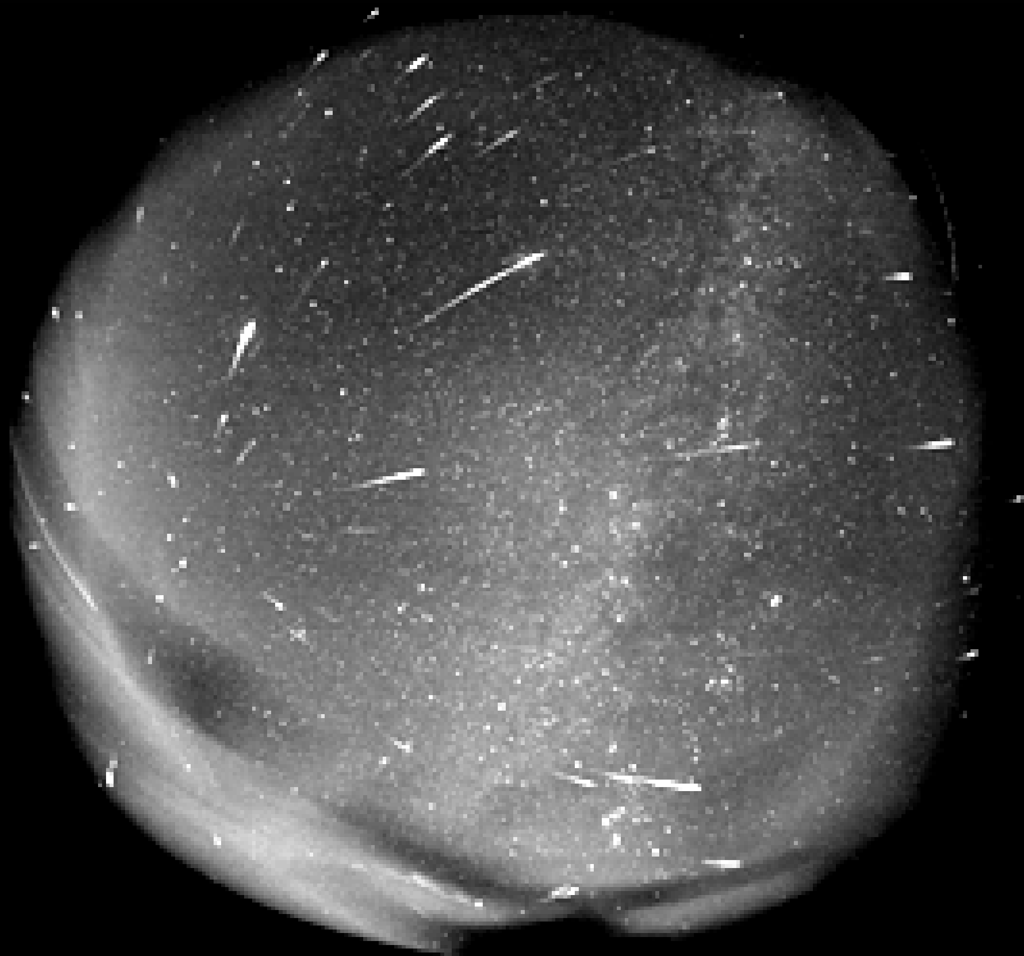
Meteors

Additional dangers to satellites from the high-altitude meteor population



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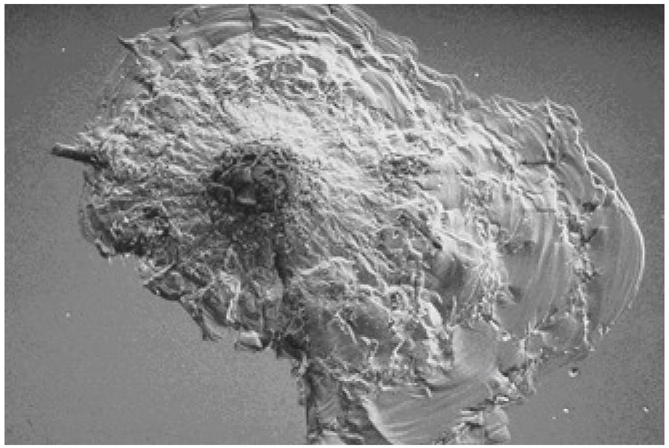
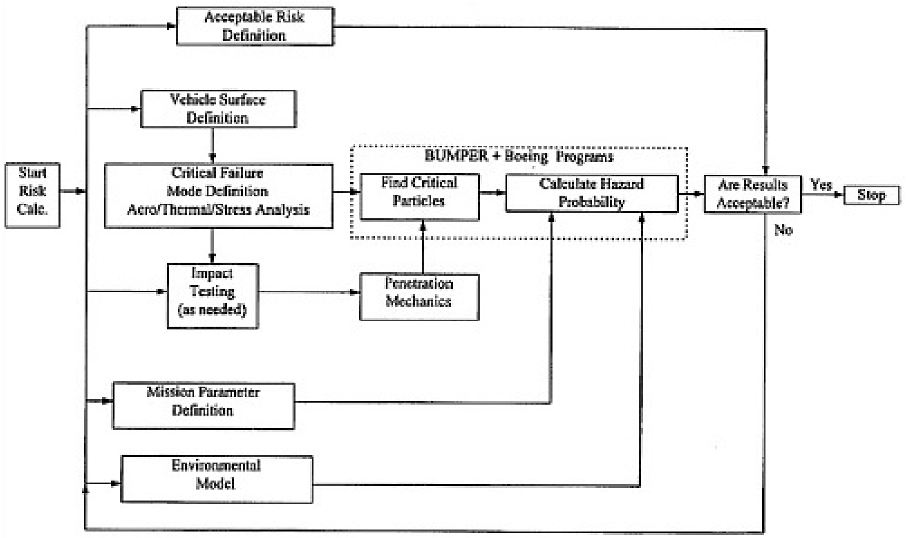
Sodankylä Geophysical Observatory

Olympus satellite failure analysis

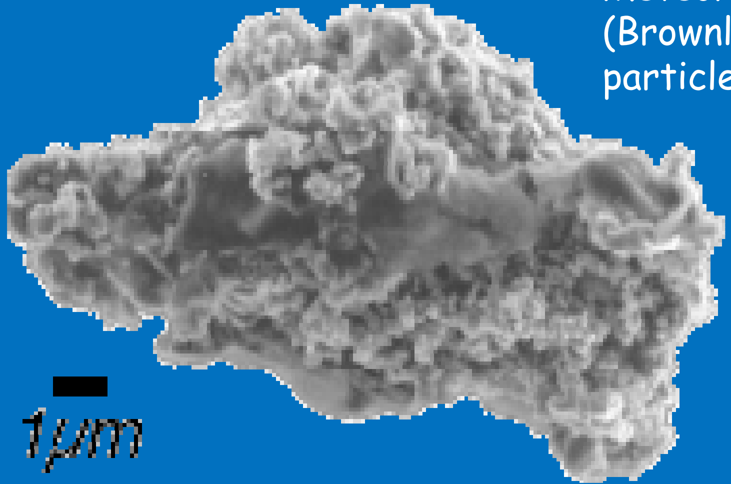
1. Meteoroid impact disables solar array pointing mechanism
2. Meteoroid impact produces plasma cloud on satellite
3. Plasma shorts wires in the satellite ACS
4. Satellite tumbles and expends most attitude-control fuel
5. Total loss of 800 M$ asset



TS-35 Space Shuttle window pit from orbital debris impact. Credit: NASA



On-orbit impact analysis methodology. Source: NAS ISBN: 978-0-309-05988-6, Meteoroid (Brownlee particle)



Meteors

Meteoroid shower in space

Fireball (bolide)

Meteorites

RESOLUTION B3

on the establishment of an International NEO early warning system.

Proposed by IAU Division III Working Group Near Earth Objects

The XXVIII General Assembly of the International Astronomical Union,

recognizing

– that there is now ample evidence that the probability of catastrophic impacts of Near-Earth Objects (NEOs) onto the Earth, potentially highly destructive to life, and for humankind in particular, is not negligible and that appropriate actions are being developed to avoid such catastrophes;

– that for the largest NEOs, thanks to the efforts of the astronomical community and of several space agencies, the cataloguing of the potentially hazardous ones, the monitoring of their impact possibilities, and the analysis of technologically feasible mitigations is reaching a satisfactory level;

– that even the impact of small- to moderate-sized objects may represent a great threat to our civilizations and to the international community;

– that our knowledge of the number, size, and orbital behaviour of smaller objects is still very limited, thus not allowing any reasonable anticipation on the likelihood of future impacts;

noting

that NEOs are a threat to all nations on Earth, and therefore that all nations should contribute to avert this threat;

recommends

that the IAU National Members work with the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) and the International Council for Science (ICSU) to coordinate and collaborate on the establishment of an International NEO early warning system, relying on the scientific and technical advice of the relevant astronomical community, whose main purpose is the reliable identification of potential NEO collisions with the Earth, and the communication of the relevant parameters to suitable decision makers of the nation(s) involved.

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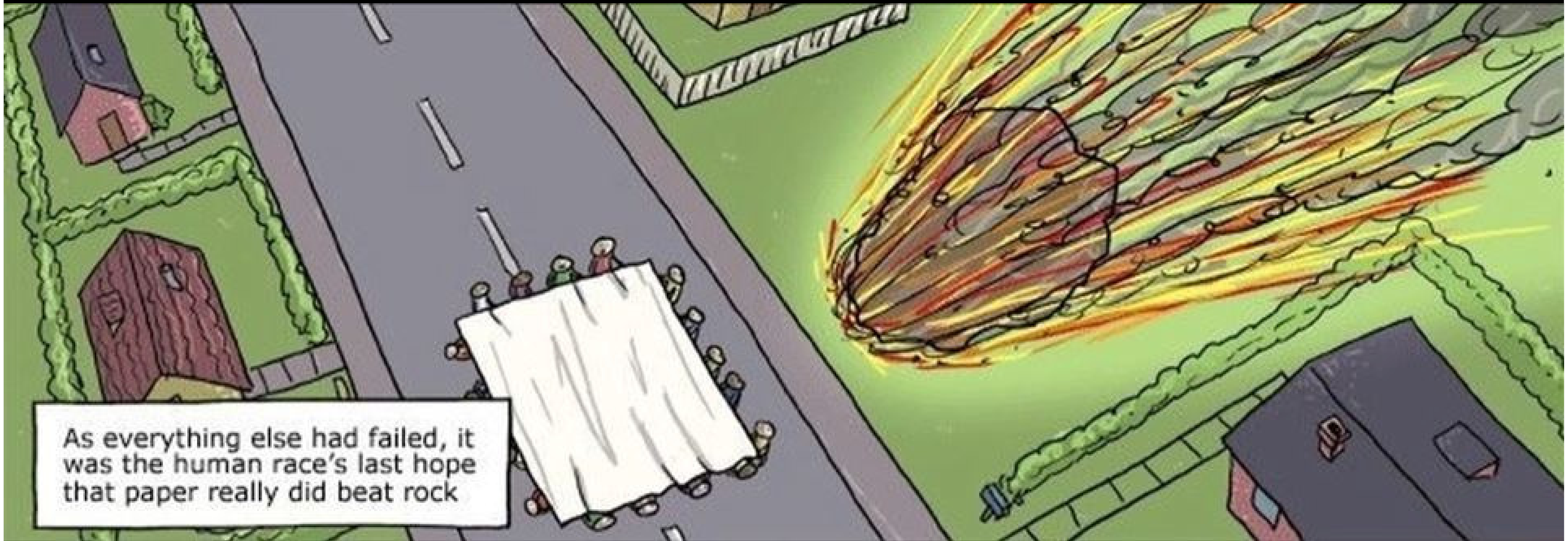
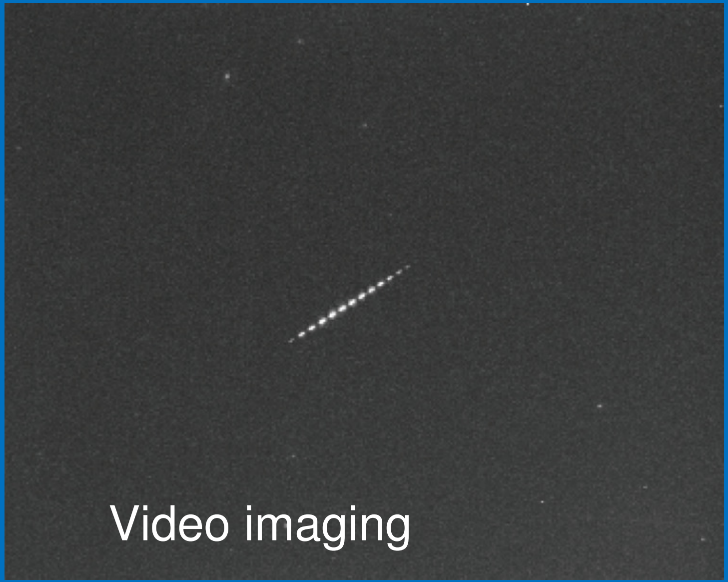

As everything else had failed, it was the human race's last hope that paper really did beat rock

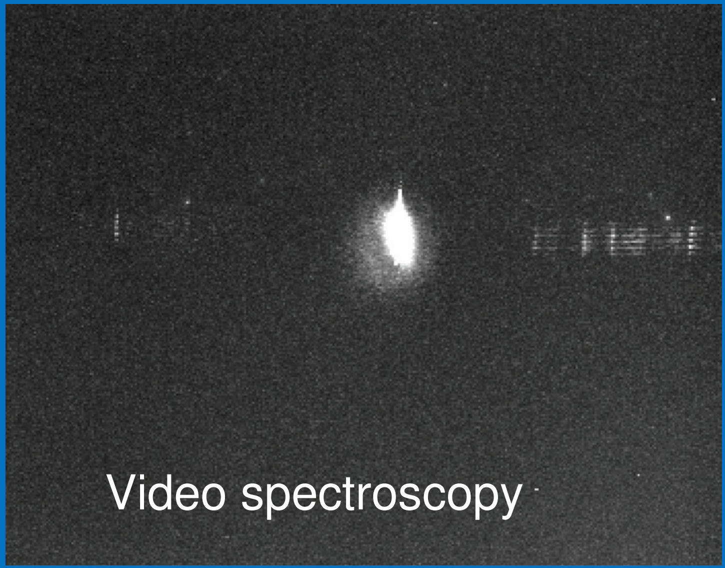
Modes of investigation

Mainly optical (high-sensitivity video)
Projected position+angular velocity
Few spectra

Some multi-site observations ➡ 3D velocities, orbits



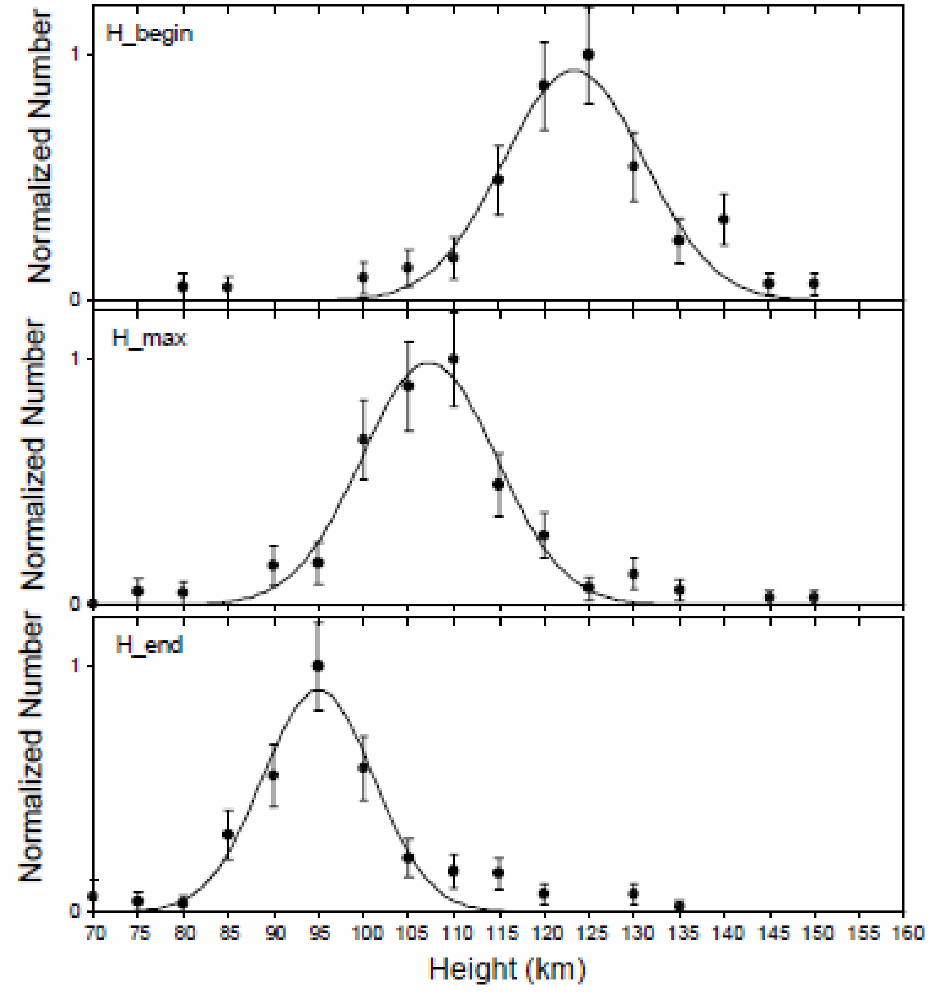
Video imaging



Video spectroscopy

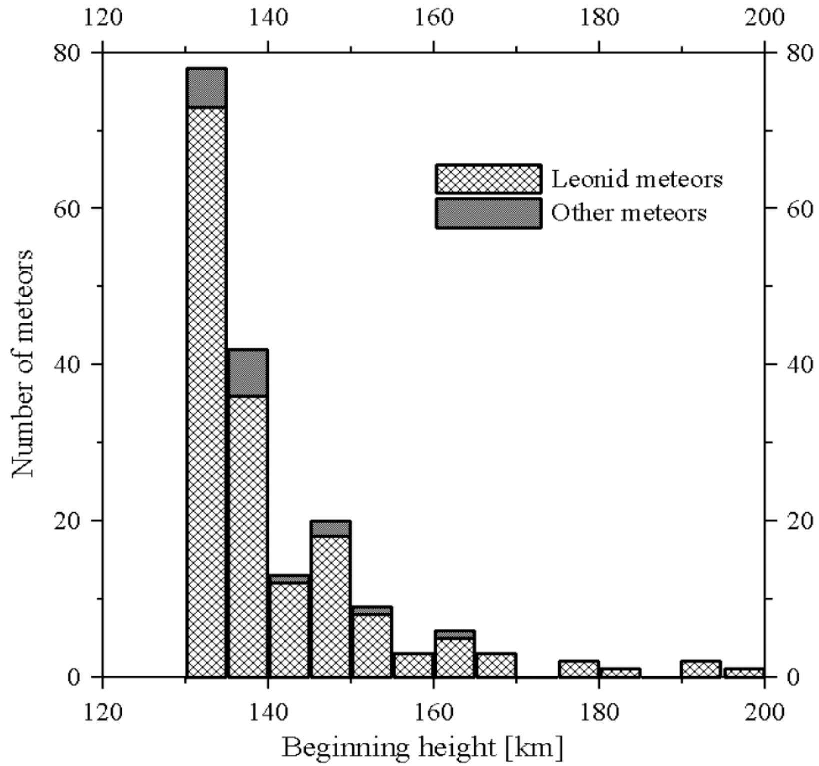
Height distribution (optical)

(classical view)

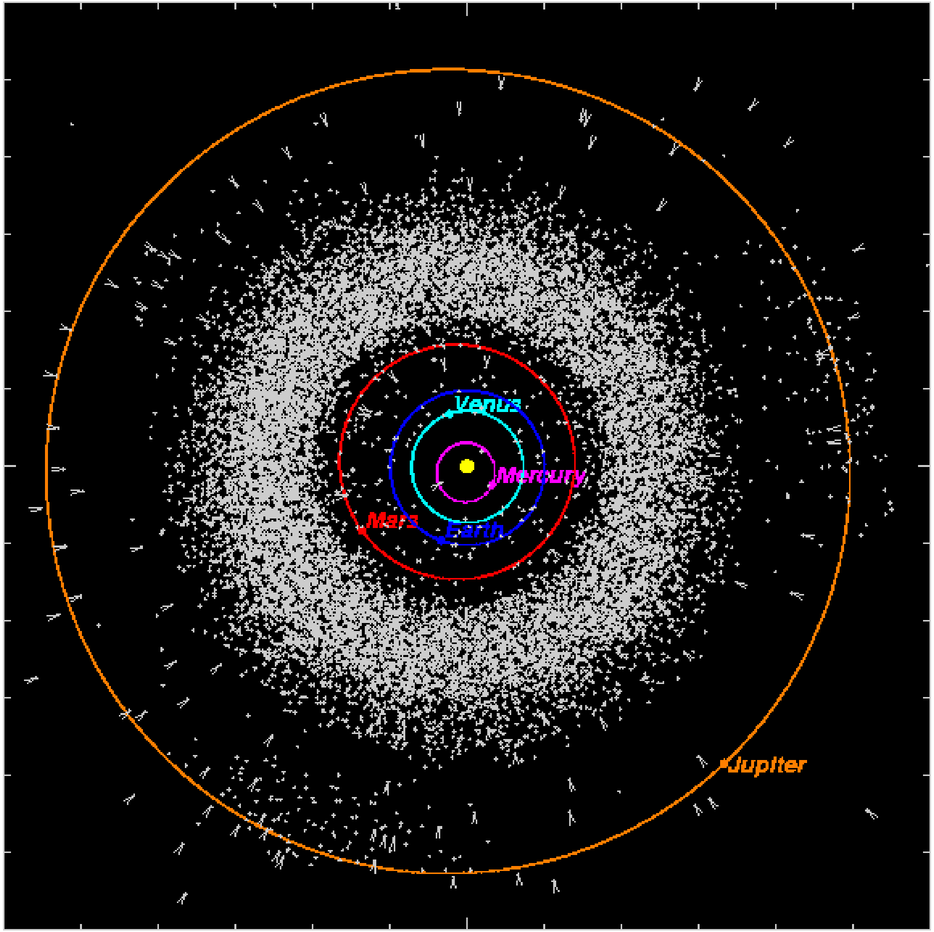


Leonid meteors from 1999

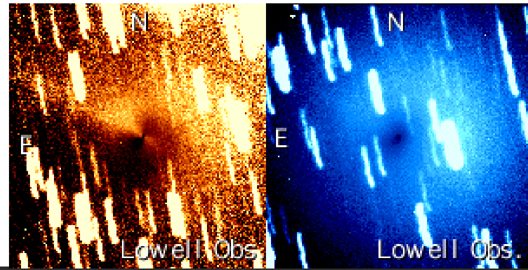
1. Most optical meteors appear at 70-120 km
2. Using high-sensitivity cameras meteors observed as high as 200 km
3. High-altitude meteors are different (physical mechanism?)

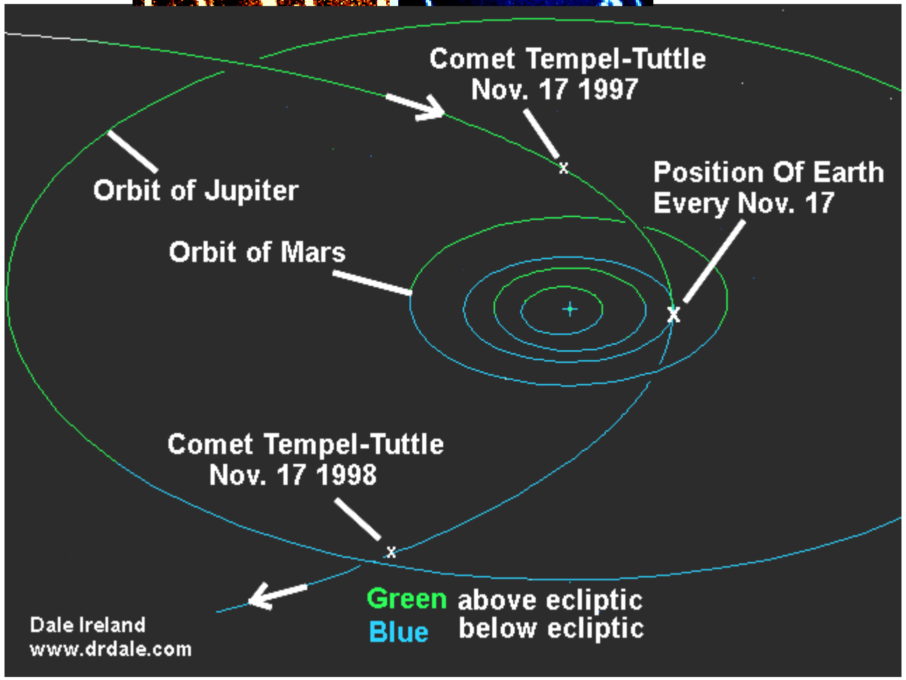


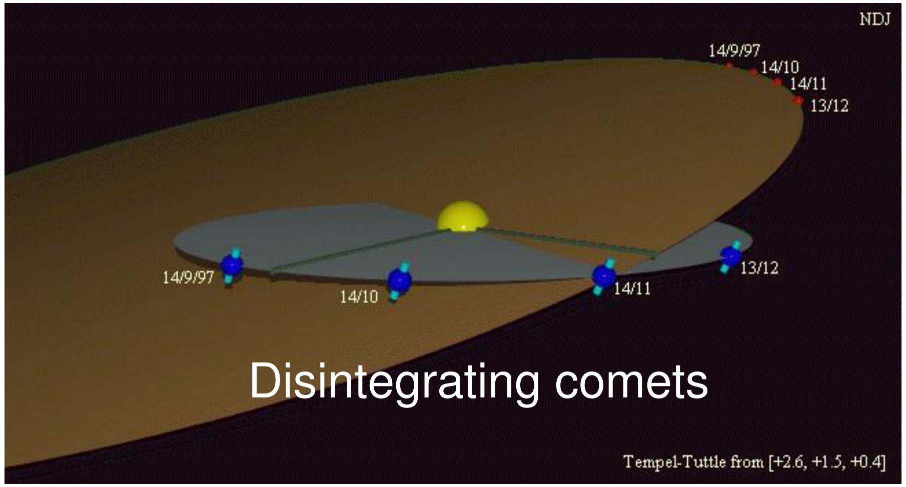
Meteor sources



Asteroid belt (smashing rocks)

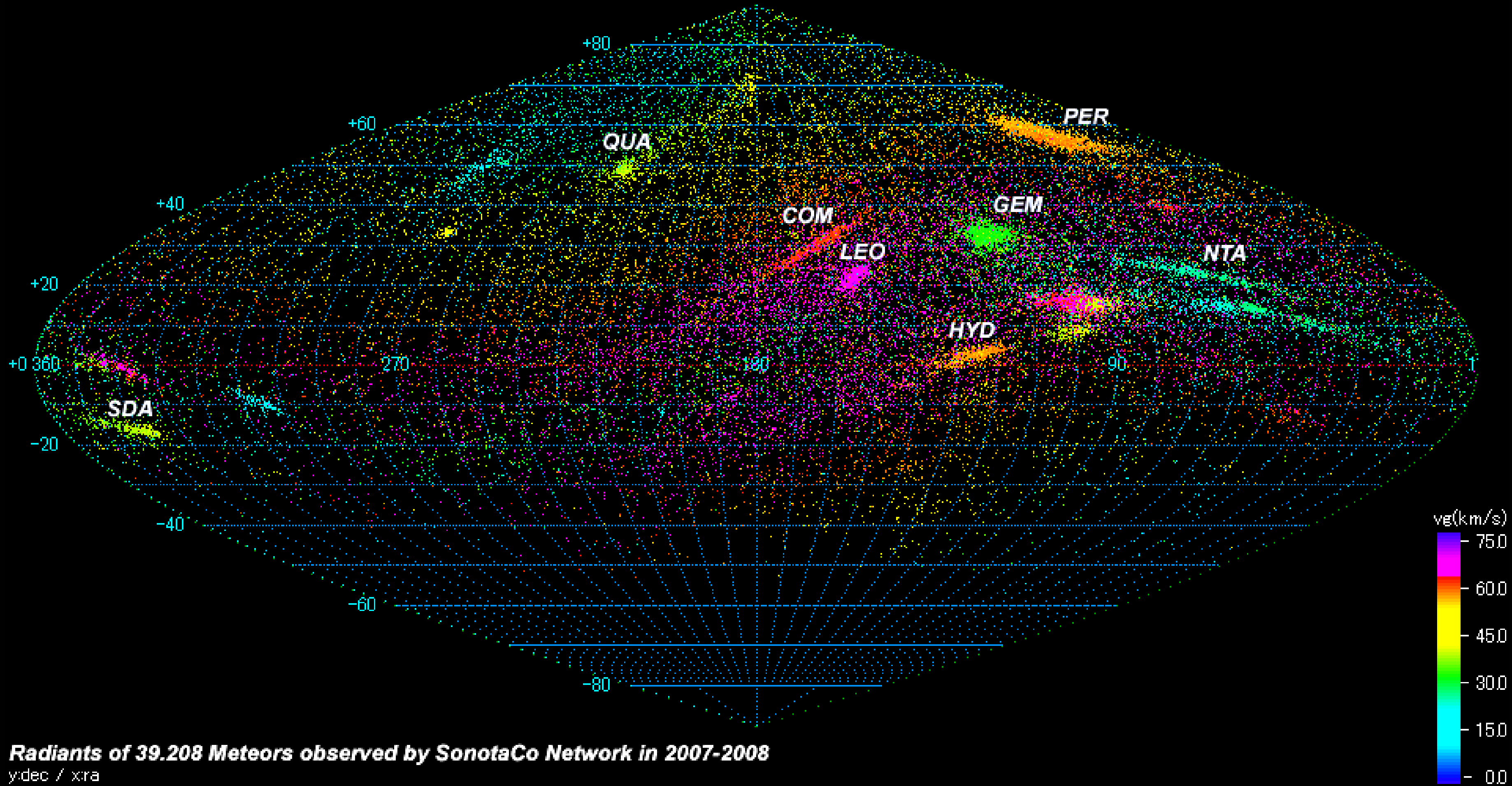






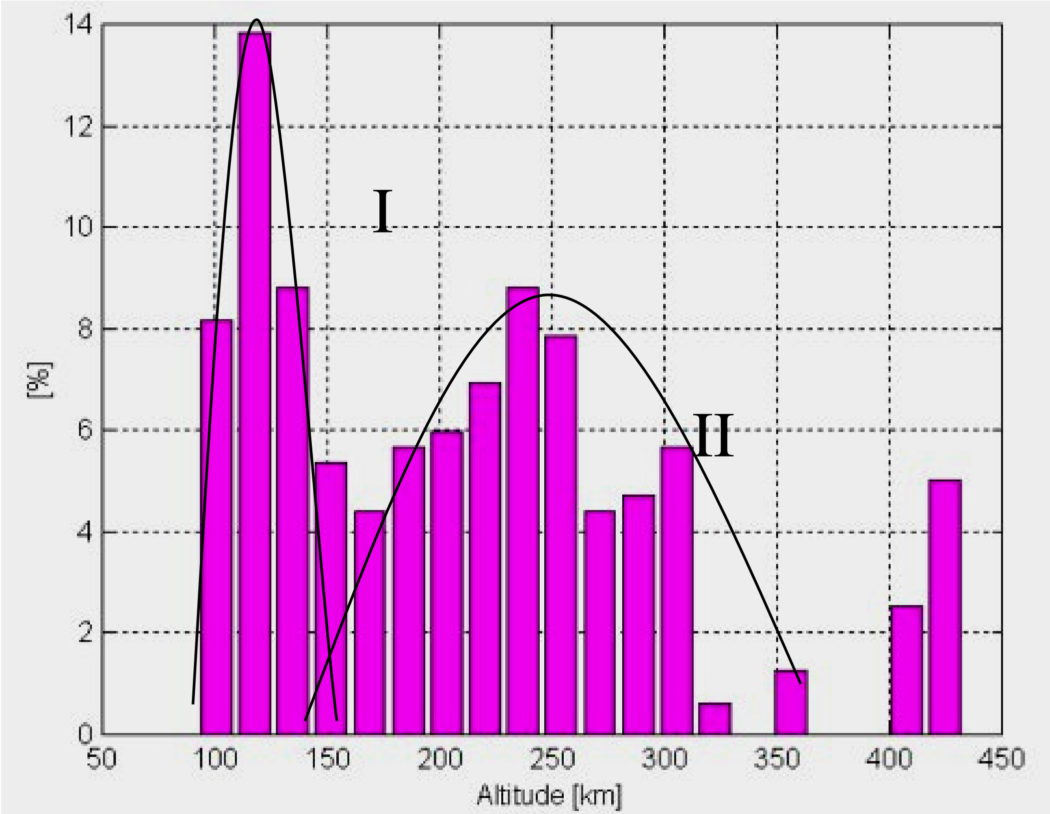
Disintegrating comets

Meteor radiants



Radiants are associated with disintegrating comets

Radar Meteors: Altitude Distribution

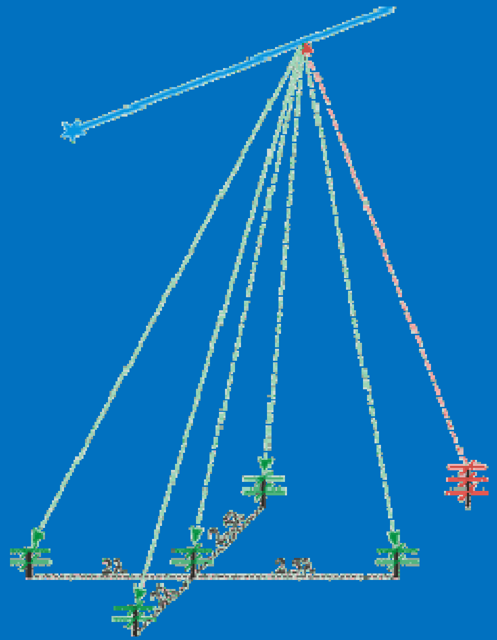


Pop. I: ablation
Pop. II: sputtering

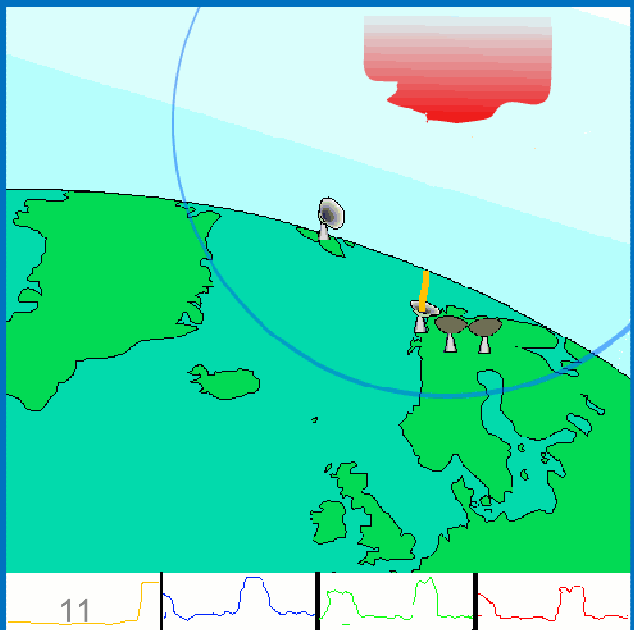
- No maximal height limit (h>70 km) for detection.
- Two populations:
  - "First class" (I) h<160 km.
  - "Second class" (II) h>160 km.
- Given the RCS bias - similar numbers of I and II populations.
- Problem: security reasons prevented the proper publication of these results
- Solution: do this with a civilian radar

Brosch et al. 2001 ESASP 495, 165

Radar and HPLA



Classical meteor radar (HF)



EISCAT, near Tromso

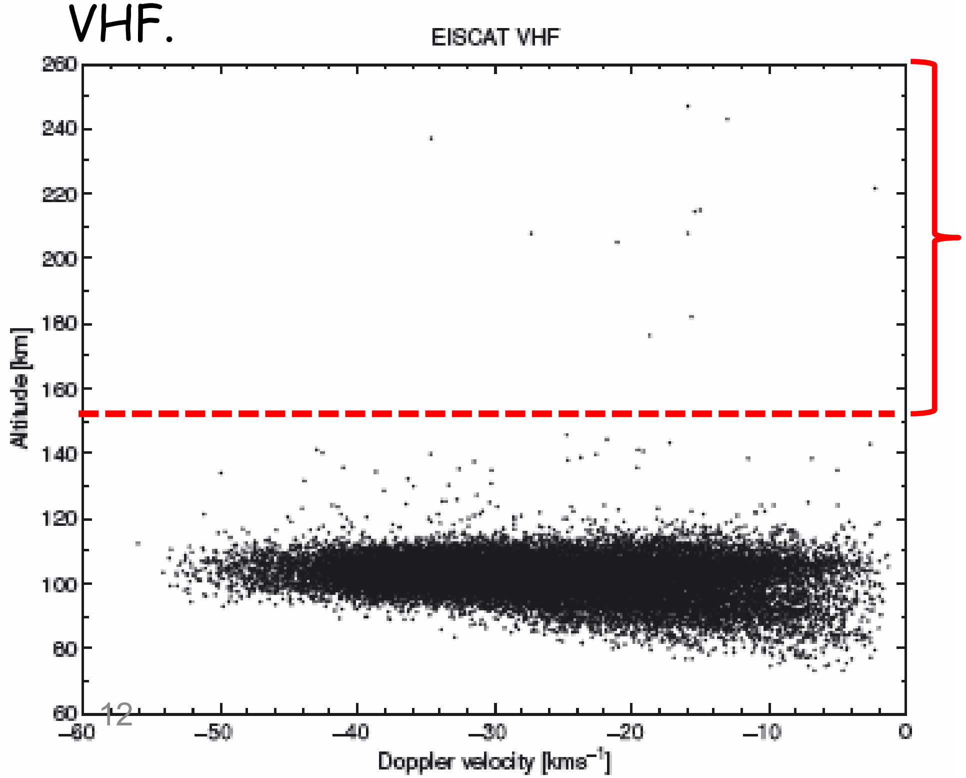
EISCAT results: I (2008)

"Unusual features in high statistics radar meteor studies at EISCAT",
Mon. Not. R. Astron. Soc. **401, 1069–1079 (2010)**

3x8-h runs on consecutive nights in 2008 December.

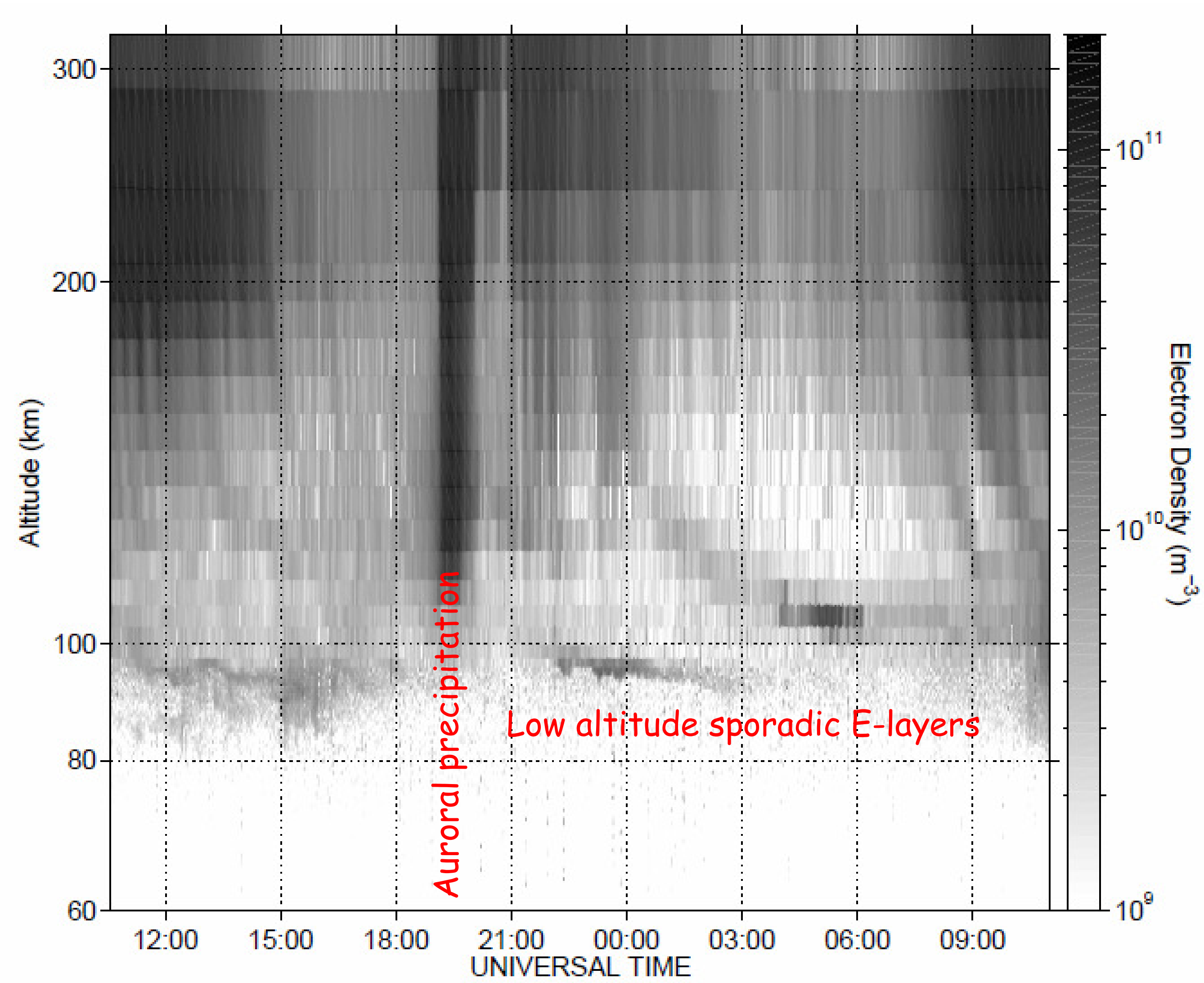
Aiming to detect and study a high-altitude (h>150-km) meteor population, along with the meteors detected at classical ~100-km altitudes

VHF detected during the 24-h period 22698 echoes identified as meteors. UHF echoes in the same period was 2138, most detected also at VHF.



Detected 11 VHF meteors at altitudes higher than 150 km. with the record highest meteor at 246.9 km. No high-altitude UHF echoes were detected and no echoes with a Doppler velocity above ~60 km/s were identified.

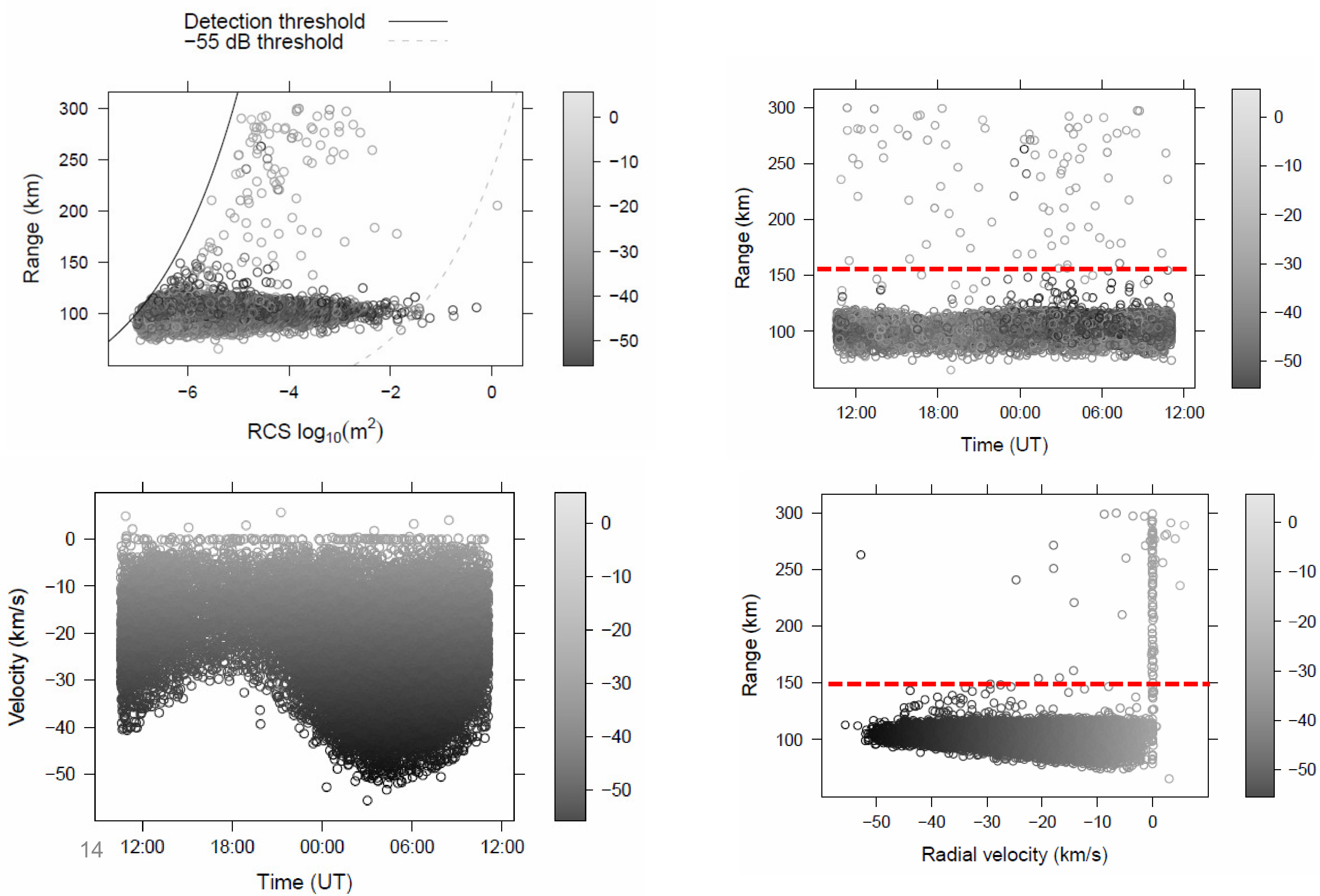
EISCAT results: II (2009)



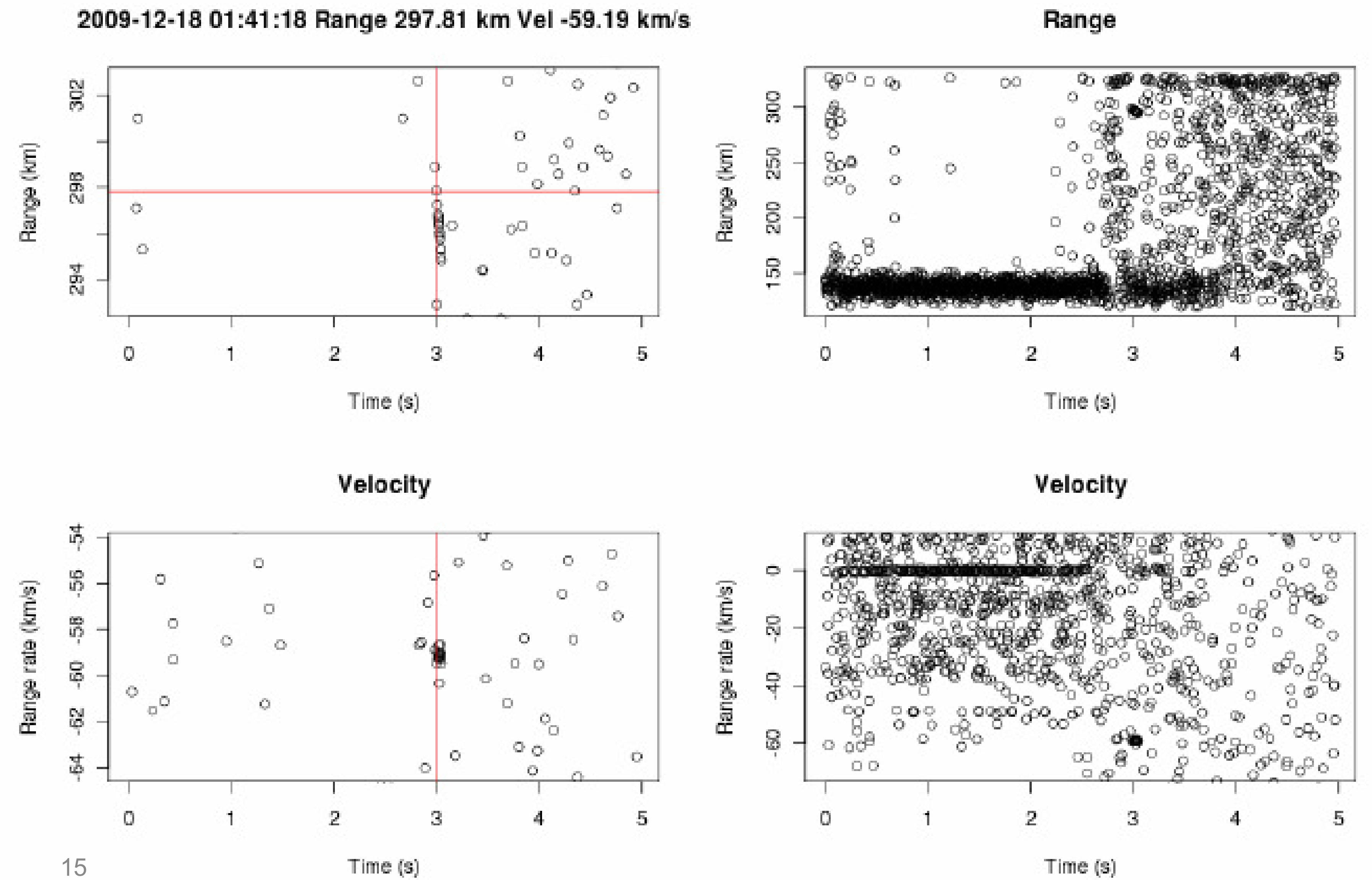
Electron density vs. altitude over Trømsø

December 17 2009, continuous 24 hours monitoring @zenith

2009 main results



Space debris vs. real meteor



Results:

1.Detected ~22000 VHF echoes in 24 hours-confirmed in two runs
2.Definite detection of the high-altitude population
3.Identification of grazing-incidence meteoroids
4.No detection of echoed with Doppler>60 km/sec

Conclusions:

The high-altitude population is real
Most objects are sporadics
Flux is $3.3\times10^{-8}\ m^{-2}\,\mathrm{sec}^{-1}$ (all altitudes)
No evidence for interstellar meteors
Models should account for High-altitude population

Interstellar meteors?

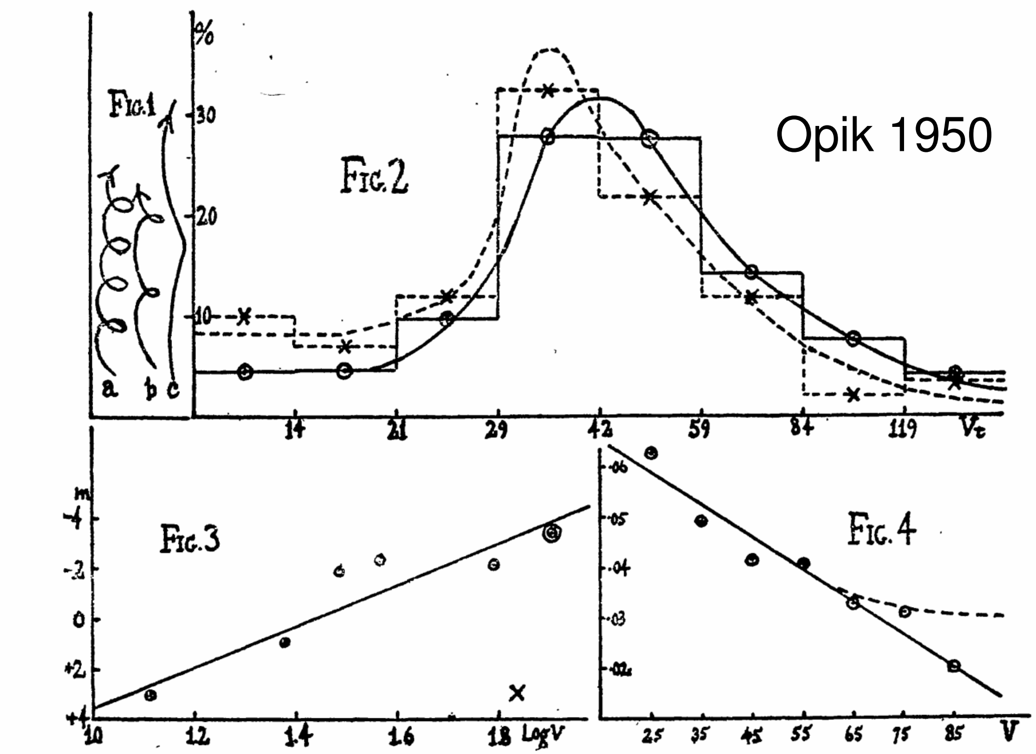


Fig. 1. Cycloid meteor trails at the Rocking Mirror.

Dust at hyperbolic velocities observed by AMOR and by spacecraft dust detectors

High altitude meteors observed visually and by radar @ hyperbolic velocities

"On July 28, 2006 the 6-m telescope of the Special Astrophysical Observatory of the Russian Academy of Sciences recorded the spectrum of a faint meteor. We confidently identify the lines of FeI and MgI, OI, NI and molecular-nitrogen (N_2) bands. The entry velocity of the meteor body into the Earth's atmosphere estimated from radial velocity is equal to 300 km/s." [Afanasiev et al. 2007 Astrophysical Bulletin, 62(4), pp.301-310]

Radar Observations of Meteors

1998-1999-2000

Example of phased-array radar:

"EL/M-2080 is a search, acquisition and fire control radar that can detect and track dozens of ballistic missiles simultaneously in a wide spectrum of ranges and heights. The large power aperture, combining state-of-the-art solid state modules, provides long detection range in the presence of undesired echoes like weather, land and sea clutter, chaff, etc. The modern signal processor embedded in the system enables flexibility in waveforms and data processing. "

ELTA web site

ARROW ATBM FC radar