地球近傍微小ダスト

Near Earth Small Meteoroids

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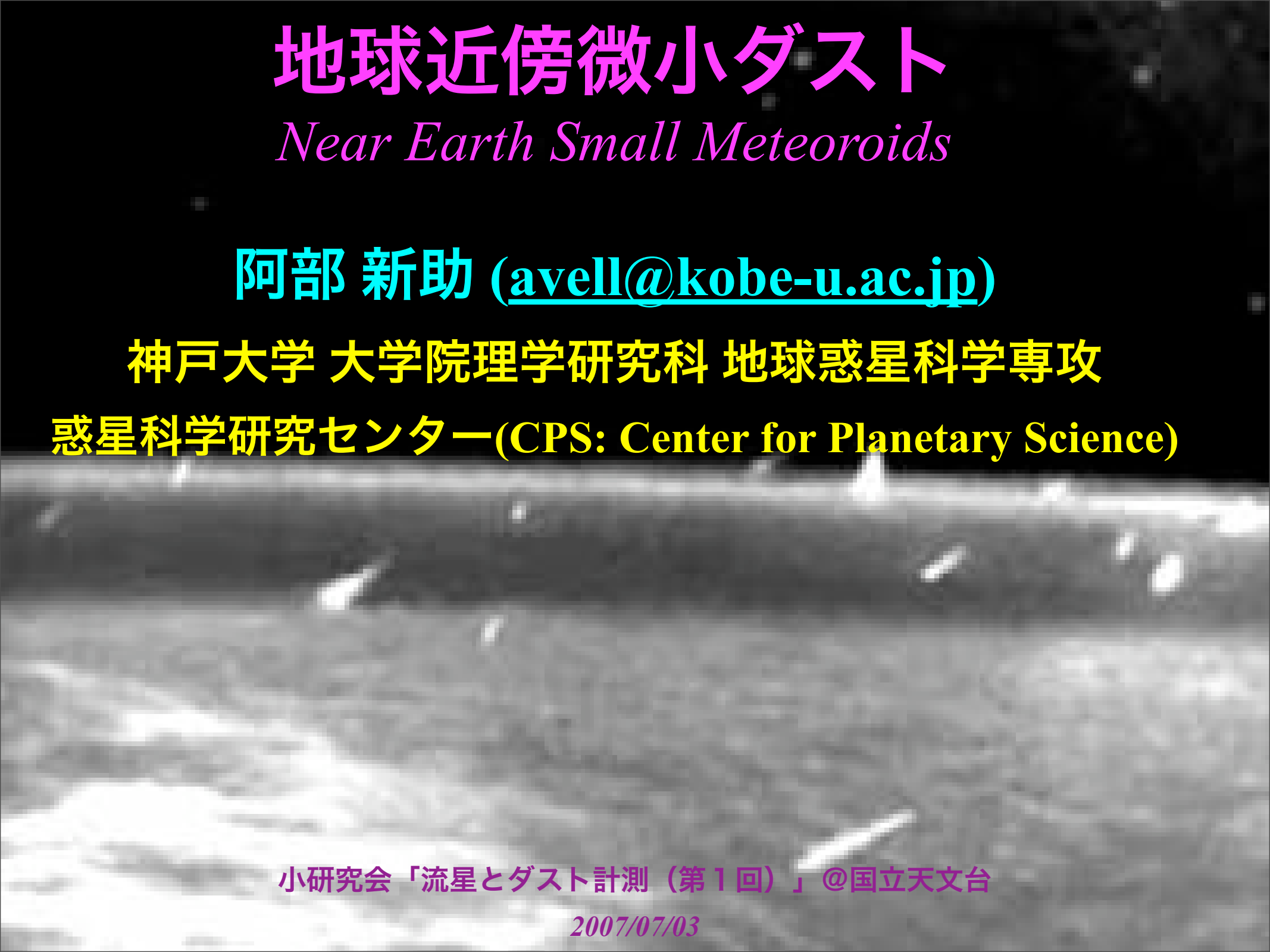
惑星科学研究センター(CPS: Center for Planetary Science)



小研究会「流星とダスト計測（第１回）」@国立天文台

2007/07/03

Source of Meteoroids

- Stream Meteoroids “流星群”
- Sporadic Meteoroids “散在”

Source of Sporadic

- **Interplanetary dusts; 短周期彗星, エンケ彗星, 小惑星(衝突破砕dust)**
- **Interstellar dust; 対地速度72km/s以上, dust直径40μm?, flux?**

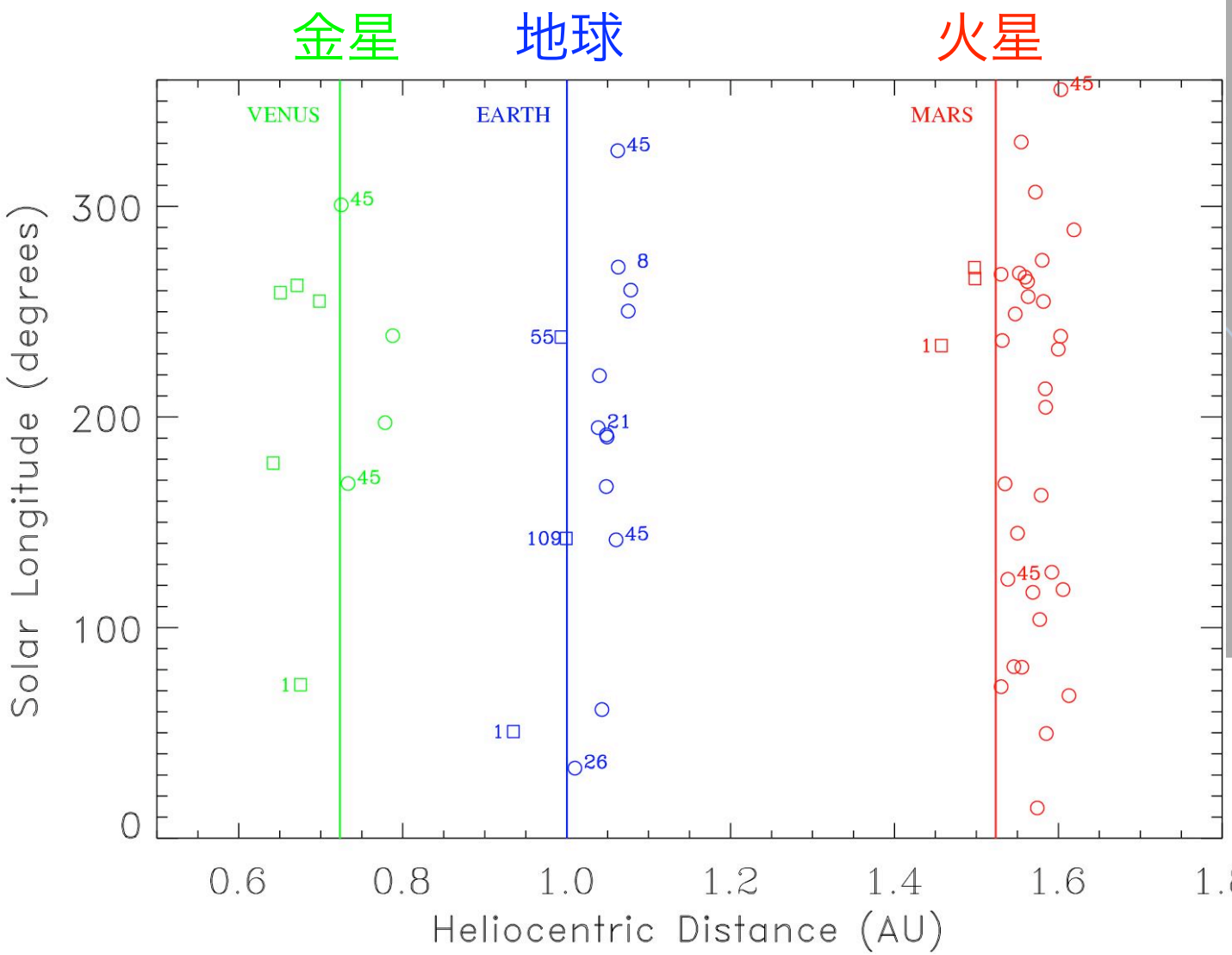
It is evident that sporadic meteors exhibit diurnal and seasonal variations in their activity.

Sporadic radiants were initially distributed isotropicly, but appear to be concentrated about the apex of the Earth because of the Earth’s orbital motion.

The seasonal variation of sporadic meteors in the strength of the apparent maxima of the helion and antihelion sources shows asymmetric features during certain periods.

Stream Meteoroids

Source; planet-approaching comets



□ : Halley Type Comets
- high speed; > 25 km/s
- strong annual activity
- outbursts

○ : Jupiter Family Comets
- low speed; > 25 km/s
- weak annual activity
- outbursts

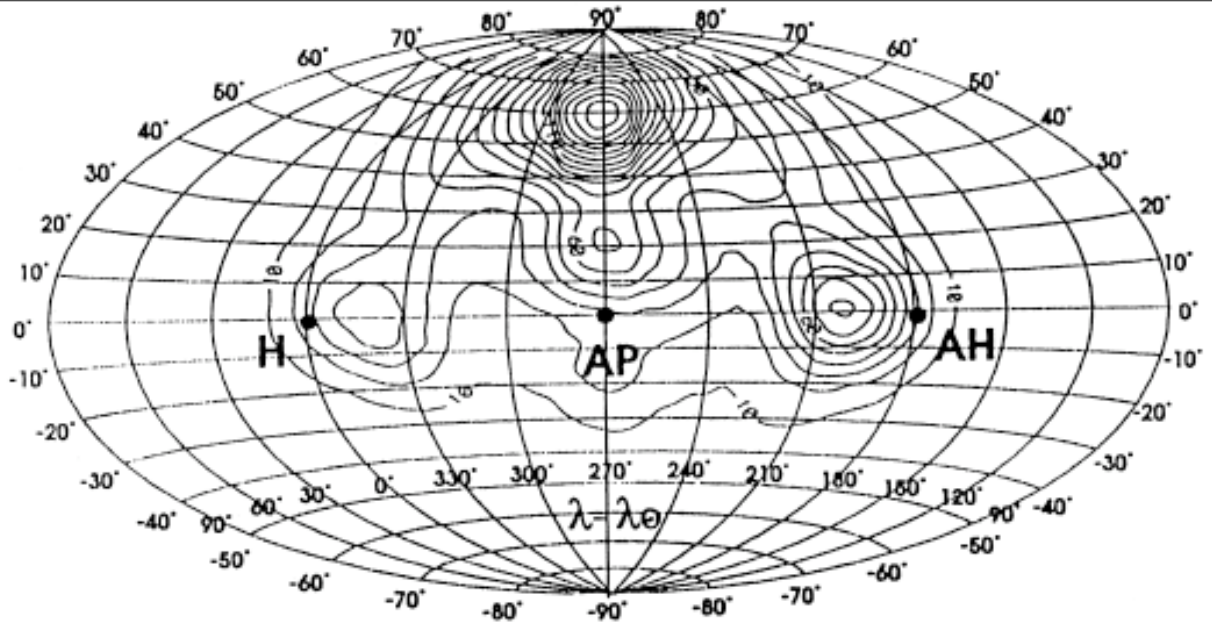
流星群発生の条件

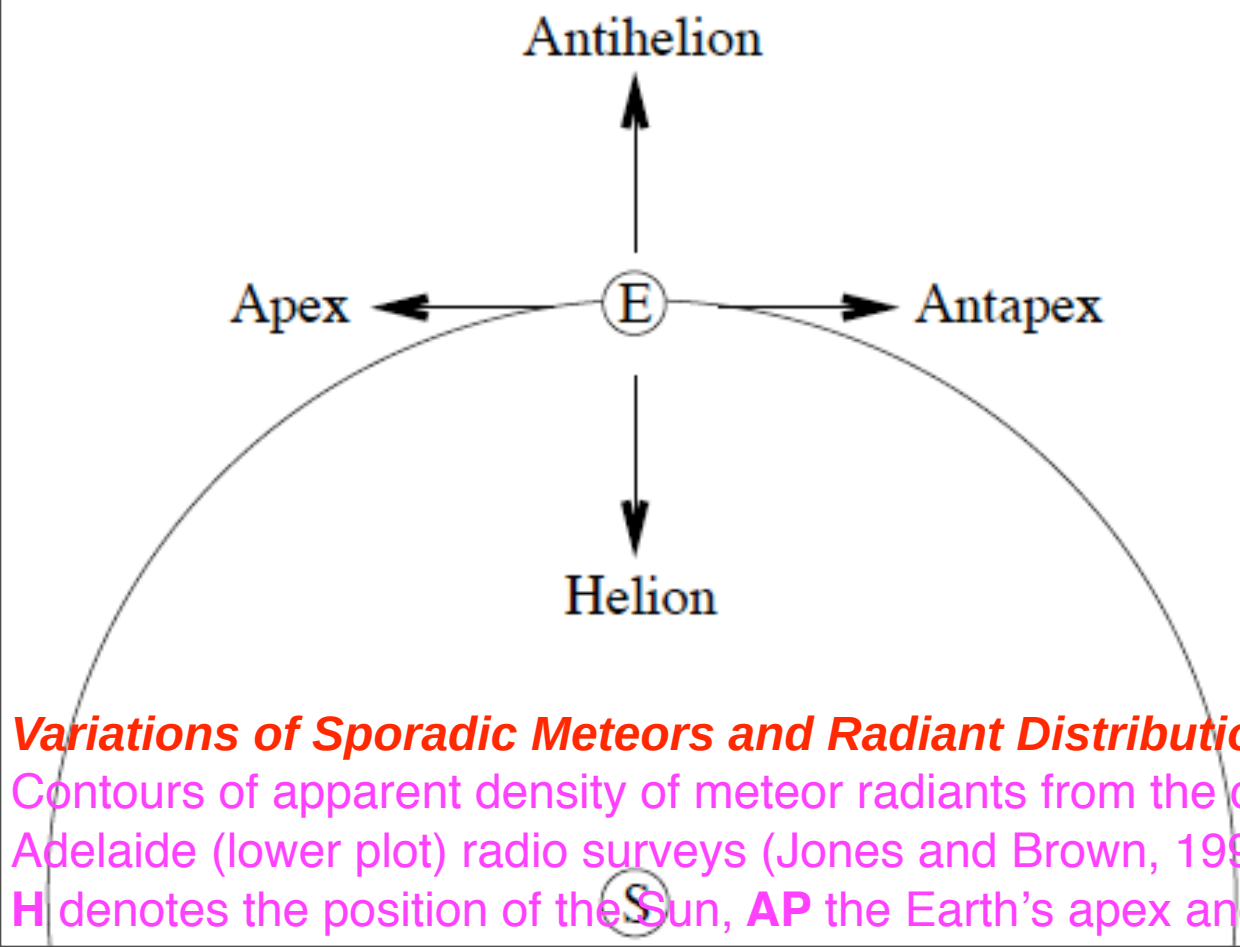
Δ<0.1 AU

☆ the contribution from JFCs is an increasing function of heliocentric distance roughly similar numbers of HTCs at the three planets

☆ two “hat trick” comets: 1P/Halley and 45P/Honda-Mrkos-Pajdusáková

Beech, MNRAS, 1998,
Christou & Beurle, P&SS, 1999,
Treiman & Treiman 2000,
Larson, AJ, 2001,
Christou, Icarus, 2004,
Selsis et al, A&A, 2004





Variations of Sporadic Meteors and Radiant Distribution

Contours of apparent density of meteor radiants from the combined Harvard (upper plot) and Adelaide (lower plot) radio surveys (Jones and Brown, 1994).

H denotes the position of the Sun, **AP** the Earth's apex and **AH** the antihelion point.

Apex(地球向点) 15-28%

Halley-type comets
Long-period comets

Source: 南北15° Apex sources
V～45-72km/s, Vmean=62km/s

Antihelion(反太陽方向)

Helion(太陽方向) 30-40%

Jupiter-family comets
Appolo-type asteroids

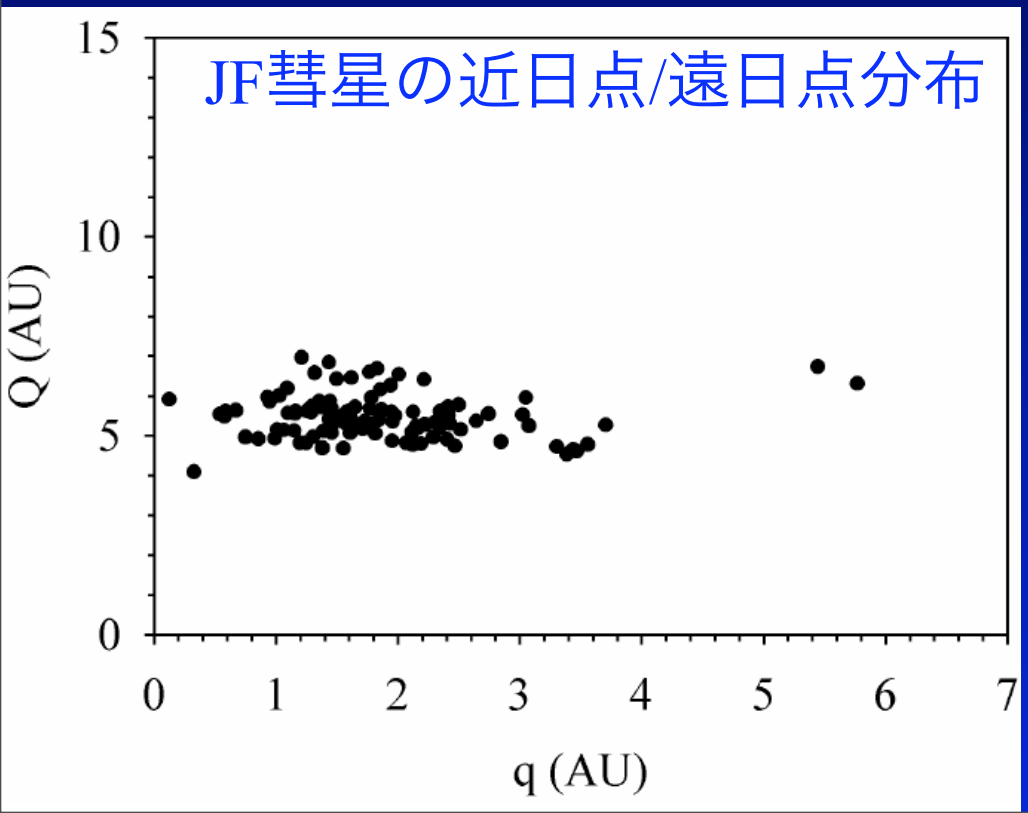
Source: ±70° from the Apex
V～11-45km/s, Vmean=20km/s
daily motion～1°/day
Ecliptic showers(黄道流星群, Zodiac)
北半球の場合: HR～15/hr in fall,
HR～5/hr in spring

N-S-Troidal 3-6%

N-S Source: ±67° latitude
a～1.0AU, e～0.3, 順行軌道
Vmean～24-42km/s?, JFCの進化天体?

Production rate of cometary meteoroids

Comet group	% of total
Jupiter family	91
Halley family	5
Long period	4



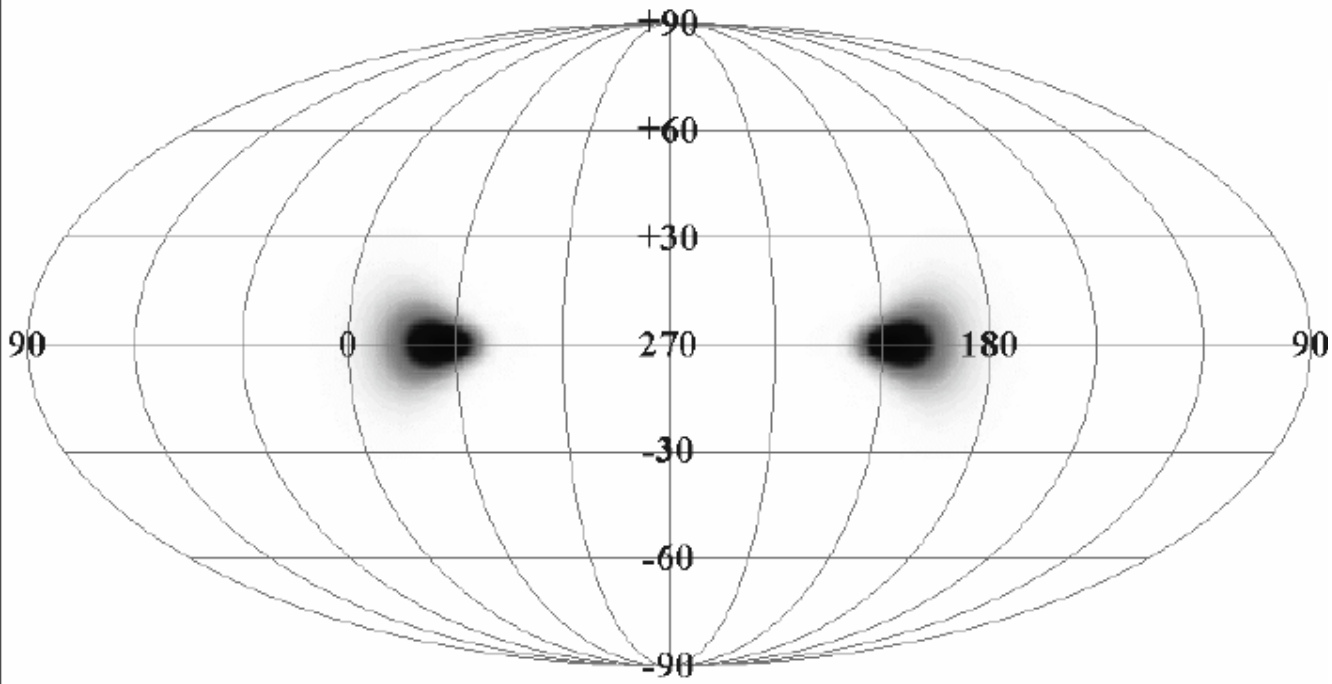
彗星起源ダスト供給源はQ<7AUのJF彗星である。

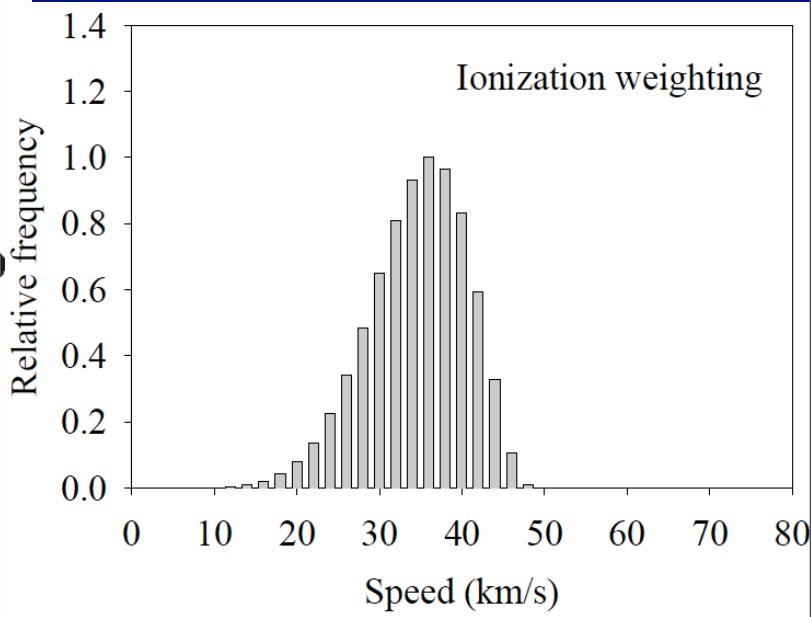
Parameter	Mean	Standard deviation
Perihelion distance	1.85	0.90
Aphelion distance	5.47	0.56
Inclination	14.2	10.0
Tisserand parameter	2.80	0.17

Activity of short period cometary meteoroids

	HRMP	CMOR (2003)
Helion long.	341 – 345 deg	338 deg
Antihelion long.	193 – 201 deg	202 deg
$\langle V_g \rangle$	31.7 km/s	34.4 km/s

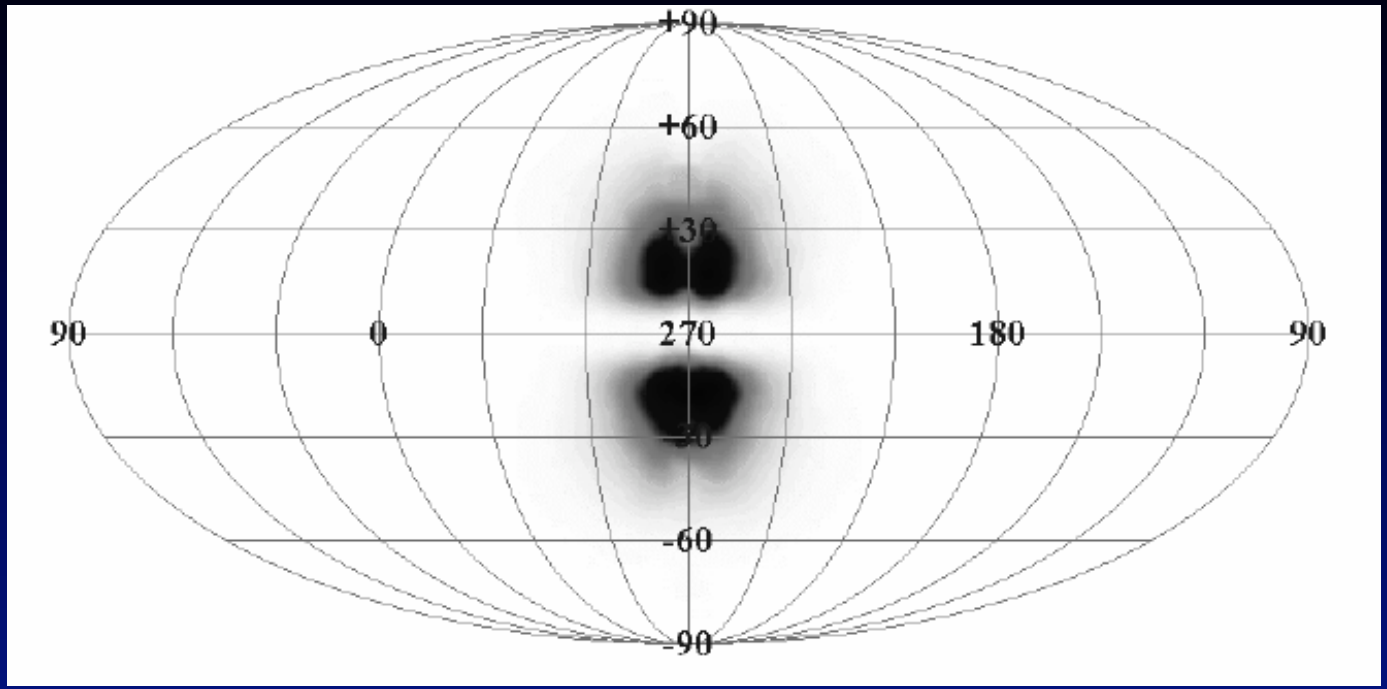
HRMP: Harvard Radio Meteor Project (Sekanina, 1967, Lindblad, 1987)
CMOR: Canadian Meteor Orbit Radar (Campbell-Brown&Jones, 2003)



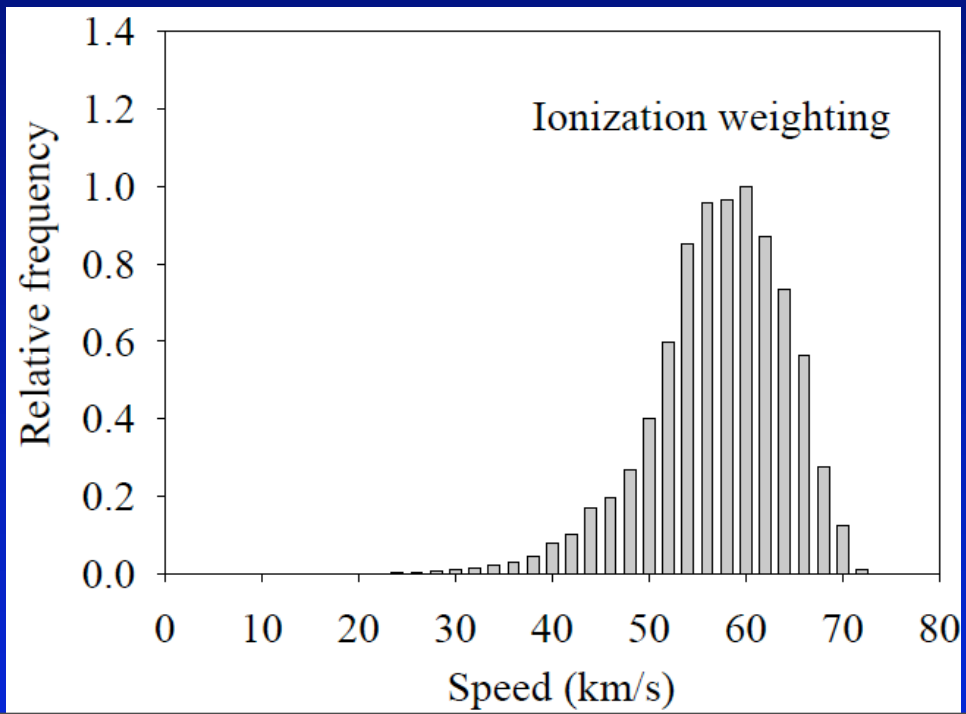


短周期彗星起源meteoroidsの輻射点分布

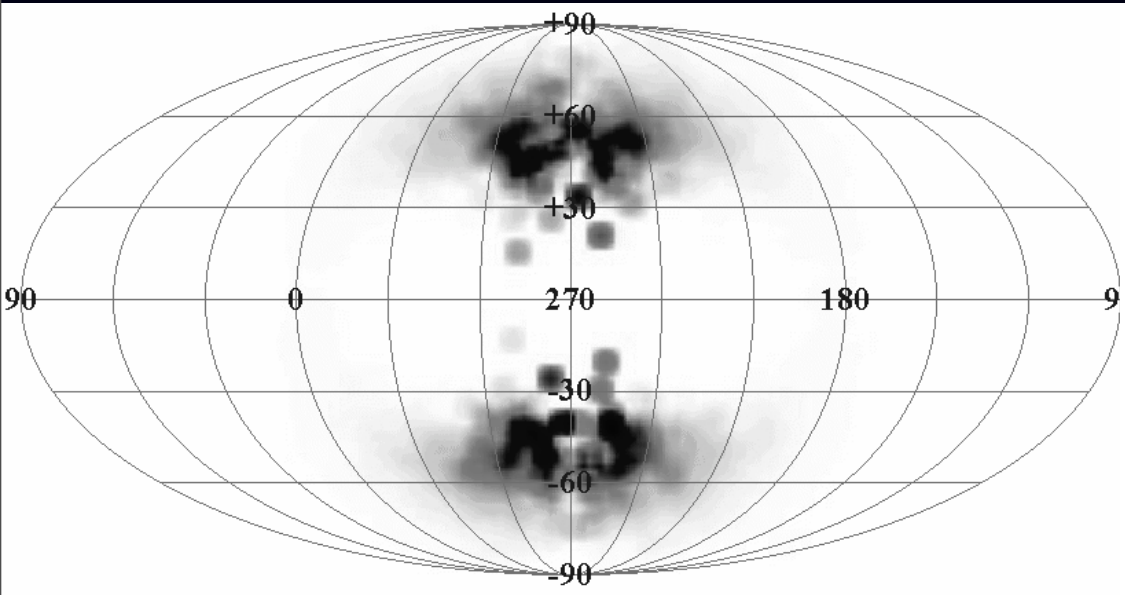
Activity of long period cometary meteoroids

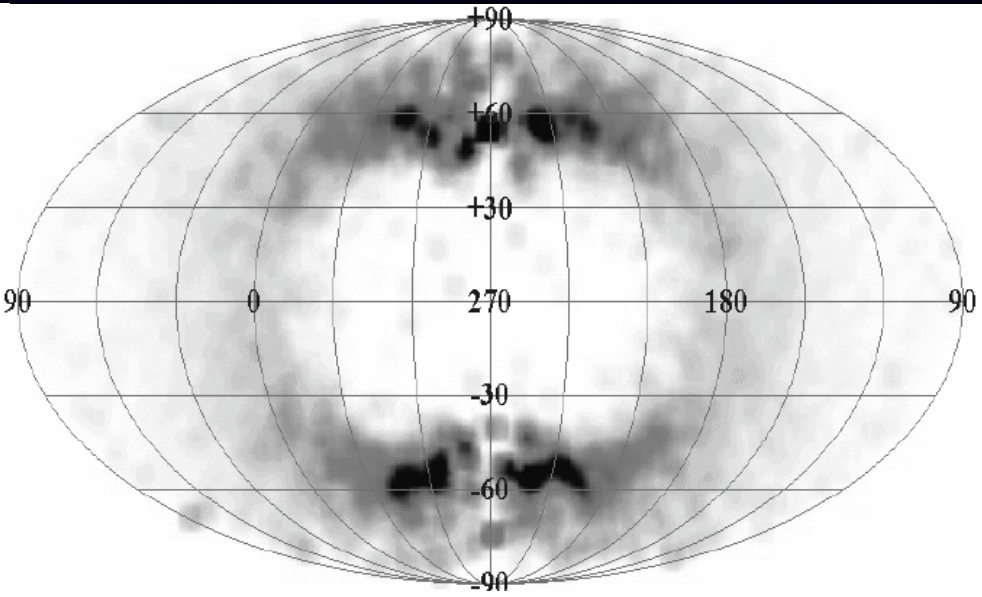


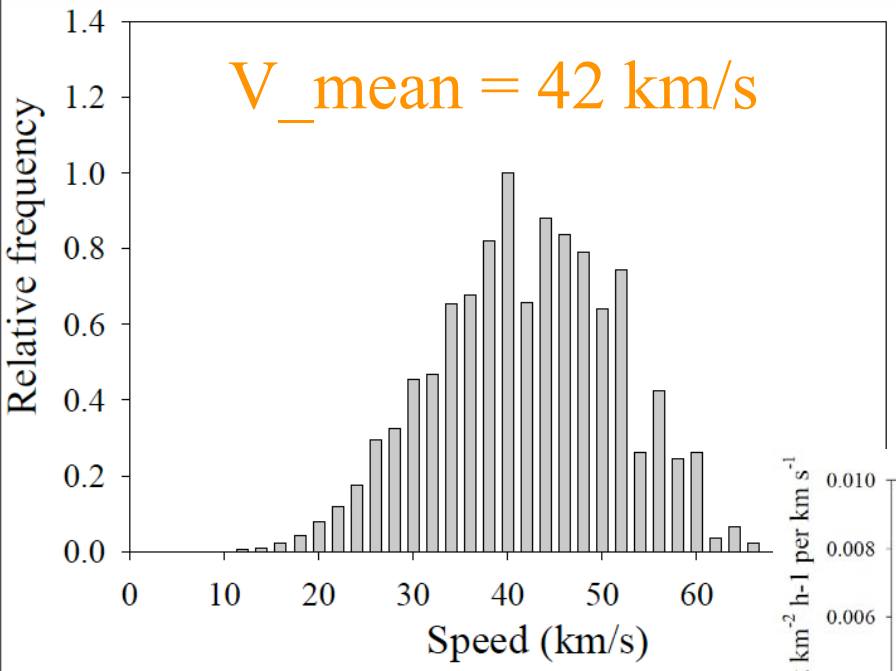
長周期彗星起源meteoroidsの輻射点分布

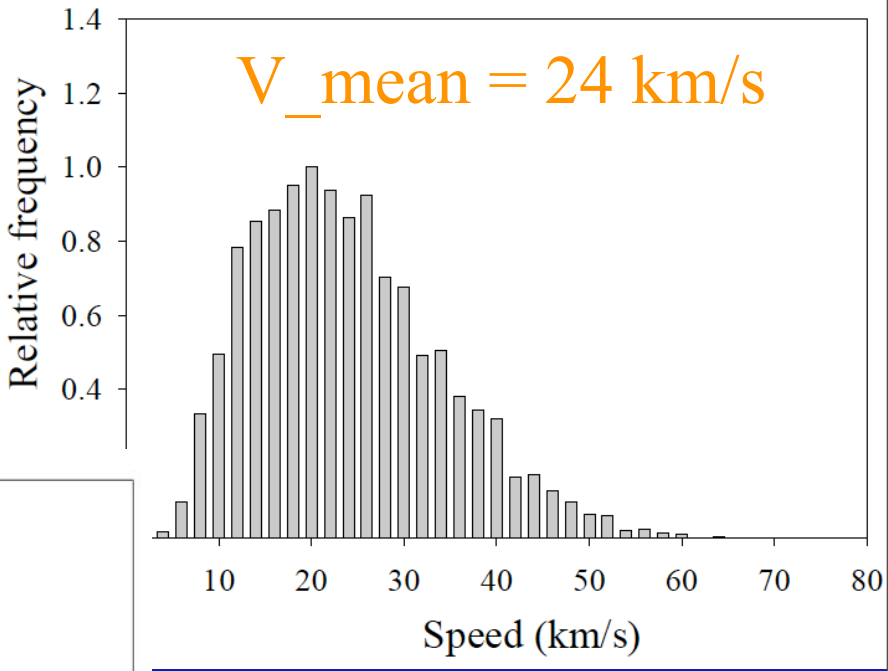


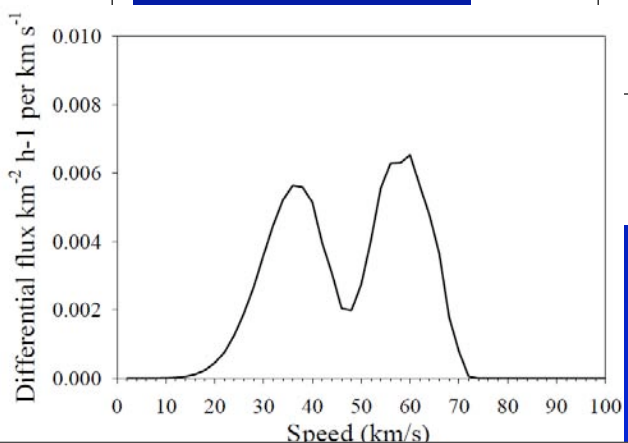
Toroidal source



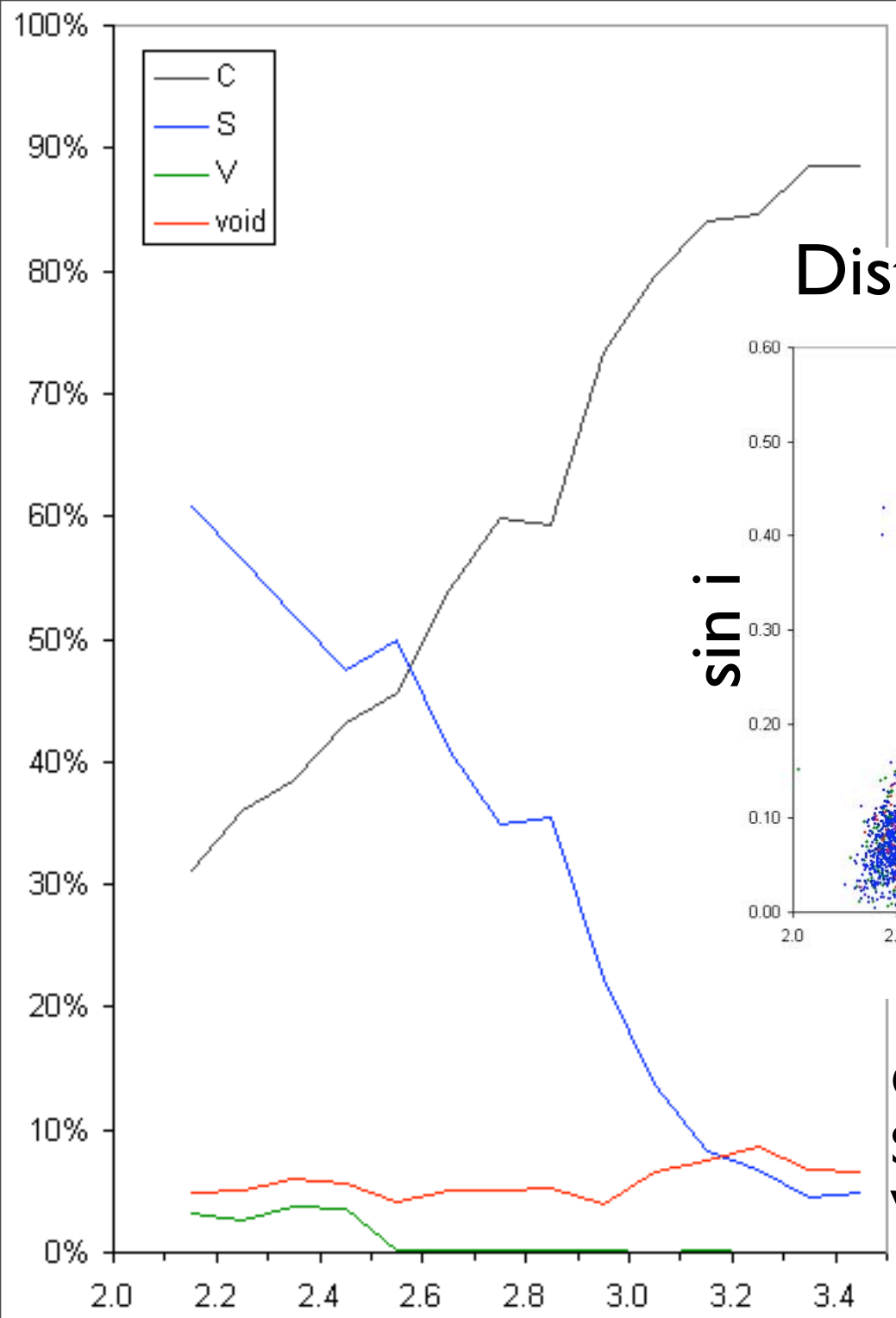


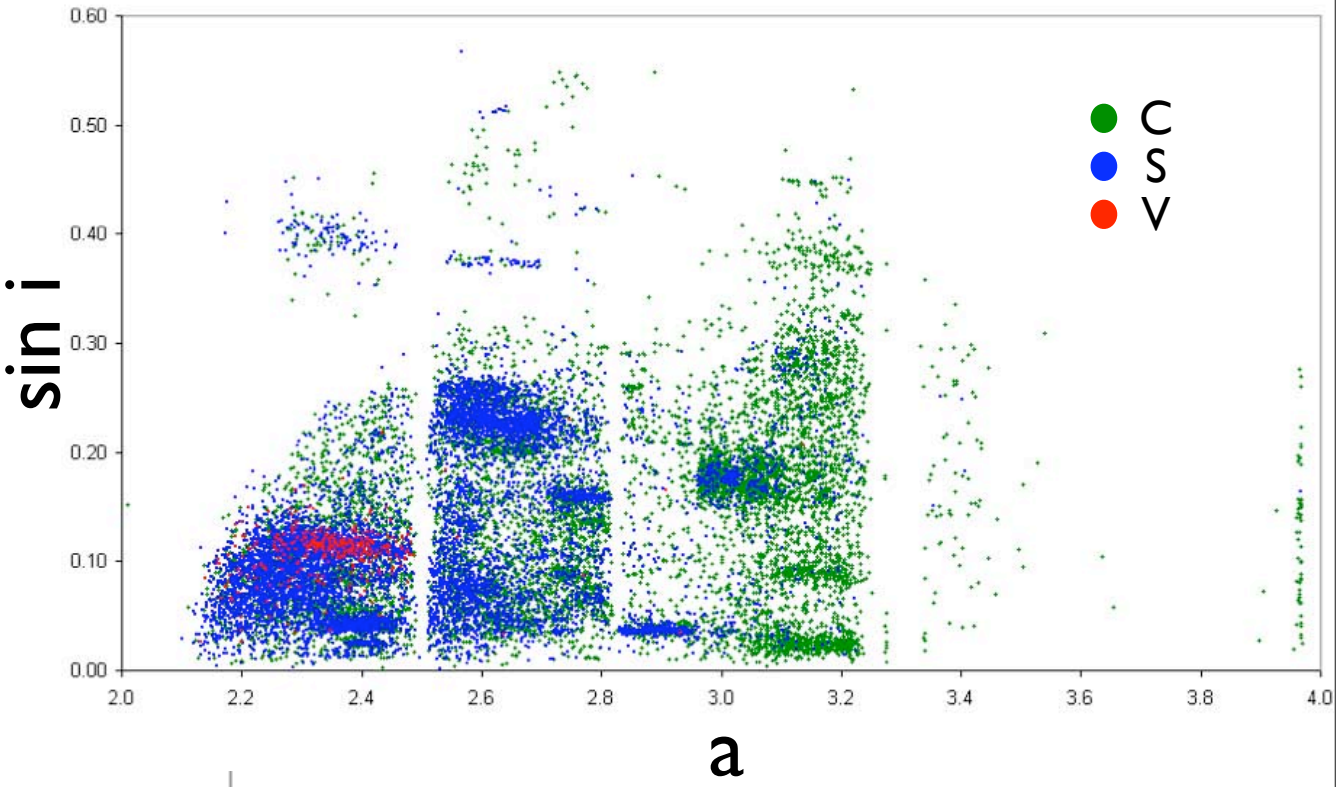






Distribution of asteroid taxonomy





C; carbonaceous chondrites, outer region

S ; ordinary chondrites, inner region

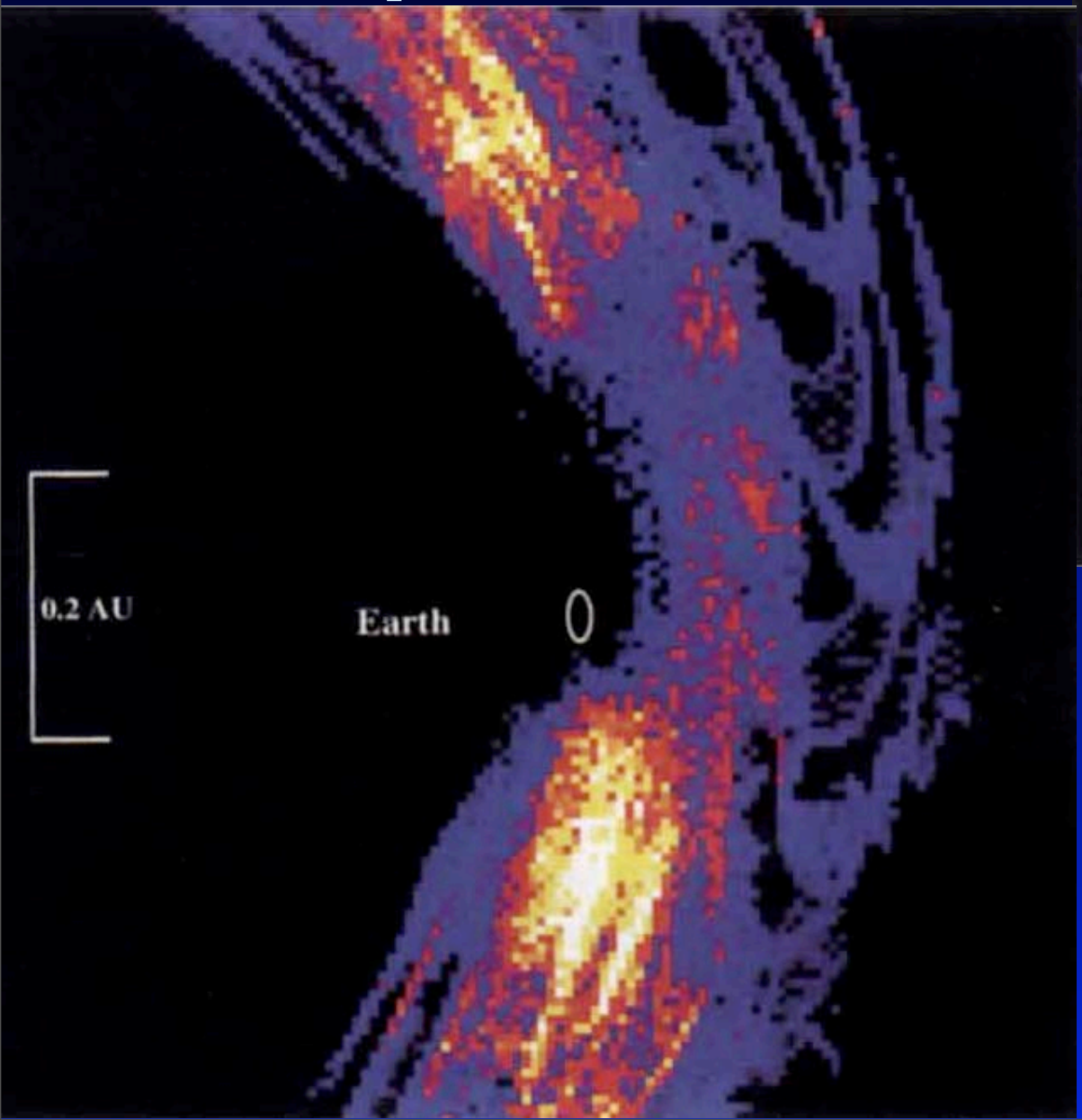
V; HED meteorites, around 2.3AU

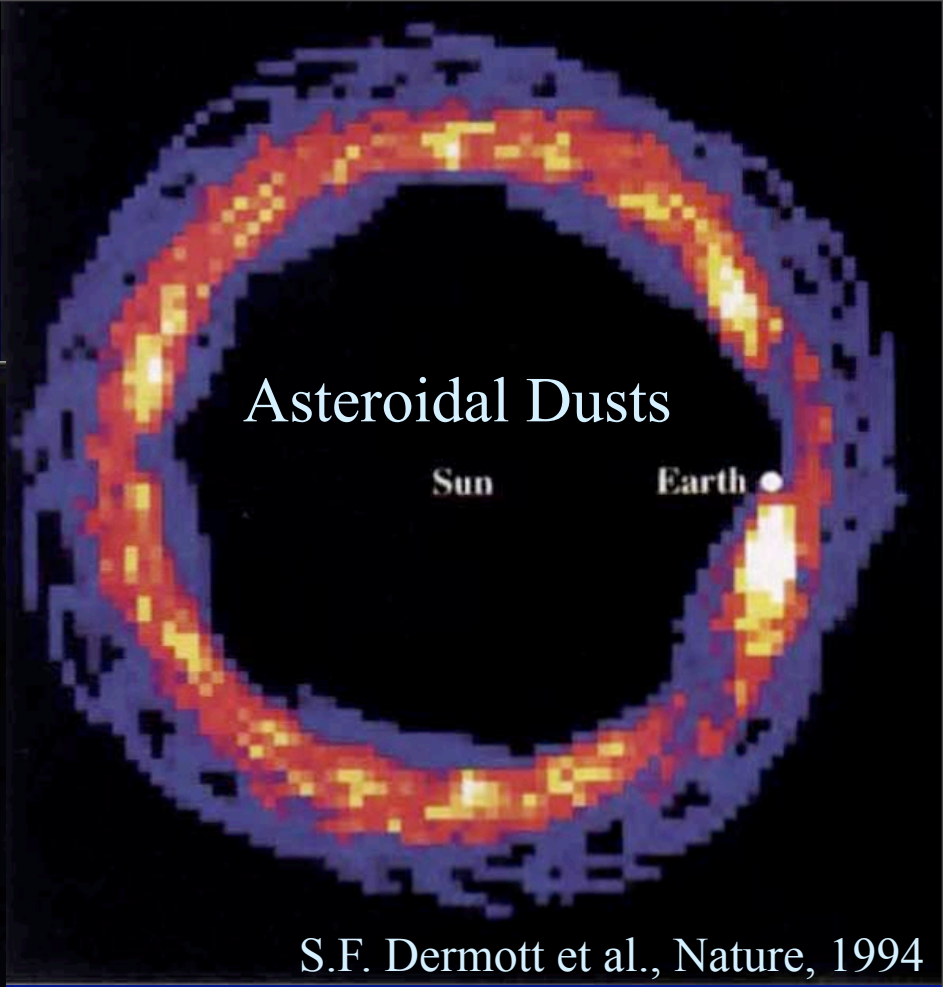
小惑星起源のダスト

小惑星イトカワ

Circumsolar ring 検出可能性

20% of 12μm asteroidal dust particles (β=0.37) trapped in resonance(3:4-17:18).
Carbonaceous particles are dominant.





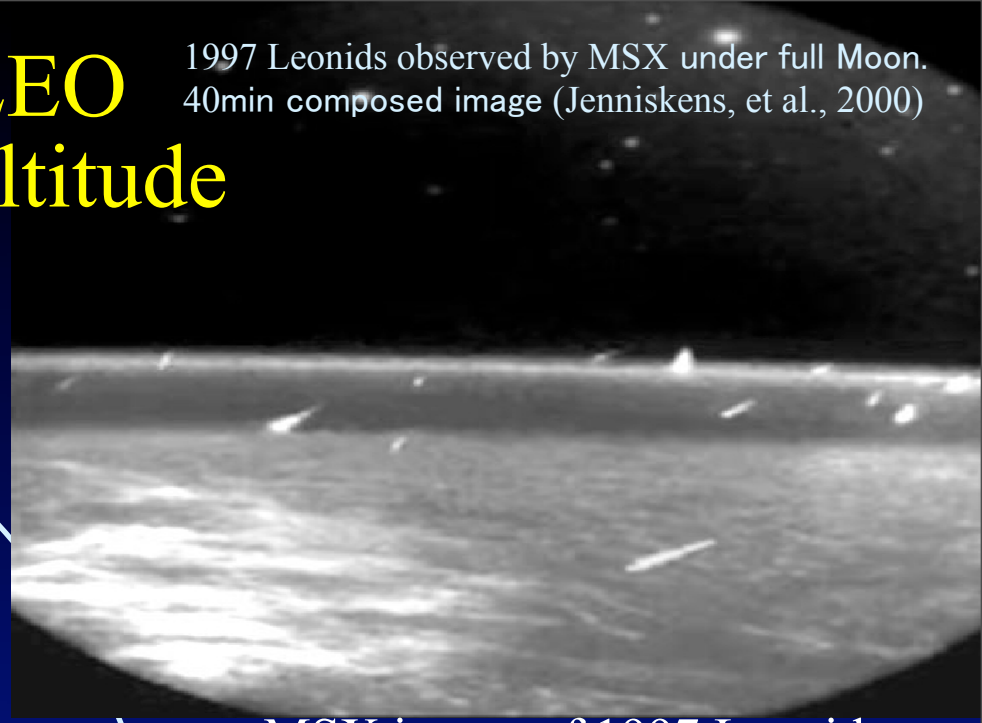
S.F. Dermott et al., Nature, 1994

ダストに働く”Drag forces”

- Light Pressure
- Poynting-Robertson
- Solar Wind

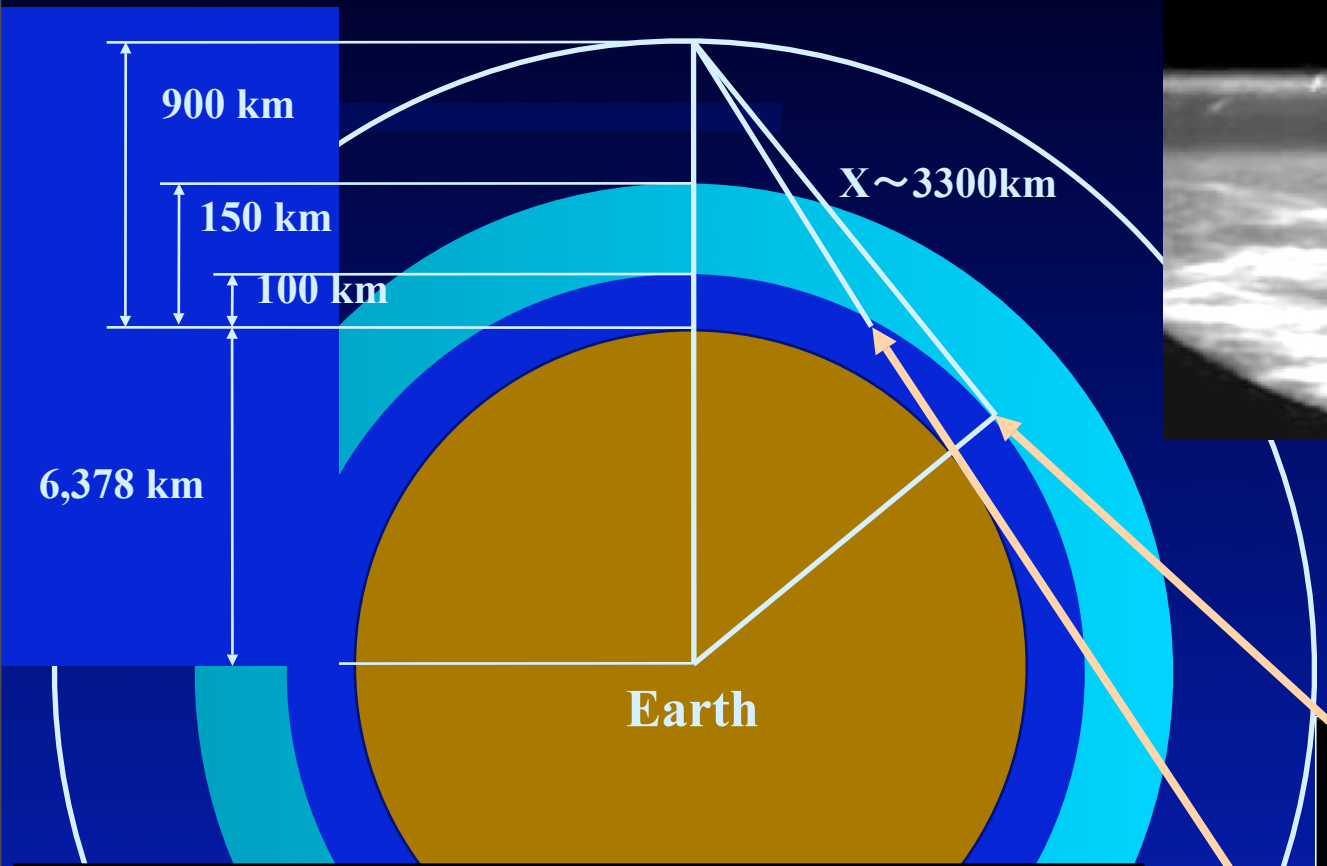
Meteor observation from LEO
Distance of Horizon at each altitude

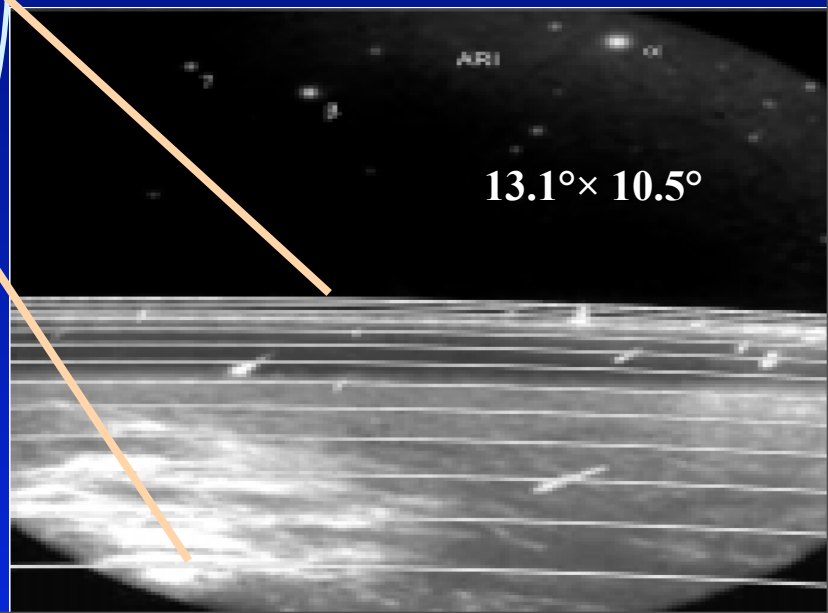
1997 Leonids observed by MSX under full Moon.
40min composed image (Jenniskens, et al., 2000)



MSX image of 1997 Leonids

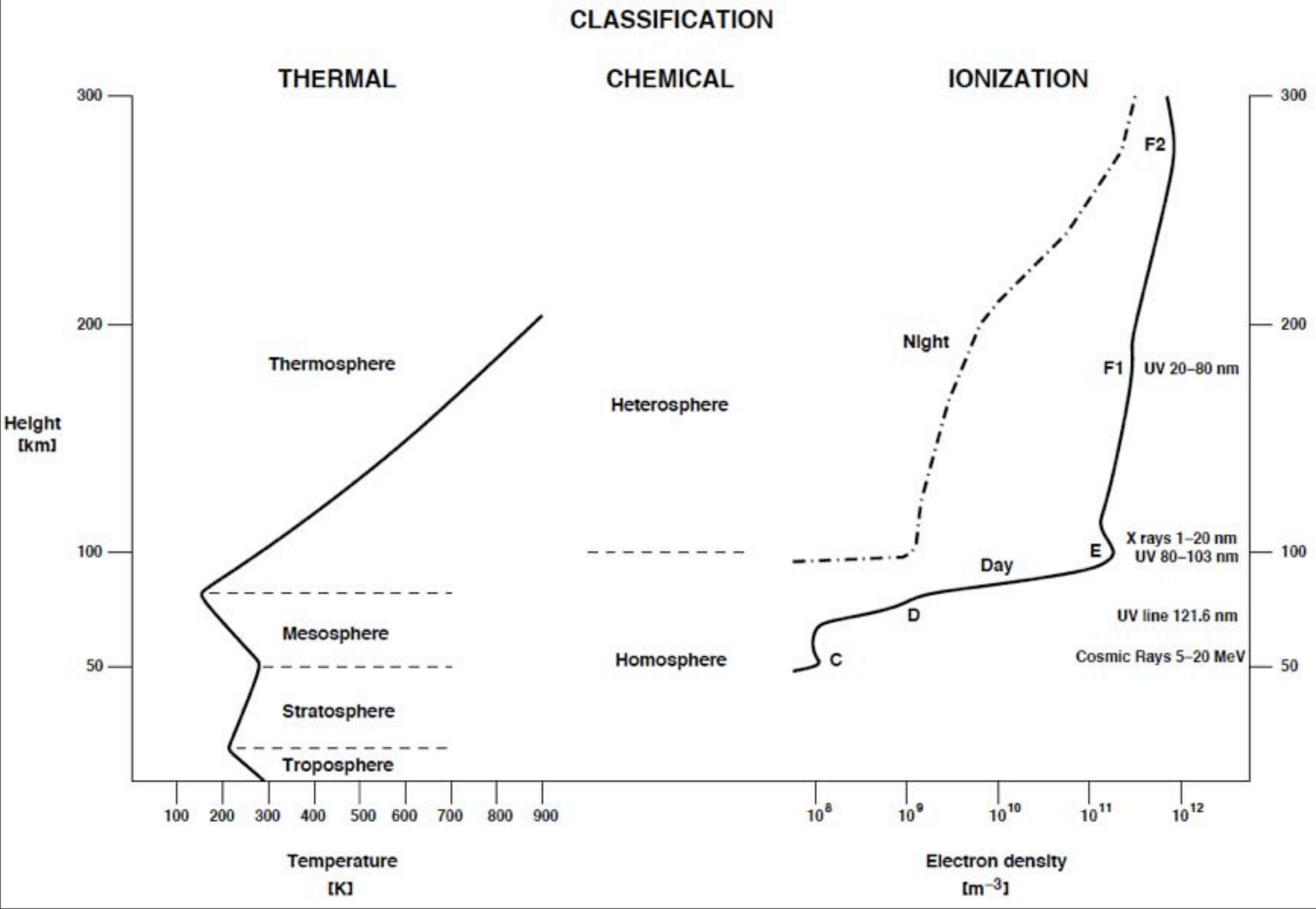
P. Jenniskens et al., 2000





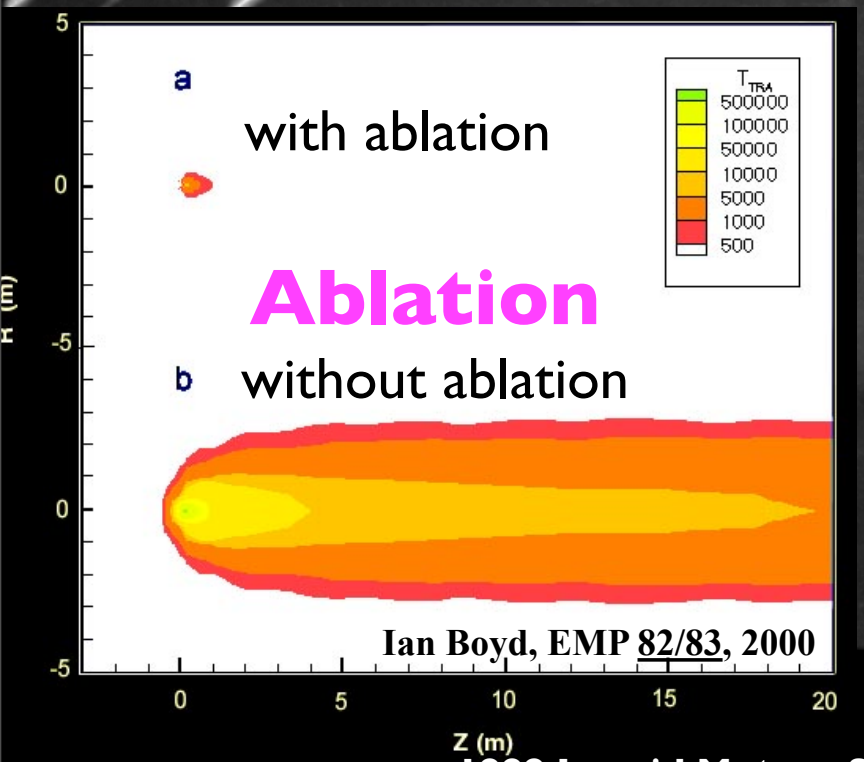
	altitude (km)	distance (km)
Leonid MAC	10	1100
ISS	400	2000
MSX	900	3300

地球大気の分類


CLASSIFICATION
THERMAL
CHEMICAL
IONIZATION
300
200
100
50
Height [km]
Thermosphere
Mesosphere
Stratosphere
Troposphere
Heterosphere
Homosphere
Night
Day
F2
F1
UV 20–80 nm
E
X rays 1–20 nm
UV 80–103 nm
D
UV line 121.6 nm
C
Cosmic Rays 5–20 MeV
100 200 300 400 500 600 700 800 900
Temperature [K]
10^8 10^9 10^{10} 10^{11} 10^{12}
Electron density [m^{-3}]

1/1000 s high speed camera image of a meteor

Hans Stenbaek-Nielsen, 2001



The term *ablation* has the meaning of mass loss of a meteoroid in any form and phase: solid as fragments, fluid as droplets and loss of hot gas, which forms always the final stage and is responsible for the observed meteor phenomenon.

Trains with duration up to 3 s are produced by the forbidden auroral line of neutral oxygen at 557.7 nm.

temperature in meteor plasma

Fe I, Mg I, Ca I, Na I .... Main component (~4,500 K)

Ca II, Mg II, Fe II ..... 2nd component (~10,000 K)

Jiří Borovička (1993)

1999 Leonid Meteor Storm, Leonid MAC, 4,000 hr^{-1} at 02:02 UT on November 18, 1999.

Yano, Abe, NHK, NASA

1999 Leonid Meteor Spectrum (V=71 km/s)

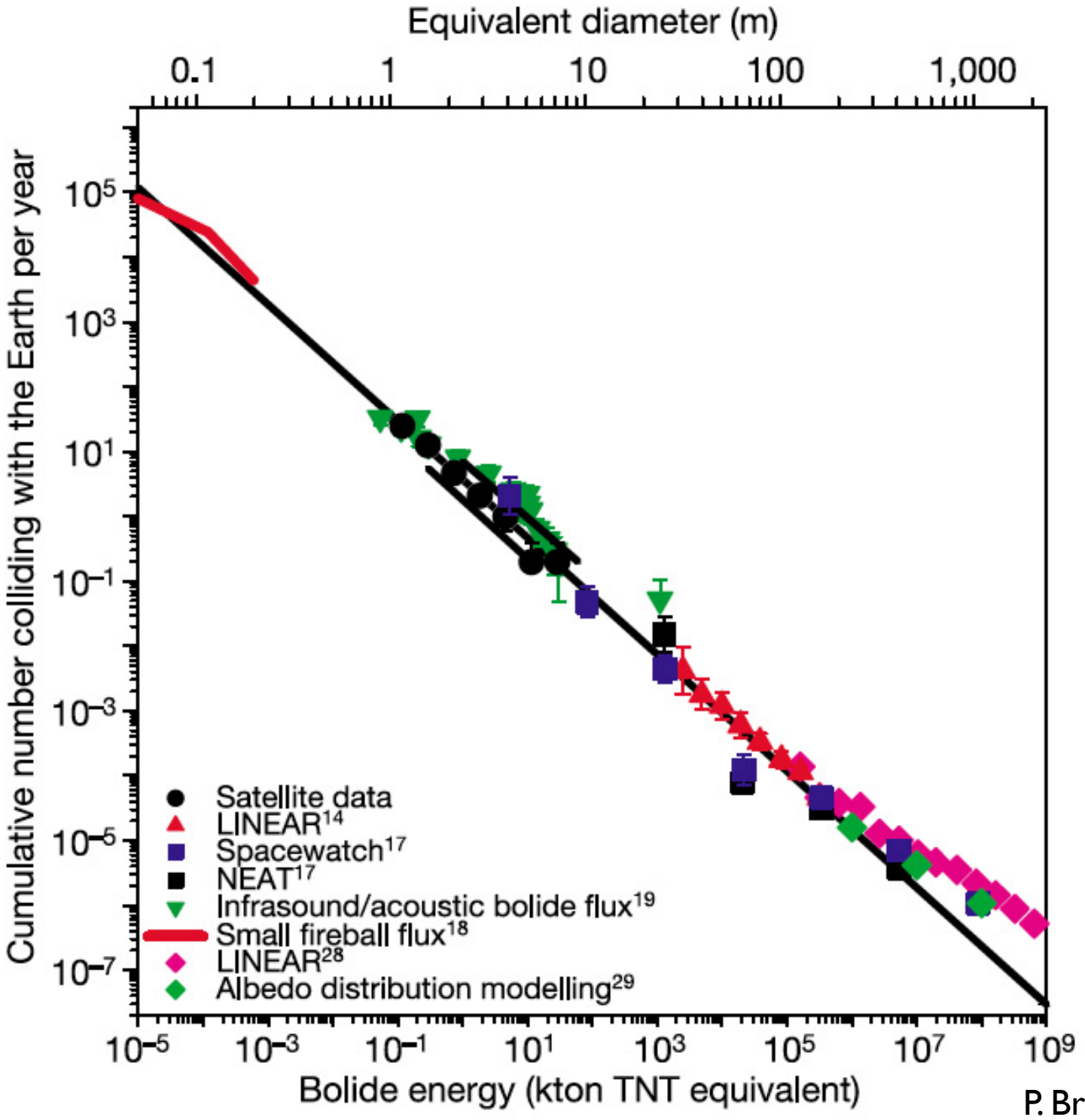
Meteor light consists mostly of radiation of discrete emission spectral lines belonging for the most part to metals and mainly to iron. More than 90% of the meteor light originates from radiation of single low-excited atoms of meteoroid material (several eV; temperatures 3000 to 5000 K).

S. Abe et al. Earth Moon & Planets, 82/83, 2000

Interplanetary Dust Models

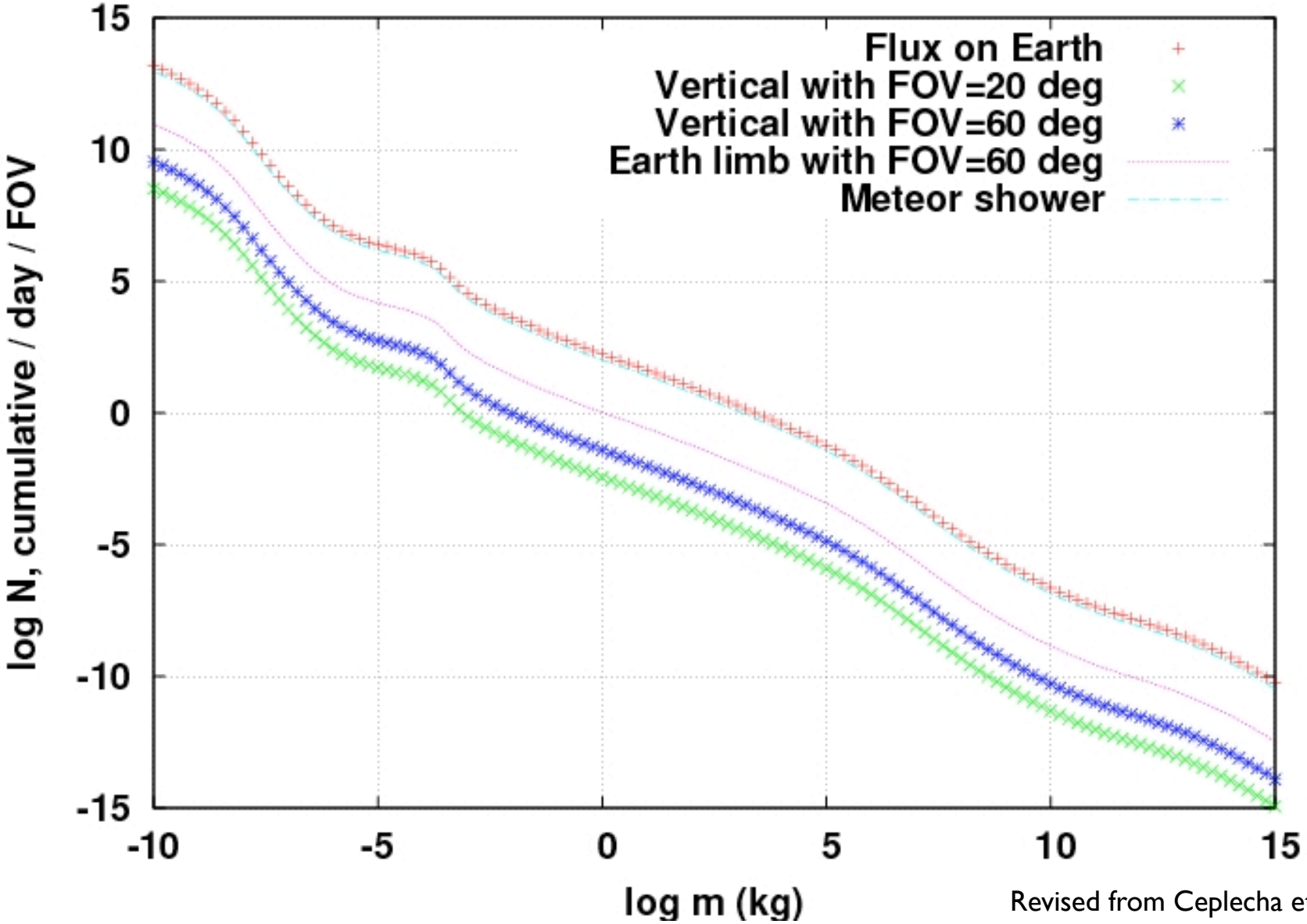
- 地球回りの単純化した”Interplanetary Dust Model”, 軌道(方向)情報なし; Grün, Zook, Fechtig and Giese (1985)
- 軌道分布を考慮した“Interplanetary dust complex”, 黄道光, impact dataや電波流星をコンパイル; Divine (1993)
- Divine's modelの問題点(速度分布のバイアス除去)を改良; Taylor (1995)
- Taylor(1995) modelを更に単純化; Garret, Drouilhet, Oliver and Evans (1999), Jehn (2000)

地球近傍巨大ダストの分布



P. Brown et al. (2002)

ISSから観測される１日当りのメテオロイド



Revised from Ceplecha et al., (1998)

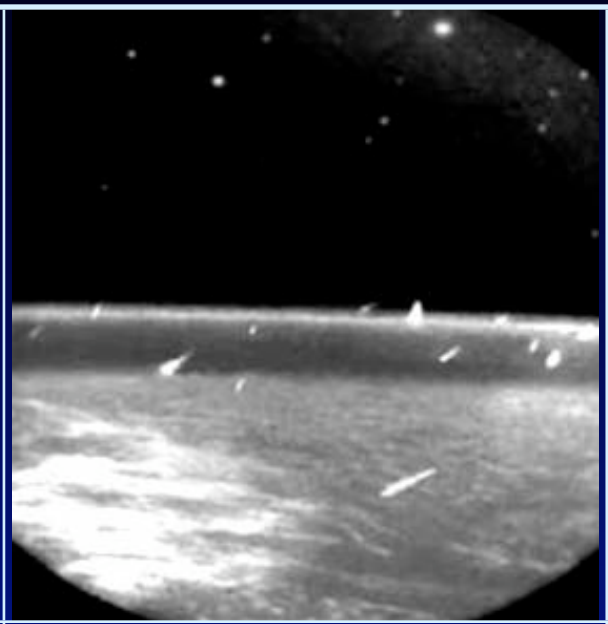
石質流星体が突入速度40km/s, 突入角45度で石質の流星が高度100kmで発光すると仮定

The interplanetary dust component of the influx is 4 x10^6 kg per year per Earth,
about 17% of the influx originates in the interplanetary dust.
about 83% in bodies mostly inside a mass range of 10^5 to 10^8 kg (10 to 100 m sizes).
Atmospheric penetration of meter and ten meter size bodies can be regularly and globally observed by satellites.

「きぼう」船外プラットフォームからの流星の観測
ISSメテオ・ウォッチャー

JAXA「きぼう」船外実験プラットフォーム第2期利用候補ミッションの公募（不採択）

本研究チームが地中海上空よりHDTVにて撮影した
1999年しし座流星雨



米国の軍事衛星MSXから撮影された
1997年しし座流星群

我々の提案によりロシアの宇宙飛行士が
ISSから撮影した流星群映像

(1) ミッション名

メテオ・ウォッチャー（Meteor Watcher）

(2) 組織名

神戸大学／国立天文台／理研／甲南大／**JAXA**／高知工科大／
DLR／ESA

(3) 代表研究者名・所属・職名

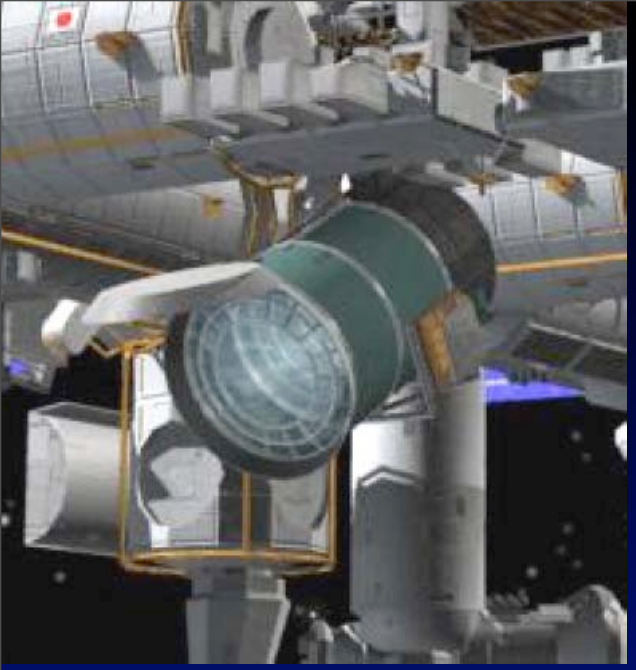
阿部新助・神戸大学理学研究科地球惑星科学専攻・助教

(4) ポート利用形態

ポート共有利用

2001しし群 by HDTV(旧NASDA提供)

日常的に発生する流星現象を、非日常的な宇宙から観察することで、地球が巨大な望遠鏡の役割を演じているということを多くの人々に認識してもらい、改めて地球という存在を意識してもらうという大きな意義が、我々が提案する「メテオ・ウォッチャー」に込められている。



JEM-EUSO

Extreme Universe Space Observatory

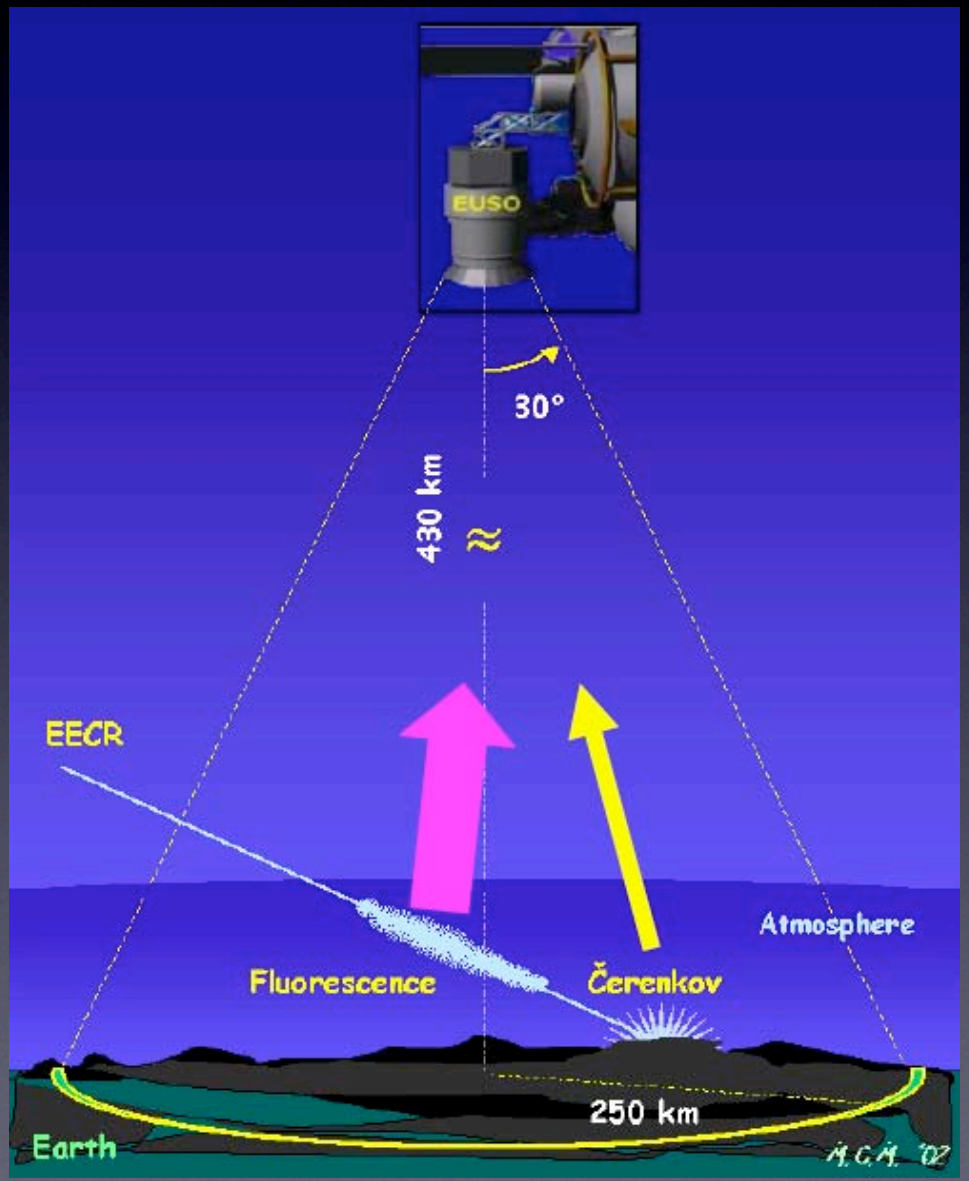
- -2005; EUSO was originally planed to be deployed by ESA
- 2005 Oct@ESTEC; Original plan was canceled because of changing situation of ESA's budget.
- 2006; Phase-A (JEM-EUSO WG) collaborating with **Italy, France, Switzerland, Germany, Portugal, Spain, Japan, USA, Brazil**, *I'm involved as a meteor analyst*
- 2007-2008; Phase-A, B ← **We were selected as phase-A**
- 2009-2012; Phase-C,D
- 2013; Launch using Japanese transport plane (HTV)

JEM-EUSO(Japanese Extreme Universe Space Observatory)

The purpose is to distinguish the source of extreme high energy particles more than 1.0E20 eV originated probably from AGNs, which relates with cosmology.

The technics is to observe the extensive air-shower induced by energetic particle entered the atmosphere.

By using EUSO main telescope, 2.5 m in diameter, Evaporated N2 and N2+ by electron shower can be observed as fluorescence, moreover Cerenkov light along the path of shower can also be detected.

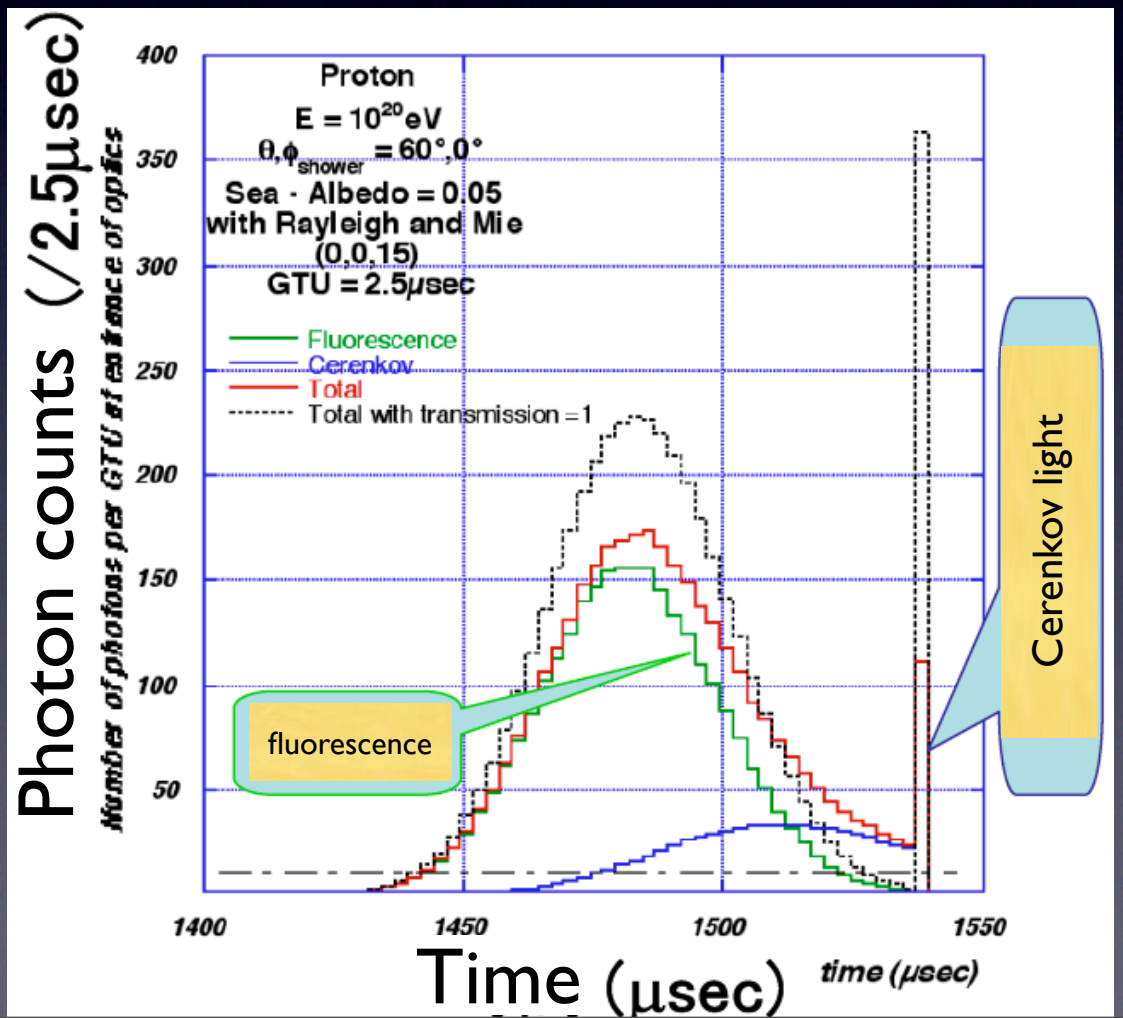


★FOV; ±30 deg from height of 430km

★Time resolution; 2.5μsec

★Spacial resolution; 9.75 x 0.75 km(0.1 deg.)

★Wavelength region; 300-400 nm



Advantages from Space

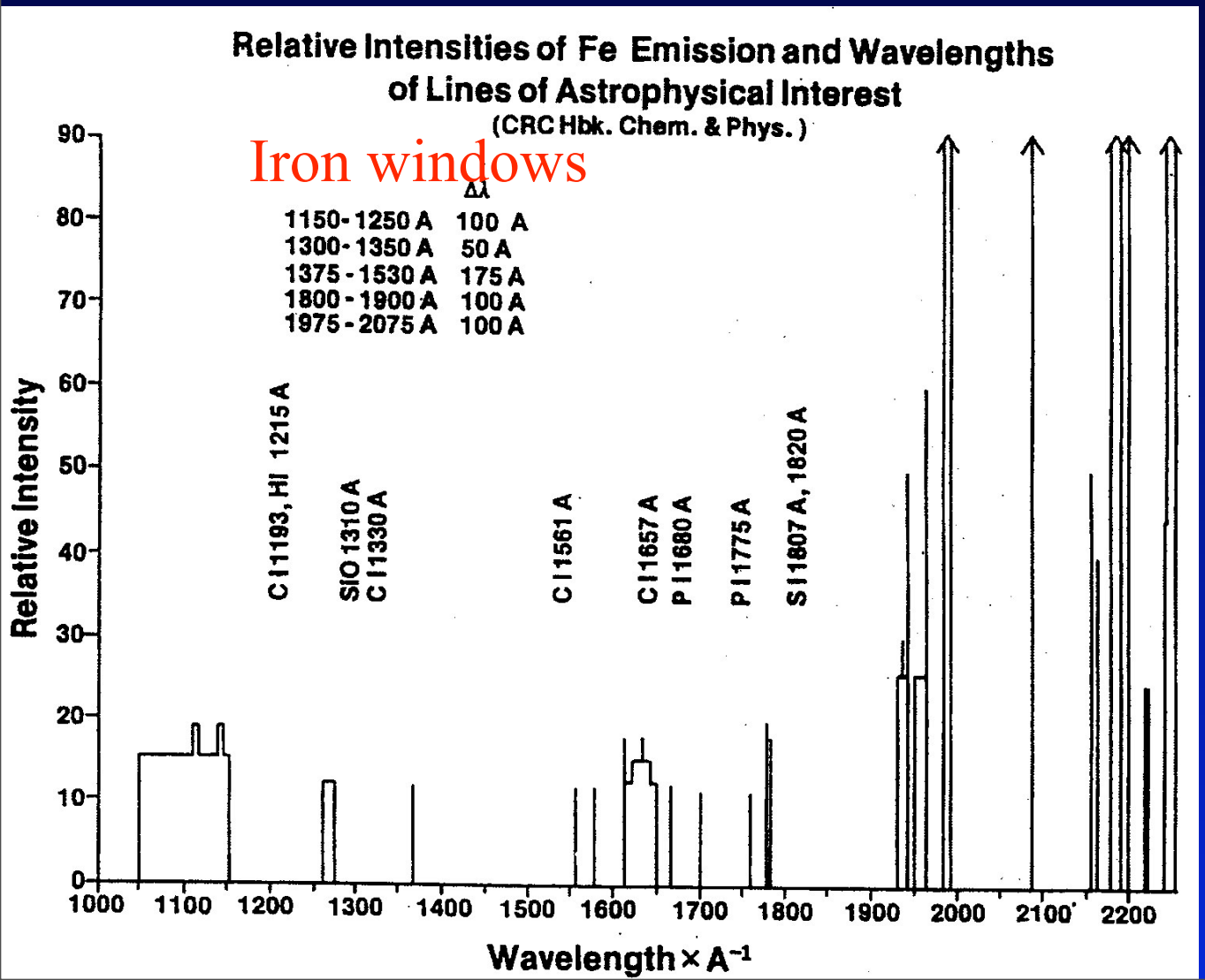
- Determination of mass distribution especially for bright-end.
  - ✓Between meteoroids and asteroids.
- Steady monitoring for sporadic meteors.
  - ✓EUSO has 2 view angles, 90 deg for perpendicular- and 45 deg for tilt-mode.
- Ultraviolet region without absorption.
  - ✓Below 300nm region is absorbed by ozone layer.
- High-altitude meteors.
  - ✓Higher than 200 km would be detected.

Disadvantages from Space

- CCD noises caused by cosmic ray.
- Limited data down-link rate, 300 Kbps from ISS.
- Disturbed by cloud, reflected moon-light and ionospheric emissions.

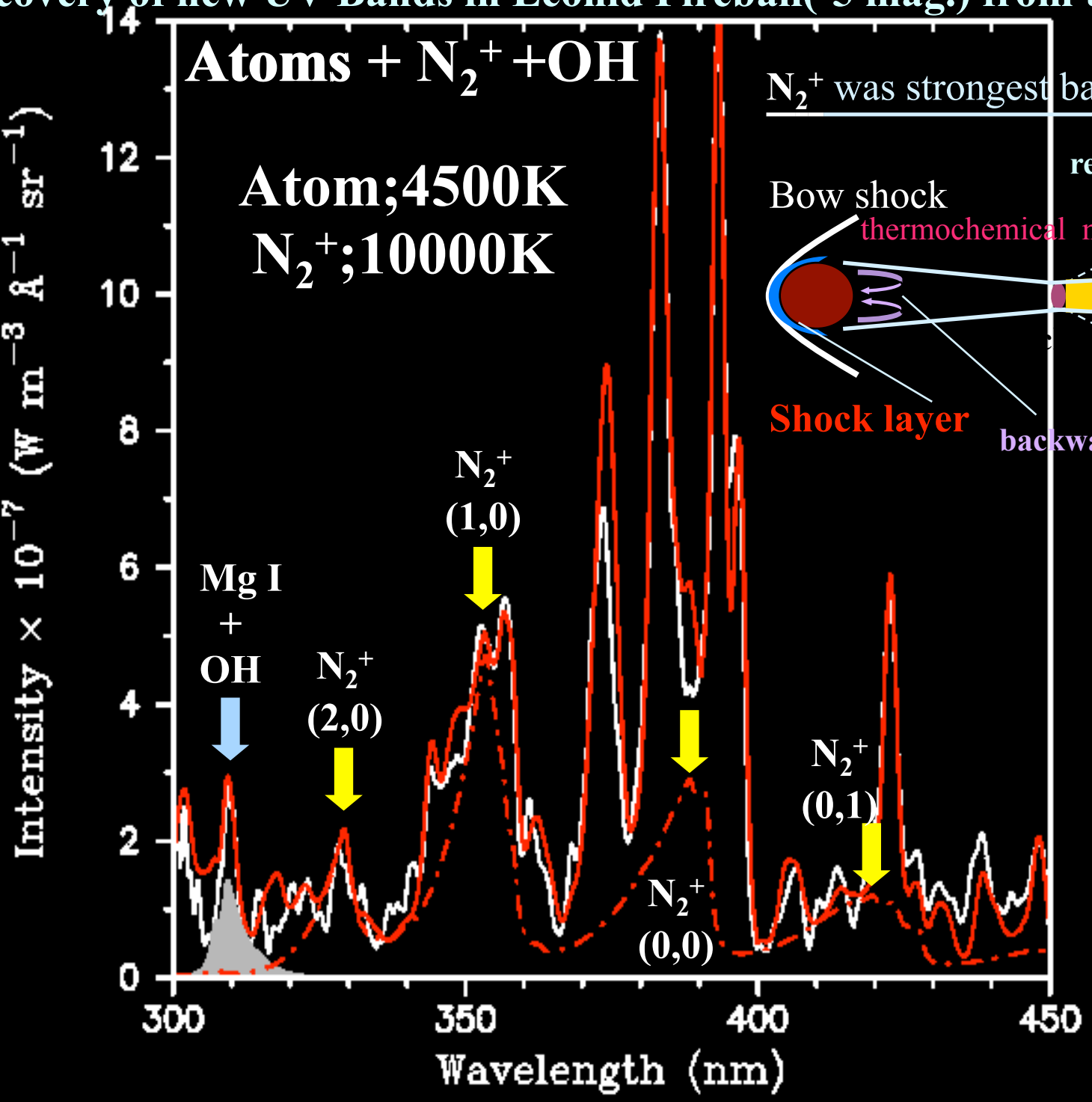
Search for organics through Iron free windows from the space

生命起源物質（有機物，水）の地球到来のプロセスを調べる上で，宇宙からの紫外線領域の分光観測が有効である。

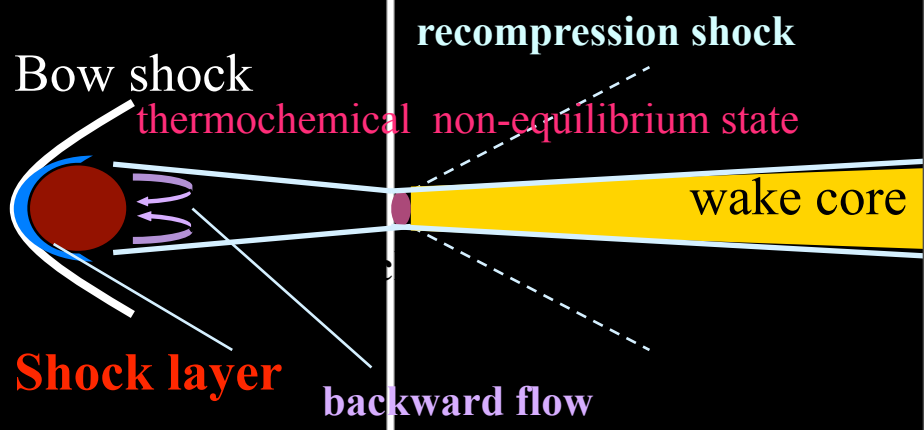


Oparin, 1924 NASA ARC

Discovery of new UV Bands in Leonid Fireball(-5 mag.) from the ground.

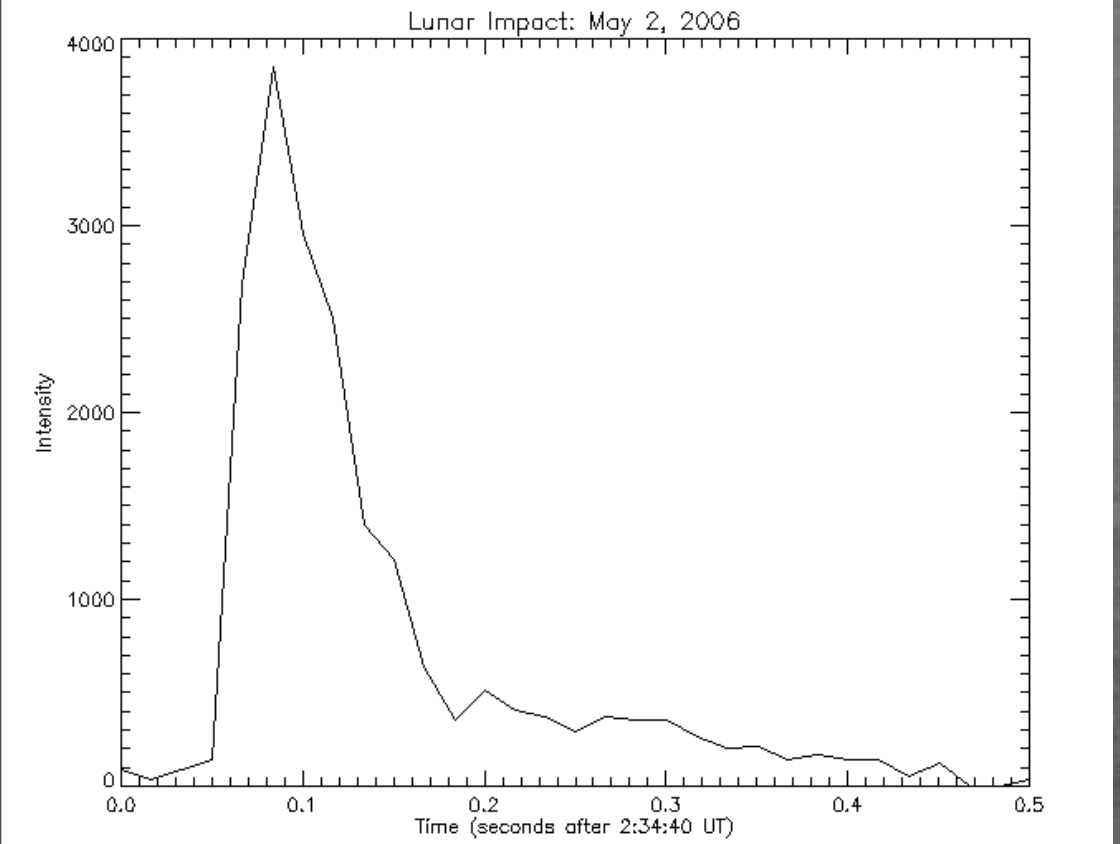


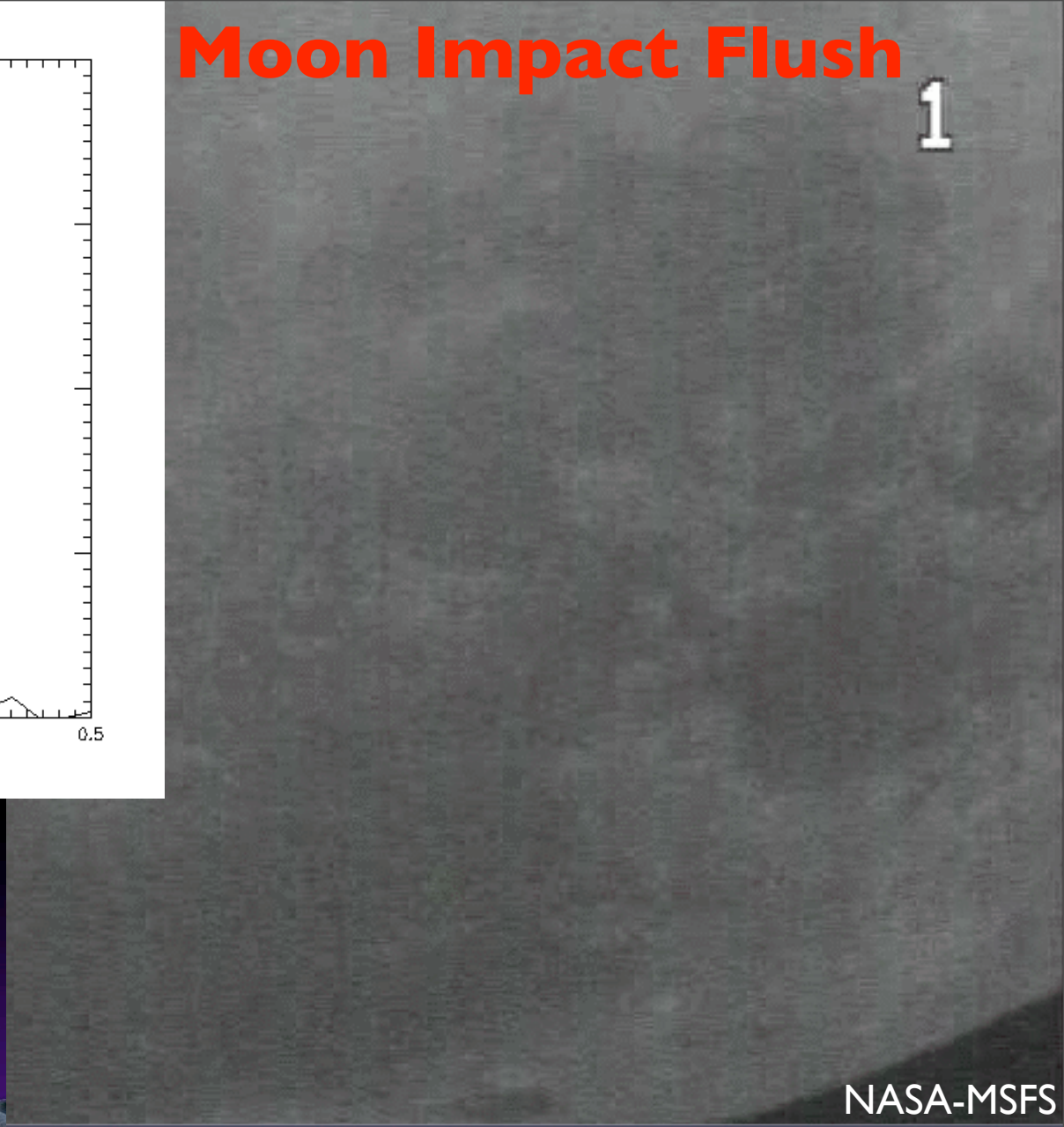
N_2^+ was strongest band in UV emission.



S. Abe et al., ApJ *618*, L141-L144, 2005.

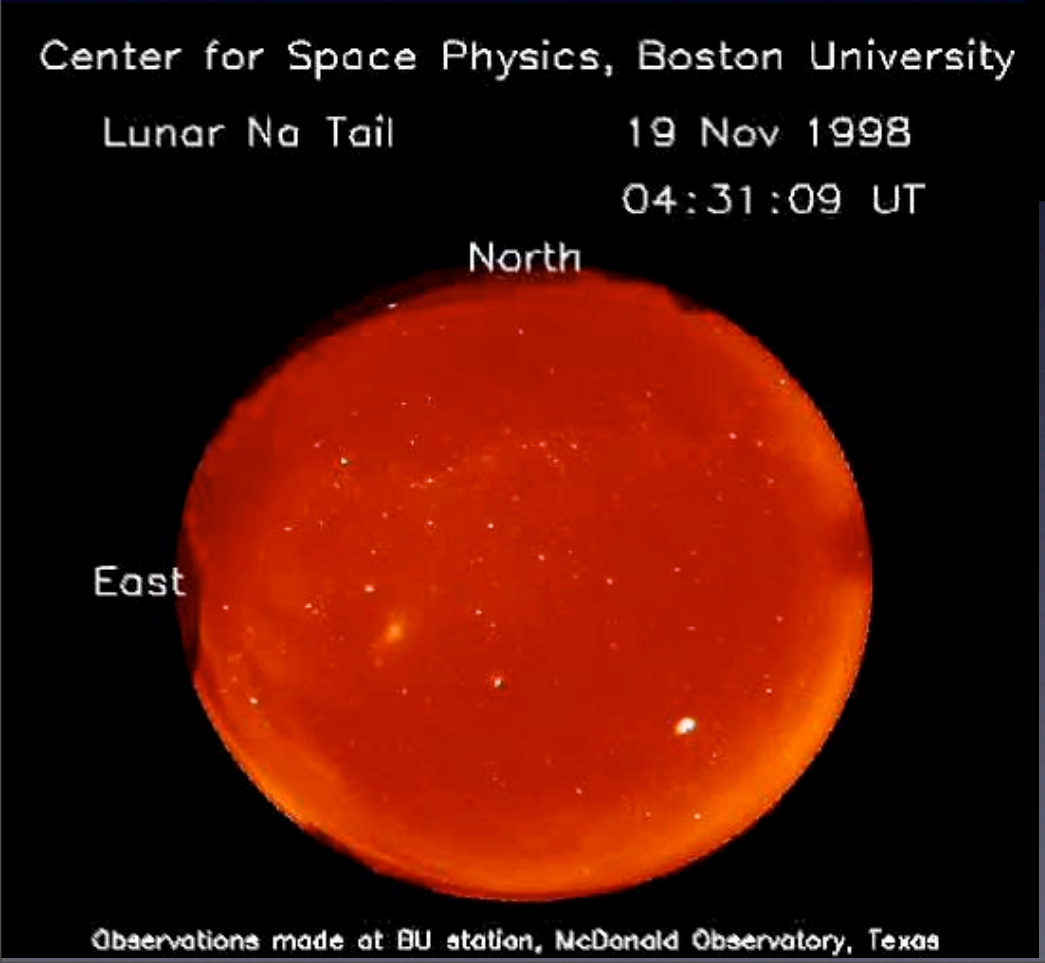
Moon Impact Flush

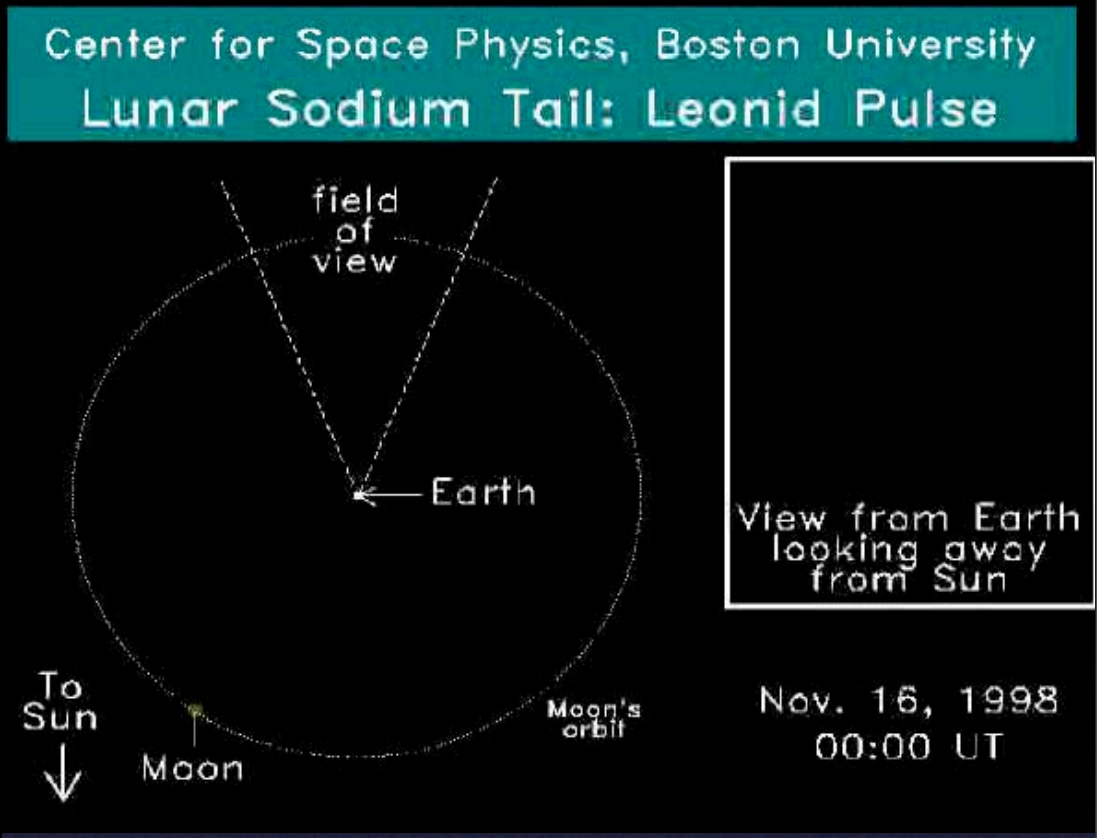




The Video plays 7x slow motion.
7th magnitude corresponds diameter of 25 cm and velocity of 38 km/s rocky meteoroid.

Sodium Tail enhanced by meteoroids impacts.





月のダスト(Na, K)の尾

（ガスの中に塵も含まれると仮定）

- 新月の昼間に月起源のダストを検出できる可能性
- 流星群活動(Stream)による超過ダストを検出できる可能性

Lunar impact prospects
セレーネ月探査機と地上との同時観測可能性

Year	Year	Year	QUA	ETA	CAP	PER	STA	LEO	GEM
2005	2024	2043	22	27	24	7	4	16	13
2006	2025	2044	4	8	5	19	15	27	24
2007	2026	2045	15	18	15	0	26	7	4
2008	2027	2046	26	1	27	11	7	19	16
2009	2028	2047	6	12	9	21	18	1	27
2010	2029	2048	18	22	19	4	29	11	8
2011	2030	2049	29	3	29	14	10	22	19
2012	2031	2050	10	14	11	25	21	4	1
2013	2032	2051	21	26	23	6	2	15	12
2014	2033	2052	3	7	3	18	14	25	22
2015	2034	2053	14	17	14	28	24	6	3
2016	2035	2054	24	28	25	9	5	18	14
2017	2036	2055	5	10	7	20	16	29	26
2018	2037	2056	17	21	17	2	28	9	6
2019	2038	2057	28	2	28	13	9	20	17
2020	2039	2058	8	13	10	23	19	2	29
2021	2040	2059	19	24	21	5	1	13	10
2022	2041	2060	1	5	2	16	12	23	20
2023	2042	2061	12	16	12	27	23	5	2

Table 10c from Jenniskens (2006)

Japanese spacecraft heading for the Moon this year:

サイエンスカフェ神戸スペシャル

（企画案）

テーマ：月と流星の激しい出会い

ゲスト：阿部新助さん（神戸大学理学研究科　助教）
伊藤真之さん（神戸大学人間発達環境学研究科　准教授）

日程：２００７年７月７日（土）または ２１日（土）　（午後）
（今回の問い合わせのご回答を考慮して決定し、
ご参加の可能性のある高校にはあらためてご連絡します）

場所：神戸大学 自然科学総合研究科３号棟
（詳細は別途ご連絡します）

地球に向かって毎日 100 トンも降り注ぐ宇宙ダストの一部は、地球大気への突入で「流れ星」のショーとなって私たちを楽しませてくれます。しかし、流星が降るのは地球だけではありません。最近、月にも流星が衝突していることが確認され、流星群の夜に、月面に衝突するダストの発光が、地上観測により発見されました。今回のサイエンスカフェスペシャルでは、流星-彗星-小惑星などの太陽系小天体を研究している阿部新助さんや、月周回衛星 SELENE に関わっている伊藤真之さんをお招きし、地球や月に降る流星が私たちに何を教えてくれるのかについて語っていただきます。

また、今年の 12 月 14 日に出現のピークを迎える「ふたご座流星群」に伴う月面衝突発光は、好条件で日本から観測できます。私たちは、キャンペーンを立ち上げ、高校生のみなさんにも観測に参加していただくことを計画しています。皆さんが観測キャンペーンに積極的に参加して頂けるよう、研究者との意見交換や、高校生からの観測に関するアイデア等を出していただく場を設けたいと考えています。皆様の参加をお待ち申し上げております。