Qualche buona ragione per voler sviluppare un Sistema coordinato di osservazioni di meteore e fireballs in Italia.

- Le meteore e le fireballs sono prodotte da oggetti di origine cometaria ed asteroidale, e quindi forniscono indicazioni sulle popolazioni di piccoli corpi del Sistema Solare.
- Fanno parte della popolazione di “Near-Earth Objects”, che include corpi potenzialmente pericolosi.
- Corpi di queste dimensioni sono difficili da osservare usando le normali osservazioni al telescopio.
- La determinazione delle traiettorie è necessaria per ricavare le orbite originarie e la provenienza degli oggetti. Inoltre, può consentire di individuare i luoghi di caduta di meteoriti e di recuperarle (quasi) subito dopo la caduta.
- Le traiettorie non possono essere determinate se non si hanno misure effettuate da più punti di osservazione.
- Sinergia con sistemi di rilevamento dallo spazio in fase di sviluppo.

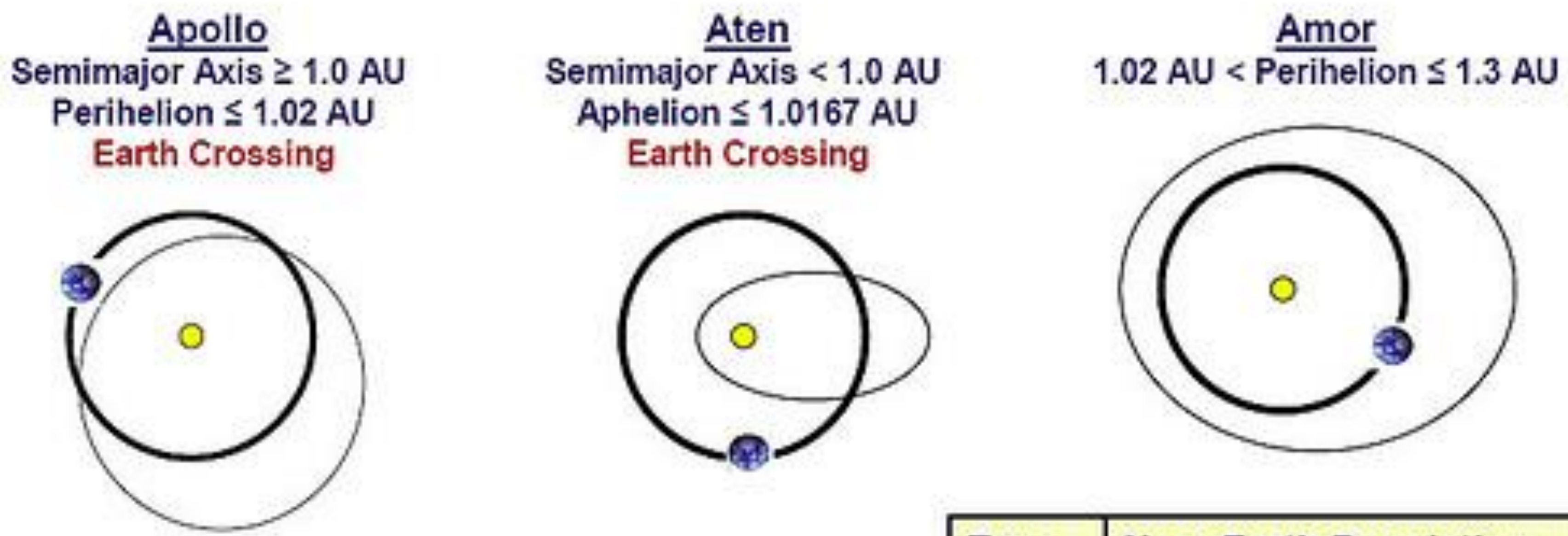
Da dove vengono?

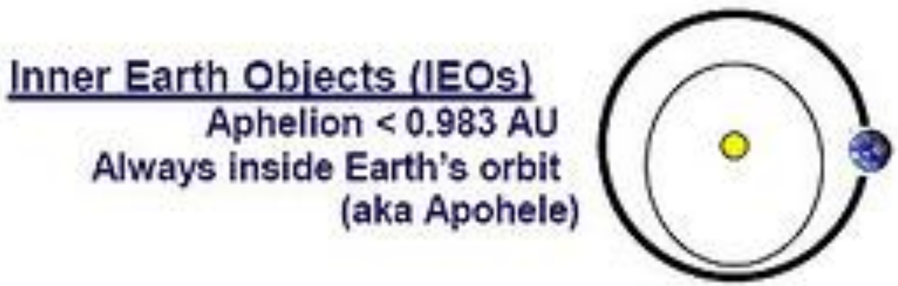
Comete

In genere particelle minuscule di polvere, rilasciate dalla cometa, e poi soggette a forze di pressione di radiazione. Esistenza di ben definiti sciami meteorici associati a comete.

Asteroidi

Oggetti di simensioni più grandi, e di densità maggiore. Rilasciati da oggetti Near-Earth, I quali a loro volta provengono da varie regioni della fascia asteroidale. Possibili origini da famiglie dinamiche di asteroidi.





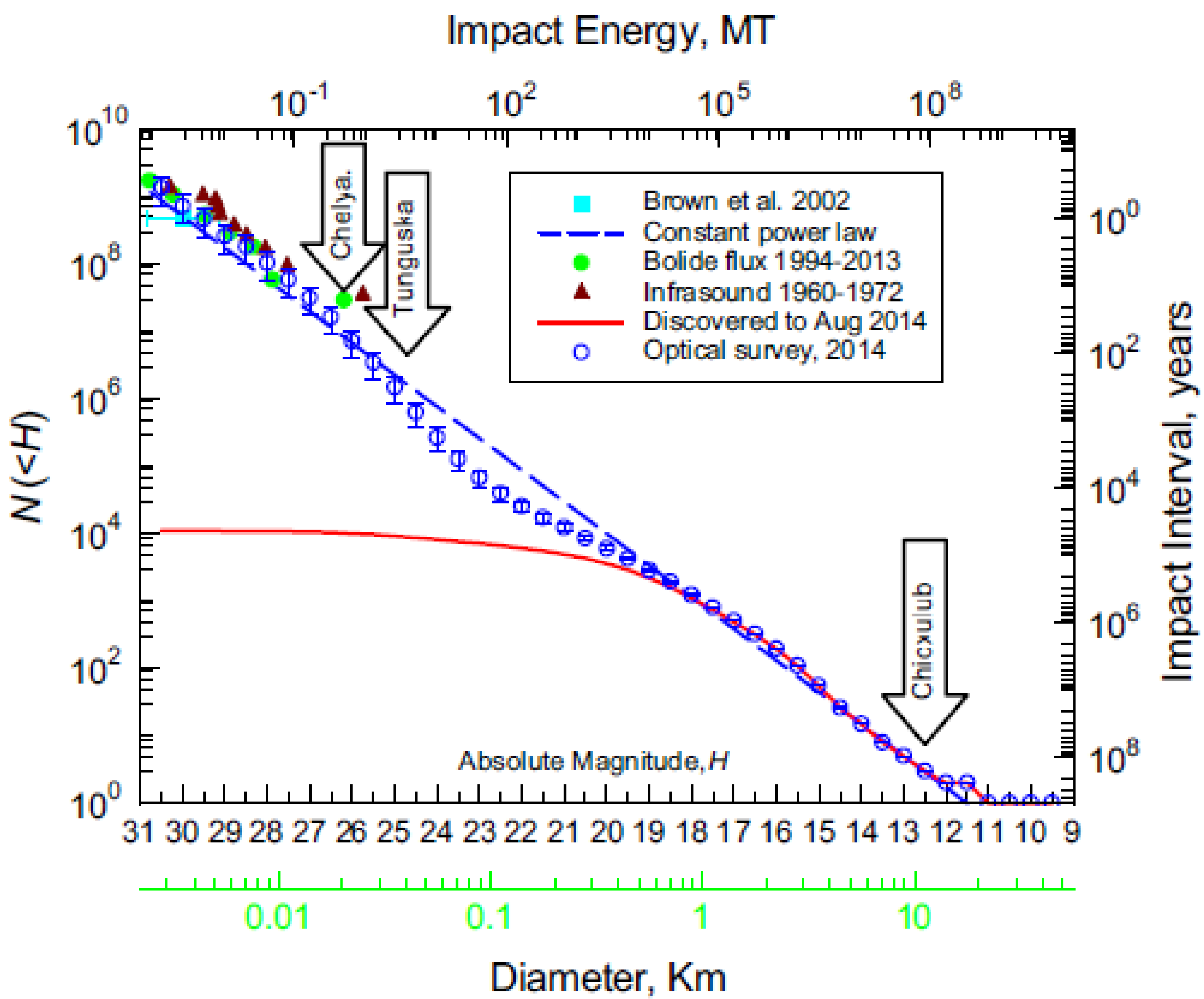
Type	Near-Earth Population
Apollo	62% of known asteroids
Aten	6% of known asteroids
Amor	32% of known asteroids
IEO	6 known asteroids

(Courtesy of NASA JPL)

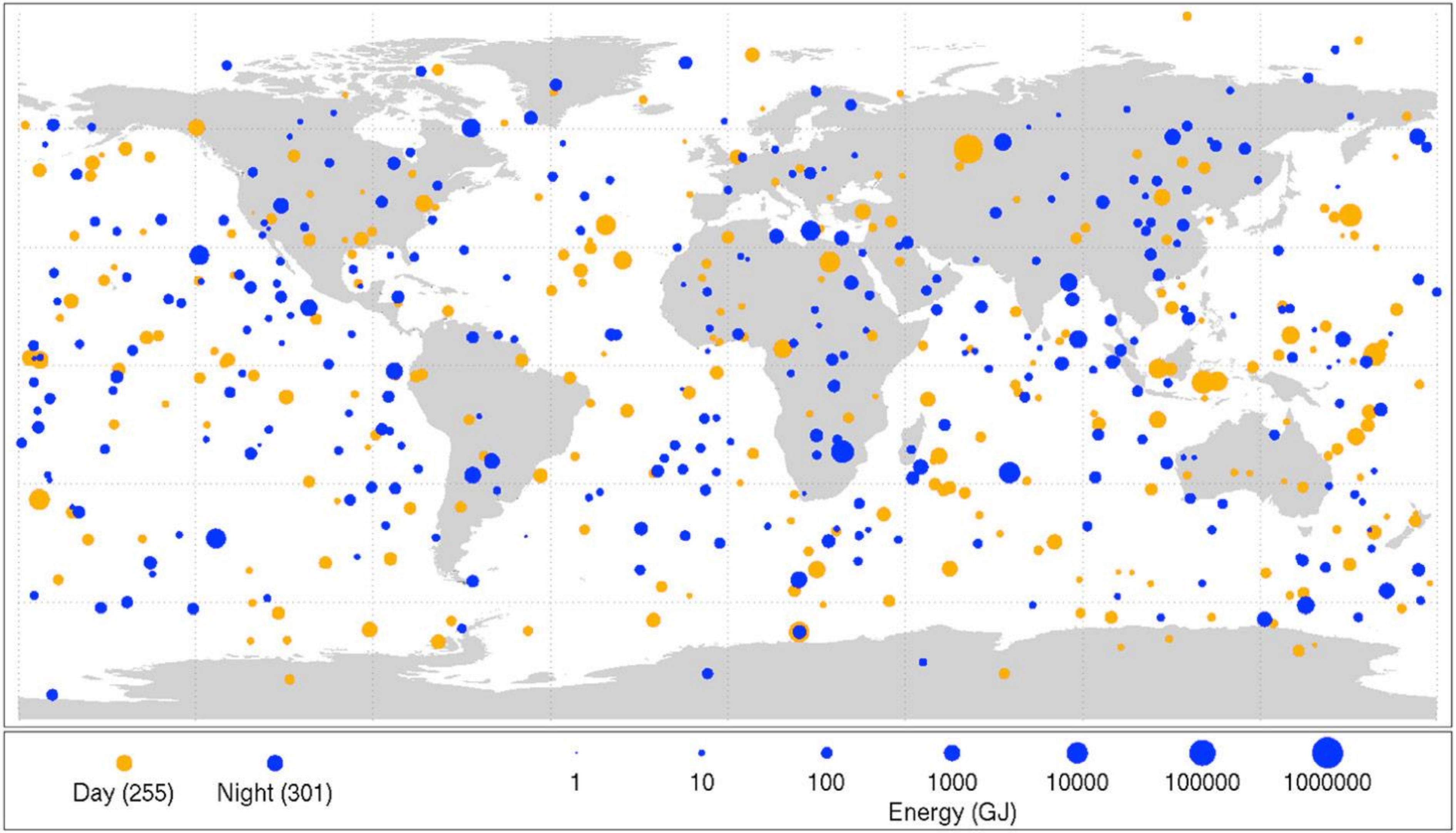
+ Near-Earth Comets !

The orbits evolve under gravitational and non-gravitational perturbations.
The origin can be from very different regions of the asteroid main belt.

Potentially Hazardous Objects (PHA): Minimum Orbit Intersection Distance (MOID) ≤ 0.05 AU, and Absolute Magnitude H ≤ 22 → (size > 150 m).



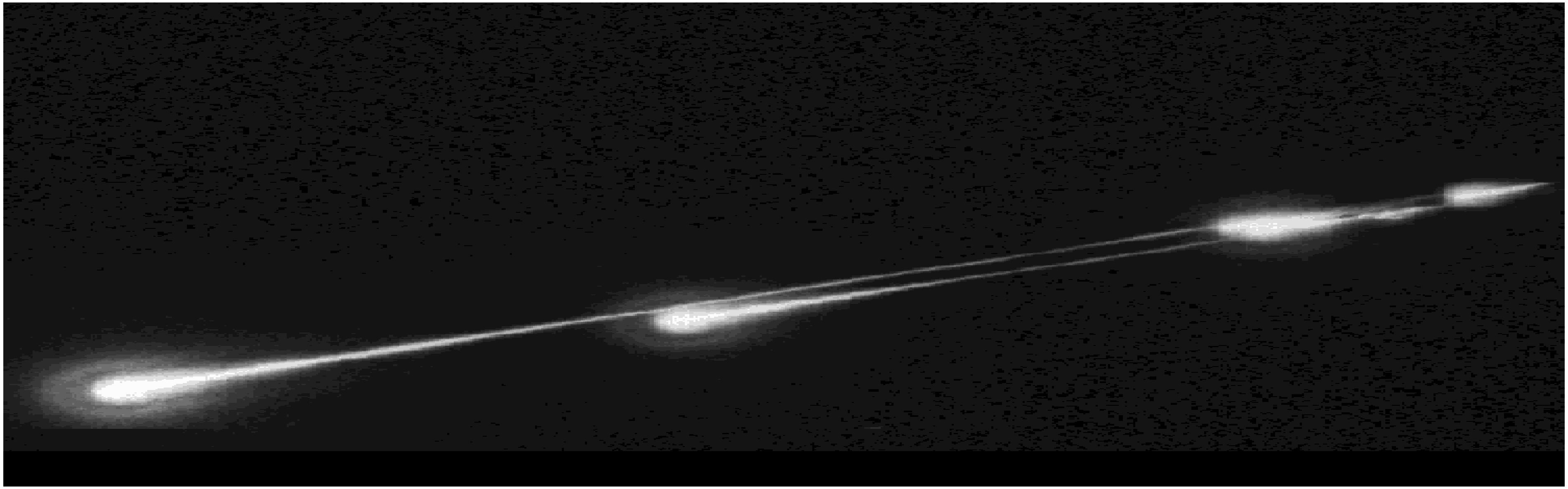
Harris & D'Abramo, Icarus, 257, 302-312 (2015)



Luoghi di impatto di bolide, nell'intervallo 1994 – 2013.

***m* < - 8 bolide or fireball** (meteoroid mass 10 ÷ 100 kg)
***m* < -17 superbolide** (meteoroid mass > 1,000 kg)

Fireball precursors, between 10m and 100 m in size, are the least known population of minor bodies in our Solar system



Mass (kg)	Diameter (m) 0.5 g/cm^3	1 g/cm^3	3.5 g/cm^3	Energy (v=20 km/s) (kT)
100,000,000	71.9	57.1	37.6	~ 5,000
10,000,000	33.4	26.7	17.5	~ 500
1,000,000	15.5	12.3	8.1	~ 50
100,000	7.2	5.7	3.8	~ 5
10,000	3.3	2.7	1.8	~ 0.5
1,000	1.6	1.2	0.8	~ 0.05

1 kT = 4.185×10^{12} J

Events developing energies of about or larger than **10^{-4} kT** are estimated **~** 10,000 - 30,000 per year**.** **About 50 events per year with mag brighter than -6.**

Typical shower meteors have kinetic energies of about **1-10 J**

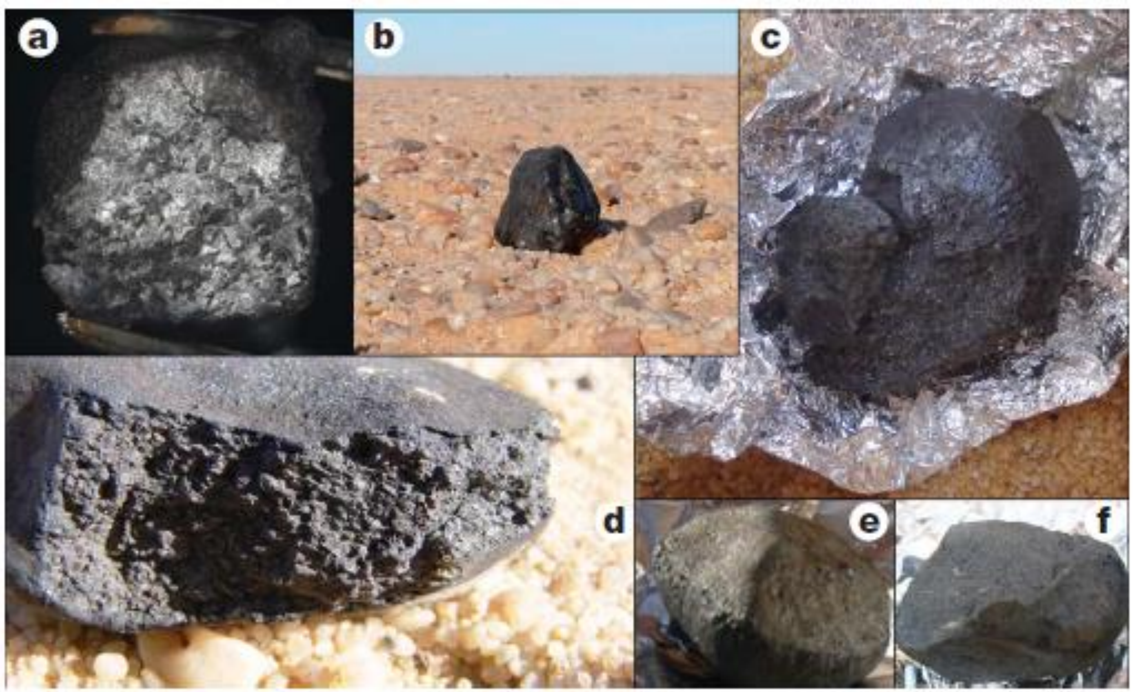
What we need to know about meteoroids

- Mass
- Density

→ Luminosity, deceleration, ablation equations

- Structure → Beginning and terminal heights
- Composition → Spectra + analysis of recovered meteorites
- Orbit → Velocity vector
- Flux (size freq.) → Number of detected events

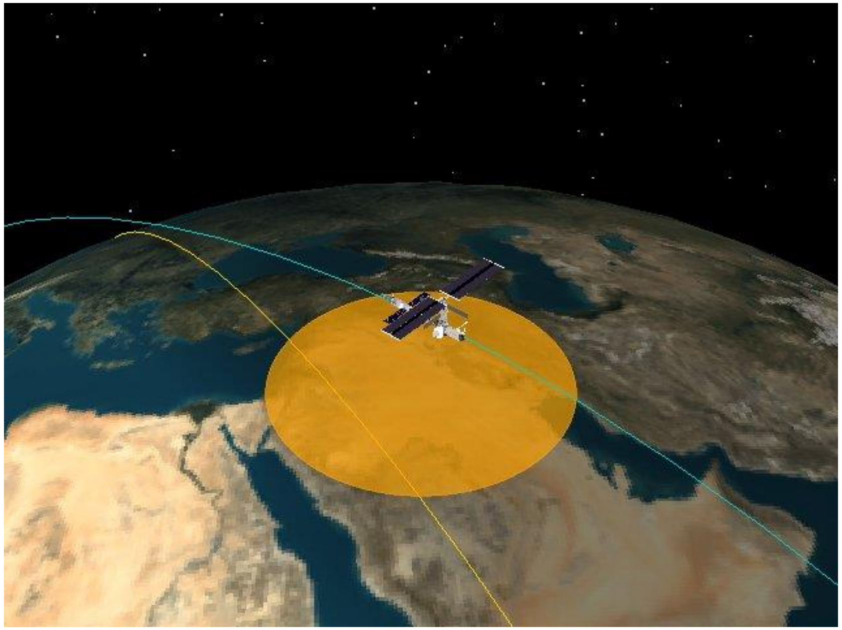
Even after many years of ground-based observations (using also radar techniques), new, accurate data are still needed to improve our understanding of the relations between observable features and physical properties.

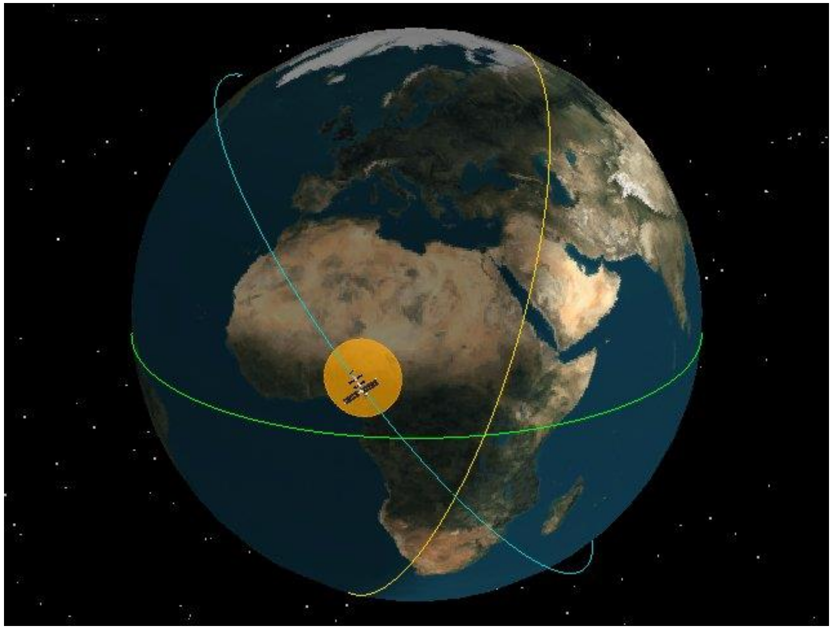


Il caso di 1998 TC3, scoperto ed osservato poche ore prima dell'impatto nel deserto della Nubia, con il successive recupero di un gran numero di meteoriti di un tipo sconosciuto in precedenza. ("polymict ureilites")

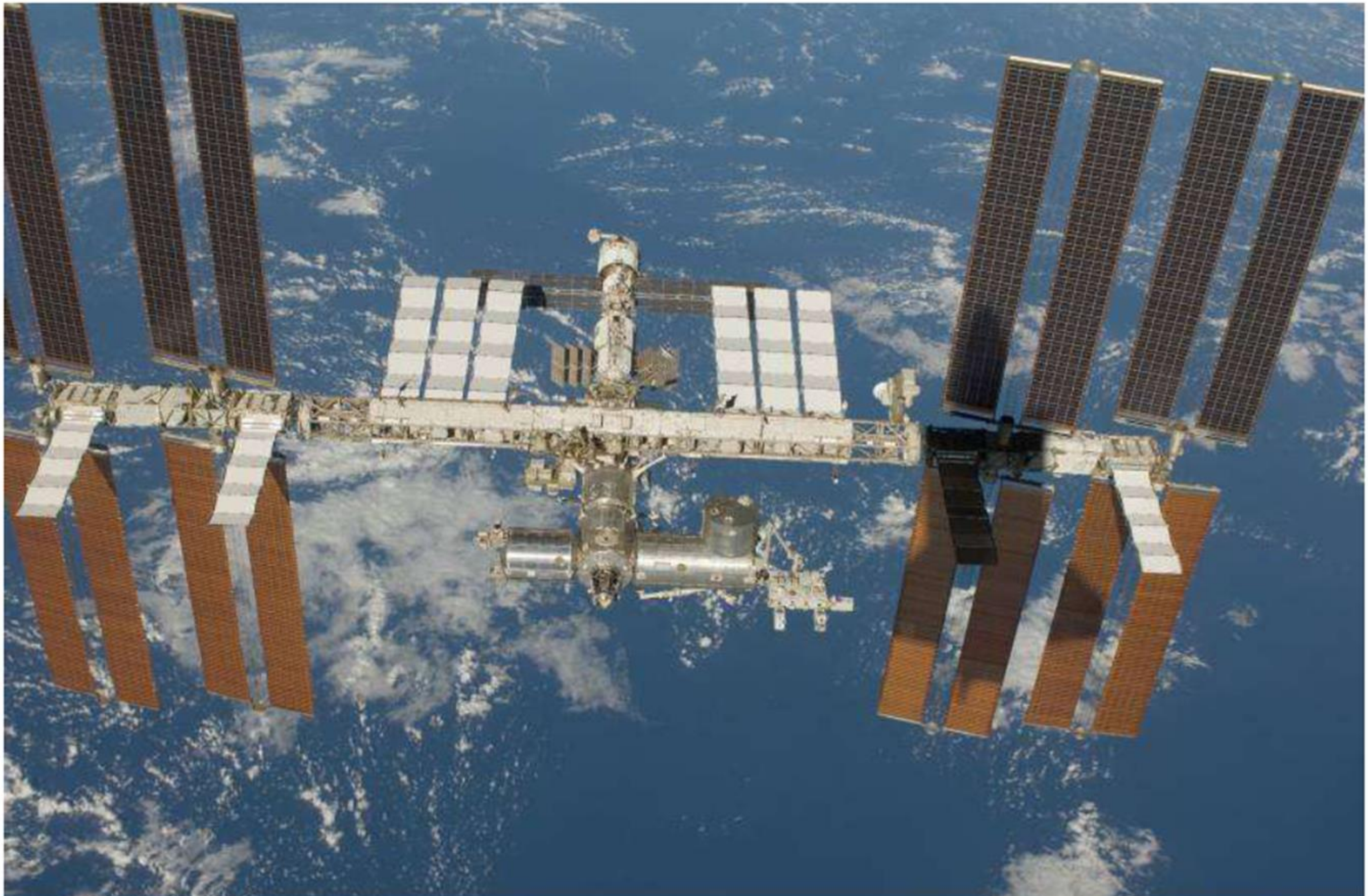
All'Osservatorio di Torino da tempo siamo coinvolti in progetti dedicati, in tutto o in parte, all'osservazione di meteore dallo spazio

Vantaggi in termini di efficienza (ampio FOV, osservazioni continue, eliminazione problemi legati alle nuvole e al tempo atmosferico).

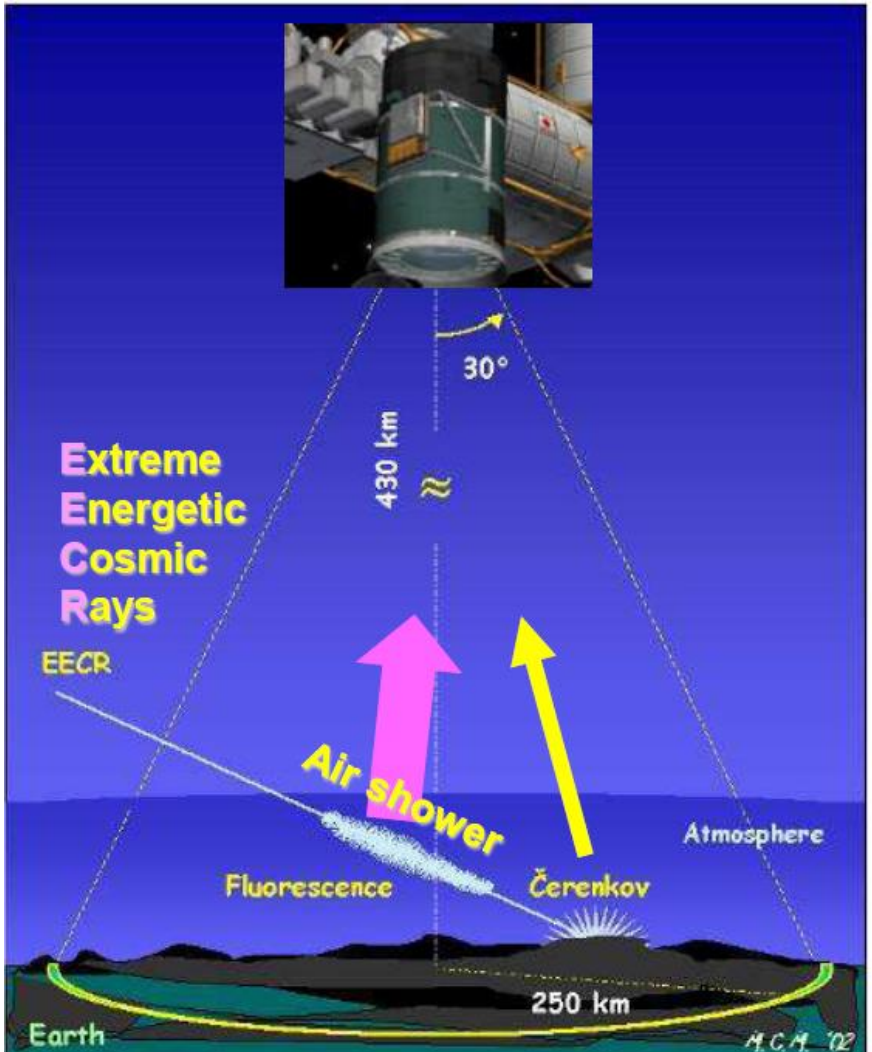




Il progetto di missione JEM-EUSO



JEM-EUSO Observational Principle



JEM-EUSO is a new type of observatory on board the International Space Station (ISS), which observes transient luminous phenomena occurring in the earth's atmosphere.

The telescope has a super wide field-of-view(60) and a large diameter(2.5m).

JEM-EUSO mission will initiate particle astronomy at ~10^{20}eV.

JEM-EUSO telescope observes fluorescence and Cherenkov photons generated by air showers created by extreme energetic cosmic rays

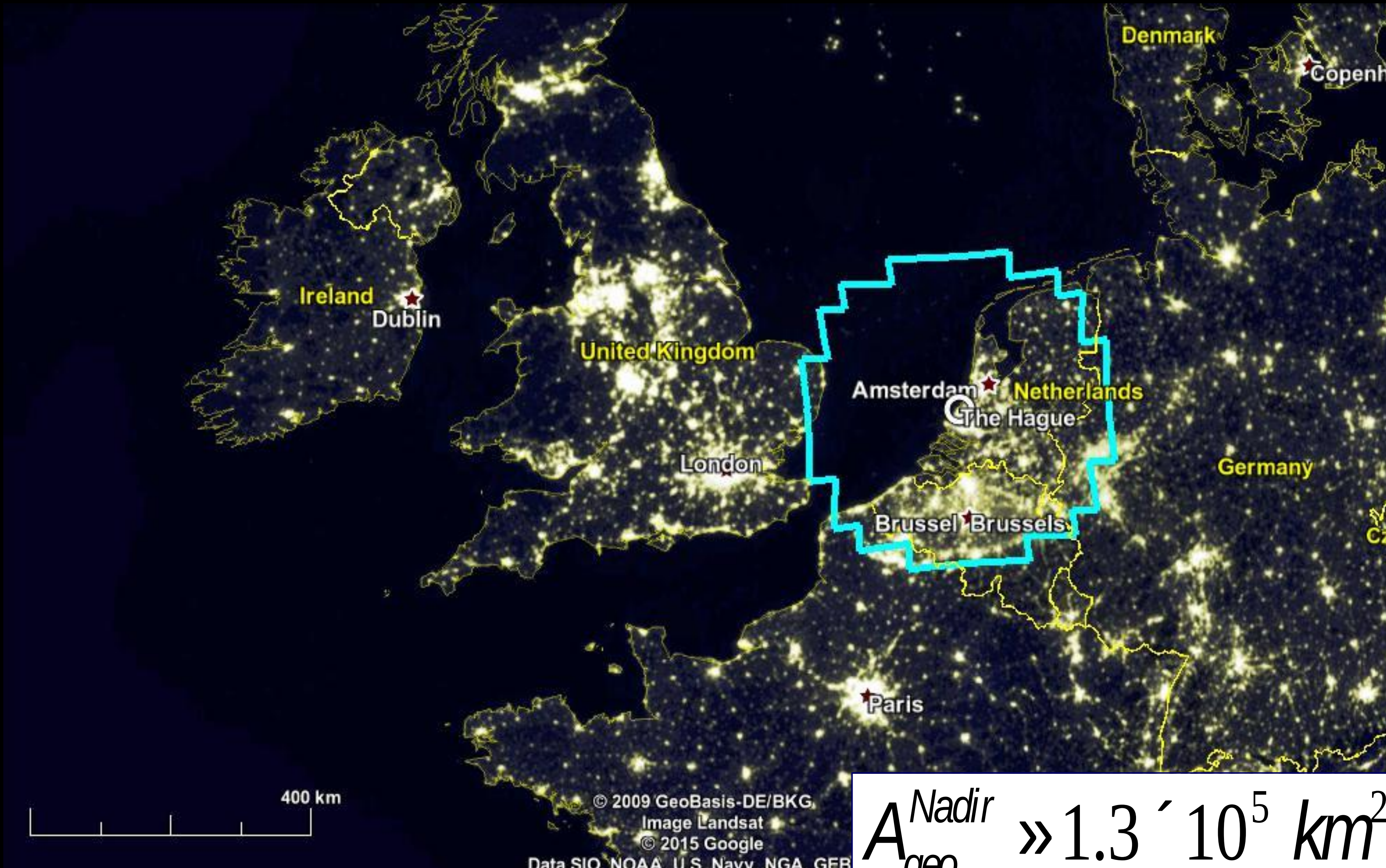
JEM-EUSO: Science Objectives

- Main Objectives :

  Astronomy and astrophysics through particle channel with extreme energies

  - Possible identification of the particle and energy sources based on the analysis of the arrival direction
  - Possible identification of the acceleration and radiation mechanisms with the measurement of energy spectrum from individual sources
- Exploratory objectives :
  - Measurement of extreme energy gamma rays
  - Detection of extreme energy neutrinos
  - Estimation of the structure of galactic magnetic field and its intensity
  - Identification of relativity and quantum gravitational effect
  - Study of atmospheric transient phenomena

Monitored Area - FoV



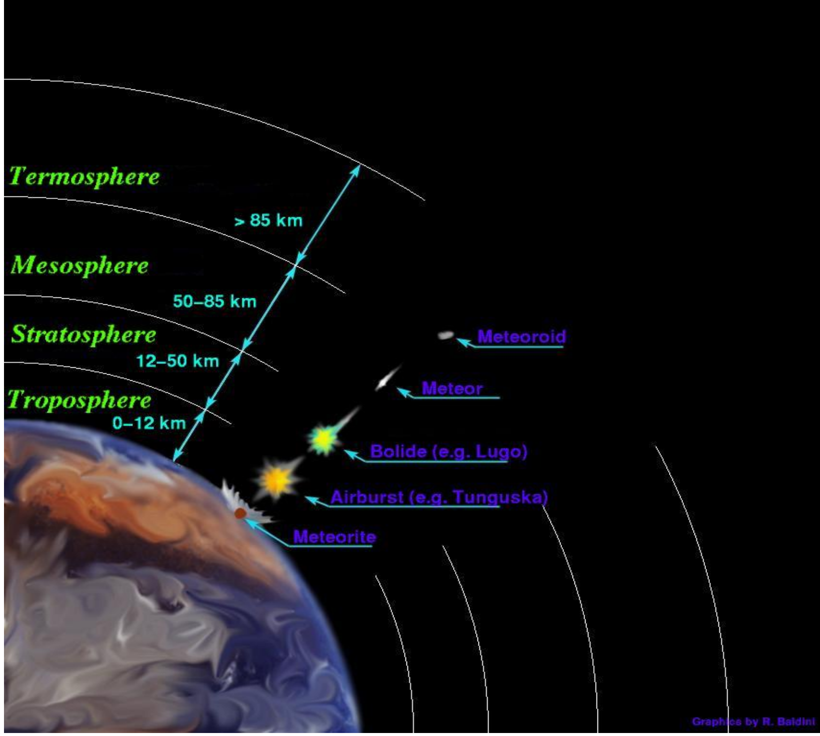
$$A_{geo}^{Nadir} \approx 1.3 \times 10^{5}\ km^{2}$$

Adams et al. , Astr. Part. Phys. 2013

METEORS

Speeds: between 12 and 72 km/sec

Durations: : ~ 0.5 ÷ 3 s



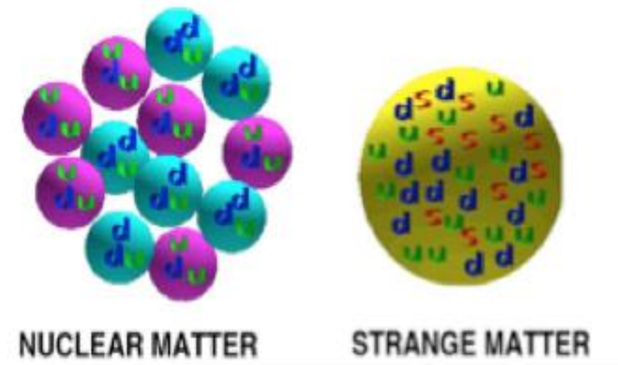
These are very slow events for JEM-EUSO !

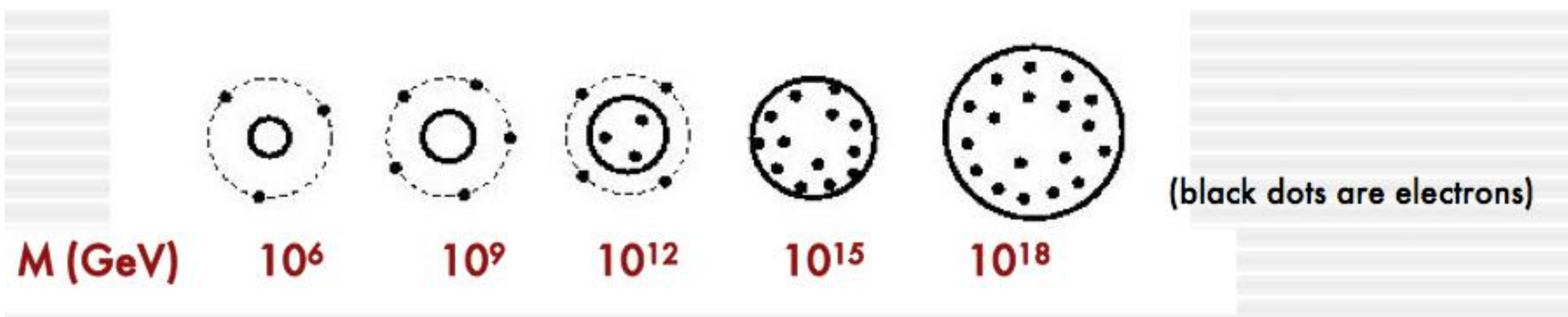
A meteor simulator has been developed. The goal of simulations is to have a phenomenological model of the expected signals, to optimize the procedure of data treatment for JEM-Euso operations.

See: Adams et al., Experimental Astronomy 40, 253-279 (2015)

Another, exciting application: Strange quark matter (nuclearites, strangelets)

- Aggregates of u, d, s quarks + electrons of equal number, density: 3.5×10^{14} g cm^{-3}.
- Ground state of nuclear matter (E/A < 930 MeV).
- Stable for any baryon number A





Nuclearites : core + electrons , neutral, $A > 10^6$
Strangelets : positively charged, $A < 10^6$

CDM candidate
Cosmic ray component

References:
E. Witten Phys. Rev. D30(1984) 272A
De Rujula & Glashow Nature 312 (1984) 734

The fraction of energy dissipated as light in possible collisions is ~ 4%. It does not depend upon radius or velocity.

Speed: of the order of 300 km/sec. No ablation.

Absolute magnitude

$$M = 15.8 - 1.67 \cdot log_{10}(m/1\mu g).$$

Expression of the magnitude derived from predicted luminosity expressed as a function of mass.

Apparent Visual magnitude : 20 g nuclearite at 400 km distance from observer → *M* = 6

Absolute magnitude : 20 g nuclearite → *M* = 3.6

Models expect a Maximum possible height for light emission

$$h_{max} = 2.7 \ln(m/1.2 \times 10^{-5}\ g)\ \ \text{km}$$

Nuclearites are expected to be essentially a low atmosphere phenomenon.

10^{-4} g nuclearite → h_{max} ~ 6 km

10^{4} g nuclearite → h_{max} ~ 60 km

E. Witten Phys Rev D30(1984) 272

De Rujula Glashow Nature 312 (1984) 734

Nuclearites with masses > 0.1 g can cross the whole Earth and move upward!

Meteor & Nuclearite simulation

INPUT

LIGHT CURVE

Meteor: yes/no secondary burst
polynomial coefficients

Nuclearite: M(mass) dependence (only)
emission for $h < h_{max}$

ISS

height of flight

velocity

METEOR

beginning height
yes/no random generation
duration
v_x, v_y, v_z
absolute magnitude
x_0,y_0 of ISS

NUCLEARITE

h_{max}
yes/no random generation
absolute magnitude (mass)
x0,y0 of ISS
v_x, v_y, v_z (any v_z possible)

METEOR / NUCLEARITE

SIMULATOR

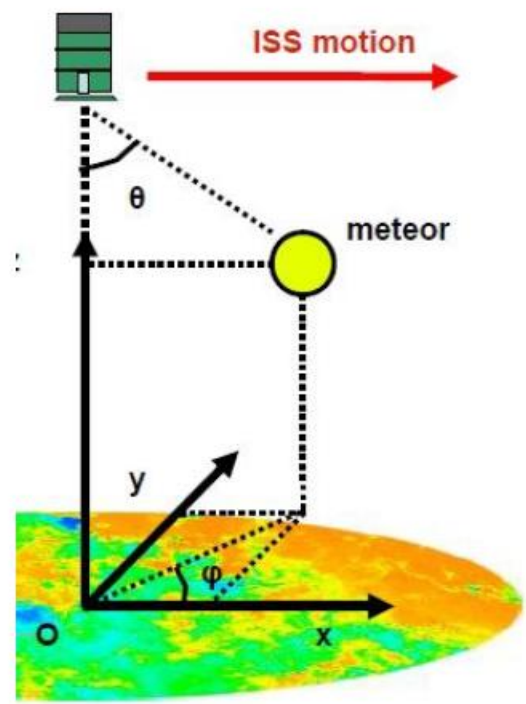
OUTPUT

METEOR/NUCLEARITE
FROM THE GROUND

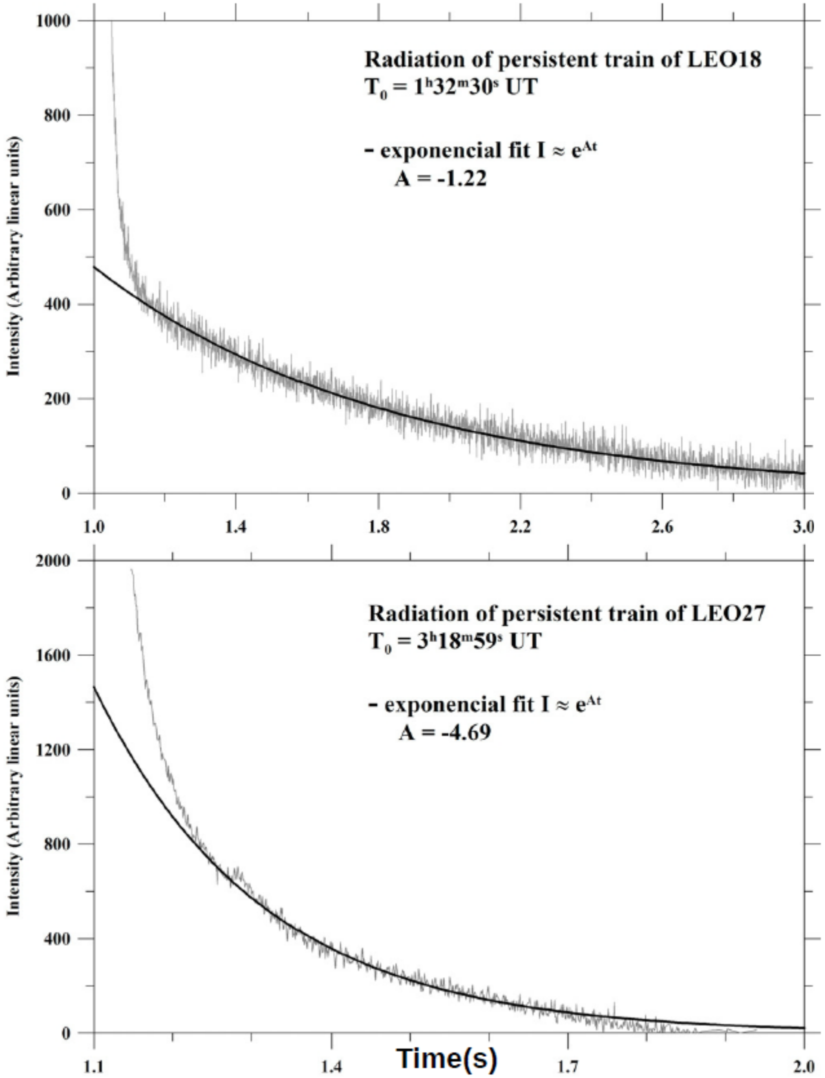
timestep
x, y, z
flux
x, y, z of the ISS

METEOR/NUCLEARITE
FROM ISS

timestep
x, y, z
flux
zenith angle (θ)
azimutal angle (φ)
x, y (pix)



Can we compute 3-D meteor orbit from JEM-Euso data taken aboard the ISS? Possibly yes, in some cases!

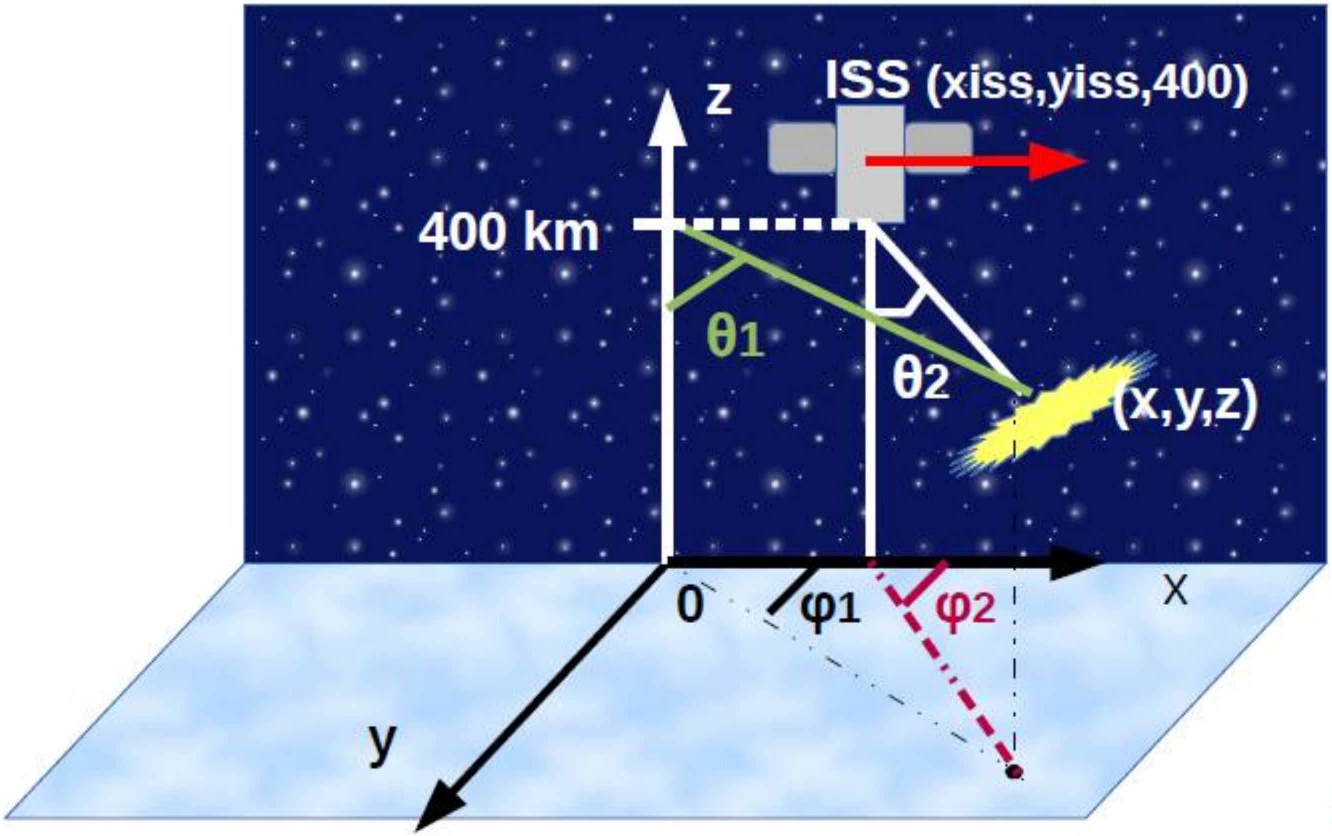


Every point of the light trajectory does not disappear instantaneously, but it decreases according to some exponential function of time:

$$I \approx e^{At}$$

A = damping coefficient

	A (counts/s)
LEO18	**-1.22**
LEO27	**-4.69**
LEO51	-19.52

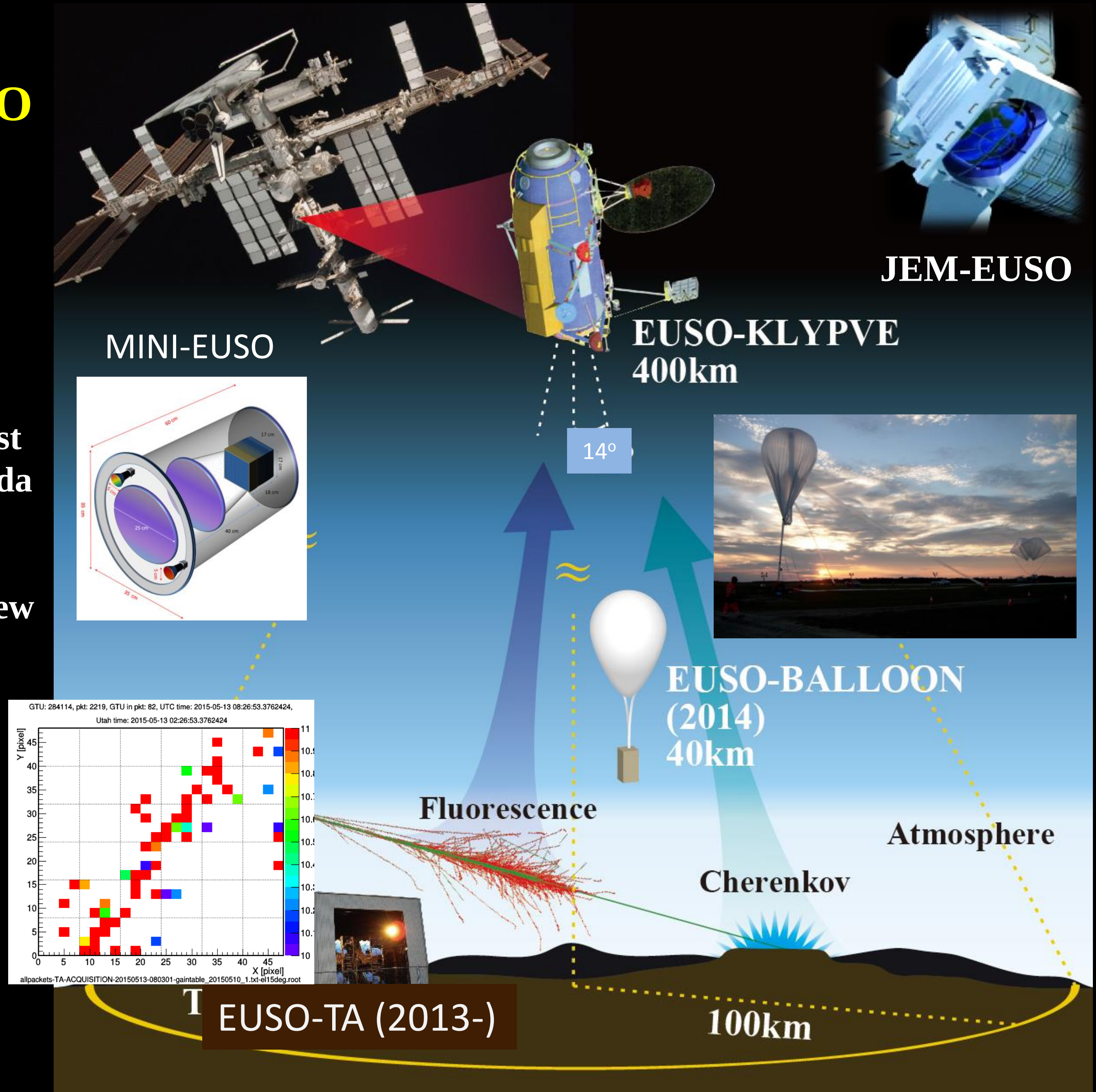


Single, fading points of the meteor track can then be seen from different directions, by exploiting the motion of the ISS (7.8 km/s)

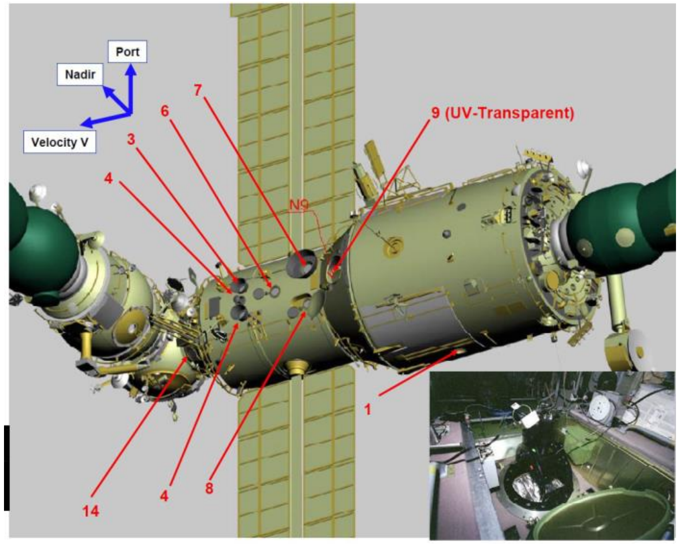
Of course, simultaneous ground-based observations are in principle extremely useful !

Steps toward the (JEM)-EUSO program

1. **EUSO-TA: Ground detector at Telescope Array site: 2013**
2. **EUSO-BALLOON: 1st flight Timmins, Canada (CNES) Aug 2014; Ultra long duration flight (EUSO-SPB) New Zealand, 2017**
3. **MINI-EUSO (2018)**
4. **K-EUSO (2019)**
5. **JEM-EUSO (>2020+)**



Mini-EUSO



It will be hosted in the **Zvezda Module of the ISS. UV transparent Nadir looking window.**

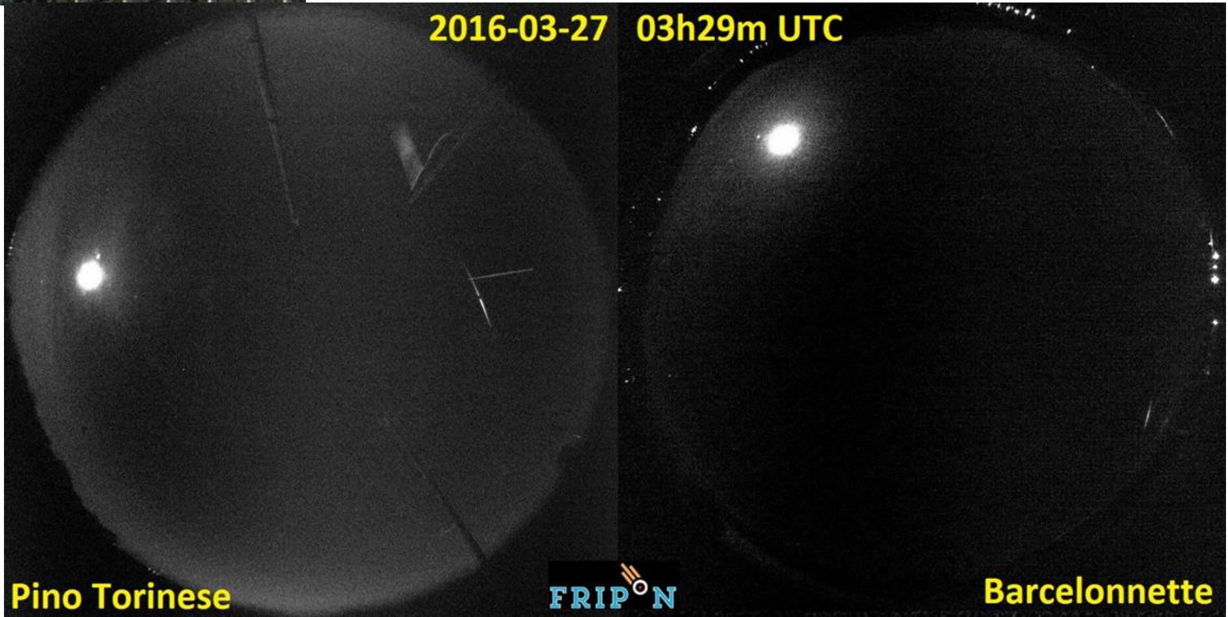
Based on a proposal approved by ASI- the Italian Space Agency

Mini-EUSO is included, with the name **UV Atmosphere,** into the Russian **"Stage program of scientific and applied research and experiments"** *Engineering model currently being tested in Rome. Delivery to Moskow planned in summer (2017).* ***Flight is scheduled in 2018***

Seguire la presentazione di Mario Bertaina questo pomeriggio

Nel frattempo, la situazione evolve in fretta nel campo delle osservazioni da Terra. Un impulso forte è venuto dal progetto FRIPON, a cui Torino si è associato fin dai primi tempi.

La camera FRIPON installata all'Osservatorio di Torino



Primo bolide osservato da Torino, la notte di Pasqua del 2016

Alcuni argomenti da discutere

- Complementare le osservazioni ottiche con osservazioni nel radio. In passato, si era fatto qualche esperimento usando un ricevitore a Padova. Il progetto francese FRIPON sta cercando a sua volta di sviluppare un segmento radio.

- Possibili applicazioni nel campo dell'osservazione di detriti spaziali richiedono un cambiamento delle modalità di funzionamento previste per FRIPON, data la necessità di osservare segnali più deboli.

- Trovare fondi ! Un progetto PRIN-MIUR è stato proposto nel 2016, ma non accettato. Bisognerebbe riprovare adesso, con una base di lavoro già partito. C'era stato anche un tentativo di rispondere ad una call europea limitata alle regioni montane, ma bisognava "venderlo" bene in termini di studi di fenomeni atmosferici, e la cosa si è fermata lì. Altre possibilità: PRIN-INAF, se mai verrà.


Grazie per l'attenzione!