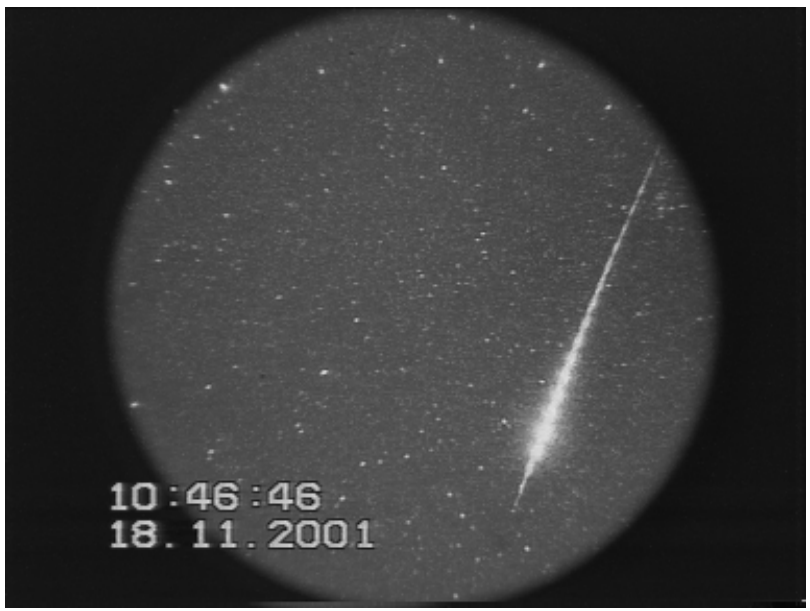
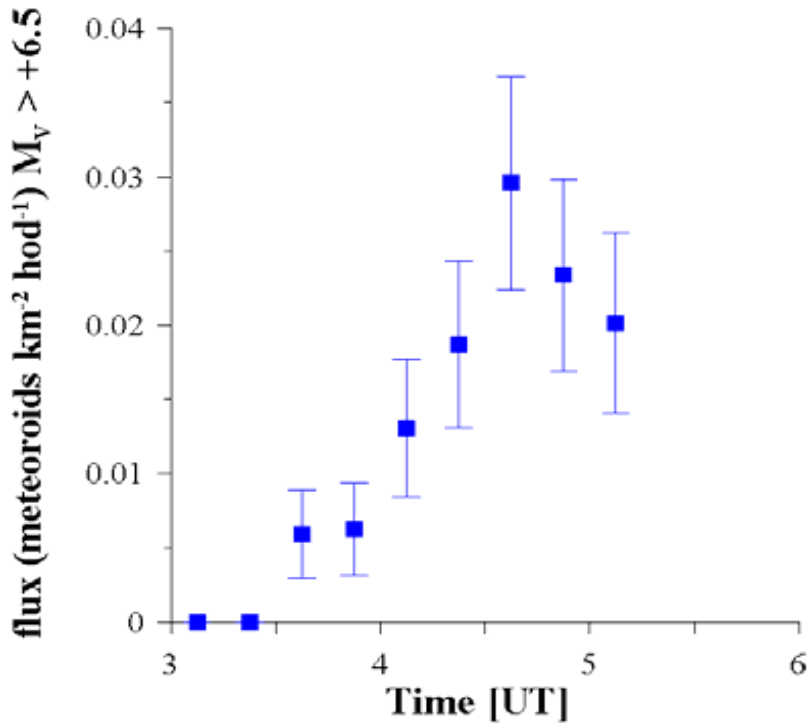
Video observations of the 2006 Leonid outburst





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Contents of the talk

- Leonids 1998 – 2002, predictions for 2006
- Observations, instrumentation, weather conditions
- Data, methods of processing
- Shower activity, mass index, flux
- Observed data vs. predictions
- Comparison with previous Leonid storms

Leonids 1998 – 2002 and 2006

- comet 55P/Temple-Tuttle last perihelion passage 1998
- several meteor storms in subsequent years (1998 – 2002)
- lot of new data – many papers published …
- after 2002 shower activity ceased

- for 2006 – small outburst associated with 1932 ejecta predicted (2 revolutions old)
- another encounter with this stream – November 17, 2000, around 8 UT (Brown et al. 2002)

- McNaught & Asher (1999) – November 19, 4:45 UT
- Lyytinen & Van Flandern (2000) – at 4:48 UT
- Vauballion et al. (2005), www – at 4:58 UT

- all models – stream rich in faint meteors, especially in radar range
- visible meteors – ZHR about 100

Video double station program

since 1998
double-station program Ondřejov – Kunžak
92.5 km station separation, 340° azimuth
during interesting meteor showers activity

personal involvement:
J. Borovička – spectra, Ondřejov station
P. Koten – software, processing, analyses
P. Spurný – second station operation, (Leonids)
R. Štork – observations, searching for meteors

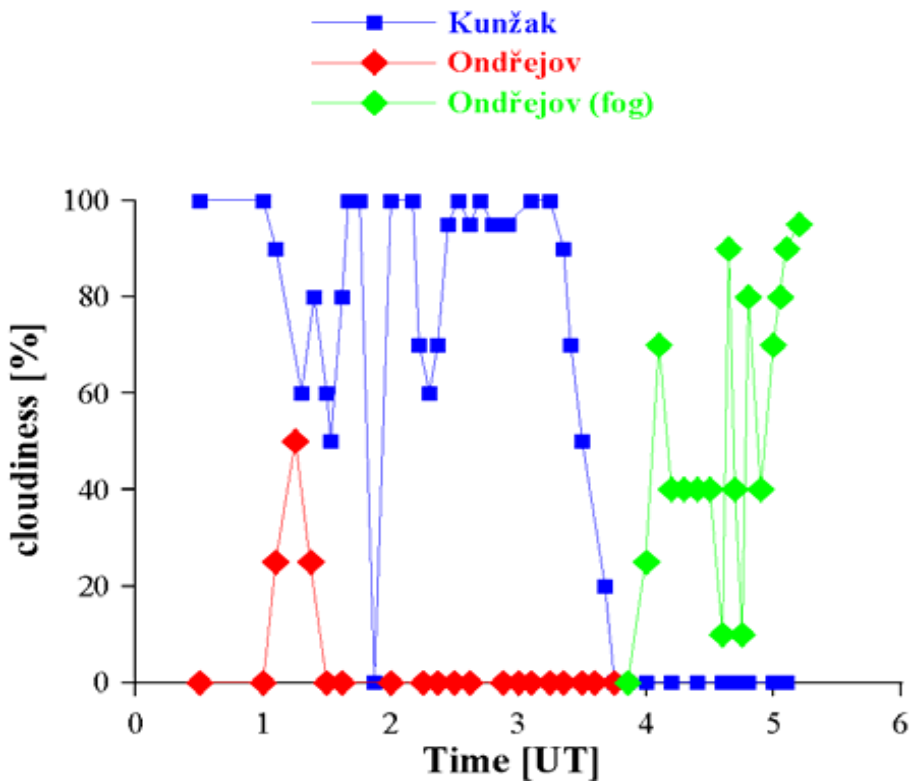
UK
Steve Evans & Andrew Elliott

Observations, equipment, weather conditions

- S-VHS Panasonic camcorder, 2nd generation intensifier Mullard XX1332
- Kunžak – Arsat 1.4/50 mm, FOV ~ 45°, MLM +5.0m, col. area 16 700 km2
- Ondřejov – Jupiter 2.0/85 mm, FOV ~ 30°, MLM + 6.0m, col. area 10 600 km2 (computed for altitude 108 km)
- Watec 120N, FOV 50° x 40°, LML +2.0m (UFOCapture)

- UK experiment
- both stations – Watec 902H, 0.8/12mm, FOV ~ 31° x 23°, MLM +4.0m
- S-VHS systems
- separation 211.5 km, azimuth 337°

- CZ – variable weather conditions



Recorded data, methods of processing

MetRec identification, digitalization – 768 x 576 px, 25 frames/s, 8bits (monochrome)
measurement (MetPhoto), reduction (Mimi)

Double station data (D-criterion):
– CZ: 27 meteors
– UK: 13 meteors

Single station data – CZ: 62 meteors

- **angular velocity & distance of prolonged path from the radiant Δ**
- **$\Delta < 3.0^{o}$ – meteor is usually accepted**
- **estimated atmospheric trajectory – heights ± 5 km**
- **(double station data – height up to 0.5 km)**
- **used only for activity profile and light curve shapes**

Activity profile

15 minutes counts

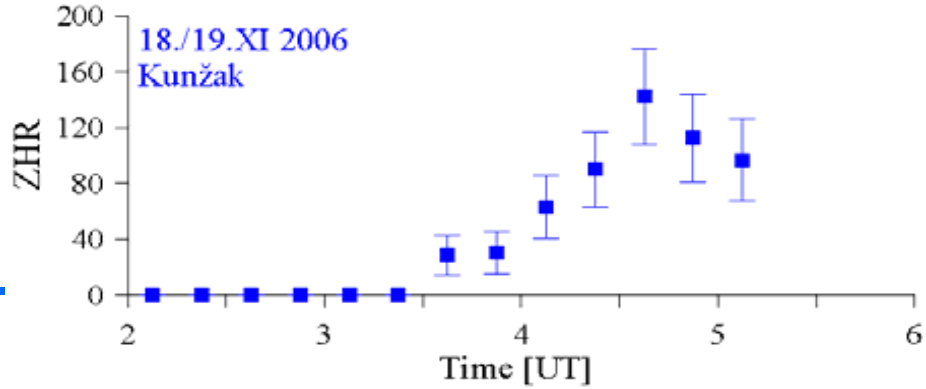
only correction – zenith distance of radiant

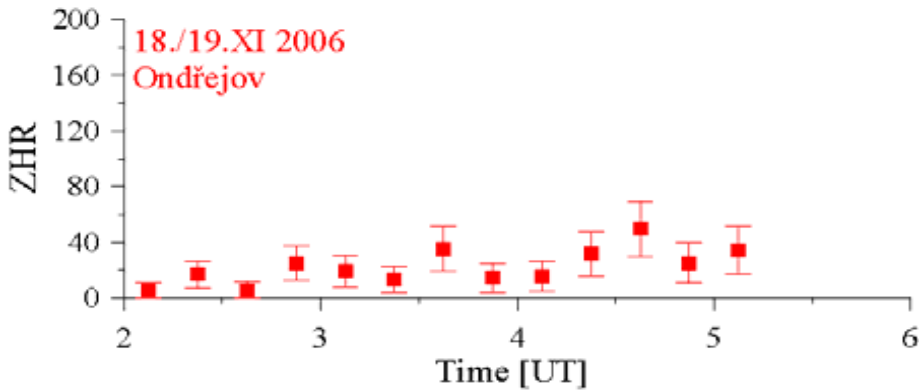
Kunžak – reliable curve – peak before 5 UT
more shallow descending branch

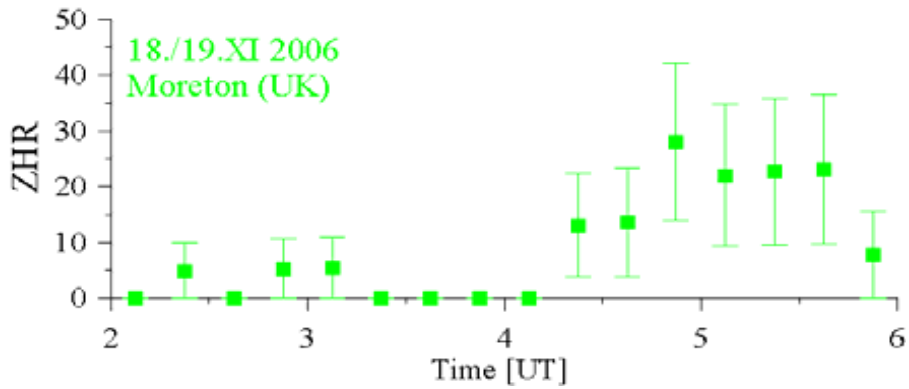
Ondřejov – strongly influenced by fog (correction not applied)

Moreton – lower counts because lower sensitivity
increase still visible

Watec – no detection!







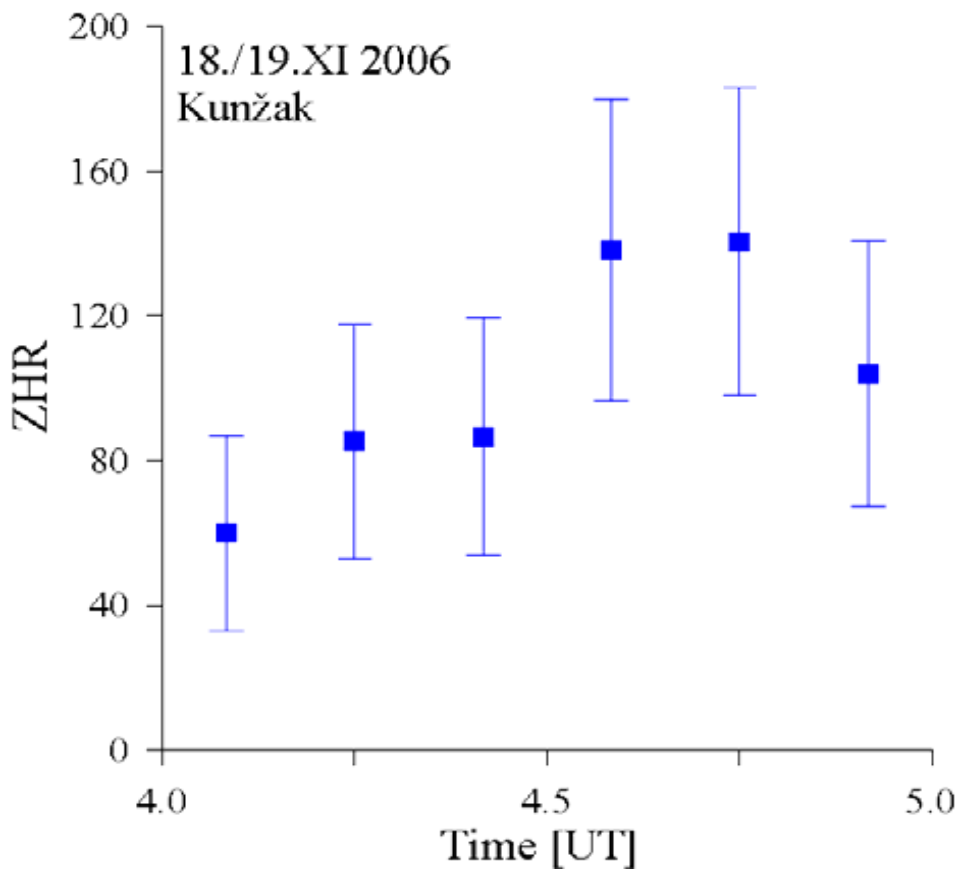
Maximum activity

detail of activity curve – 10 minutes intervals (shorter intervals useless)

peak occurred around 4:45 UT
± 10 minutes
$\lambda_o = 236.613^o \pm 0.007^o$

impossible to determine more precisely

Moreton – peak at 4:52 UT
even lower number of meteors (only 24)
previous night – 4-5 times lower number of Leonid meteors



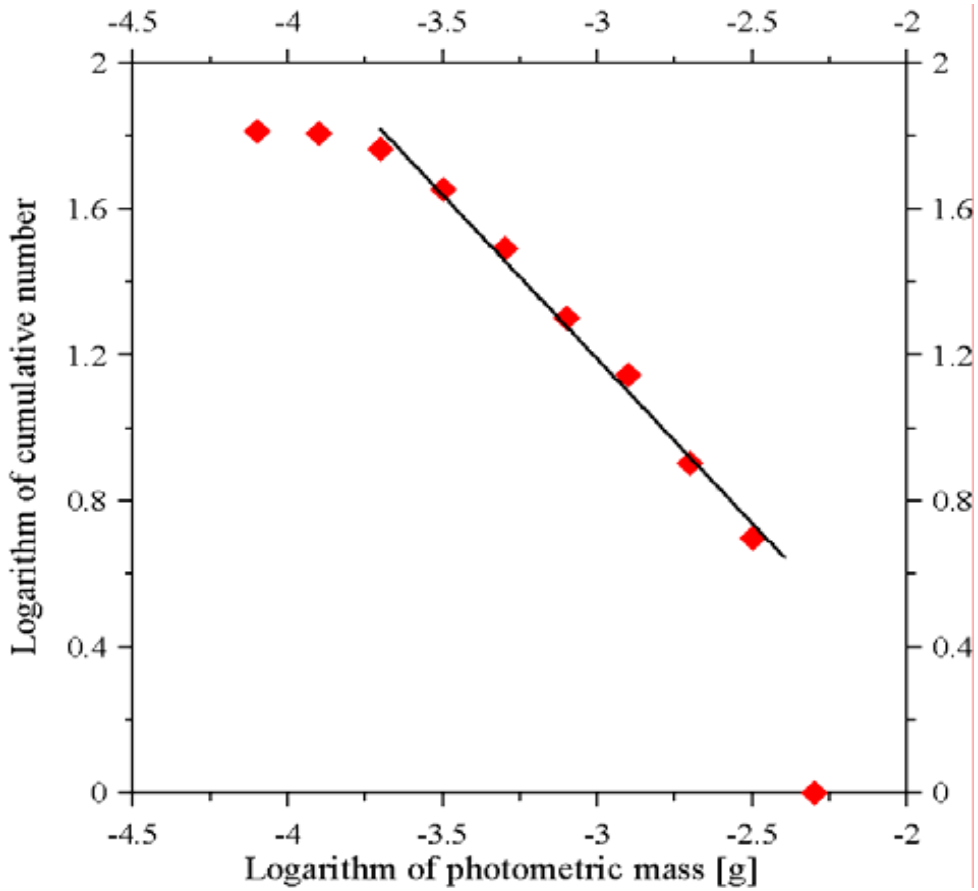
Mass and population index

Kunžak – 65 Leonid meteors

mass distribution index $s = 1.9$
population index $r = 2.3$

comparison with 2002 encounter:
$s = 1.7$ (Brown et al.)
2006 – shower richer in faint meteors
(no bright meteor, no spectra)

other Leonids:
2001 (7 rev.) $s = 1.75$
1999 (3 rev.) $s = 1.8$



Flux of meteoroids

collection area – flux up to MLM

for comparison – flux of meteors brighter than $+6.5^m$

2000: (Brown et al., 2002)

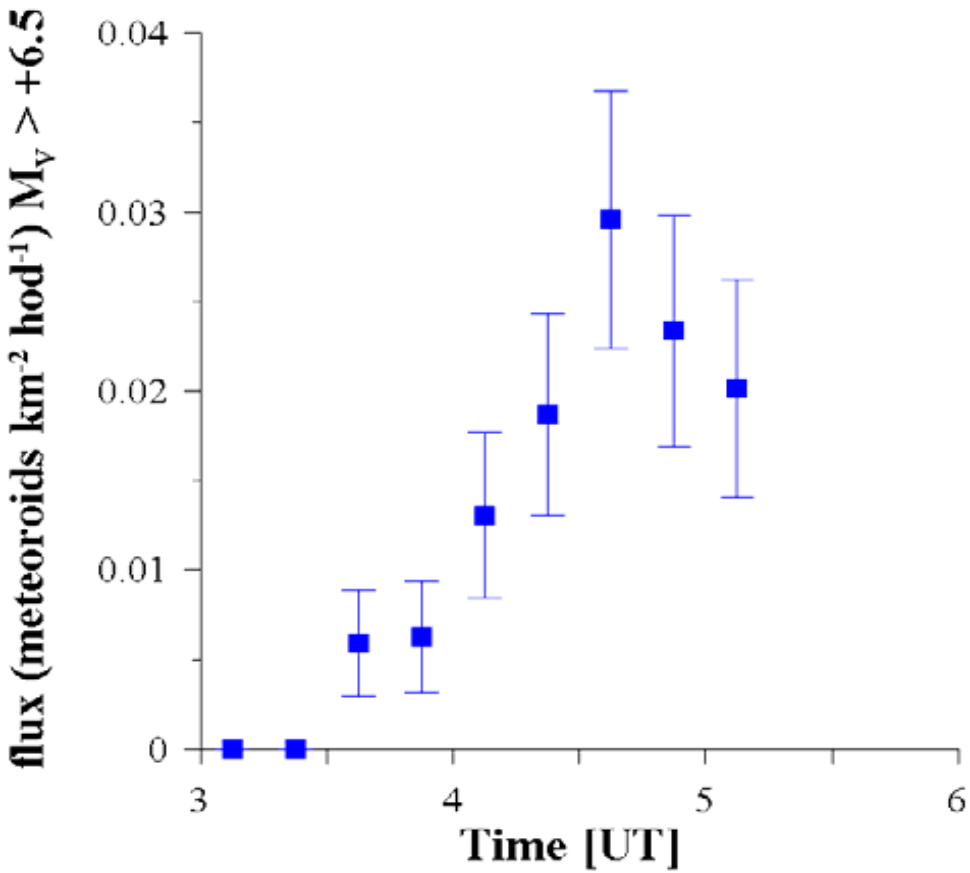
flux ($+6.5^m$) = 0.15 ± 0.02 $km^{-2}h^{-1}$

ZHR ~ 900

mass index $s = 1.7$

5 times lower activity in 2006

moreover fainter meteors



Comparison of both encounters

McNaught & Asher (1999):

	2000	2006
Δa_o	+0.30	+0.96
$r_E - r_D$	-0.0012	-0.0001
f_M	0.55	0.53

encounter with less dense part of the stream (2006)

Lyytinen & Van Flandern (2000):

comparable parameters of encounter particles about ¼ mm in diameter

Vaubaillon et al. (www):
even smaller particles – high activity
0.05 – 0.1 mm
lower activity – 0.1 – 0.5 mm (our data)

Ondřejov radar out of the service ☹

Heliocentric orbits

iterative procedure for shower membership determination – all double station meteors

15 meteors (between 4 and 5 UT = 2 revolution old filament)

very close orbits

mean orbit:

e = 0.932 q = 0.9856 ω = 174.715 Ω = 236.612 i = 162.823

mean "internal" D-criterion among them is 0.06

Radiants

15 meteors

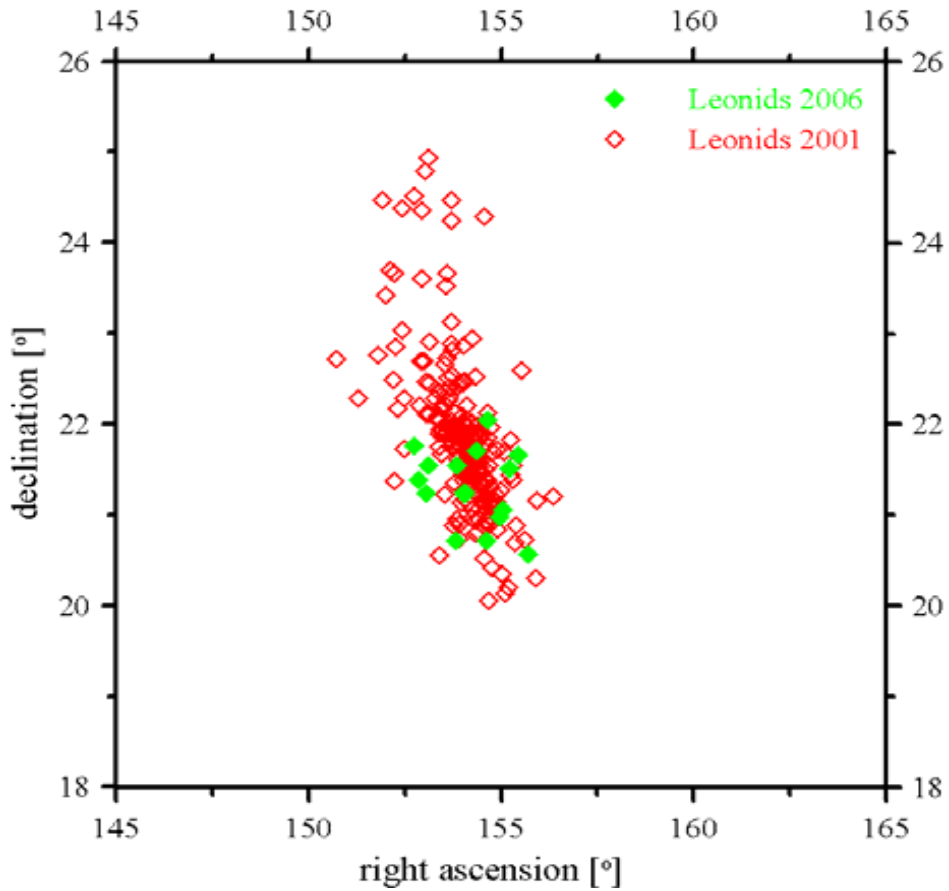
very compact radiant:

$\alpha_G = 154.24^o \pm 0.25^o$

$\delta_G = 21.35^o \pm 0.01^o$

comparison with 2001 Leonids
(7 revolution old)
± 1 hour around maximum

bigger dispersion of radiants

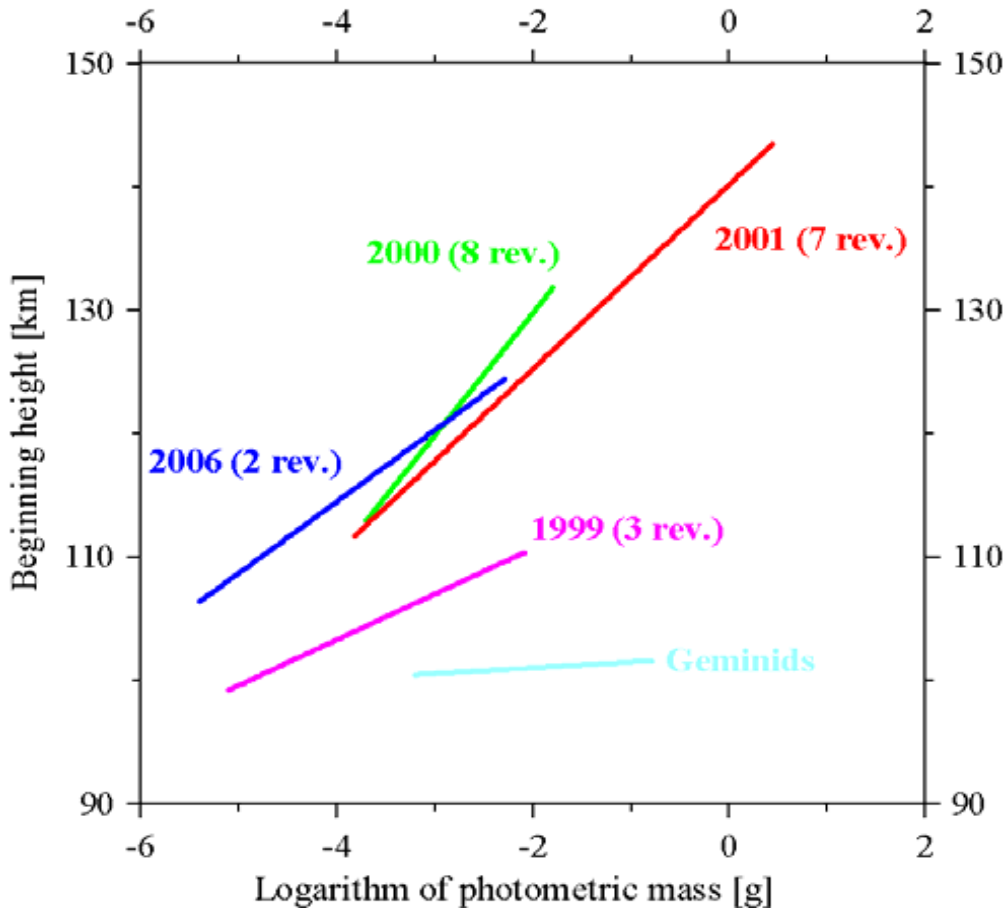


Beginning heights

steeper slope H_B vs. m_p = more fragile particles
(Koten et al., 2004)

more compact – deeper penetration into atmosphere
(1999, 3 rev.)

comparison with Geminids



Light curves

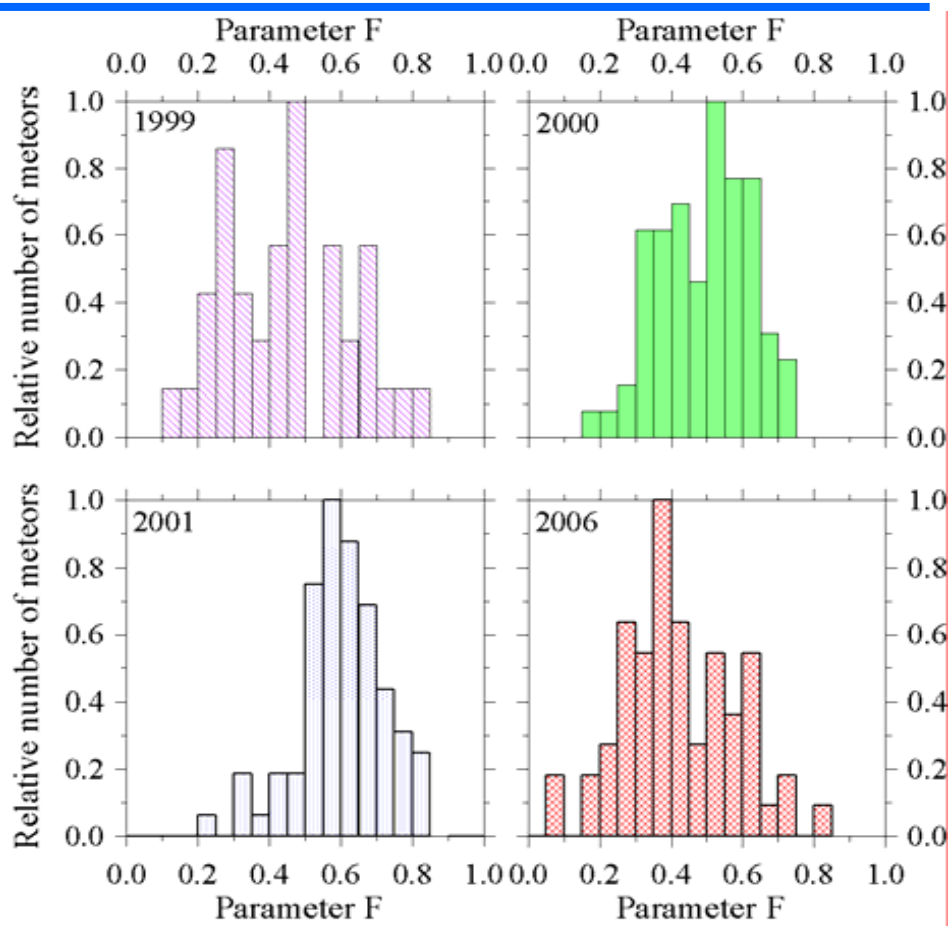
absolute brightness vs. height

traditionally used parameter F – location of the maximum

it should hint internal structure of the meteoroids

higher F = more compact body

comparison between several filaments



Physical structure of meteoroids

in comparison with other showers Leonids 2006 are fragile (F low almost as for Draconids!)

Leonid streams – different properties

	1999 3 rev.	2000 8 rev.	2001 7 rev.	2006 2 rev.
slope H_B	3.75	9.9	7.8	5.8
mean F	0.48±0.03	0.53±0.02	0.56±0.04	0.43±0.02

relation between time from ejection and structure?

shorter time – lower slope and lower F (more porous)

longer – loss volatiles, become more sintered (?)

Conclusions

- Significant activity of the Leonid meteor shower in 2006 was recorded
- Activity peaks at around 4:45 UT on November 19 – this peak well matches predictions made 7 and 6 years earlier – timing, ZHR and brightness of meteors!
- The outburst was rich in faint meteors – in radio maybe even more intensive
- very close orbits and radiants of 2 revolution old stream
- meteoroids very fragile – on the bottom end in comparison with other filaments recorded in previous years
- possible relation between “age” and physical properties

Acknowledgements

Support for this work was provided by:

1. **Grant Agency of Academy of Sciences of Czech Republic – grant No. KJB300030502**
2. **Academy of Sciences of Czech republic scientific project AV0Z10030501**

THANK YOU FOR YOUR ATTENTION!