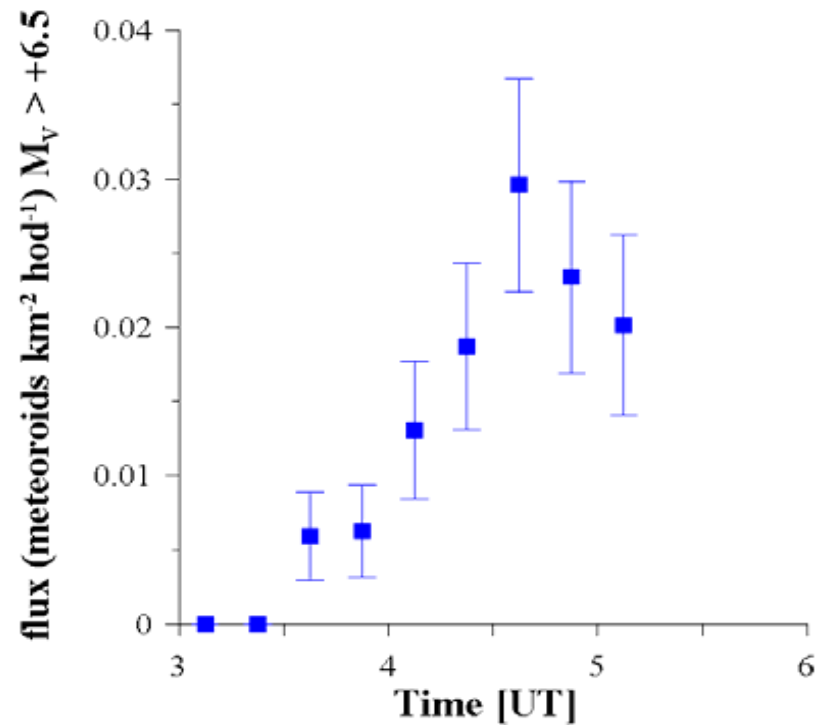


Video observations of the 2006 Leonid outburst



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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. Koteň – software, processing, analyses

P. Špurný – second station operation, (Leonids)

R. Štork – observations, searching for meteors

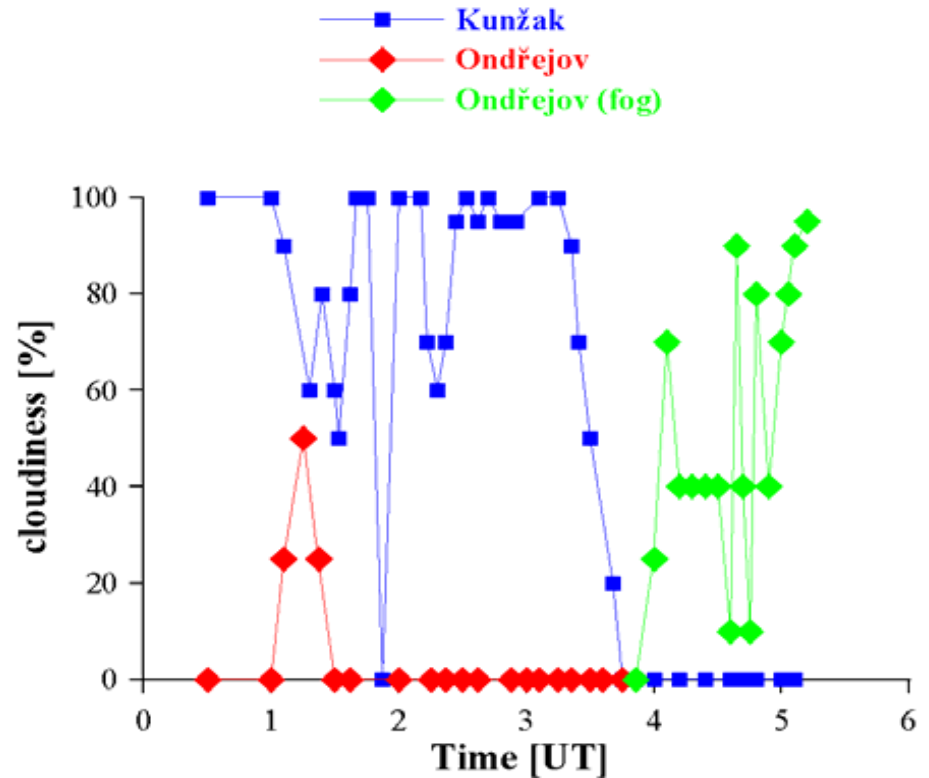
UK

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 +5.0^m, col. area 16 700 km²
- Ondřejov – Jupiter 2.0/85 mm, FOV ~ 30°, MLM + 6.0^m, col. area 10 600 km² (computed for altitude 108 km)
- Watec 120N, FOV 50° x 40°, LML +2.0^m (UFOCapture)
- UK experiment
- both stations – Watec 902H, 0.8/12mm, FOV ~ 31° x 23°, MLM +4.0^m
- 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**
- **$\Delta < 3.0^\circ$ – 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

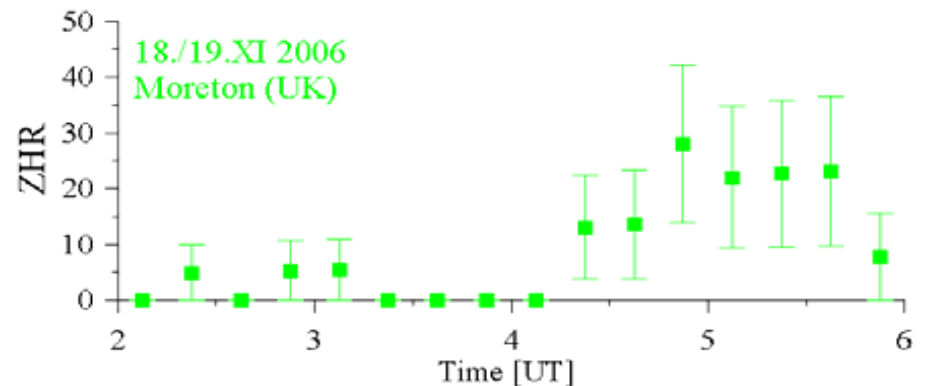
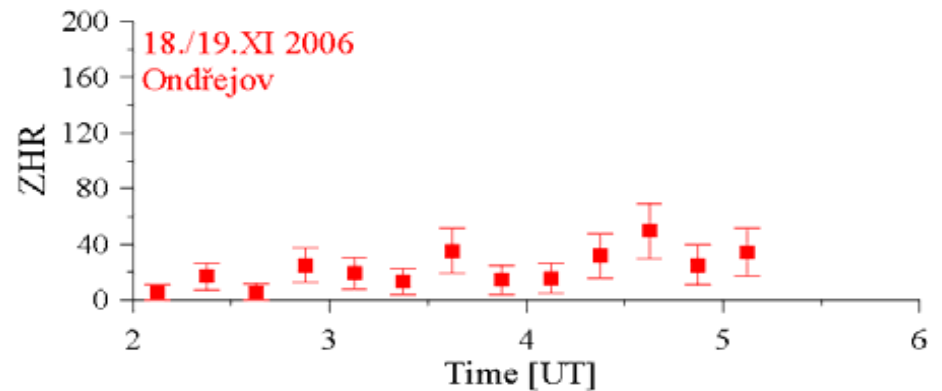
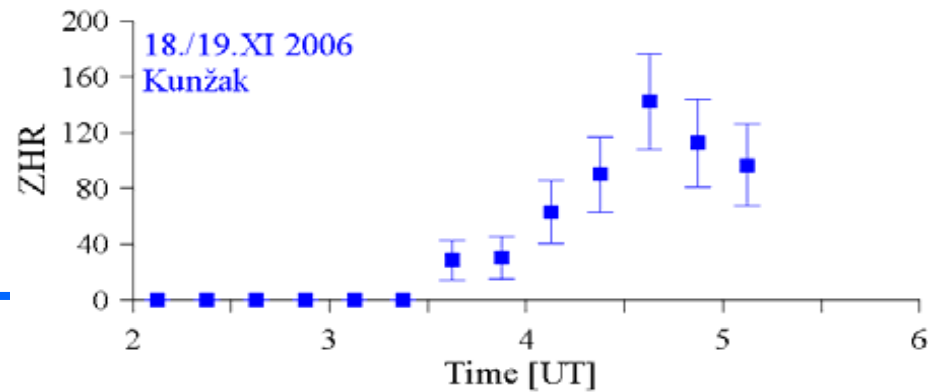
only correction – zenith
distance of radiant

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)

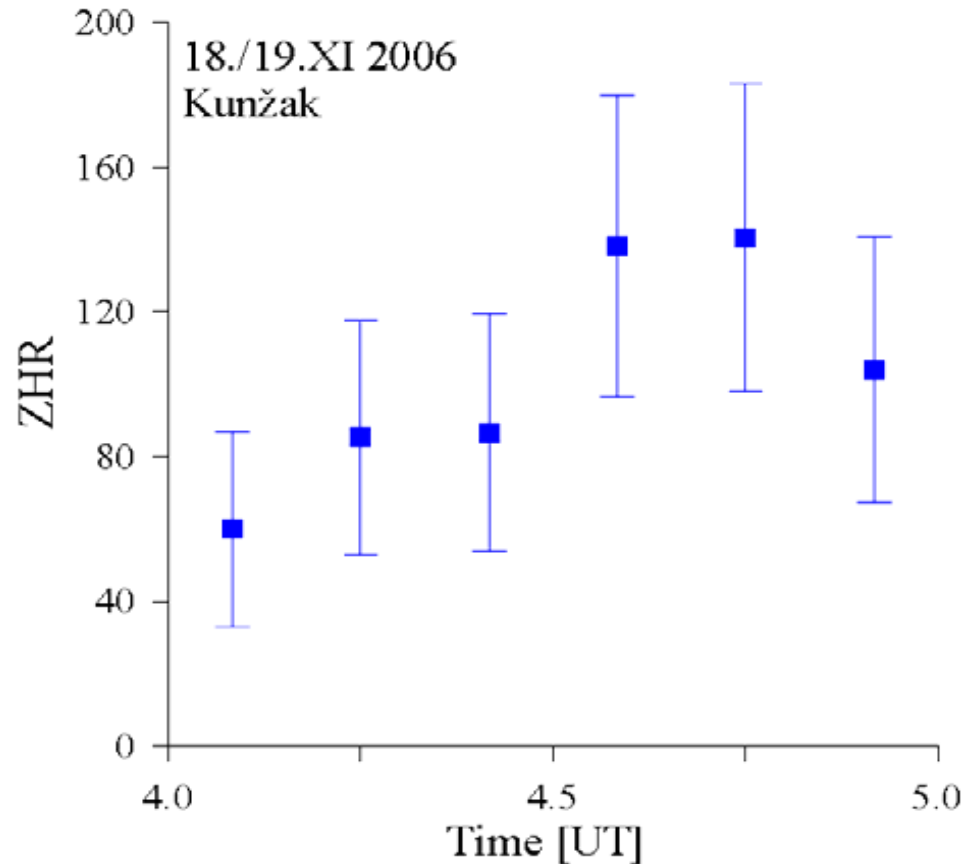
peak occurred around 4:45 UT
 ± 10 minutes

$$\lambda_0 = 236.613^\circ \pm 0.007^\circ$$

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.)

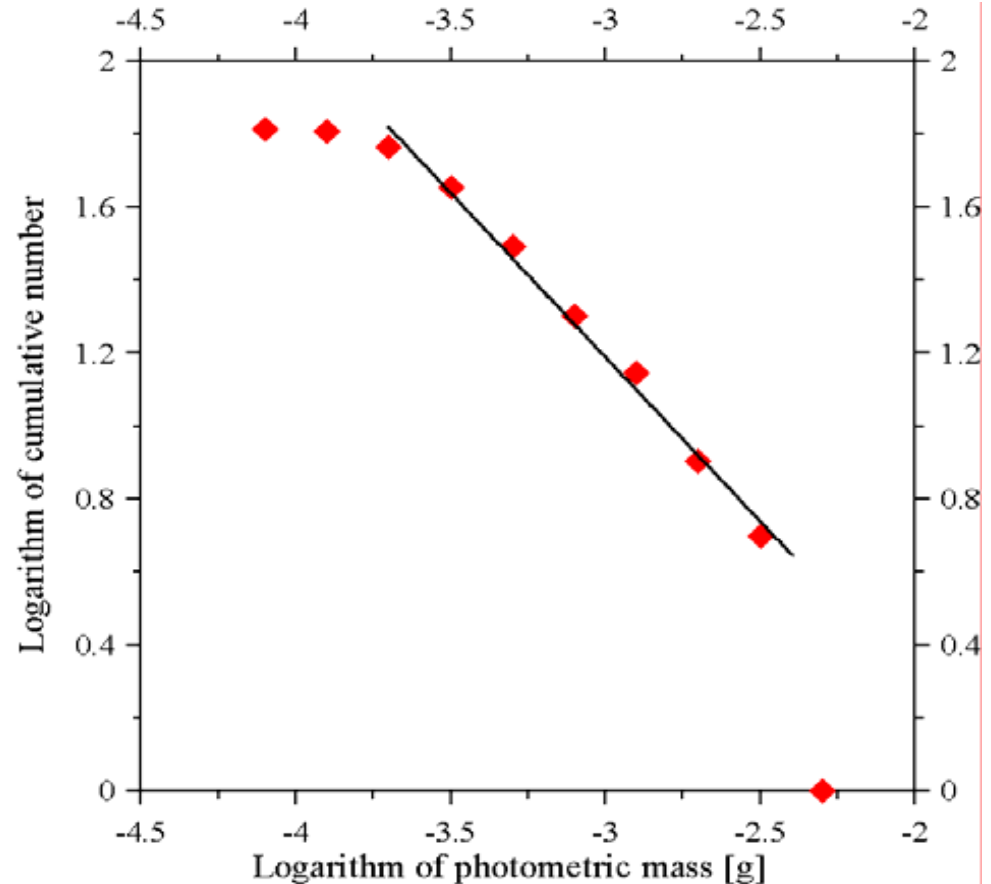
2006 – shower richer in faint
meteors

(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)

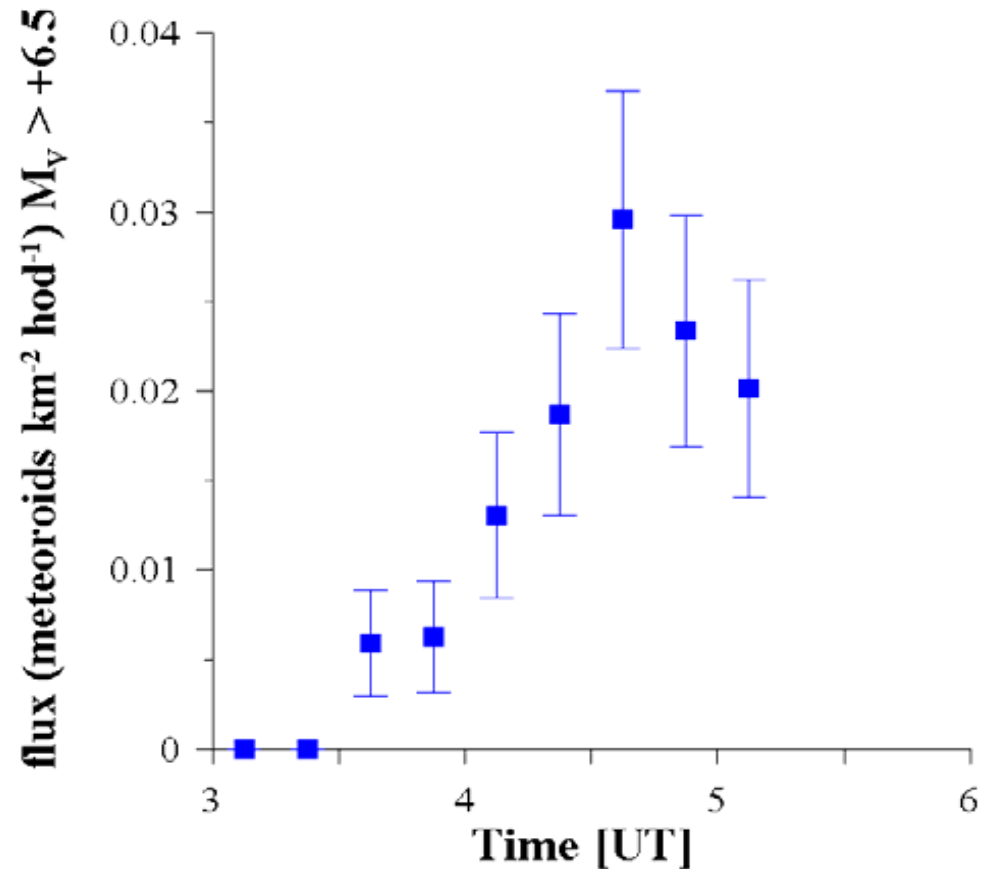
flux (+6.5^m) = $0.15 \pm 0.02 \text{ km}^{-2}\text{h}^{-1}$

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_0	+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 $\frac{1}{4}$ mm in diameter

Vaubailon 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:

$e = 0.932$ $q = 0.9856$ $\omega = 174.715$ $\Omega = 236.612$ $i = 162.823$

mean “internal” D-criterion among them is 0.06

Radiants

15 meteors

very compact radiant:

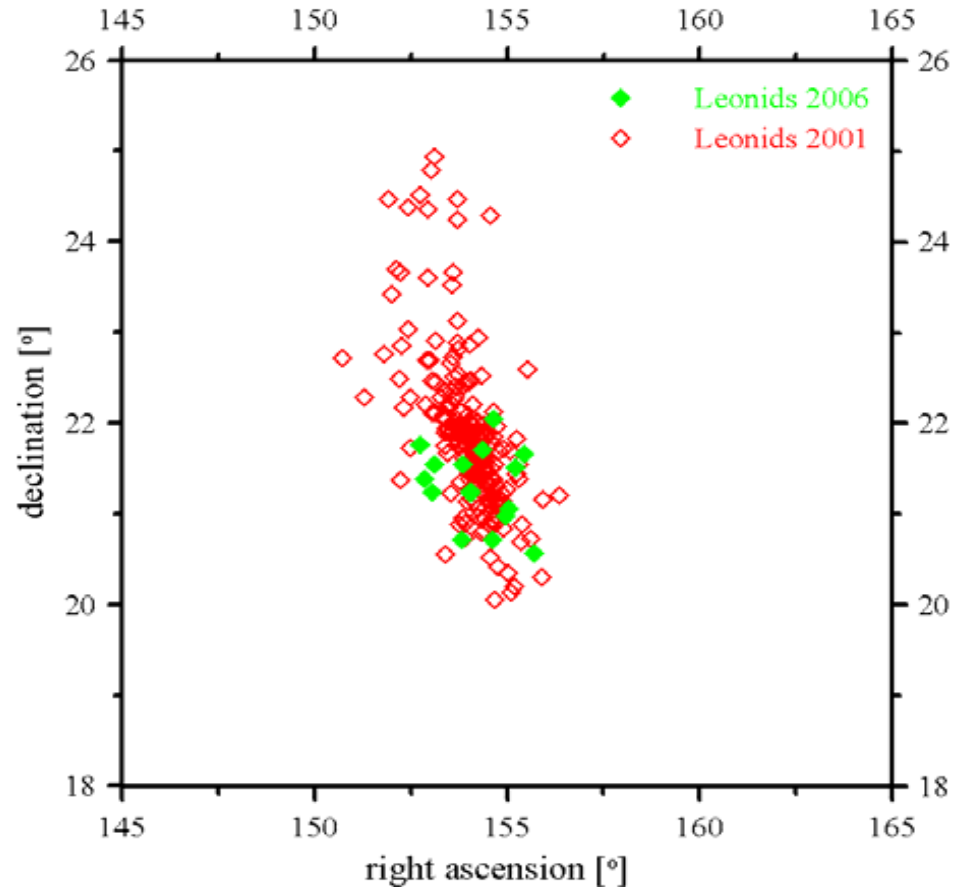
$$\alpha_G = 154.24^\circ \pm 0.25^\circ$$

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

**comparison with 2001 Leonids
(7 revolution old)**

± 1 hour around maximum

bigger dispersion of radiants

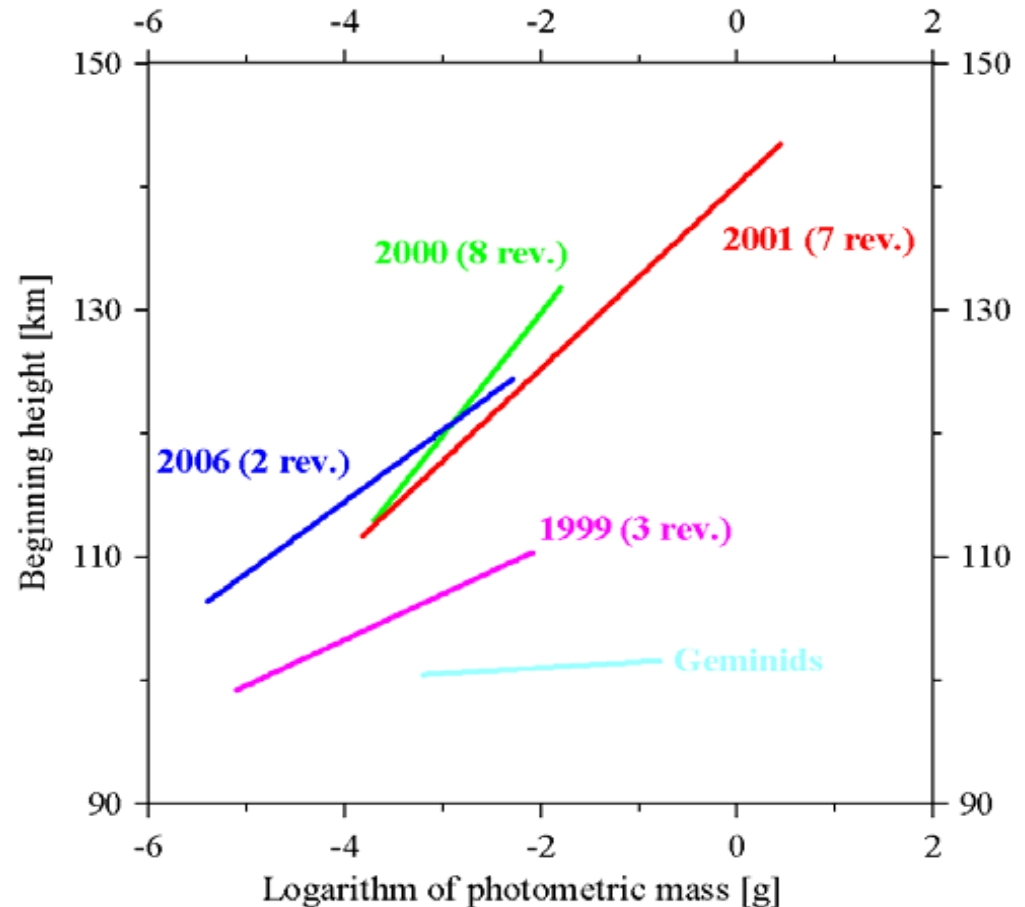


Beginning heights

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

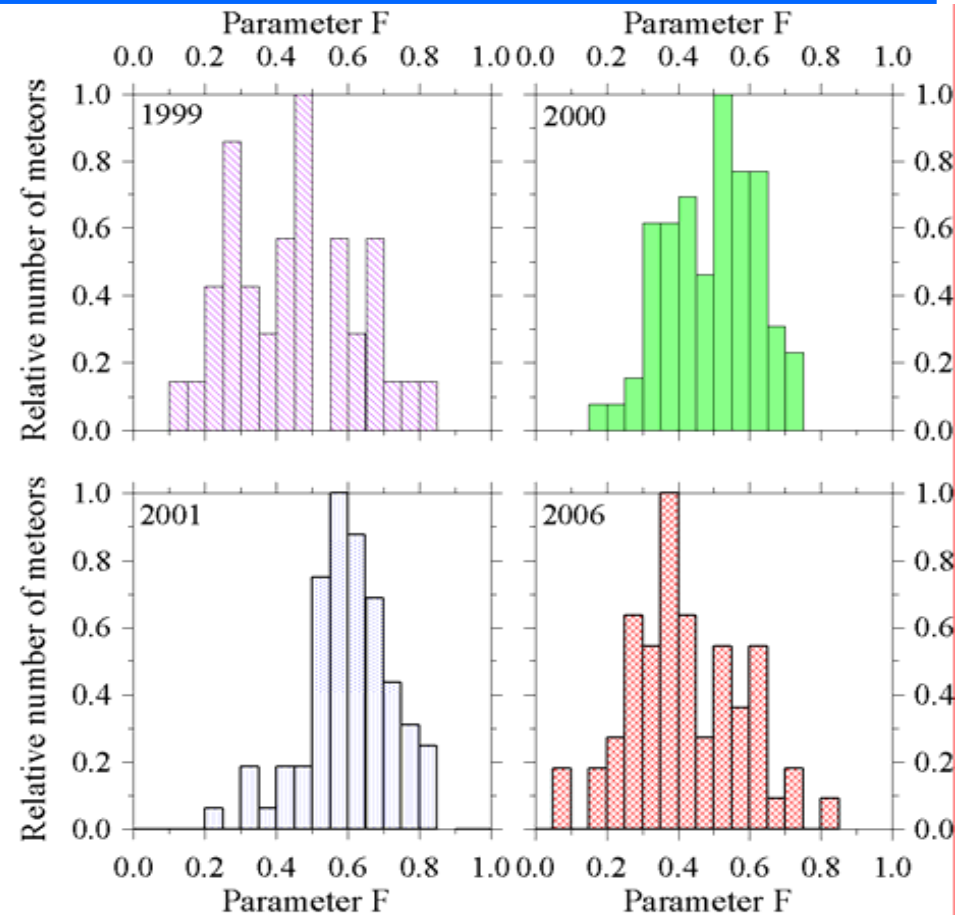
absolute brightness vs. height

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**

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