"Current status of the Spanish Fireball Network: all-sky and video system monitoring and recent daylight events"

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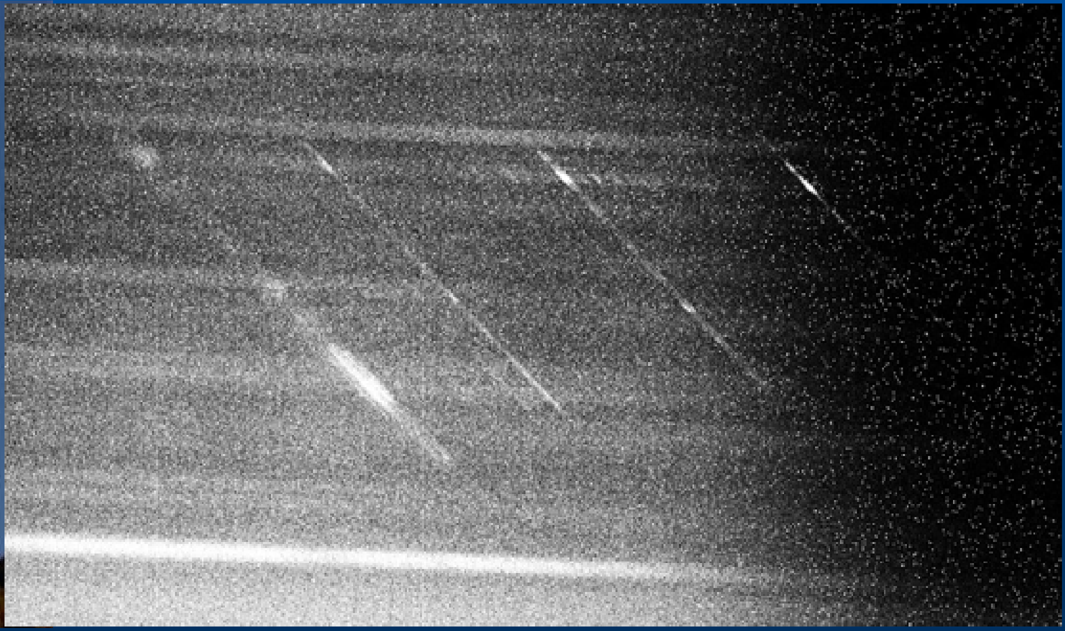
Villalbeto de la Peña meteorite fall, January 4, 2004.



Perseid CCD fireball spectrum, August 12, 2004.

FIREBALL NETWORKS' ROLE

- European Fireball Network:
  - Recovery of Pribram meteorite in 1959. First orbital determination.
  - 2002 Neuschwanstein puzzle.
- Prairie Network (1964-1974):
  - 16 stations around Nebraska.
  - Recovery of Lost City meteorite (H5) in 1970 .
- Canadian Photographic Network (1971-1985):
  - Recovery of Innisfree in 1977 (LL5).
- Direct and unique orbital and spectral information (!):
  - Most bodies are not recovered.
- Good news: 2 new networks in development:
  - Spain: SPMN
  - Australia

SPANISH FIREBALL NETWORK

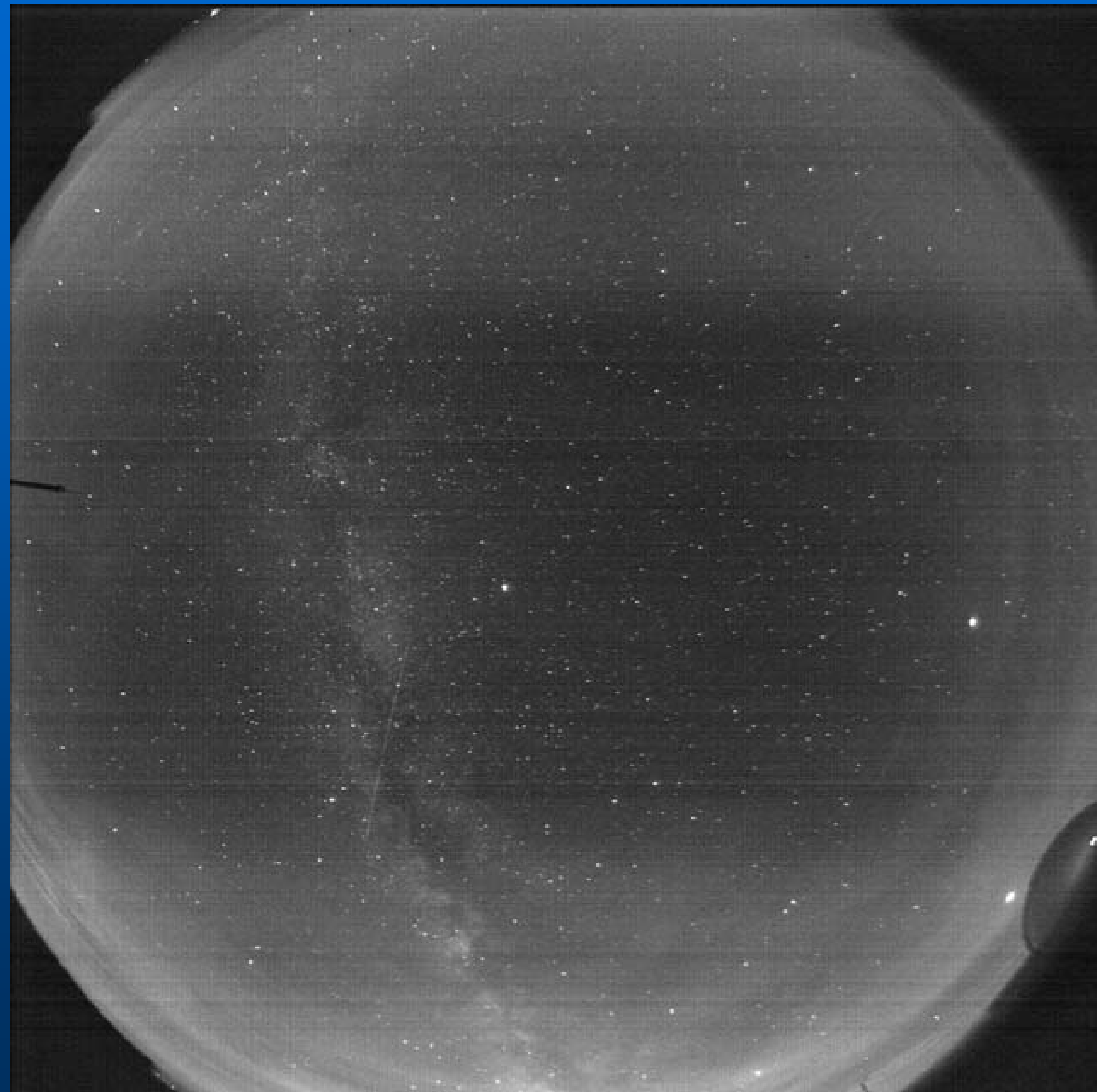
- SPanish Meteor Network (SPMN):
  - First campaigns: 1999
  - First all-sky images 2002.
  - Double-station operations: Since June 2004.
    - La Mayora and El Arenosillo (BOOTES)
  - Present all-sky station in Montseny
  - Future two stations in Valencia.
- Homepage:
  - Participation of public.
  - Popularization of this field in Spain.
    - Creation of social interest
  - Homepage: www.spmn.uji.es
- Some exciting results:
  - Several superbolides studied
    - One meteorite recovery
  - Research on meteor storms: Leonid and Perseid studies

CCD ALL-SKY CAMERAS

- All-sky CCD image of a Perseid Earth-grazing fireball, Aug.12, 2004 (La Mayora station)
- Our team developed this high-res all-sky CCD system (details in next MET07)

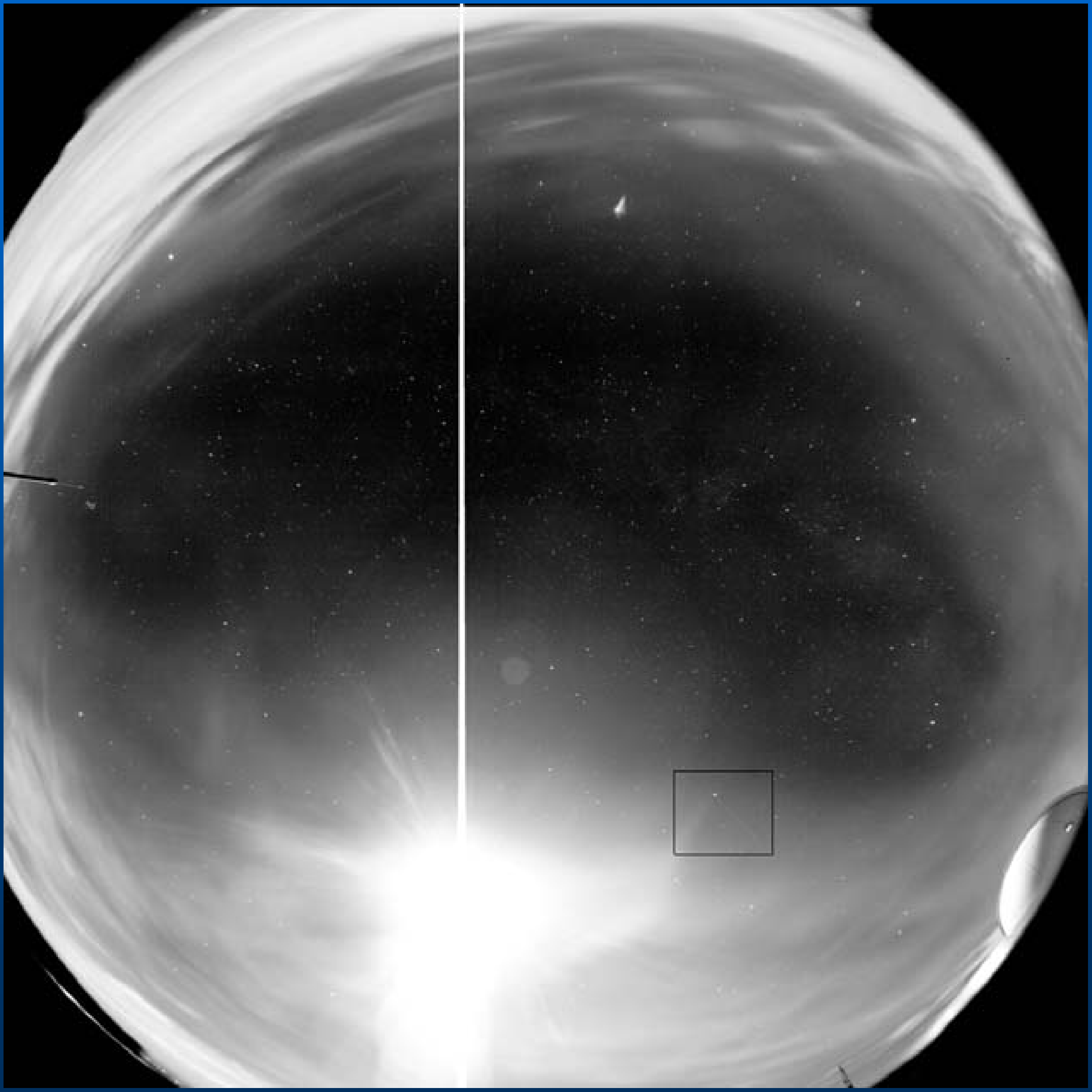
FIRST AUTOMATISED PROTOTYPE

+2 magn. North δ Aquarid, Aug. 12, 2006



Night sky Montsec Astronomical Observatory (IEEC), July 24 2006

A CONTINUOUS MONITORING

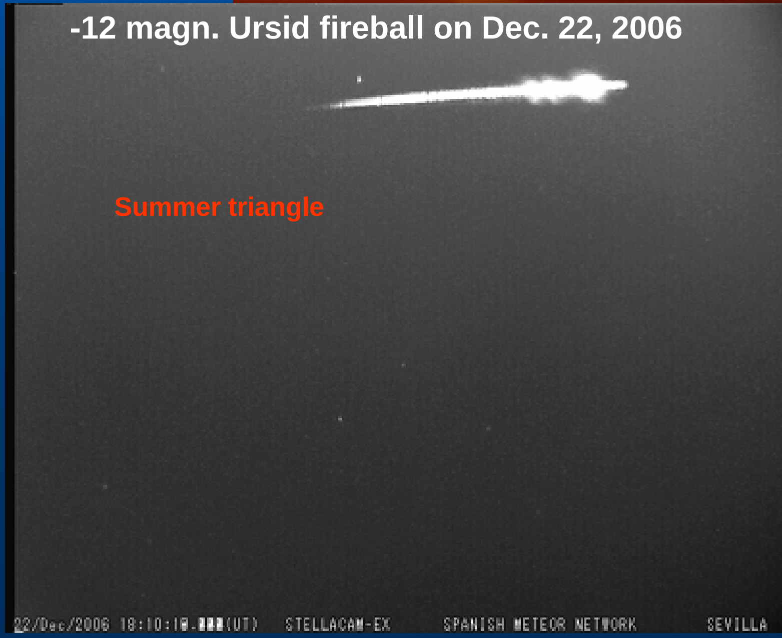


- All sky CCD cameras have extraordinary sensitivity:
  - They can be operated under unfavorable conditions
  - Detection of meteors and fireballs (Mv<+3)

Image of a 2006 Perseid meteor (Full Moon and cloudy skies)

SPMN VIDEO STATIONS

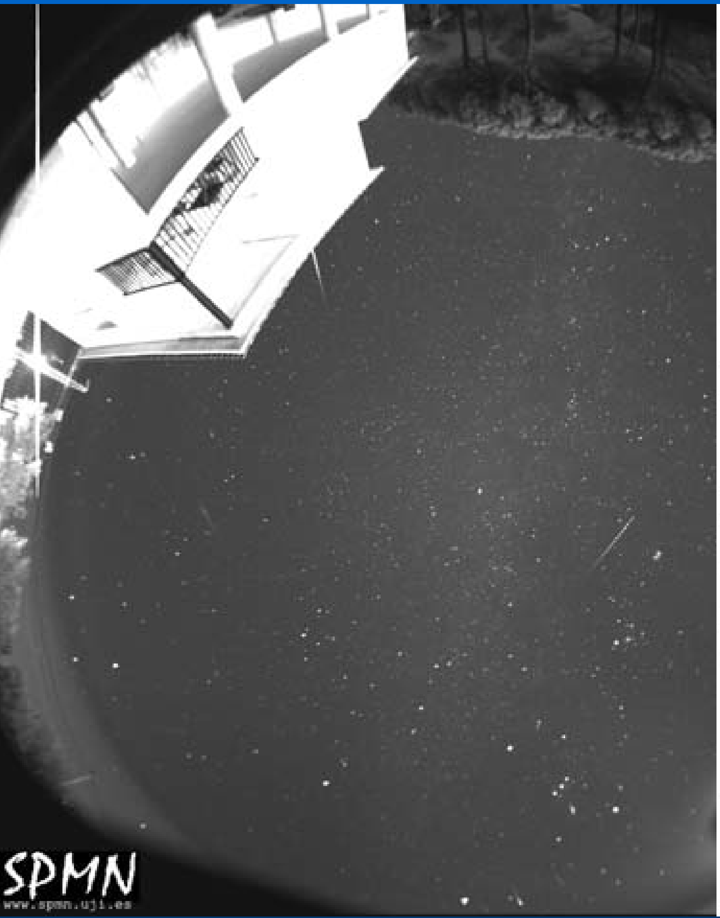
- Three video stations in Andalusia (Sevilla and Huelva provinces) operating continuously from July 2006
- All of them are equipped with a 1/2" Sony interline transfer CCD image sensor
- Nine of these cameras are manufactured by Watec and other two by Mintron
- Aspherical fast lenses with focal length ranging from 2.6 mm (fisheye) to 12 mm and focal ratio between 1.2 and 0.8 are used for the imaging objective lens
- Different areas of the sky are covered by every camera and point-like star images are obtained across the entire field of view
- Video imagery at 25 fps with a resolution of 720x576 pixels

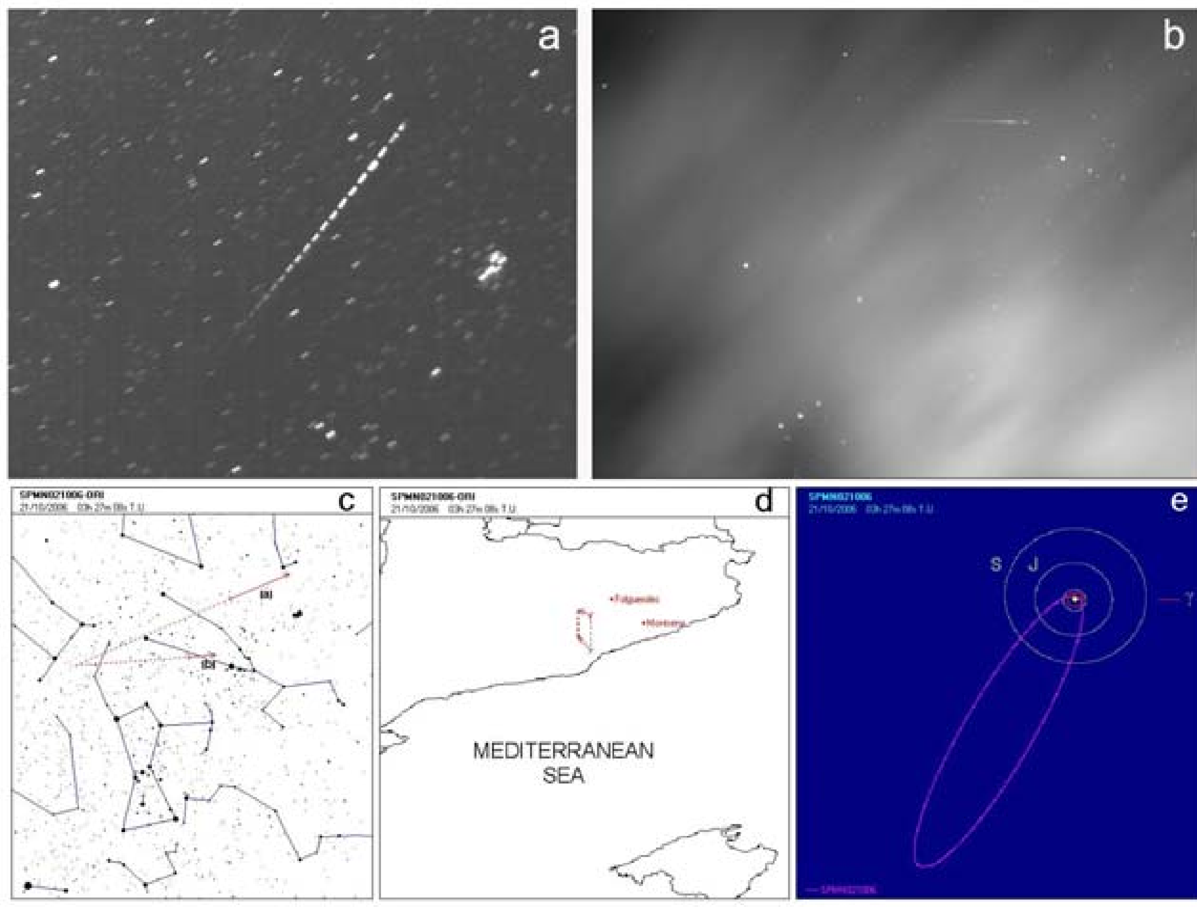


some examples…


20/Aug/2006 00:04:35.953(UT) 0204 WATEC 902H

2006 ORIONIDS' OUTBURST DETECTION





Trigo-Rodríguez et al. (2007), MNRAS, in press

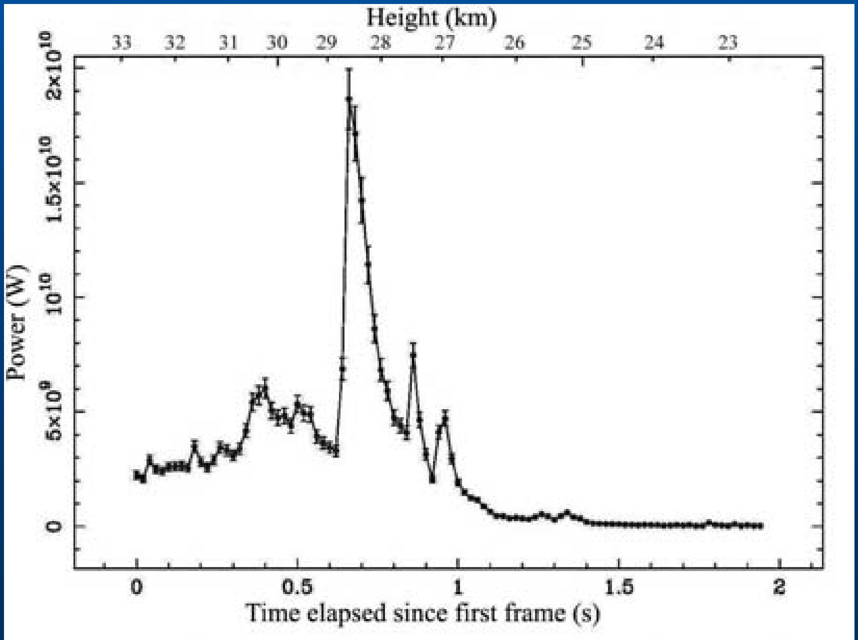
"The 2006 outburst imaged by all-sky CCD cameras from Spain: meteoroid spatial fluxes and orbital elements"

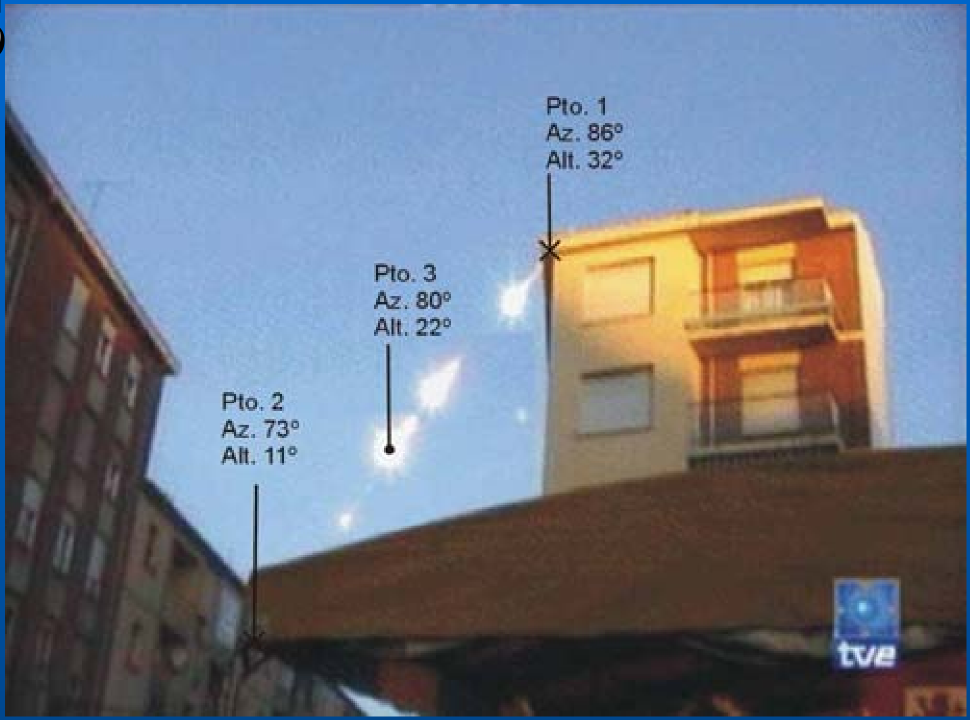
- **Fireball "BELLATERRA" (SPMN021006)**
- **2006 Oct. 20, 3h25m48s UTC**

SPMN MAIN RESEARCH TARGET: METEORITE FALLS

- VILLALBETO DE LA PEÑA FALL
- Casual daylight event.
- Daylight bolide of magnitude -18±1
- January 4, 2004 at 16h46m45s UTC
- Initial meteoroid mass: 760 ± 150 kg
- SPMN infrastructure allowed the bolide study and meteorite recovery

Papers already published in MAPS

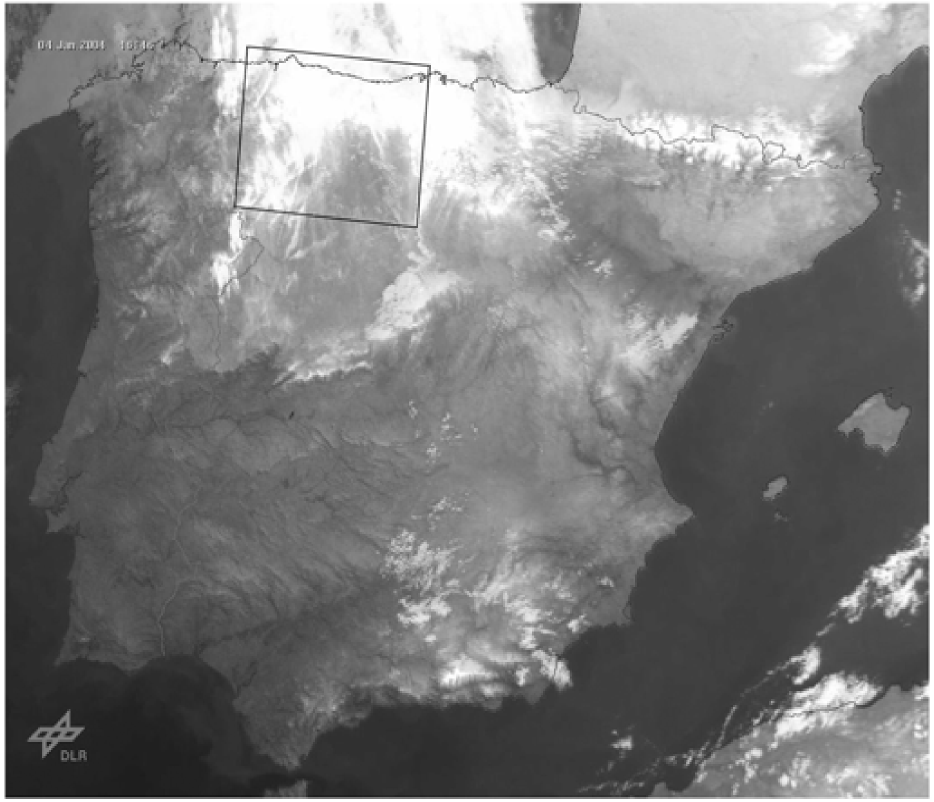


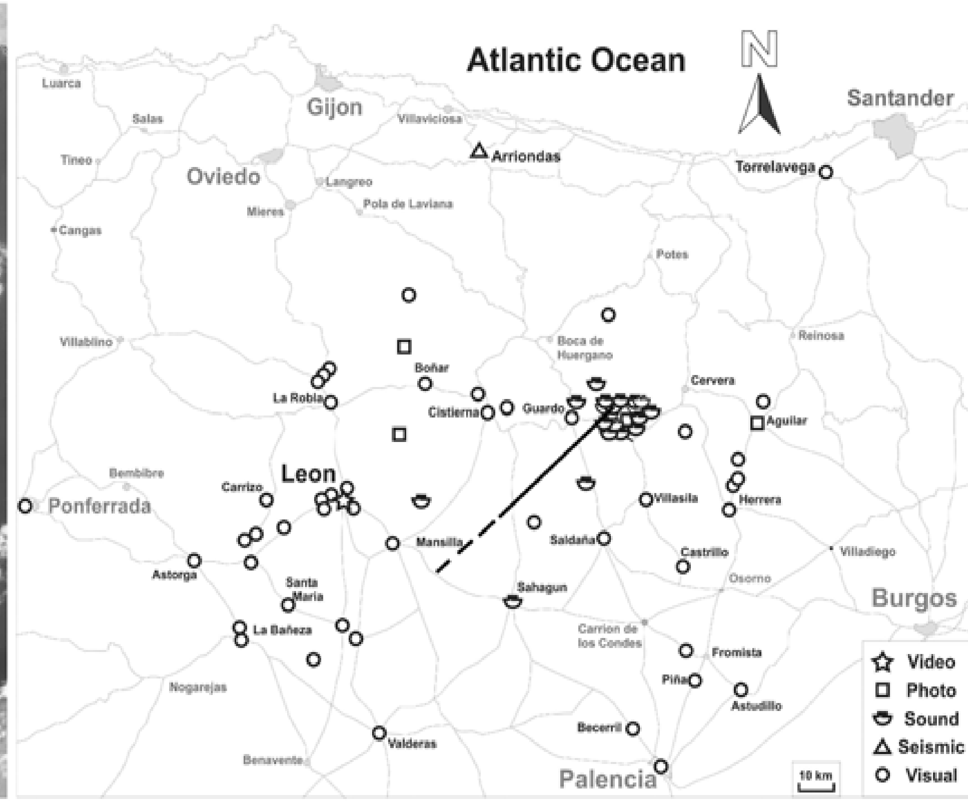


Composite frame sequence of the video recorded from Leon.

- Total light emission: 5.7×10^9 J from the analysis of the video
- Energy: ~0.022 kilotons
  - Consistent with photometric, seismic, and infrasonic data.
- Determination of the trajectory and orbit.

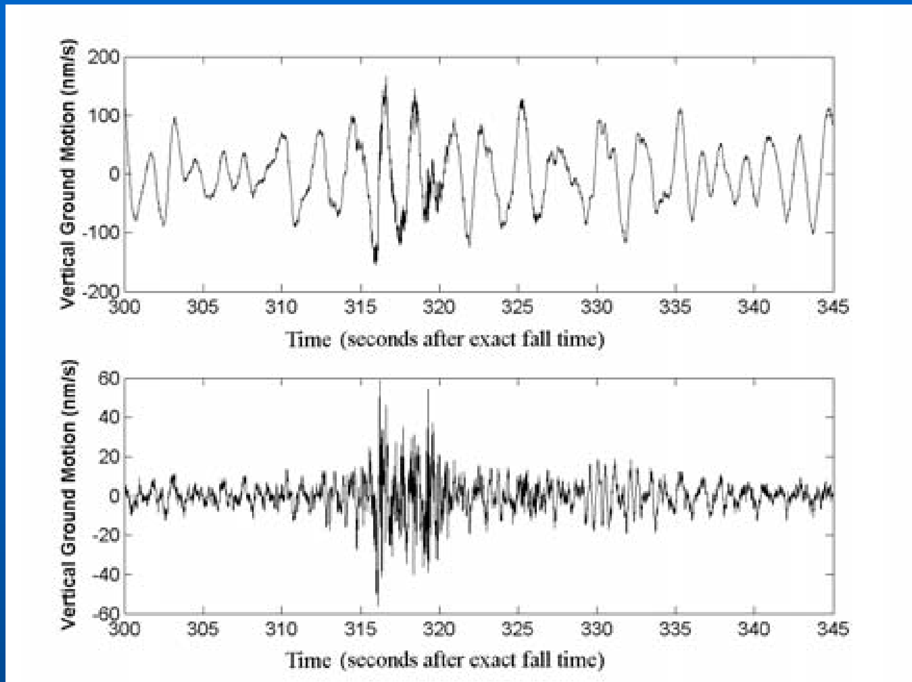
VILLALBETO OBSERVING CONDITIONS



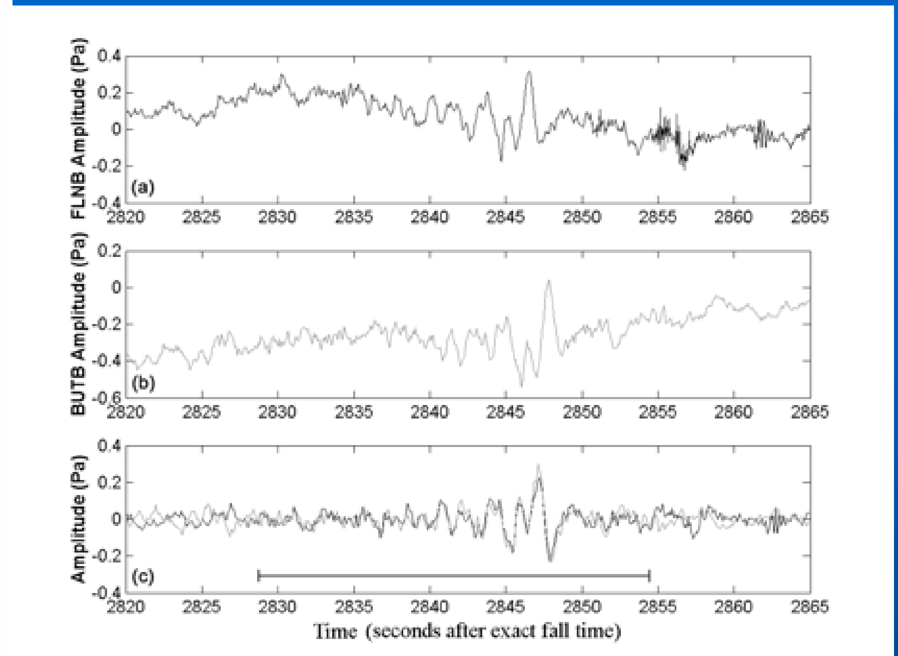


- The Earth receives ~10 impacts with such energy every month:
  - Appeared in broad daylight when thousands of people were attending diverse festivities in the northern part of the Iberian Peninsula.
  - Increasing availability of digital cameras makes it possible for eyewitnesses to obtain valuable records of daylight fireballs.

SEISMIC AND INFRASOUND DETECTIONS



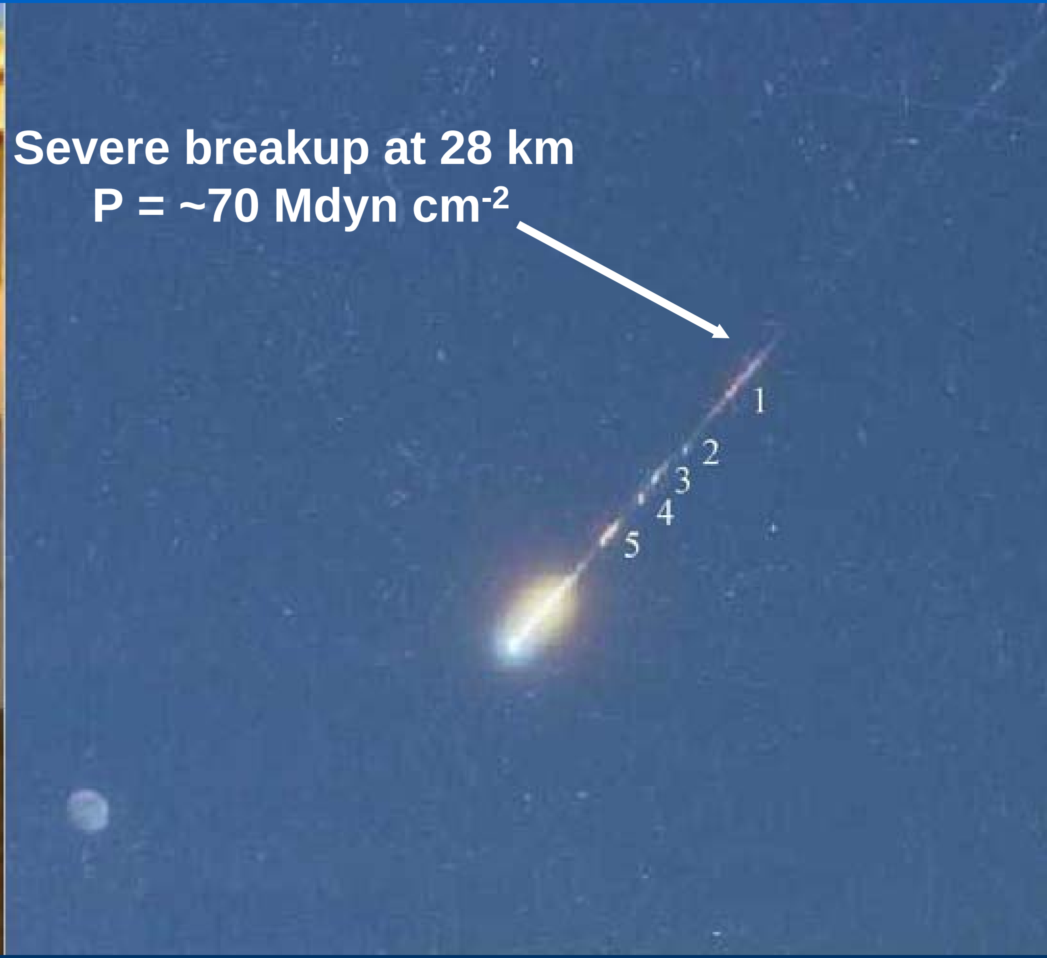
Infrasound detection from Le Fleurs (France)



Seismic detection of the airblast during massive fragmentation at an height of 28 km. Arriondas seismic station (Asturias)

Picture taken before main fragmentation from Las Hoces (León). Image Salvador Díez

VILLALBETO FALL: FRAGMENTATION EVENTS



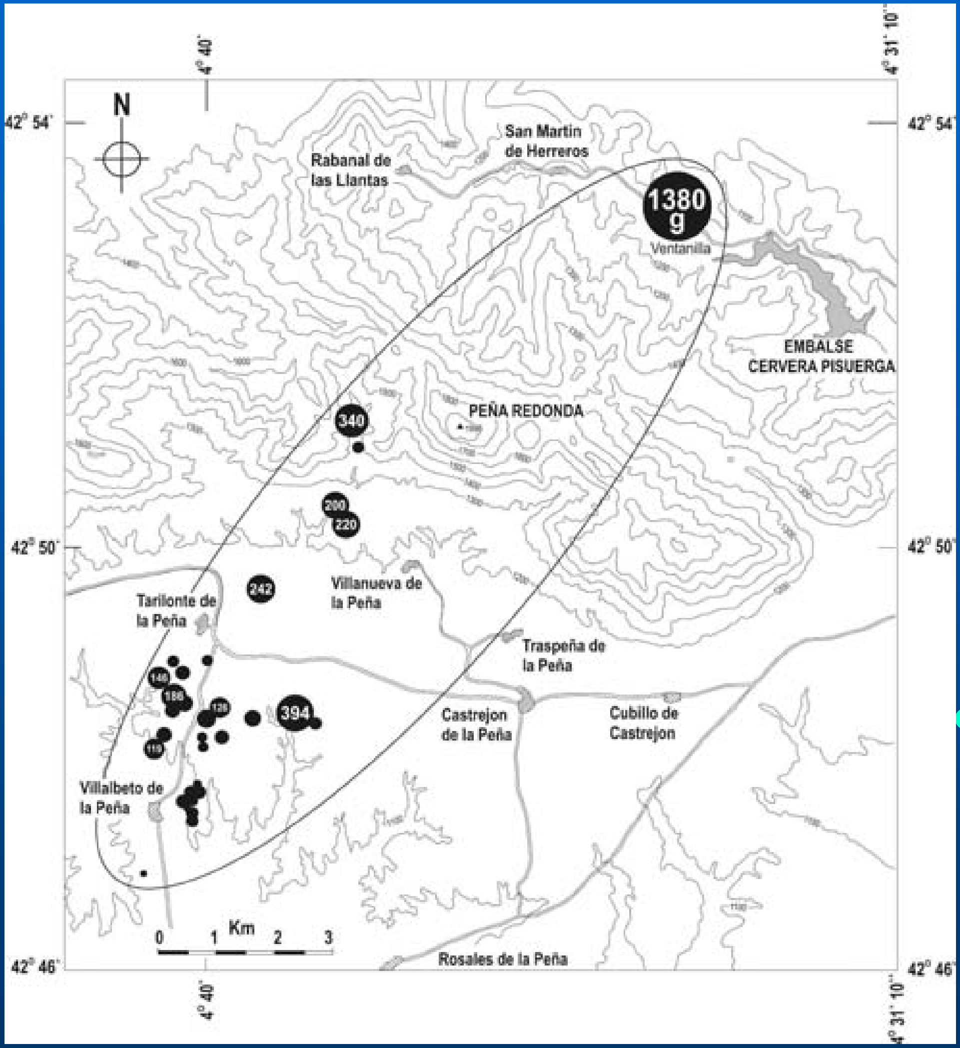
- Video frame at the same moment from León
- Picture of the bolide obtained from Santa Columba de Corueño (León). Image Maria Robles
- And the Moon appears for calibration of both pictures !!!

TRAJECTORY DETERMINATION

- 65 calibration points were selected in every frame (right). In the 110 frames, a total of ~7,000 points were accurately measured.
- Calibration images were obtained for all locations where the fireball was imaged. Astrometric reduction was made by following the procedures of Borovicka et al. (2003).
- On the right is a calibration picture containing stars from constellations of Boötes, Hercules and Draco.

From Trigo-Rodríguez et al., MAPS (2006)

VILLALBETO STREWN FIELD



The Villalbeto de la Peña strewn field is ~20×6 km^2

First recovered meteorites by our team.

- **Best documented case of a meteorite fall in Spain:**
  - **A video tape and two direct pictures.**
  - **Tens of images of the persistent train.**
  - **4.6 kg of meteorites recovered.**

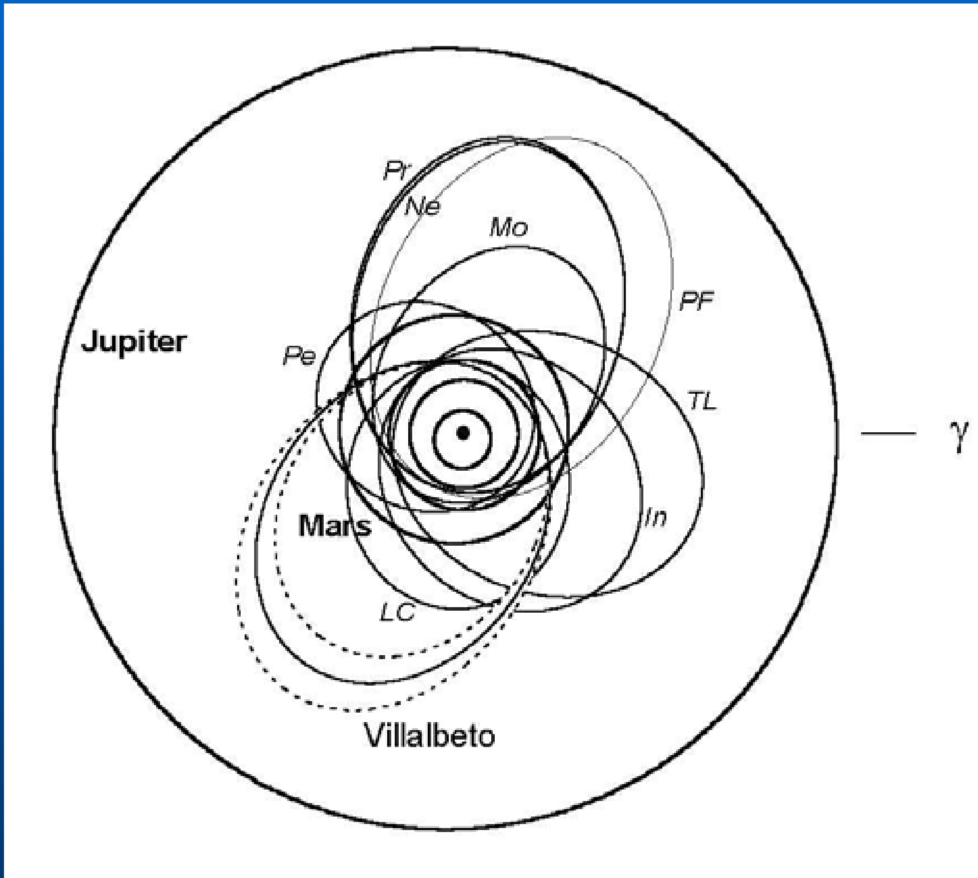
VILLALBETO FALL: ORBITAL DATA

Villalbeto de la Peña is the ninth meteorite with a known heliocentric orbit.

MAIN DATA:

- **Initial velocity: 16.9 ± 0.4 km/s**
- **Heliocentric velocity: 37.7 ± 0.5 km/s**

- **Orbital period: 3.5 ± 0.5 yr**
- **Aphelion distance: 3.7 ± 0.4 AU**
- **Eccentricity: 0.63 ± 0.04**
- **Semimajor axis: 2.3 ± 0.2 AU**
- **Inclination: 0.1 ± 0.2 º**
- **Argument of perihelion: 132.3° ± 1.5°**
- **Perihelion distance: 0.860 ± 0.007 AU**
- **Longitude of perihelion: 56.0° ± 1.5°**



Orbit of Villalbeto (considering the uncertainty in the orbital elements) compared with previously determined orbits of meteorites.

VILLALBETO’S ORIGIN

- Using the source-region model for NEAs of Bottke et al. (2001), and taking into account the uncertainties in the orbital elements, Villalbeto de la Peña could have originated in four regions:

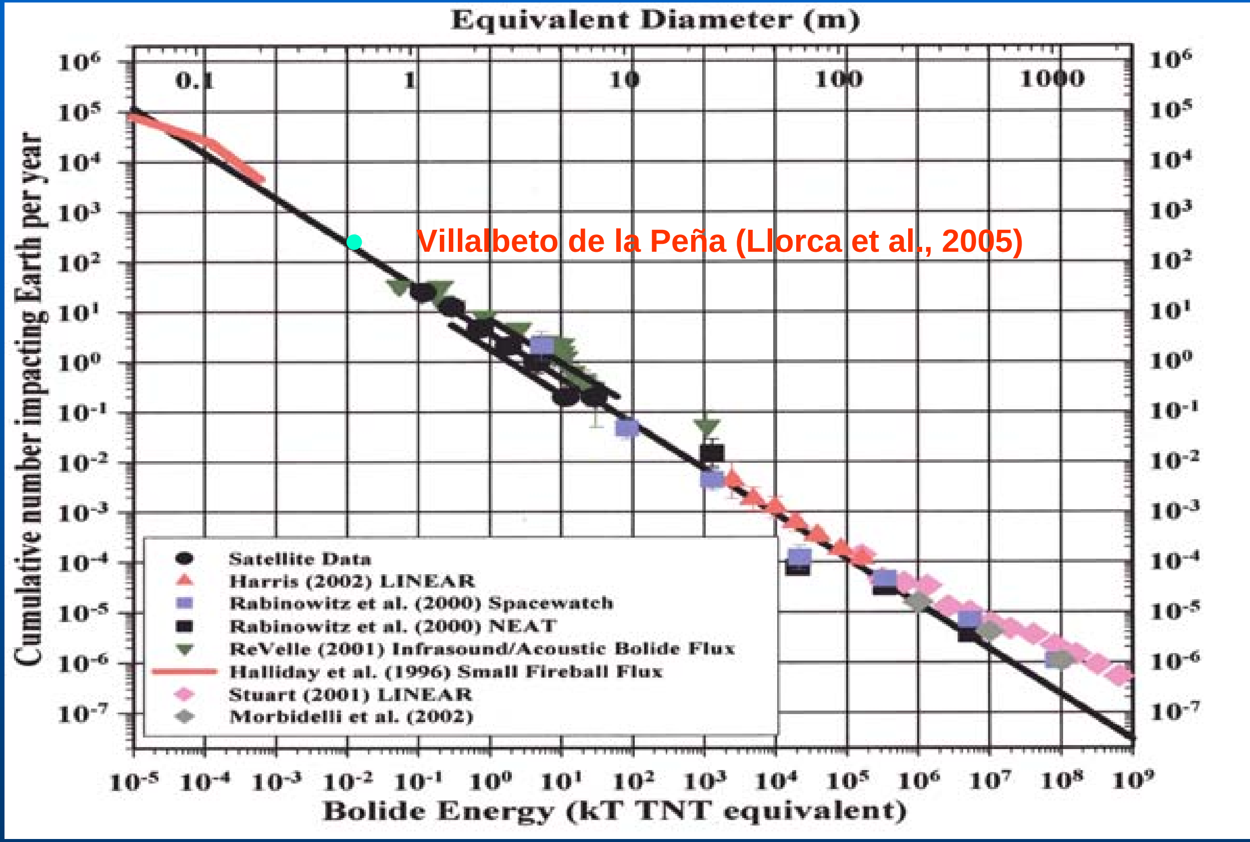
  - The 3:1 jovian resonance,
  - The ν_6 resonance,
  - The Mars-crossing region,
  - The outer main belt.

However, the similar probabilities for these four regions make
it difficult to determine the exact source of the meteorite.

THE PRESENT FLUX OF BODIES

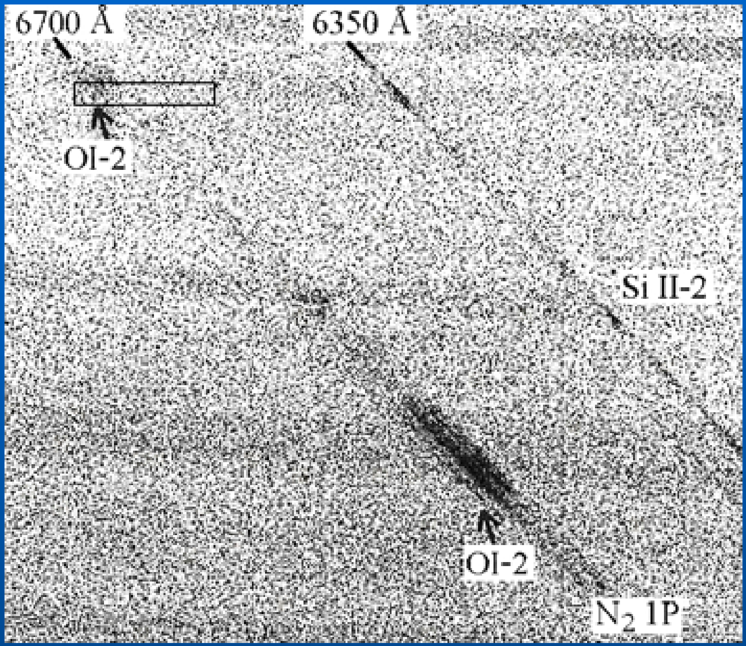
Brown et al., (2002)

- In the mass range: $0.1 \leq M_{\infty} \leq 2\times10^3$ kg
- Fireball network studies provide information on bodies that are not detectable with telescopes.
    - Direct estimations of the energy released in impacts
- Evidence for weak interplanetary materials that are unable to survive atmospheric interaction

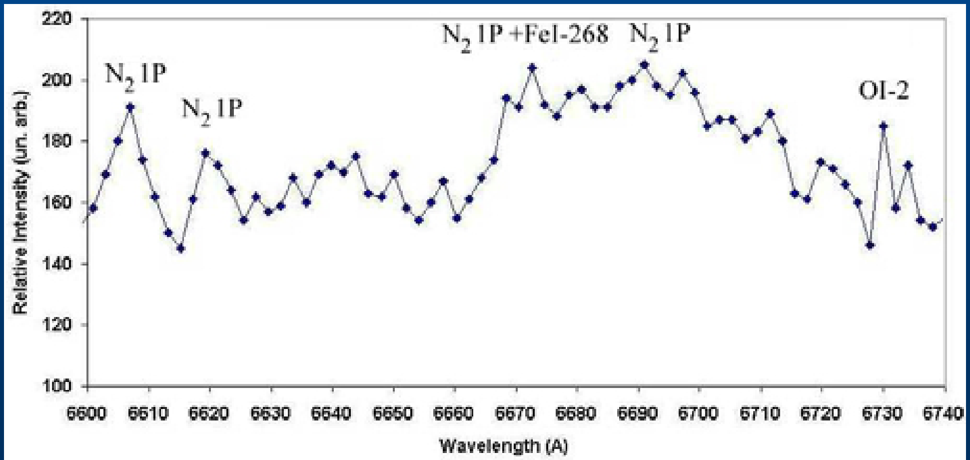


The Earth receives one impact in the range of 2 to 10 ktons annually and one impact of 0.3 ktons monthly.

SPMN HIGH-RES CCD SPECTROSCOPY



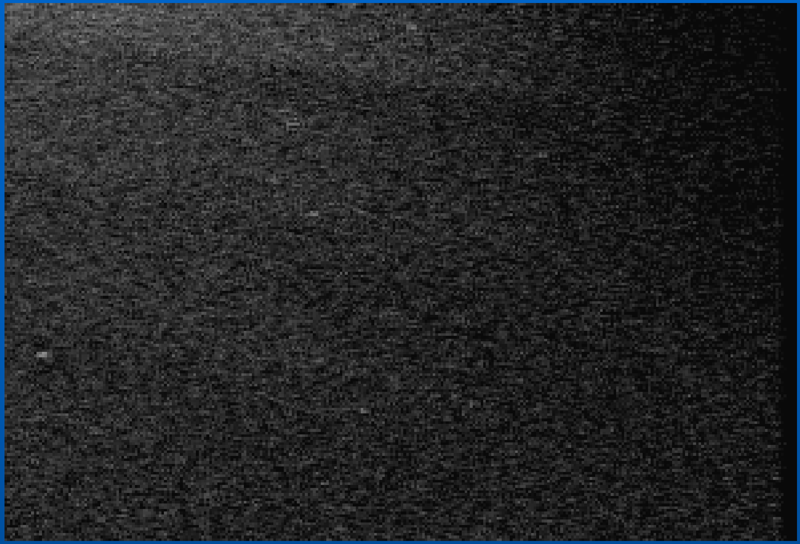
Trigo-Rodríguez et al. (2005)



- **A high resolution spectrum obtained of a Perseid fireball by the SPMN revealed the presence of O and H lines**
  - **Decomposition of H_2O or OH contained in the meteoroid into radicals O and H (?):**
    - **Water in clay minerals would be surviving for long periods in the interplanetary medium.**
  - **Importance of the development of CCD meteor spectroscopy**
    - **First evidence: Jenniskens et al. (2004) in Astrobiology 4-1 and Abe et al. (2005) detection of OH**
    - **Hydrated minerals would be frequent in cometary meteoroids (Rietmeijer et al., MAPS, 2004)**
    - **Are they missing in “pristine” comets? (Brownlee et al., 2006)**

SPMN VIDEO SPECTROSCOPY

- **The video network in Andalusia is currently obtaining video spectra of meteors and fireballs**
- **Such spectra are showing the relative abundances of the main rock-forming elements**
  - **Chemical information is very valuable together with the orbital one to get clues on the nature of the parent bodies of meteoroids**
  - **An example is the video obtained of this -4 magn. sporadic fireball appeared on May 12, 2007**



CONCLUSIONS AND FUTURE WORK

- Importance of the study of interplanetary matter from fireball networks:
  - Casual imaging of fireballs provide valuable information, but require a devoted research framework to collect and reduce all available data
  - Fireball networks can provide accurate trajectory data in shorter time
  - New technology is available: CCD and video cameras can patrol the skies
  - From these data the flux of meter-sized bodies to the Earth can be estimated

- Orbital data provide information:
  - On the sources of meteorites: asteroidal and cometary (?) parent bodies.
  - By knowing more orbits we could improve our knowledge of delivery mechanisms
- Meteor Spectroscopy:
  - It offers the chemical composition of meteoroids coming from a large variety of sources
  - It is a complementary source of chemical data compared to expensive sample-return missions

    HOT QUESTIONS WE TRY TO ANSWER:

    - Are cometary meteoroids efficiently delivering organics and water to the Earth?
    - Do comets evolve into asteroids? 3200 Phaeton and Geminids.
    - Exist important chemical differences among comets?
    - Is cometary matter able to survive atmospheric interaction producing meteorites?

If you are interested in joining efforts in these fields you are welcome to contact us:

spmn@ieec.uab.es