EDMOND
European viDeo MeteOr Network Database

Pozorovanie meteorov kamerami AMOS

a spolupráca s okolitými sieťami

L. Kornoš a kol.

PROGRAM CEZHRANIČNEJ SPOLUPRÁCE
SLOVENSKÁ REPUBLIKA
ČESKÁ REPUBLIKA
2007 2013

EURÓPSKA ÚNIA
EURÓPSKY FOND REGIONÁLNEHO ROZVOJA
SPOLOČNE BEZ HRANÍC

BESKYDY BÍLÉ - BIELE KARPATY

FOND MIKROPROJEKTŮ

SPOLEČNĚ POD TMAVOU OBLOHOU

Projekt Společně pod tmavou oblohou

Na čo je to dobré

Celkový prítok hmoty na Zem

Meteoricke roje

- známe meteorické roje – stredné dráhy, filamentárna štruktúra, hmotnostné rozdelenie, zmeny aktivity na dlhej časovej škále
- nové meteorické roje, najmä južná pologuľa
- potenciálne materské telesá

Sporadické pozadie

- rozloženie radiantov, dráhových a geofyzikálnych parametrov, zdroje

Jasné bolidy

- svetlá fáza letu, decelerácia, fragmentácia
- tmavá fáza letu, dopadová oblasť a zbytková hmotnosť

Spektrálna klasifikácia meteorov

- identifikacia zdrojovej oblasti na základe dráh

Slovak video meteor network

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Faculty of Mathematics, Physics and Informatics
Comenius University in Bratislava

- kamera AMOS – All-sky Meteor Orbit System
- začiatok systematického pozorovania r. 2007
- 2009 – 2. stanica
- 2012 – 3 st., 2013 – 4. st.

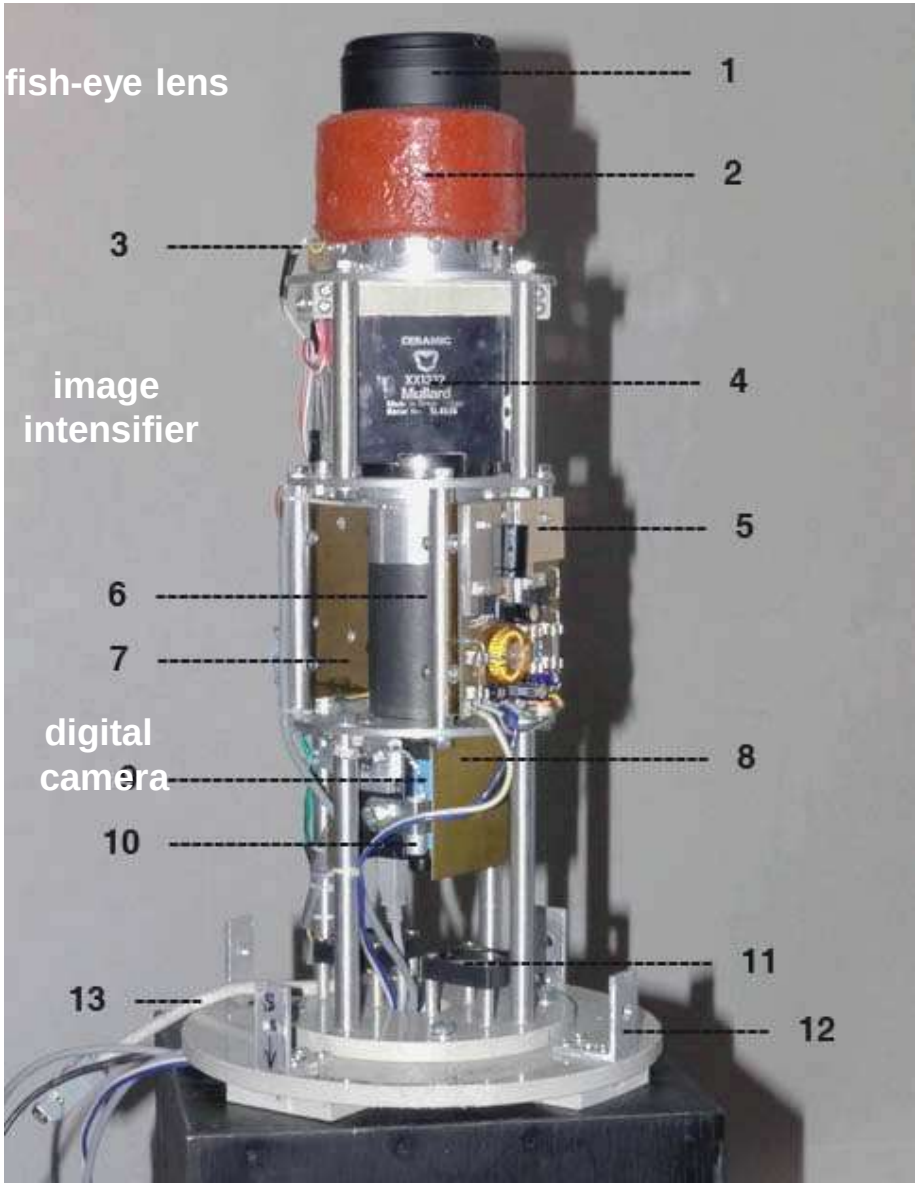
SVMN – Slovak Video Meteor Network

All-sky Meteor Orbit System - AMOS

Astronomické a geofyzikálne observatórium FMFI UK Modra

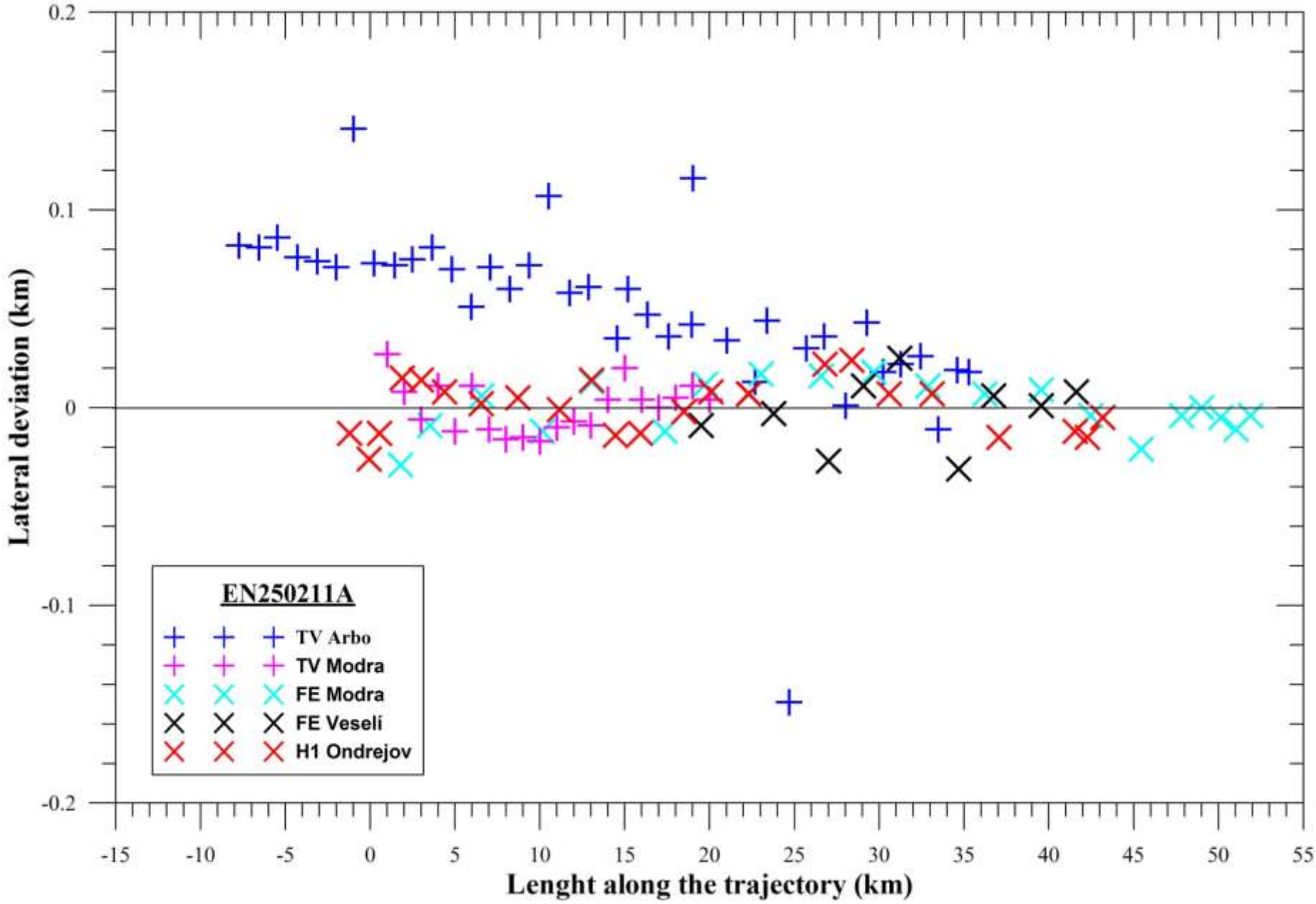
4 stanice v sieti

Slovak Video Meteor Network



All-sky digital video setup of fish-eye lens …

- noncompressed *.avi files with moving objects are stored
- 15 frames/s
- 1280 x 960 pixels
- resolution ~ 8 arcmin/pixel
- field of view 180° x 140°
- limiting stellar magnitude ~ +5.5
- faintest meteors ~ +4.0 mag.


0.2
0.1
0
-0.1
-0.2
Lateral deviation (km)
-15
-10
-5
0
5
10
15
20
25
30
35
40
45
50
55
Lenght along the trajectory (km)
EN250211A
TV Arbo
TV Modra
FE Modra
FE Veseli
H1 Ondrejov

Central European Meteor Network

- CEMeNt – Central European Meteor Network
  - stations in Czech Republic and Slovak Republic
  - Amateur astronomers' network
  - started in 2009
  - cooperation with SVMN
  - advantage to both – multi-station, weather conditions

Networks' cooperation

- 2009 - SVMN – CEMeNT - first common data, mostly bolides
- 2010 (spring) – PFN and HMN
  - combined data obtained by using different detection and processing tools (UFO, MetRec)
- 2011 Draconids campaign – IMTN
  - paper in WGN 40:4, 2012, p. 117-121
- also French and UK observers started to share data

- **European viDeo Meteor Observation Network**
- **EDMONd** *http://www.fireball.sk/edmond_map.html*

EDMOND

IMC 2012 La Palma:

- **European viDeo MeteOr Network Database** – **EDMOND**
  - new database of meteor orbits
  - ~ 25 000 orbits
  - collected data allow us to utilize unused single-station meteors
- 2012 : **IMO** VMN data – a huge number of single-station meteors
    - **significant contribution, 2000 – 2012 yrs**

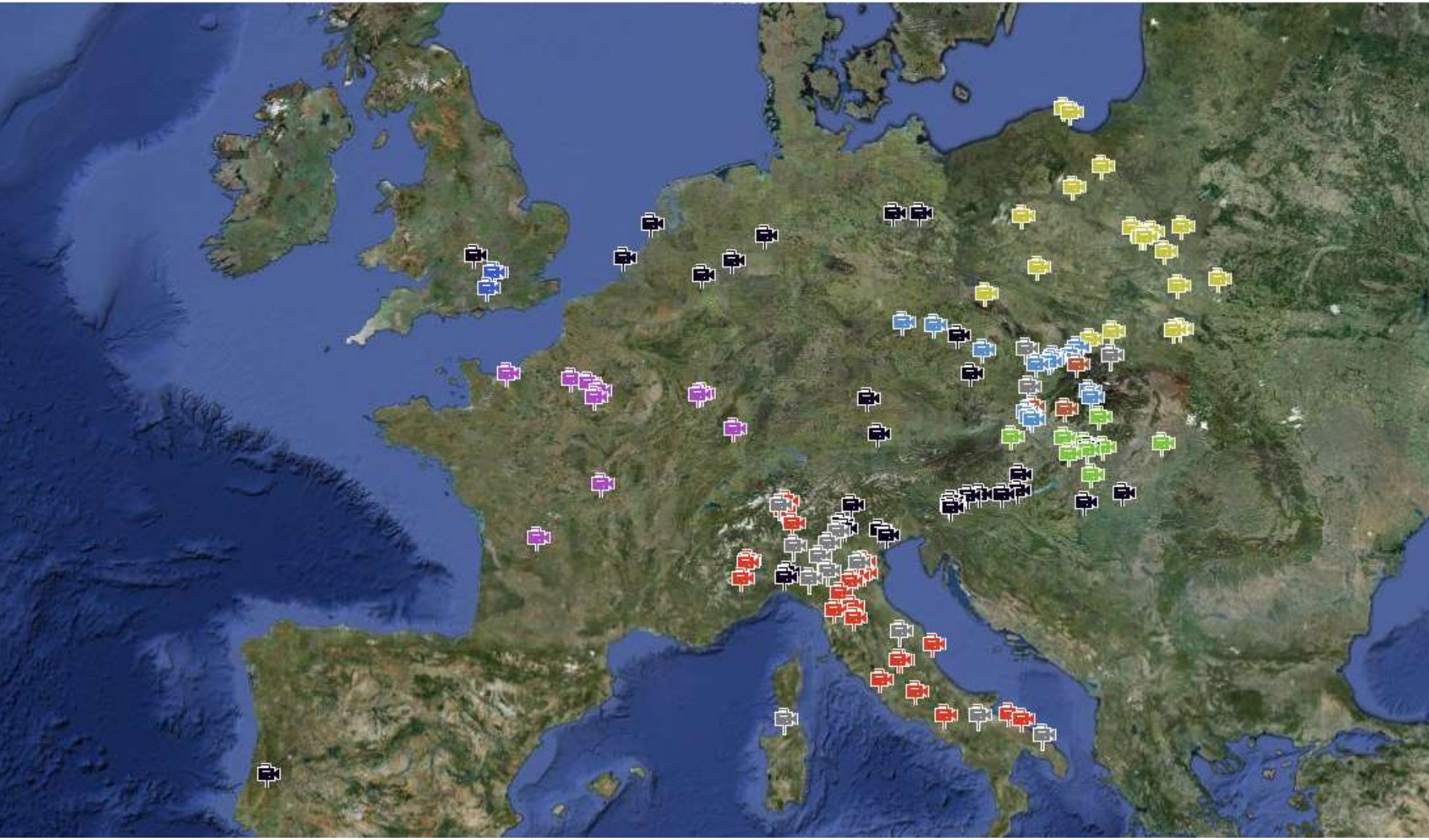
software – record and analyse single meteors:

- **MetRec** – S. Molau (1999)
- **UFO** – SonotaCo (2009)

EDMONd and IMO VMN

- **BOAM** - France BOAM network / Base des Observateurs Amateurs de Météores
- **HMN** - Hungarian Meteor Network / Magyar Hullócsillagok Egyesület
- **IMTN** - Italian Meteor and TLE network
- **PFN** - Polish Fireball Network / Pracownia Komet i Meteorów, PKiM
- **UKMON** - UK Meteor Observation Network
- **CEMeNt** - Central European Meteor Network, Czech and Slovak AA
- **IMO VMN** - IMO Video Meteor Network
- Ukrajna, Bosnia, Herzegovina and Srbsko, Brazília
- **SVMN** - Slovak Video Meteor Network, CU

EDMONd / European viDeo Meteor Observation Network

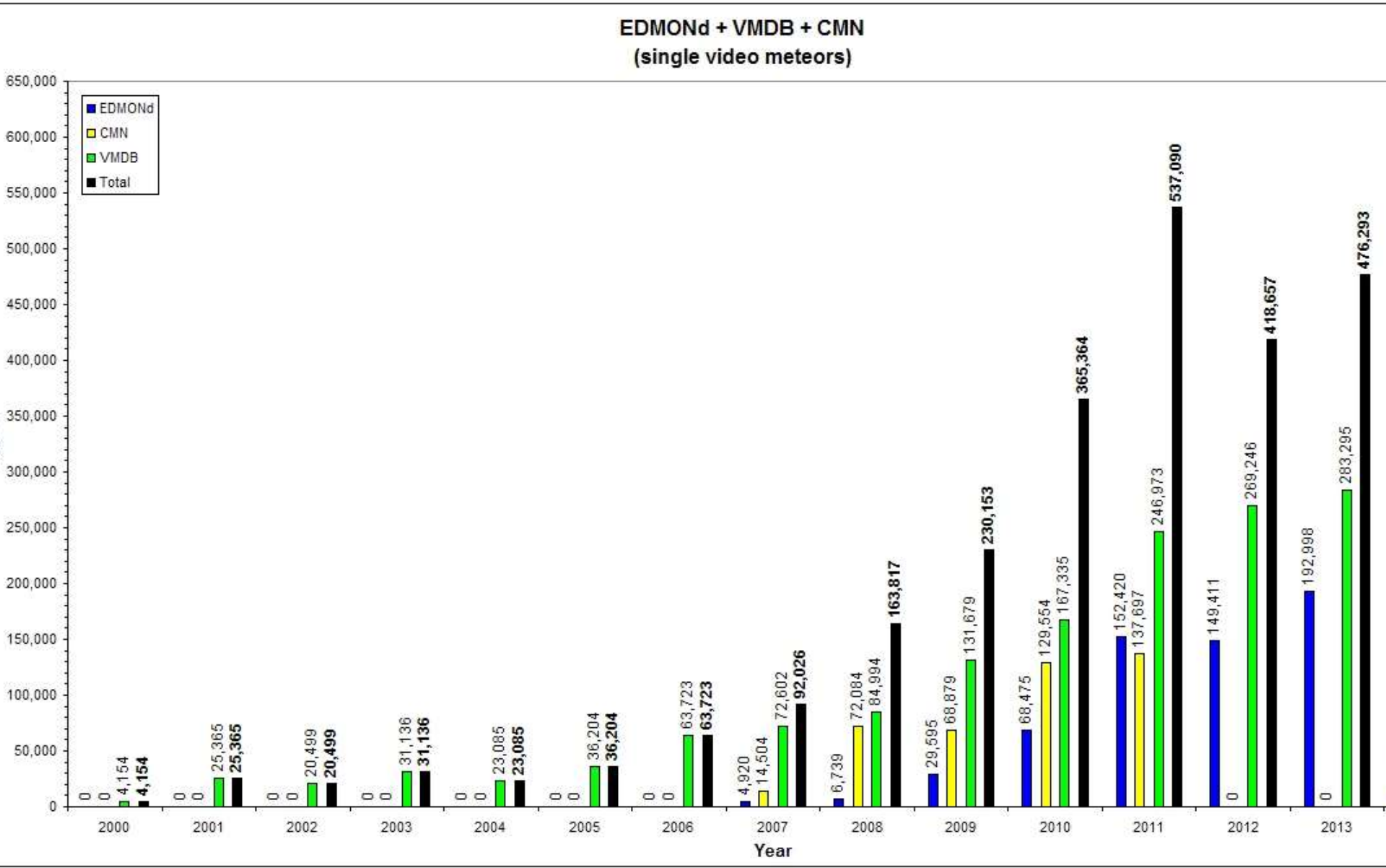


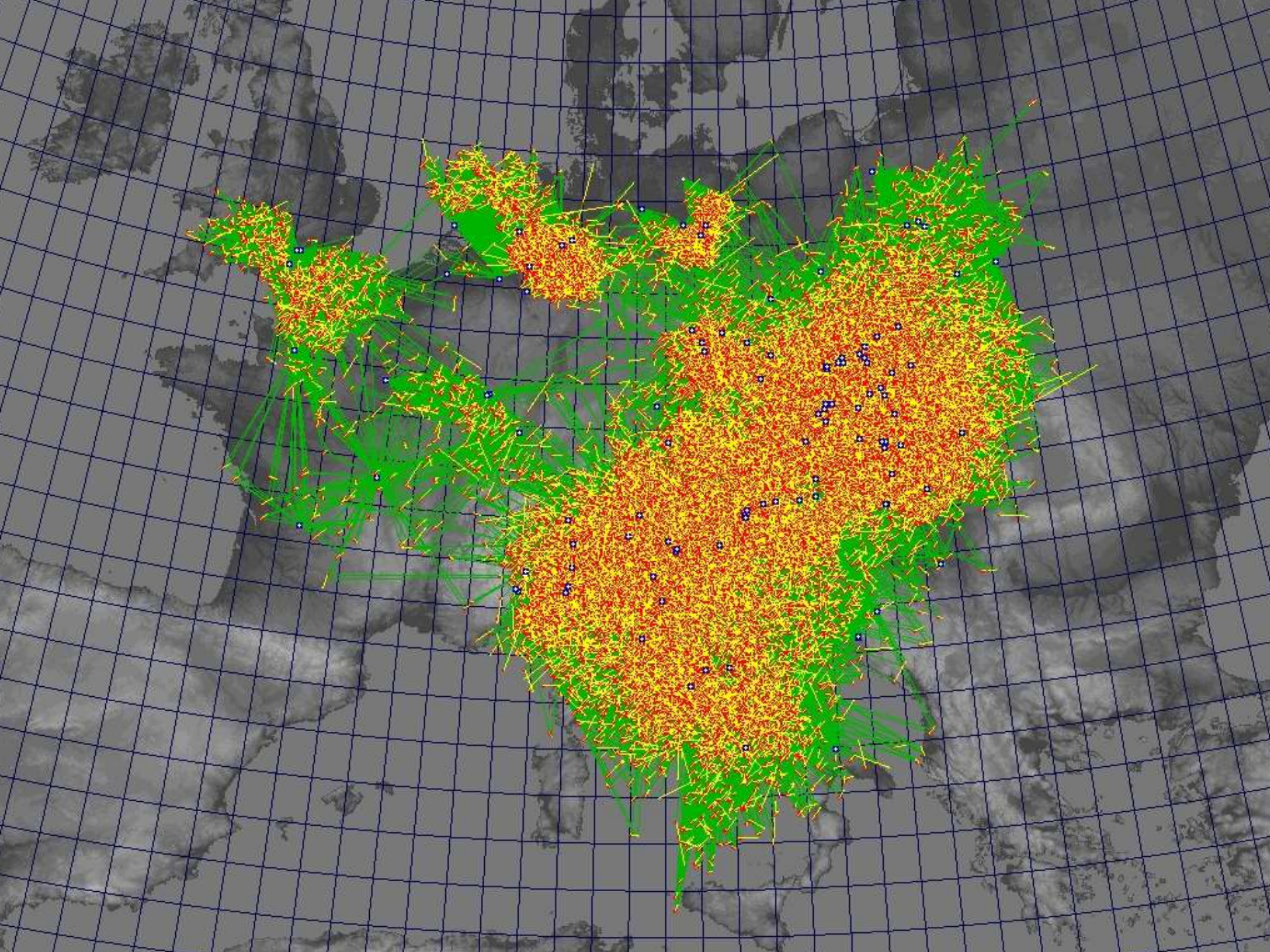
http://www.fireball.sk/edmond_map.html

Networks and single meteors in 2000 – 2013 (30.6.)

Network	Number of stations	Meteors (single)	
BOAM	10	26 779	**UFO**
CEMeNt	15	40 742	**UFO**
HMN	13	167 534	**MetRec**
IMNT	15	135 534	**UFO**
PFN	23	30 576	**MetRec, UFO**
SVMN	3	39 257	**UFO**
UKMON	4	3 372	**UFO**
Bosnia	4	1 390	**UFO**
Serbia	1	58	**UFO**
MeteorsUA	6	1 742	**UFO**
IMO VMN	61	1 192 092	**MetRec**
Sum	**155**	**1 639 358**	

Single Video Meteors 2000 - 2013





Effort to create a common database

- the main computation of orbits – **UFOOrbit (***SonotaCo***)**
  - **Q_0, dt = 5 sec**
  - Q_0 – all possible combinations
  - dt – some stations – problems with time precision

- ~ 40 % MetRec data in 2012
- ~ 72 % at present

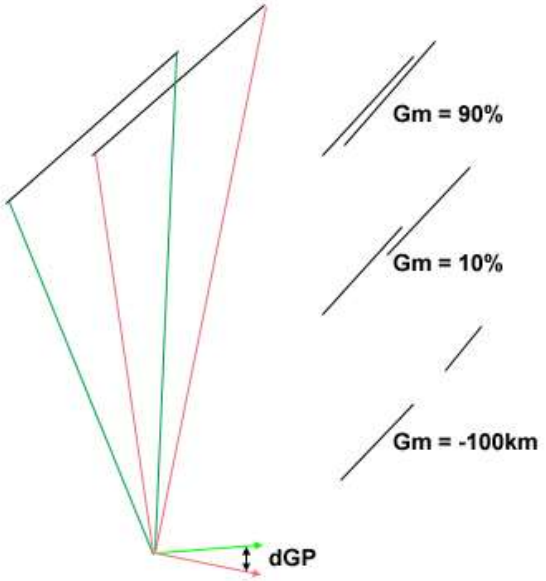
- conversion from MetRec to UFO format - **INF2MCSV** sw (*SonotaCo*)
  - the best transfer method is (Y)

- **J8** – a new UFO reference catalogue of meteor showers – IAU MDC

Computing process

Q_0 (new set of parameters):

- **dt** = 5 sec
- **$H_{1,2}$** : (15, 200) km - beginning and terminal heights
- **Gm%** > -100 - overlapping of a meteor from two
- **dV** < 7 km/s - diff. of velocity among all stations meteor orbit
- **QA** > 0.15 - empirical quality parameter from (



2d filter – eliminate less precise orbits

- **Q_0** > 1 deg - angle of observed trajectory
- **dur** > 0.1 sec - duration of meteor
- **dGP** < 0.5 deg - diff. of 2 poles of ground trajectory
- **Q_c** > 10 deg - convergence angle
- **dv12%** < 7.07 %

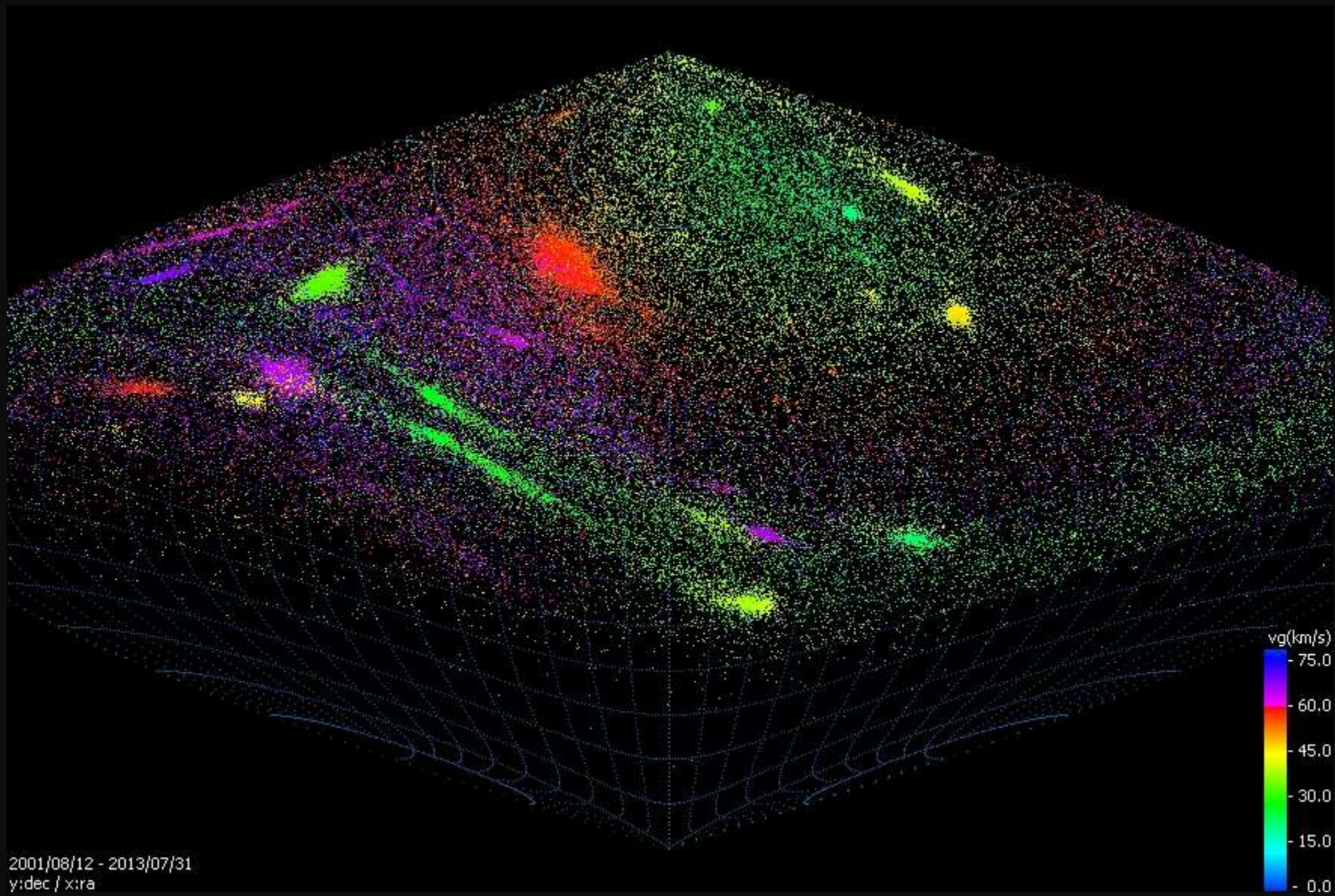
- 2d filter is applied to '_UNIFIED' – **166 905 orbits** (ver. 05a)
- to every station of the meteor – **144 749 orbits** (ver. 05b)

EDMOND – preliminary 2007 – 2014

year	orbits 05 a	orbits05 b
2007	2 527	2 278
2008	5 982	5 569
2009	8 976	8 260
2010	21 891	19 497
2011	41 817	36 099
2012	39 838	33 982
2013	44 852	38 164
2014	1 022	900
sum	166 905	144 749

hyperbol_b : 8 125 = 5.6%

RADIANTS – 0 deg



EDMOND - závery

- spojilo sa niekoľko sto pozorovateľov z viacerých krajín Európy
- dáta z 8 sietí, 155 staníc, ~ 145 000 dráh (2001 – 2014)
- využité dáta na výpočet dráh, ktoré by v samostatných sieťach ostali jednostaničné

- parametre dráh v EDMOND sú porovnateľné napr. so SonotaCo dátami
- EDMOND je súbor dráh, kde sa uplatňuje kompromis
  - snaha získať čo najviac dráh ↔ prijateľná kvalita
- pri analýze treba robiť vlastný výber v závislosti cieľa výskumu

Drakonidy 2011 – AMOS

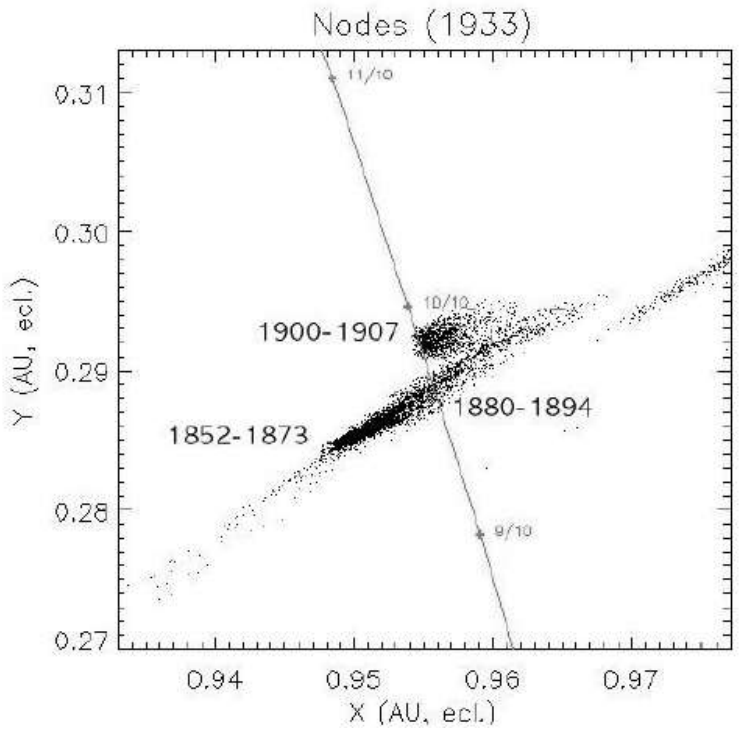
J. Tóth, Š. Gajdoš, J. Villági,
P. Zigo, D. Kalmančok, F. Ďuriš, L. Kornoš

Minulá aktivita

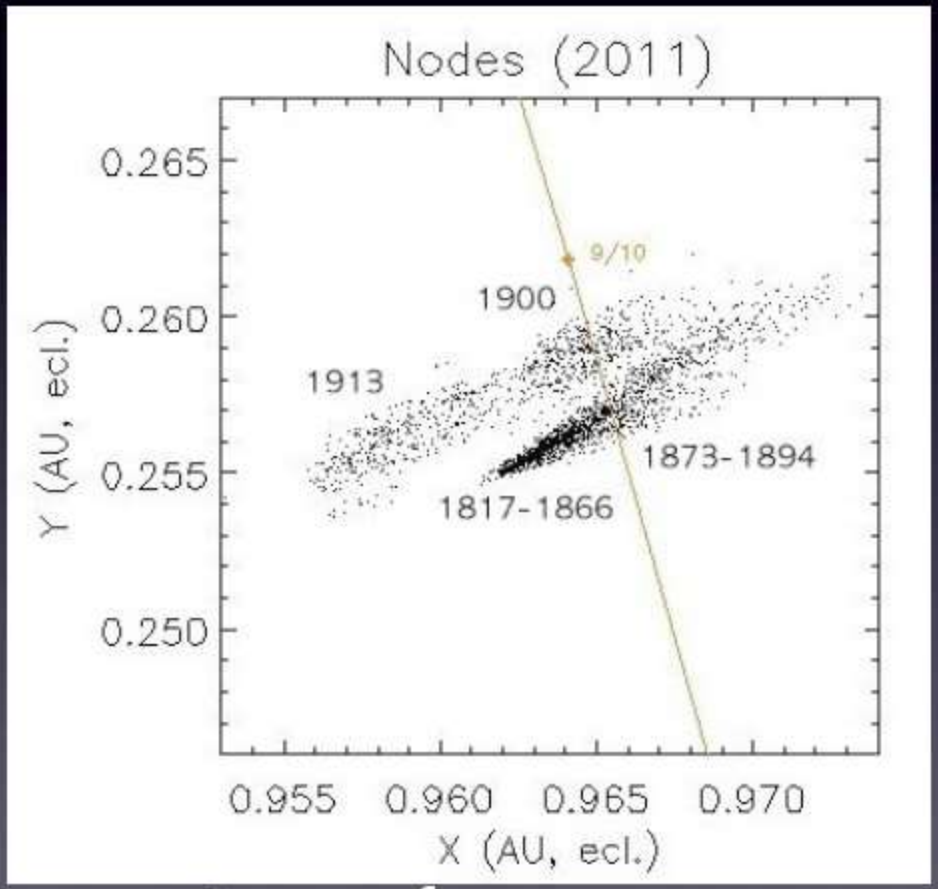
- meteorické dažde v 1933 a 1946 (10 000 / hod)
- zjasnenia 1952 (250/hod), 1985 (550/hod), nečakané v 2005 – malé častice

Budúce predpovede

- numerické integrácie,
- fyzikálny model ejekcie častíc z kométy
  - ako test slúžili 1933 a 1946
  - Vaubaillon (2011) – z prúdov z rokov 1900 a 1907 → 1933 a 1946, ale aj v r. 2011



The 2011 Draconids



www.imcce.fr

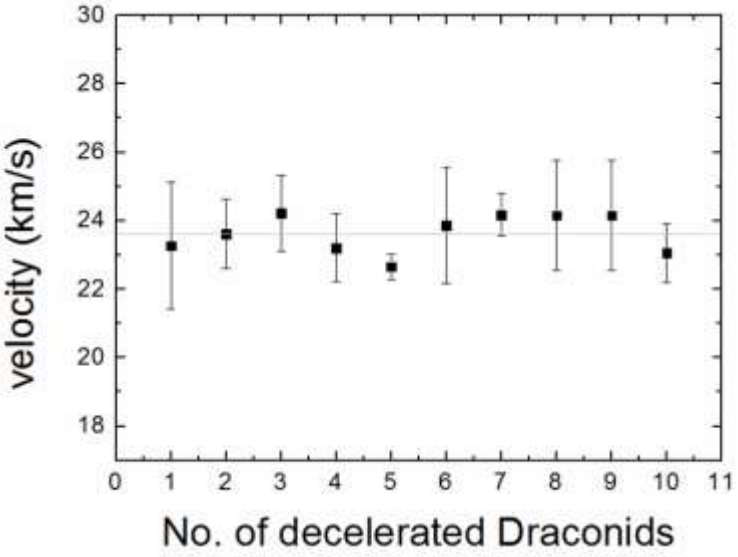
model	time on Oct 8th (UT)	ZHR (/hr)
Sato, Watanabe (2008)	17:05	100
Sato, Watanabe (2008)	20:36	500
MSFC (Moser 2007)	19:11	800
Maslov	20:42	40-50
1900 trail (Vaubaillon)	19:57	~600
1873-1894 trails	17:09	~60 (?)

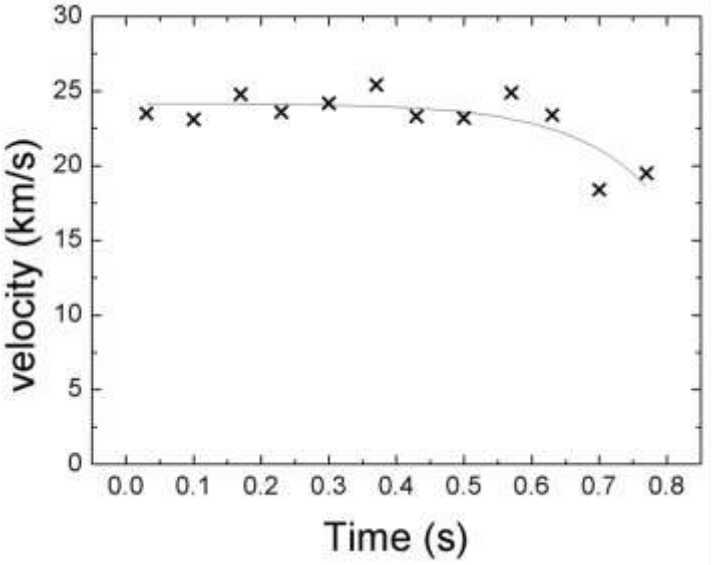
- modely ukázali možné zvýšenie aktivity
  - dve maximá
- predpovede sa líšili, najmä v odhade počtu meteorov
- dráha materskej kométy – JFC, silné perturbácie
- aktivita kométy v minulosti nedostatočne zmapovaná (Watanabe, Sato 2008)
- pozorovanie v 2011 :
  - kalibrácia minulých pozorovaní (boli ZHR v 1933 a 1946 tak vysoké?)
  - test modelovania vývoja prúdu
  - čo bolo s kométou pred objavom v 1900? (prvé maximum)

ITMN, PFN, CEMeNt, SVMN - 9 staníc

Pozorovanie a spracovanie

- 62 Dra v intervale 17:56 - 23:22 UT
- radiant nad horizontom 68 - 29 deg
- 43 Dra s prijateľnou presnosťou
- silná fragmentácia a decelerácia
  - meranie rýchlosti problém
- predpokladaná vstupná rýchlosť **23.57 km/s** (Koten et al., 2007)
  bez tohoto predpokladu – podobné výsledky, ale väčší rozptyl

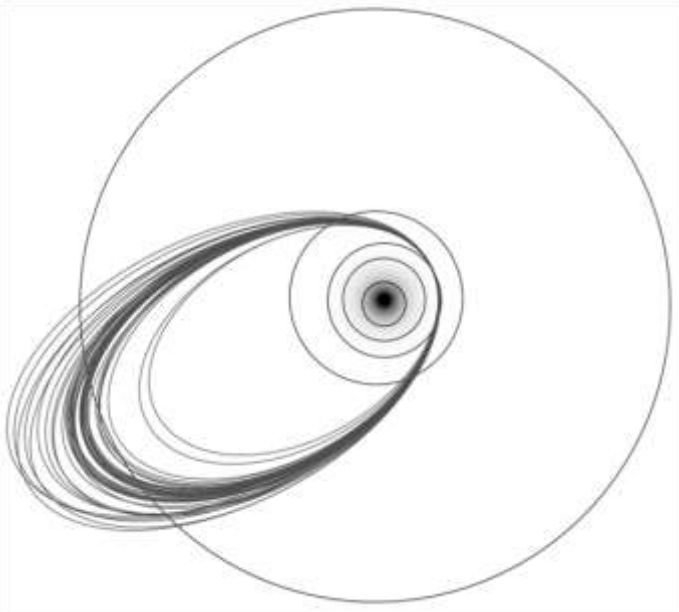




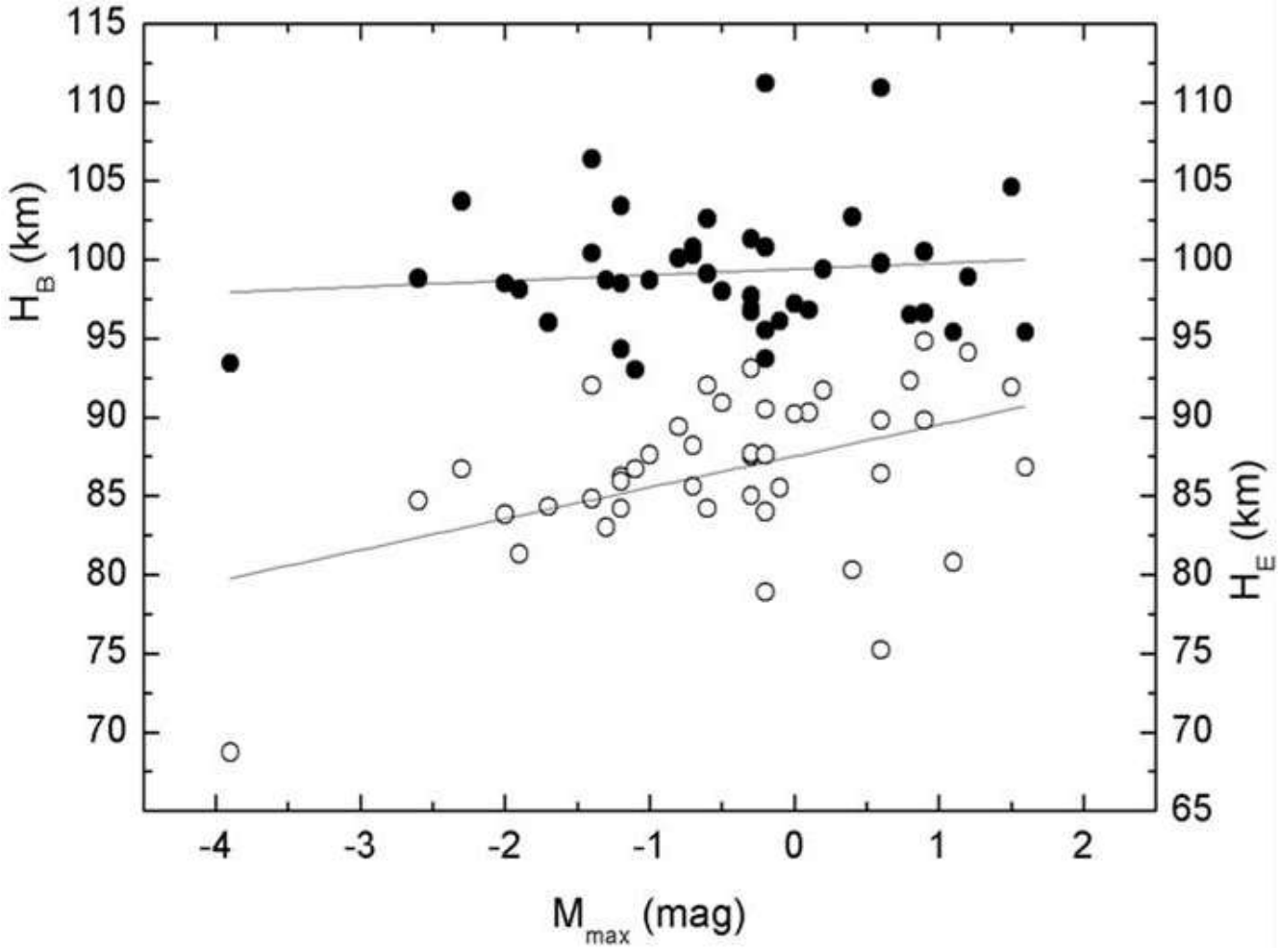
Stredná dráha Dra z 9 staníc (Italy)

	a (AU)	q (AU)	e	i (°)	ω (°)	Ω (°)	α (°)	δ (°)
Mean value	**3.58**	**0.9964**	**0.720**	**31.70**	**173.51**	**194.944 - - 195.167**	**263.25**	**55.61**
std	**± 0.29**	**± 0.001**	**± 0.023**	**± 0.34**	**± 1.10**		**± 1.47**	**± 1.00**
Comet 21P	**3.52**	**1.0320**	**0.707**	**31.91**	**172.57**	**195.403**	**263.20**	**55.80**

Kométa 21P integrovaná z epochy 1900 do epochy pozorovania. Dráha z JPL.



Počiatočné a koncové výšky



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)

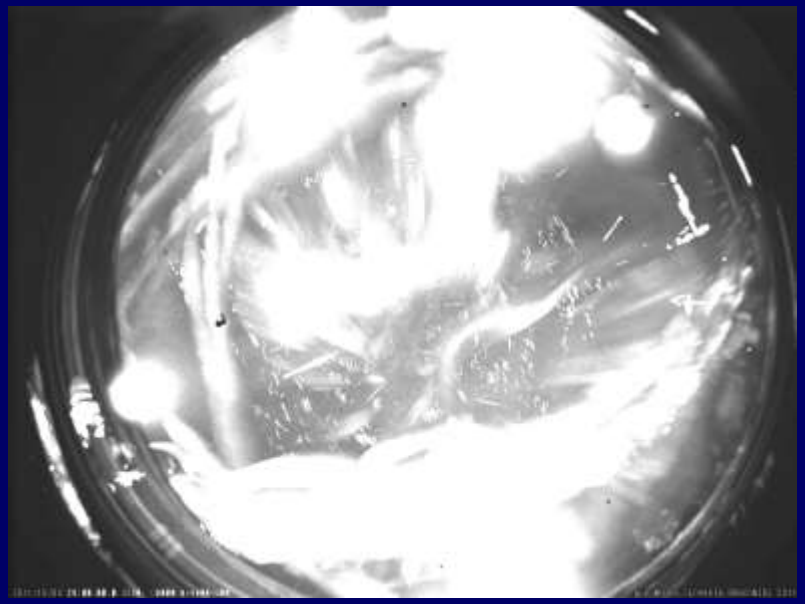
Airborne observation

Kiruna, Sweden, Oktober 8th, 2011

Airborne observation

- time interval 19:15 - 21:44 UT
  - blackout between 20:12 - 20:28 UT
- turbulence caused the movement of the sky background
  - 2 min clips + break to save
- AMOS contains also the image intensifer
- high background - full Moon, aurora (after 21 UT)

Processing of data

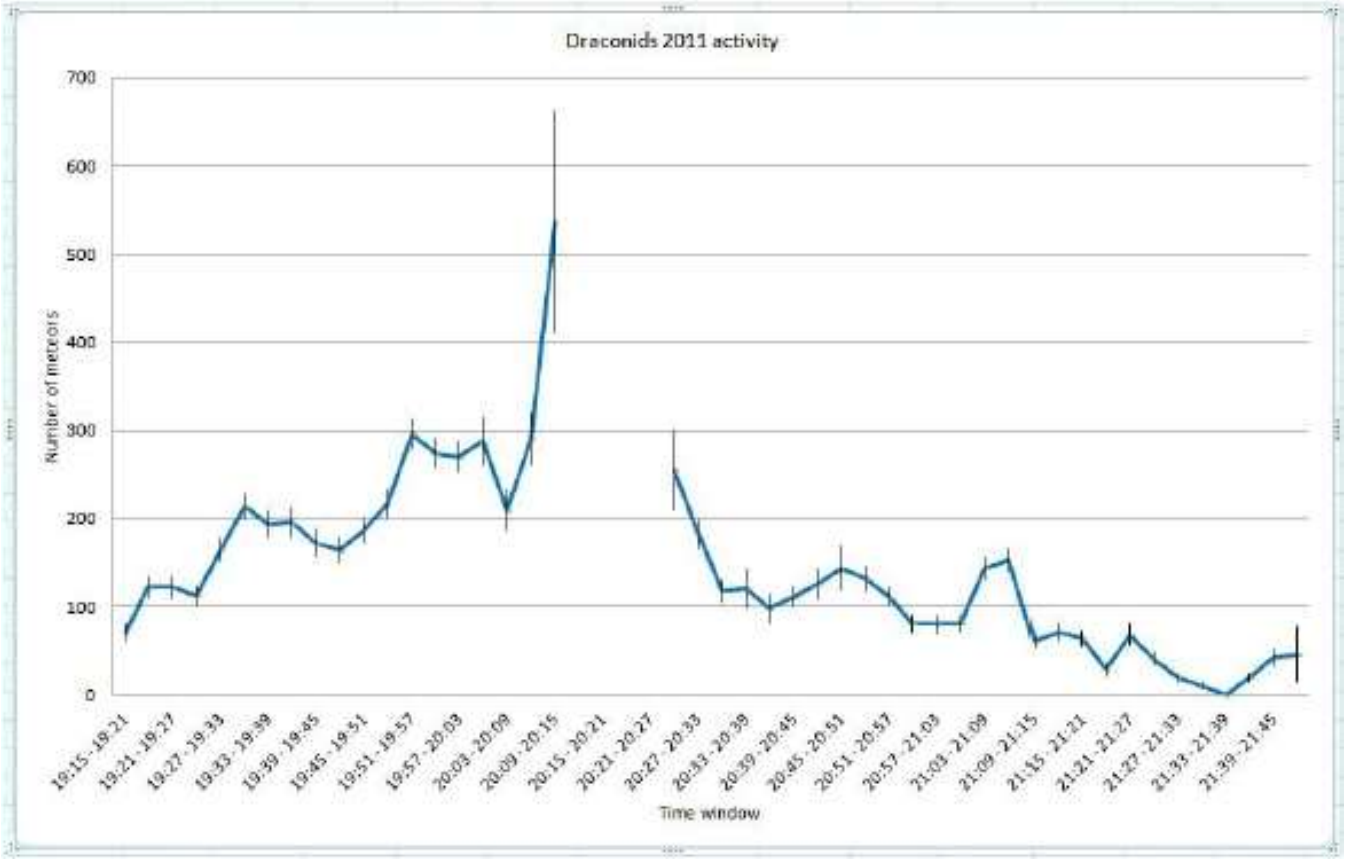


- detection of meteors manually
  - high background, sw did not work
- short clips containing only meteors
  - 1 sec - meteor - 2 sec
- astrometry by UFOAnalyzer
  - actual position of camera - airplane from GPS data

Results

- more than 250 Draconids recorded by AMOS camera
- brightness from -3 to +3 mag
- astrometric data corrected
  - precession, nutation, aberration
  - to join France / Safire aircraft
  - compute orbits
- activity profile - 6 min. time interval
  - influenced due to aurora phenomena, mainly after 21 UT
  - ZHR could not be derived

Activity profile from airborne observation AMOS

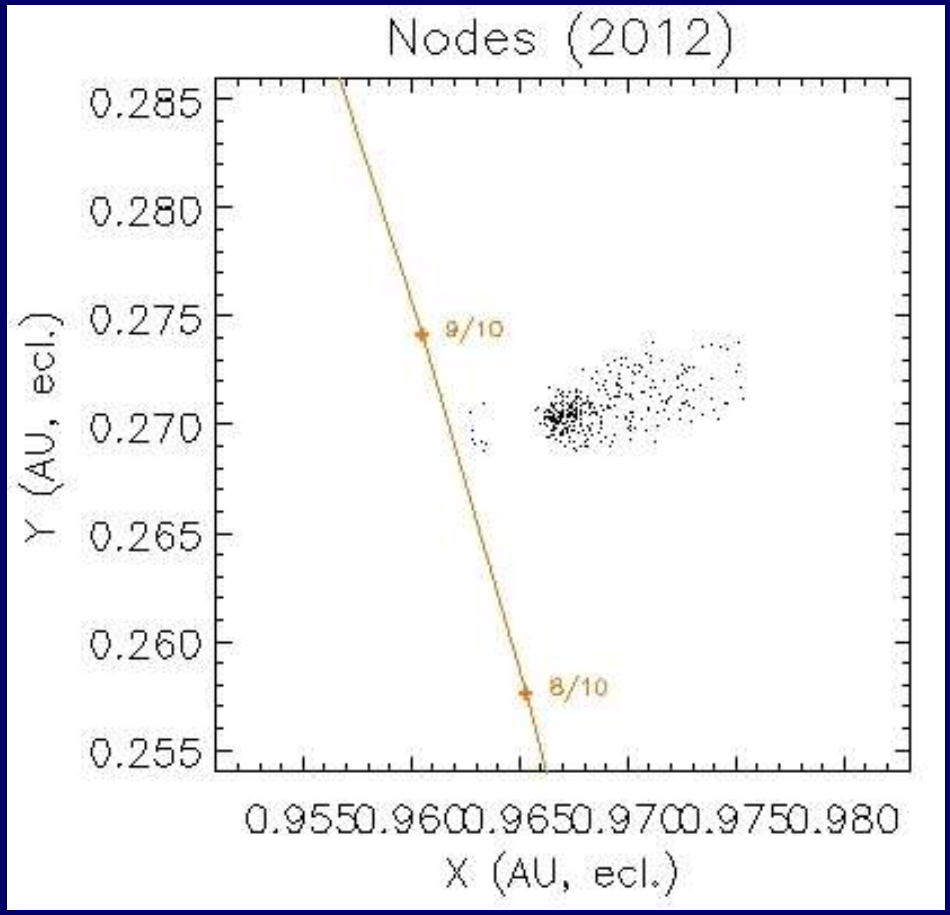


Výsledky

- hlavné max. aktivity v súlade s predpoveďou
- našli sa ďalšie dve maximá, jedno spojené s prechodom perihéliom pred r. 1900
- ZHR ~ 350
- F-faktor – veľká variabilita – tvary svetelných kriviek
- radianty podľa predpovede
- dráhy – ovplyvnené pohybom lietadiel, veľké neistoty
- preto nie je možné hľadať rozdiely medzi filamentami uvoľnenými pred a po r. 1900

Októbrové Drakonidy 2012

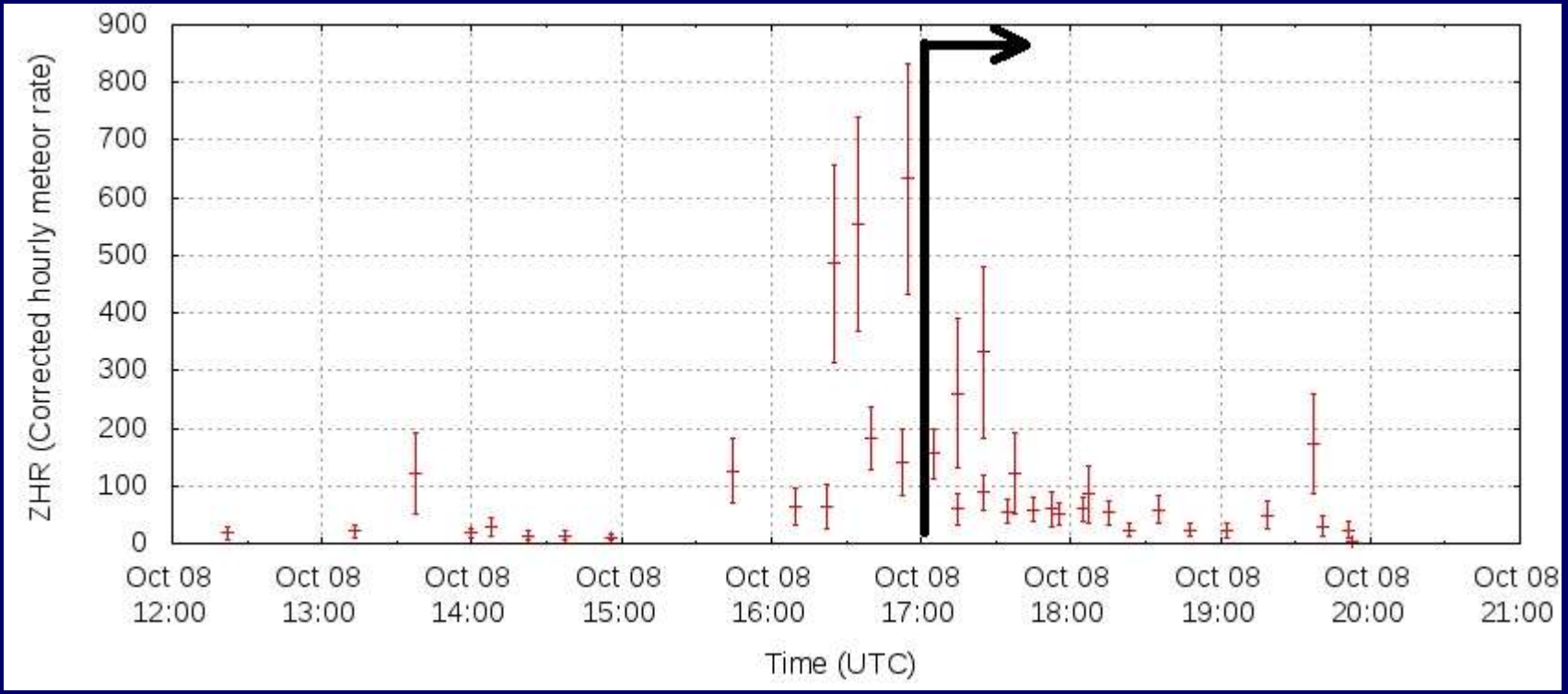
- na r. 2012 žiadna predpoveď výraznej aktivity
- Maslov (2011) – slabá aktivita z návratov 1959 a 1966



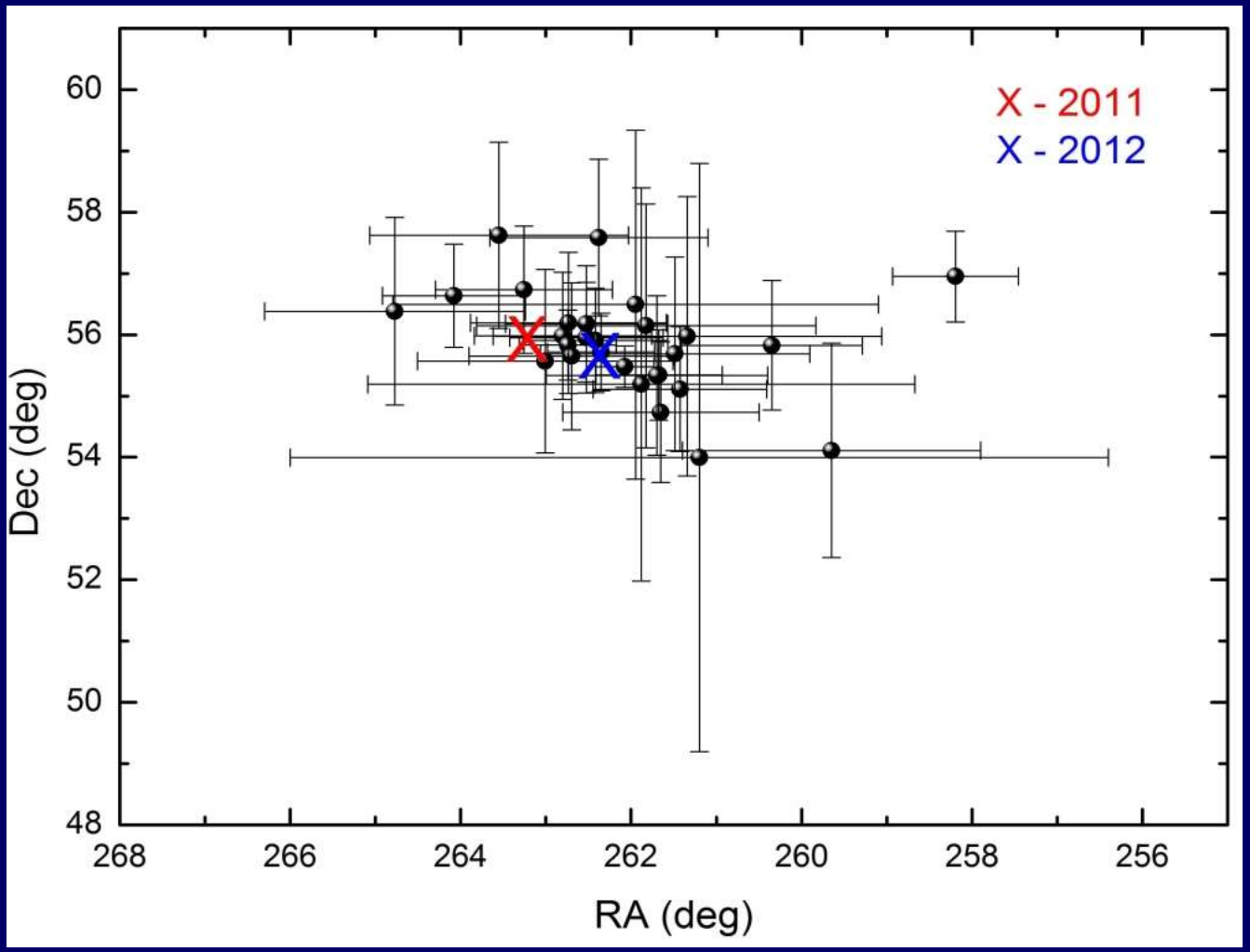
Októbrové Drakonidy 2012

- **nečakané zvýšenie 8. 10. 2012 okolo 17 UT**
- **stanice CEMeNt, PFN, HMN, SVMN – 28 dráh**

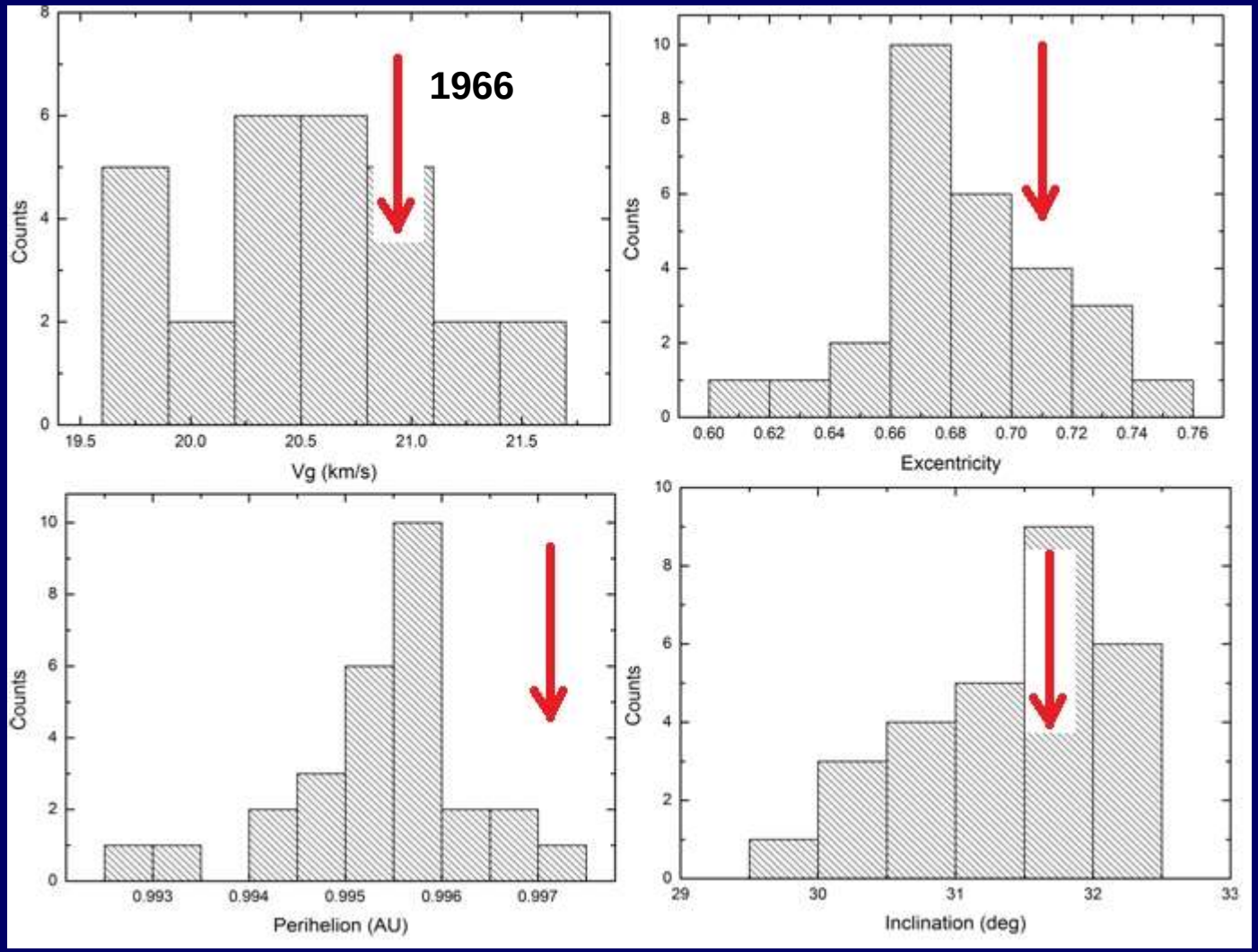
IMO



Drakonidy 2012



Drakonidy 2012



Vyhľadávanie v databázach

- **IAU Meteor Data Center**
  - **Established – 95 rojov**
  - **Working list – 462**
    - **pro tempore – 81** (väčšinou len niektoré parametre)

Metódy vyhľadávania:

- **voči referenčnému katalógu niektorým z kritérií**
  - **D_{SH}, D_D, Valsecchi – Jopek - Froeschlé a i.**
- **nezávislé vyhľadávanie niektorým iteračným procesom**
- **pracujeme na kombinácii dráhového krit. a pozorovaných param. v iterácii**

Vyhľadávanie v EDMONDe

- **Radiant – V_g voči katalógu**
  - diff. in RAD – 5 deg
  - diff. in velocity – 10 %

- **iteračná metóda** (*Porubčan Gavajdová, 1994, D_{SH}*)
  - citlivá na inicializačnú dráhu

- **identifikovaných 249 meteorických rojov** (5 meteorov a viac)
  - **62 established a 187 z working list (**44 ‘pro tempore’) (august 2013)

- **slúži na spresnenie TV dráh, radiantov, Vg, výšok horenia a ďalších parametrov**

Pro tempore roje v EDMONDe

Welch (2001) metóda (1. časť)
aplikovaná na predošlý výsledok vyhľadávania

$$\rho_j = \sum_{i=1}^{N} \left(1 - \frac{D_{ij}^2}{D_c^2} \right) \quad ; \qquad D_{ij} \leq D_c$$

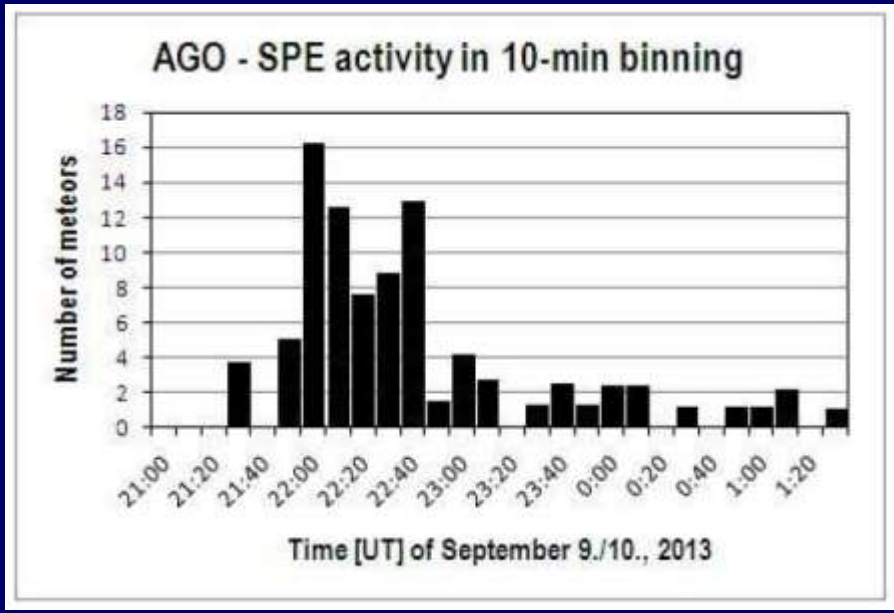
- váhované priemery parametrov
- ρ_{max} - ? → IAU MDC (rozdiely väčšinou v $\mathbf{L_{SUN}}$, radiant)
- porovnanie s databázami SonotaCo a CAMS

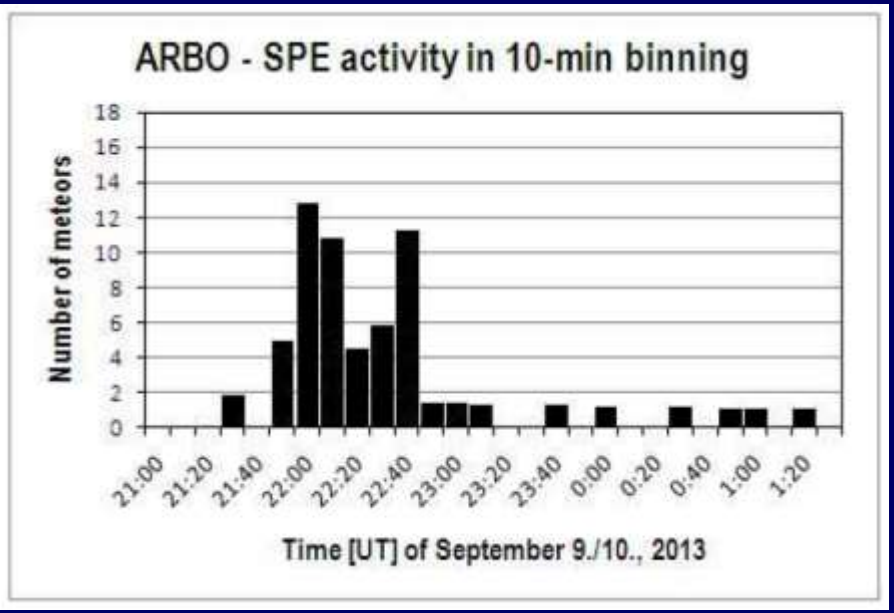
- **22 rojov identifikovaných spoľahlivo**, 18 s neistotou,
  25 neidentifikovaných

- **viaceré stredné parametre rojov uvedené prvýkrát**

Stredná dráha a profil SPE 2013

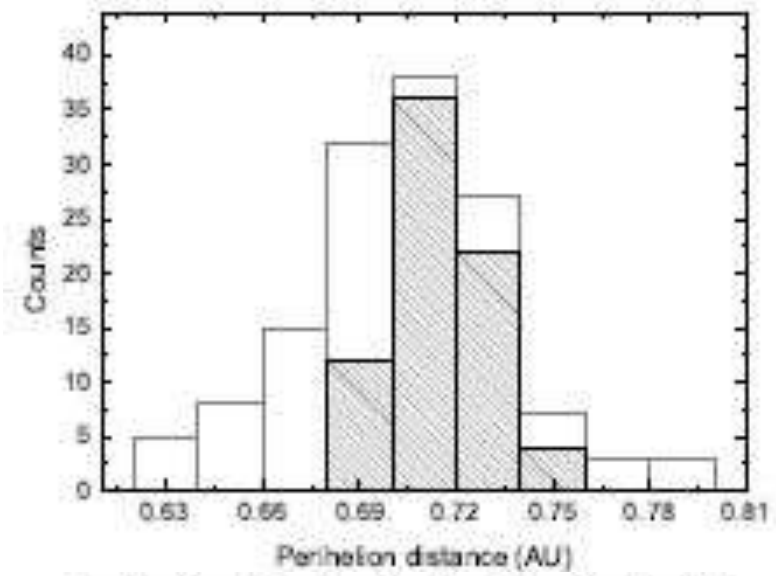
Method	RA [°]	DEC [°]	V_g [km/s]	q [AU]	e	ω [°]	Ω [°]	i [°]	a [AU]	D_{SH}
IAU MDC	50.2	+39.4	64.5	0.742	—	241.9	171.3	138.9	31.1	—
SPE 2013	47.6	+39.4	64.3	0.714	0.959	246.1	167.2	139.1	17.4	0.04
SD	0.7	0.5	0.52	0.012	0.032	1.8	0.0	1.1	—	0.02

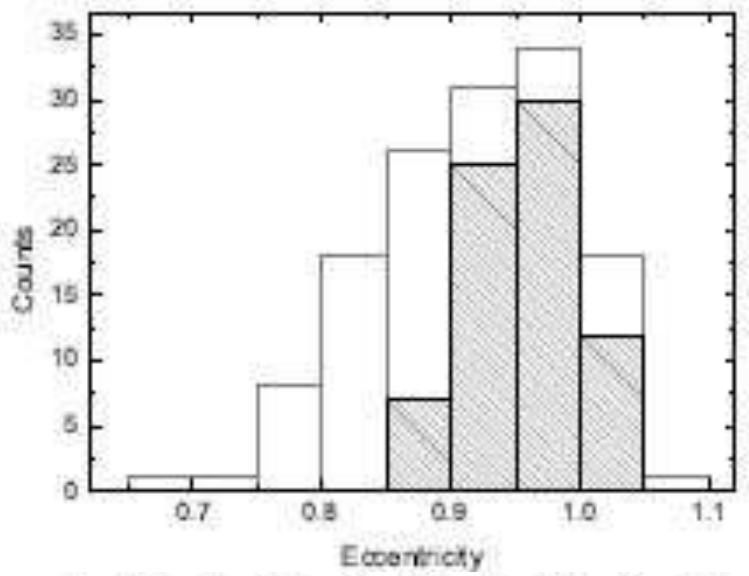


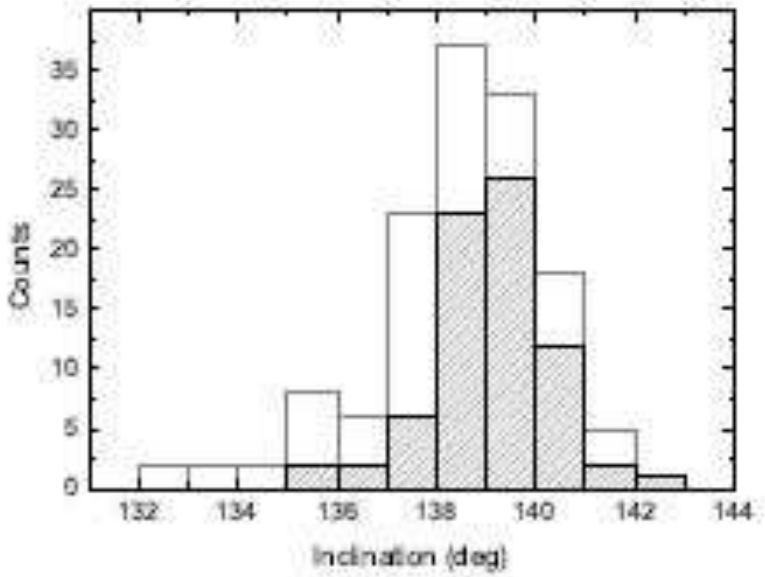


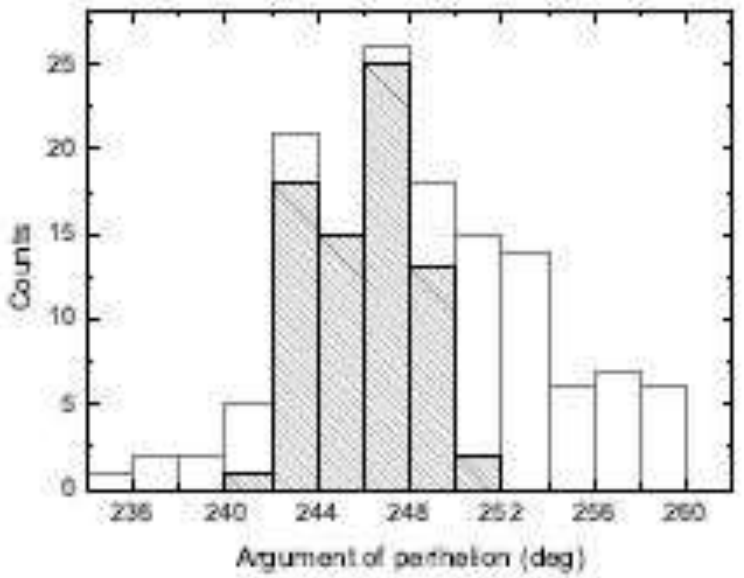
Gajdoš et al. 2014

138 dráh SPE vs. jadro 74 SPE

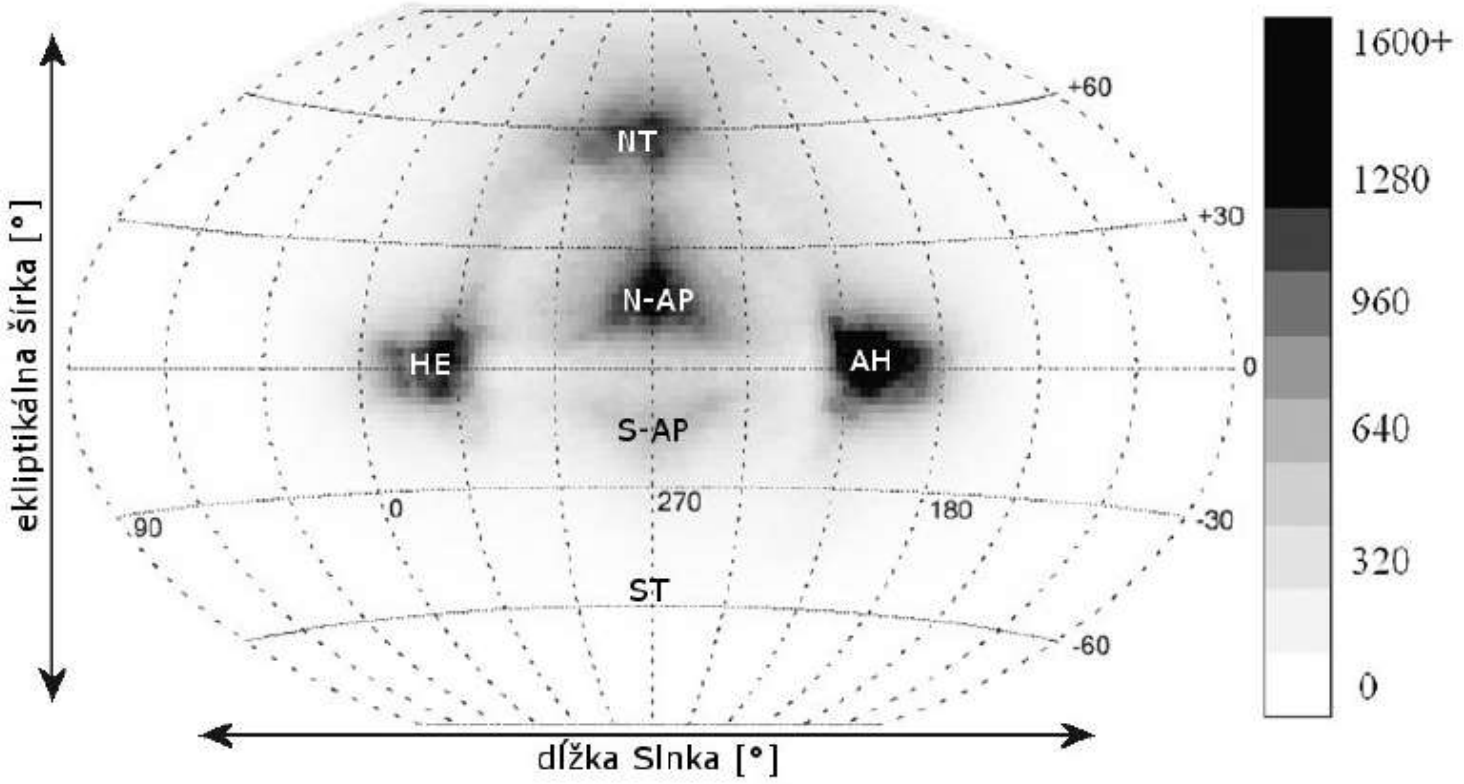








Sporadické pozadie

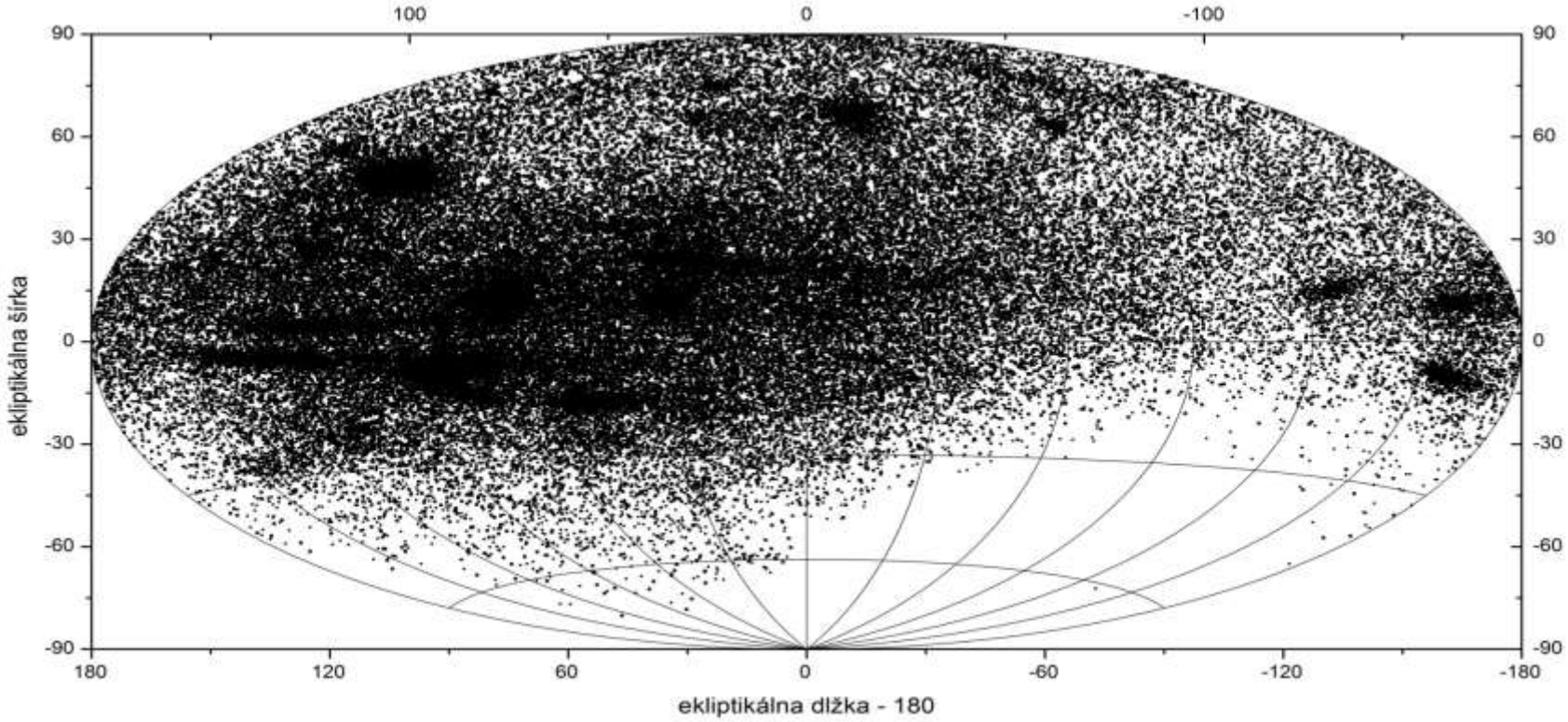


CMOR

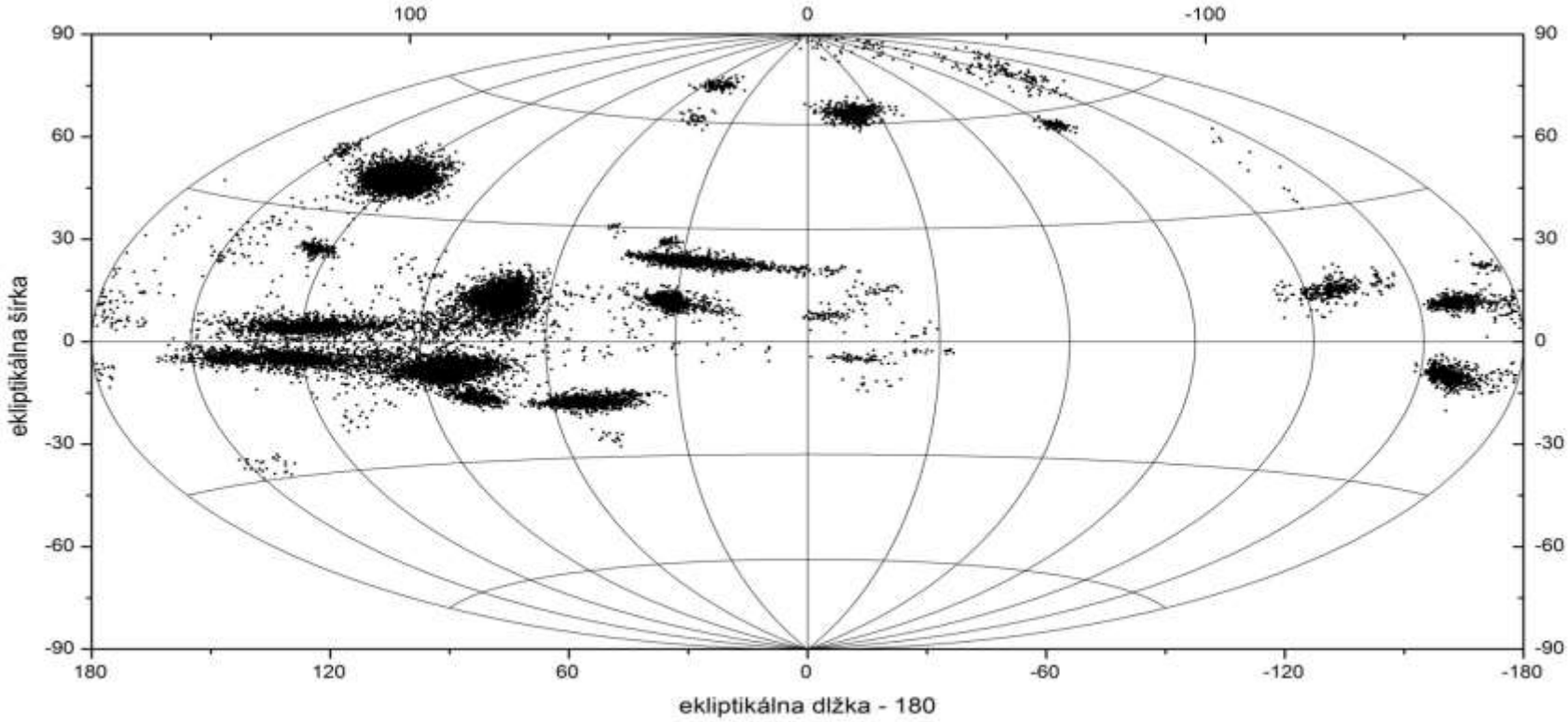
- anaýza ~ 118 000 dráh SonotaCo

  Porubčan, Jakšová (2014)

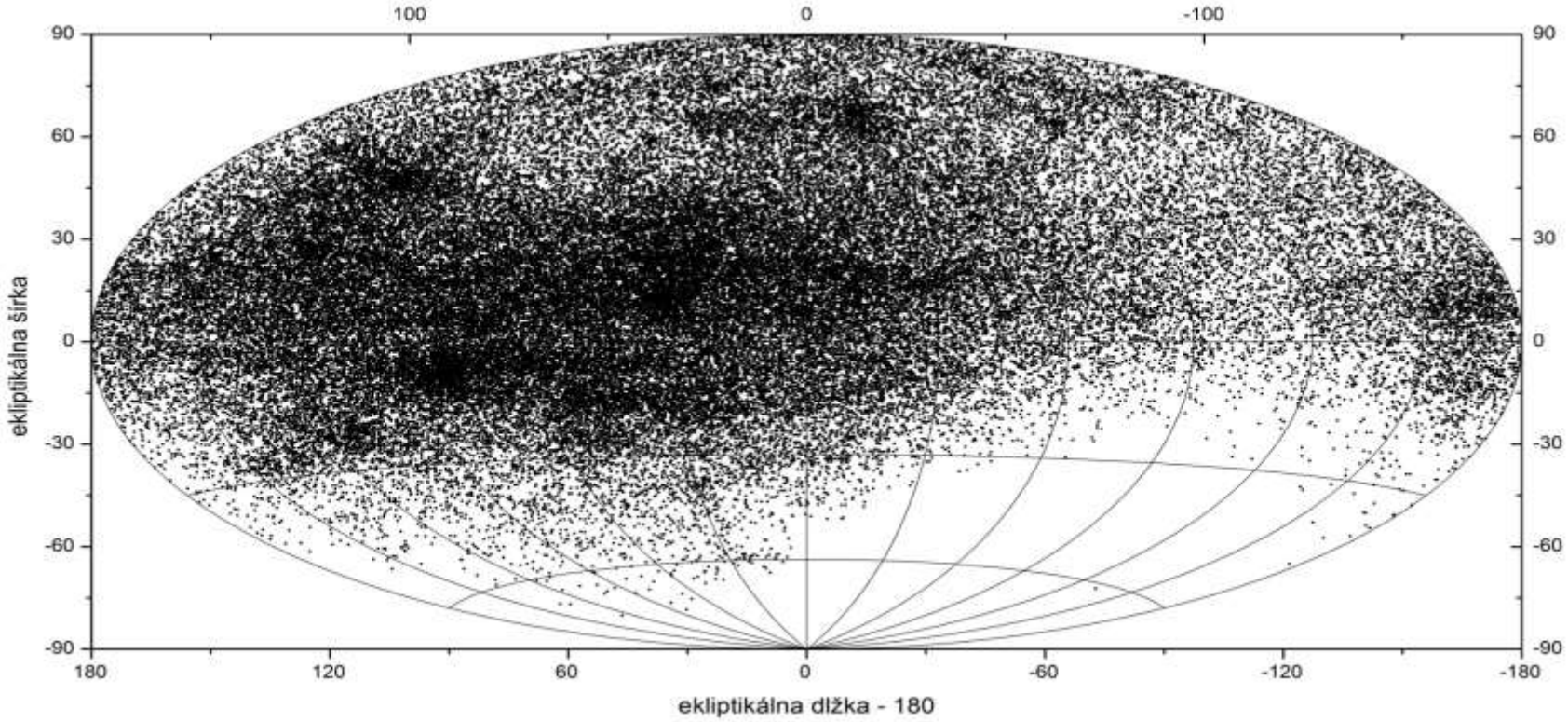
Všetky meteory 2007-2012



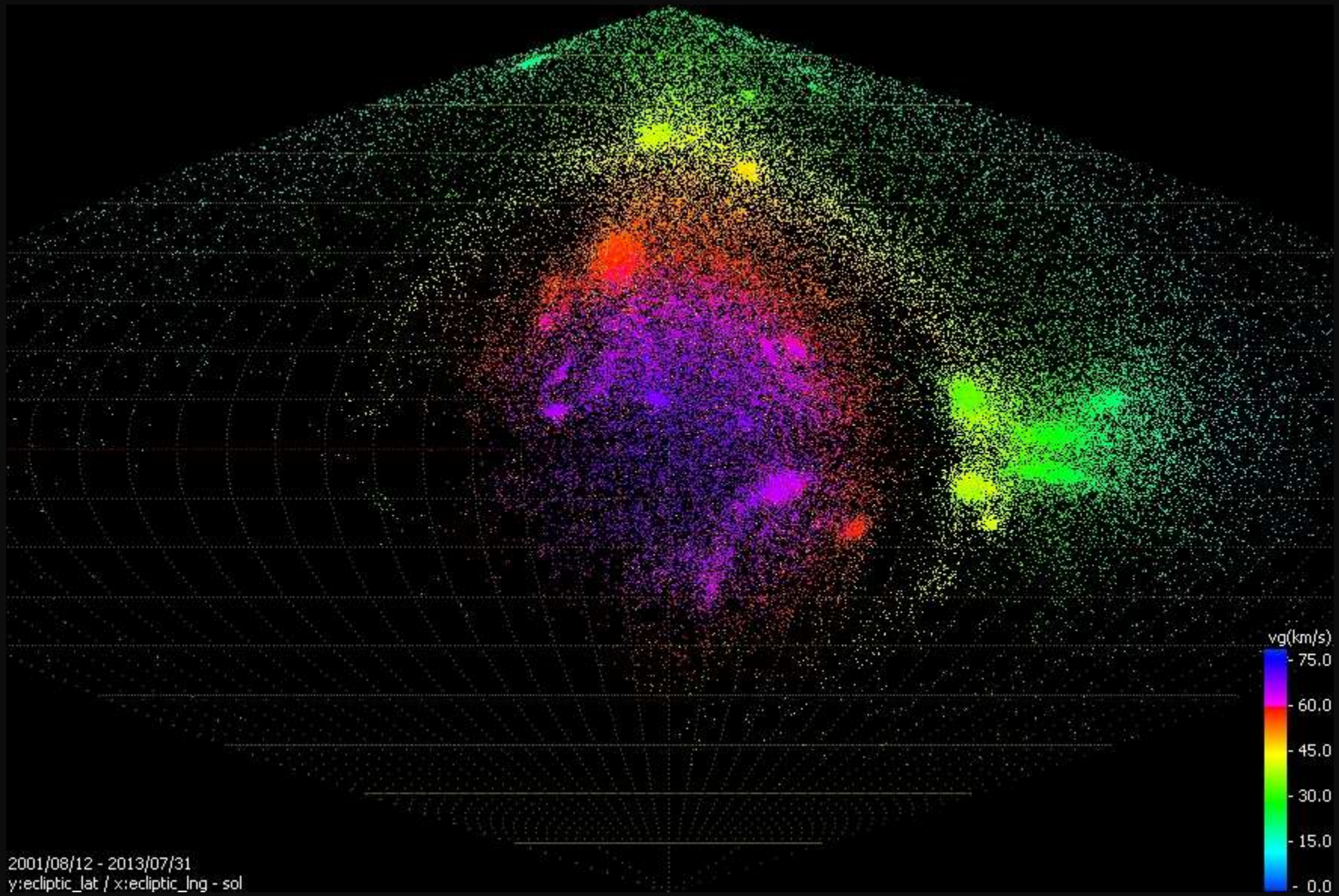
Meteorické roje 2007-2012



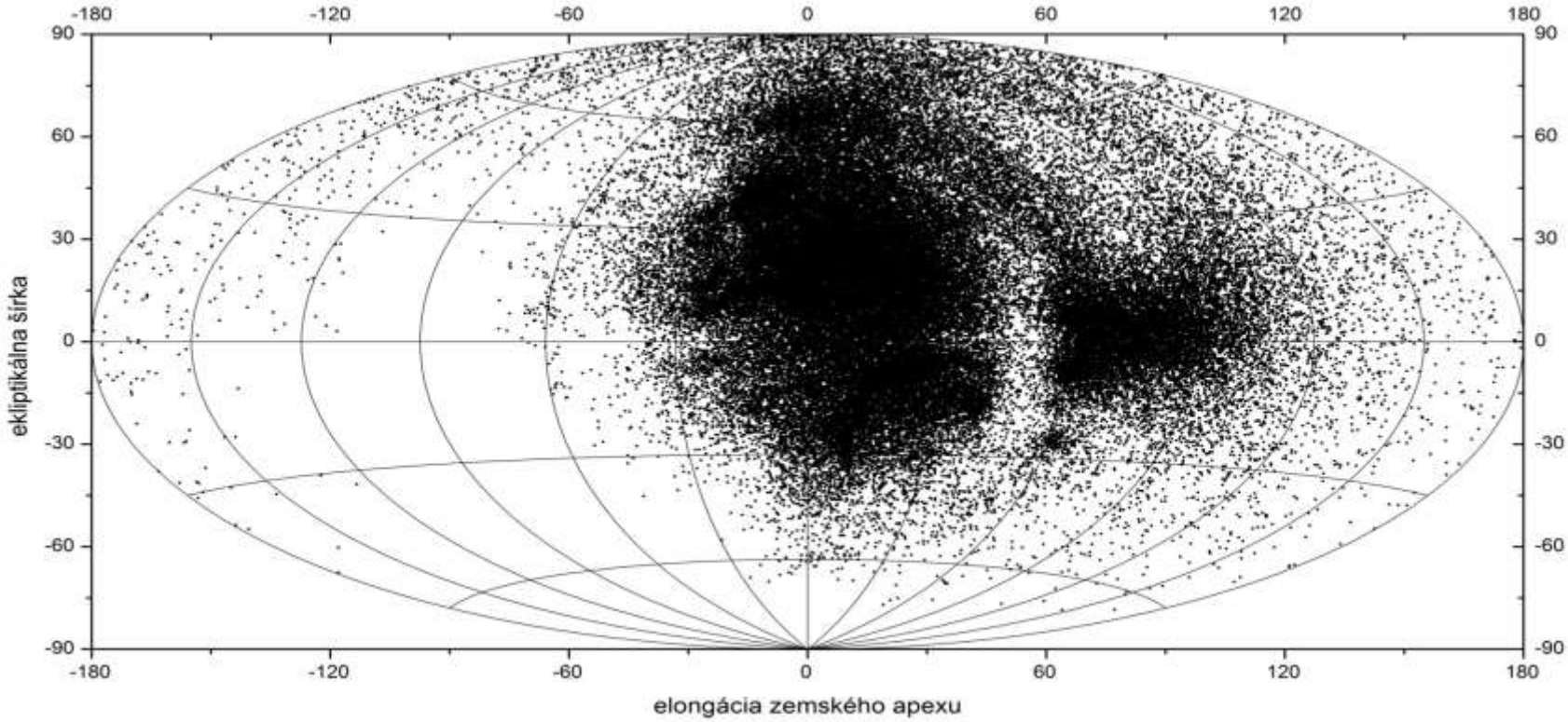
Sporadické meteory 2007-2012



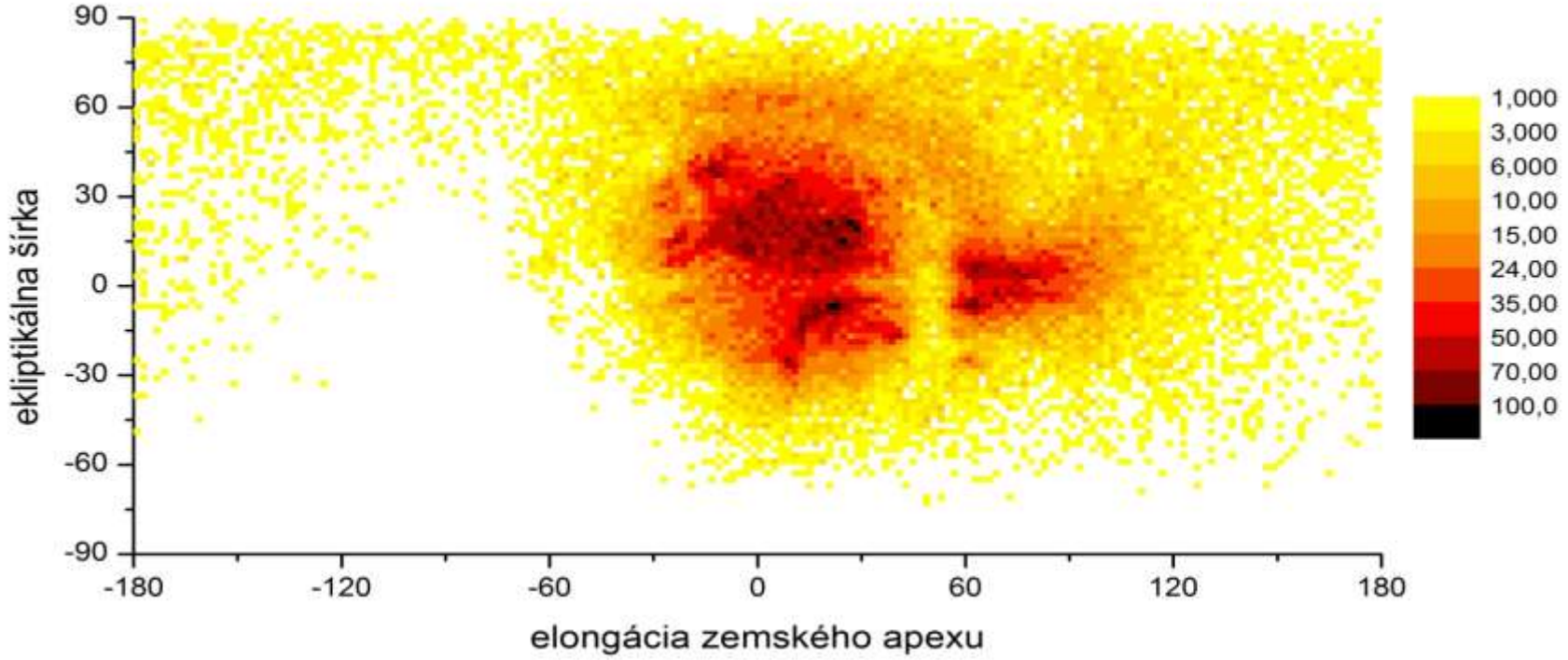
RADIANTS – apex



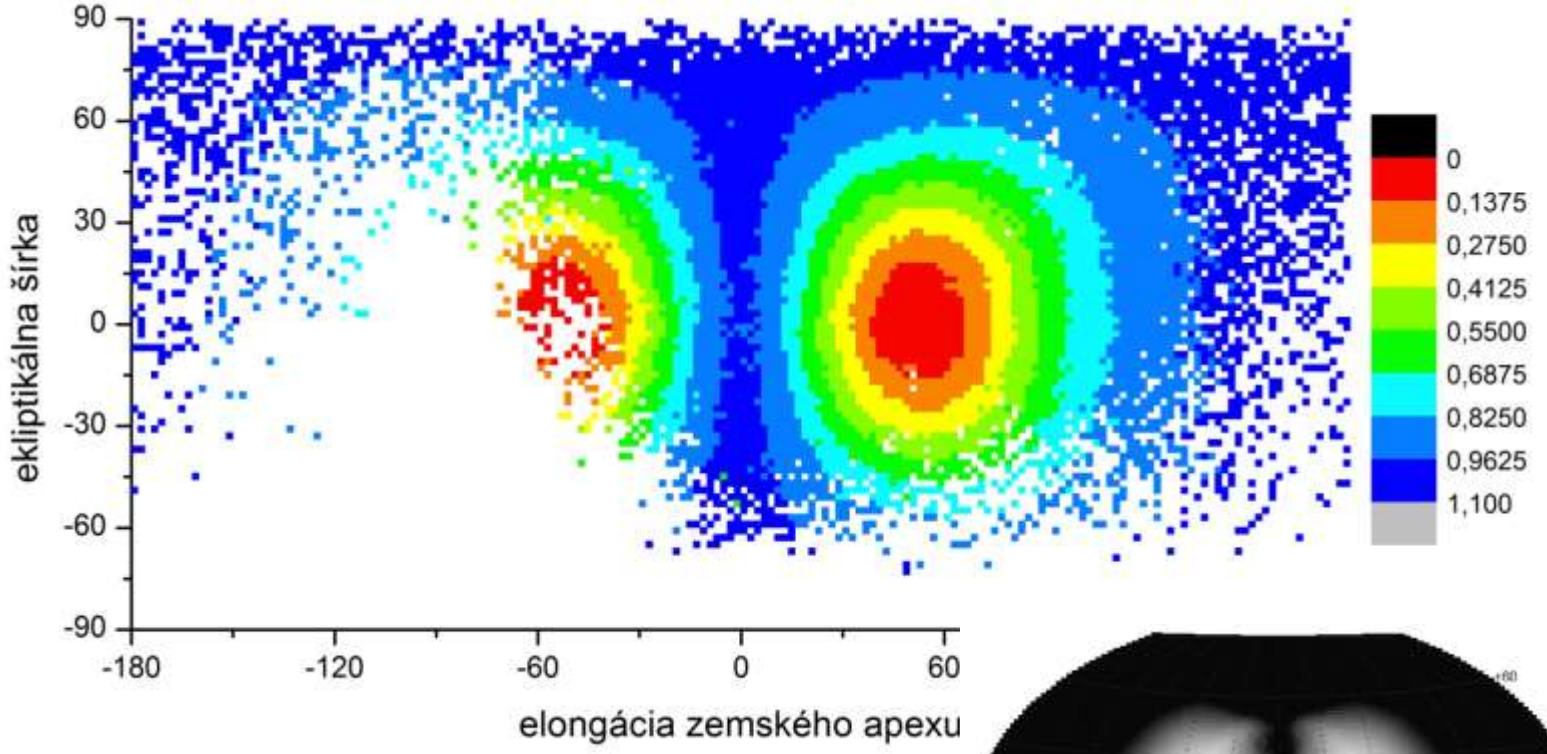
Sporadické pozadie po oprave na apex Zeme



Hustotné rozdelenie 2007-2012



Perihéliové vzdialenosti



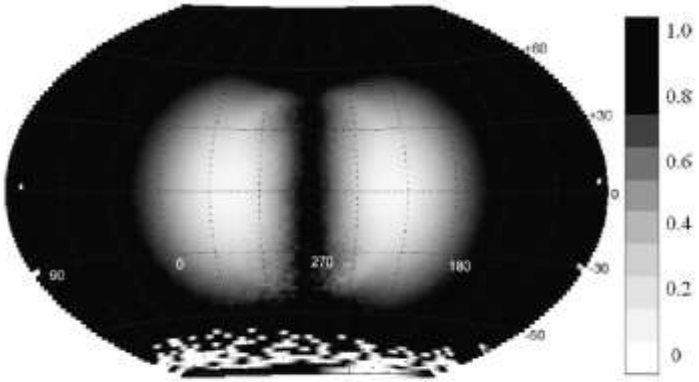
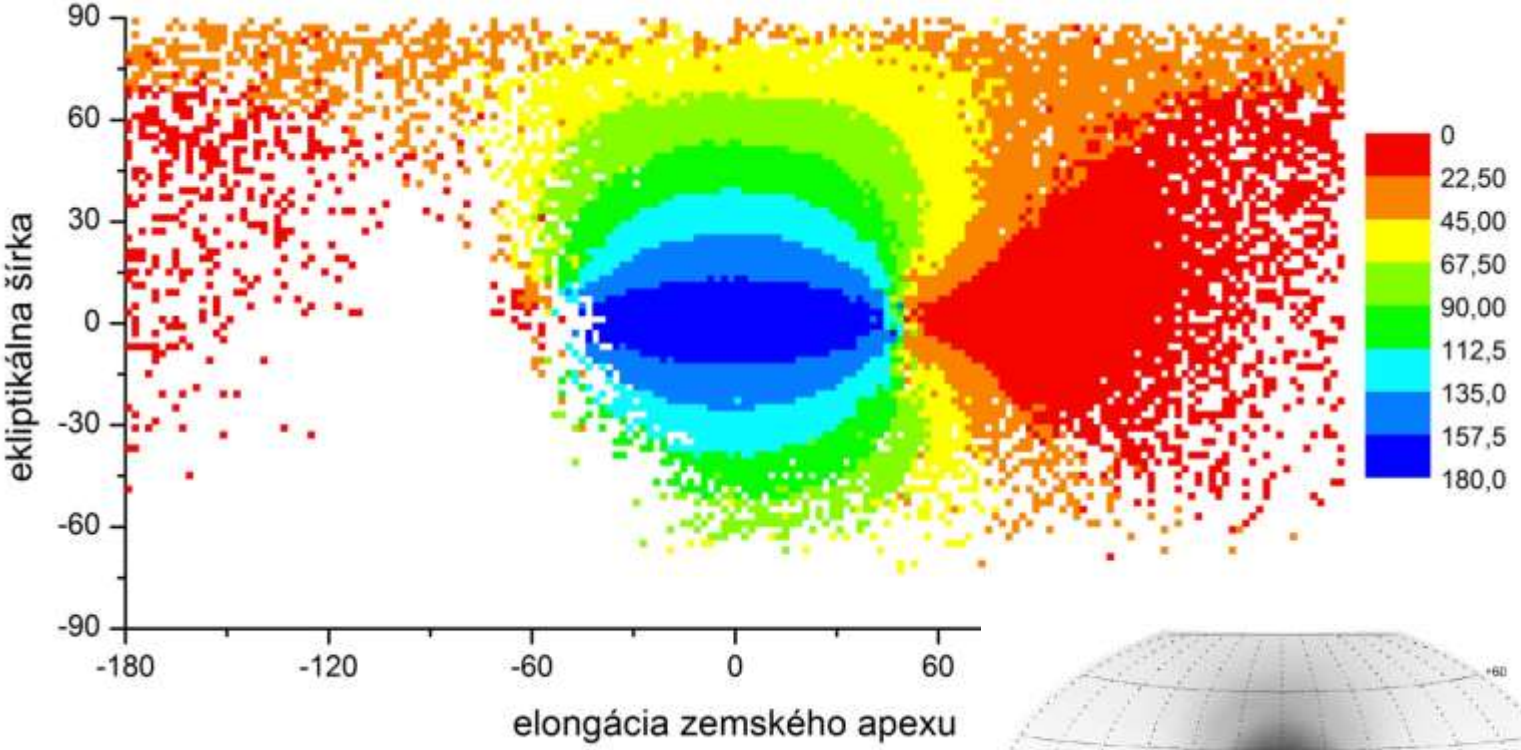


Fig. 22. Perihelion distance of CMOR meteors, in AU.

Sklony



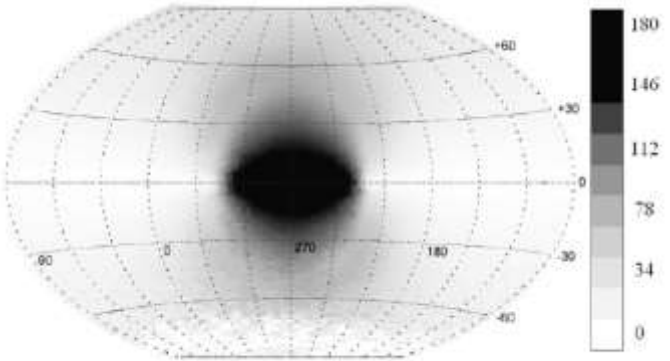
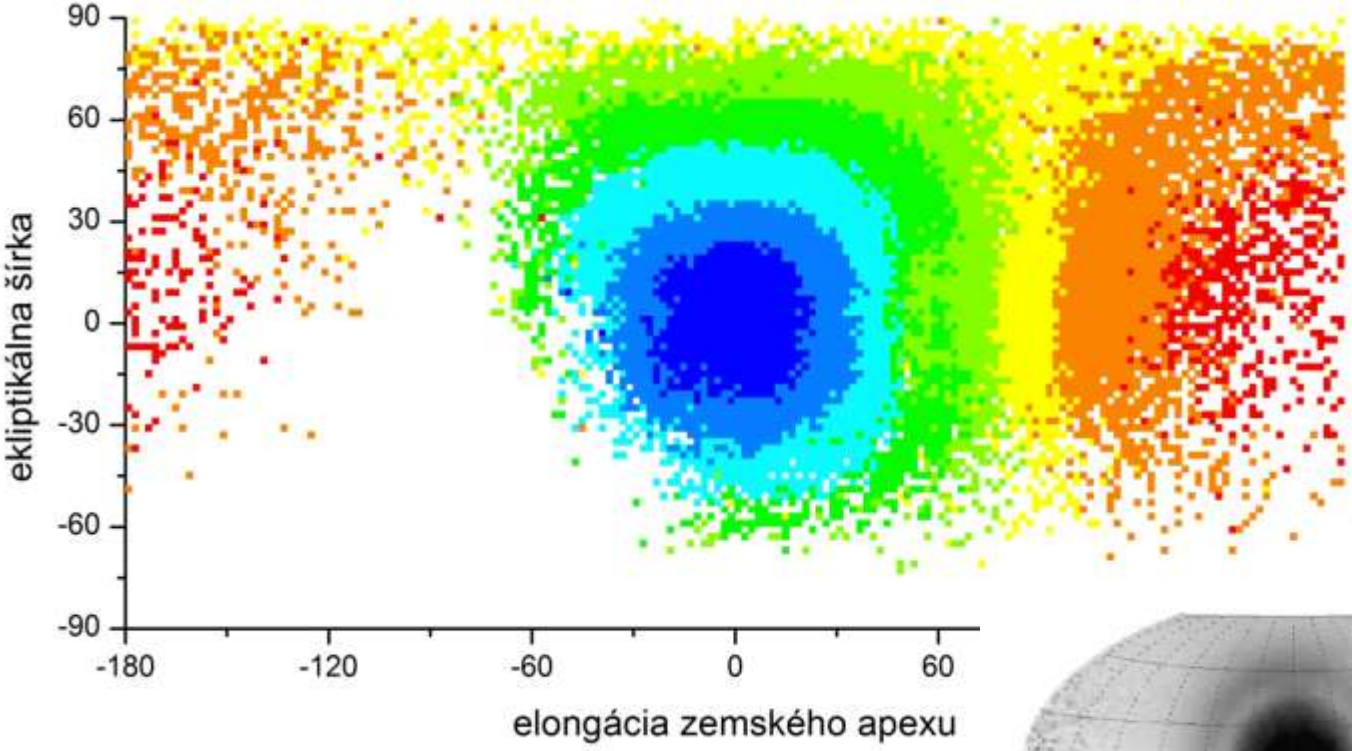


Fig. 19. Inclination of CMOR meteors, in degrees.

Geocentrické rýchlosti



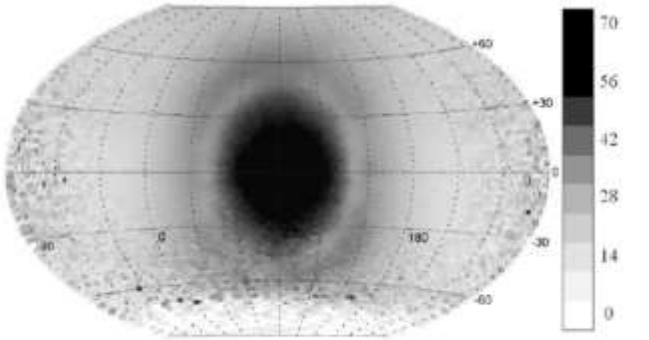
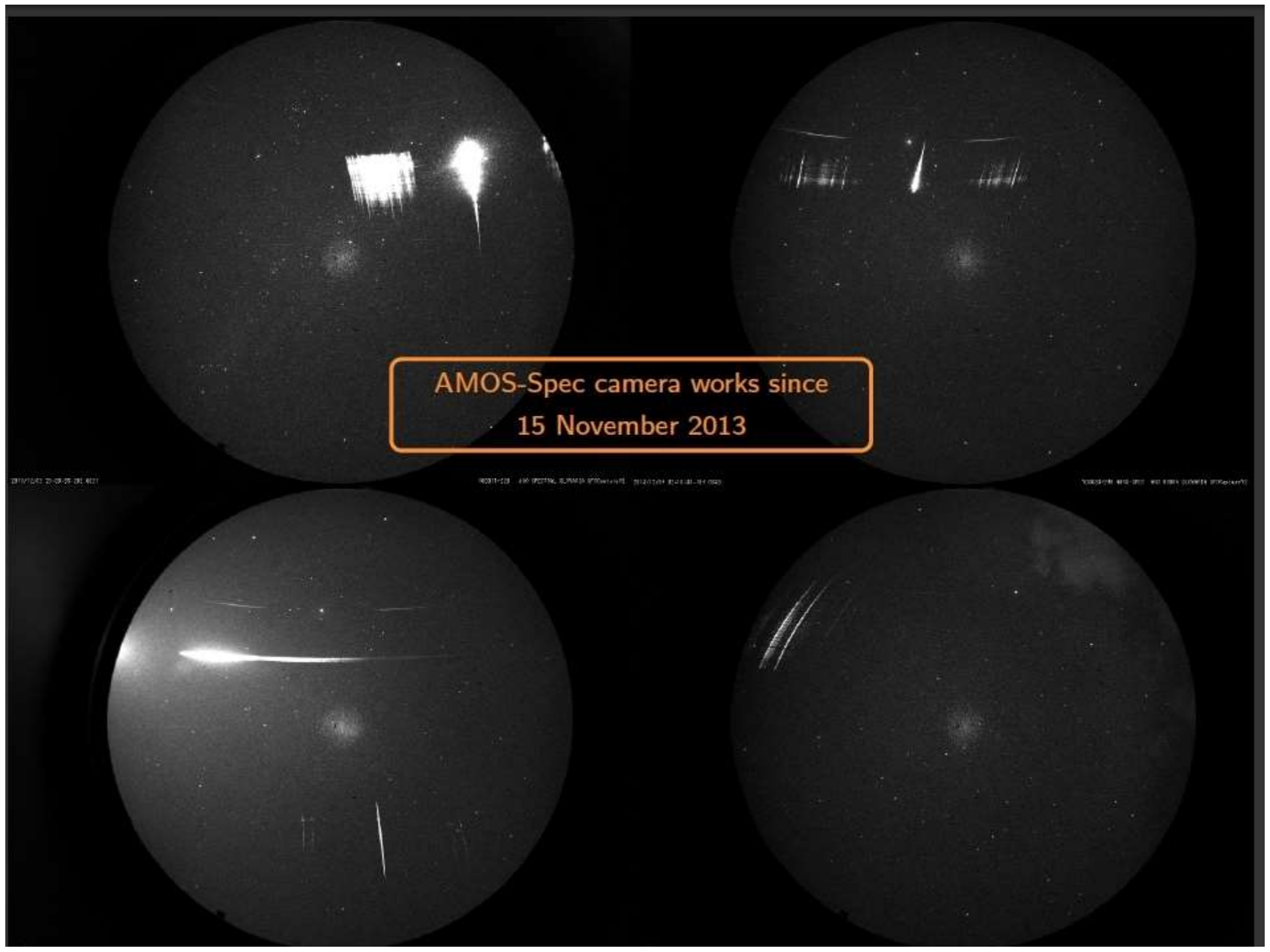


Fig. 16. Geocentric speed of meteors, in km/s, as a function of ecliptic latitude and Sun-centered longitude.

AMOS – spektrá

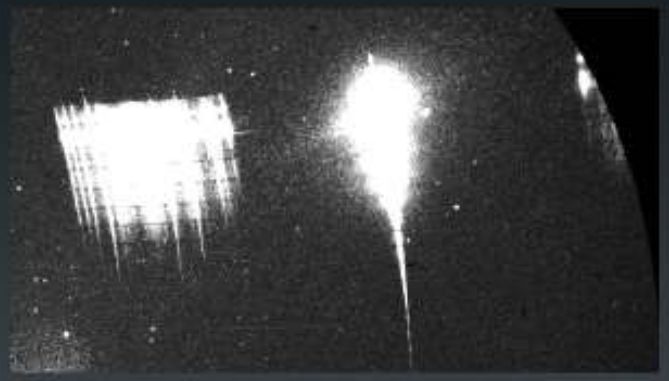
R. Rudawska, J. Tóth , D. Kalmančok,
P. Zigo


AMOS-Spec camera works since
15 November 2013

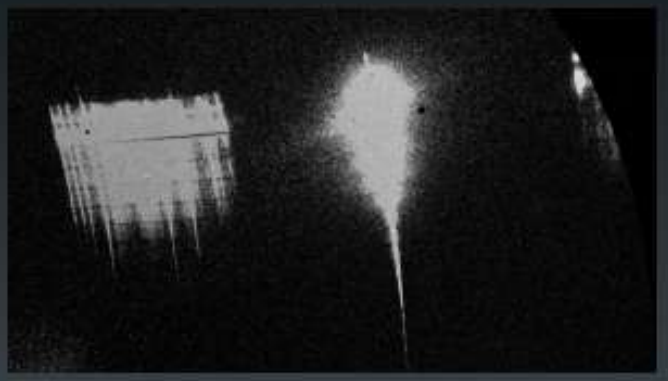
Lens:	30 mm, f/3.5
Grating:	500 grooves/mm
FOV:	140 x 100 deg

w/:	45 (13)
w/o:	469

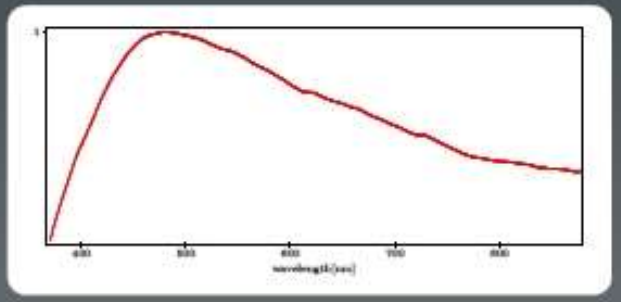
Data reduction



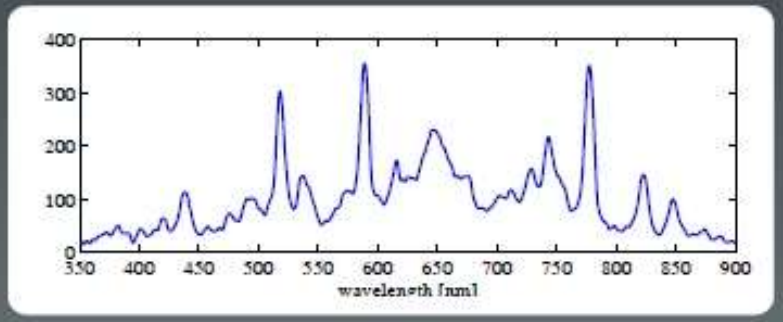
dark, flat



background

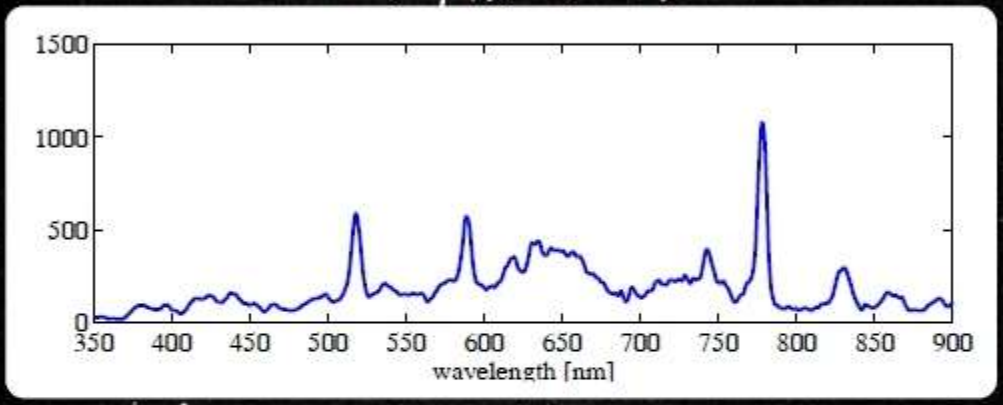


spectral responsibility
Jupiter spectrum

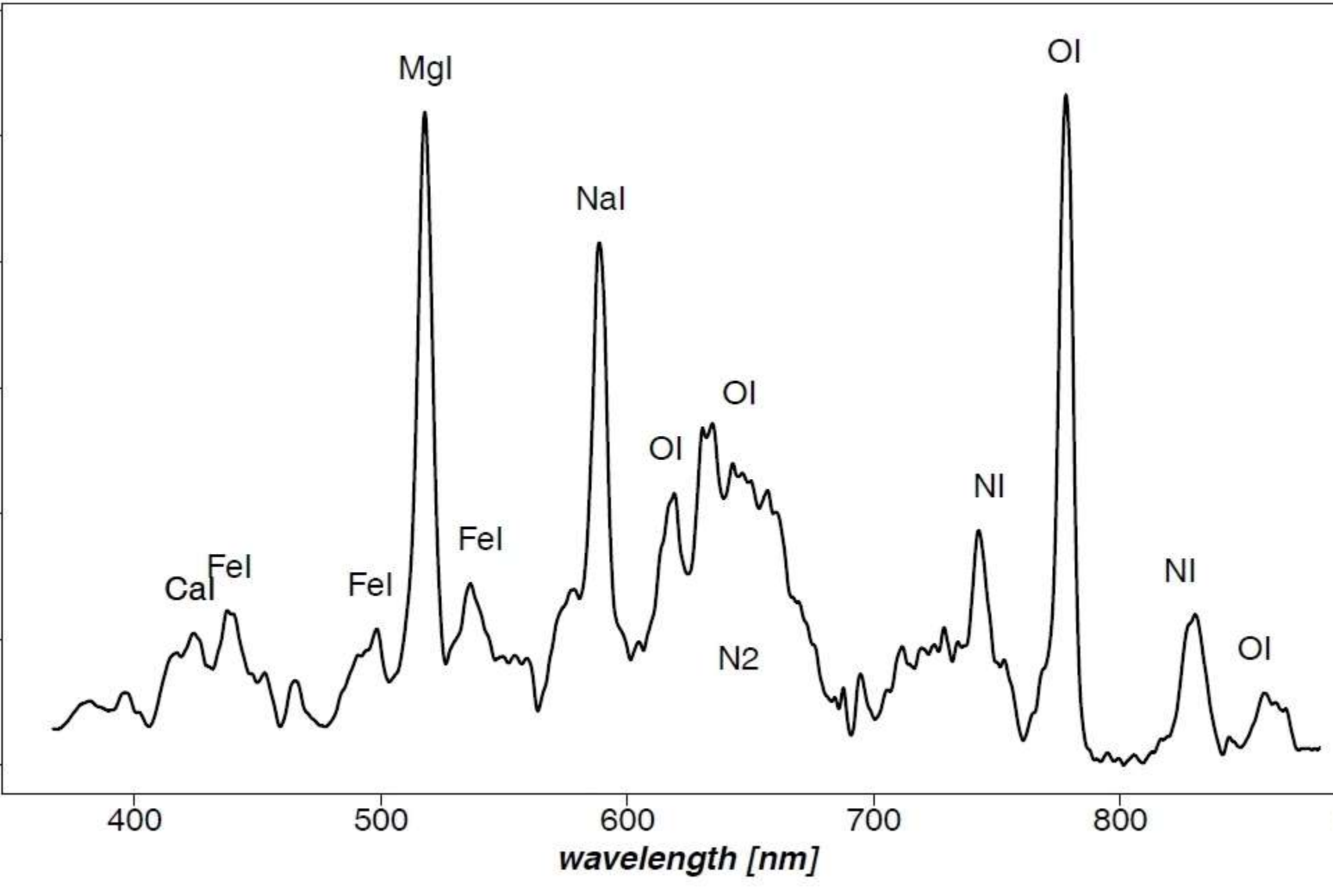


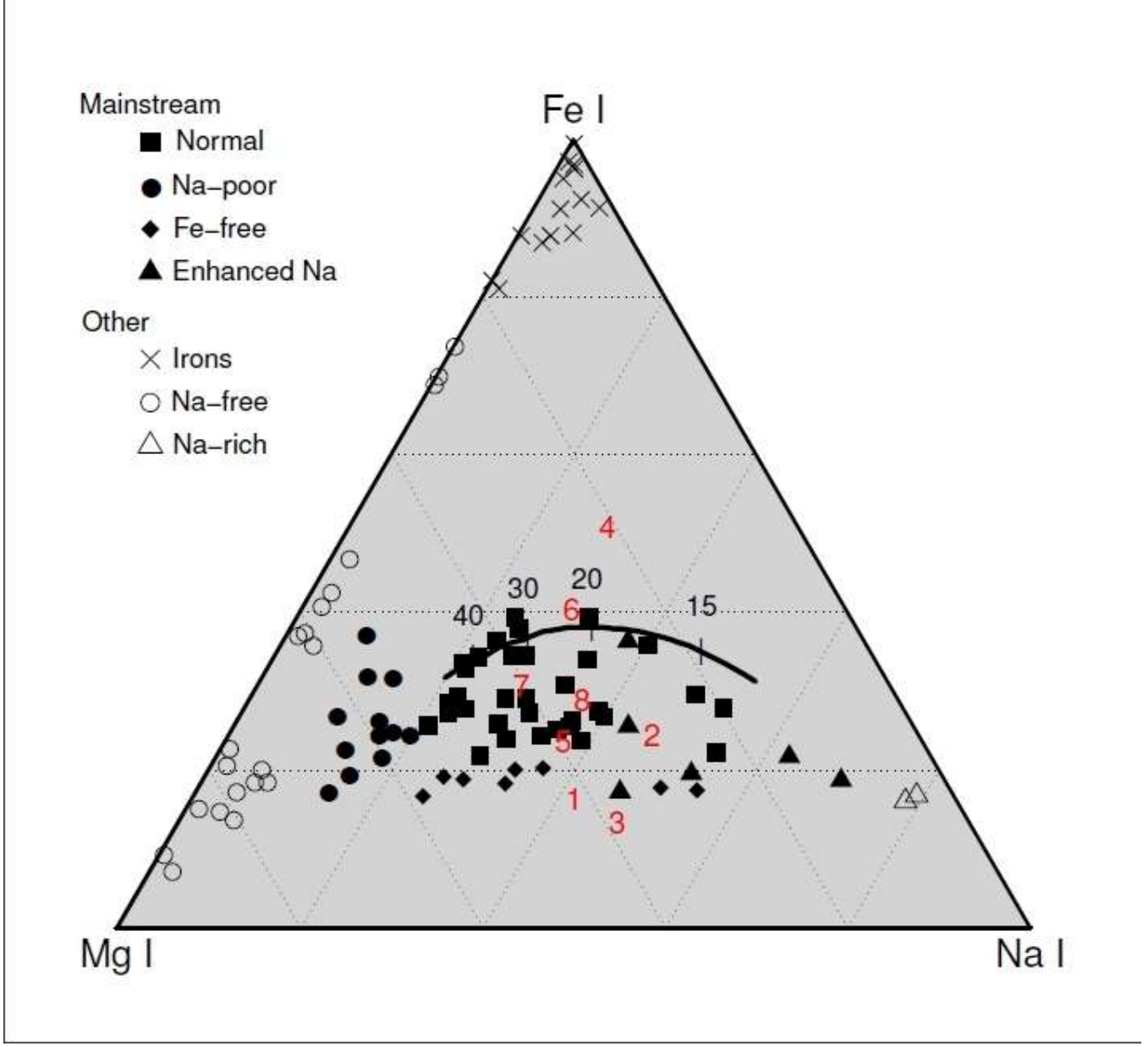

December 4, 2013 – Modra, Slovakia
2013/12/04 02:10:38.888 0033 00088
V00888+888 ANOS-SPEC AGO MODRA SLOVAKIA UFOCaptureV2

σ Hydrids (#016, HYD)



a [AU]	e	ω [deg]	Ω [deg]	i [deg]
15.5	0.984	120.8	71.9	128.7


MgI
OI
NaI
OI
OI
FeI
FeI
CaI
FeI
NI
NI
OI
N2
400
500
600
700
800
wavelength [nm]



Borovička et al. 2005

Asteroidálny pôvod prúdov

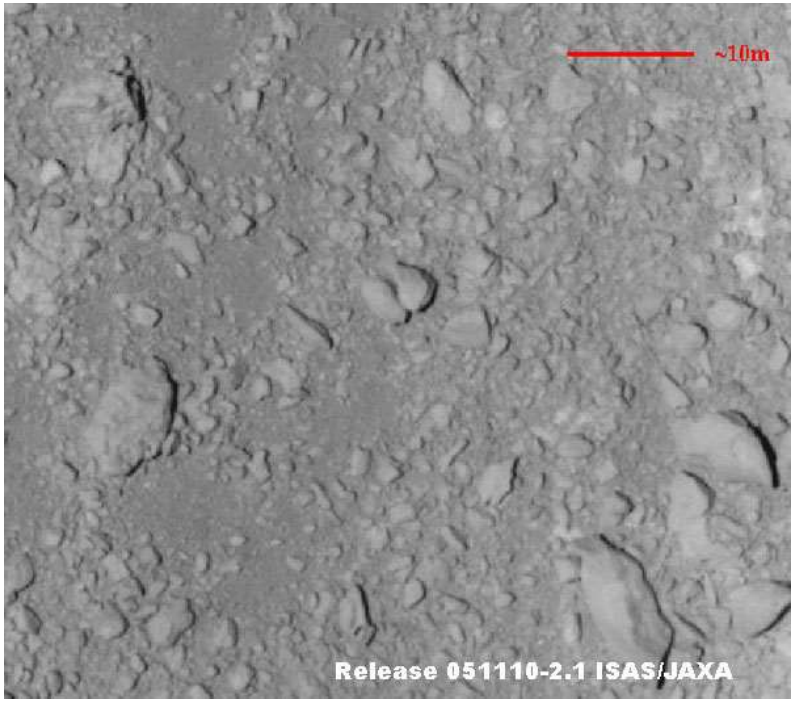
kométa
asteroid → meteorický prúd

- **asteroid –** jednorazová udalosť
  - zrážka s iným asteroidom
  - **slapový rozpad**
  - tepelné pnutie
  - YORP efekt – rotácia

Argumenty pre:

- snímky štruktúry povrchu Itokawy
- rotačná bariéra asteroidov (~ 2.2 hod)
- pohyb materiálu na povrchu (Itokawa)

povrch asteroidu Itokawa



Jaxa

Asteroidálne meteoroidy

- Pád meteoritu Neuschwanstein (2002) na identickej dráhe meteoritu Příbramu (1959)

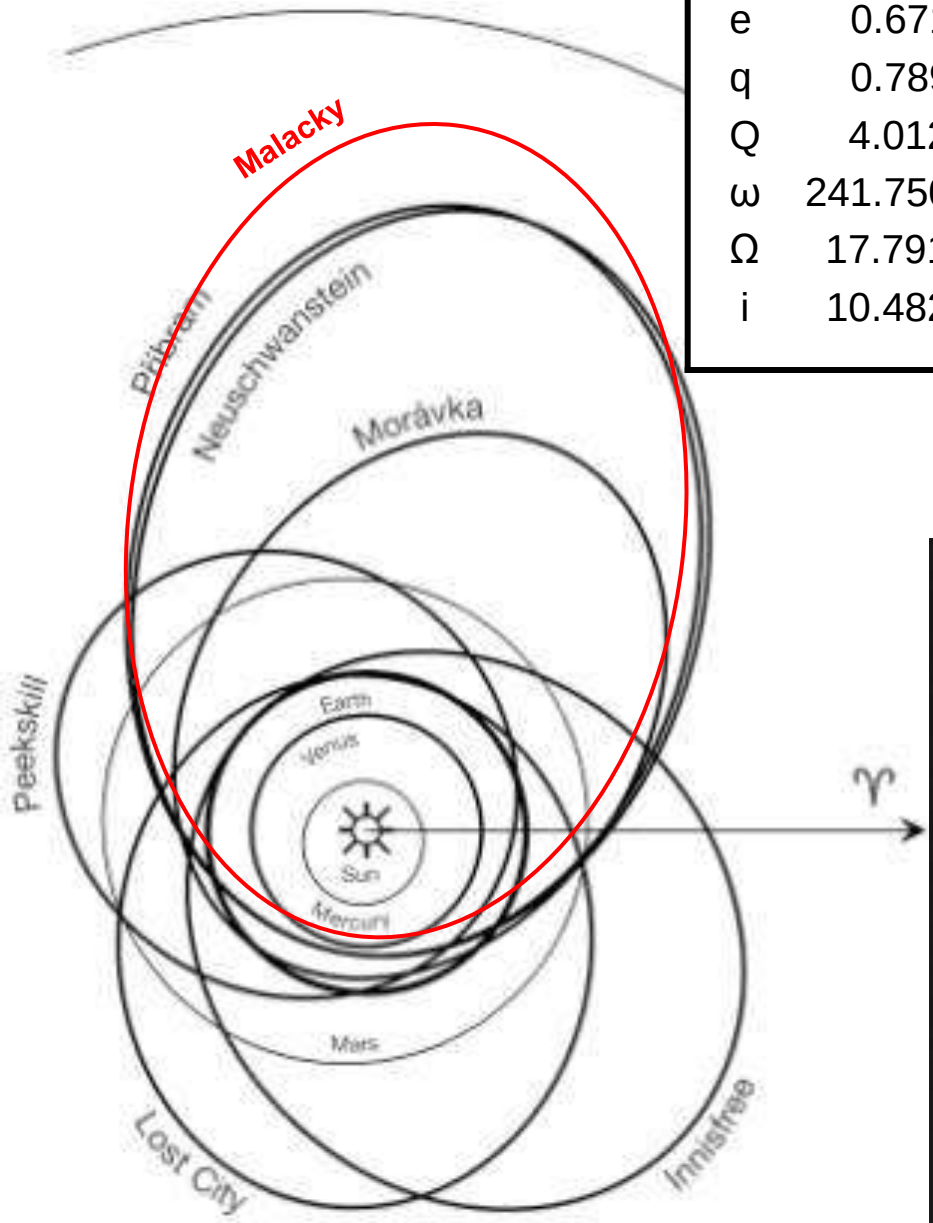
- odlišné typy meteoritov a rozdielny kozmický vek

  heterogénny prúd?
  (*Spurný P. et al., 2003*).

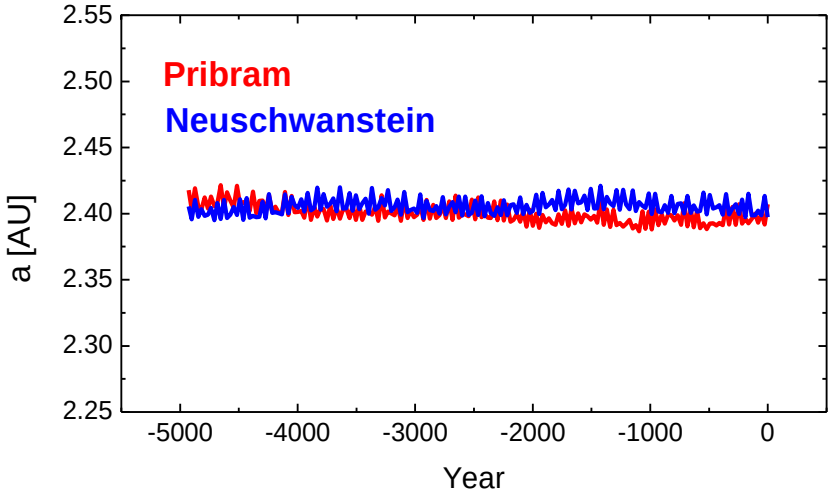
- Frekvencia veľmi tesných priblížení (~ $2R_{Earth}$) NEA s veľkosťou Itokawy (0,5 km) je ~ 1 za 25 000 rokov (*Ivanov, 2006*). (bez rotácie)

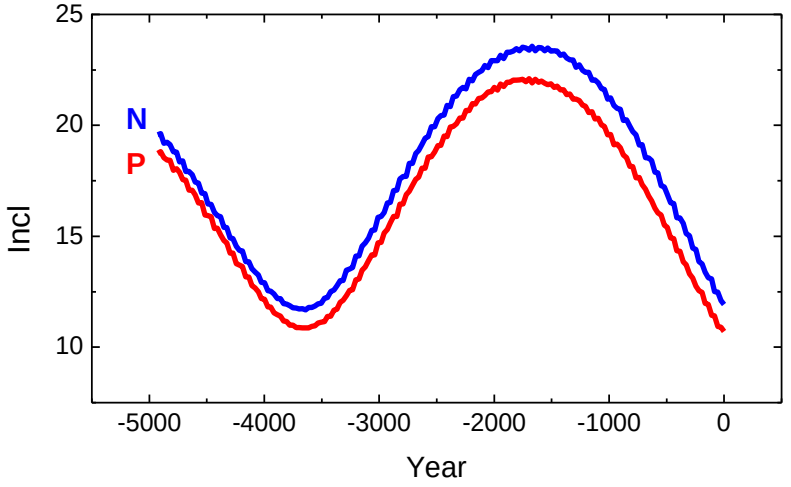
	Příbram	Neuschwanstein	Malacky
a	2.401 ± 0.002	2.40 ± 0.02	2.61 ± 0.02
e	0.6711 ± 0.0003	0.670 ± 0.002	0.718 ± 0.002
q	0.78951 ± 0.00006	0.7929 ± 0.0004	0.7347 ± 0.0008
Q	4.012 ± 0.005	4.01 ± 0.03	4.48 ± 0.04
ω	241.750° ± 0.013	241.20° ± 0.06	248.7 ± 0.1
Ω	17.79147° ± 0.00001	16.82664°	17.40482
i	10.482° ± 0.04	11.41° ± 0.03	9.46 ± 0.06

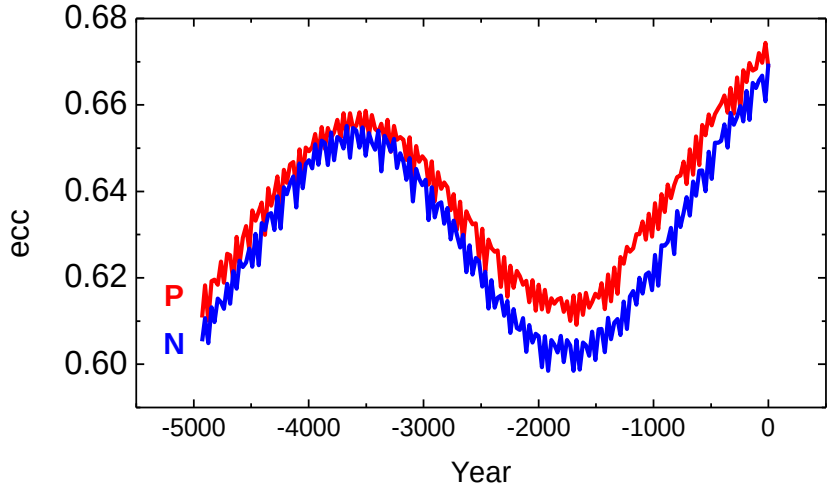
(Spurný et al., 2003, 2008)

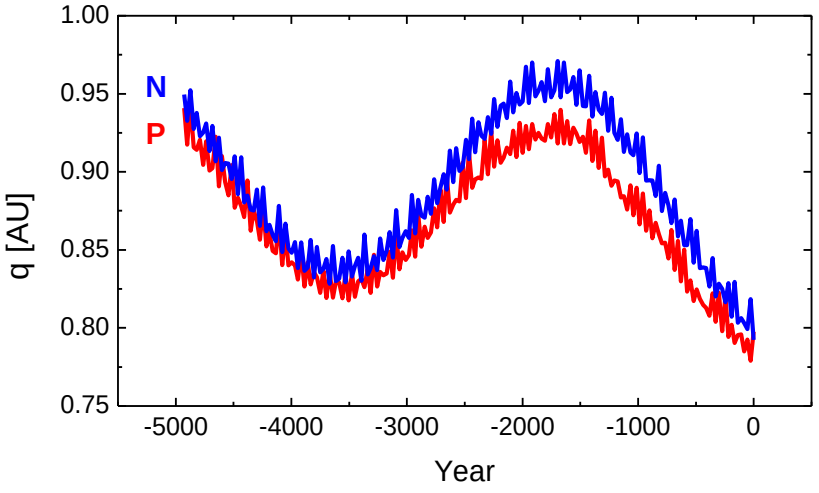


Příbram and Neuschwanstein orbital evolution





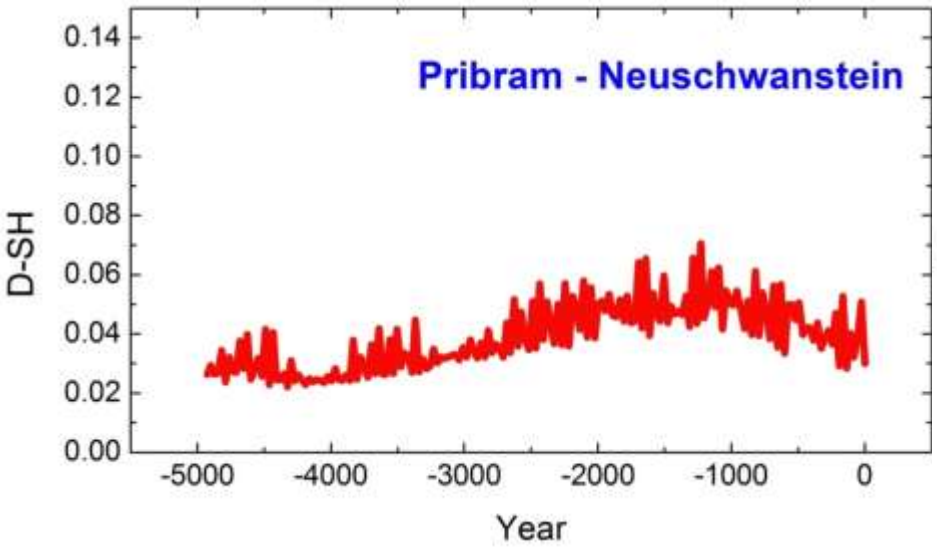




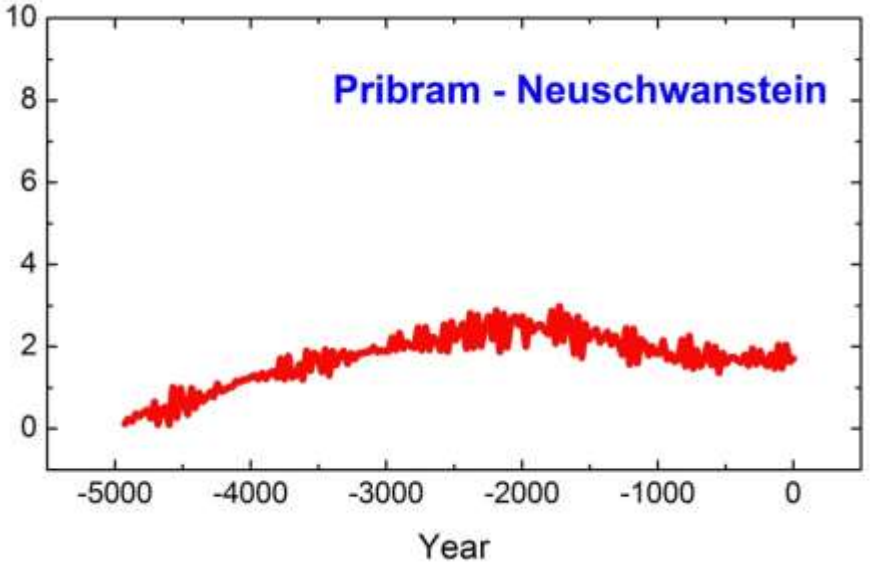
Kornoš, Tóth, Vereš (2008), *Earth Moon Planets* 102, 59-65

Příbram and Neuschwanstein orbital evolution

D-criterion

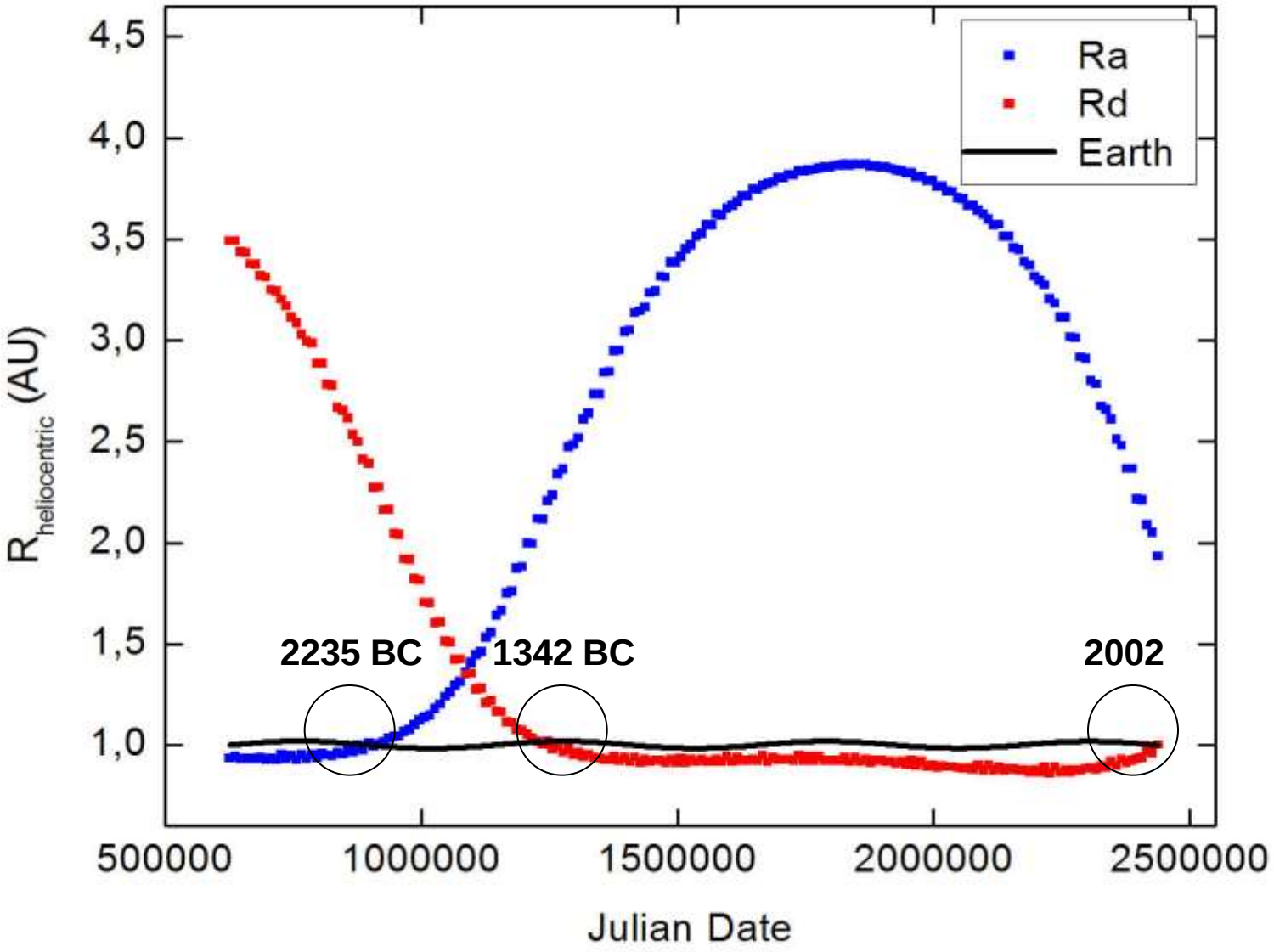


Longitude of perihelion



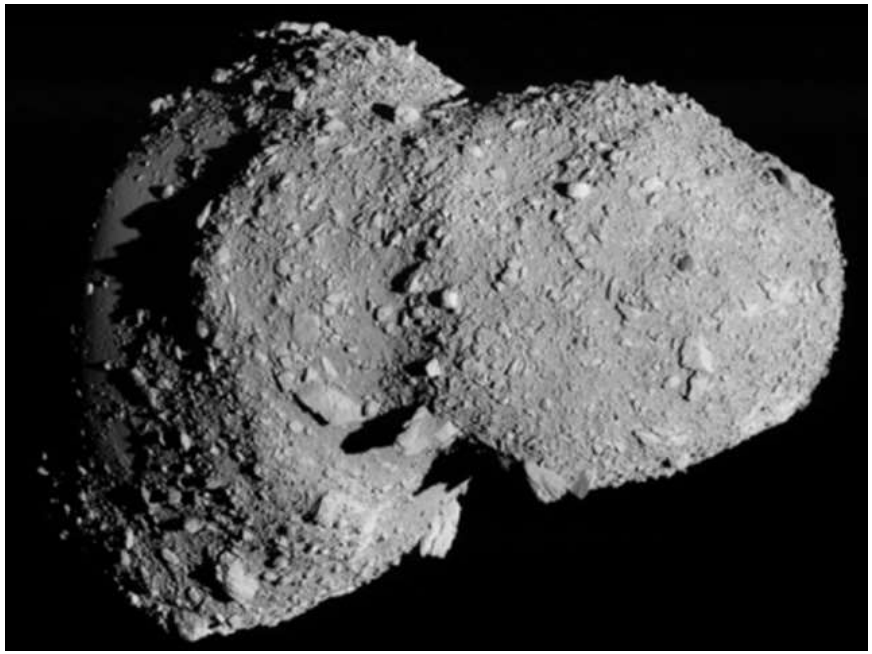
Kornoš, Tóth, Vereš (2008), *Earth Moon Planets* 102, 59-65

Rozpad „ltokavy“ v dvoch okamihoch v minulosti



Slapový rozpad

Itokawa ~ 500 m

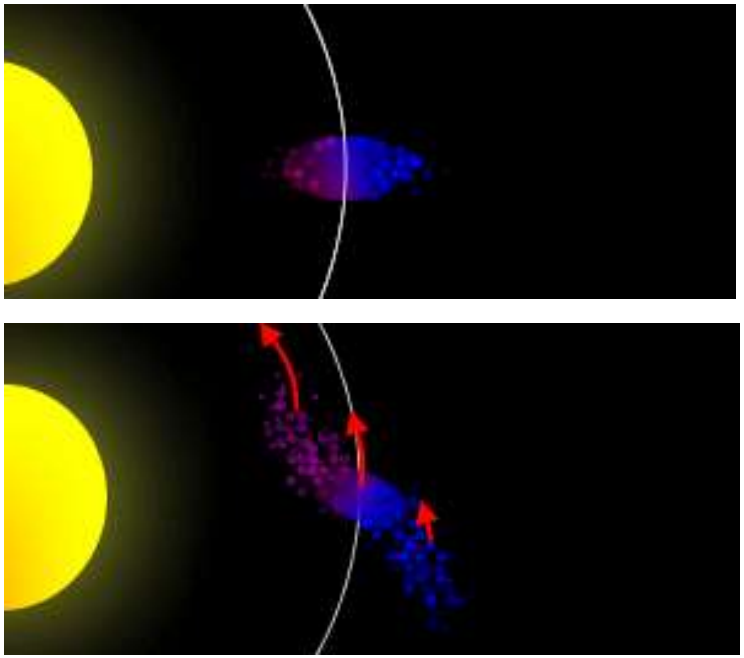


Jaxa

- **dráha Příbram - Neuschwanstein typ Apollo**
- **Roche hranica ~ $2R_{Earth}$ (13 min.)**
- **teleso podobné Itokawe**
- **distribúcia veľkosti častíc – ako na povrchu Itokawy**
- **únikové rýchlosti ~ 10 cm/s**
- **za niekoľko storočí distribúcia pozdĺž dráhy**
  - **veľmi kompaktný prúd**

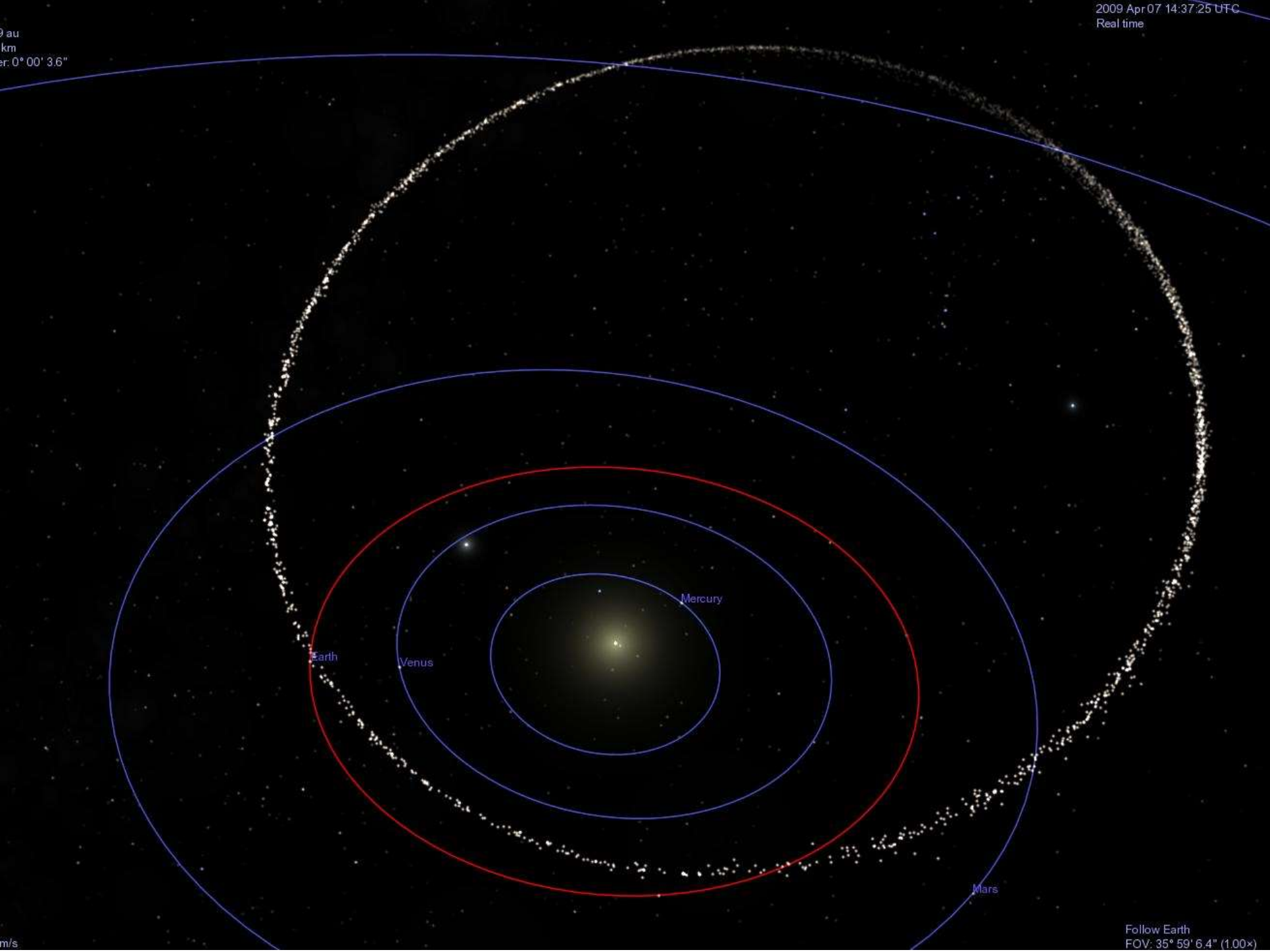
Slapový rozpad

- **dráha Příbram - Neuschwanstein typ Apollo**
- **Roche hranica ~ $2R_{Earth}$ (13 min.)**
- **teleso podobné ltokawe**
- **distribúcia veľkosti častíc – ako na povrchu ltokawy**
- **únikové rýchlosti ~ 10 cm/s**

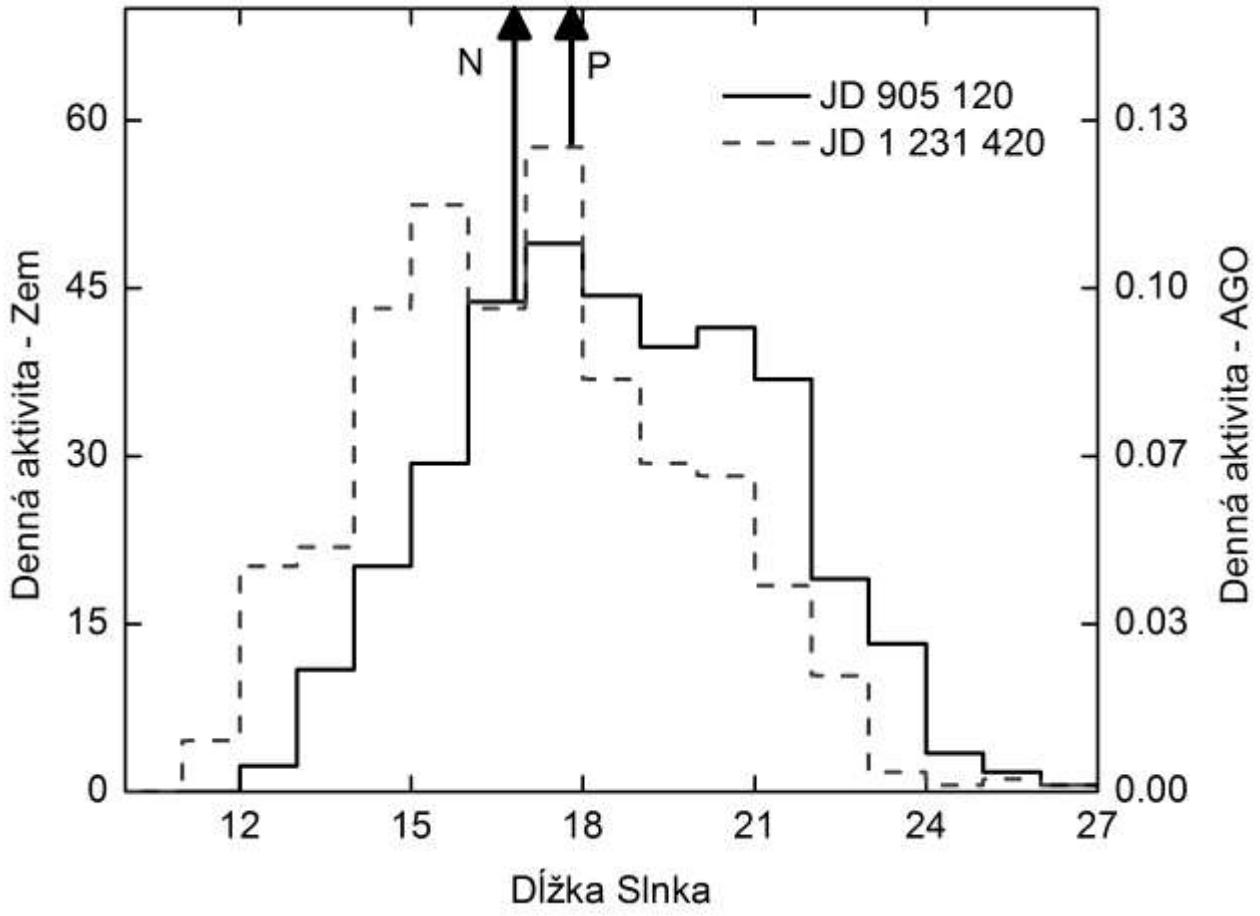


- **za niekoľko storočí distribúcia pozdĺž dráhy**
  - **veľmi kompaktný prúd**

Tóth, Vereš, Kornoš: (2011), Mon. Not.R. Astron. Soc. 415, pp. 1527-1533


2009 Apr 07 14:37:25 UTC
Real time
Mercury
Venus
Earth
Mars
Follow Earth
FOV: 35° 59' 6.4" (1.00×)

Aktivita v súčasnosti (1 cm častice)



Bude potrebné viacročné pozorovanie na potvrdenie / vyvrátenie existencie prúdu Příbramíd

AMOS cameras at Canary Islands
April 2-8, 2014

AMOS cameras in Canada
May 22-24, 2014

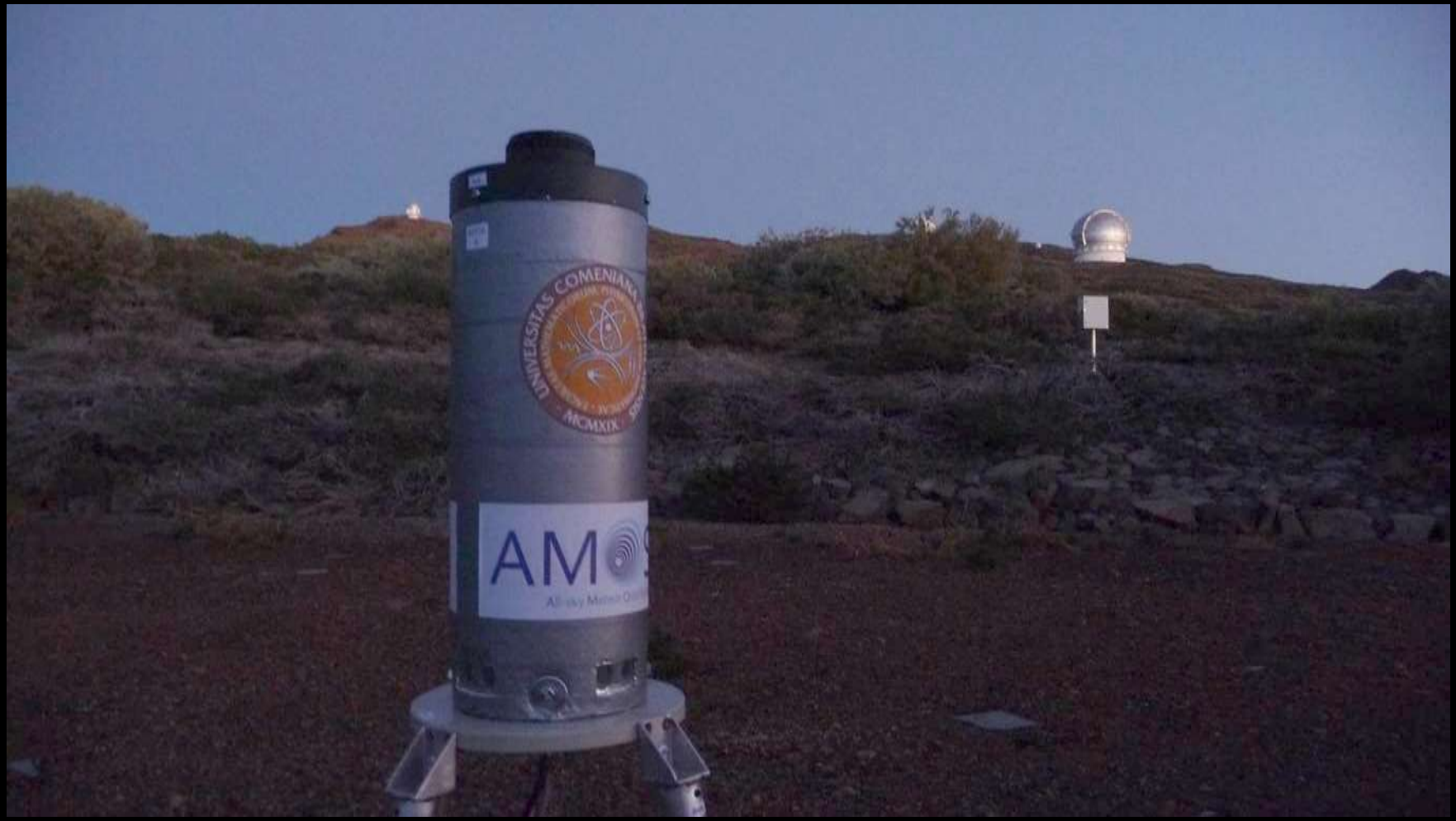
Motivation

1. **Test the Canary Islands observatories sites for future permanent AMOS stations**

2. **Test of the effeciency of AMOS cams in excelent observing conditions**

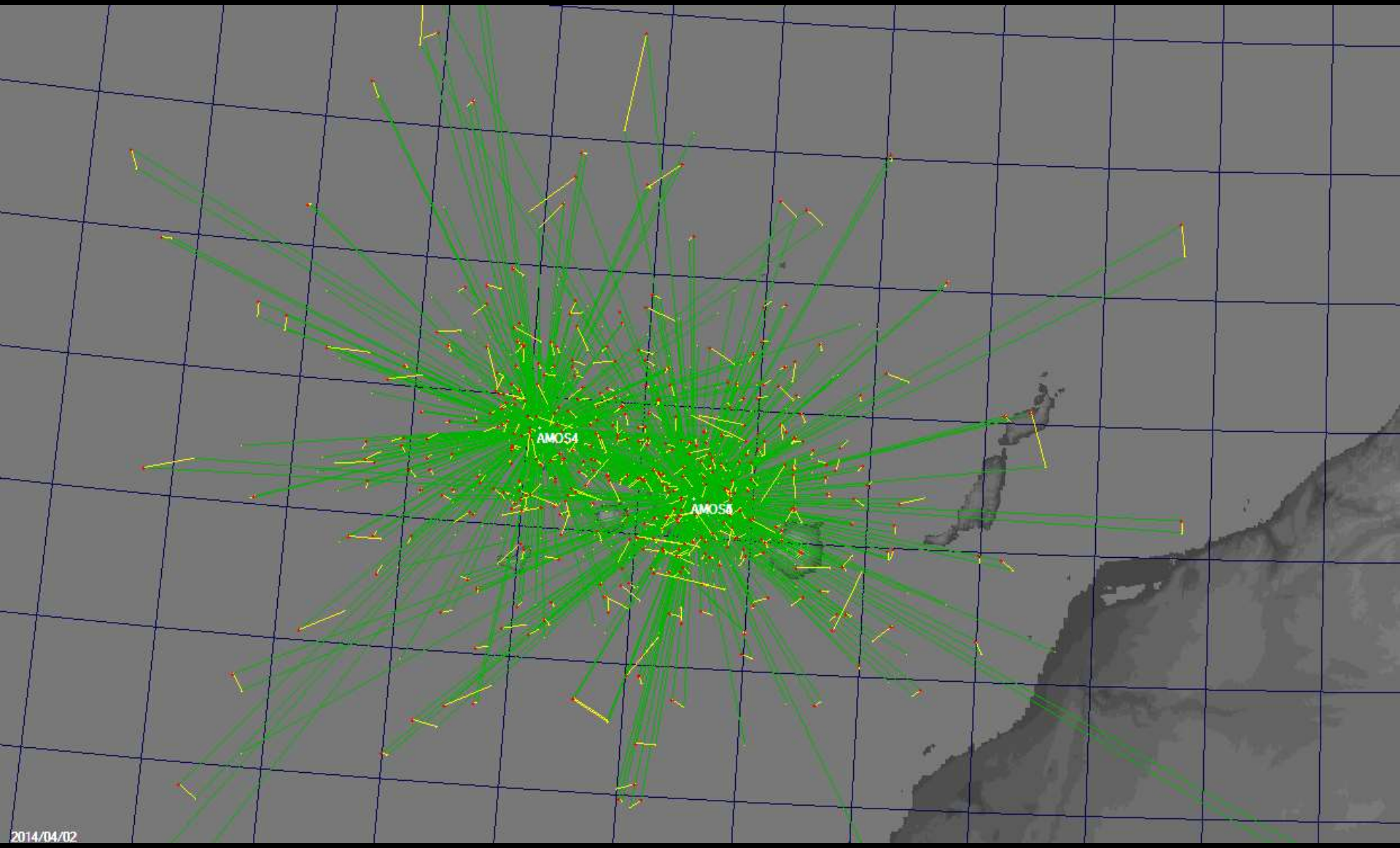
3. **Confirm the potential / predicted meteor shower of asteroidal origin in the orbits of Příbram and Neuschwanstein meteorites** **(**Spurný et al, 2003, Tóth et al., 2011, Koten et al., 2014**).**


La Palma
Isla de la Palma
Santa Cruz de Tenerife
Tenerife
Canary Islands
Arona
Las Palmas de Gran Canaria
Gran Canaria
Canary Ridge
Maspalomas
Puerto del Rosario
Fuerteventura
Lanzarote
Arrecife
Laayoune
Google earth



Vietor ~ 70 km/h

	La Palma AMOS4	Tenerife AMOS5	Slovakia AGO	Slovakia ARBO	Slovakia KNM	Slovakia VAZEC
2.4.2014	48	50	26	7	9	6
3.4.2014	49	50	2	1	6	15
4.4.2014	46	60	4	2	4	-
5.4.2014	55	68	-	-	-	-
6.4.2014	38	56	15	-	6	13
7.4.2014	45	48	11	-	5	16
8.4.2014	29	38	-	-	-	-
Σ	310	370	68	10	30	50
	100%	119%	22%	3%	10%	16%
			4,3 x SlovakVideoMeteorNetwork			


AMOS4
AMOS4
2014/04/02

AMOS cameras at Canary Islands, April 2-8, 2014

- **7 night of observations (Sol. long. 12.8 – 19.1°) -> 680 meteors**
- **about 1/1 ratio of sporadic and shower meteors,**
- **magnitude range -3 to +4, majority from 0 to +2**
- **weak meteor activity (1 established shower, 10 working list)**

SPORADICS ~ 3 HR
LVI, KVI ~ 0.3 HR
ZSE, SLE, DAL, ALO ~ 0.2 HR
SVI, NVI ~0.1 HR
KSE ~ 0.1 HR
ACO, AAL ~ 0.1 HR
and others …

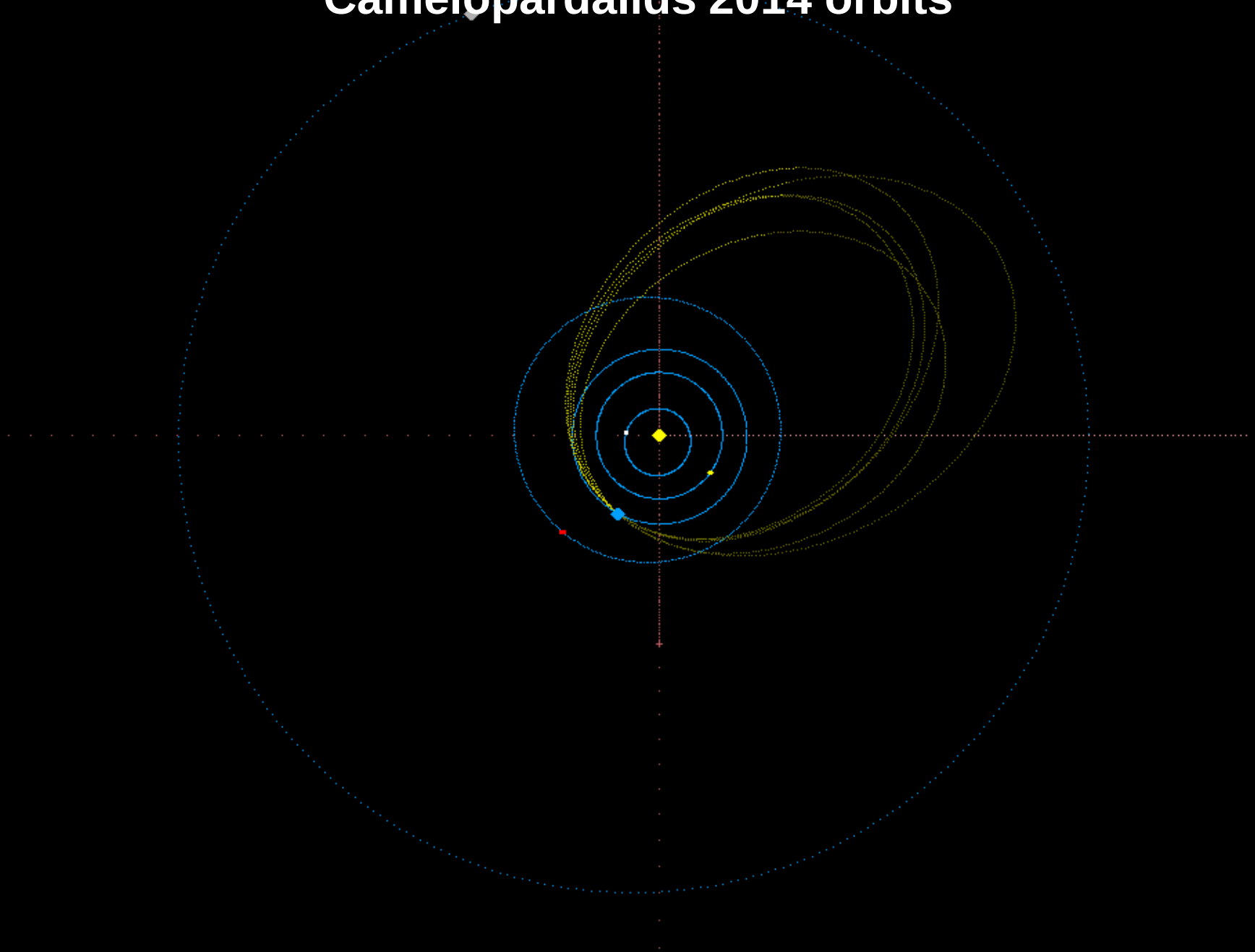
- **5 nights of double station obs. (145 km distance) -> 516 meteors**
- **about 20% of them simultaneously observed**
- **geometrical and other selection criteria resulted into 54 orbits**
- **5 orbits suspected to have close relation to ACO (Pribramids) meteor stream, need to be critically analyzed, discussed**


MSC/SMC-CMC GOES 2014-04-25 21:00 UTC IR
AMOS cameras in Saskatchewan
and
Camelopardalids 2014
Juraj Tóth
Pavol Zigo

Saskatchewan view

The Crossing Resort – setup of AMOS cams

Camelopardalids 2014 orbits




Any questions?


Ďakujem za pozornosť
2011/10/01 01:21:32.3 0147
V00074+116 ARBO DIGi SLOVAKIA UFOCaptureV2