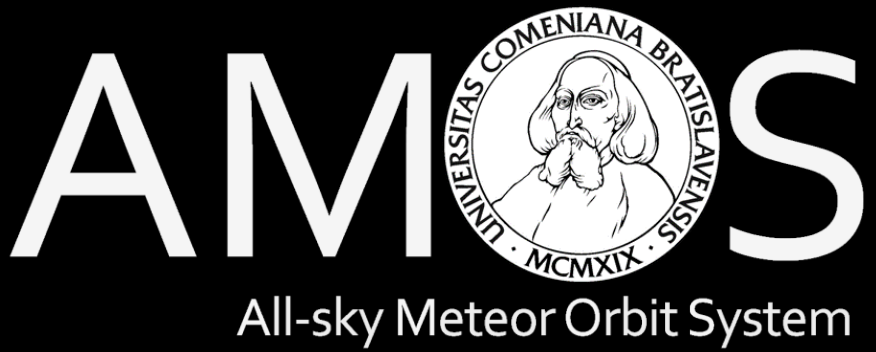
# Fyzika ,,padajúcich hviezd” – čo vidí AMOS?




doc. RNDr. Juraj Tóth, PhD.

Fakulta matematiky, fyziky a informatiky UK v BA

+

AMOS Team

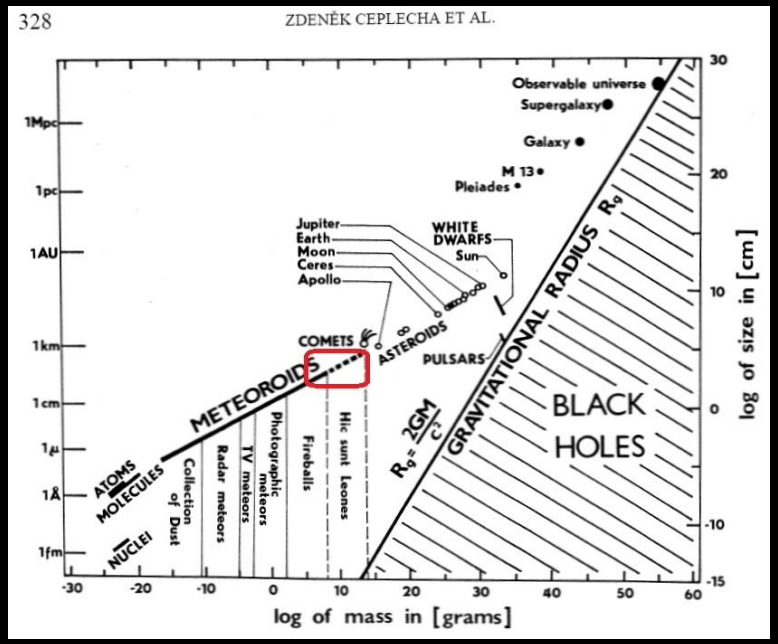
# Outline of the talk:

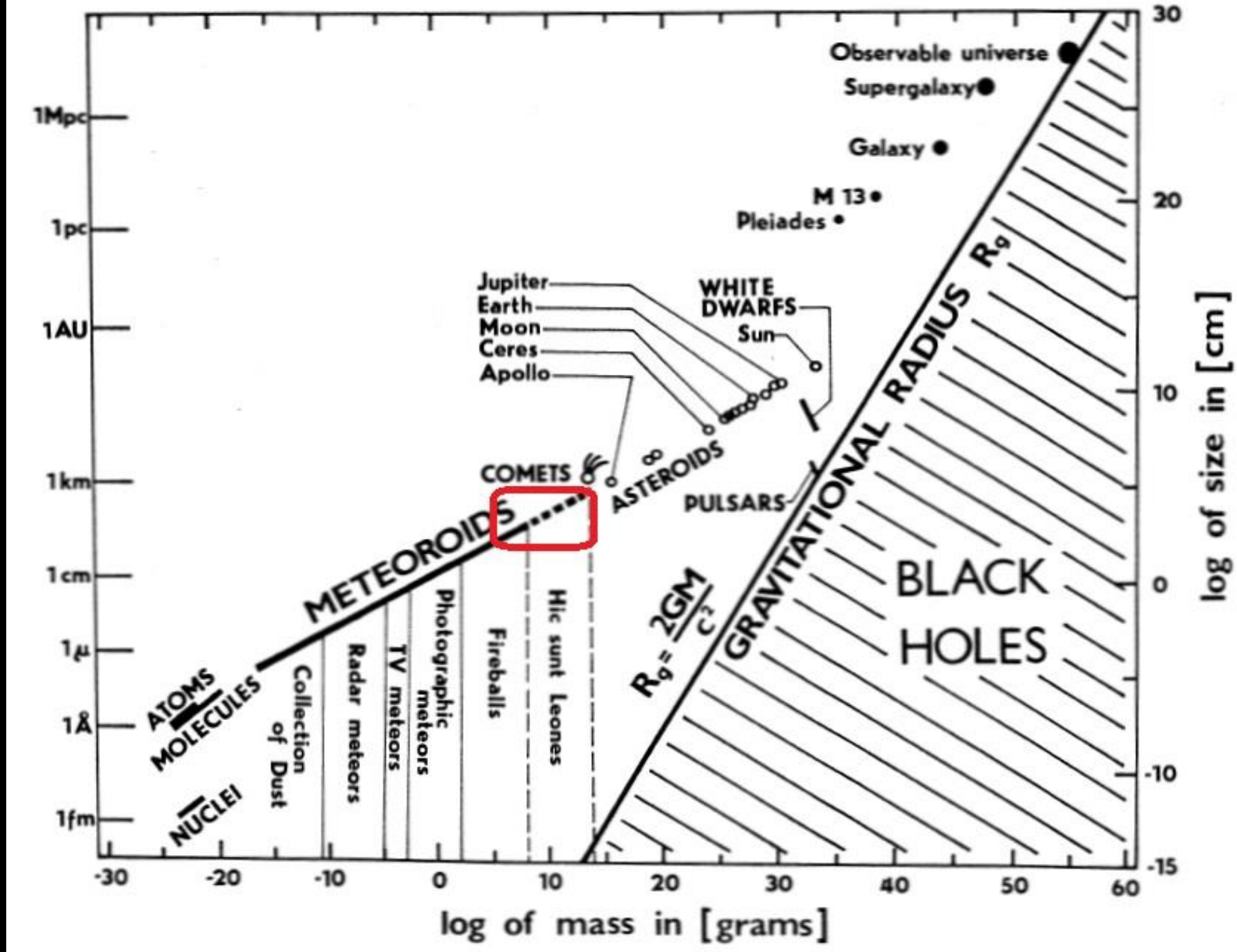
- Introduction to meteroroid’s world
- Motivation for the AMOS system and the network
- AMOS system description
- Network
- Some results

# What is a meteoroid?

- IAU definition of meteoroid: natural object 30µm – 1m

- mostly fragments of comets and asteroids
- few samples returned from space (Stardust, Hayabusa)
- natural delivery of planetary material daily/nightly
- Detection: eye, photo, video, CCD, radar, infrasound
- We learn: dynamical, chemical and physical properties by optical systems
- Dynamics -> parent bodies




Observable universe
Supergalaxy
Galaxy
M 13
Pleiades
Jupiter
Earth
Moon
Ceres
Apollo
WHITE DWARFS
Sun
COMETS
ASTEROIDS
PULSARS
METEOROIDS
ATOMS
MOLECULES
NUCLEI
Collection of Dust
Radar meteors
TV meteors
Photographic meteors
Fireballs
Hic sunt Leones
GRAVITATIONAL RADIUS $R_g$
$R_g = \frac{2GM}{c^2}$
BLACK HOLES
1Mpc
1pc
1AU
1km
1cm
1μ
1Å
1fm
30
20
10
0
-10
-15
-30
-20
-10
0
10
20
30
40
50
60
log of size in [cm]
log of mass in [grams]

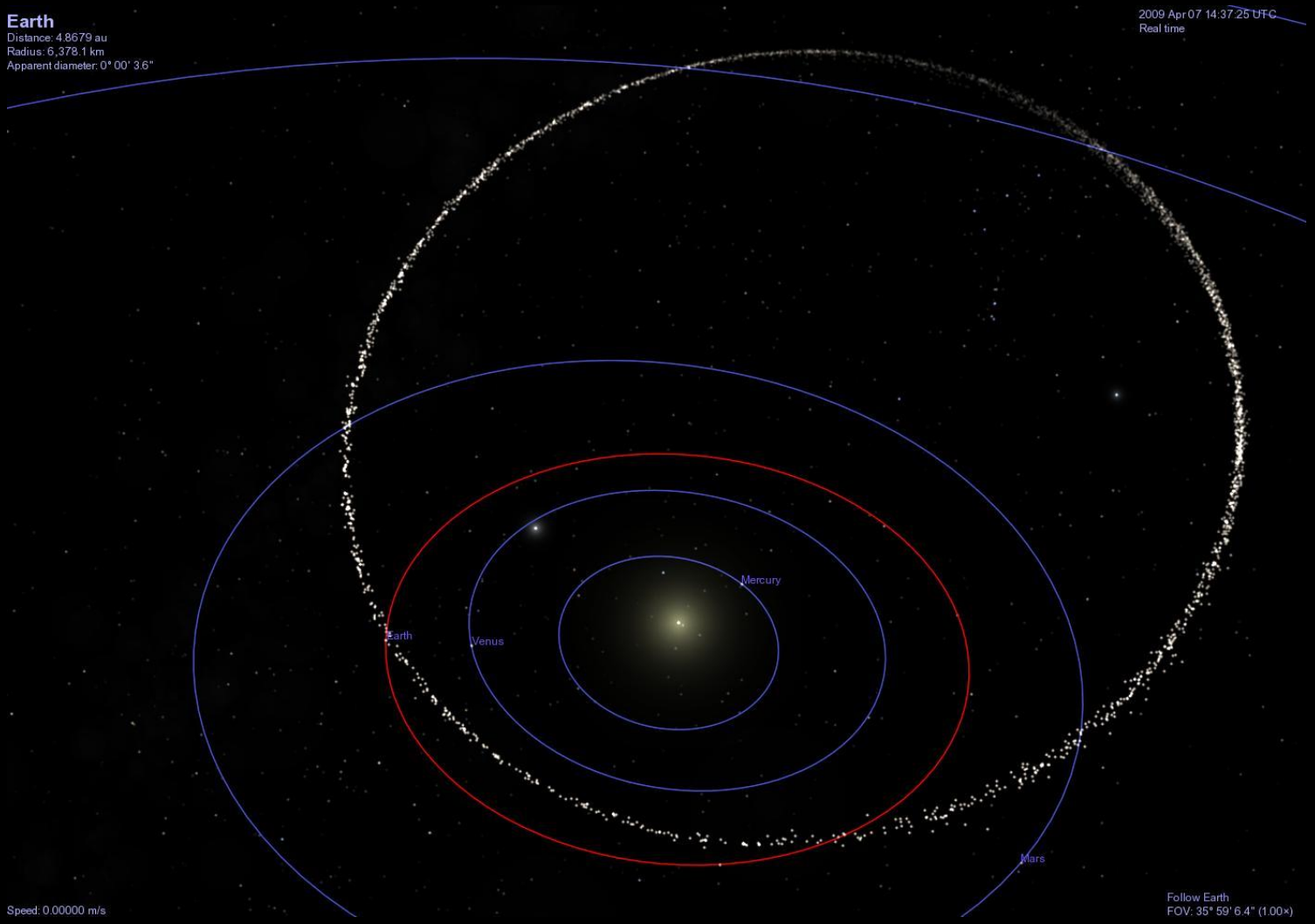
# From comets & asteroids to meteoroids

- Gas drag, impacts, tidal break-ups, …


67/P, ESA

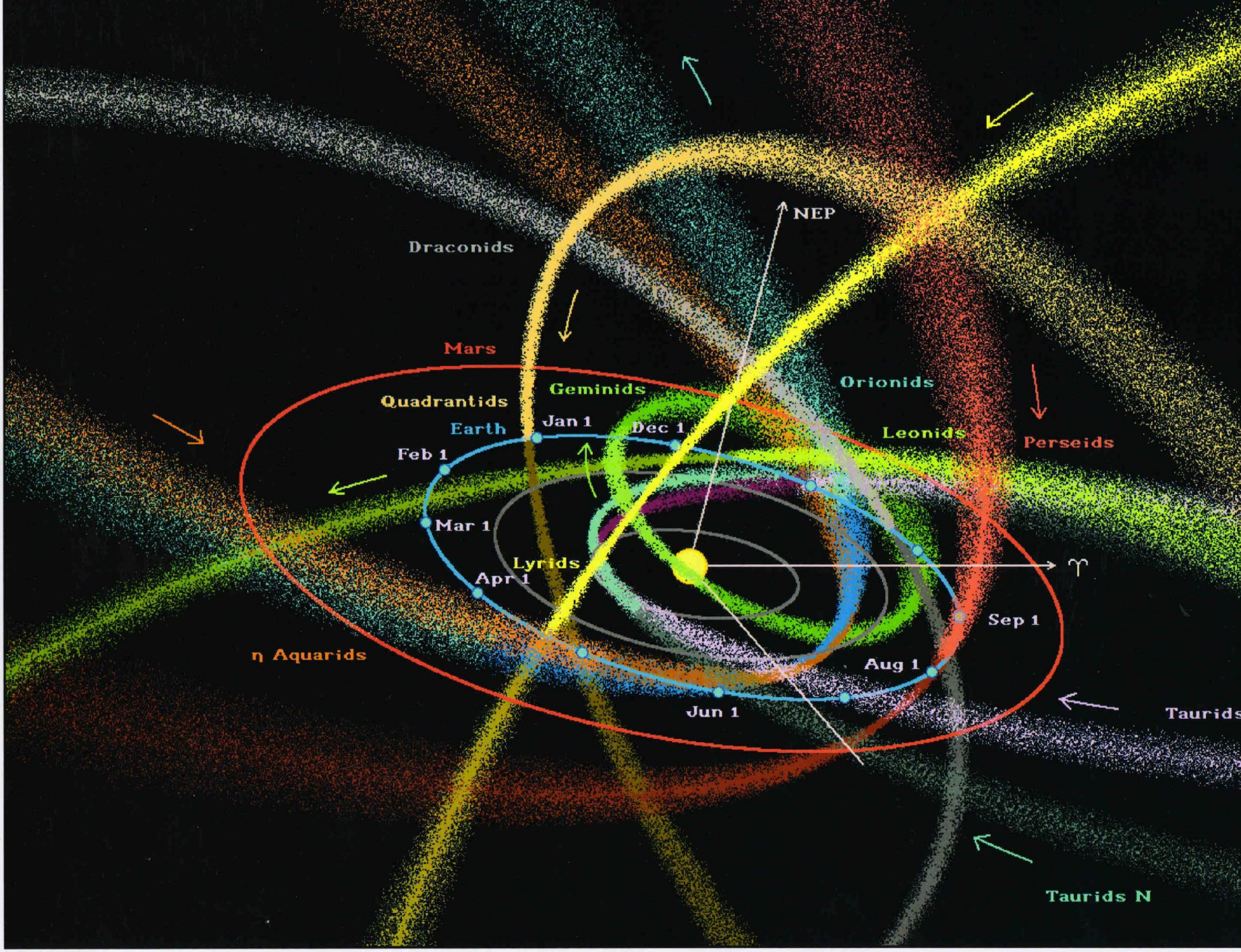
Asteroid Itokawa, JAXA

# Meteoroid stream …




Tóth, Vereš, Kornoš, MNRAS, 2011

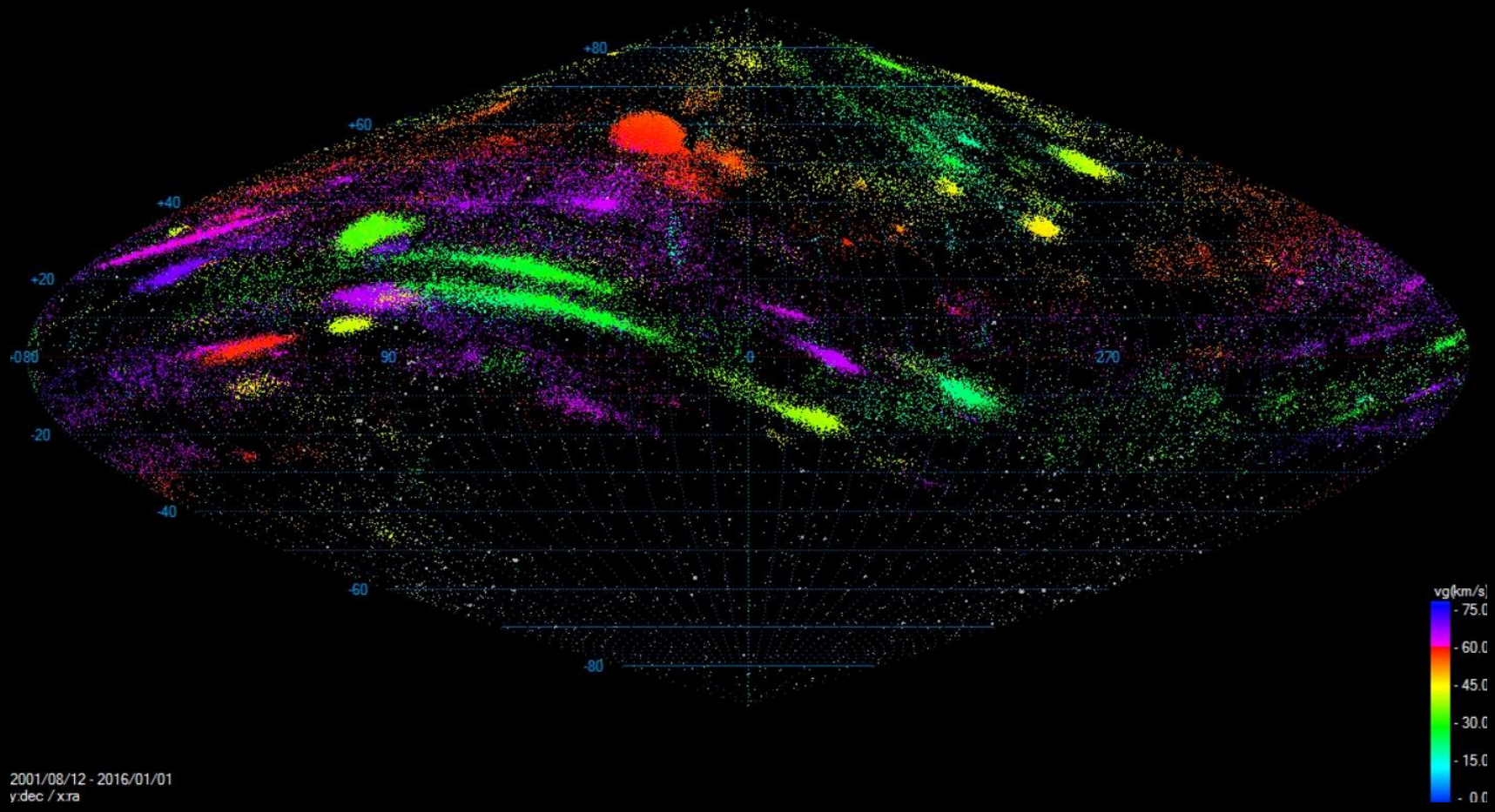
Celestia software




See inside front cover

# Meteoroids meet the Earth: meteor shower

- 112 established, 820 on the working list of m. showers (IAU MDC)

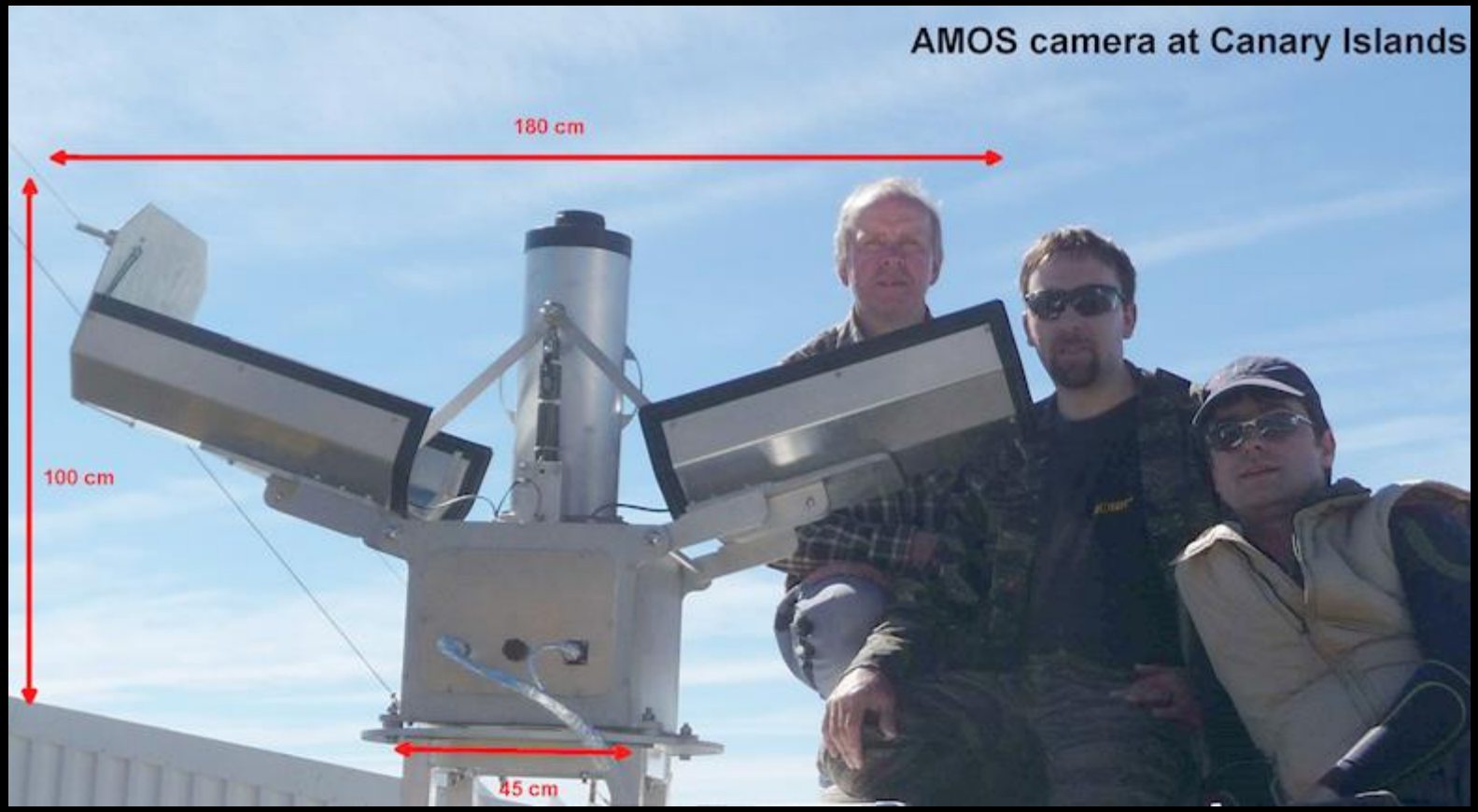


# AMOS (All-Sky Meteor Orbit System)

- our own developed and patented system

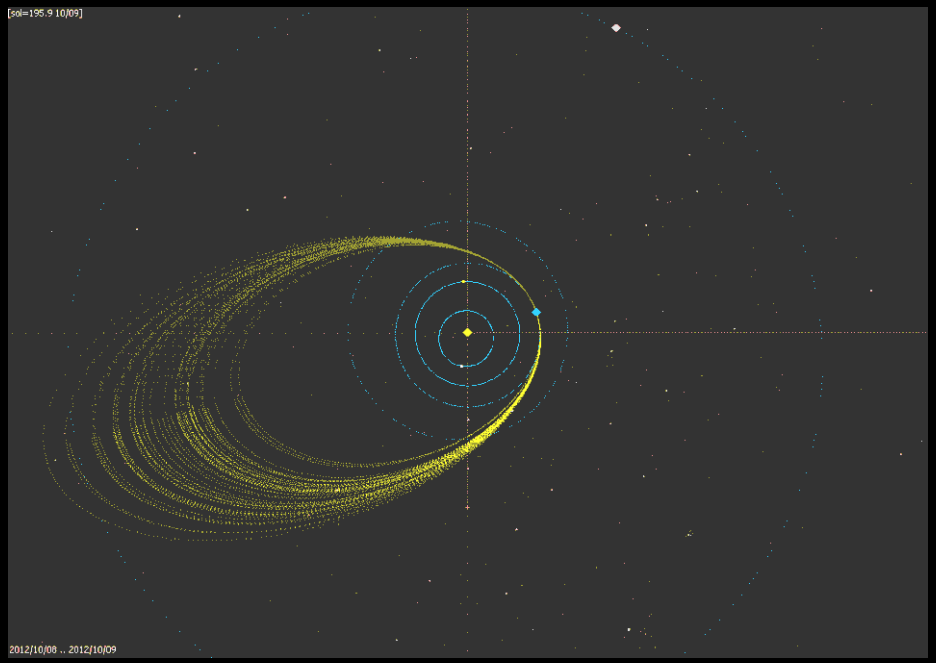
# AMOS instrumentation:

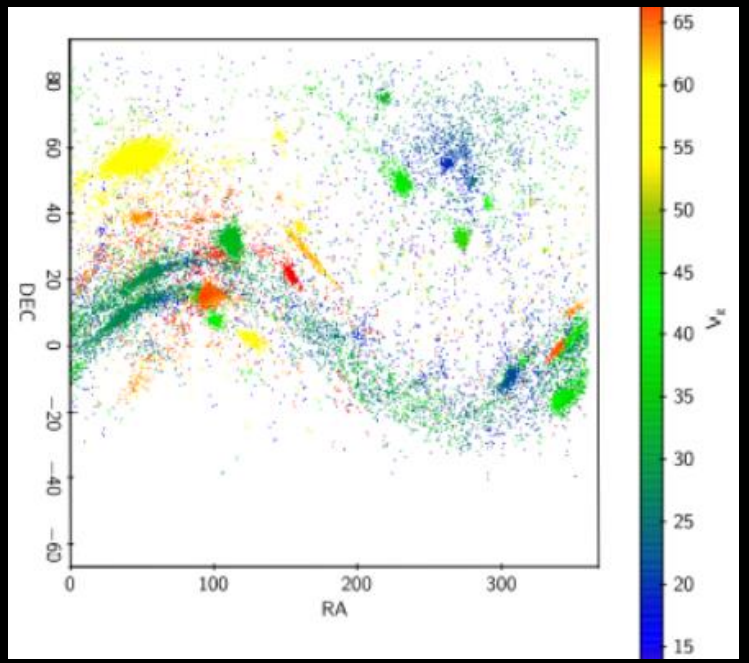
- Autonomous intensified optical video system
- Field of view 180 x 140 deg
- Resolution 1600 x 1200, 20 fps
- Stellar limiting magnitude + 5.0



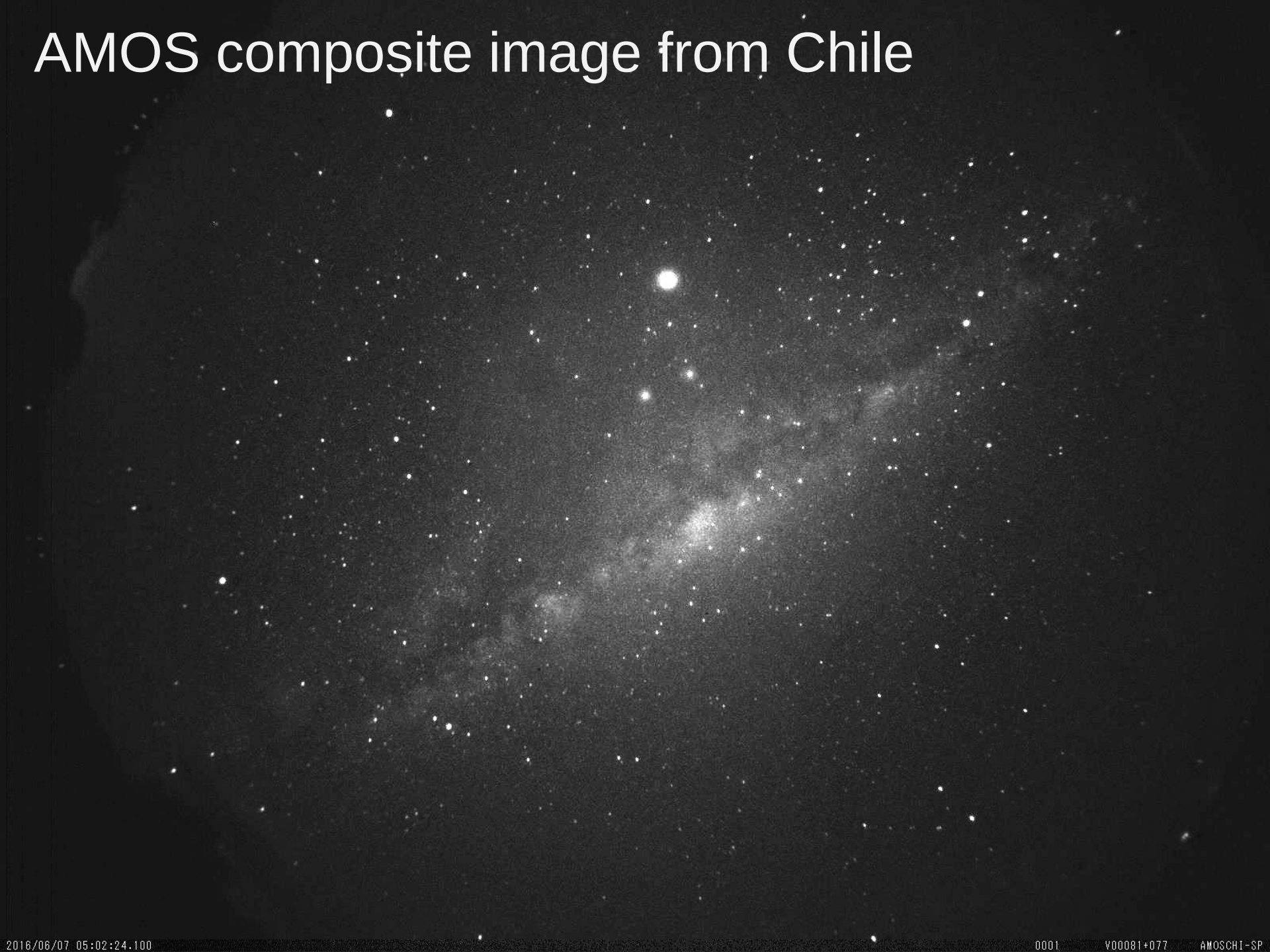
# AMOS (All-Sky Meteor Orbit System)

- dynamics of meteoroids, streams vs. parent comets/asteroids
- meteoroid flux variations
- spectral study of meteors in the atmosphere
  - orbital distribution of primitive and evolved meteoroids
- meteorites recoveries – e.g. Košice meteorite (15th case with the known orbit)



# AMOS composite image from Chile

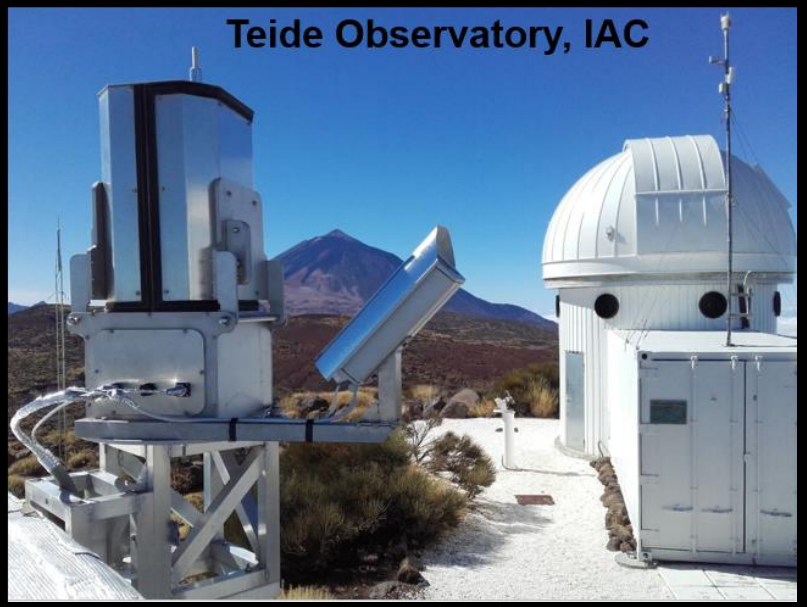


# One thousand Geminids above Tenerife Dec.13/14, 2017

AMOS, Teide, IAC
Tóth et al., 2017

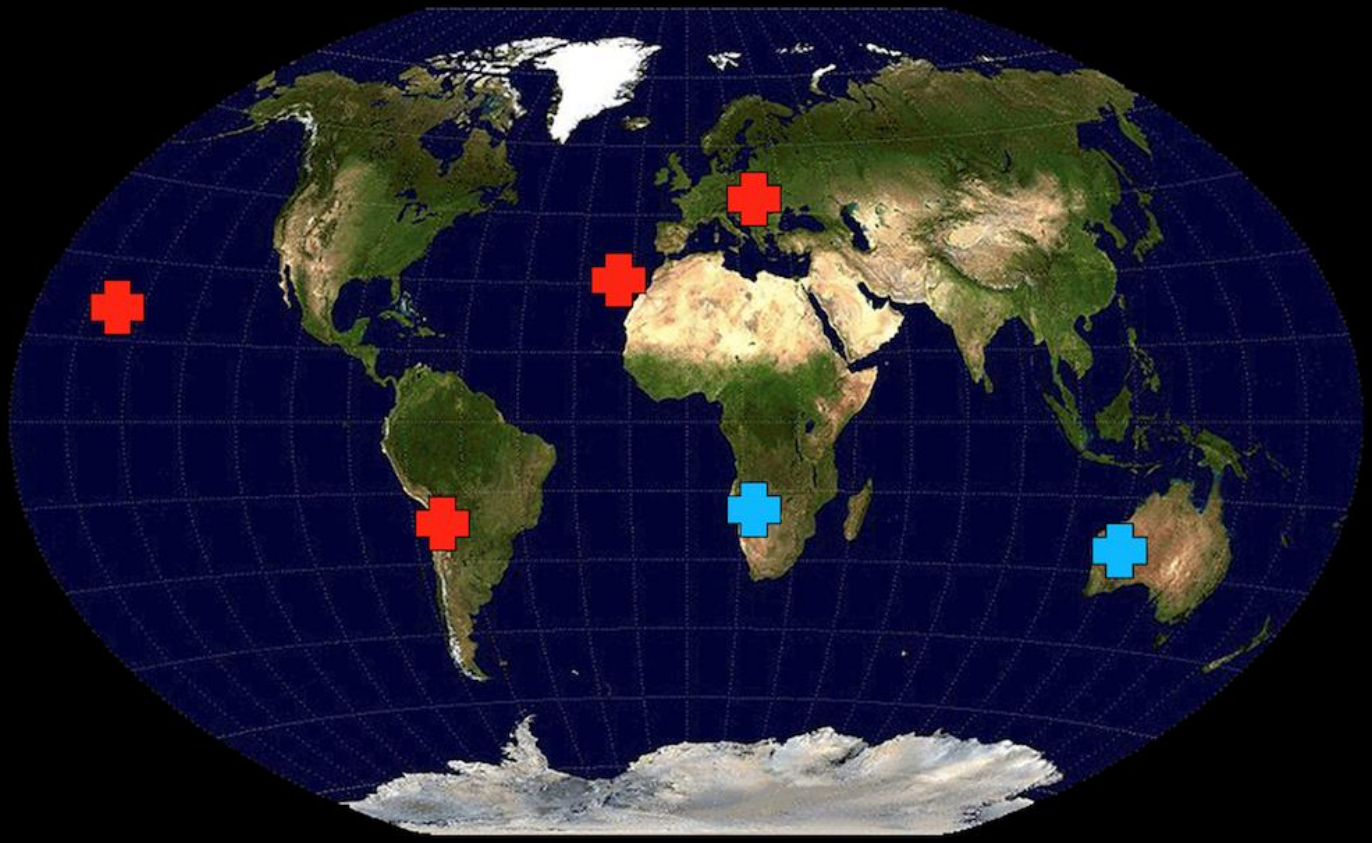
# AMOS (All-Sky Meteor Orbit System) network



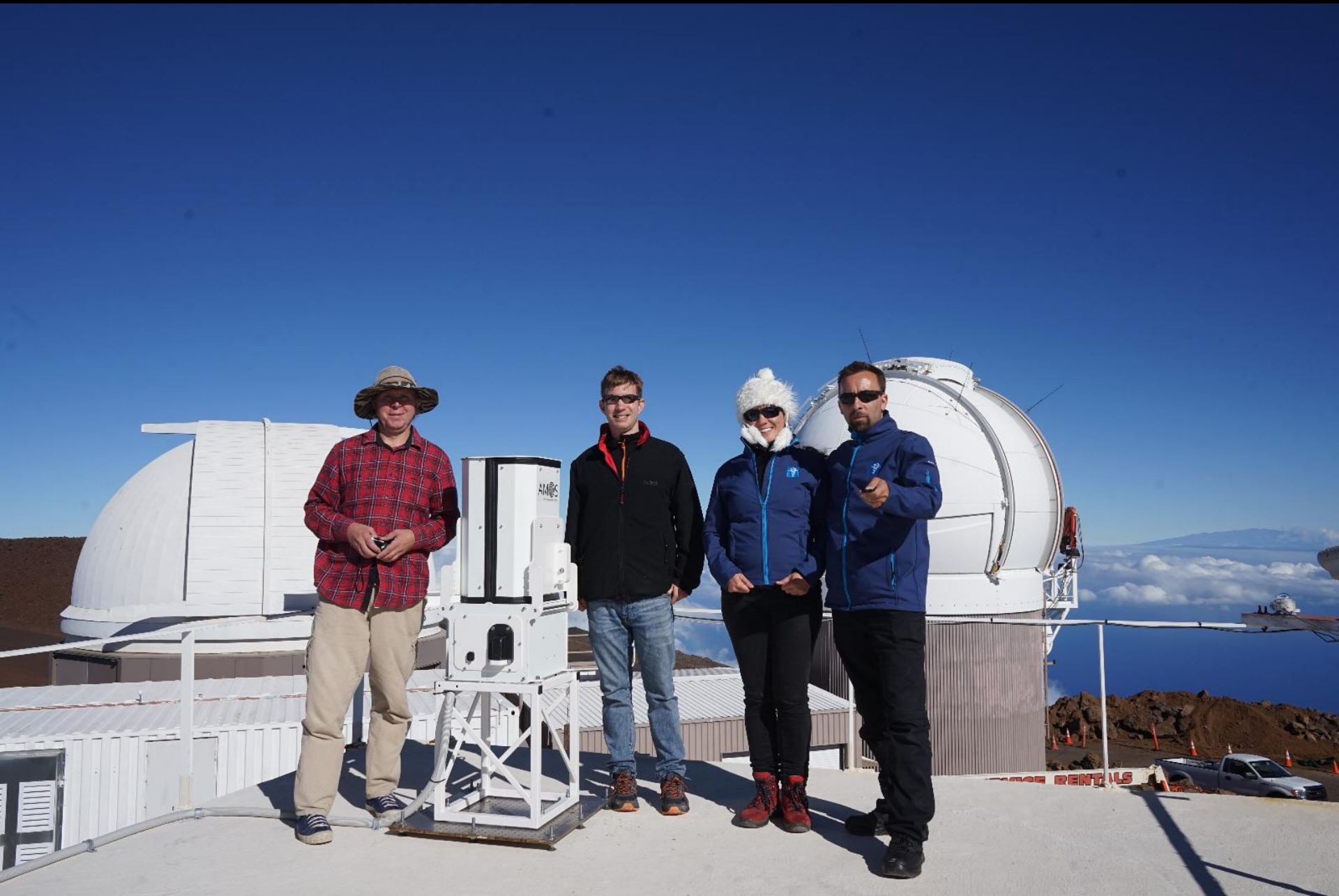
# AMOS global network – 10 stations on 4 locations

- Slovak Video Meteor Network 2009
- Canary Islands 2015
- Chile, Atacama 2016
- Hawaii, 2018



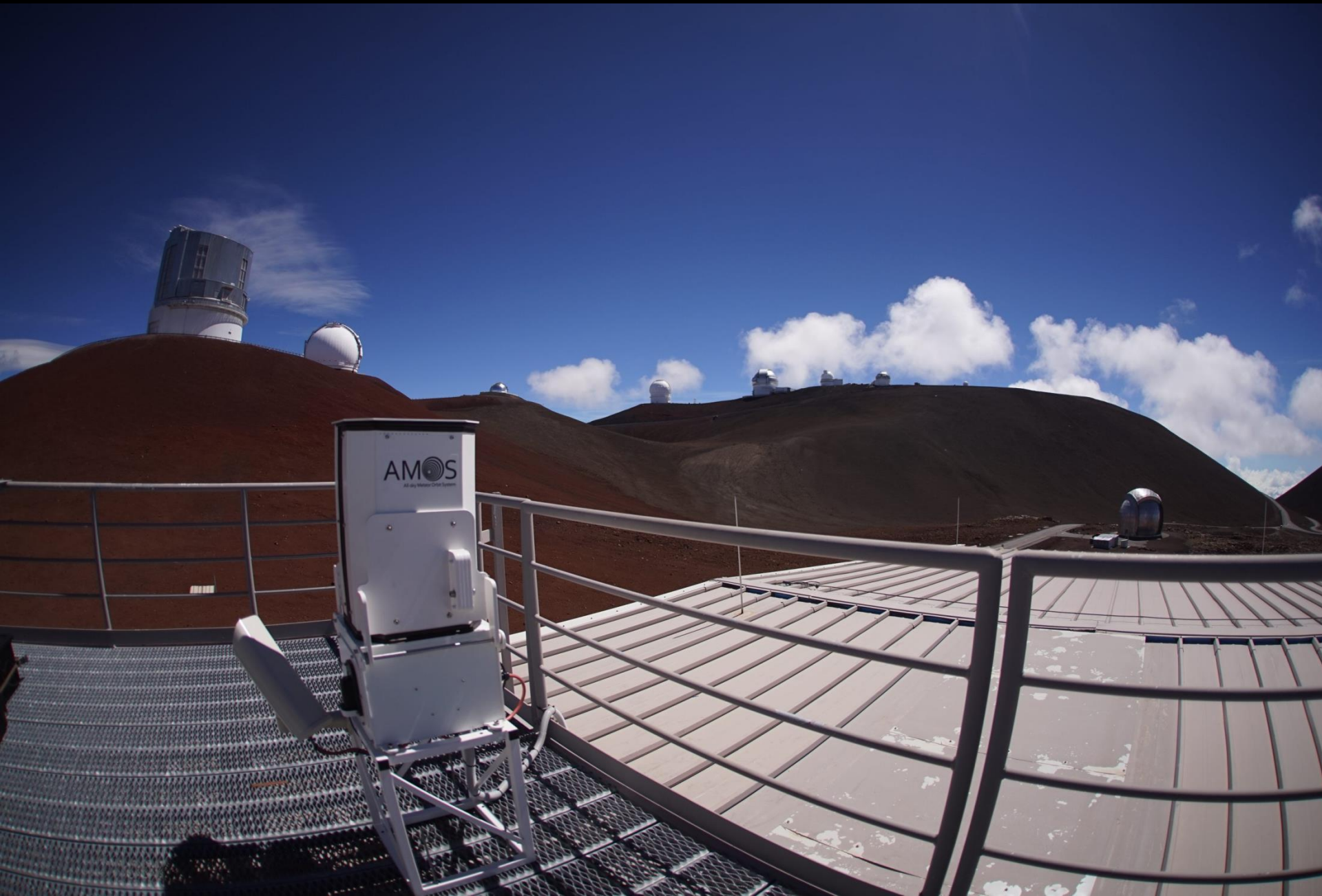
# … site selection on Haleakala

# … just installed on Haleakala



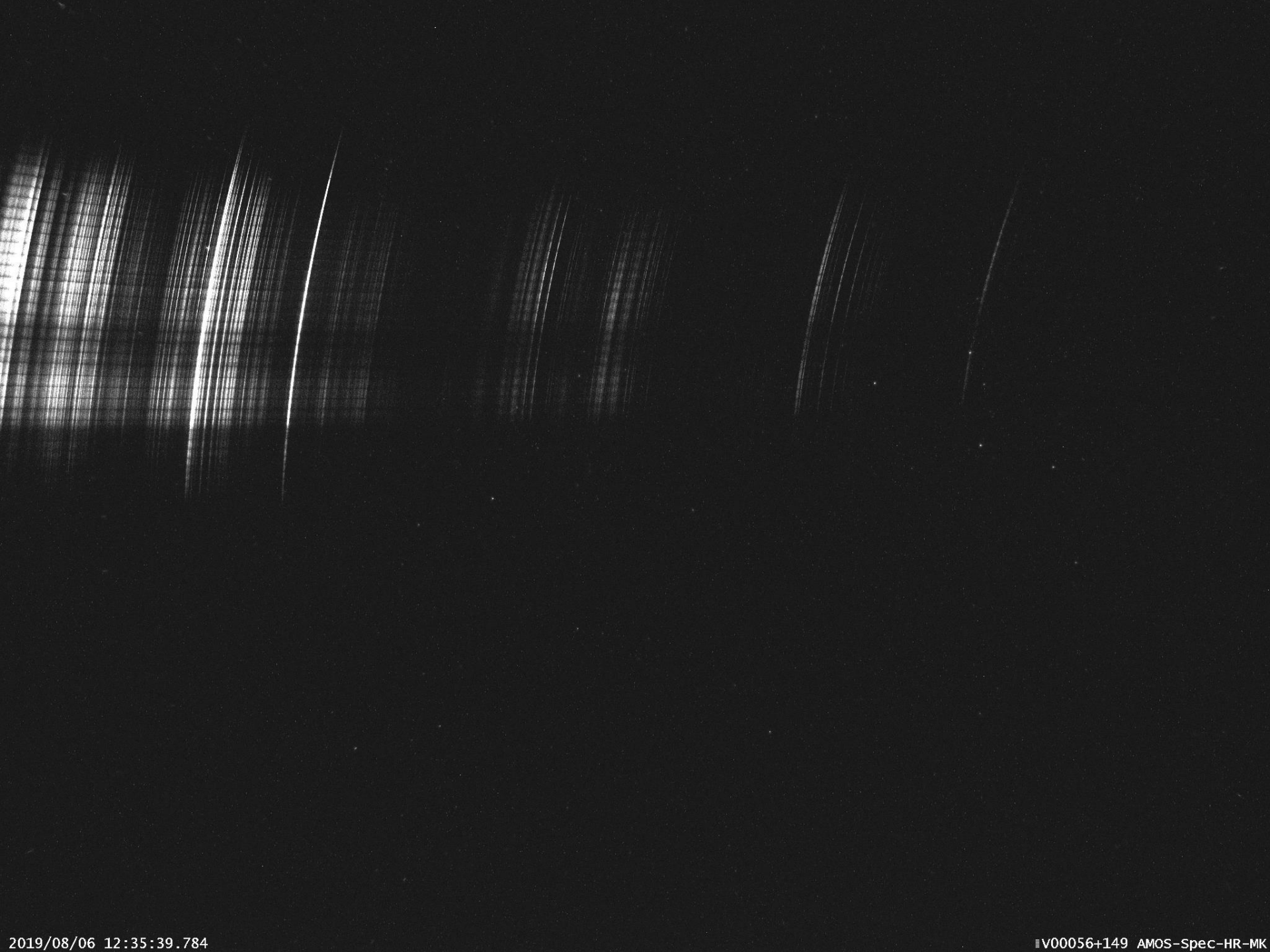
# … just installed on Haleakala

# … just installed on Mauna Kea




2020/02/05 15:39:56.345 0074
V00005+098 AMOS-HK


2020/02/04 15:56:33.213
0085
V00007+104 AMOS-MK


2019/08/06 12:35:39.784
V00056+149 AMOS-Spec-HR-MK

2018/12/03 14:53:23.601 0188 V00017+239 AMOS-HK

# The first European meteor observation airborne campaign

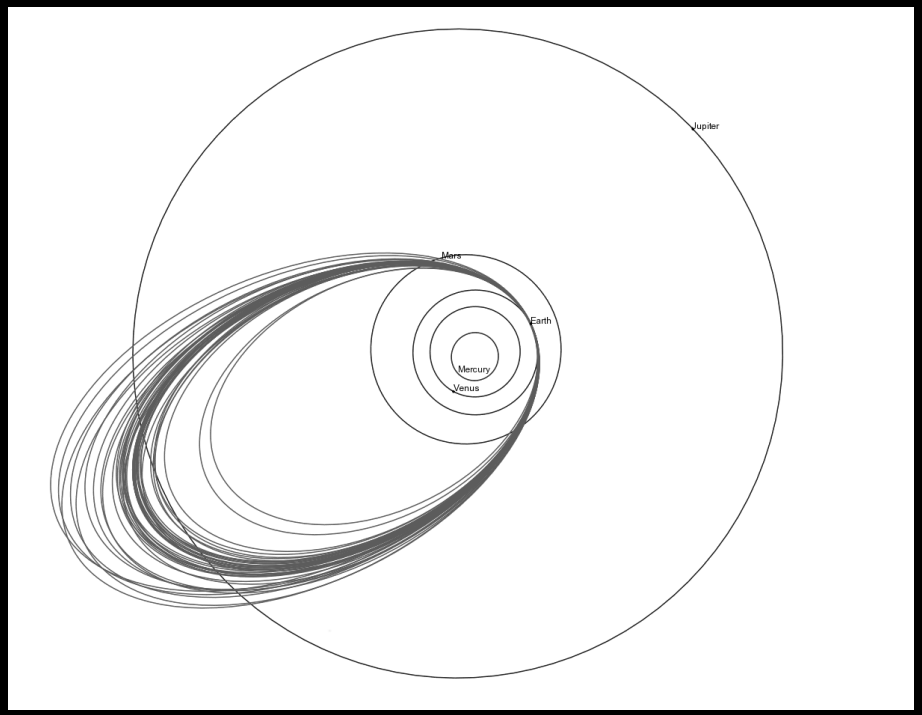

J. Vaubaillon (IMCCE, PI)
J. McAulliffe (INSA/ESA)
D. Mautet (USU)


SAFIRE
The atmosphere is our laboratory
AIRBORNE ENVIRONMENT RESEARCH SERVICE

P. Koten (Ondrejov obs, PI)
J. Zender (ESA)
J. Toth (Univ. Bratislava)

# Draconid meteor airborne campaign

- Main scientific results:
- Orbital parameters in agreement with the modeling
- Activity, flux profile as an input for the meteoroid ejection model and confirmation of activity of parent comet 21P/G-C prior its discovery




**Three Peaks of 2011 Draconid Activity Including that Connected with Pre-1900 Material**

Pavel Koten · Jeremie Vaubaillon · Juraj Tóth · Anastasios Margonis · František Ďuriš

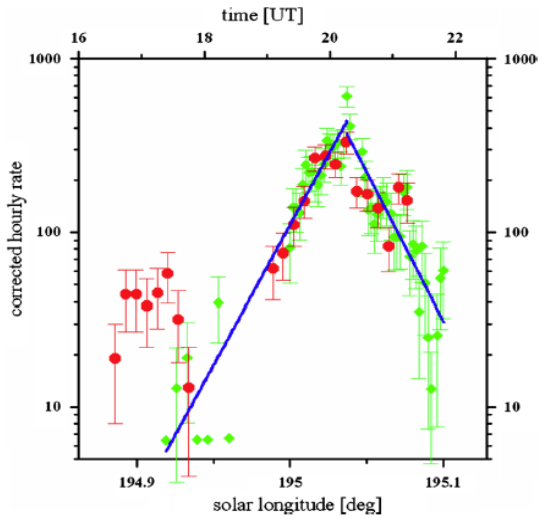
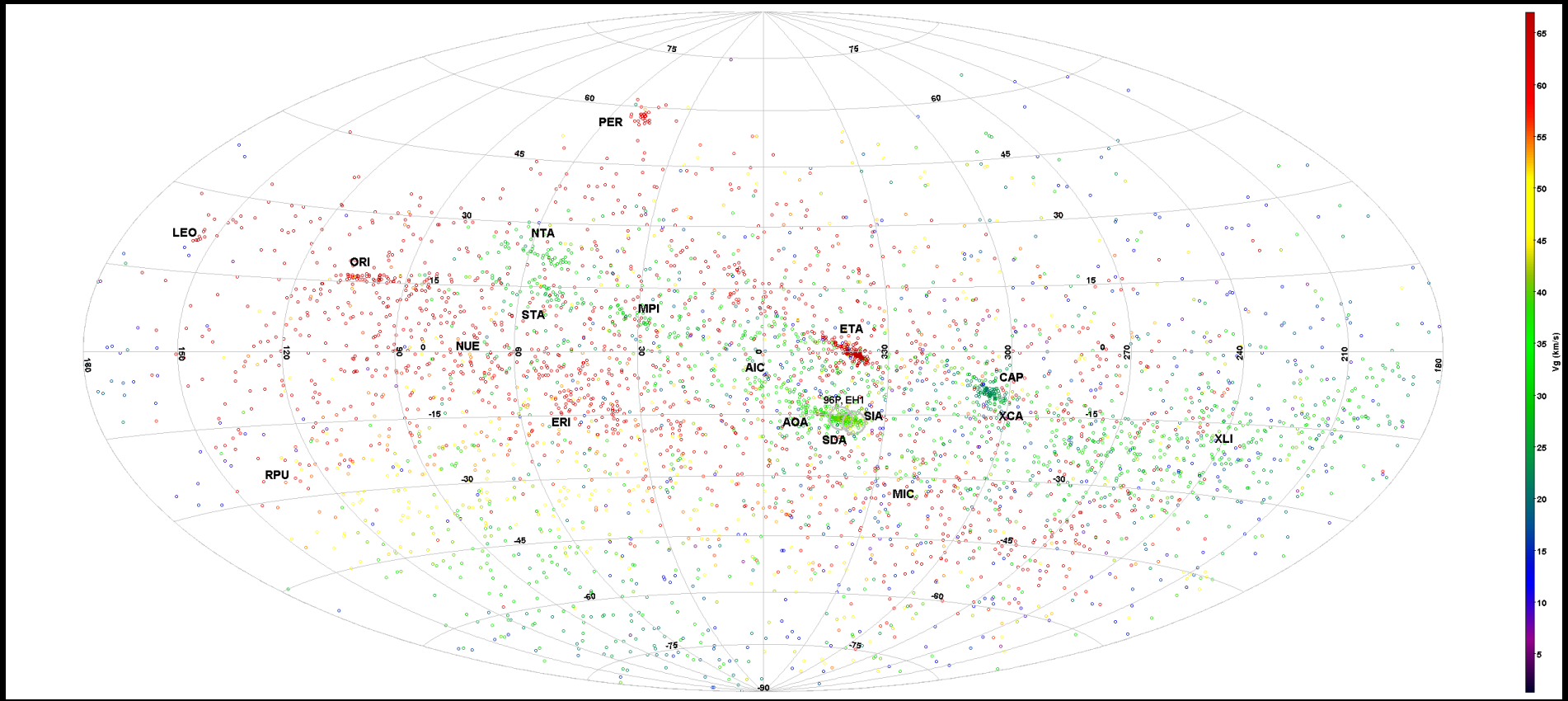



**Fig. 4** Profile of Draconid outburst activity in logarithm scale based on all the data recorded by the all-sky and SPOSH cameras. *Blue lines* show exponential fits on the all-sky camera data for ascending and descending branches. The figure shows that the profile is more symmetrical when the ground based data are included. *Red circles* represent data recorded by SPOSH camera. The first peak of activity around 17:20 UT is clearly visible

# AMOS in Chile, Atacama desert

- Radiant distribution of 4463 meteors, 03/2016 – 11/2016
- 68 meteor streams confirmed
- Agreement with the 96P/Machholz and 2003 $EH_1$ modelling and observed filaments



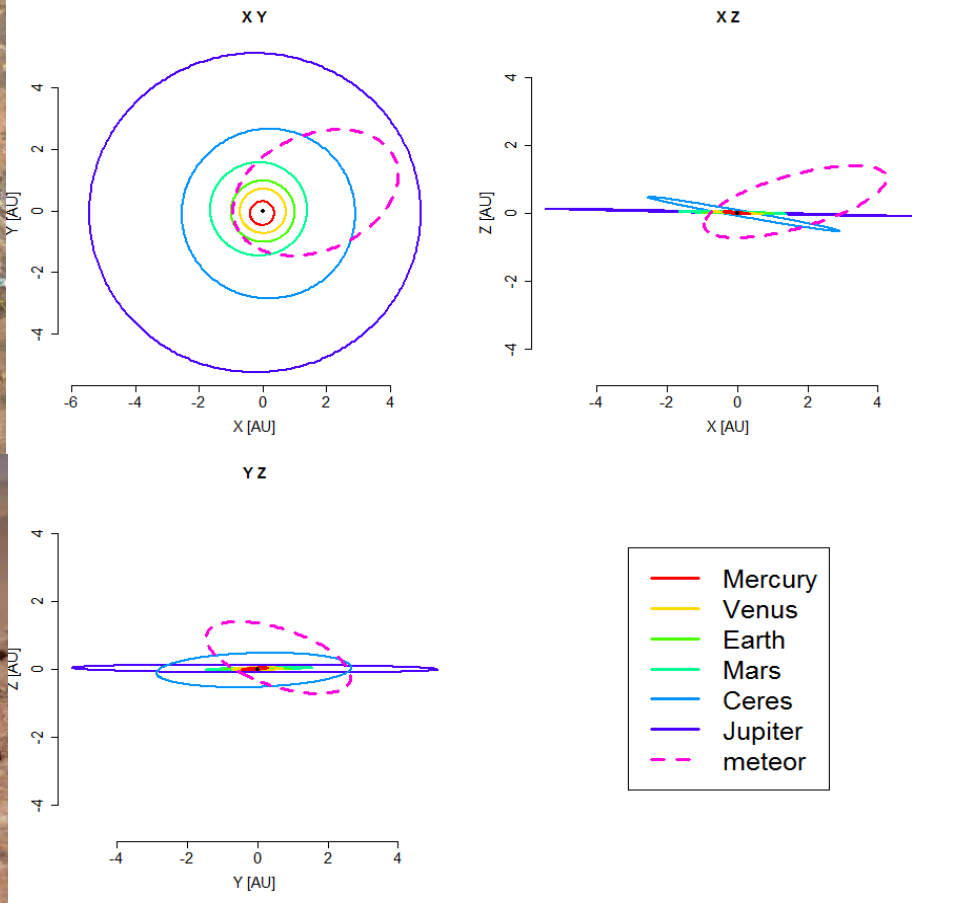
# Fireball May 1, 2016 by AMOS, Chile, $M_v$=-9$^{mag.}$

# Fireball May 1, 2016 by AMOS, Chile, $M_v$=-9$^{mag.}$

# Fireball May 1, 2016 by AMOS, Chile, $M_v$=-9$^{mag.}$

## Trajectory
$H_B$ = 90km, $H_E$ = 43km


## Orbit
a=2.85 AU, e=0.66, i=28.7°



# AMOS Spectral Instrumentation

## AMOS-Spec

| | |
|---|---|
| Camera: | 1600x1200, 12 fps |
| Grating: | 1000 grooves/mm |
| Resolution: | 1.5 nm/px |
| FOV: | 100 deg circular |
| Lim. mag.: | -2.0 |

AGO Modra (Slovakia) - since 11/2013

Supplemented by 4 AMOS stations (Slovak Video Meteor Network)

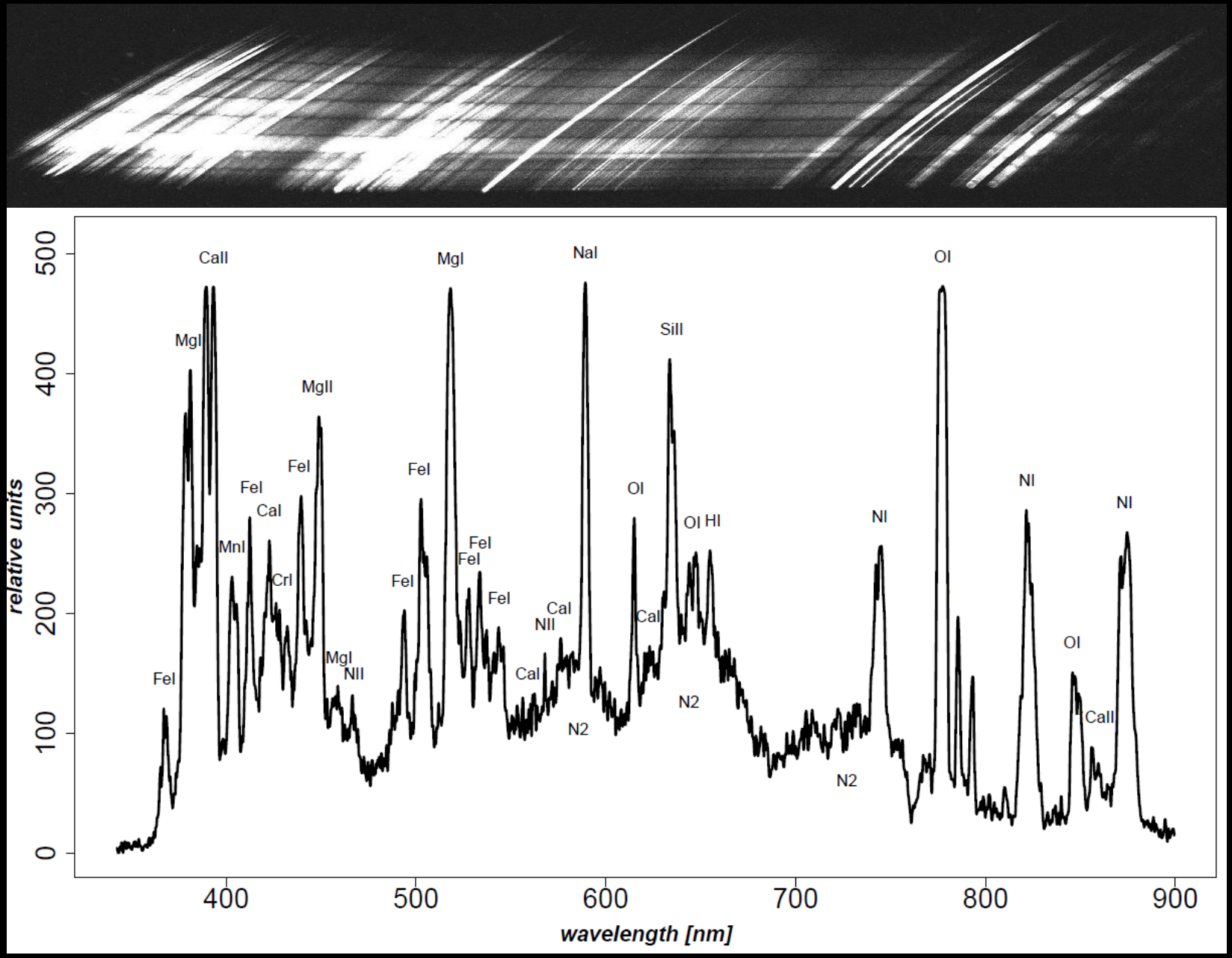
## AMOS-HS

| | |
|---|---|
| Camera: | 2048x1536, 15 fps |
| Grating: | 1000 grooves/mm |
| Resolution: | 0.5 nm/px |
| FOV: | 60 x 45 deg |
| Lim. mag.: | -1.5 |

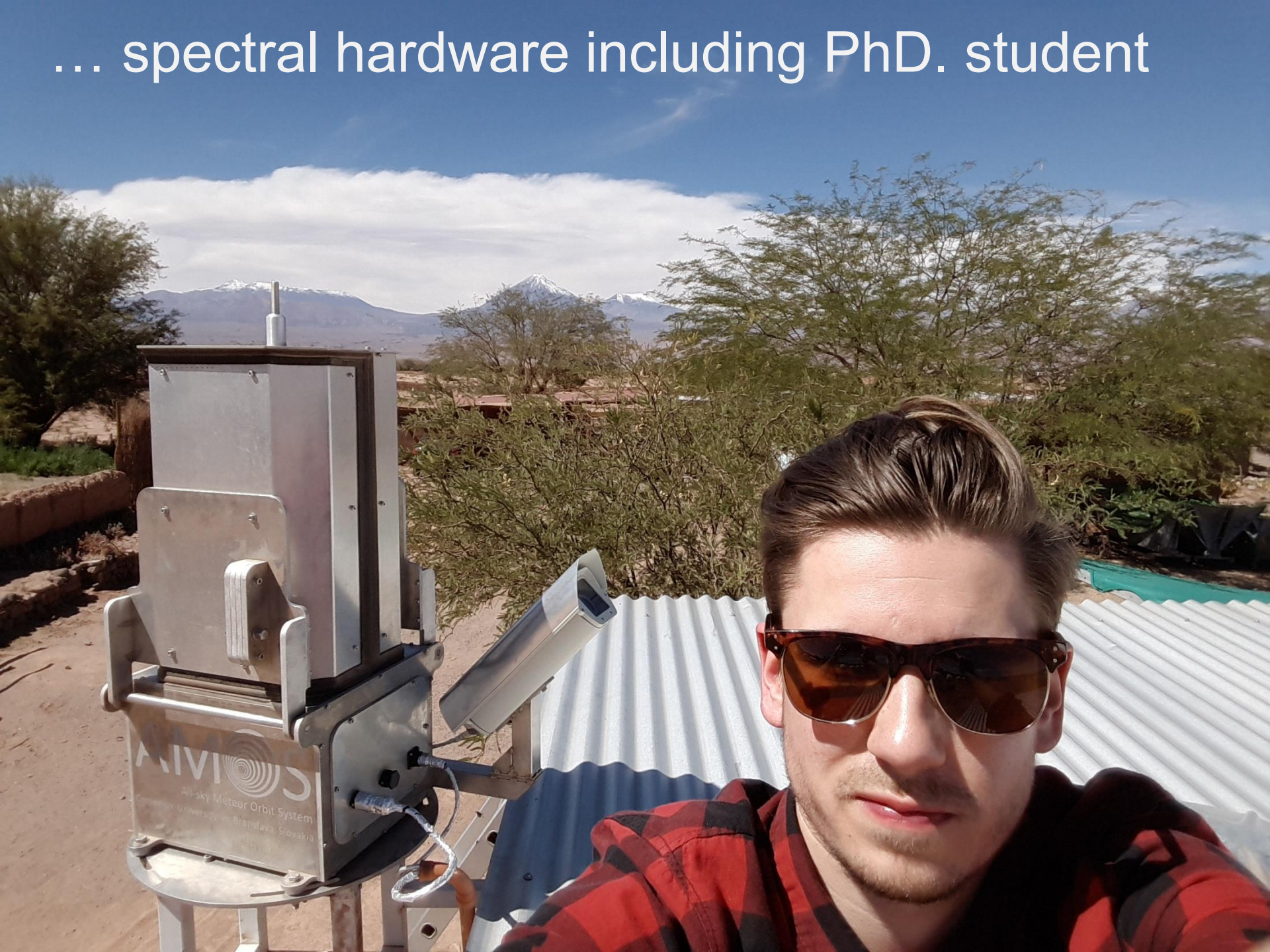
Canary Islands and Chile - since 12/2016

Supplemented by 2 AMOS stations on Canary Islands, Chile and Hawaii

# AMOS – spectral observations

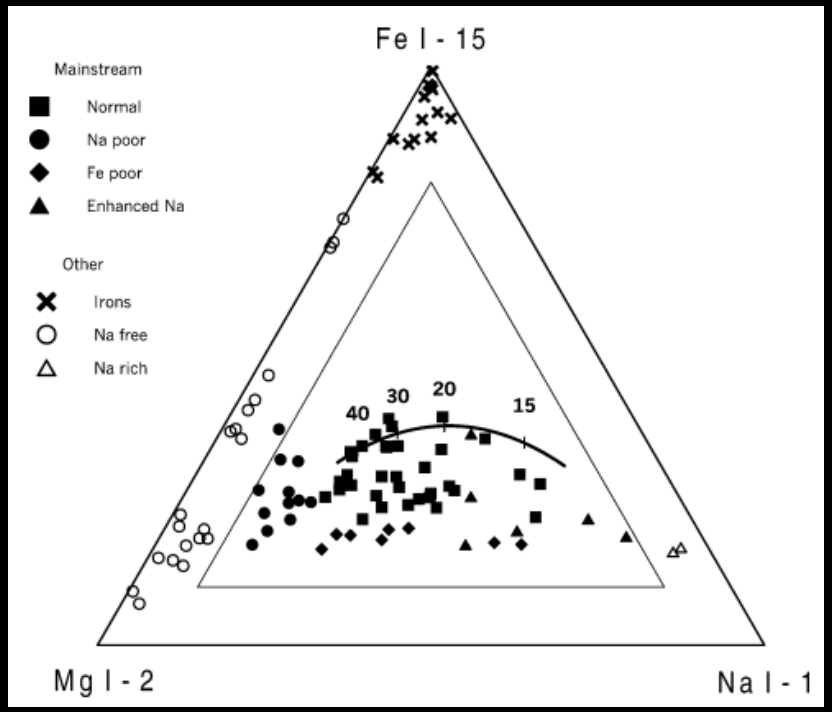


# … spectral hardware including PhD. student

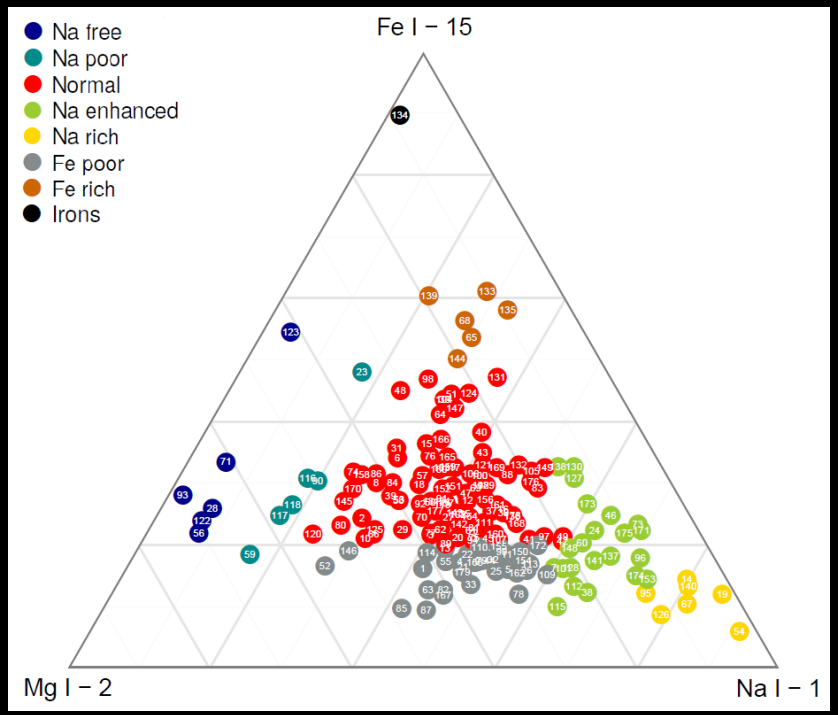


# AMOS – spectral observations, open issues

- higher Na/Mg ratio for larger meteoroids
- low number of pure iron meteoroids for cm – dm sizes
- new population of Fe rich meteoroids
- higher amount of Na rich meteoroids on Apollo orbits




(Borovička et al., 2005)

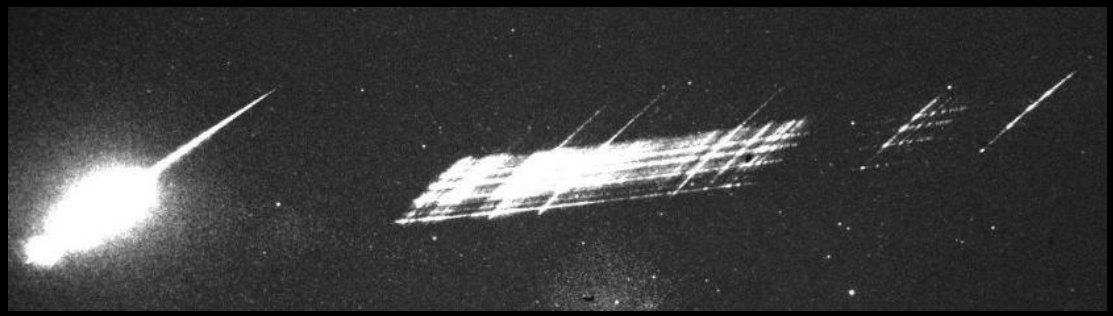



(Matlovič et al., 2019, A&A)

# Streams and implications for parent objects:

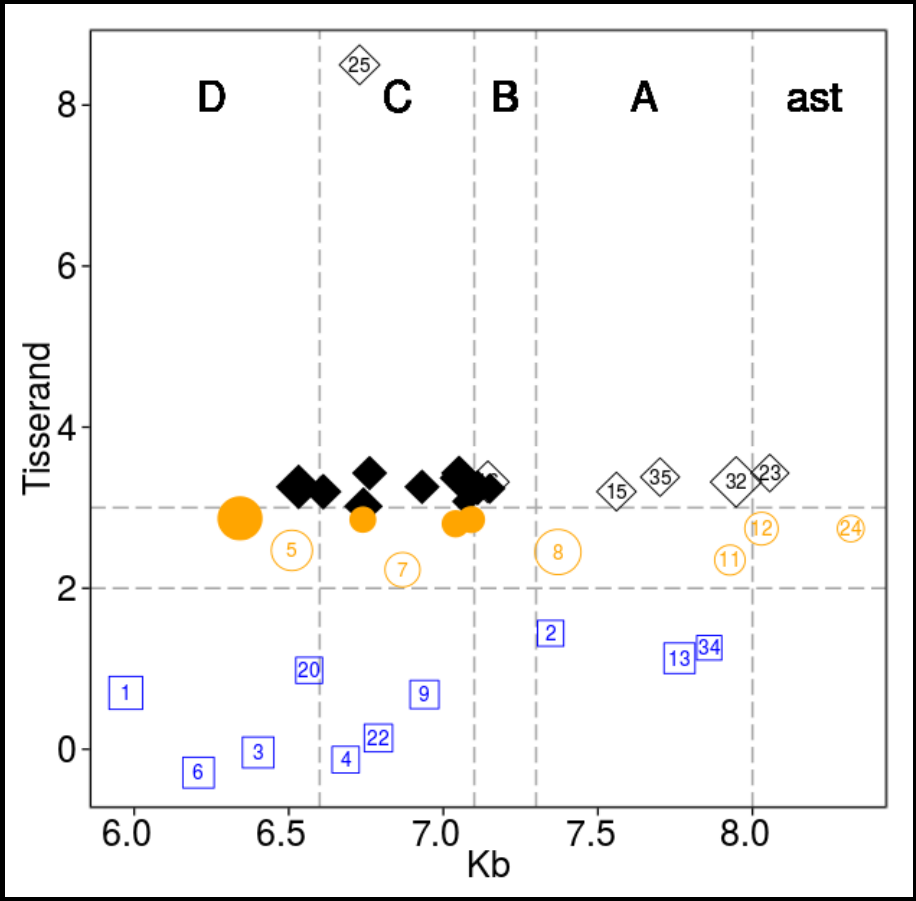
## Taurid meteoroid complex

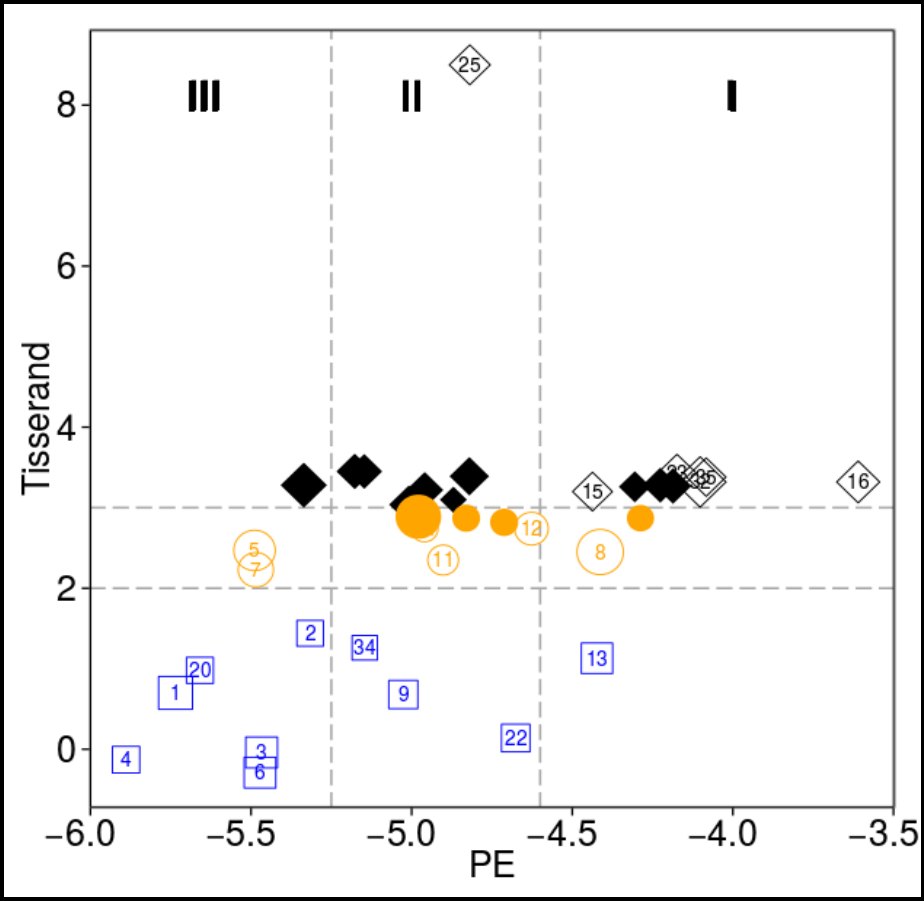
- Unique stream associated with short-period comet 2P/Encke
- Questionable origin, slow orbital evolution unlikely
  1. Origin in the main asteroid belt (Jewitt, 2012)
  2. Major fragmentation of earlier larger comet (Whipple, 1940)
- Linked with several catastrophic incidents:
  - Paleolithic extinctions (12900 BP) (Napier, 2010)
  - Tunguska event of 1908 (Kresák, 1978)
- Proposed relation to over 20 Apollo asteroids, 2 carbonaceous met. falls (Babadzhanov, 2001; Porubčan et al., 2006; Haack et al., 2011)

# Material strength vs. Tisserand parameter

## Taurids 2015 results



# Results: Taurid meteoroids

2015 Taurid outburst - ejected by the 7:2 resonance with Jupiter (Asher, 1991) captured by our systems in Slovakia and Chile:

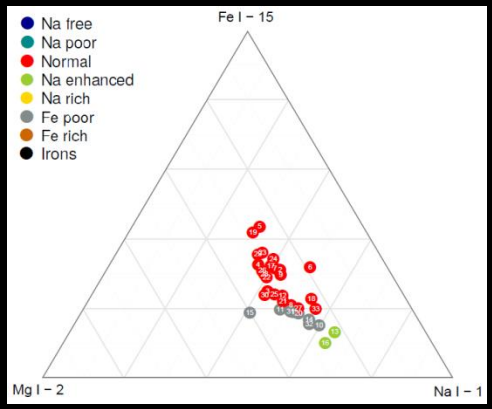
"Spectra and physical properties of Taurid meteoroids" (Matlovič et al., 2017)

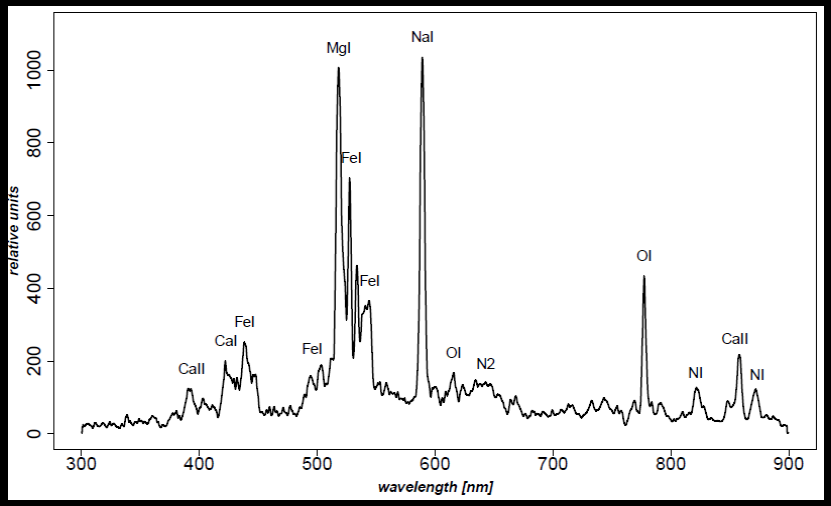
Confirmed orbital associations with several NEOs (2015 TX24, 2003 UV11, 2007 UL12)

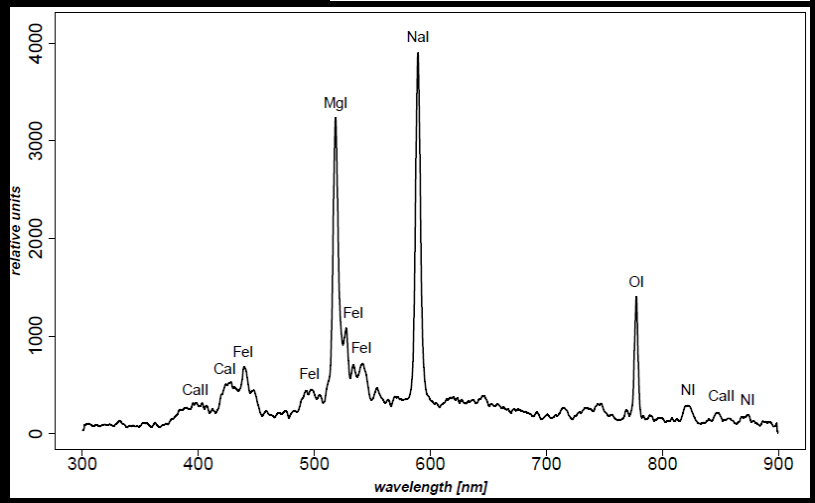
Large variations of iron content

Enhancement of Na/Mg in all meteoroids

Heterogeneous content of Na - aging effect



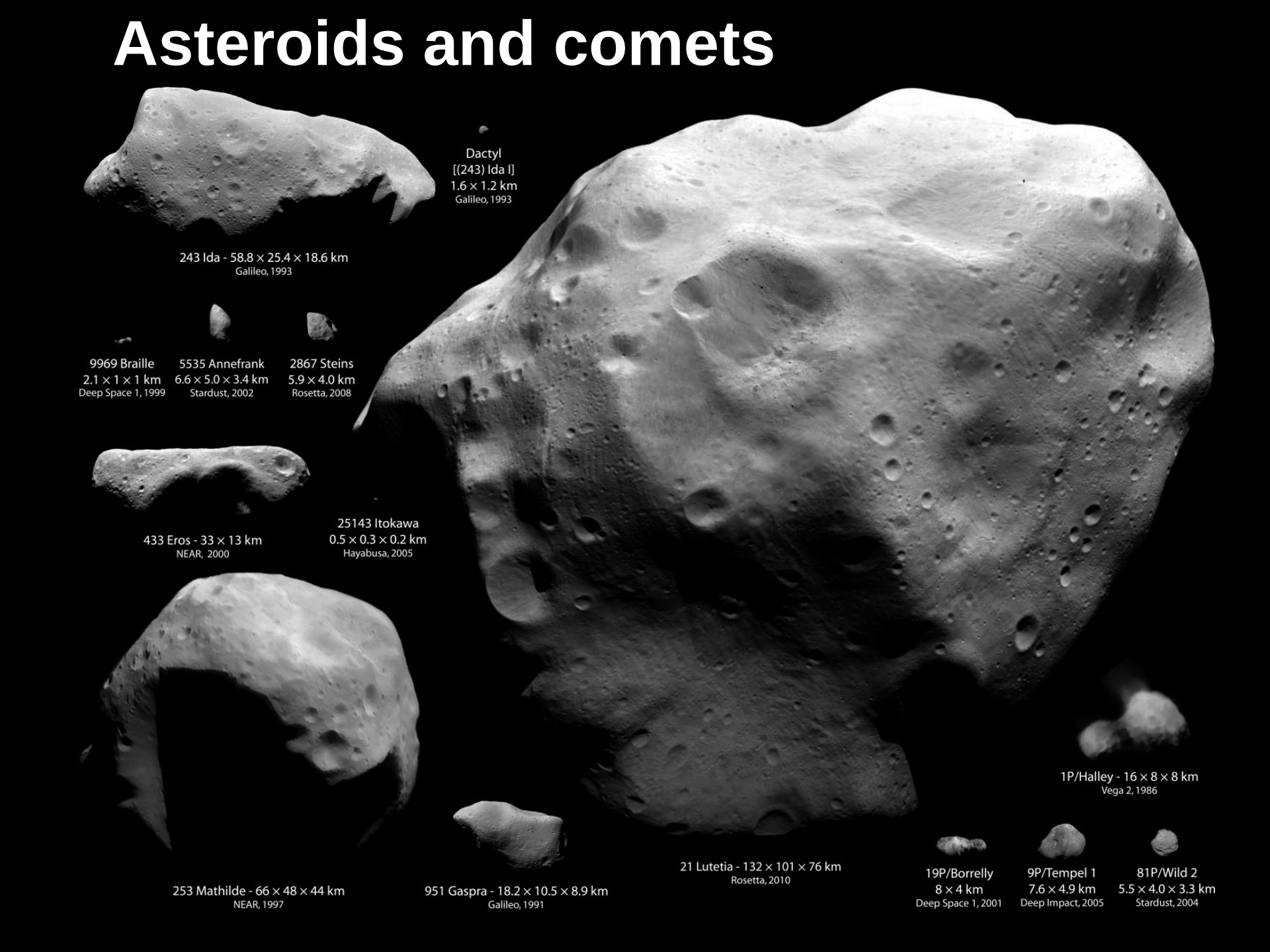



# Meteorites material laboratory tests ...

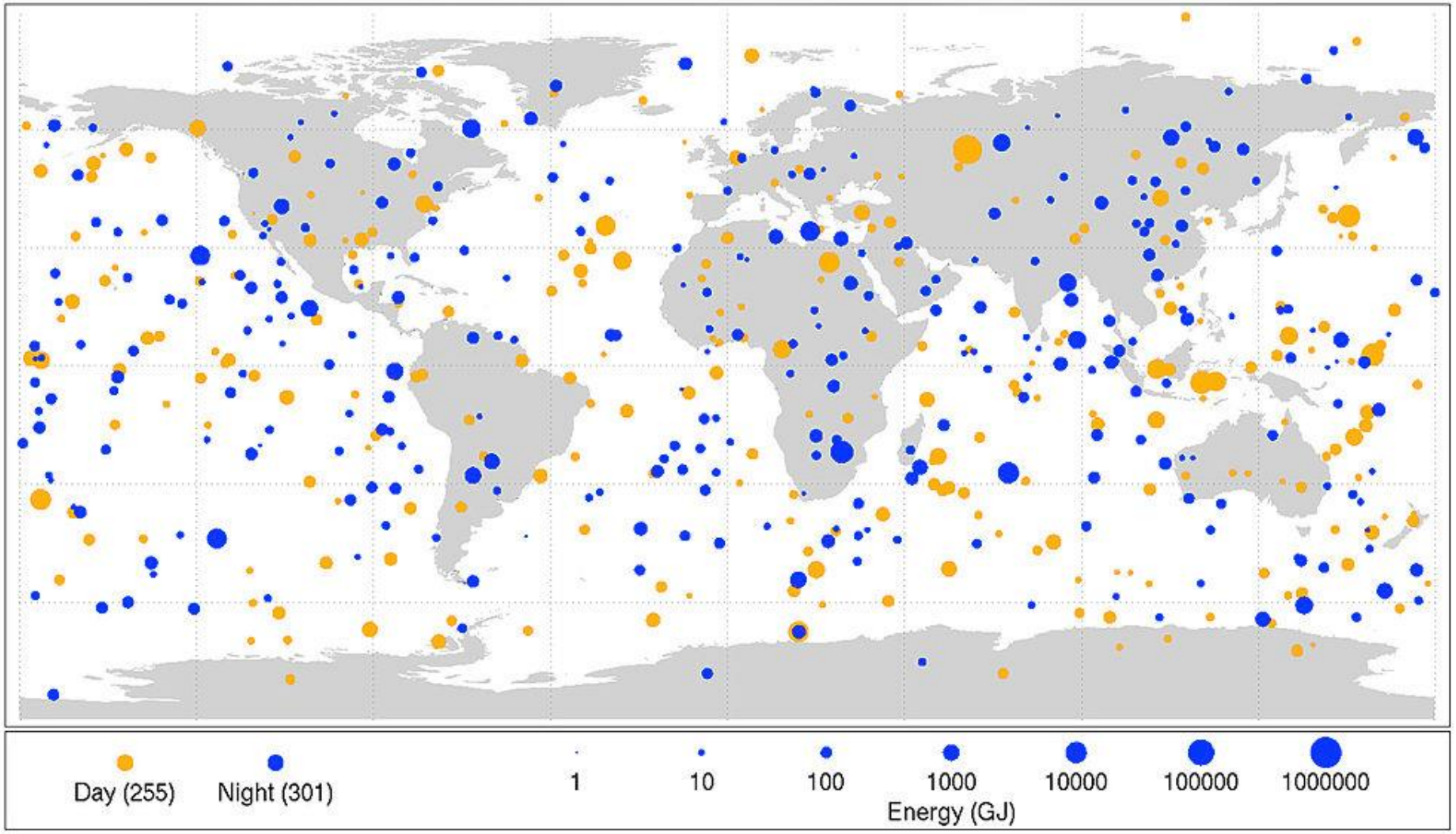

Any questions?

# Asteroids and comets



# Bolide events 1994-2013

(Small asteroids that disintegrated in the Earth's atmosphere)




NASA/JPL

# 20 m meteoroid - asteroid v okolí Čeljabinska, Rusko, 15. februára 2013

# Čeľabinský prípad, Rusko 2013

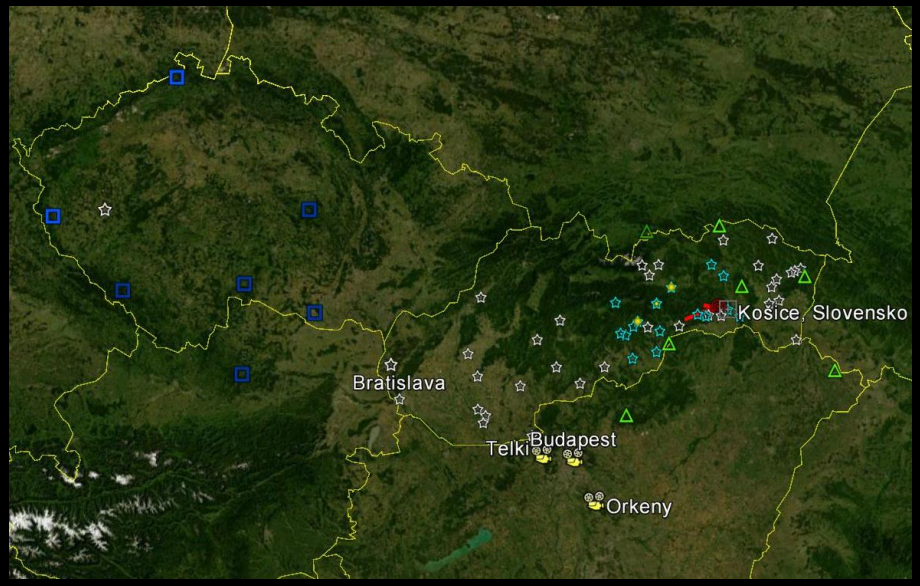
# Hľadanie meteoritov na Slovensku a v okolí:

Morávka 2000
Turji-Remety, Ukrajina, 2001
Šášov 2006
Martin 2007
**Košice 2010**
Komjatná 2010
Zlatnô 2010
Podolie,  2010
Kajárpéc, HU, 2011
Piliscsaba, HU,  2013
Miskolc, HU, 2016

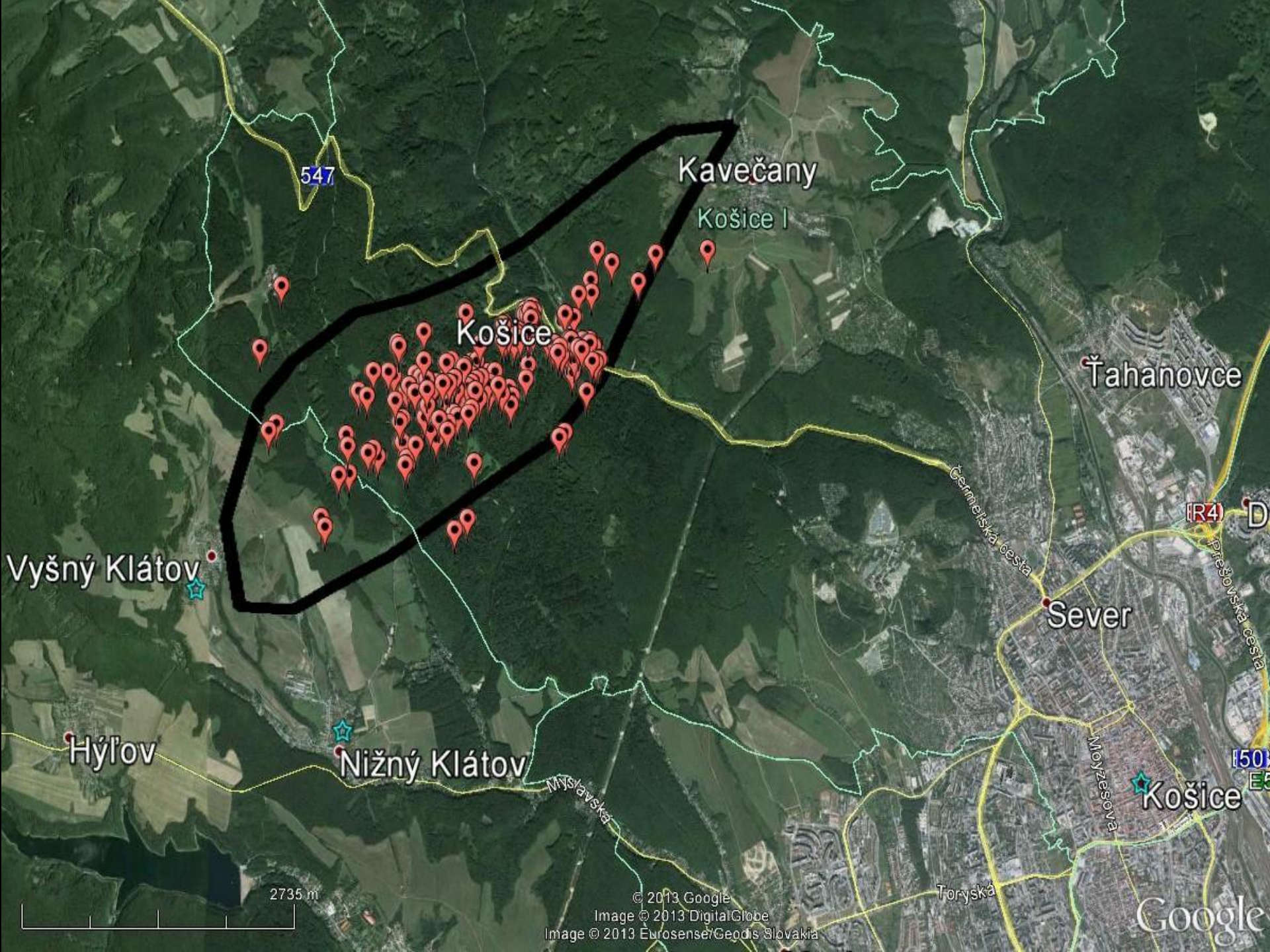
# Meteorite Košice

- Fall of meteorite on Feb. 28, 2010
- Superbolide -17 magnitude with bright light, sound phenomena
- Recovery 20 days after the fall
- Complex strew field, 218 fragments (0.5g – 2.4kg)

First recovered meteorite on my hand ...




Map of Slovakia and surroundings - instrumental records.


547
Kavečany
Košice I
Košice
Ťahanovce
Vyšný Klátov
Sever
Hýľov
Nižný Klátov
Košice
Čermeľská cesta
Prešovská cesta
Moyzesova
Toryská
Nyskavská
R4
2735 m
© 2013 Google
Image © 2013 DigitalGlobe
Image © 2013 Eurosense/Geodis Slovakia
Google

# Meteorite Košice – fragments distribution

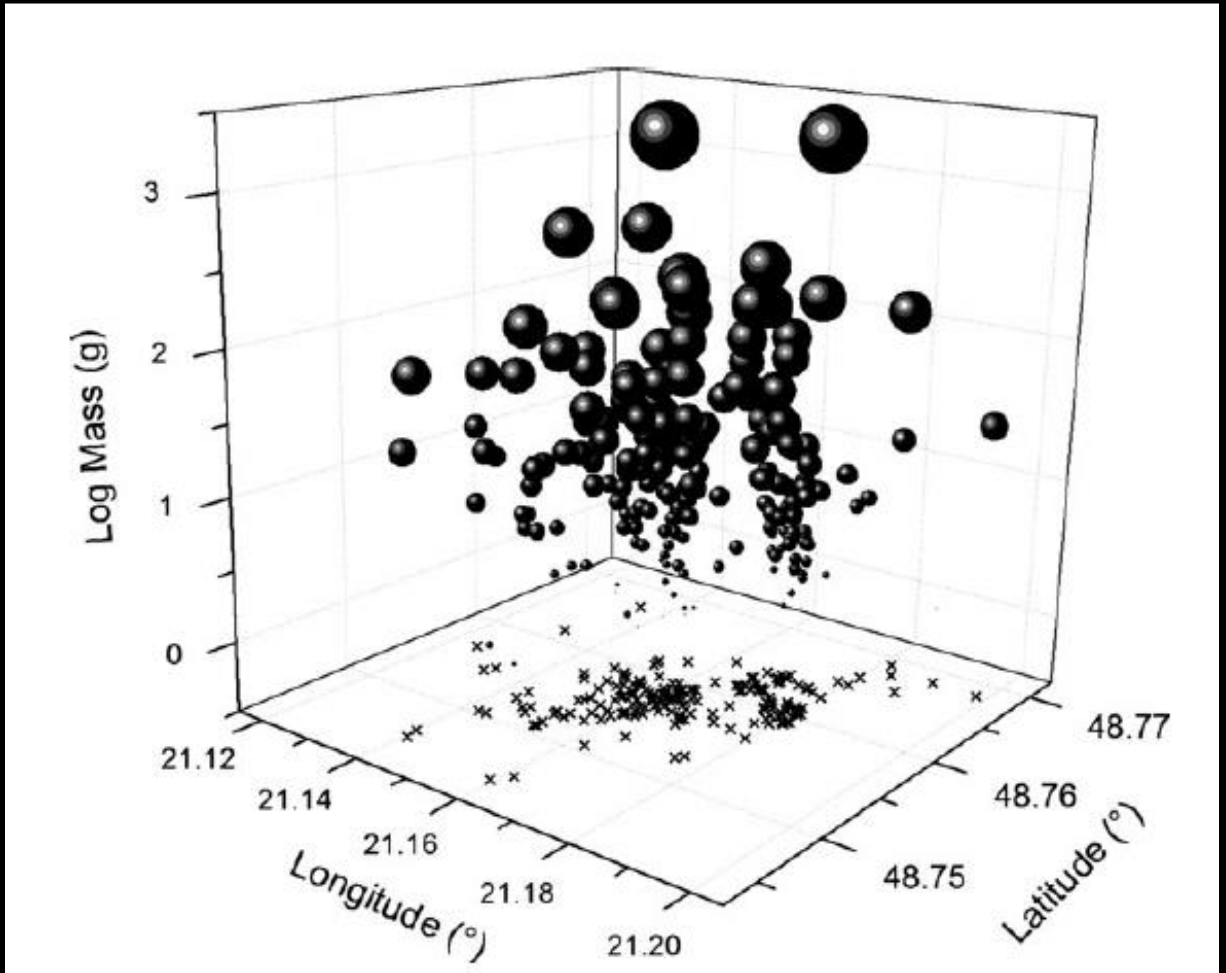



Fig. 5. The distribution of all fragments (218) in the strewn field in 3-D visualization. Two main concentrations of different masses around 2 kg fragments are visible.

Tóth et al., 2015


1

2

4,5

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17

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45

46

48



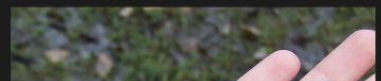
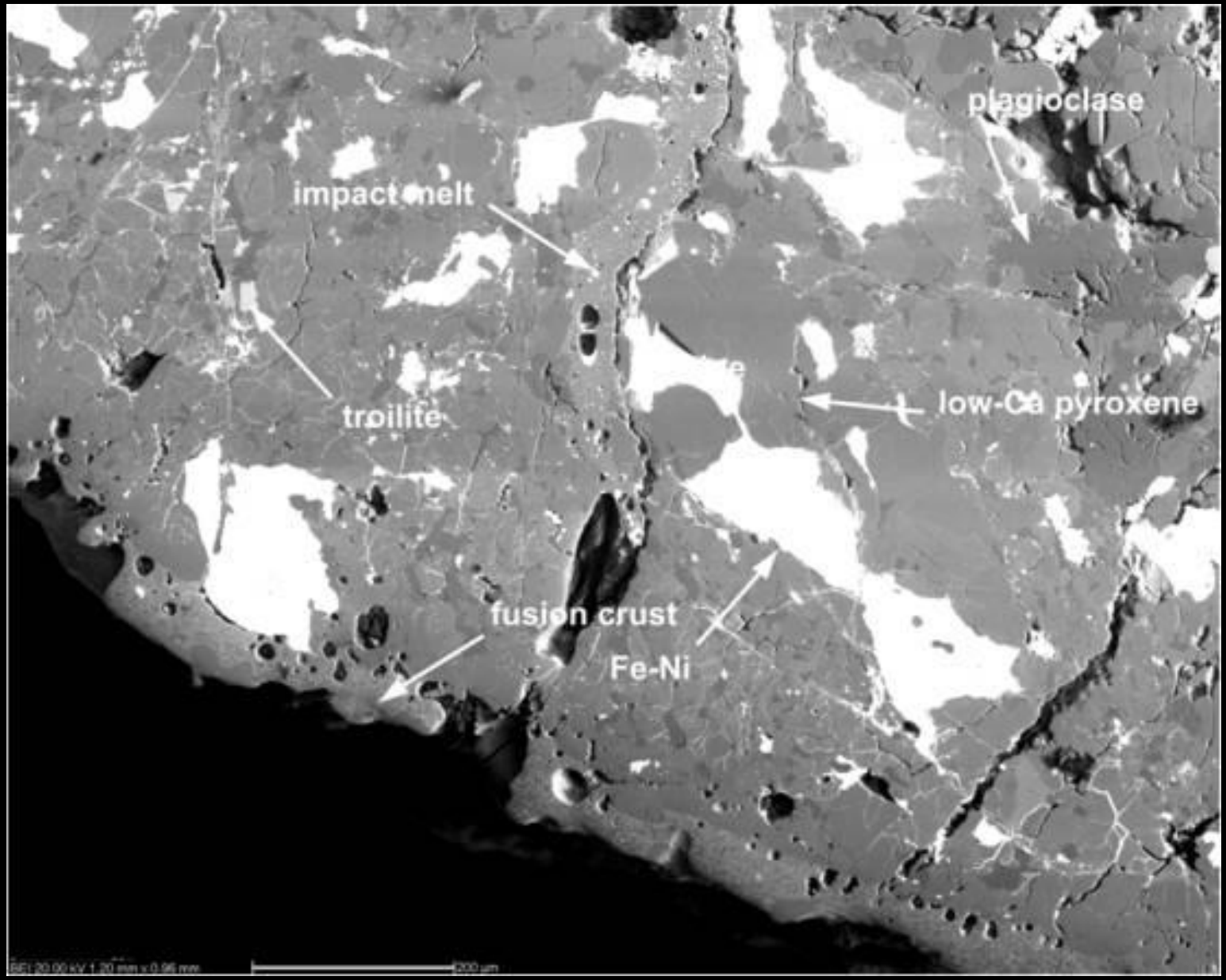



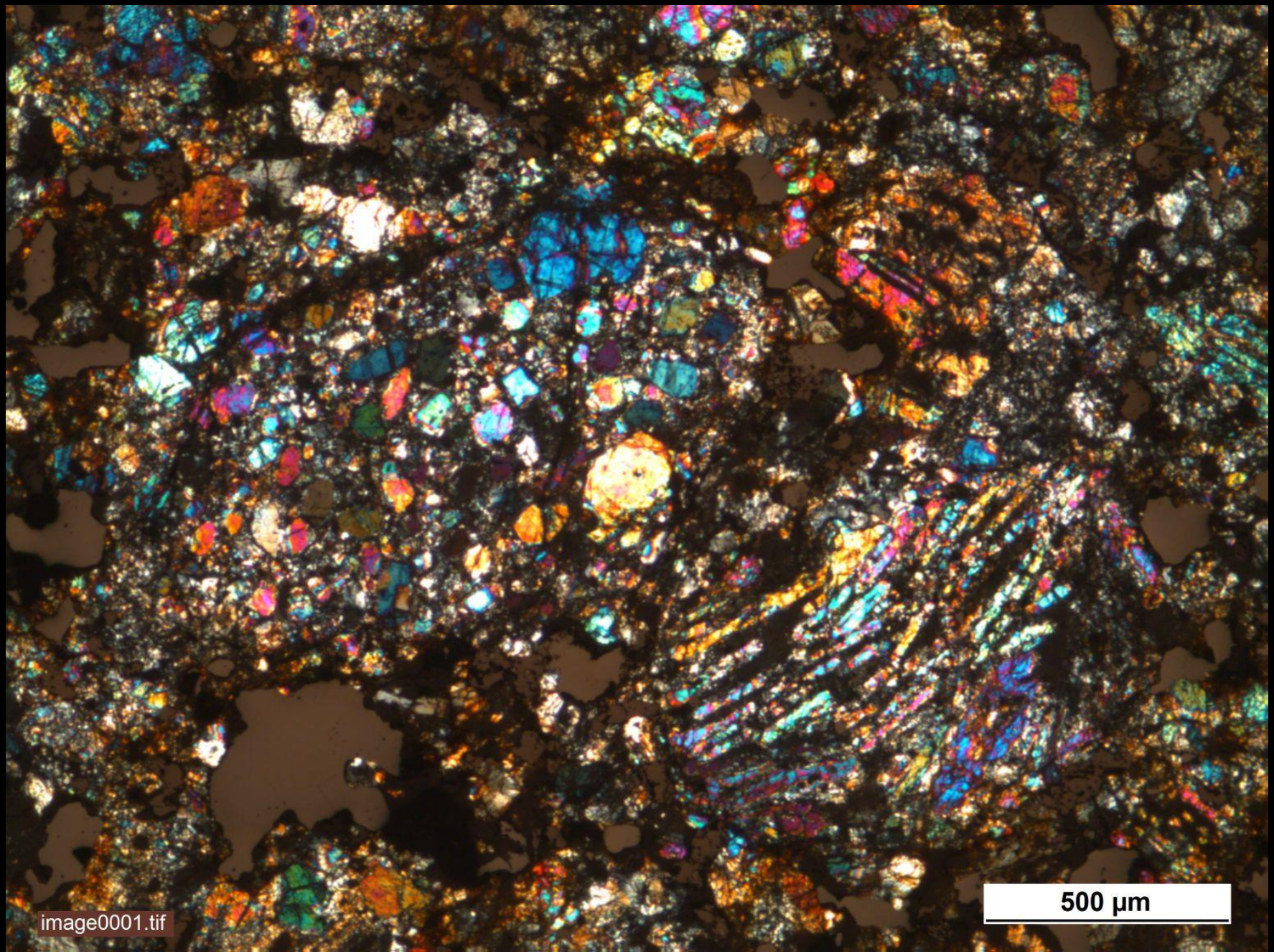
Fig. 9. Two views of the second largest Košice meteorite (2.17 kg) found close to the Alpínka settlement by Tereza Krejčová on March 25, 2010.

# Košice Meteorites Recovery and Strew Field - fusion crust differences

# Meteorite Košice –(dr. J. Haloda Czech Geological Survey)

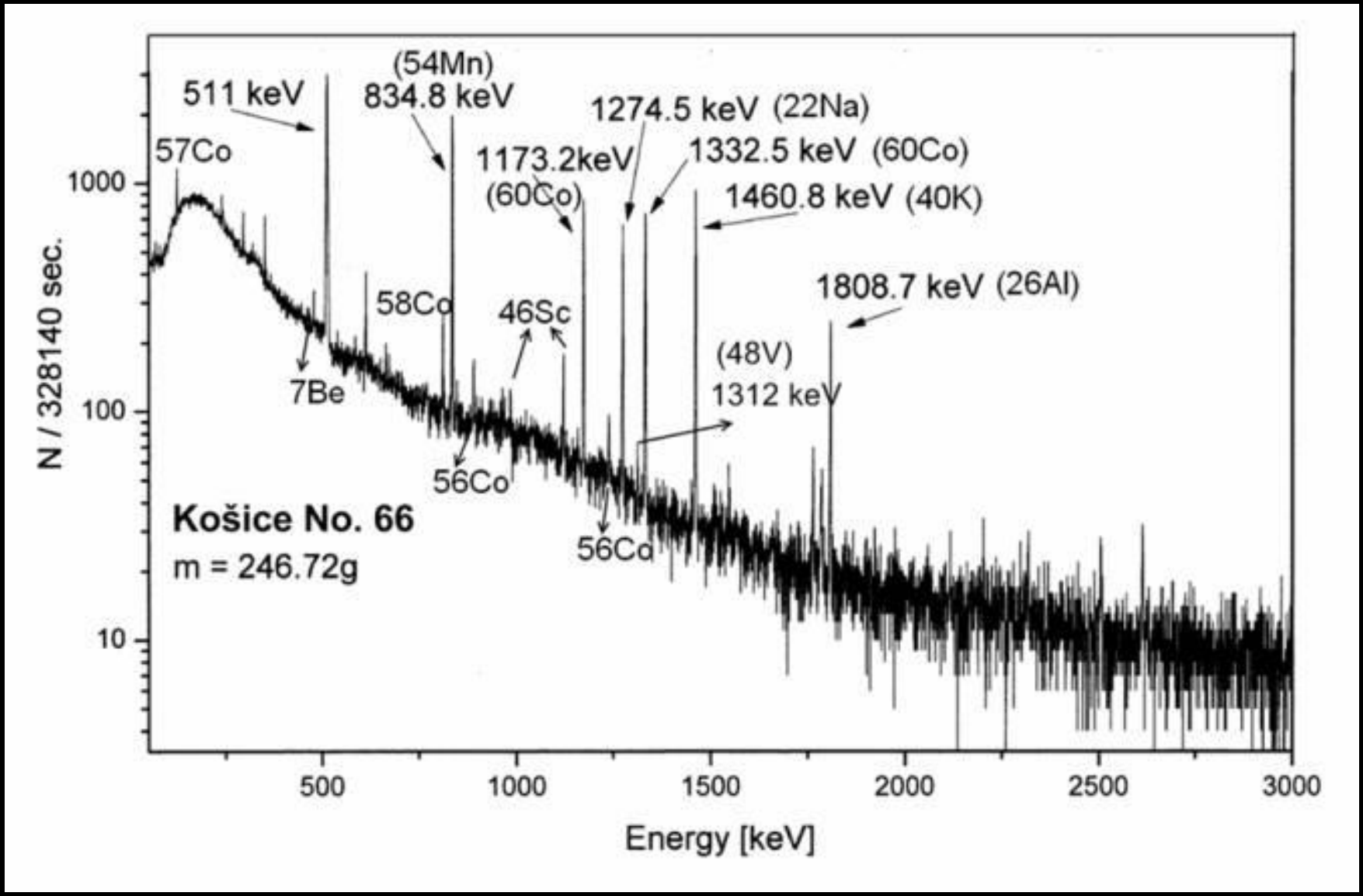


## Meteorit Košice (dr. D. Ozdín, doc. P. Uher PRiF UK)



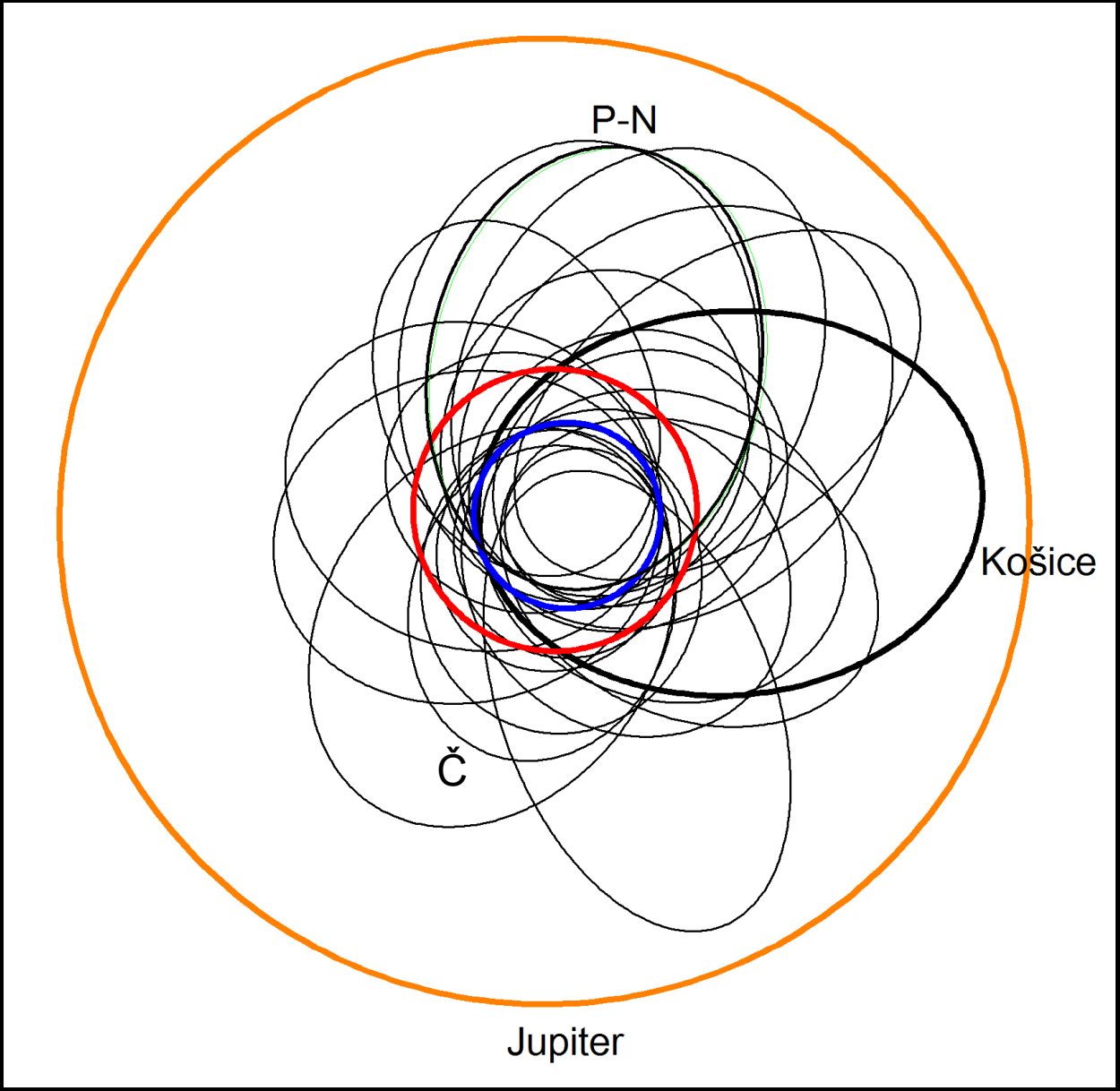
## Košice Meteorites Analyses

• non-destructive gamma-spectrometry showed the presence of 9 cosmogenic radionuclides at 19 meteorites



# Bulk, mineralogical density and magnetic susceptibility measurements

# Meteorite Košice – 15th case of known orbit




Vyšnoklátovský
meteorit
Vyšnoklátovský
meteorit


3
NÁUČNÝ CHODNÍK ❖ Klátovské meteority
Klátov's meteorites ❖ EDUCATIONAL TRAIL
BLÍZKOZEMSKÉ ASTEROIDY
NEAR EARTH ASTEROIDS
FRESH