Meteor layers in the martian and venusian ionospheres: Their connection to meteor showers

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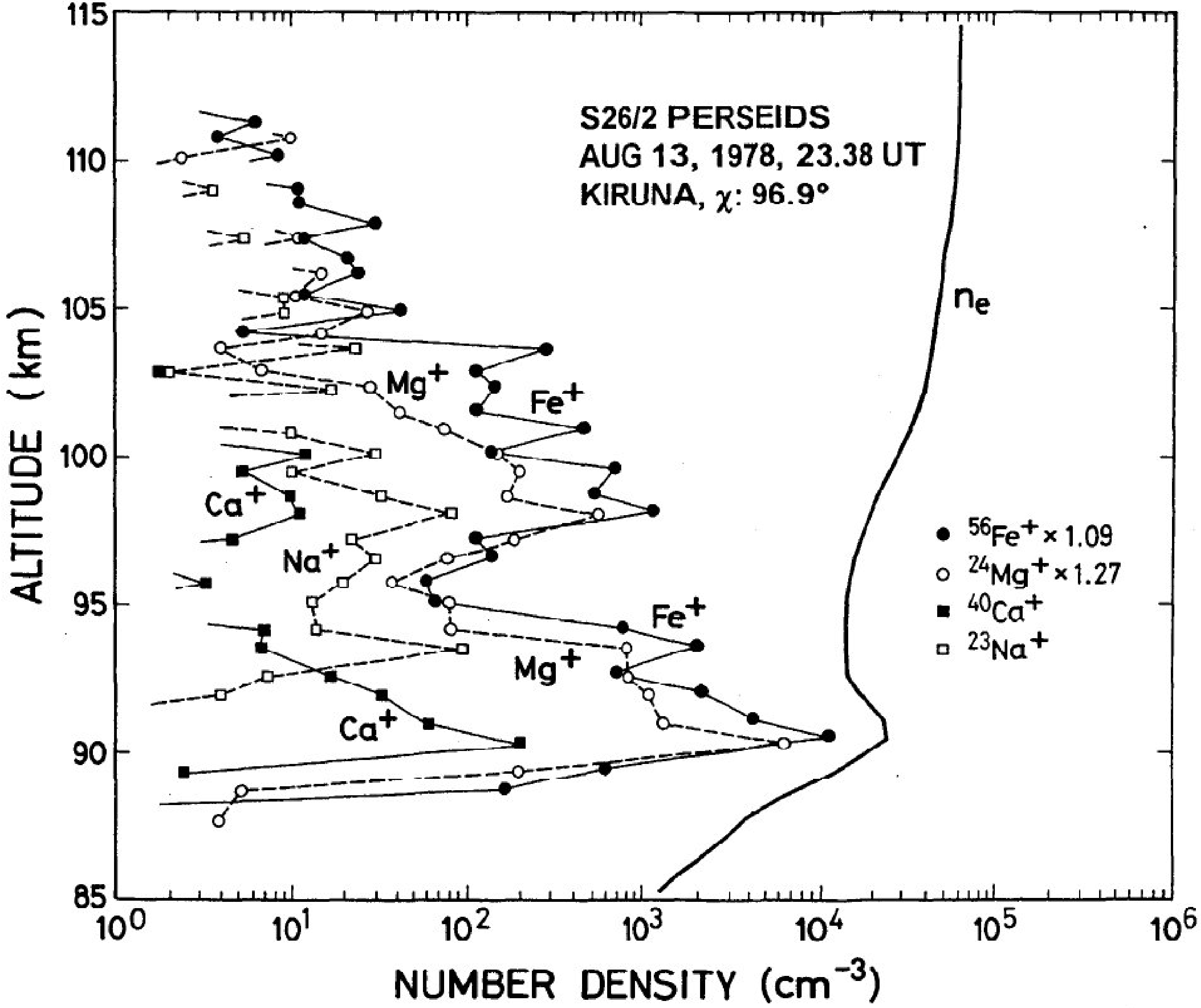
Terrestrial context

- Models predict that meteor showers should double metallic ion densities and major storms should increase densities by an order of magnitude
- BUT analyses of current observations have been inconclusive on whether meteor showers affect terrestrial meteoric layers
- Normal variations in densities are very large, which makes it difficult to observe increases and attribute them to specific causes



Rocket data one day after Perseid maximum, 1978. From Kopp (1997).

612 J.M. Grebowsky et al./Journal of Atmospheric and Solar-Terrestrial Physics 60 (1998) 607–615

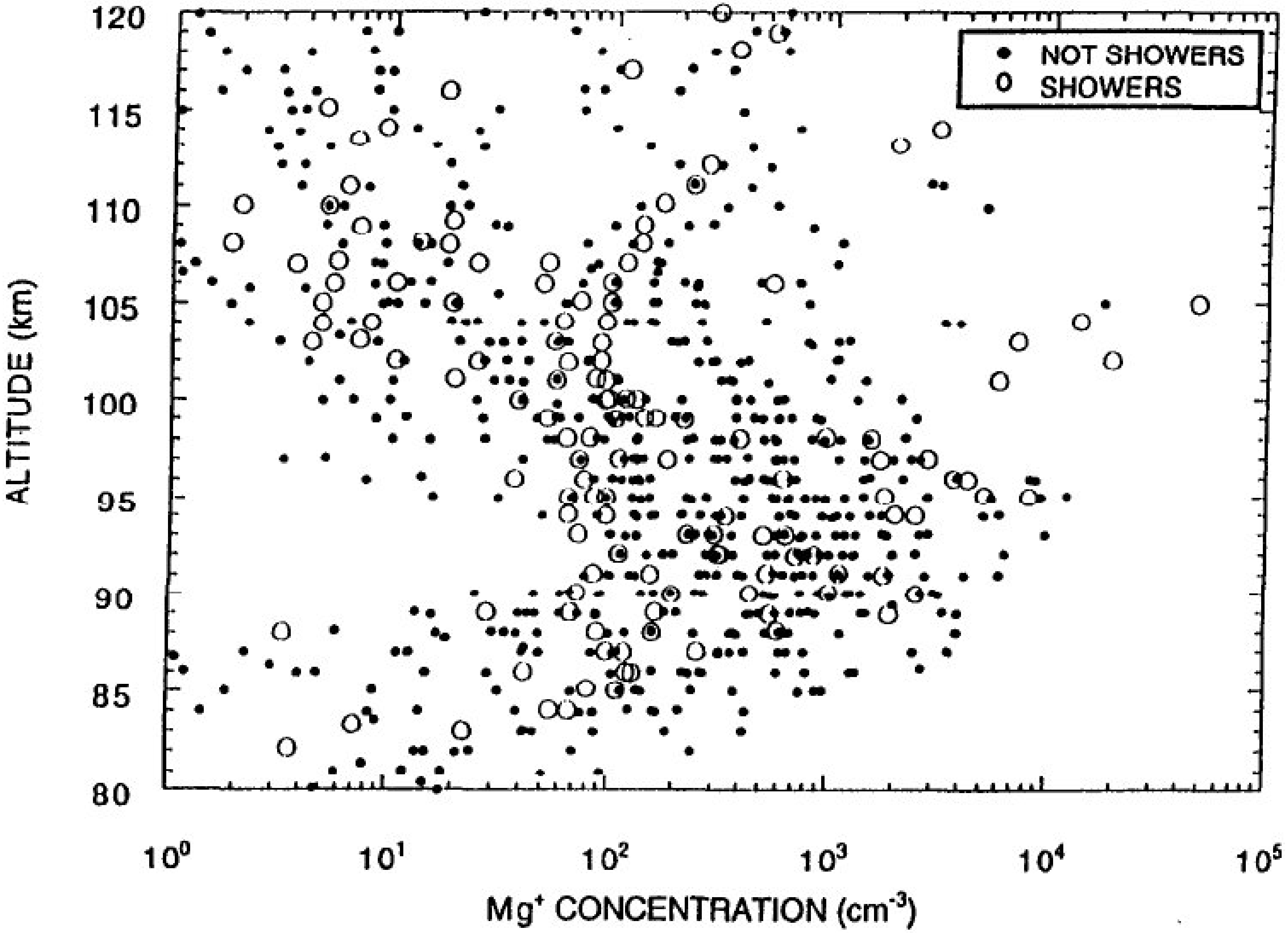


Fig. 3. Measurements of Mg^+ concentrations from 32 sounding rocket flights. Events during meteor showers (open circles) are distinguished from the non-shower observations (solid dots).

Mg^+ data from 32 flights. No obvious difference between showers and normal.
From Grebowksy et al. (1998).

J.M. Grebowsky et al./Journal of Atmospheric and Solar-Terrestrial Physics 60 (1998) 607–615 613

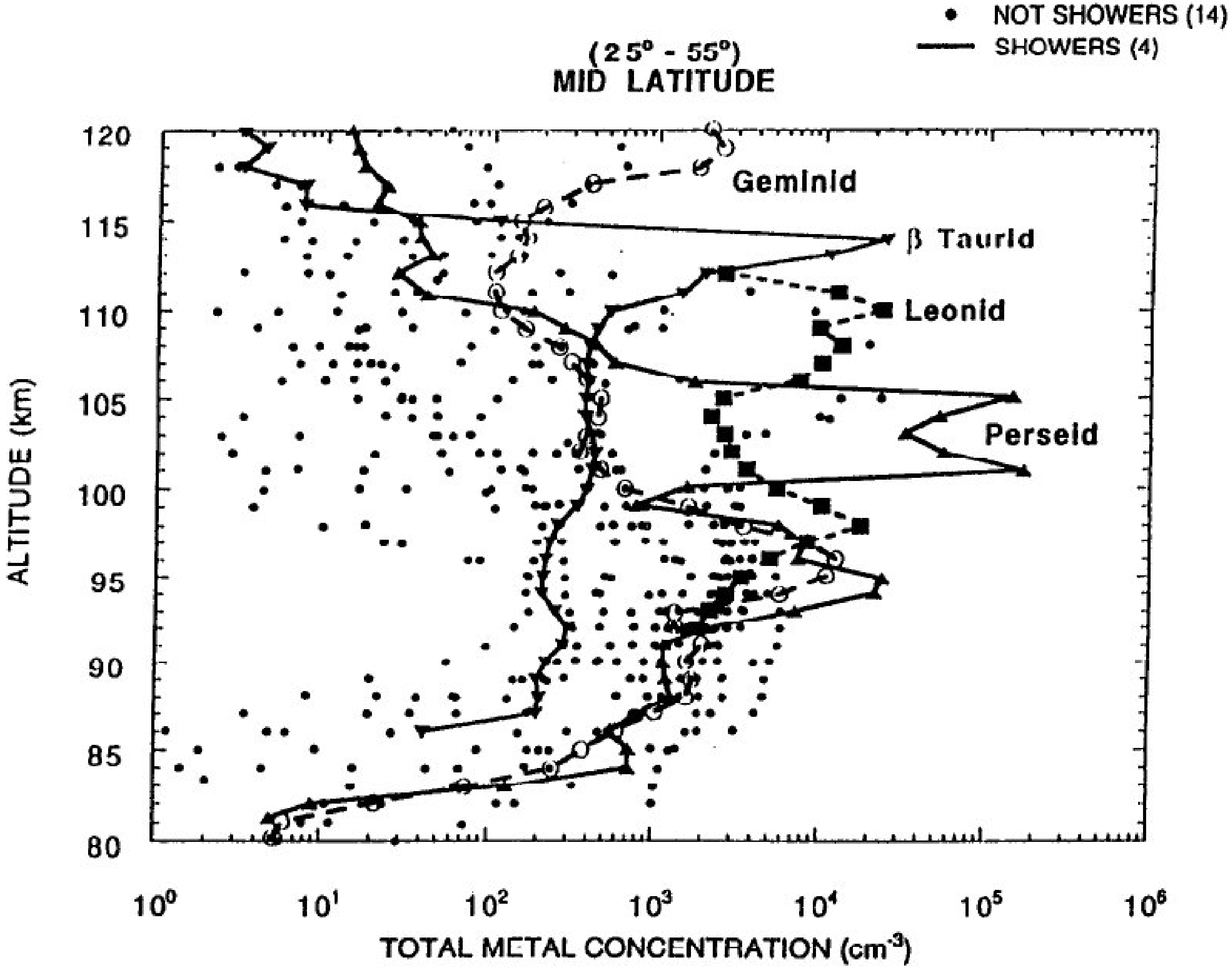
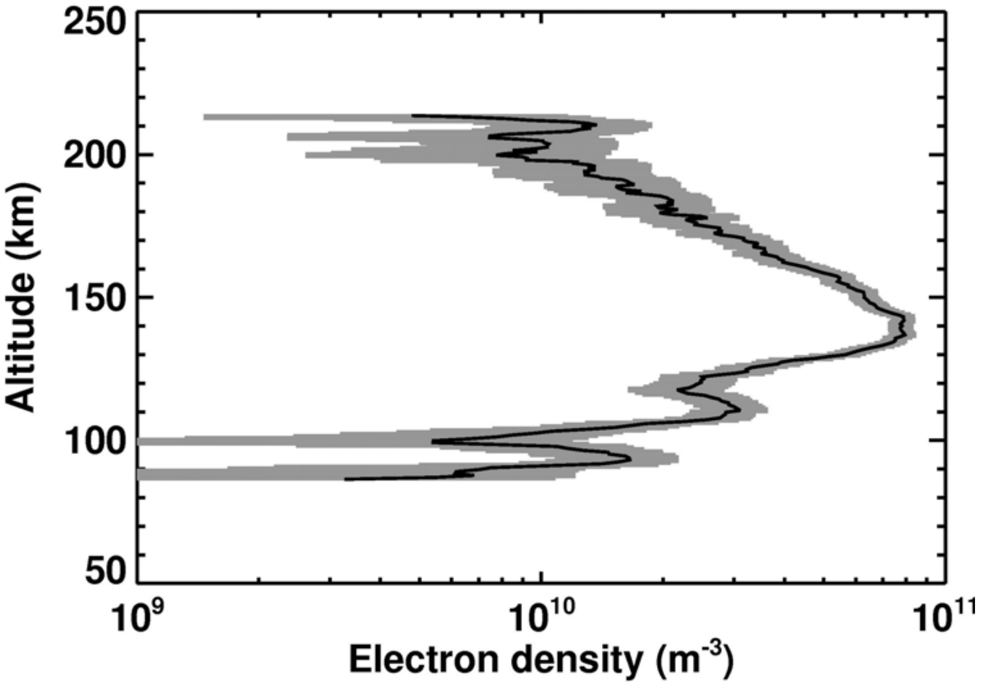


Fig. 5. Comparison of shower and non-shower total metallic ion concentrations in a mid-latitude zone (latitudes with absolute values between 30 and 55°). The shower data are shown as curves and non-shower data as points.

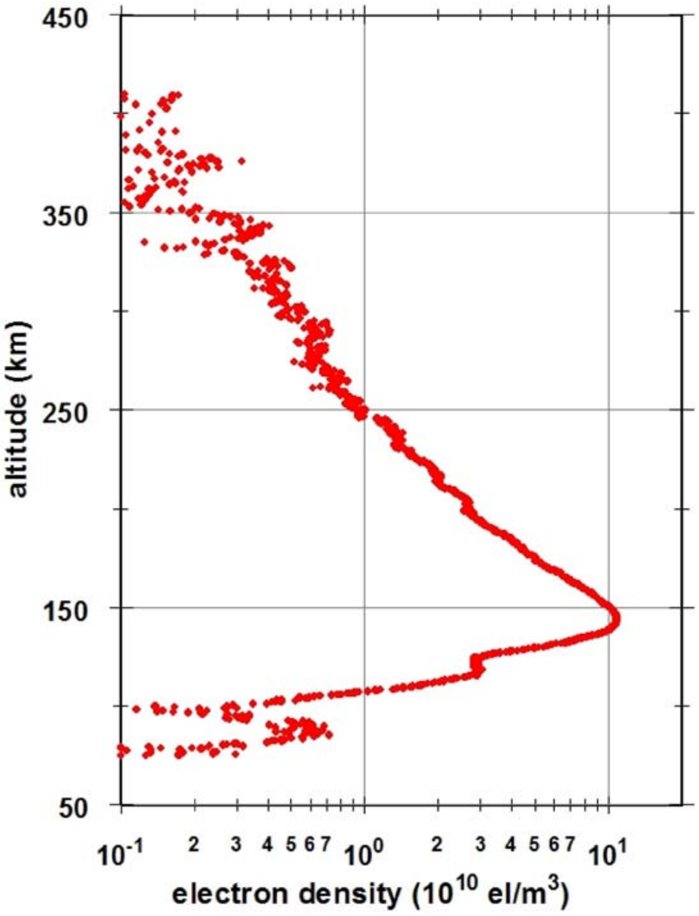
Metallic ions from 18 flights. Peak densities during showers seem larger than normal. Results inconclusive due to large variations. From Grebowsky et al. (1998).

Mars – Datasets

- 5600 electron density profiles from Mars Global Surveyor (MGS), 71 (1.3%) with meteoric layers
- 465 profiles from Mars Express (MEX), 75 (16.1%) with meteoric layers
- Difference in occurrence rate probably due mostly to differences in instrument sensitivity



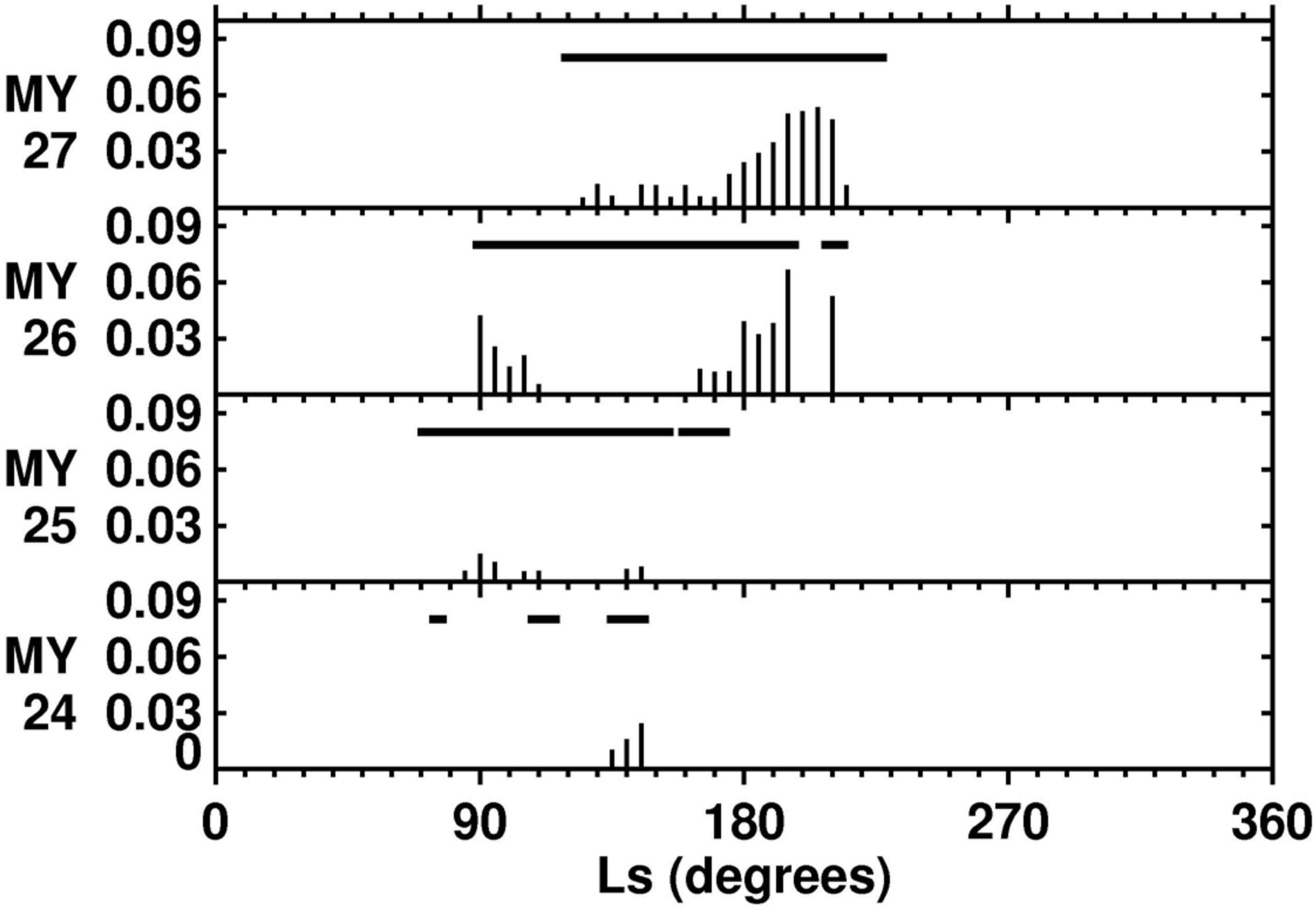
MGS profile with meteoric layer



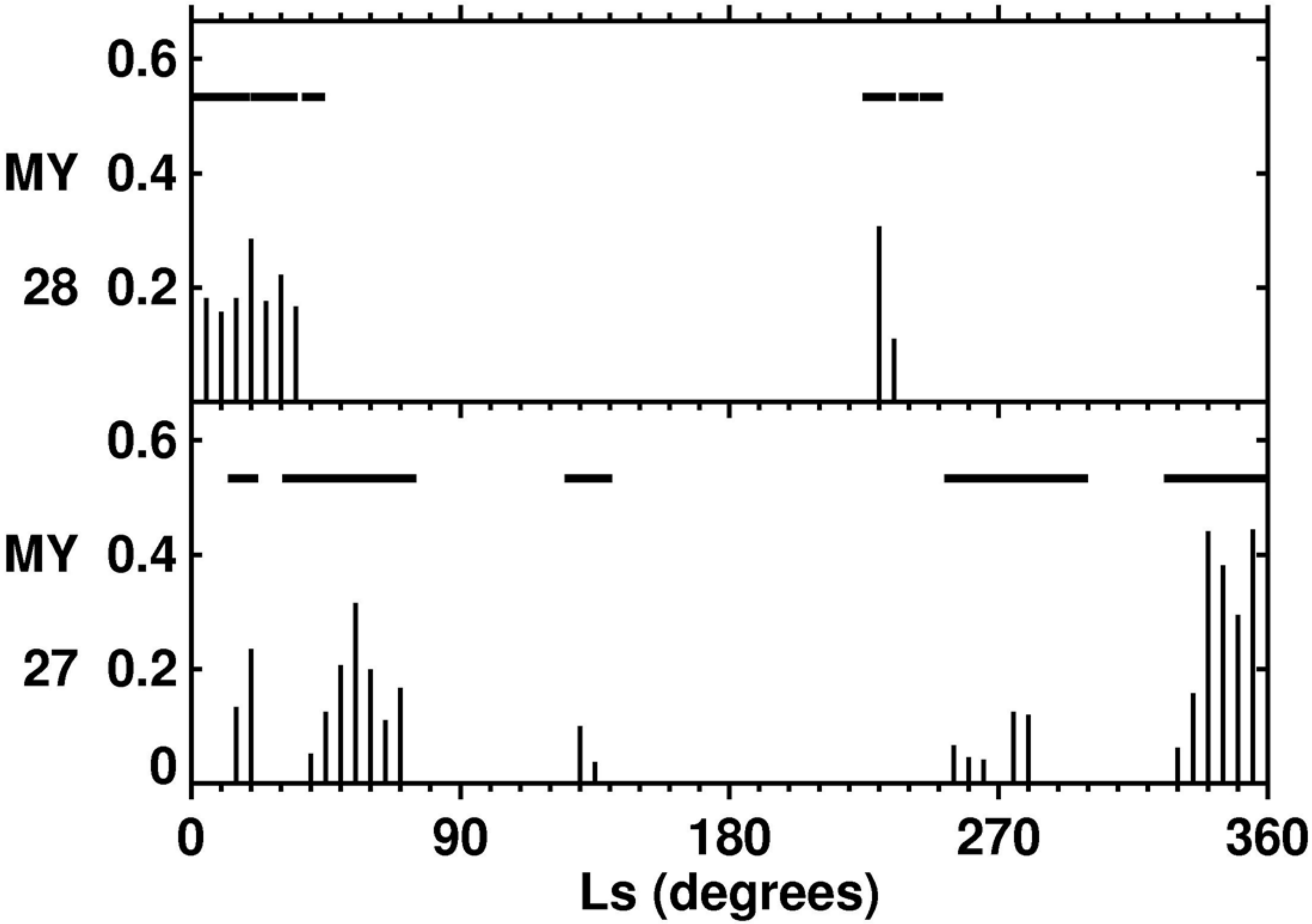
MEX profile with meteoric layer

Mars – Seasonal Variations

- Occurrence rate is not constant with time. It varies by one order of magnitude for MGS.
  - Observations have varying solar zenith angle and latitude. It is perhaps possible that these variations affect the apparent seasonal trends. Simplest explanation for observations is seasonal dependence.
- 110 < Ls < 180, 13/2923 (0.4%)
- 190 < Ls < 230, 30/802 (3.7%)



Occurrence rate for MGS profiles as function of season (Ls) and Mars Year (MY). Horizontal lines show data coverage. Occurrence rate varies with Ls, trends repeat from year to year.



Occurrence rate for MEX profiles as function of season (Ls) and Mars Year (MY). Horizontal lines show data coverage.

Abundant meteoric layers

- Ten consecutive MEX profiles from 14-19 December 2005 (Ls = 340-343) all contain the meteoric layer.
- [I want to show figures of all/some of these profiles, perhaps the same as Martin’s 2006 DPS presentation.]

Competing seasonal hypotheses

- Seasonal variations in transport and loss processes
  - Controlled by atmospheric properties, such as changes in winds and associated plasma transport
  - Endogenic
  - Dominant on Earth
- Seasonal variations in meteoroid input
  - Controlled by meteoroid properties, such as gradual variations in sporadic meteoroids or sharp variations in shower meteoroids
  - Exogenic
  - Not dominant on Earth

Problems with hypotheses

- Atmospheric hypothesis
  - These processes, which are important on Earth, depend on strong magnetic field
  - Venus has no internal magnetic field, although solar wind can impose one on the ionosphere
  - Mars has patchy internal magnetic field, but very weak for all MGS profiles
- Meteor shower hypothesis
  - Not a major factor on Earth, so why should it be important on Venus and Mars?

Testing hypotheses

- Very few models of martian meteoric layers exist, none have studied variability
- We don’t know how the atmosphere varies with season
  - Atmospheric hypothesis is untestable at present
- Find when Mars crosses cometary orbits, correlate with high occurrence rates
  - Meteor shower hypothesis is testable

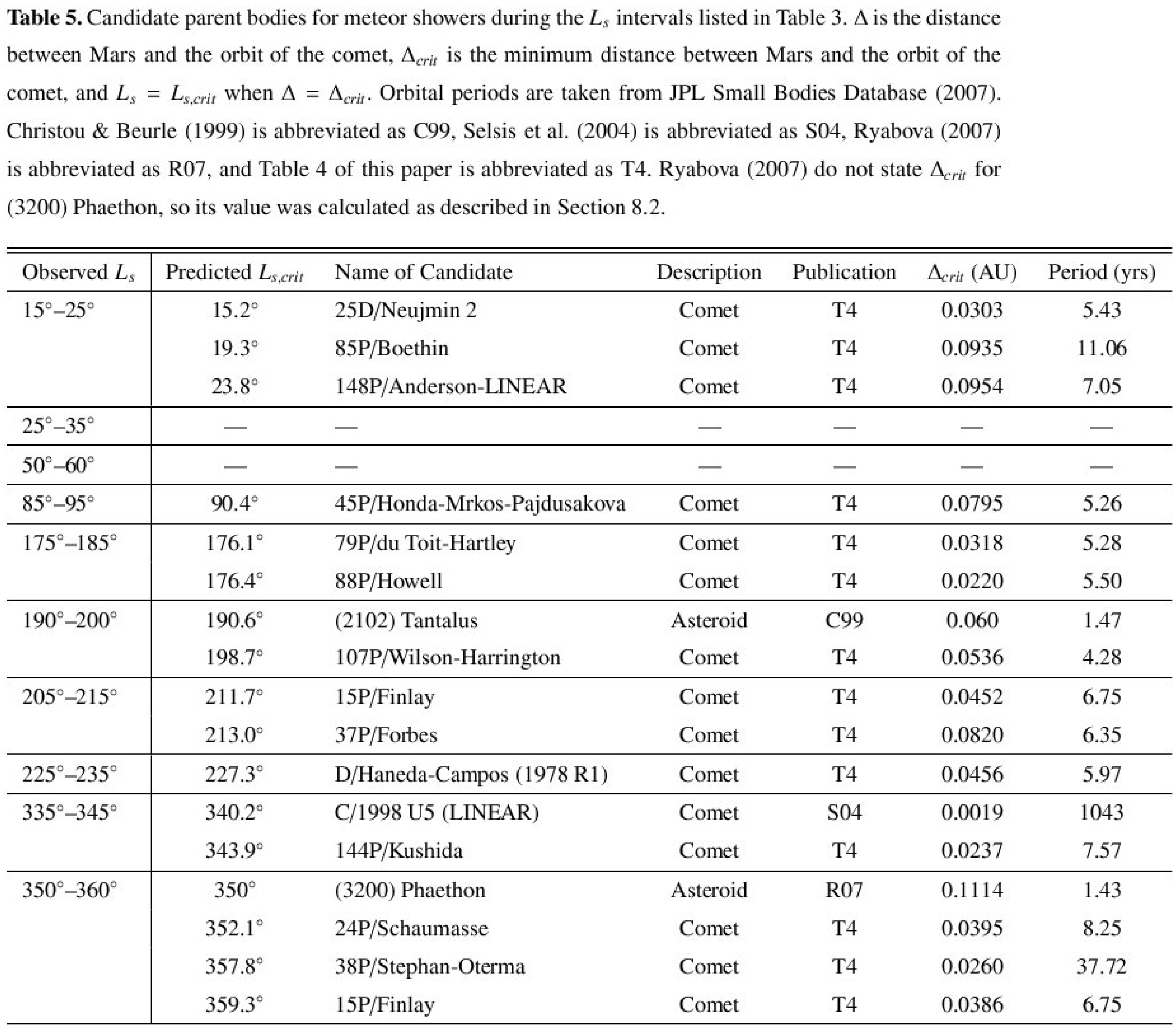


Table 5. Candidate parent bodies for meteor showers during the L_s intervals listed in Table 3. Δ is the distance between Mars and the orbit of the comet, Δ_{crit} is the minimum distance between Mars and the orbit of the comet, and $L_s = L_{s,crit}$ when $\Delta = \Delta_{crit}$. Orbital periods are taken from JPL Small Bodies Database (2007). Christou & Beurle (1999) is abbreviated as C99, Selsis et al. (2004) is abbreviated as S04, Ryabova (2007) is abbreviated as R07, and Table 4 of this paper is abbreviated as T4. Ryabova (2007) do not state Δ_{crit} for (3200) Phaethon, so its value was calculated as described in Section 8.2.

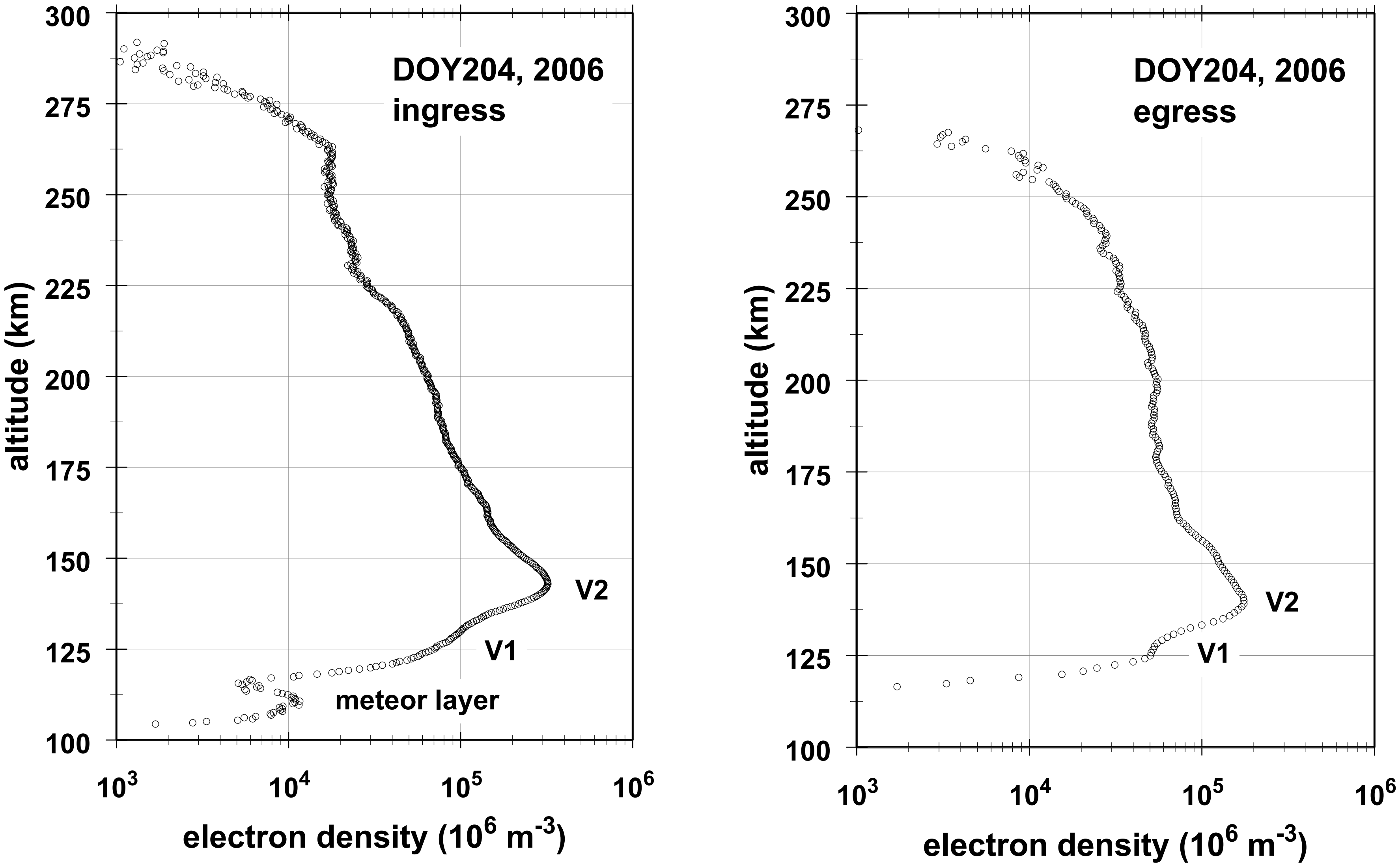
Observed L_s	Predicted $L_{s,crit}$	Name of Candidate	Description	Publication	Δ_{crit} (AU)	Period (yrs)
15°–25°	15.2°	25D/Neujmin 2	Comet	T4	0.0303	5.43
	19.3°	85P/Boethin	Comet	T4	0.0935	11.06
	23.8°	148P/Anderson-LINEAR	Comet	T4	0.0954	7.05
25°–35°	—	—	—	—	—	—
50°–60°	—	—	—	—	—	—
85°–95°	90.4°	45P/Honda-Mrkos-Pajdusakova	Comet	T4	0.0795	5.26
175°–185°	176.1°	79P/du Toit-Hartley	Comet	T4	0.0318	5.28
	176.4°	88P/Howell	Comet	T4	0.0220	5.50
190°–200°	190.6°	(2102) Tantalus	Asteroid	C99	0.060	1.47
	198.7°	107P/Wilson-Harrington	Comet	T4	0.0536	4.28
205°–215°	211.7°	15P/Finlay	Comet	T4	0.0452	6.75
	213.0°	37P/Forbes	Comet	T4	0.0820	6.35
225°–235°	227.3°	D/Haneda-Campos (1978 R1)	Comet	T4	0.0456	5.97
335°–345°	340.2°	C/1998 U5 (LINEAR)	Comet	S04	0.0019	1043
	343.9°	144P/Kushida	Comet	T4	0.0237	7.57
350°–360°	350°	(3200) Phaethon	Asteroid	R07	0.1114	1.43
	352.1°	24P/Schaumasse	Comet	T4	0.0395	8.25
	357.8°	38P/Stephan-Oterma	Comet	T4	0.0260	37.72
	359.3°	15P/Finlay	Comet	T4	0.0386	6.75

Note that the unique case of ten consecutive meteoric layers matches smallest Δ

Venus

- 118 profiles from Venus Express (VEX), but about half are nightside profiles
- 18 dayside profiles have meteoric layers (about 30%, twice as common as for MEX)

- If occurrence rate varies with season at fixed solar zenith angle, etc., then cause must be external to Venus as Venus has no seasons.
  - Excellent test



Two VEX profiles from same orbit

Venus: meteor layer occurences in the lower ionosphere observed by VEX VeRa										possible cometary originators			
year	DOY	I = Ingress E=Egress	Date	latitude	SZA	n_{max}	h_{max}	range			impact latitude	SZA	Ref
				(deg)	(deg)	(10^{11} m^{-3})	(km)	(km)	(km)	comet name	(deg)	(deg)	
2006	202	E	21.07.2006	75.9	81.3	0.13	121	111	124	141P/Machholz 2	45	58	CHR,NES,JEN
										Southern Taurids	1	170	
										Northern Taurids/2004 TG10	+6/7	172	CHR
										C/1937 D1 (Wilk)	-47	128	BEE,NES
	204	I	23.07.2006	-42.0	83.0	0.11	110	105	115	Southern Taurids	1	170	
										Northern Taurids/2004 TG10	+6/7	172	CHR
	212	E	31.07.2006	86.0	88.0	0.08	123	118	127	12P/Pons-Brooks	62	99	BEE,CHR,NES,JEN
										27P/Crommelin	72	102	BEE,CHR,SEL,NES,JEN
	218	E	06.08.2006	88.6	91.0	0.04	115	110	119	12P/Pons-Brooks	62	99	BEE,CHR,NES,JEN
										122P/de Vico	-58	95	BEE,CHR,NES,JEN
2007	3	E	03.01.2007	-68.8	83.2	0.04	114	111	116	C/1964 L1 (Tomita-Gerber-Hon	-10	110	
										P/2007 T2 (Kowalski)	-29	135	
										Northern Delta Aquarids	5	153	CHR
	14	I double peak	14.01.2007	80.8	84.5	0.19 0.22	114 110	100	122	alpha Capricornids	-2	155	CHR
										C/1858 L1 (Donati)	36	71	
	14	E	14.01.2007	-35.7	69.7	0.08	114	105	116	alpha Capricornids	-2	155	CHR
										C/1858 L1 (Donati)	36	71	
	16	I	16.01.2007	79.6	83.9	0.11	110	105	120	alpha Capricornids	-2	155	CHR
										C/1858 L1 (Donati)	36	71	
	16	E	16.01.2007	-29.3	67.3	0.11	115	109	119	alpha Capricornids	-2	155	CHR
										C/1858 L1 (Donati)	36	71	
	18	I	18.01.2007	78.3	83.2	0.17	113	109	116	C/1858 L1 (Donati)	36	71	
										169P/NEAT	28	137	
										alpha Capricornids	-2	155	CHR
										P/2004 X1 (LINEAR)	-23	99	
	24	I double peak	24.01.2007	73.3	80.4	0.29 0.37	120 110	102	122	169P/NEAT	28	137	
										35P/Herschel-Rigollet	-64	107	BEE,NES,JEN
										Daytime Sextantids	-19	26	
	26	E	26.01.2007	8.3	59.6	0.17	113	105	126	169P/NEAT	28	137	
										35P/Herschel-Rigollet	-64	107	BEE,NES,JEN
										Daytime Sextantids	-19	26	
	31	E	31.01.2007	36.2	64.0	0.23	107	102	124	none			
	164	E	13.06.2007	80.4	81.5	0.10	111	107	118	none			
	166	E	15.06.2007	79.0	80.0	0.07	109	105	114	none			
	170	E	19.06.2007	75.6	76.4	0.17	113	107	119	none			
	173	E double peak	22.06.2007	72.4	73.1	0.12 0.14	116 106.5	112 104	120 111	Southern Taurids	1	170	
										1P/Halley	8	72	CHR,NES,JEN
										Daytime Arietids	6	26	
										P/2006 U1 (LINEAR)	-20	157	
	176	E	25.06.2007	68.5	68.9	0.19	112.5	109	121	1P/Halley	8	72	CHR,NES,JEN
										Daytime Arietids	6	26	
										Southern Taurids	1	170	
										P/2006 U1 (LINEAR)	-20	157	

observed with the Venus Express Radio Science Experiment VeRa

SZA = solar zenith angle at 120 km altitude; still illuminated by the Sun

n_{max} = peak density at altitude h_{max}

range = minimum and maximum altitude of meteor layer coverage

BEE = Beech, M., Mon. Not. R. Astron. Soc. 294, 259 (1998)

CHR = Christou, A.A., Icarus, 168, 23 (2004)

SEL = Selsis, F., Brillet, J., Rappaport, M., A&A 416, 783 (2004)

NES = Neslusan, L., Contr. Astron. Obs. Skal. Pleso 35, 163 (2005)

JEN = Jenniskens, P., Appendix Table 10a, Meteor Showers and their Parent Comets, CUP (Cambridge), 2006

Future work

- More observations will be valuable, especially if they give range of Ls at fixed SZA.
- The lack of active numerical models of meteoric layers is a big problem.
- Need to move beyond orbit-orbit distance as sole predictor of meteor showers.
- Stronger connections between extra-terrestrial and terrestrial meteoric layer communities will be beneficial to both.

Conclusions

- Occurrence rate of martian meteoric layers is not constant. Probably a seasonal variation, although it is difficult to completely exclude aliasing from solar zenith angle and latitude.
- Endogenic hypothesis is untestable at present and it is hard to see how important terrestrial mechanisms work in the unmagnetized ionosphere of Mars. Narrowness of high occurrence rate intervals argues against atmospheric control.
- There are many Mars-crossing comets that could produce meteor showers, but no convincing explanation for why shower meteoroids are more important than sporadics.
- Venus studies are less mature, but promising.