From Rates to Fluxes of Meteoroid Streams

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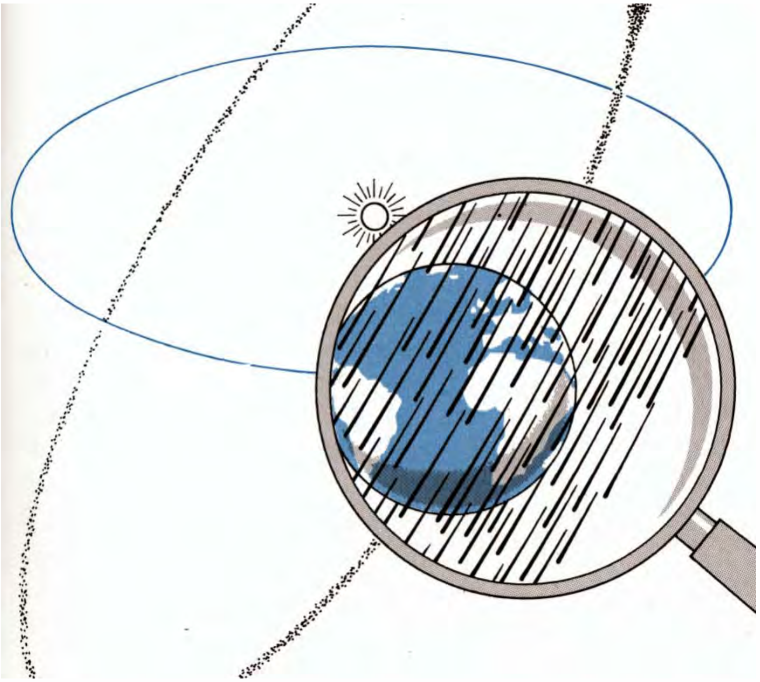
Outline

- Meteor shower observable data
  - Numbers & magnitudes
  - Calibration quantities
- To physical meteoroid stream parameters
  - Population index r and mass index s
  - ZHR
  - Spatial number density (and meteoroid flux)
- Example and summary

Meteor shower data

- Observer in a poor situation:
- Only last and disturbed part of a meteoroid's orbit
- Small collecting area compared to the stream dimension
- Limited sample
- Observing errors
- Visual and video observations similar

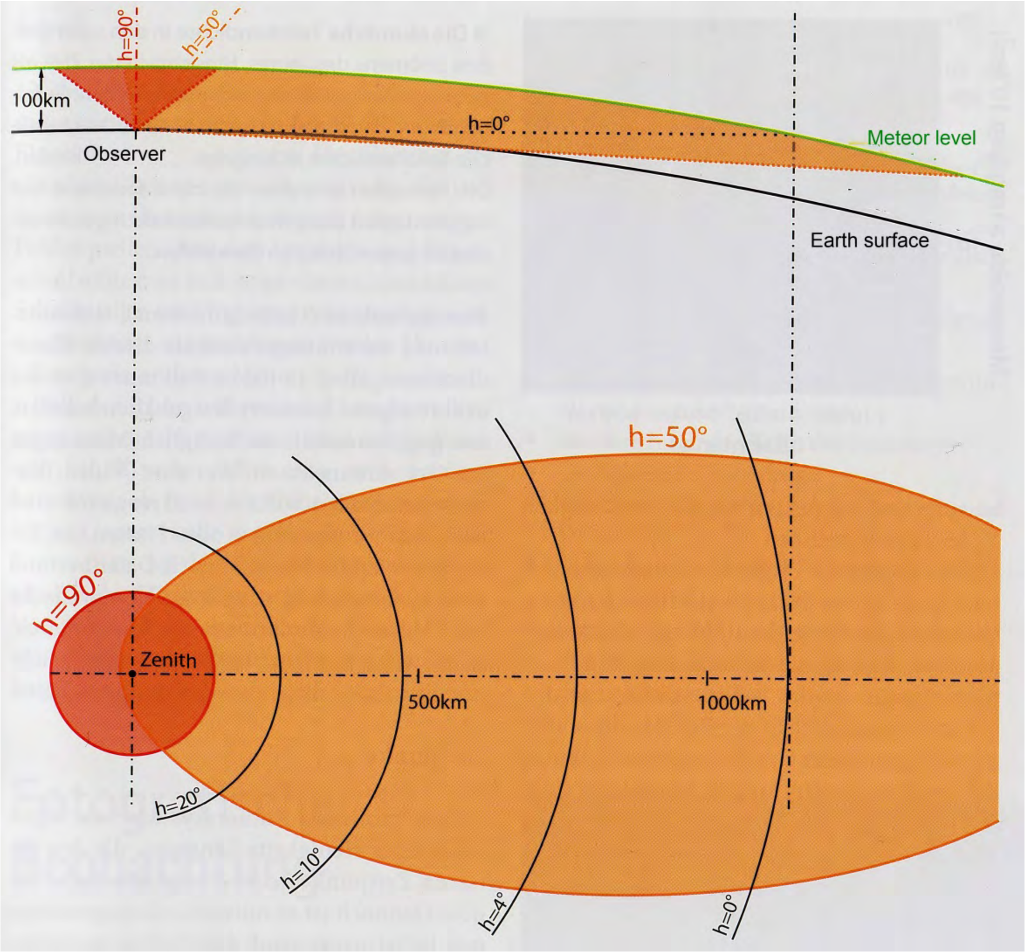


Meteor shower data

- Observable quantities:
  - Number of meteors per shower (association with uncertainties)
  - Apparent magnitudes (subject to atmosphere situation: elevation, distance to observer etc.)

Aim: meteoroid stream data

- Additional necessary data:
- Observed field
- Mass distribution



Aim: meteoroid stream data

- Additional necessary data:

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Viewing direction:

Zenith – small field, simple geometry

Horizon – huge field, different meteor distances

(field size: visual → 100° diameter;

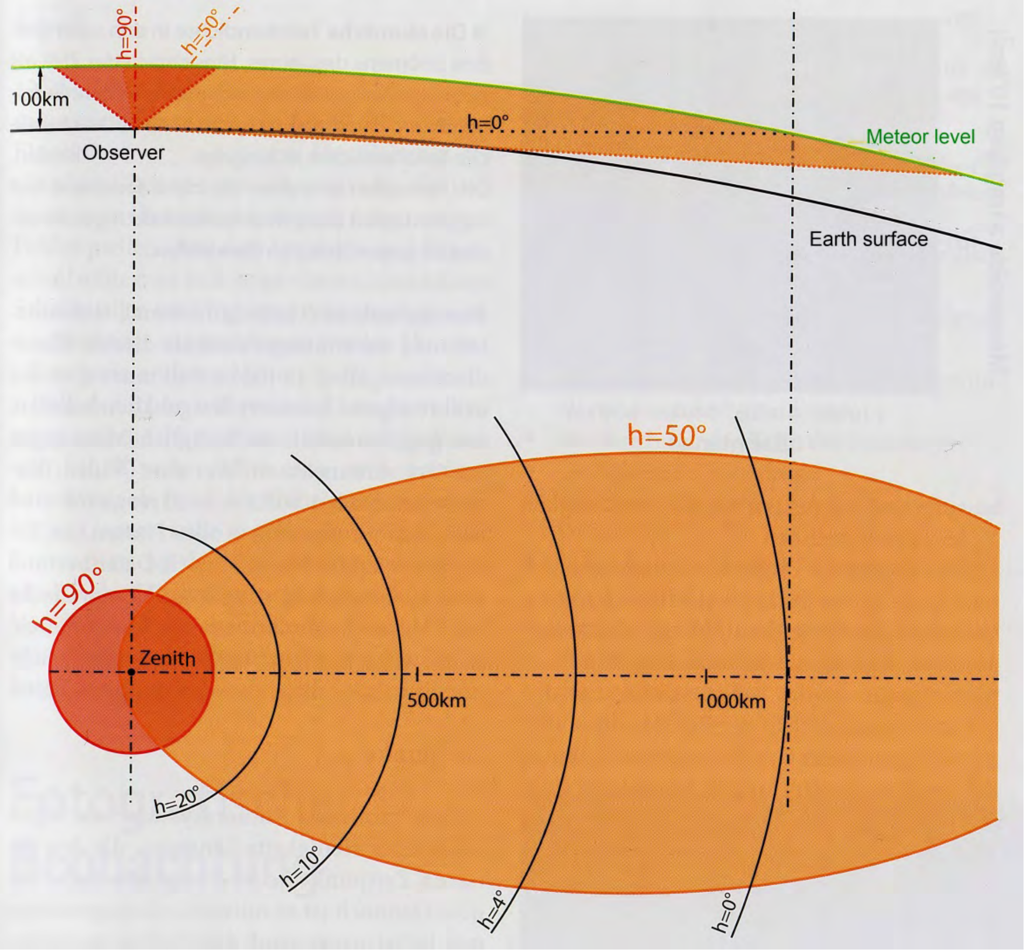
video → lens determined)

volume gain ~ $\sin^3 h$

extinction loss ~ $1/\sin h$ (in useable range)

meteor magnitude loss ~ $1/r^2$ → ~ $1/\sin^2 h$

Effects seem to compensate



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Attempt to use a defined volume

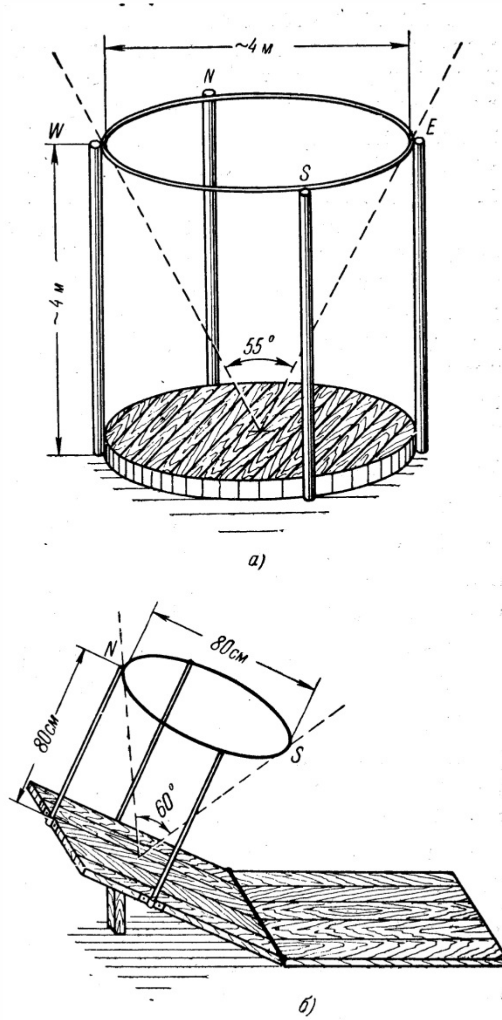
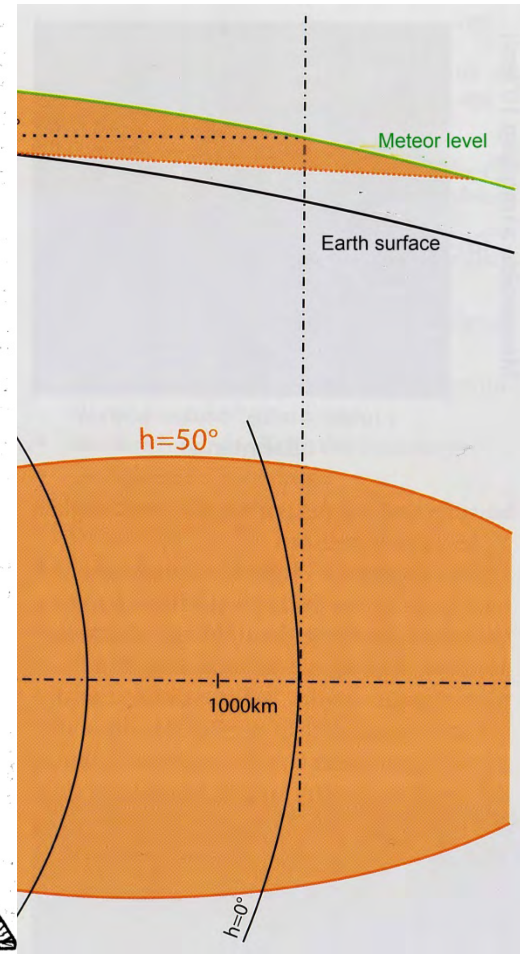


Рис. 149. Рамки для счета метеоров: а) для нескольких наблюдателей; б) индивидуальные.



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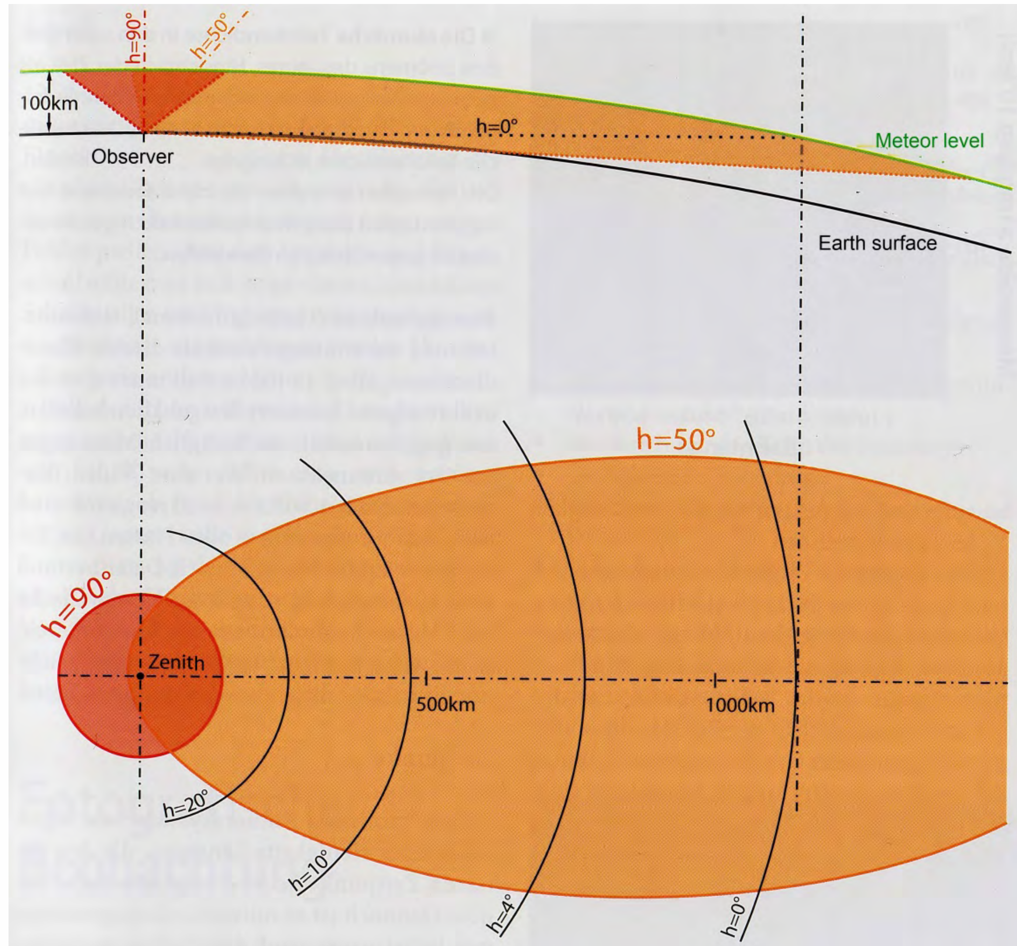
Conclusion:

visual field center h 50°-90°

Video: avoid near horizon fields



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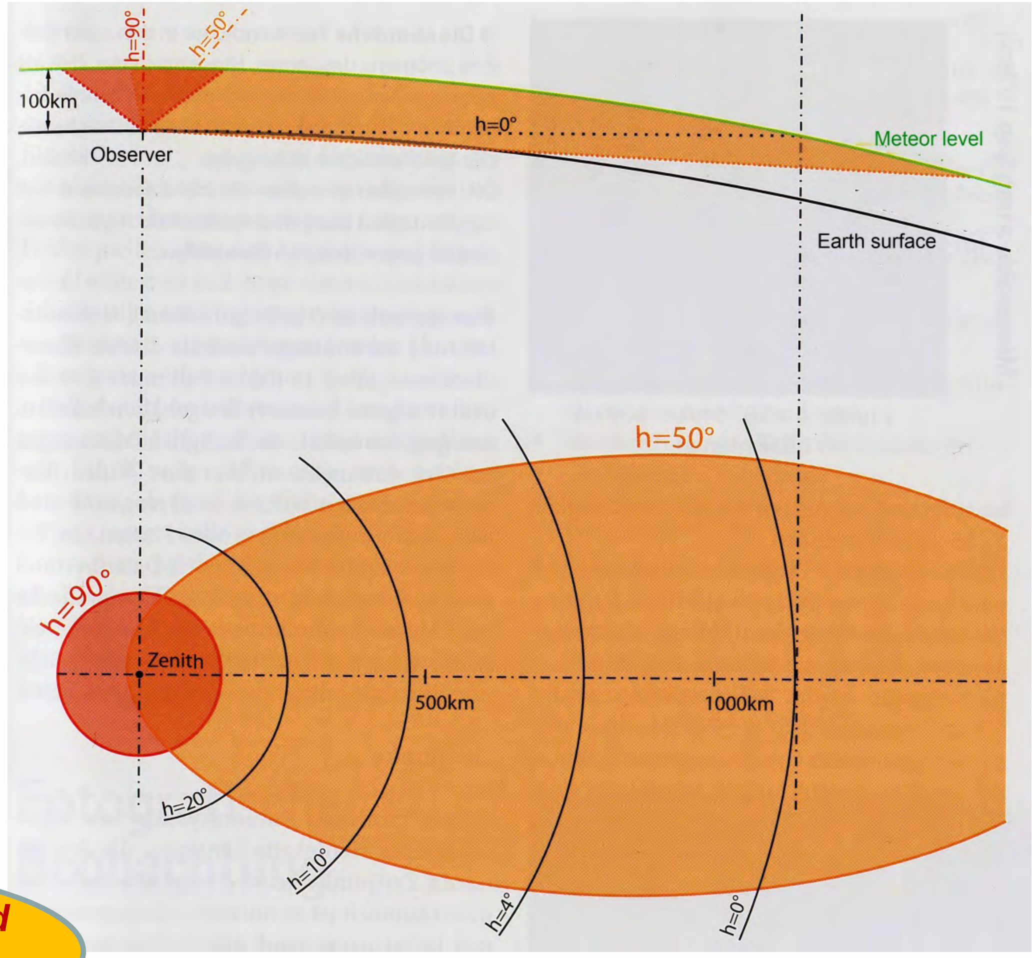
Detailed look: effects depend strongly on r! – why and how?



Aim: meteoroid stream data

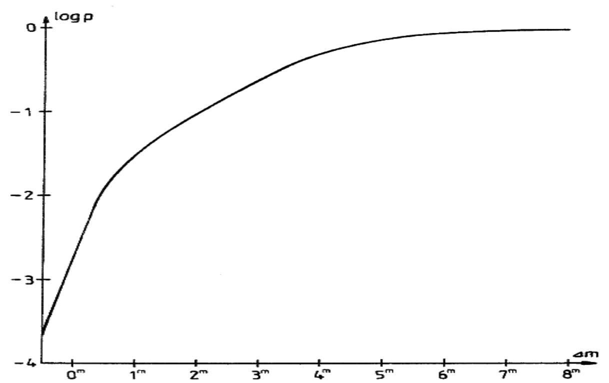
- Additional necessary data:

- Mass distribution

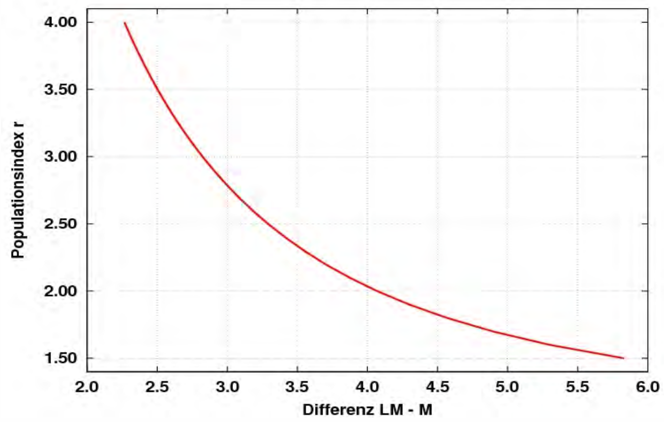
apparent magnitudes
→ population index *r*

3 purposes:

1. number of particles as a function of particle mass (properly converted → mass distribution)
2. construct the ZHR; info about missed meteors if LM ≠ +6.5
3. convert ZHR into spatial number density and flux



Probability of perception p as a function of Δm (difference to LM) for visual data (Koschack & Rendtel, 1990)



Population index as function of difference LM – mean mag (Arlt, 2003)

Aim: meteoroid stream data

- Additional necessary data:

- Mass distribution

population index *r* → mass index *s*

s = 1 + 2.5 lg r

r = 10^ (s-1)/2.5

(if a constant fraction of the kinetic energy is transformed into meteor luminosity)

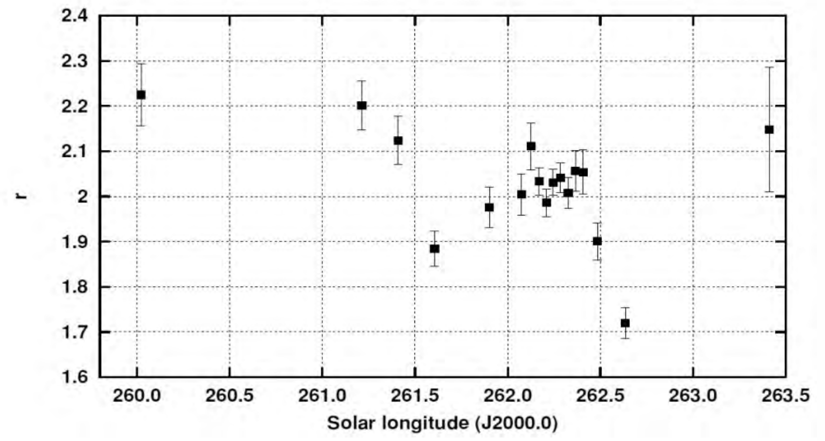
Typical range for r:

2.0 – central stream regions

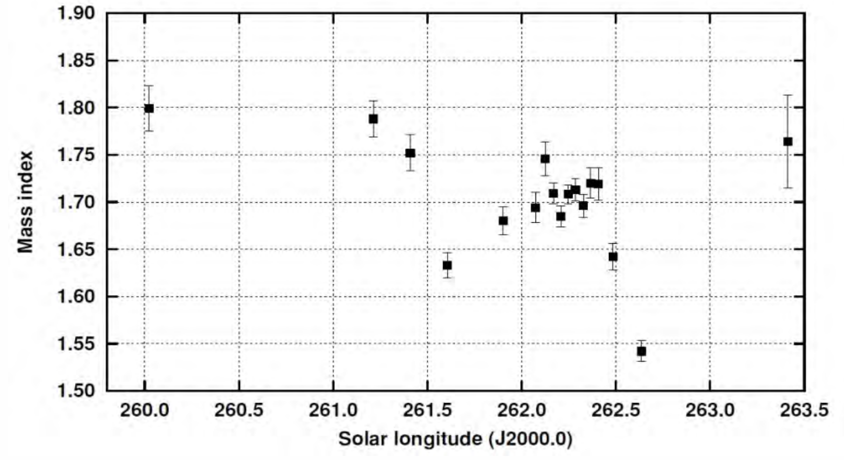
2.5 – outer regions of streams

3.0 – sporadic meteors

3.5 – few showers with a high fraction of small meteoroids



Population index profile, Geminids 2004 (Arlt & Rendtel, 2006),



Mass index profile, Geminids 2004 (Arlt & Rendtel, 2006)

AIP

Aim: meteoroid stream data

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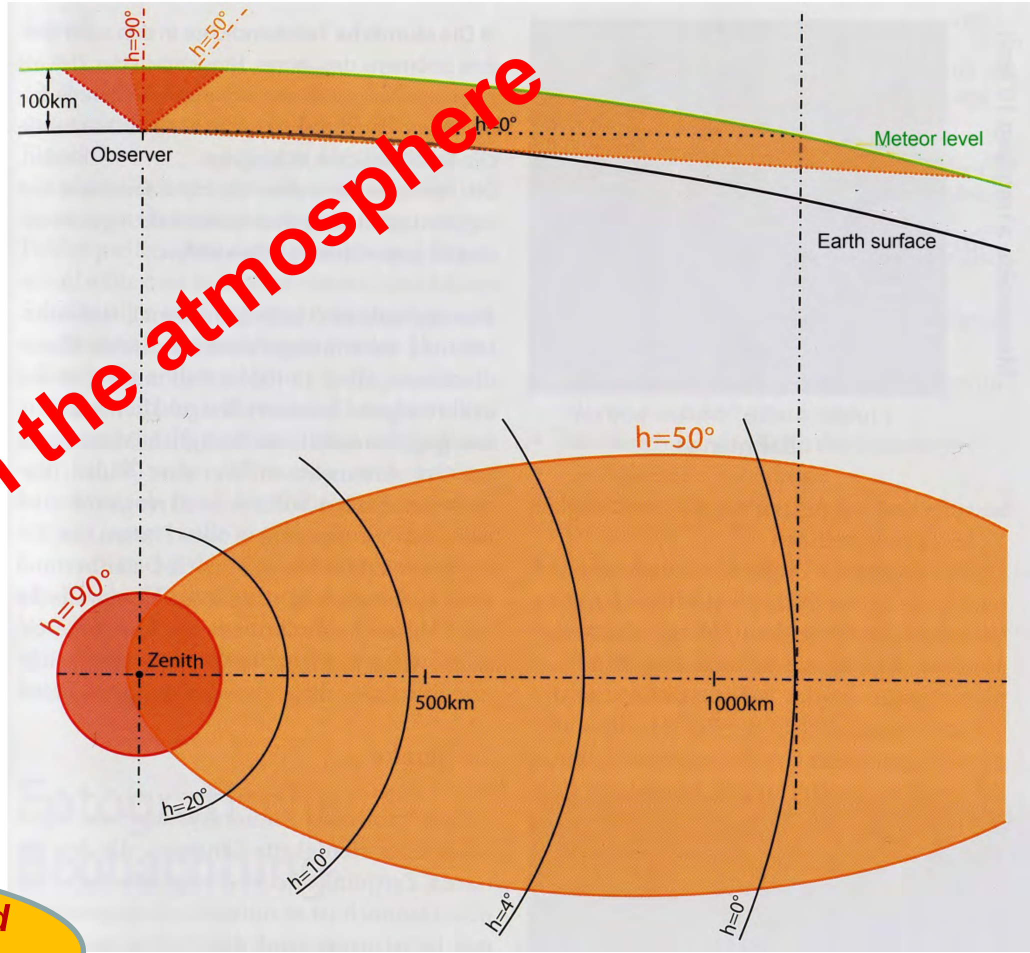
Back to the field in the atmosphere



Aim: meteoroid stream data

Two extreme examples to clarify the effect:

(1) Only very bright meteors
- **observer sees ALL meteors**
- **compensations complete**

(2) Real shower, *r = 2…3*
- **many faint meteors**
- **most in distant part of volume**
- **apparent magnitude decreased**
- **determine calibrated field A(red)**
- **r low – large calibrated field**
- **r high – small A(red)**

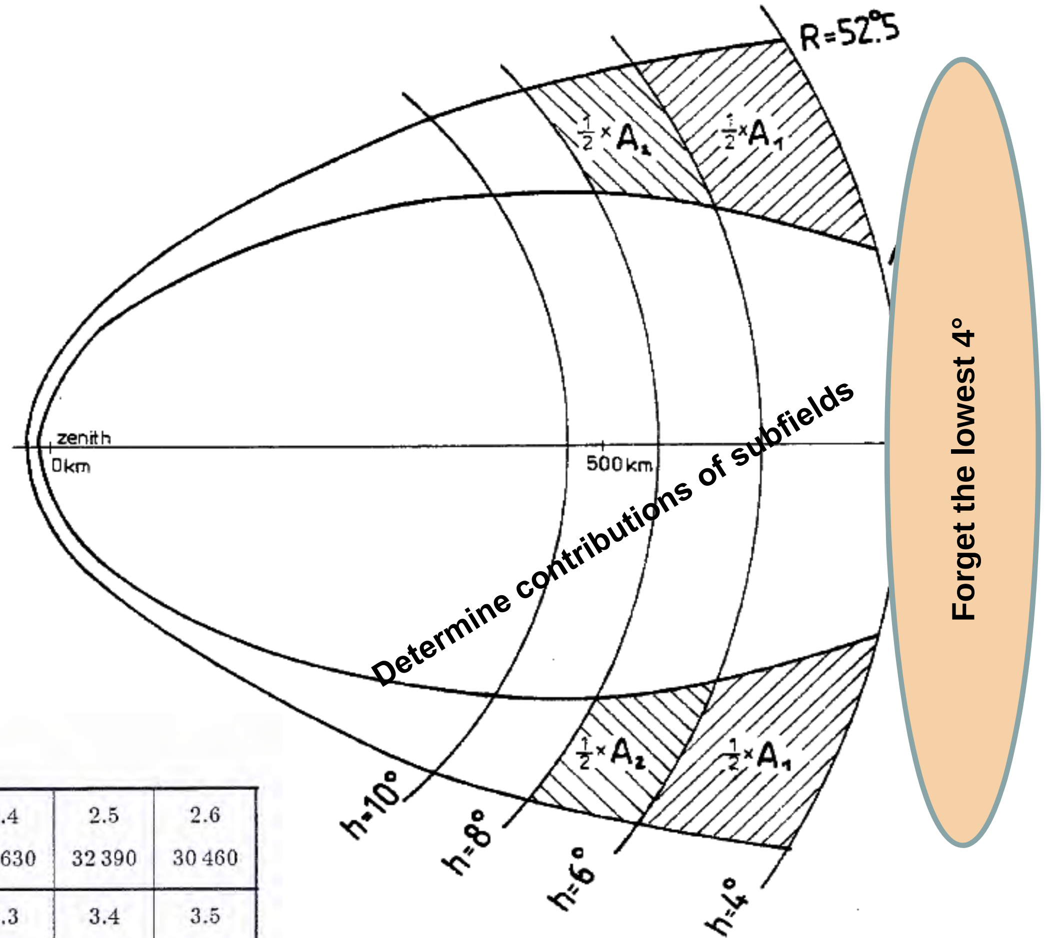


Table 3 – Area A_{red} in dependence on r for $h_f = 50°$ and $H = 100$ km.

r	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6
A_{red} (km^2)	62 120	54 750	48 940	44 260	40 450	37 290	34 630	32 390	30 460
r	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5
A_{red} (km^2)	28 790	27 330	26 050	24 920	23 910	23 000	22 190	21 450	20 770

(Koschack & Rendtel, 1990)

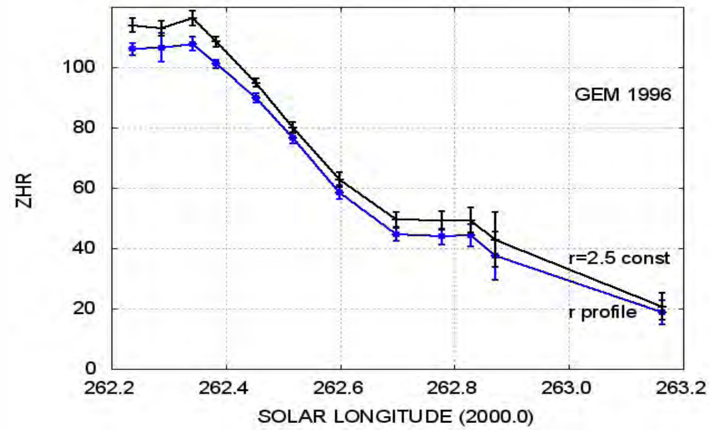
ZHR to Number Density/Flux

ZHR calculation straightforward

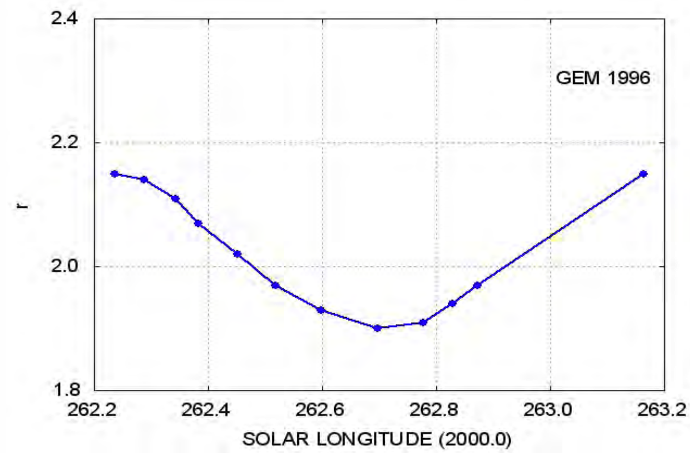
ZHR = N * C with

$$C = \frac{r^{6.5-\mathrm{LM}} F}{T_{\mathrm{eff}} \sin h_{\mathrm{R}}}$$

Effect of the population index *r* on ZHR is visible, about 10% difference



ZHR profile, Geminids 1996: r=const=2.5 vs. calculated r



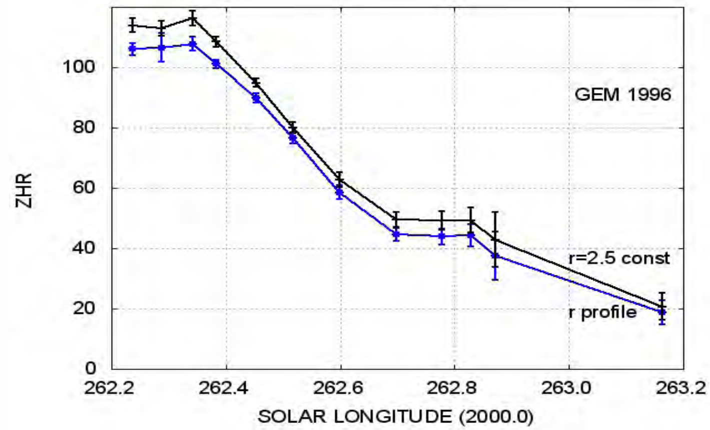
Calculated population index profile, Geminids 1996

ZHR to Number Density/Flux

Considering the calibrated field

A(red)=178700 r^-1.82 [km^2]

Effect of the population index *r* on the field is significant!



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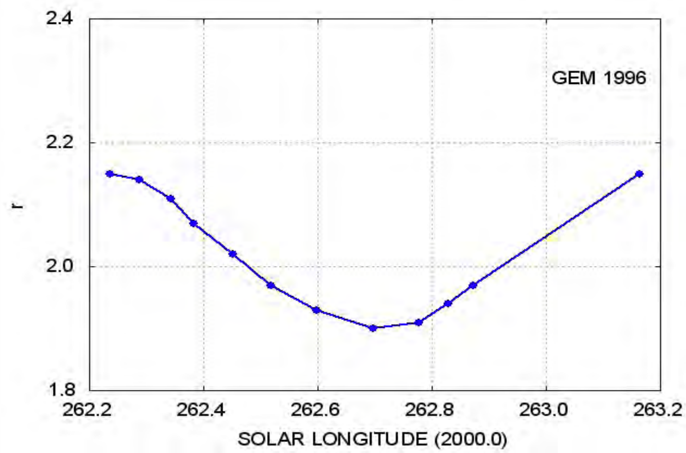

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ZHR to Number Density/Flux

Calculation of the spatial number density

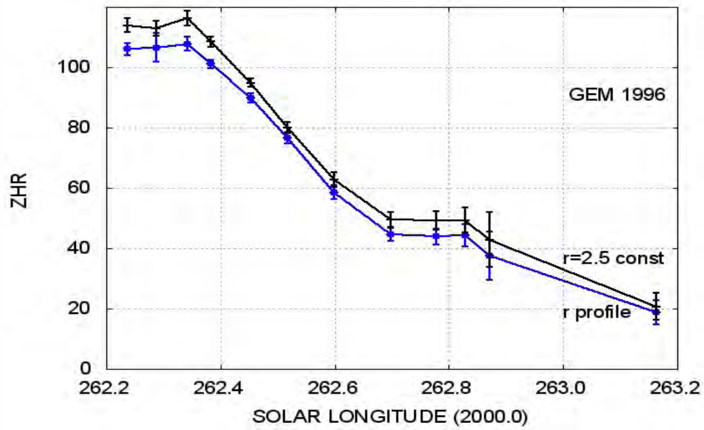
$$ND\,(m<+6.5) = \frac{ZHR_0 \quad c(r)}{3600 \quad A_{red}(r) \quad v_\infty}$$

Where c(r) is a correction including the probabilities of perception and is also depending on r as

c(r) = 10.65 * r -12.15

(Koschack & Rendtel, 1990)

c(r) range: 10 (r=2.0) … 20 (r=3.0)



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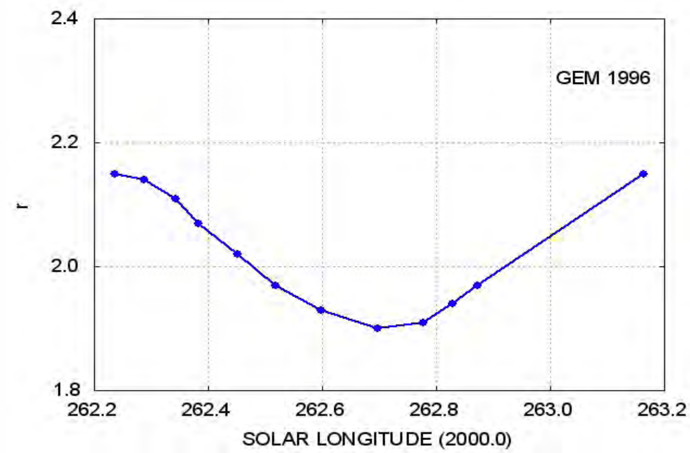

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ZHR to Number Density/Flux

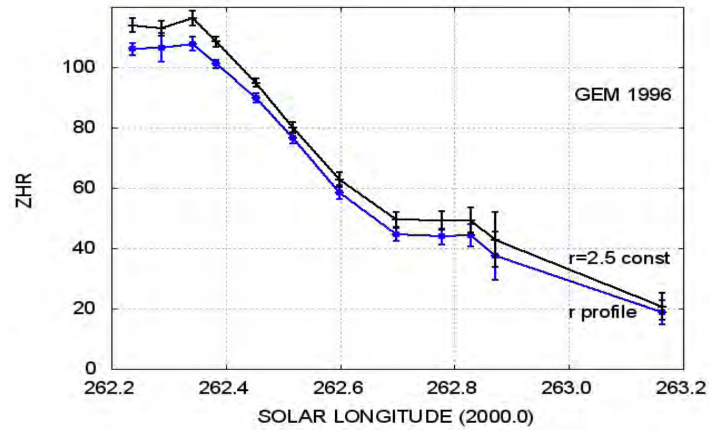
Calculation of the meteoroid flux:

F = ND * V

10^-9 km^-3 * km s^-1 [*3600 s/h]

3.6*10^-6 km^-2 h^-1

Earth moving at V through the stream volume



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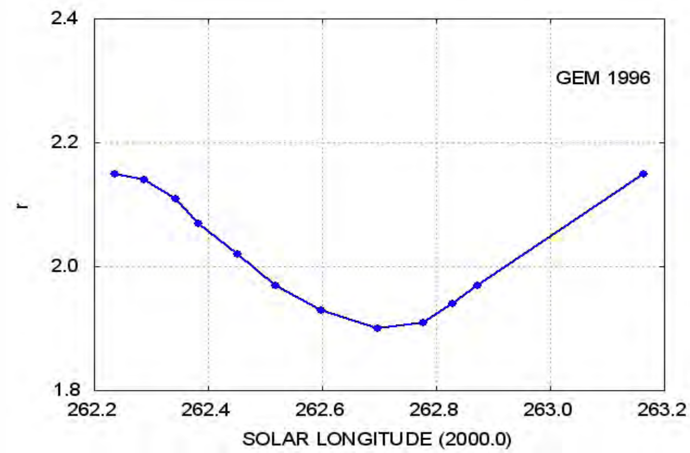


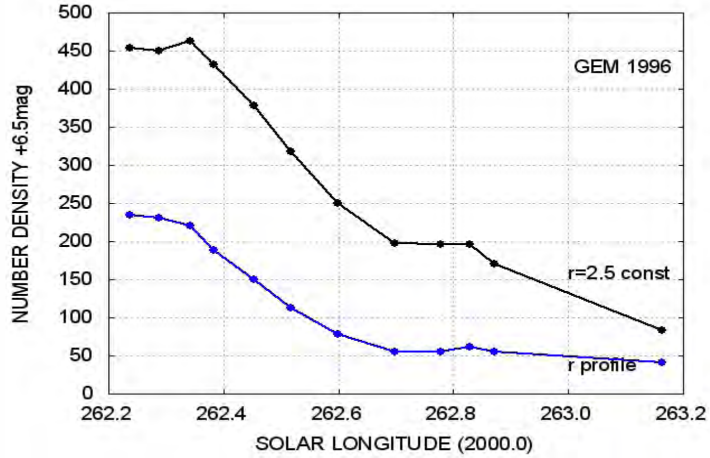
Calculated population index profile, Geminids 1996

Comparison of meteoroid streams best in terms of spatial number density, while the effect on spacecraft or the Earth‘s atmopshere is better described by flux (flux follows ZHR)

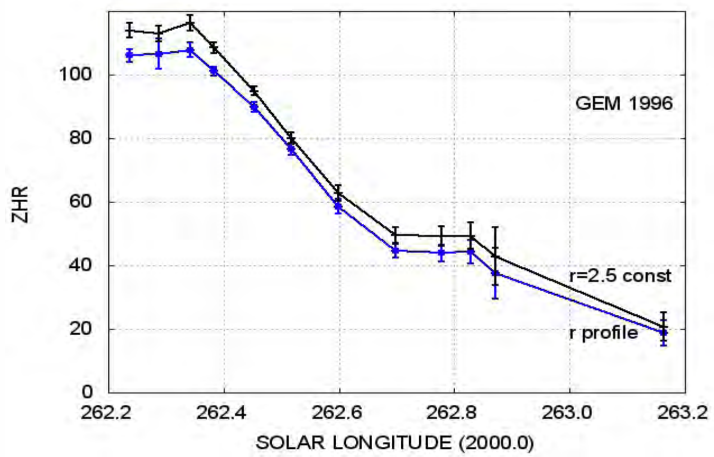
ZHR to Number Density/Flux

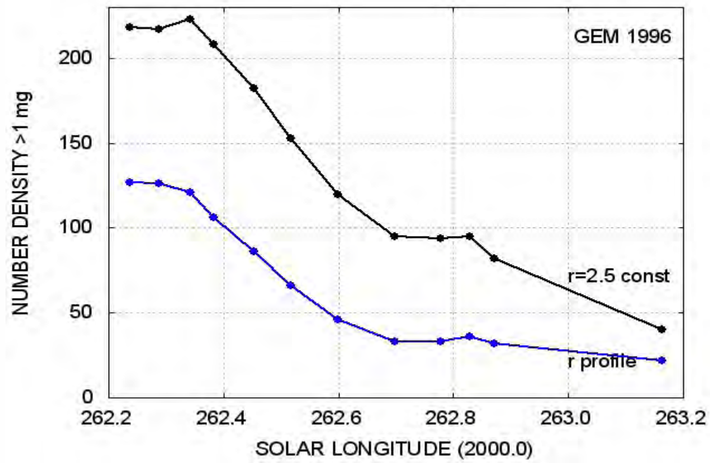
Effect of the population index *r* (2.5 or calculated values) on spatial number density

ca. factor 2



ND profile meteoroids +6.5 mag, Geminids 1996: r=2.5 / calculated r

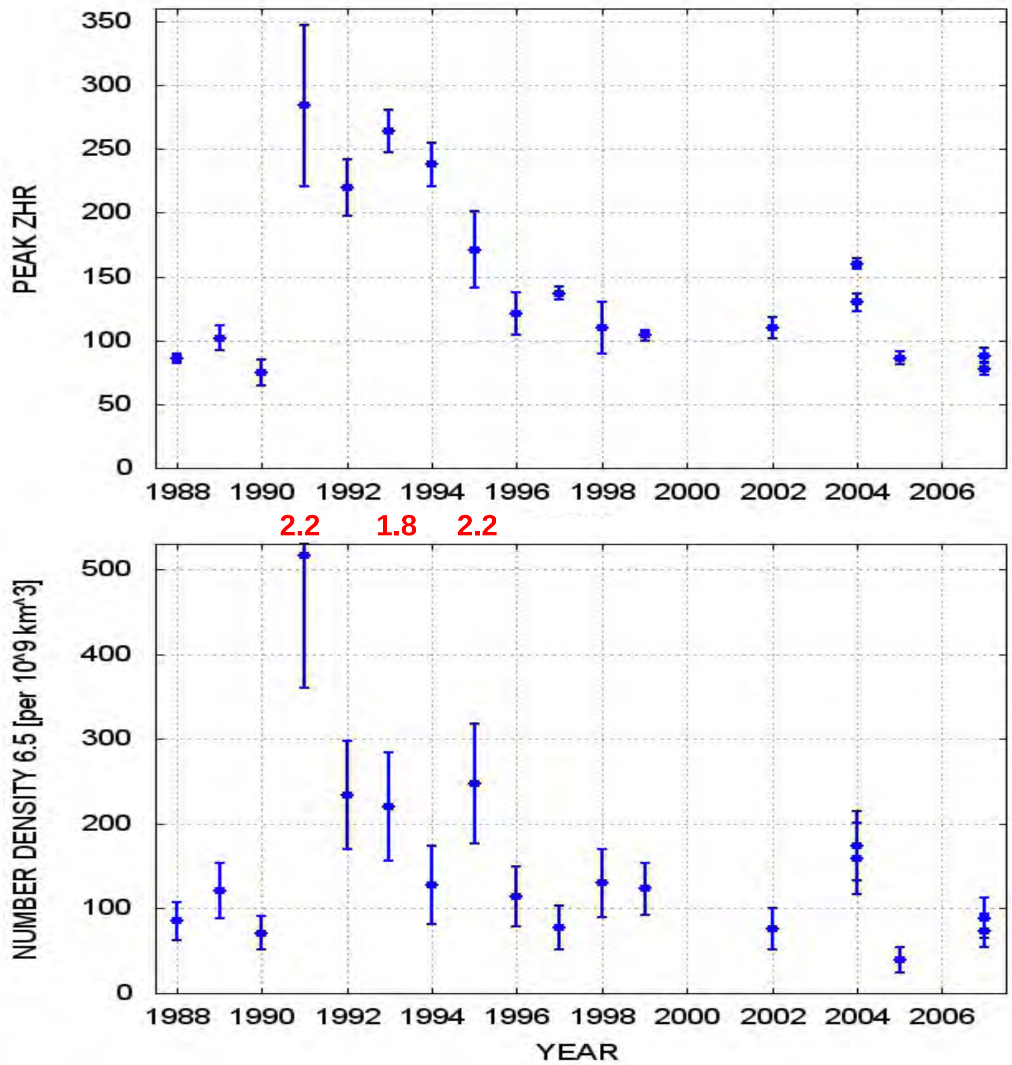




ND profile meteoroids >1mg, Geminids 1996: r=2.5 / calculated r

Example: Perseids 1988-2007

Compilation of rate, spatial density and flux data from IMO analyses (re-calculated)



Perseid peak ZHR

Perseid spatial number density +6.5 mag

Example: Perseids 1988-2007

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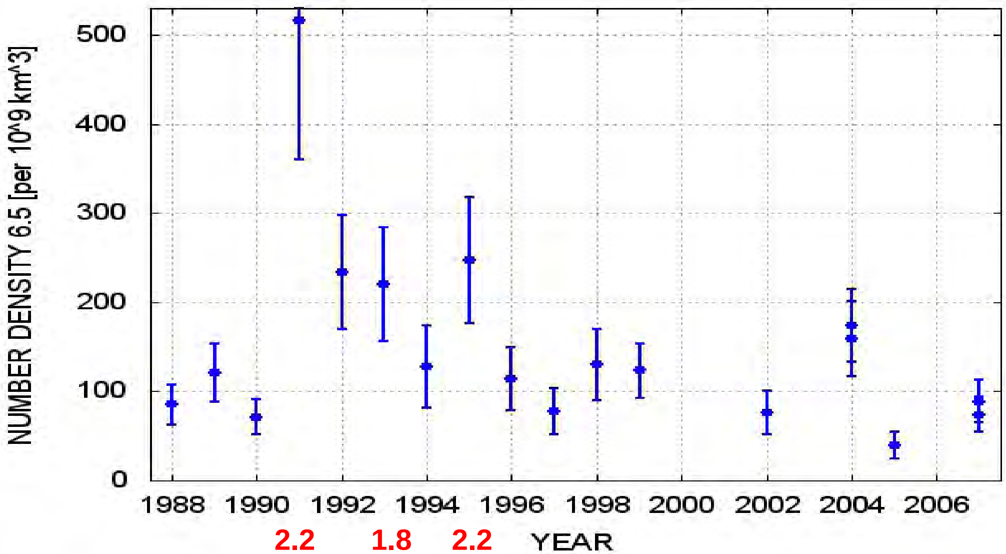
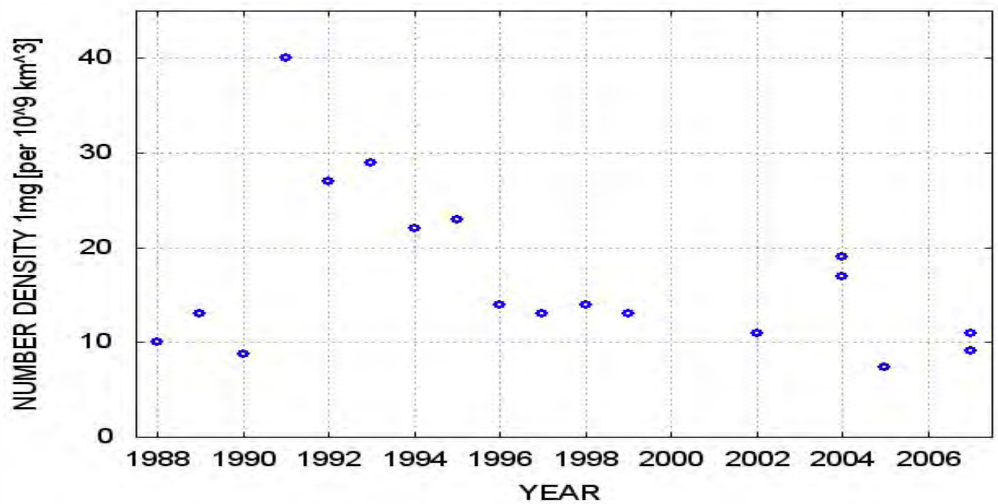
Perseid spatial number density +6.5 mag



Perseid spatial number density >1 mg



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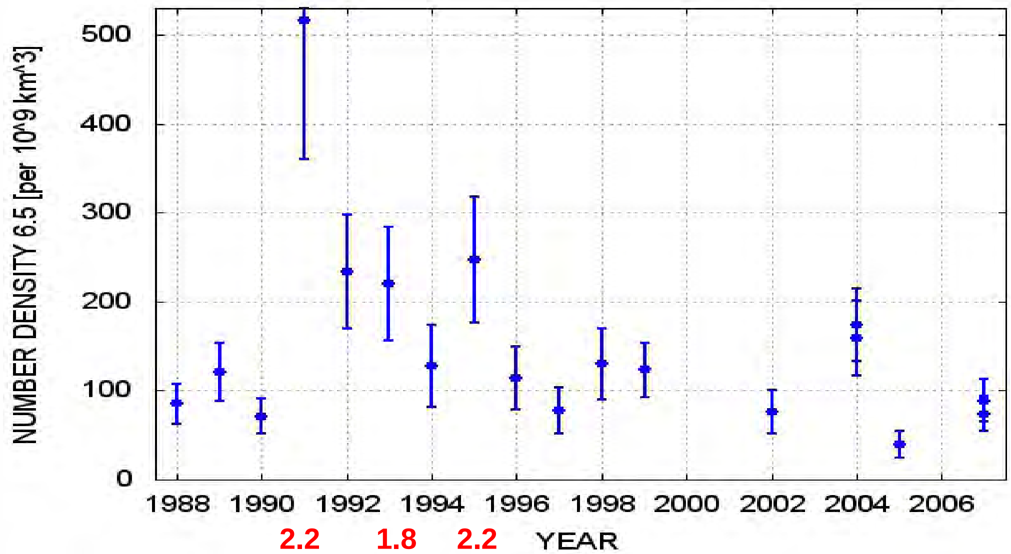
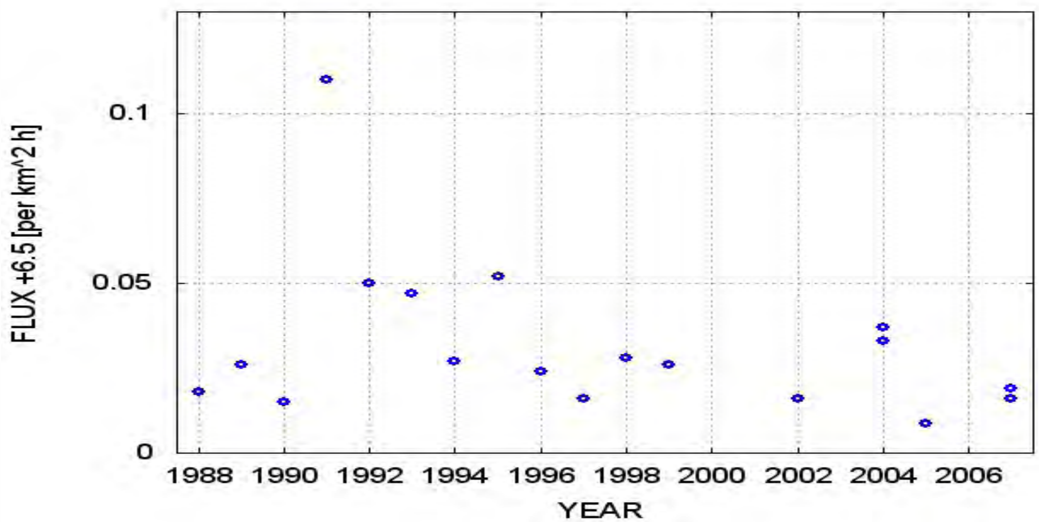
[Paper iunder preparation]



Perseid spatial number density +6.5 mag



Perseid flux +6.5 mag
(only multiplied by velocity)

Summary

We need a complete data set, consisting of:

- Magnitude data (magnitude distributions)
- Rate data (numbers per shower)
- Calibration data (observing direction, LM)

Analysis steps:

- Population index r profile
- ZHR profile
- Spatial number density and flux

Similar for visual and video observations

Live-graphs at www.imo.net are preliminary data (r=const)!

Aim: motivation of observers, first view at activity profile, peaks, filaments etc.