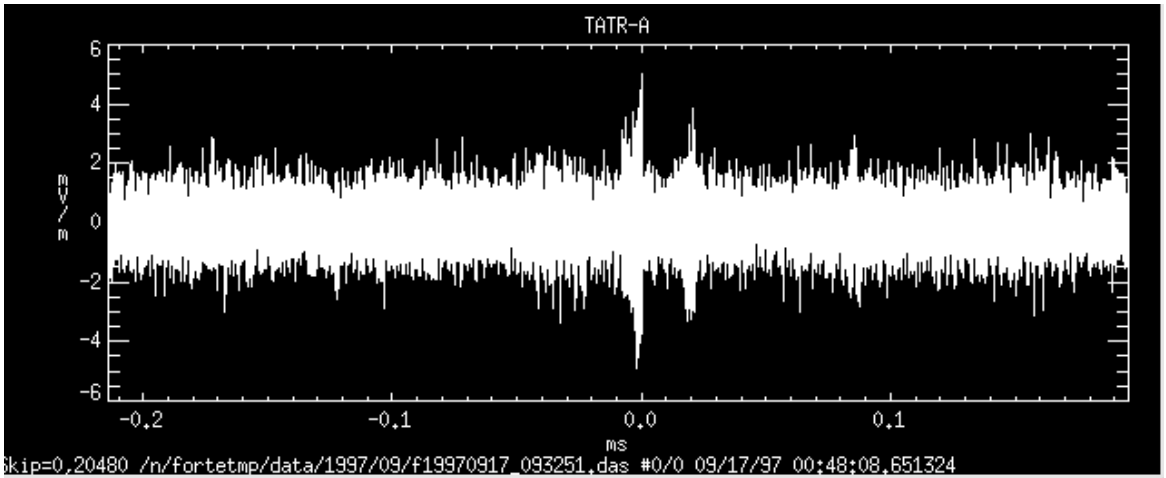
Distribution of RF Power from FORTE shows a very unusual high-power tail.



Prompt onset, long duration, large amplitude, and multiple narrow band characterize RF bursts.



Anomalous signals differ greatly from normal lightning signals.

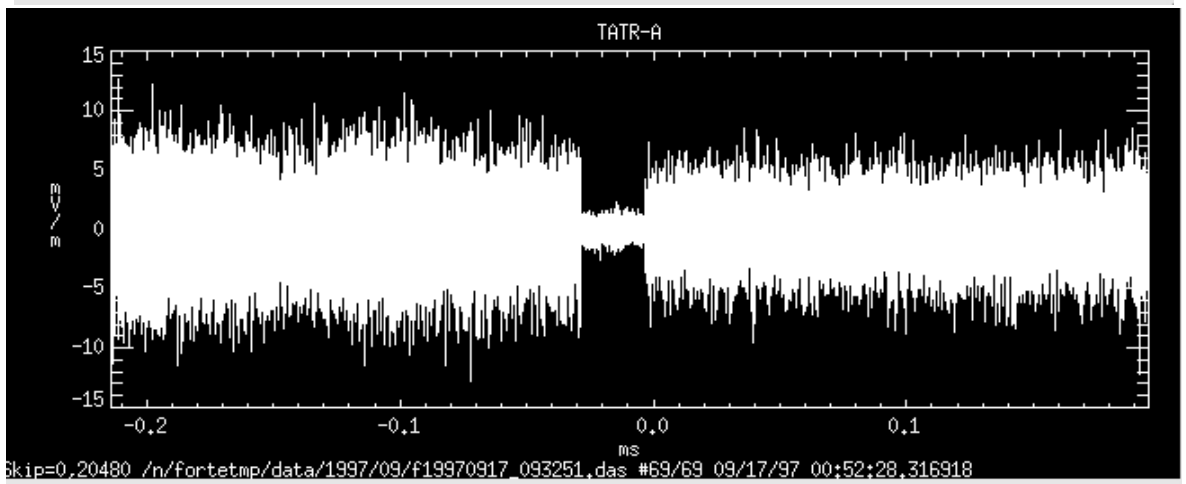


Normal

Lightning record

2 mV/m

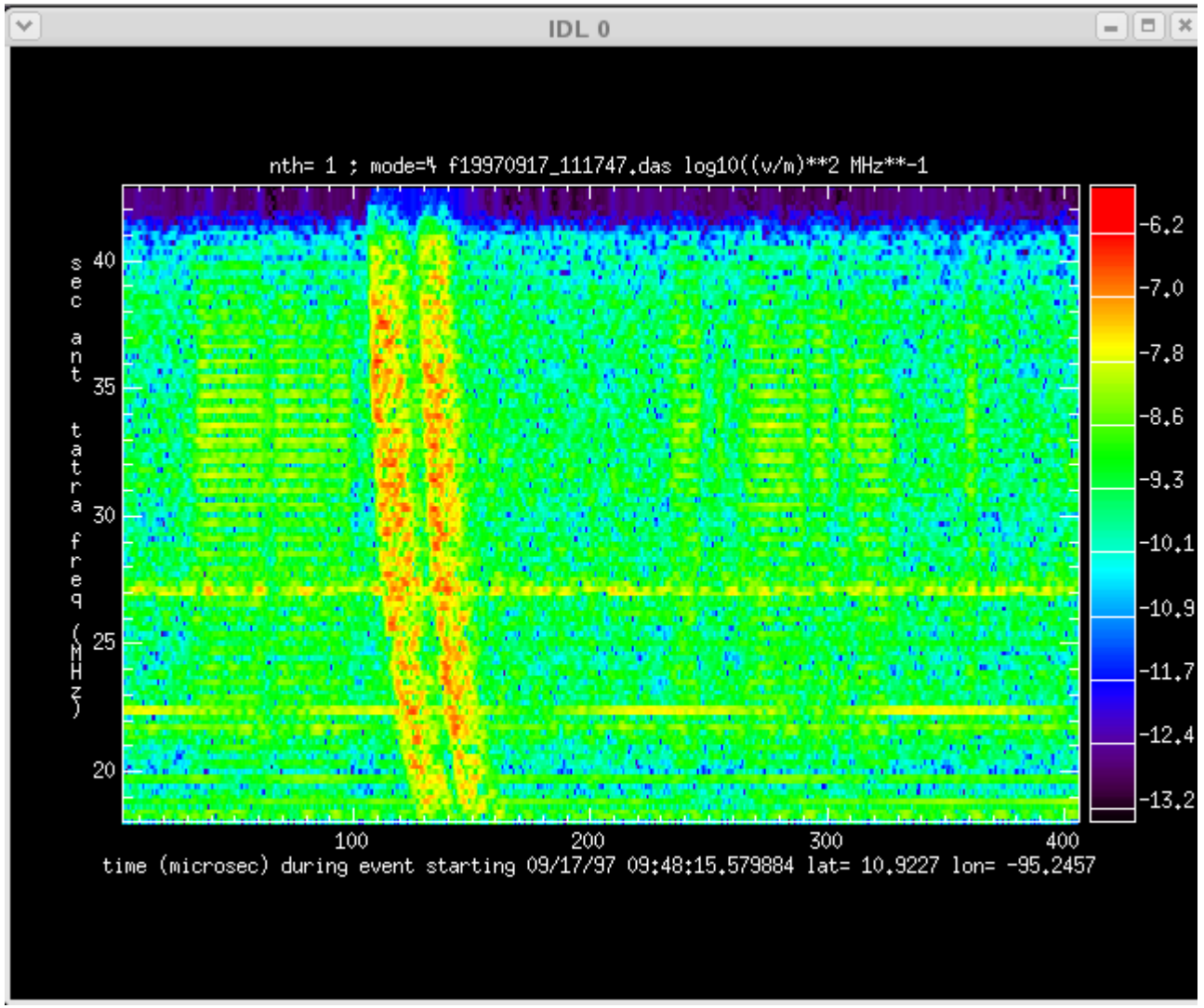
baseline



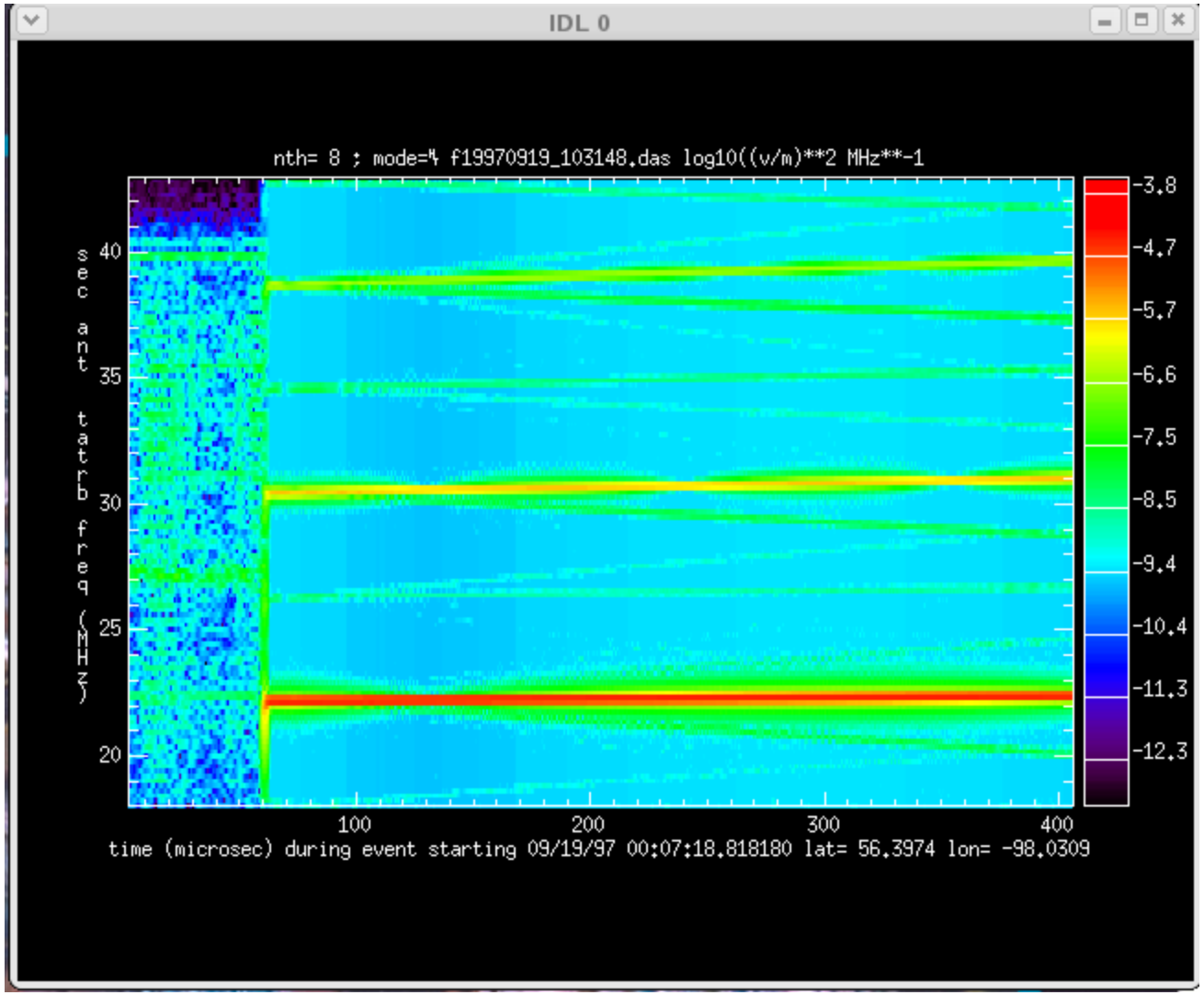
Possible Ball Lightning (PBL) Record

7 to >30 mV/m

Low frequency dispersion by passage through the ionosphere is evident for normal lightning.

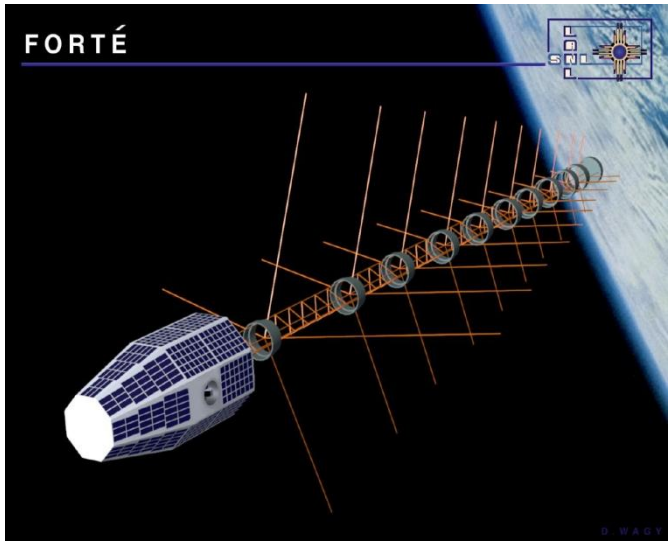


Lack of time delay indicates space origin of some or all of the FORTE signals.

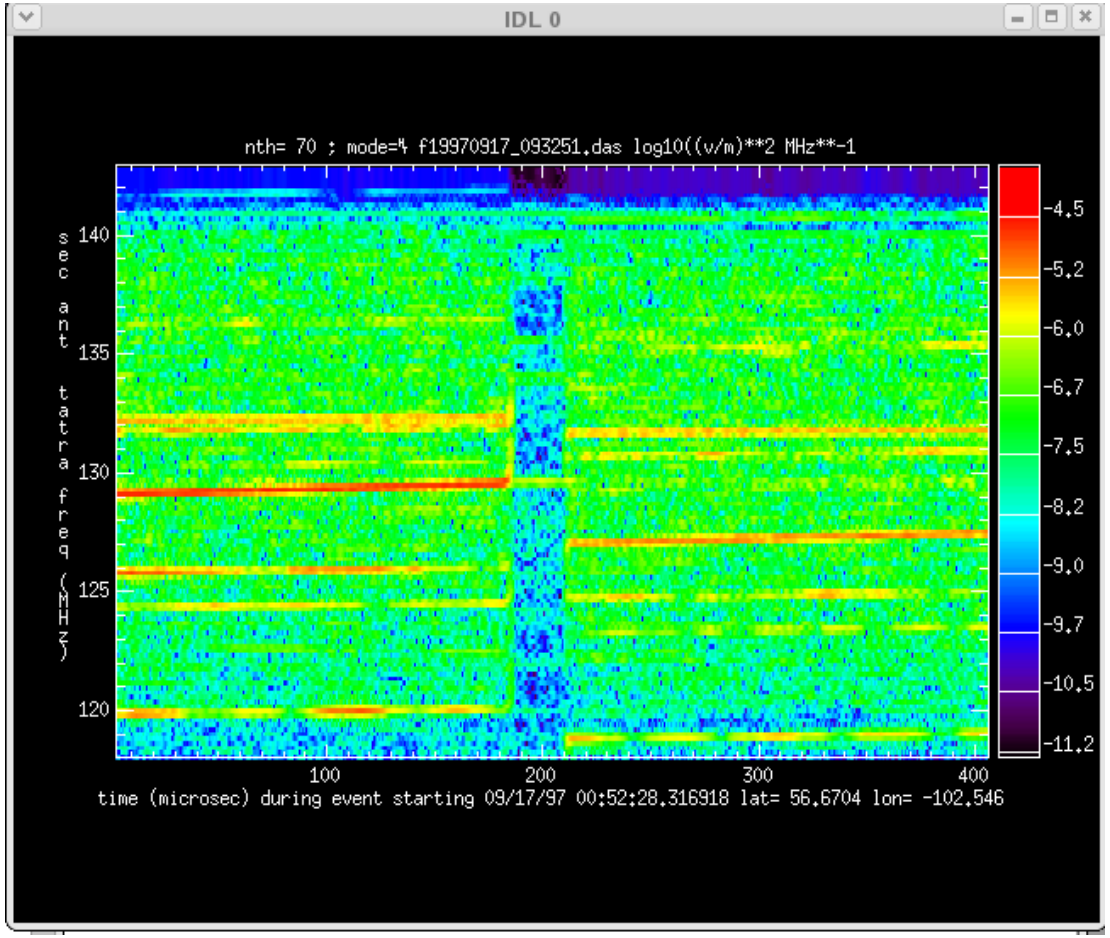


Tracking the trajectory is the next right step.

RF emissions from a GEA should be observable by FORTE.



- **5.9 MHz to 300 MHz**
- **400 microsecond windows**
- **Two months of narrow band data for 10 % of the time in September and October 1997**
- **FORTE recorded 5000 unexplained bursts in about 50 pulse trains.**



$10^{4+/-1}$ events per year.

Estimated ~400 impacts a year at ~10^5 kg is consistent with Dark Matter.

- **Assume PBHs compose significant fraction of dark matter.**
- **Mass of galaxy ~10^{42} kg (including dark matter)**
- **Volume of galaxy ~10^{61} m^3**
- **Density of galaxy ~10^{-19} kg/m^3**
- **Mass of PBH ~$10^{3+/-3}$ kg/PBH [Largest uncertainty]**
- **Density of PBH = n ~$10^{-22+/-3}$ PBH/m^3**
- **Cross sectional Area of earth =A~2x10^{14} m^2**
- **Galactic distribution suggests <v> ~10^5 m/s**
- **Number of PBH hitting earth per year=nA<v>t_{yr} ~4x$10^{4+/-3}$ per year**

If Dark Matter is primordial black holes expected frequency of events ~4x$10^{4+/-3}$ per year

I am pleased to represent an international and interdisciplinary team.

Pace VanDevender, Sandia National Laboratories, VE, Los Alamos National Laboratory, USA, Plasma Physics

- **Aaron VanDevender**, University of Illinois, NIST, USA, Quantum Physics
- **Peter Wilson**, University of Ulster, Northern Ireland, UK, Geomorphology
- **Nial McGinley**, County Donegal, Historian
- **Peter Van Doorn**, Tornado and Storm Research Organization, England, UK, Meteorology