The parent body search

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September 15-18, 2011

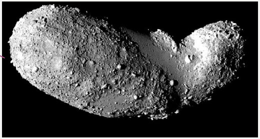
Meteors

METEOROIDS

Comets

- ice sublimation
- comet disintegration

Asteroids



- collisions
- tidal forces
- YORP

Meteoroid stream identification methods

How the search procedure looks like?

- Choose a meteoroid streams search algorithm:
  - iterative methods,
  - method of indices,
  - single linking method,
  - wavelet transform technique.
- Choose a dynamical similarity function - D-criterion.
- Choose a similarity threshold D_c.

Meteoroid stream identification methods

Dynamical similarity functions

- D-criterion based on the orbital parameters (q, e, i, Ω, ω).

$$D_{SH}^2 = [e_B - e_A]^2 + [q_B - q_A]^2 + \left[2 \cdot \sin \frac{I_{BA}}{2}\right]^2 + \left[\frac{e_B + e_A}{2}\right]^2 \left[2 \cdot \sin \frac{\pi_{BA}}{2}\right]^2$$

where

e_A, e_B – eccentricities of orbits A and B,

q_A, q_B – perihelion distances of orbits A and B,

I_{BA} – the angle between the orbital planes,

π_{BA} – the difference between the longitude of perihelion, measured from the intersection point of the orbital planes.

I_{BA} and π_{BA} are expressed in terms of angular orbital elements (inclination i, longitude of the ascending node Ω and argument of periapsis ω).

Southworth, R. B., Hawkins, G. S. 1963, Smithson. Contr. Astrophys, 7, 261

Meteoroid stream identification methods

Dynamical similarity functions

- D-criterion based on the orbital parameters (q, e, i, Ω, ω).

$$D_H^2 = [e_B - e_A]^2 + \left[\frac{q_B - q_A}{q_B + q_A}\right]^2 + \left[2 \cdot \sin\frac{I_{BA}}{2}\right]^2 + \left[\frac{e_B - e_A}{2}\right]^2 \left[2 \cdot \sin\frac{\pi_{BA}}{2}\right]^2$$

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Jopek, T. J., 1993, Icarus, 106, 603

Meteoroid stream identification methods

Dynamical similarity functions

- D-criterion based on dynamical quasi-invariants.

$$\begin{aligned} D_V^2 &= w_{h1}(h_{B1}-h_{A1})^2 + w_{h2}(h_{B2}-h_{A2})^2 + 1.5\, w_{h3}(h_{B3}-h_{A3})^2 \\ &+ w_{e1}(e_{B1}-e_{A1})^2 + w_{e2}(e_{B2}-e_{A2})^2 + w_{e3}(e_{B3}-e_{A3})^2 \\ &+ 2\, w_E(E_B+E_A)^2 \end{aligned}$$

where

h – the angular momentum vector,

e – the Laplace vector,

E – the energy constant,

w_h, w_e, w_E – the weighting factors.

Jopek, T. J., Rudawska, R., Bartczak, P. J. 2008, EM&P, 102, 73

Meteoroid stream identification methods

Dynamical similarity functions

- D-criterion based on dynamical quasi-invariants.

$$D_J^2 = \left(\frac{C_{A1} - C_{B1}}{0.13}\right)^2 + \left(\frac{C_{A2} - C_{B2}}{0.06}\right)^2 + \left(\frac{C_{A3} - C_{B3}}{14.^\circ 2}\right)^2$$

where

C_1 – corresponds to the z-component of the orbital angular momentum,

C_2 – is taken from the secular model of Lidov,

C_3 – invariant is the longitude of perihelion.

Jenniskens, P., 2008, Icarus, 194, 13

The streams and their parent bodies

Our parent body search procedure

The streams and their parent bodies

Meteoroid orbits sample

The model of generation and evolution of meteoroid stream in the solar system is taken from Vaubaillon *et al.* (2005)

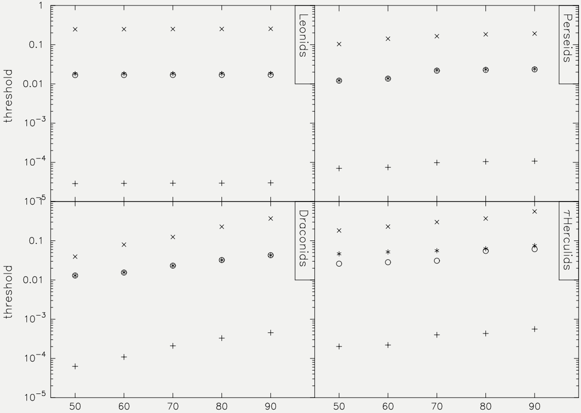
- the nucleus is a mixture of water ice and dust,
- the nucleus is spherical and homogeneous,
- the water is produced in the sunlit hemisphere of the nucleus,
- the dust particles are spherical, homogeneous,
- the particles are ejected within 3.0 AU, from the Sun, in the sunlit hemisphere,

- the particles are submitted to the gravitational force of the Sun, the nine planets and the Moon, as well as to non-gravitational forces.

Vaubaillon, J., Colas, F. & Jorda, L., Astronomy and Astrophysics, Vol. 439, p. 751, 2005

Results

Determining the threshold from experimental data



+ D_V
∗ D_{SH}
○ D_H
× D_J

D_{SH}
8.401×10^{-2}

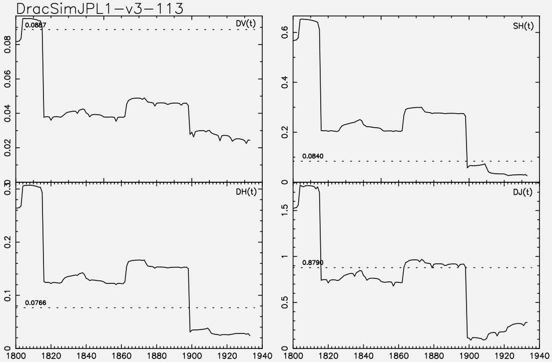
D_H
7.661×10^{-2}

D_V
8.870×10^{-4}

D_J
8.790×10^{-1}

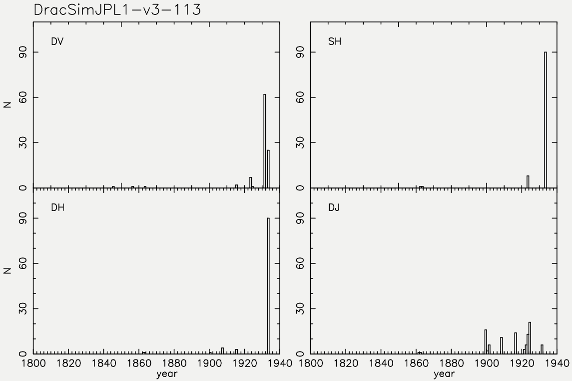
Results

Looking for the epoch of ejection



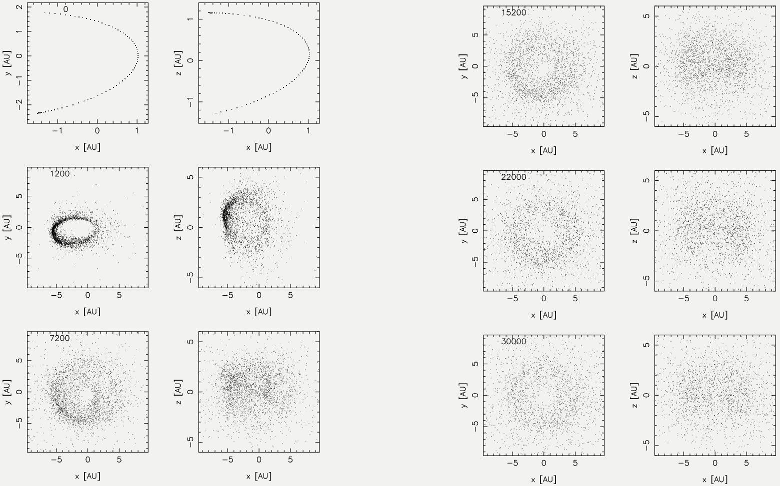
Results

Looking for the epoch of ejection



The streams and their parent bodies

Orbital evolution of the Draconids stream



Rudawska, R., 2010, In Ph.D. dissertation, A. M. University, Poznan

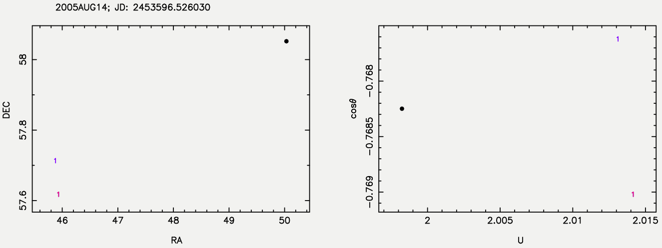
Results

Application

- The obtained values of thresholds were applied to a sample of the Armagh Observatory meteor data.
- Atreya, P., 2009, In Ph.D. dissertation, Armagh Observatory, Armagh, Northern Ireland.
- Double station meteors: 457 meteor orbits.

Results

Application

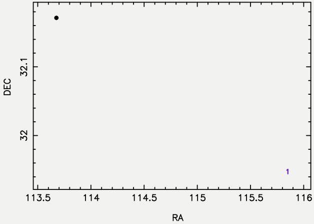


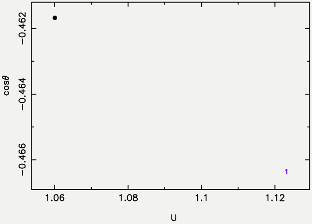
	RA	DEC	Vgeo	U	$\cos\theta$	d_RaDec	d_Ucosθ	
	50.0328	58.0521	59.0382	1.9982	−0.7682			: meteor
1	45.9321	57.6114	59.4196	2.0141	−0.7690	4.1243	0.0159	: 109P/Swift−Tuttle
1	45.8760	57.7067	59.4074	2.0131	−0.7676	4.1711	0.0149	: 109P/Swift−Tuttle
1	45.9321	57.6114	59.4196	2.0141	−0.7690	4.1243	0.0159	: 109P/Swift−Tuttle

Results

Application

2007DEC14; JD: 2454448.709213



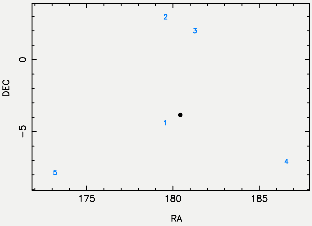


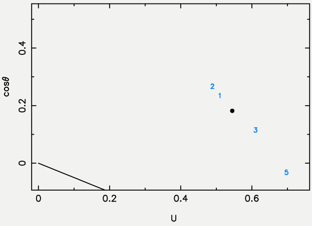
	RA	DEC	Vgeo	U	cosθ	d_RaDec	d_Ucosθ	
	113.6751	32.1712	31.7751	1.0601	−0.4617			: meteor
1	115.8492	31.9443	34.0965	1.1231	−0.4664	2.1859	0.0633	: Phaethon
1	115.8492	31.9443	34.0965	1.1231	−0.4664	2.1859	0.0633	: Phaethon

Results

Application

2006APR02; JD: 2453827.549039

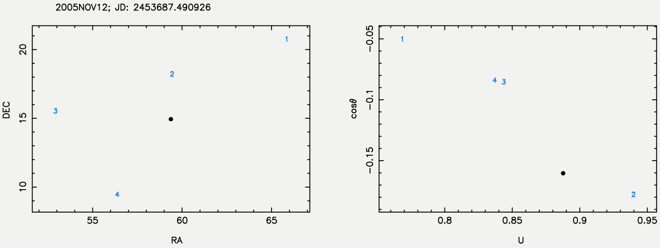




	RA	DEC	Vgeo	U	cosθ	d_RaDec	d_Ucosθ
	180.4290	−3.8414	16.7103	0.5448	0.1819		: meteor
1	179.5448	−4.5413	18.4479	0.5101	0.2269	1.1277	0.0569 : 2003 BD44
2	179.5763	2.8180	14.1462	0.4890	0.2594	6.7137	0.0955 : 2009 FP32
3	181.2776	1.8558	14.8791	0.6100	0.1075	5.7600	0.0990 : 2006 BC10
4	186.5776	−7.2185	7.3052	0.0461	5.6353	7.0150	5.4762 : 2002 JQ97
5	173.1768	−7.9903	21.2457	0.6972	−0.0396	8.3552	0.2688 : 2004 ST26

Results

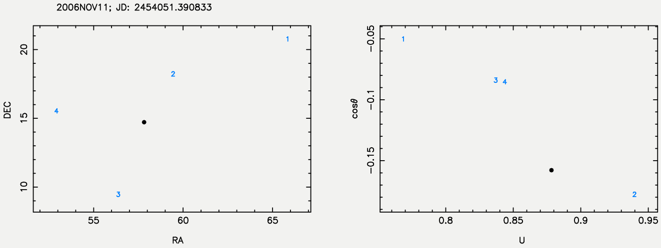
Application



	RA	DEC	Vgeo	U	cosθ	d_RaDec	d_Ucosθ	
	59.3718	14.9404	26.2150	0.8877	−0.1603			: meteor
1	65.8418	20.6078	14.4153	0.7685	−0.0520	8.6011	0.1611	: 2005 UW6
2	59.4412	18.0680	24.7943	0.9398	−0.1795	3.1283	0.0555	: 2010 TU149
3	52.9191	15.3793	26.9481	0.8437	−0.0871	6.4676	0.0854	: 2003 WP21
4	56.3755	9.3088	25.2534	0.8370	−0.0858	6.3791	0.0902	: 1999 VK12

Results

Application



	RA	DEC	Vgeo	U	cosθ	d_RaDec	d_Ucosθ	
	57.8217	14.7193	25.9175	0.8783	−0.1578			: meteor
1	65.8418	20.6078	14.4153	0.7685	−0.0520	9.9497	0.1525	: 2005 UW6
2	59.4412	18.0680	24.7943	0.9398	−0.1795	3.7197	0.0652	: 2010 TU149
3	56.3755	9.3088	25.2534	0.8370	−0.0858	5.6004	0.0831	: 1999 VK12
4	52.9191	15.3793	26.9481	0.8437	−0.0871	4.9467	0.0787	: 2003 WP21

The parent body search

Conclusions

- We obtained the value of the upper limit of tested D-criteria.
- The threshold value depends on the stream and its orbital evolution.
- We confirm associations with known meteoroid streams for orbits collected in Armagh meteor sample.
- We need to do more analysis and test methods on real data.
- Close encounters clearly prevent us from reconstructing the epoch of origin, even for a slightly perturbed trails.


THANK YOU
FOR YOUR ATTENTION!

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