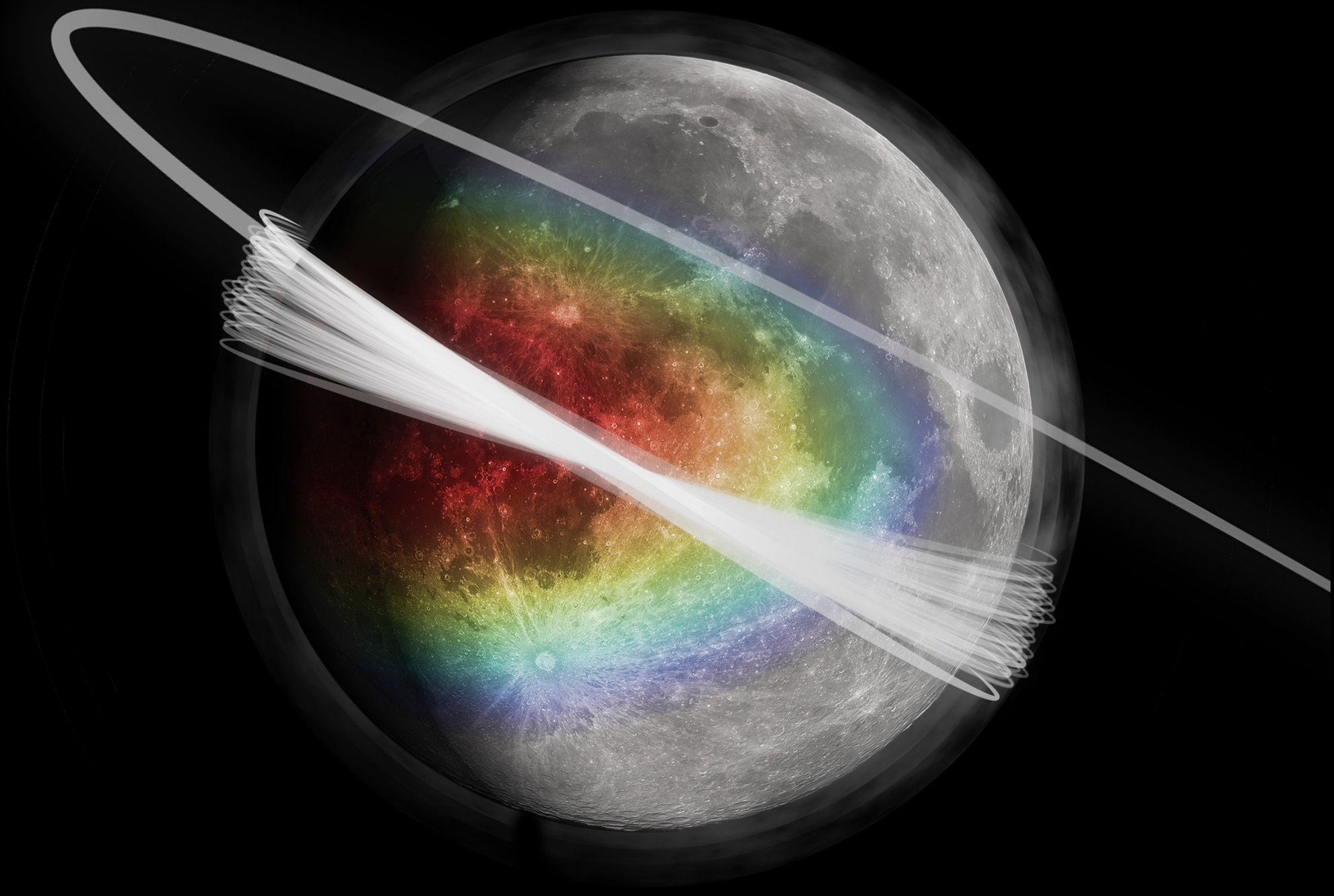
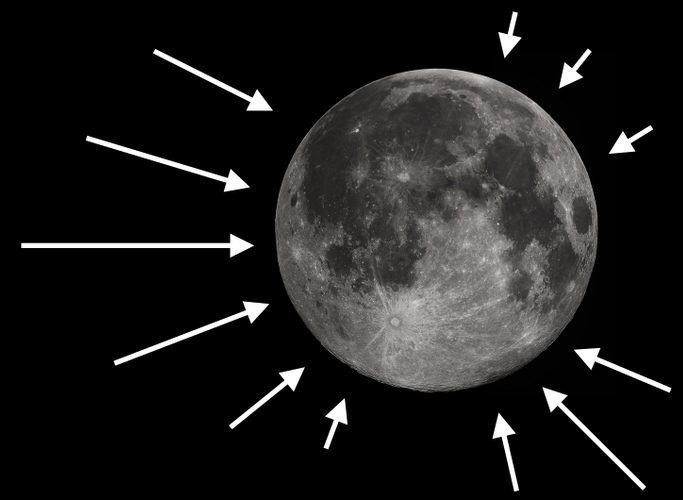
Using the Moon to Characterize the Near-Earth Meteoroid Environment

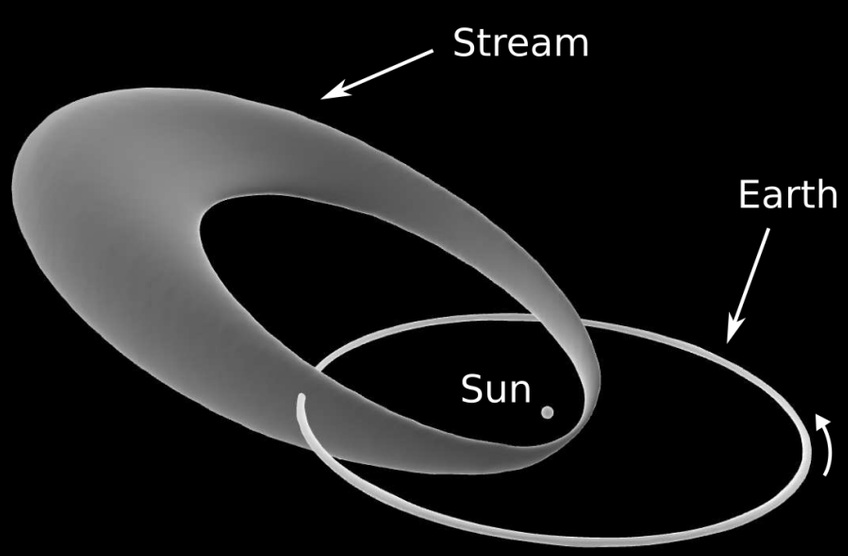
Jamey Szalay, Mihaly Horanyi, Sascha Kempf, Zoltan Sternovsky



Meteoroid Sources

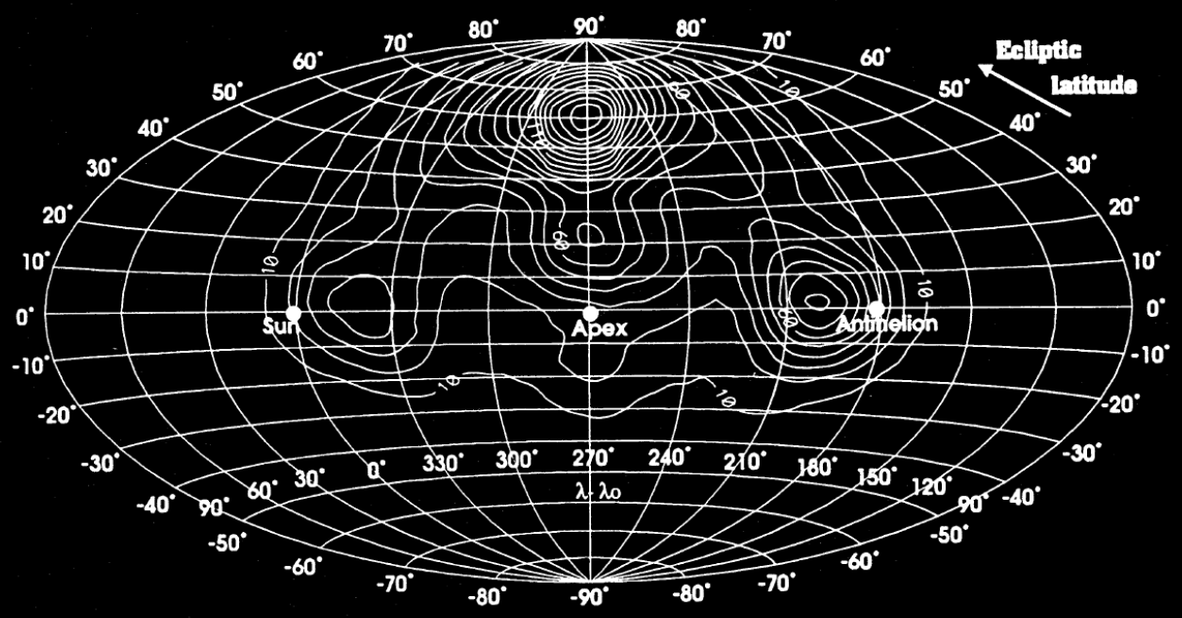


Meteor Showers



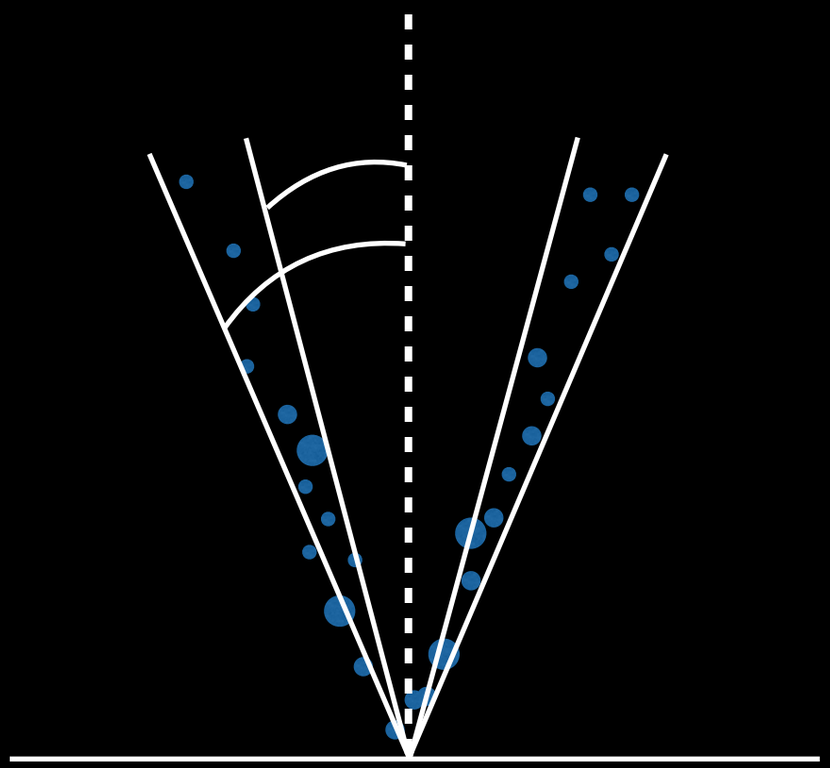
Barensten and Lefevre, 2006

Sporadic Meteoroids

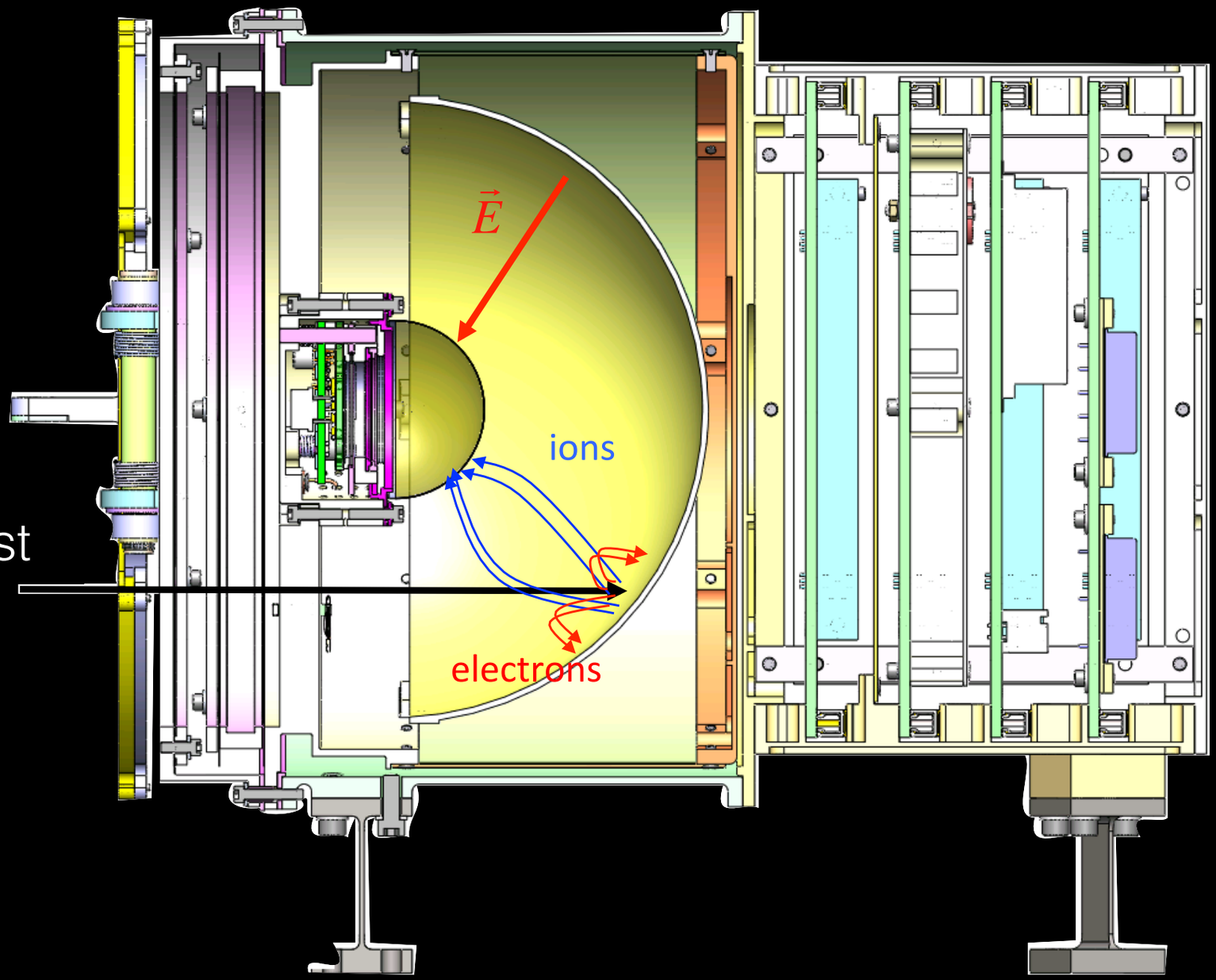


Jones and Brown, 1993

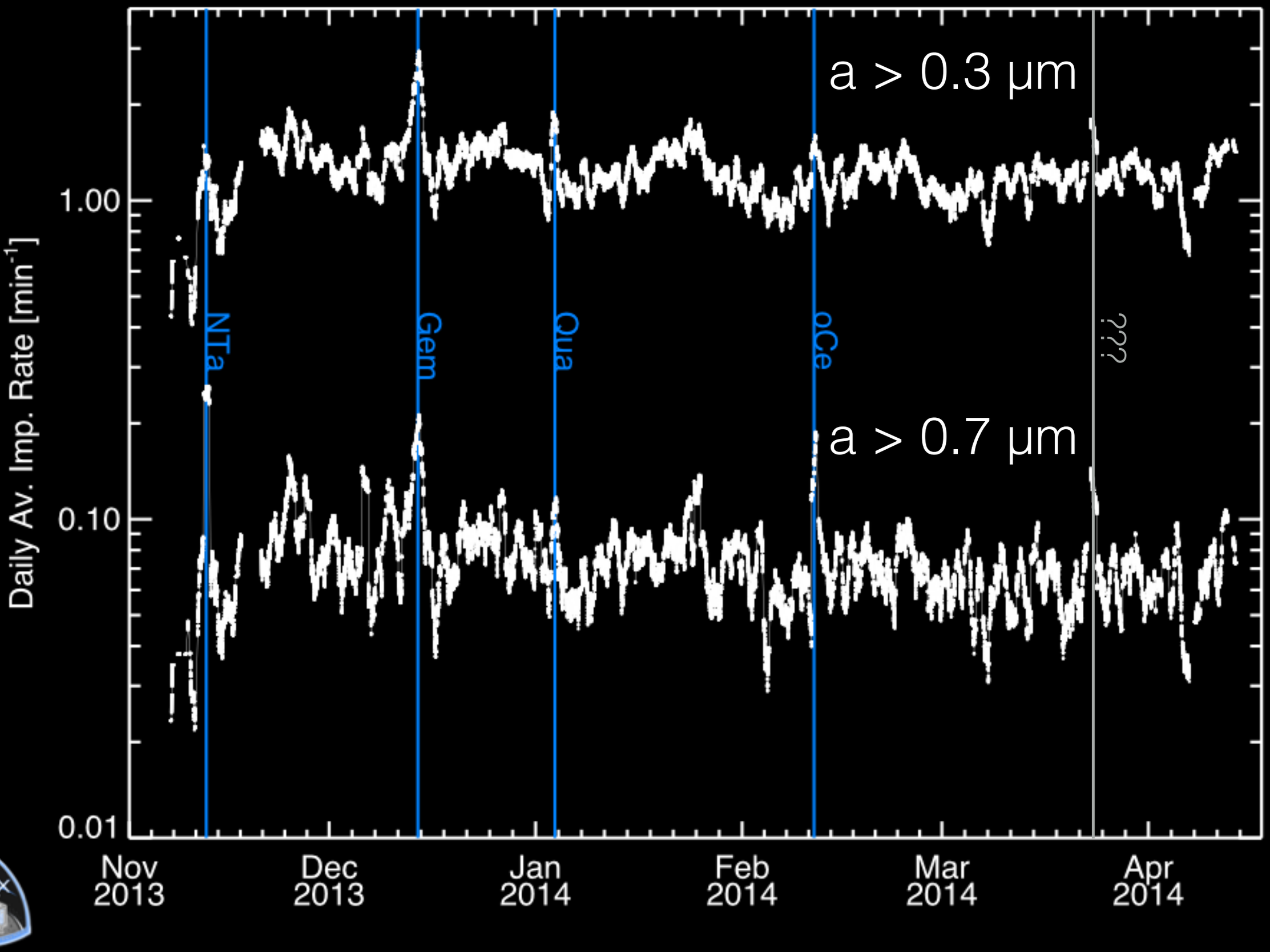
LDEX



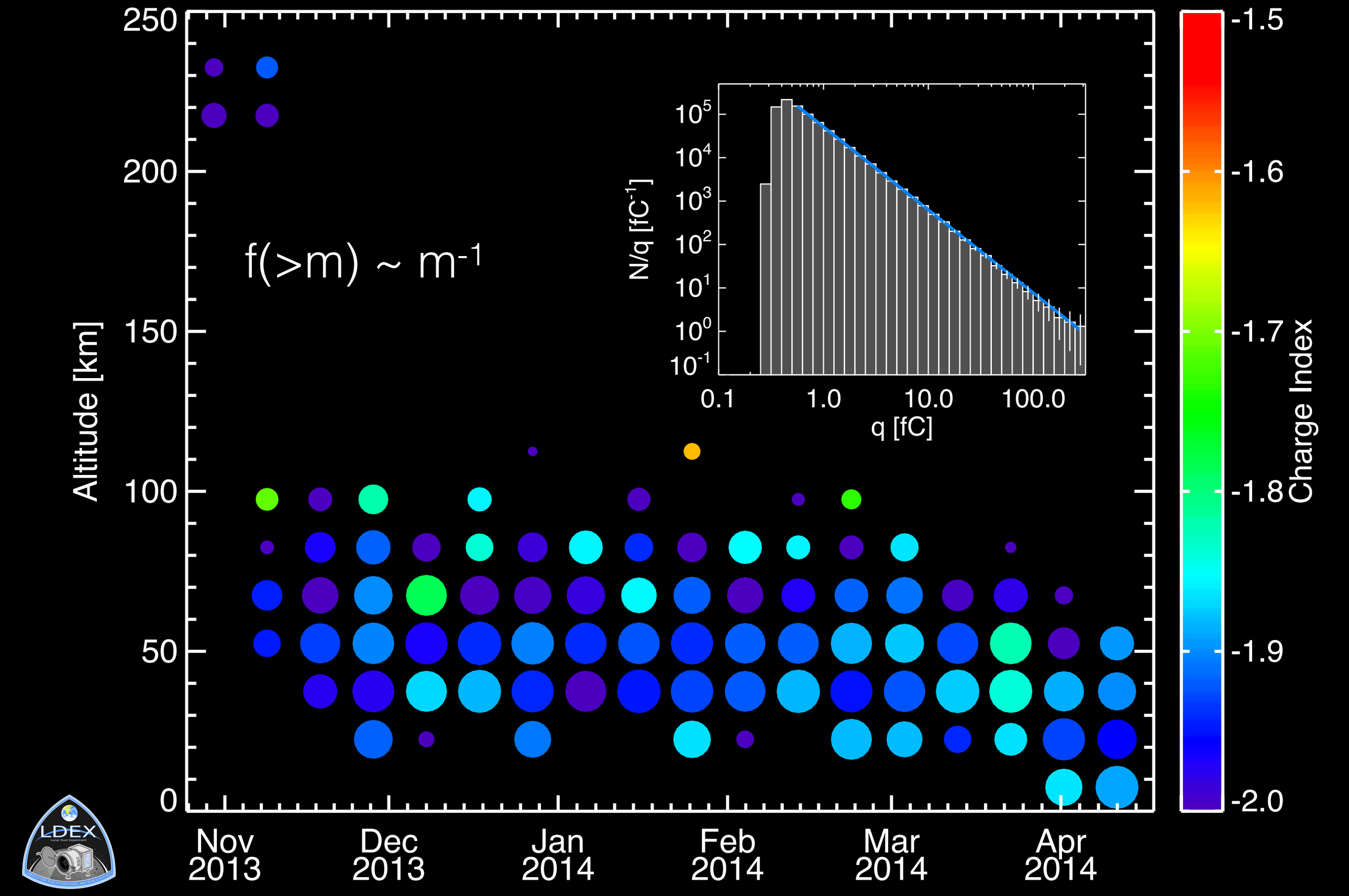
Dust



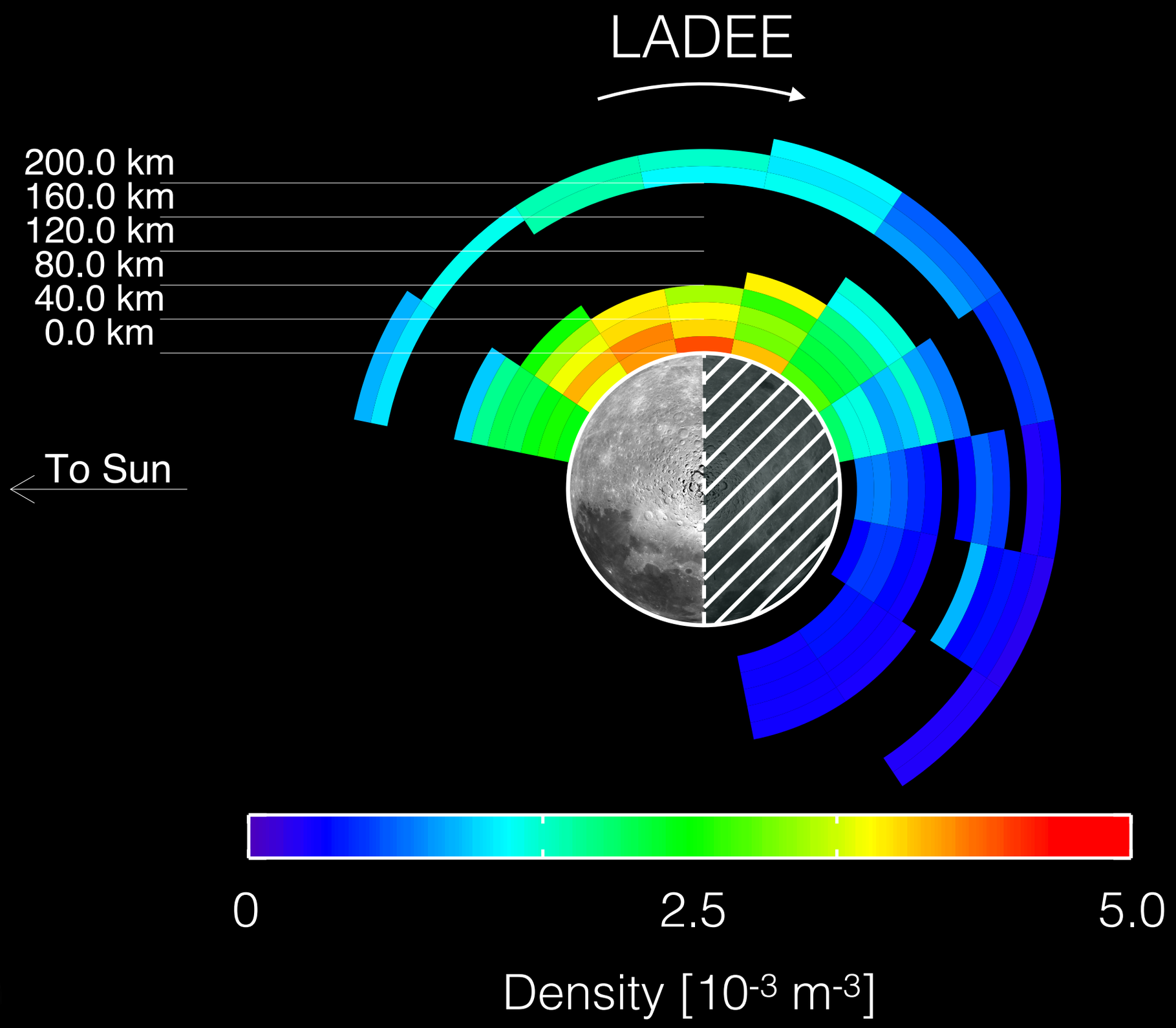
Impact Rate


a > 0.3 µm
a > 0.7 µm
Daily Av. Imp. Rate [min^{-1}]
1.00
0.10
0.01
NTa
Gem
Qua
oCe
¿¿¿
Nov 2013
Dec 2013
Jan 2014
Feb 2014
Mar 2014
Apr 2014

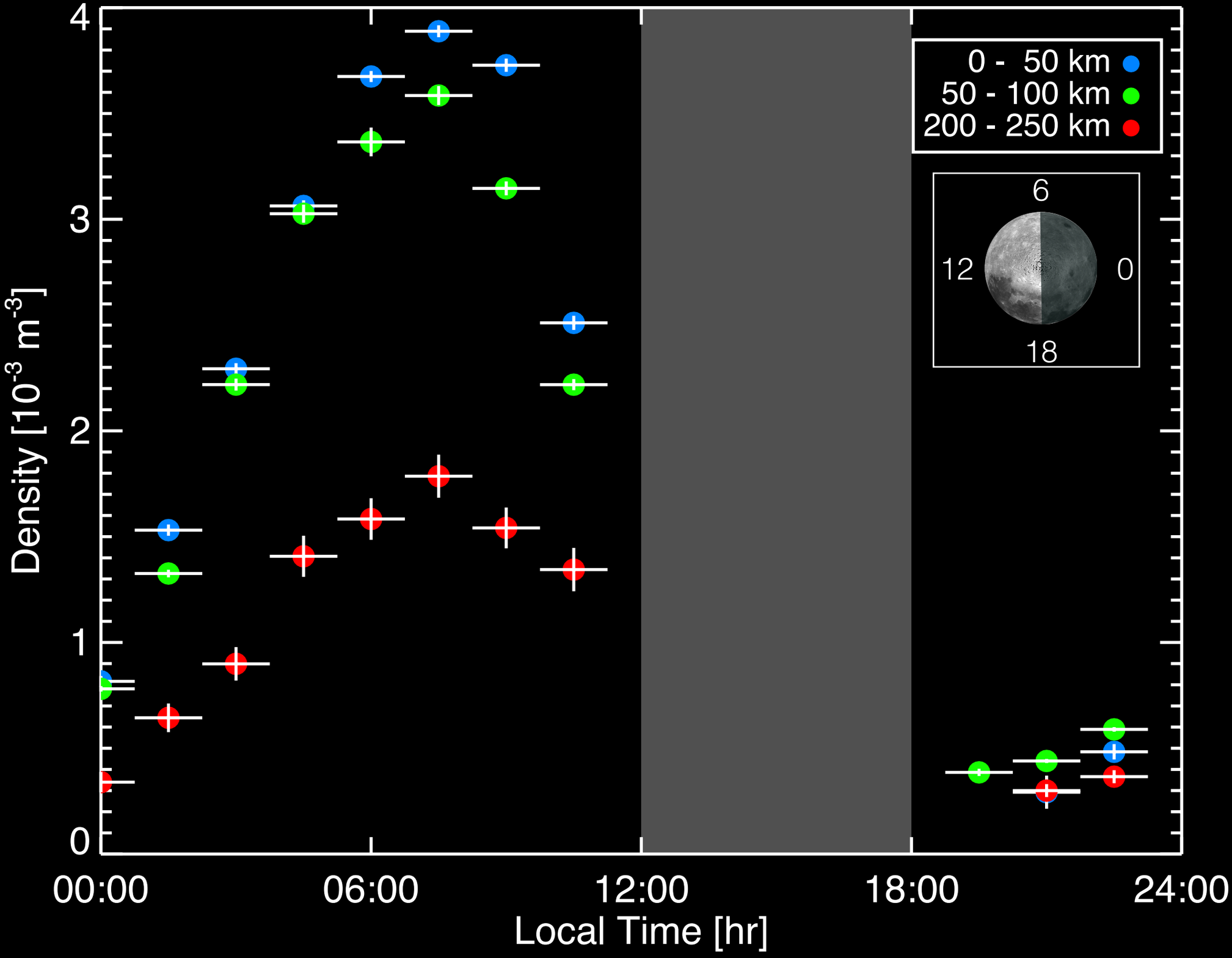
Slope of Charge Distribution vs. Time & Altitude



Density (a > 0.3 μm)



Density (a > 0.3 μm)



Mass Flux

F_{imp} [10^{-18} kg m^{-2} s^{-1}]

800
600
400
200
0

AH
AP
HE
AA

6
12
0
18

Nov-13
Dec-13
Jan-14
Feb-14
Mar-14
Apr-14
Average

00:00
06:00
12:00
18:00
24:00

Local Time [hr]

LDEX
Lunar Dust Experiment

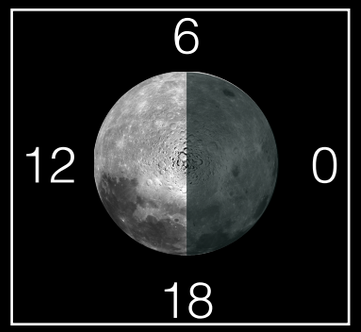
Mass Production

$M^+ = 30 F_{imp} m^{0.2} v^{2.5}$

(Koschny & Grun, 2001)

M^+ [10^{-12} kg m^{-2} s^{-1}]

10
8
6
4
2
0

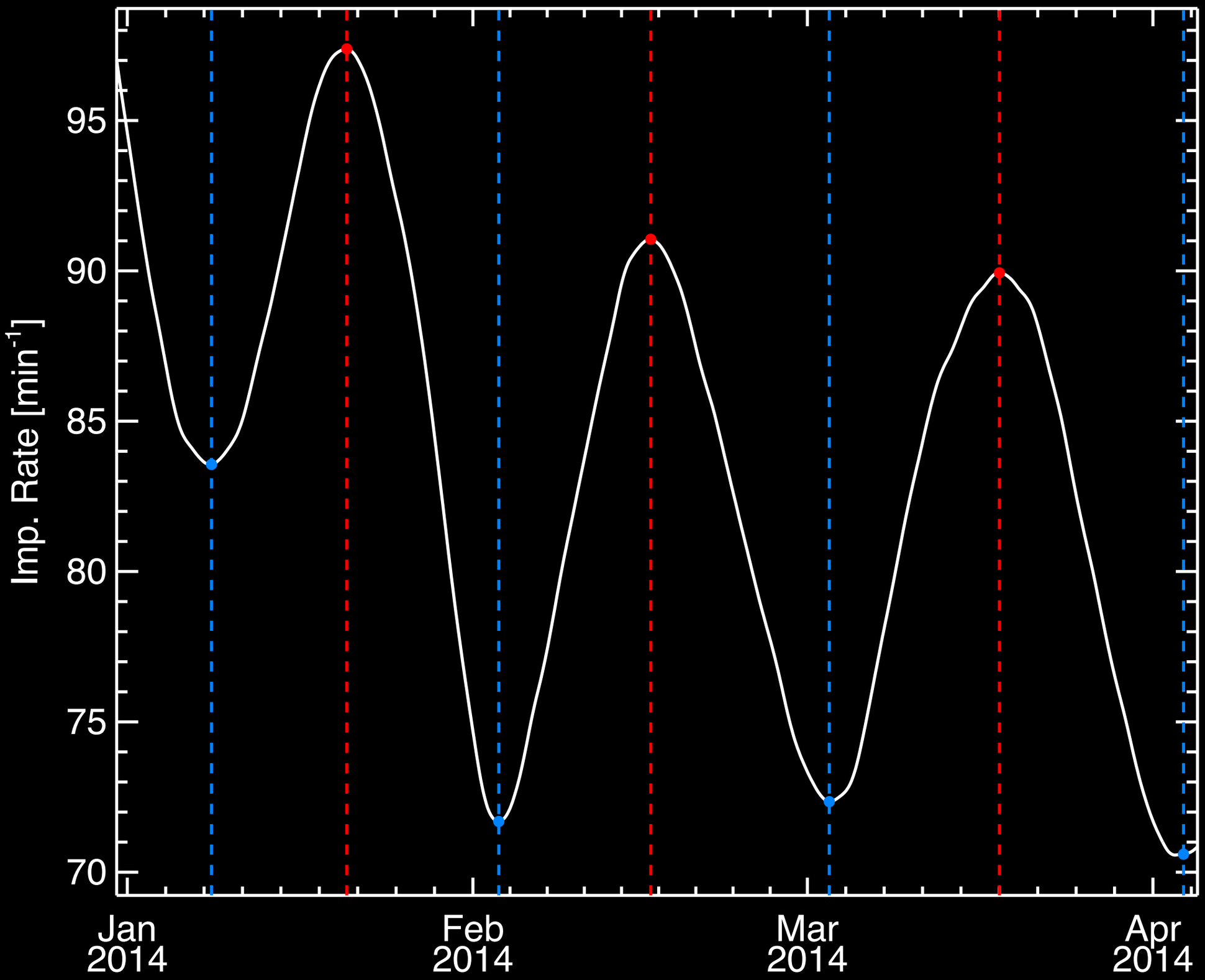


Nov-13
Dec-13
Jan-14
Feb-14
Mar-14
Apr-14
Average

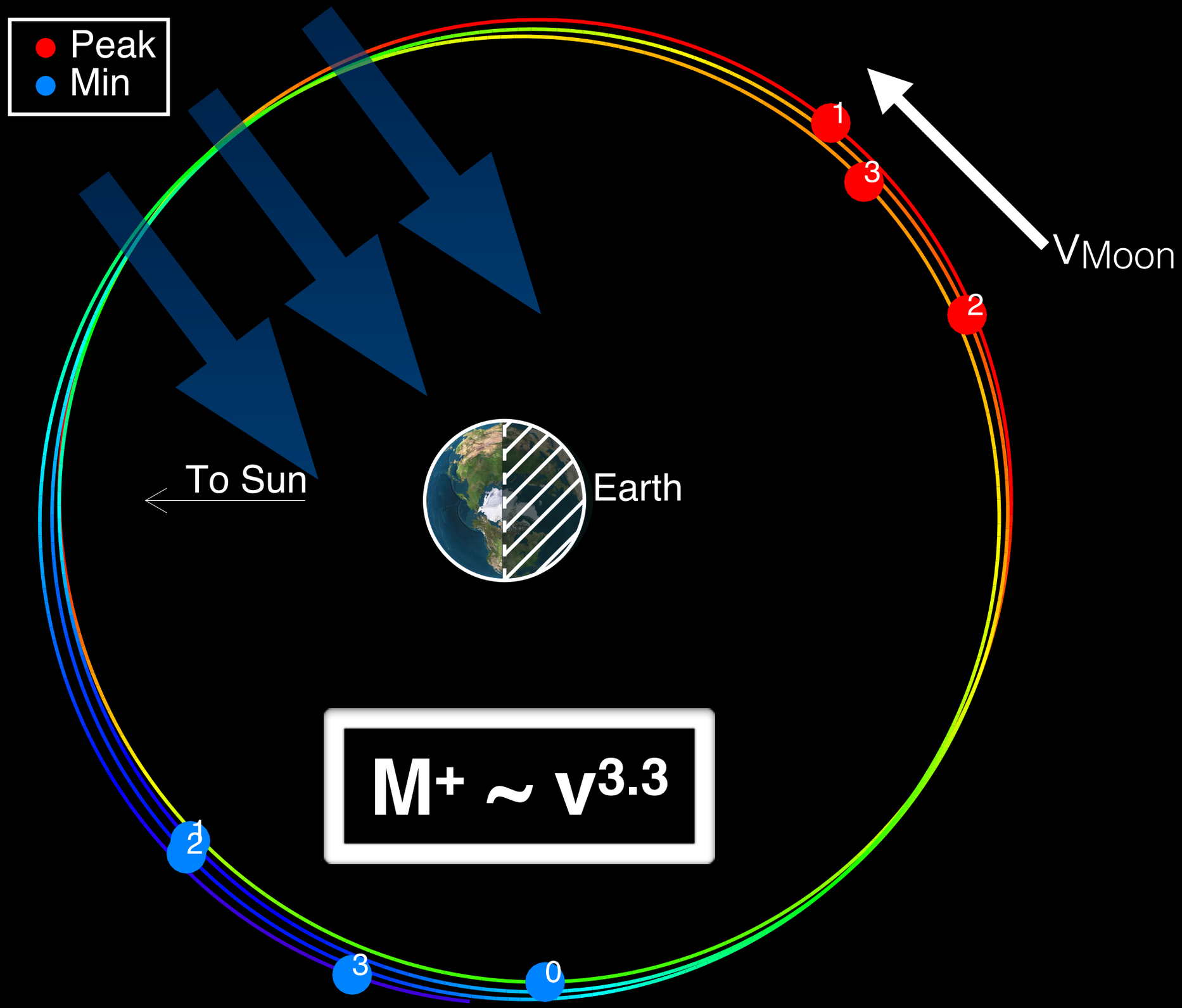
00:00
06:00
12:00
18:00
24:00

Local Time [hr]

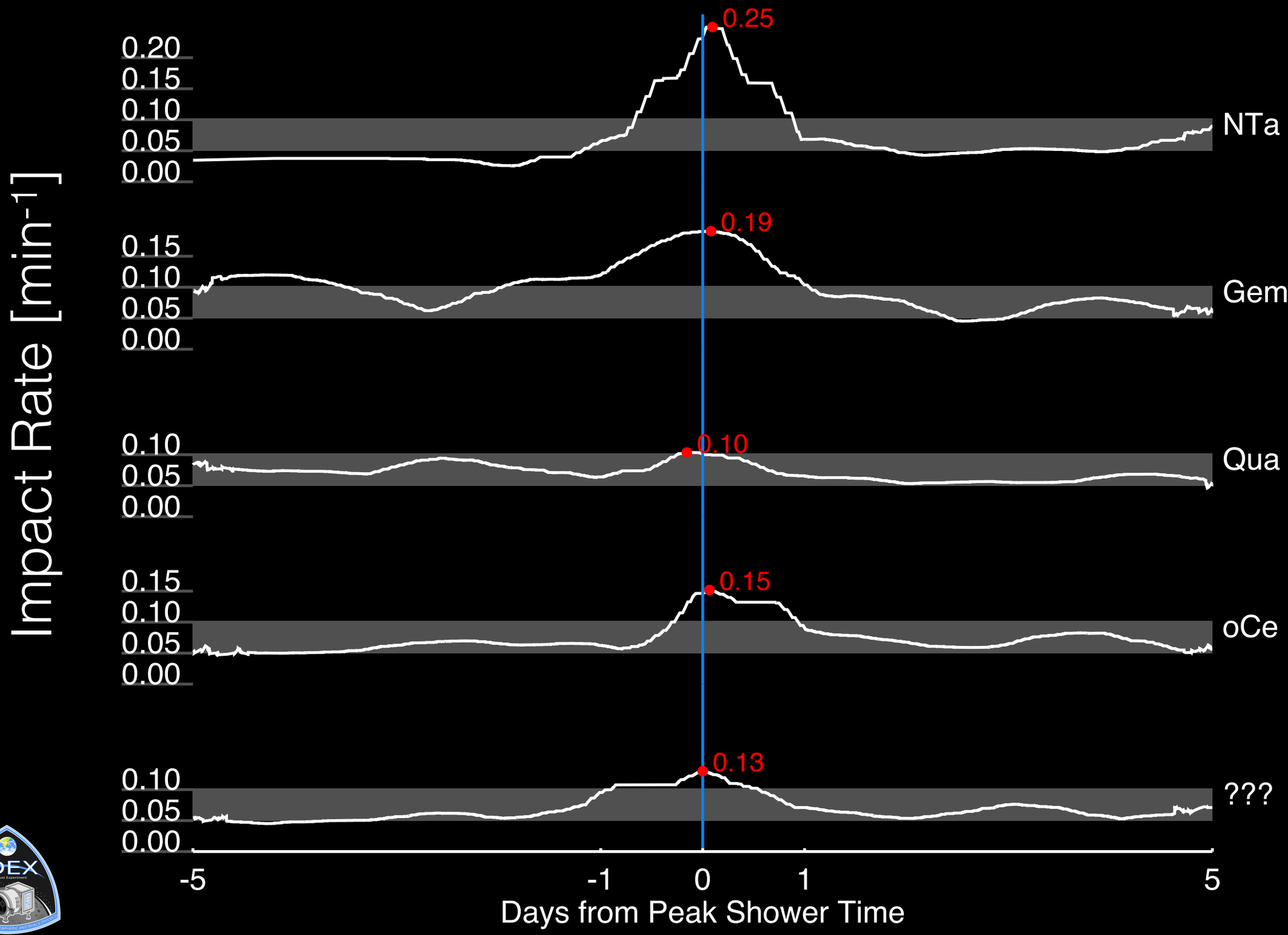
Monthly Modulation



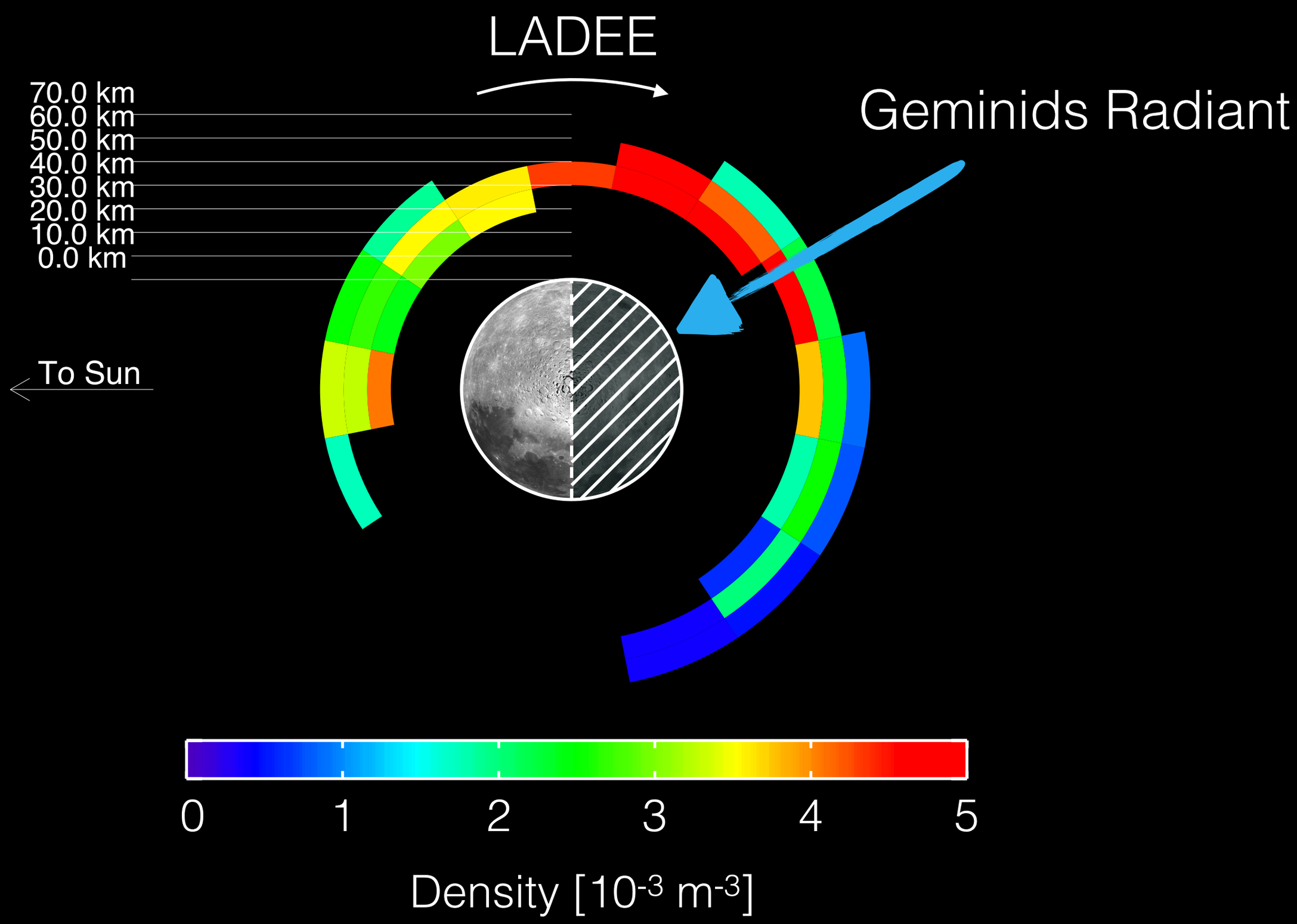
Monthly Modulation



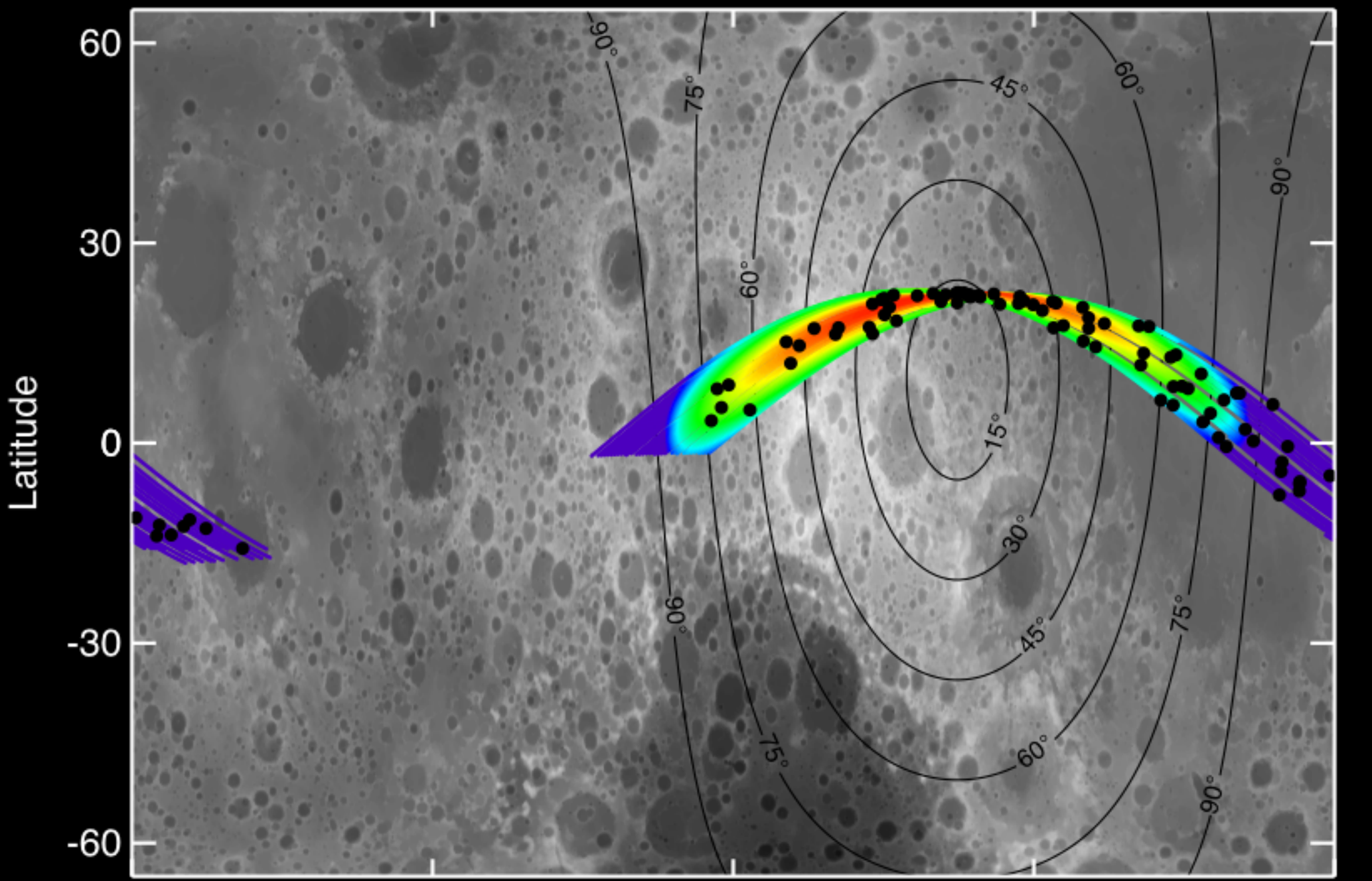
Meteor Showers



Geminids


LADEE
Geminids Radiant
70.0 km
60.0 km
50.0 km
40.0 km
30.0 km
20.0 km
10.0 km
0.0 km
To Sun
0
1
2
3
4
5
Density [10-3 m-3]

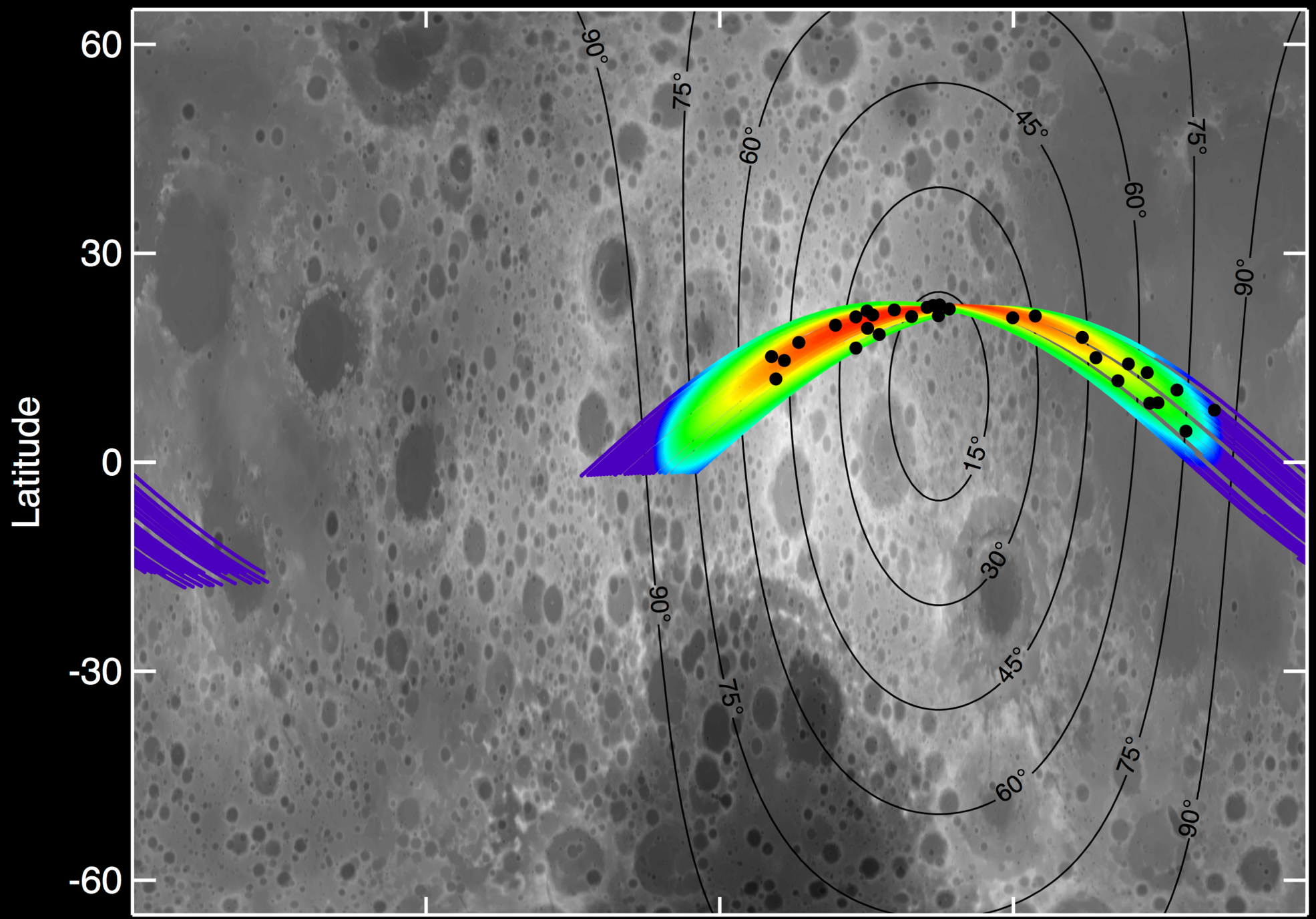
Geminids Trajectory Overlay



$$P(n,T) = 1 - e^{-\mu T} \sum_{\ell=0}^{n-1} \frac{\mu T}{\ell!}$$

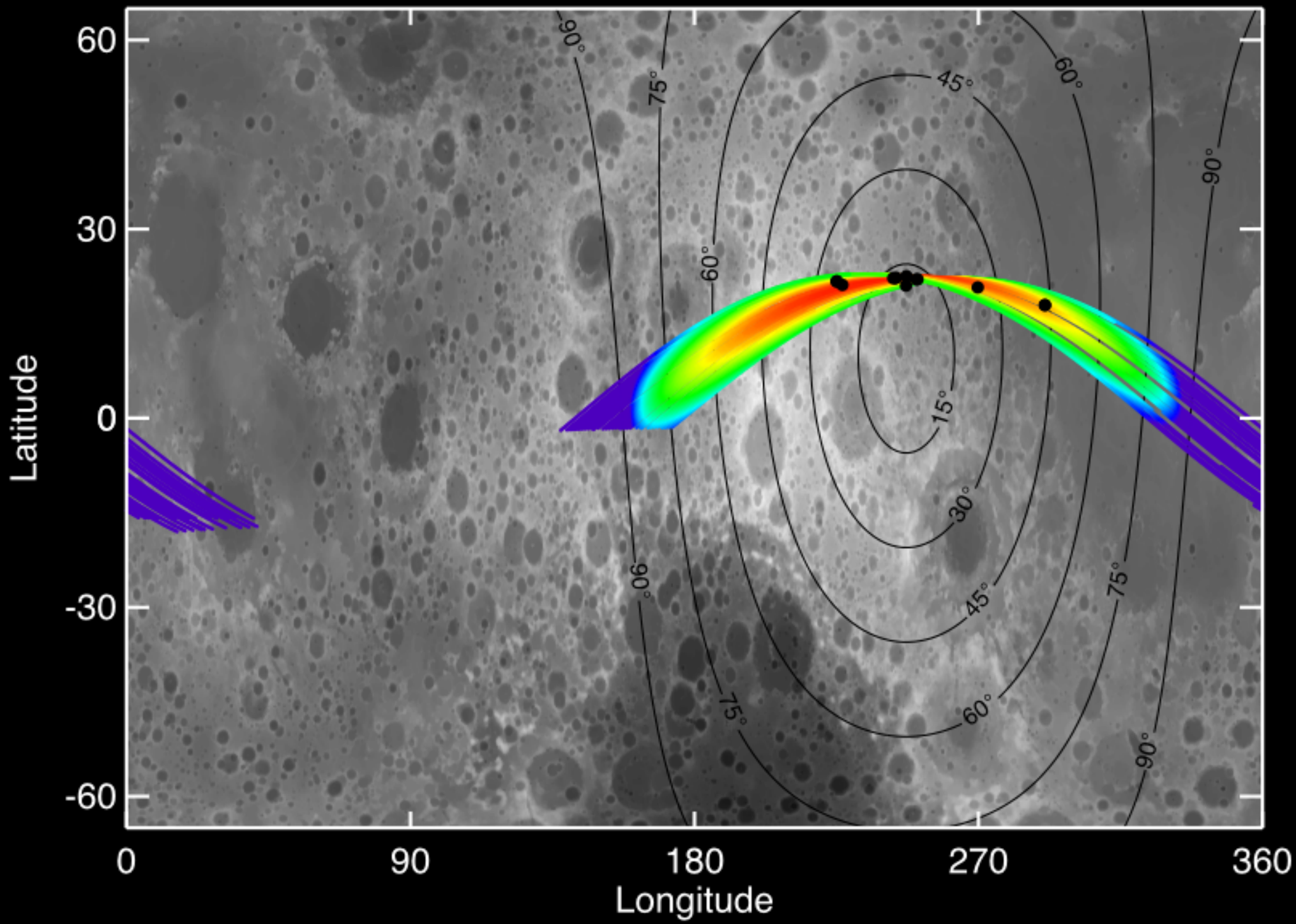
$P \leq 10^{-1}$ Events

Geminids Trajectory Overlay



$P \leq 10^{-3.5}$ Events

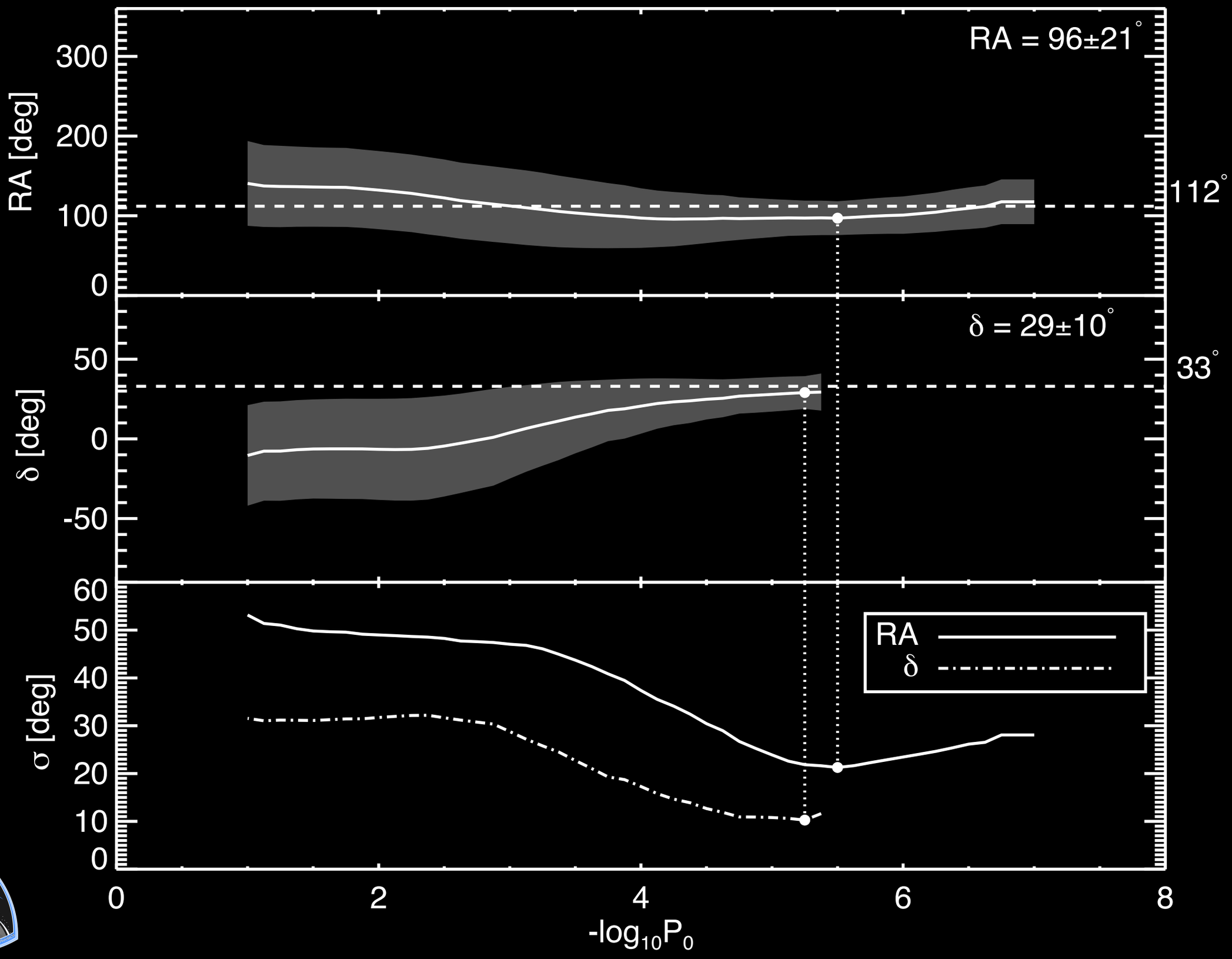
Geminids Trajectory Overlay



$P \leq 10^{-5}$ Events

Poisson Process

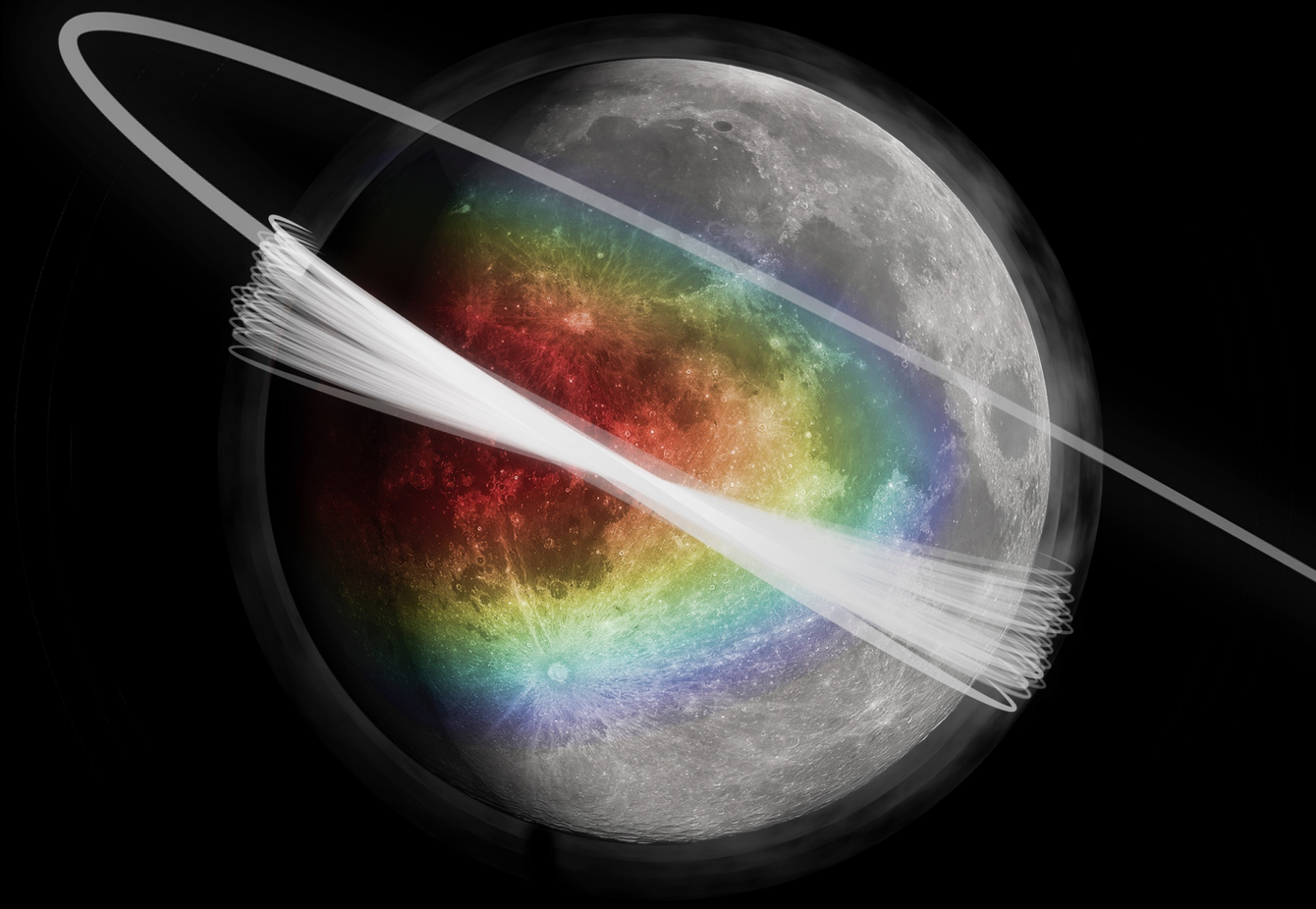
$$P(n,T) = 1 - e^{-\mu T} \sum_{\ell=0}^{n-1} \frac{\mu T}{\ell!}$$



id	L/E	λ	RA	δ	$n(\gamma = 3.5)$
		[deg]	[deg]	[deg]	
Gem	L	**261.8 ±.3**	**96±21**	**29±10**	31
Gem	E	261.6	112	33	
Qua	L	**284.6 ±.3**	189±37	-12±19	12
Qua	E	284.4	230	49	
oCe	L	**325.4±.3**	263±23	-10±32	10
oCe	E	325.1	175	-55	
NTa	L	**227.8±.3**	135±37	-9±25	7
NTa	E	227.7	58	22	
???	L	**4.1±.3**	275±38	-23±13	7

Conclusions

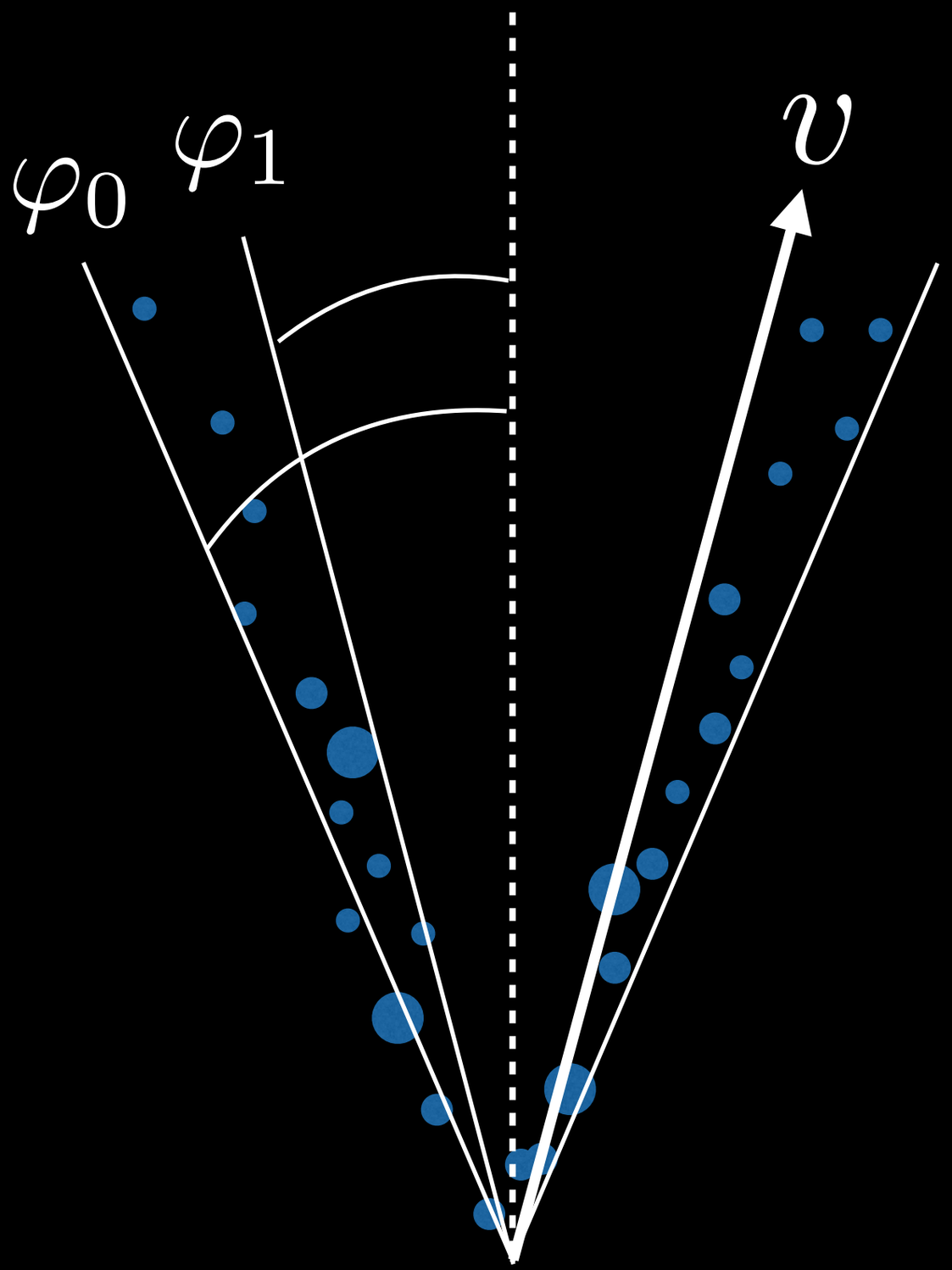
- LDEX has successfully measured the mass distribution of lunar ejecta.
- The Moon can be used as a large-scale laboratory for testing impact ejecta phenomena.
- Impact ejecta processes occur on all airless bodies in the solar system and can be used to understand the meteoroid environment in various systems.



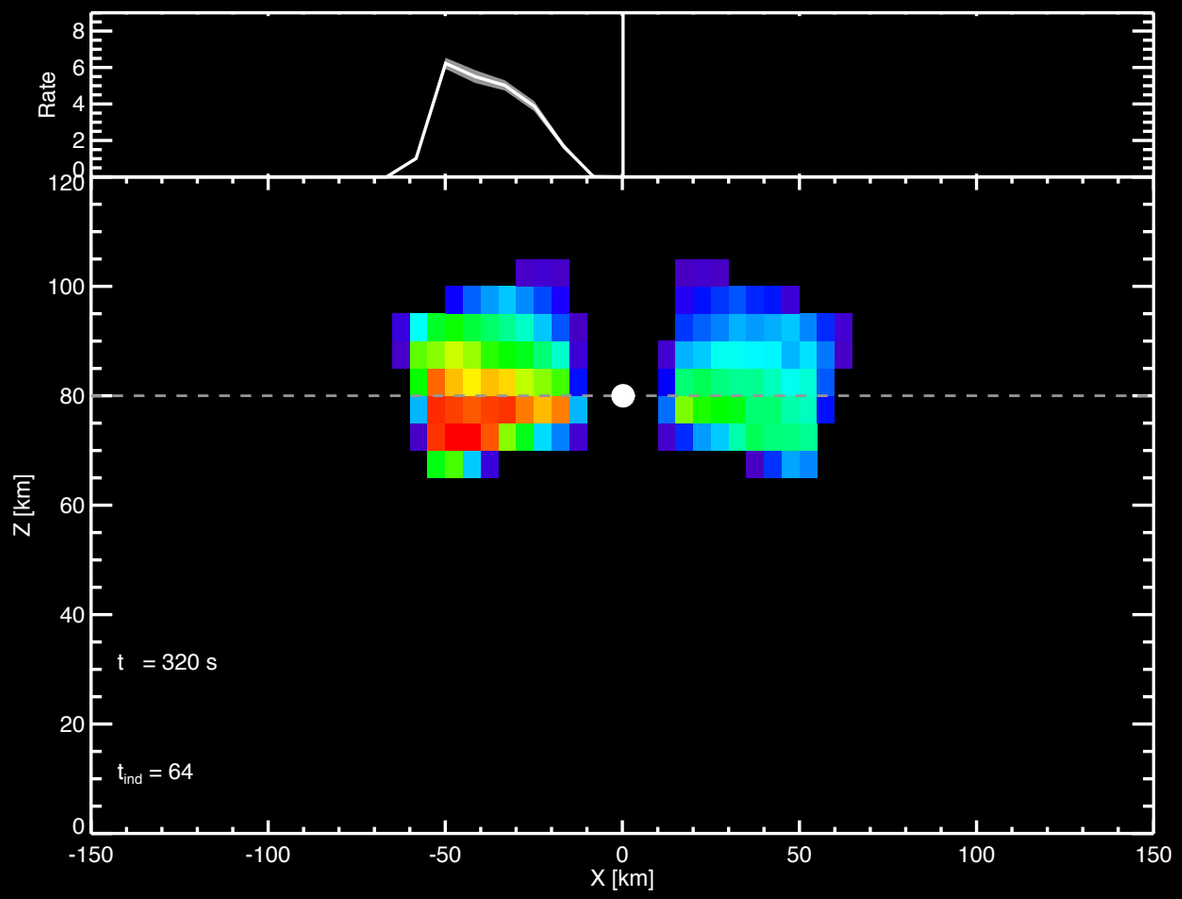
Ejecta Model

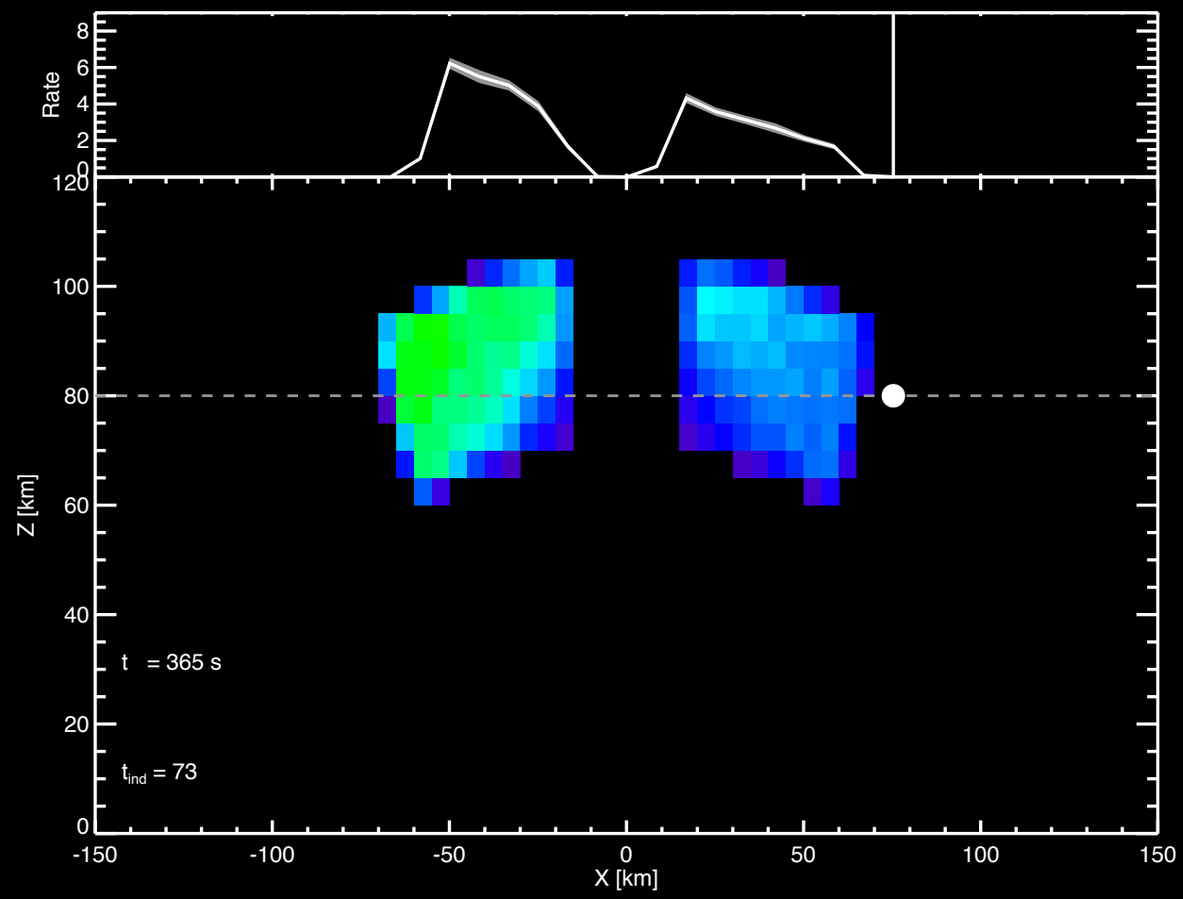
$$f(v) = \frac{1-\mu}{v_0^{1-\mu}} v^{\mu}$$

$$f(\varphi) = \frac{\sin\varphi}{\cos\varphi_1 - \cos\varphi_0}$$

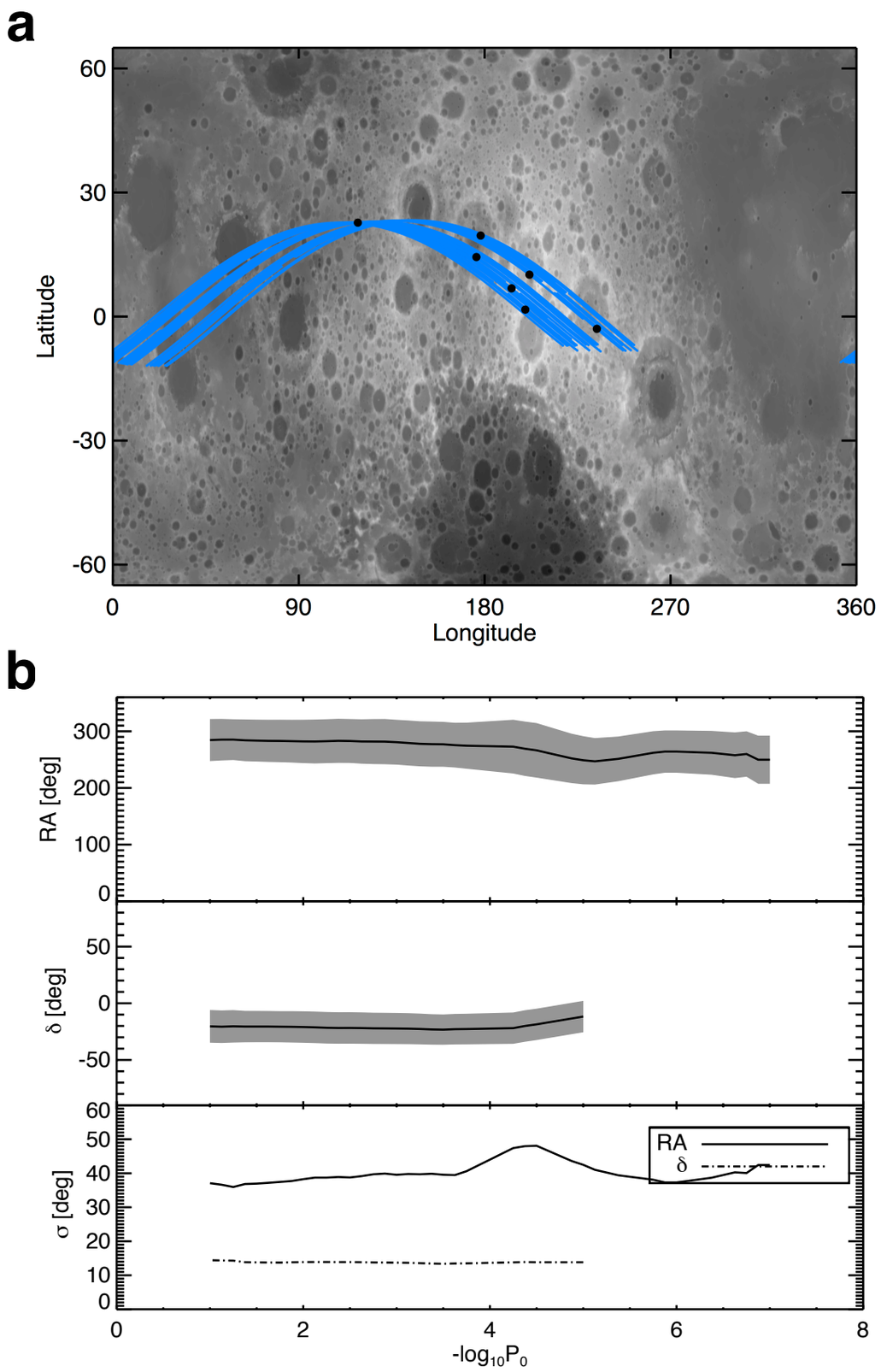


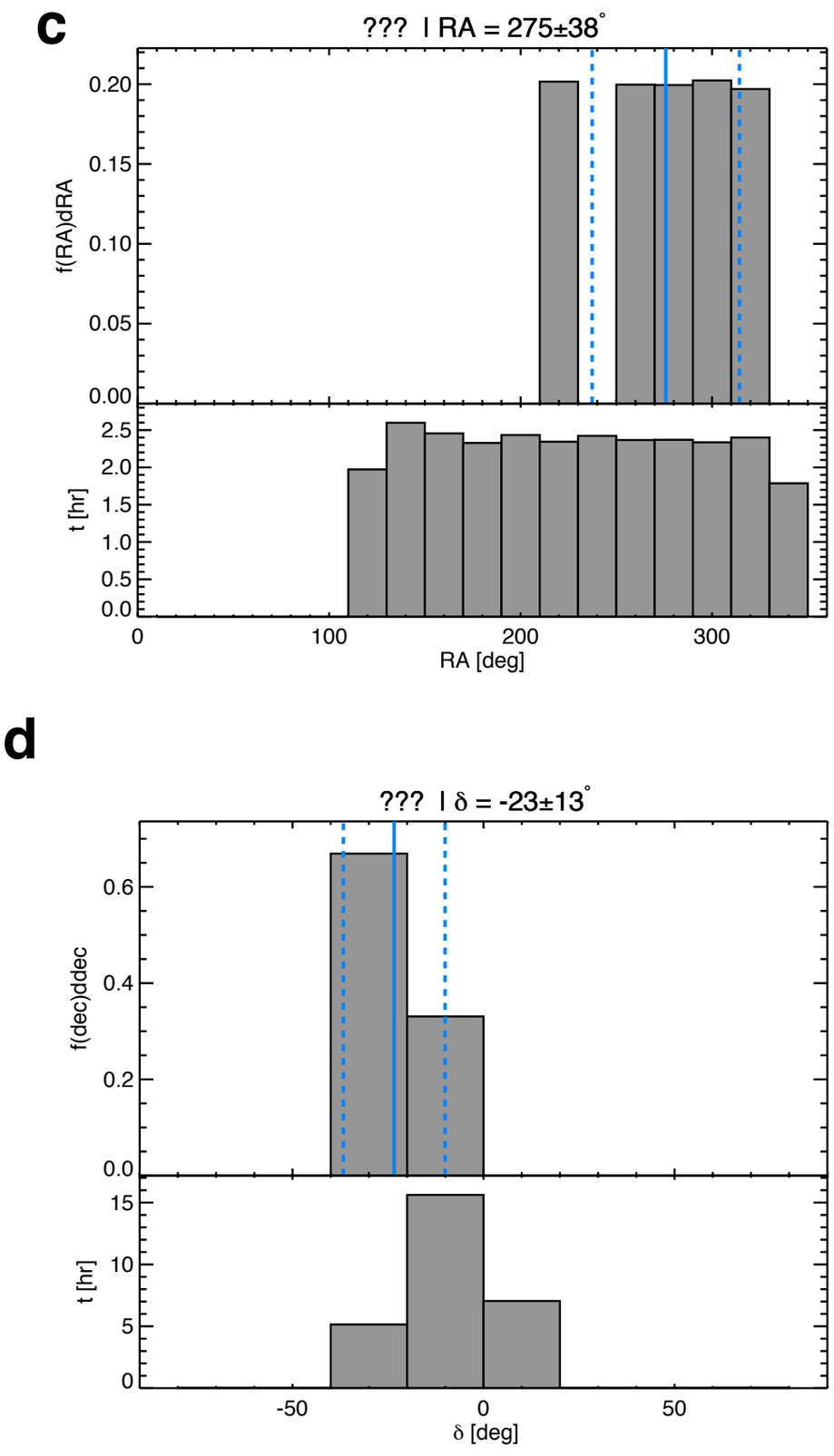
Impact Rate


Rate
8
6
4
2
0
120
100
80
60
40
20
0
Z [km]
t = 320 s
t_ind = 64
-150
-100
-50
0
50
100
150
X [km]

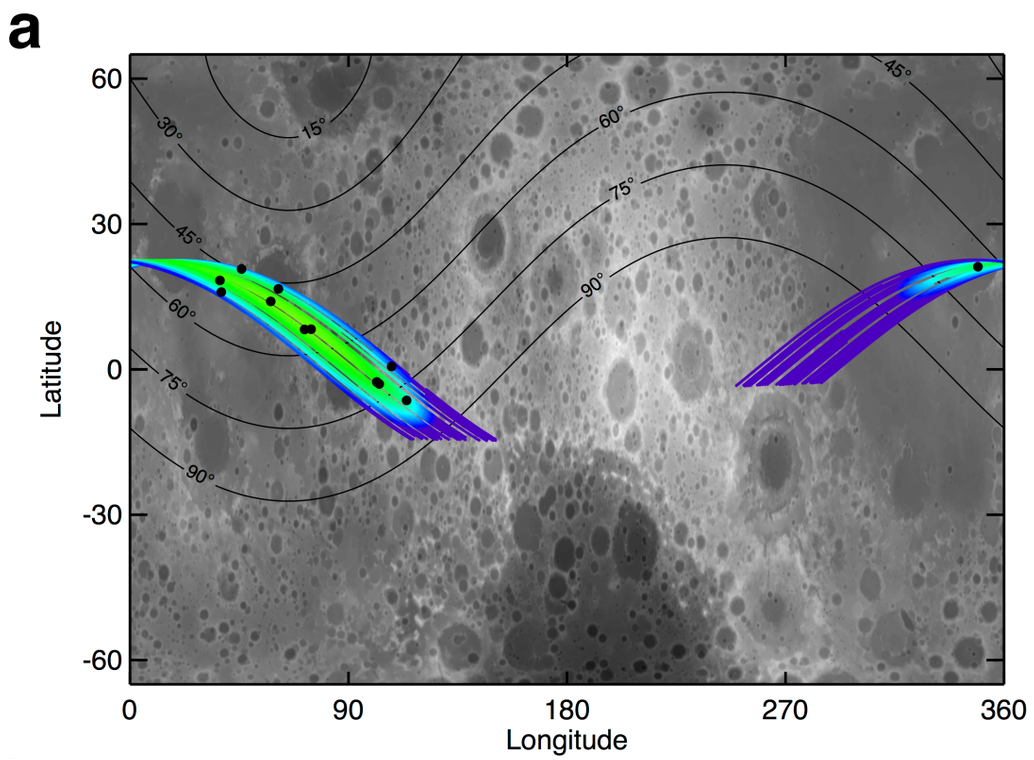

Rate
8
6
4
2
0
120
100
80
60
40
20
0
Z [km]
t = 365 s
t_ind = 73
-150
-100
-50
0
50
100
150
X [km]

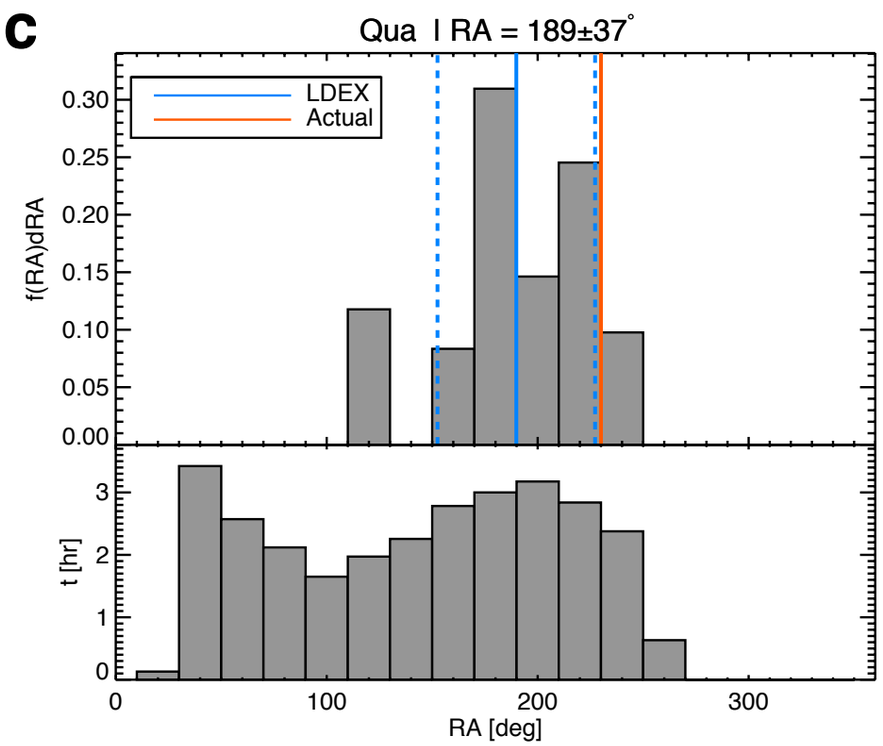
Unidentified Stream

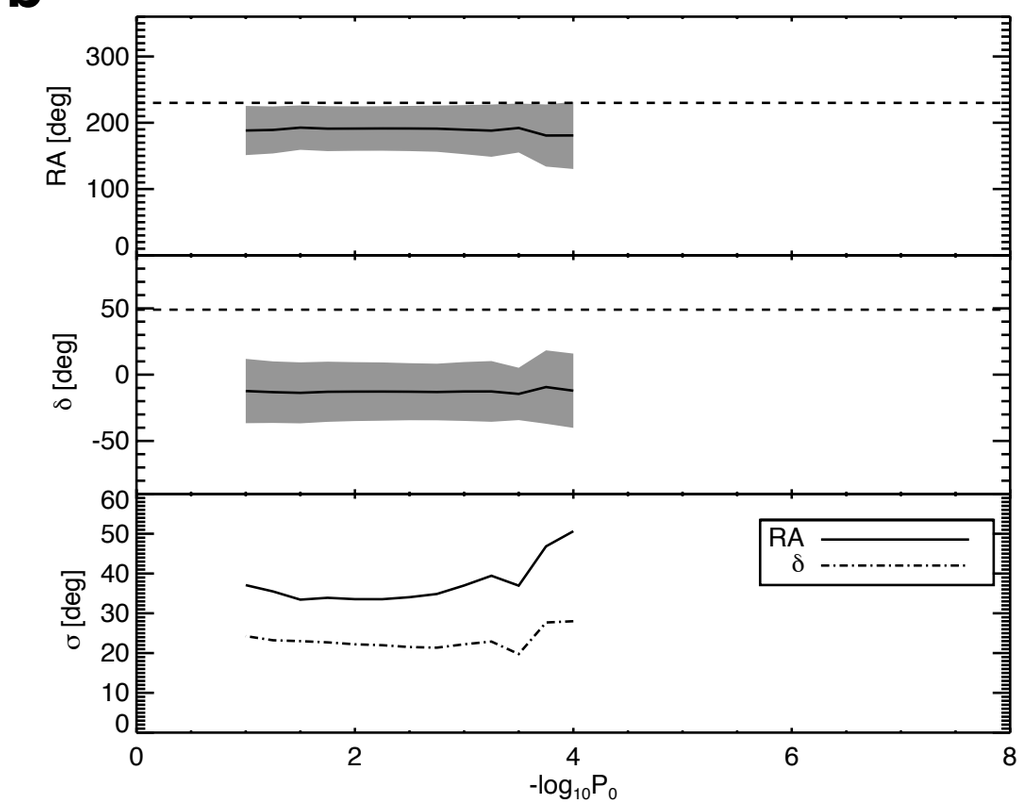


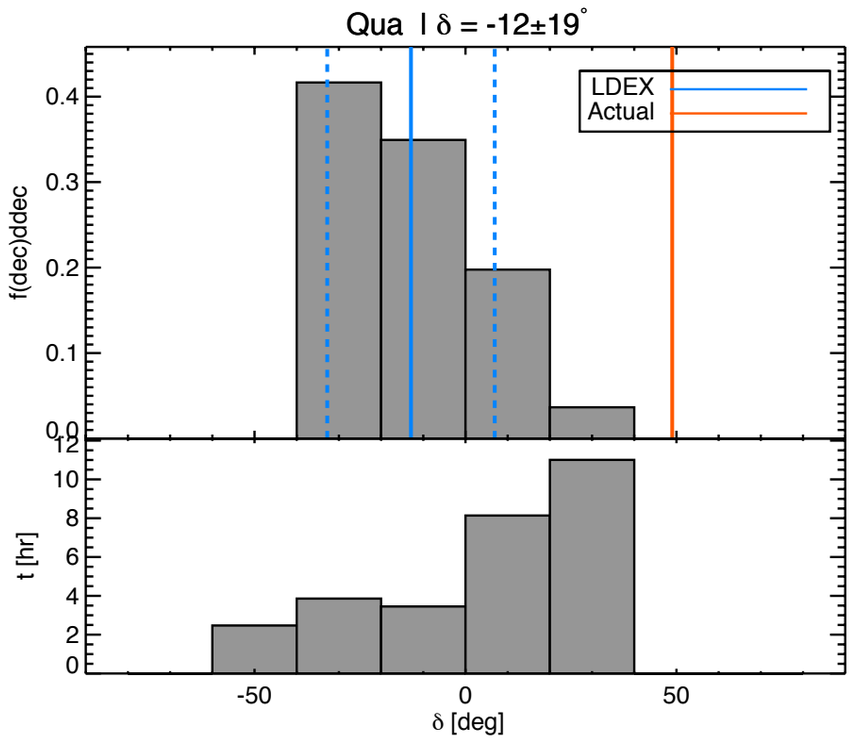


Quadrantids

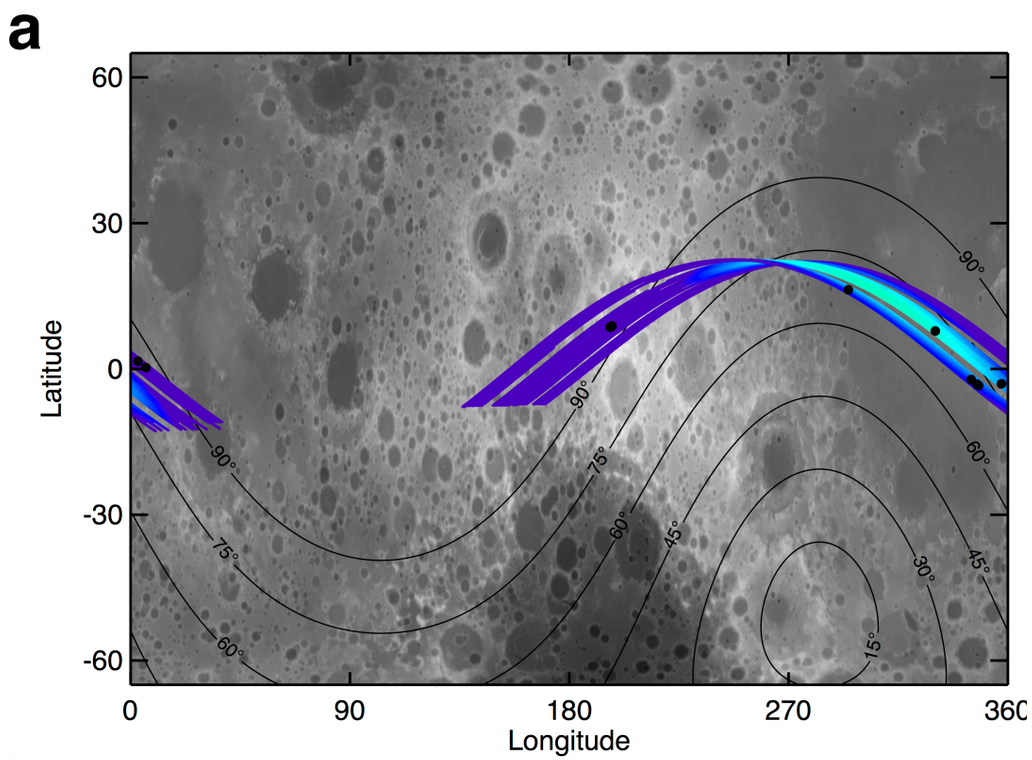


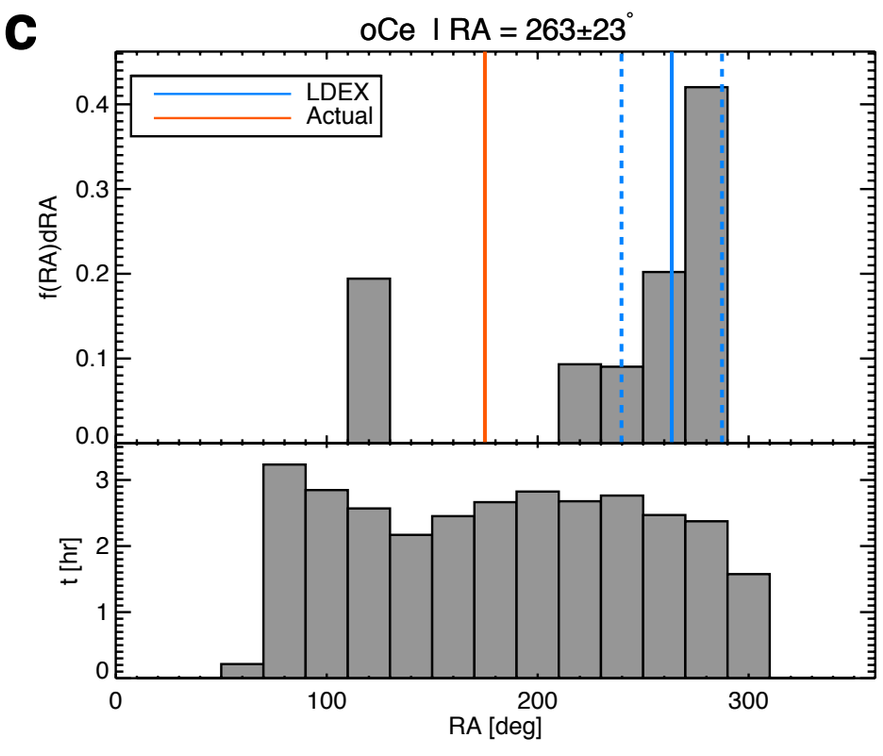


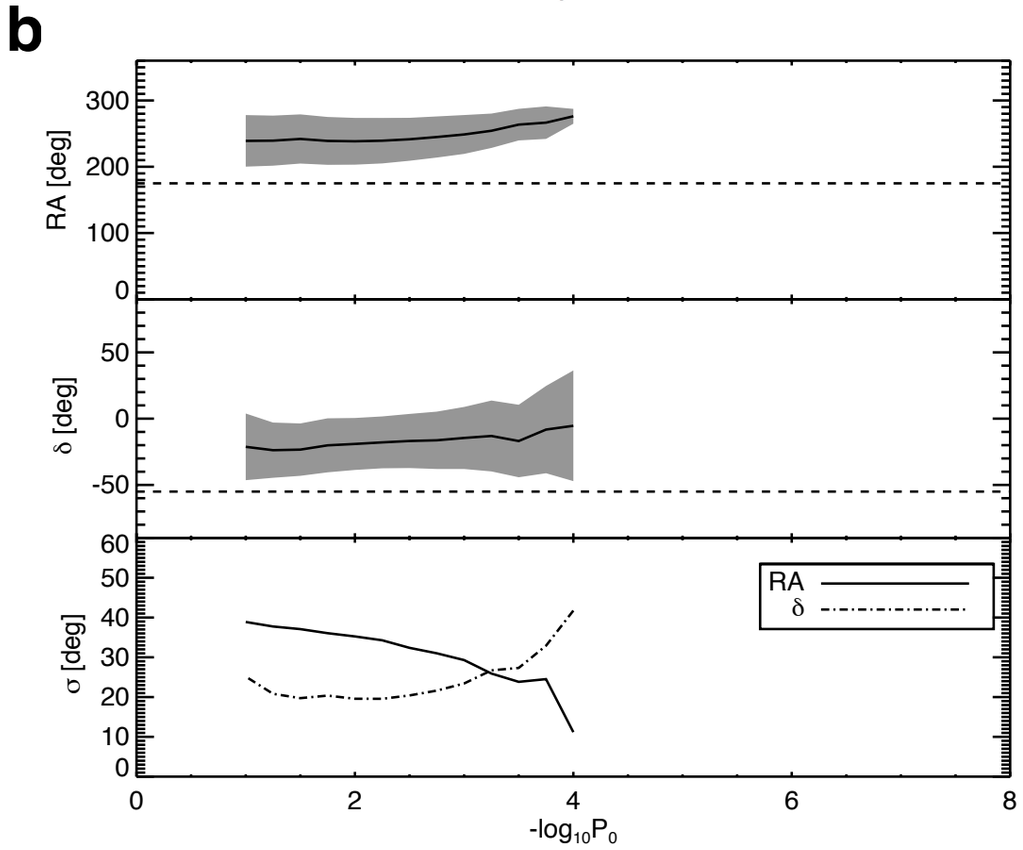


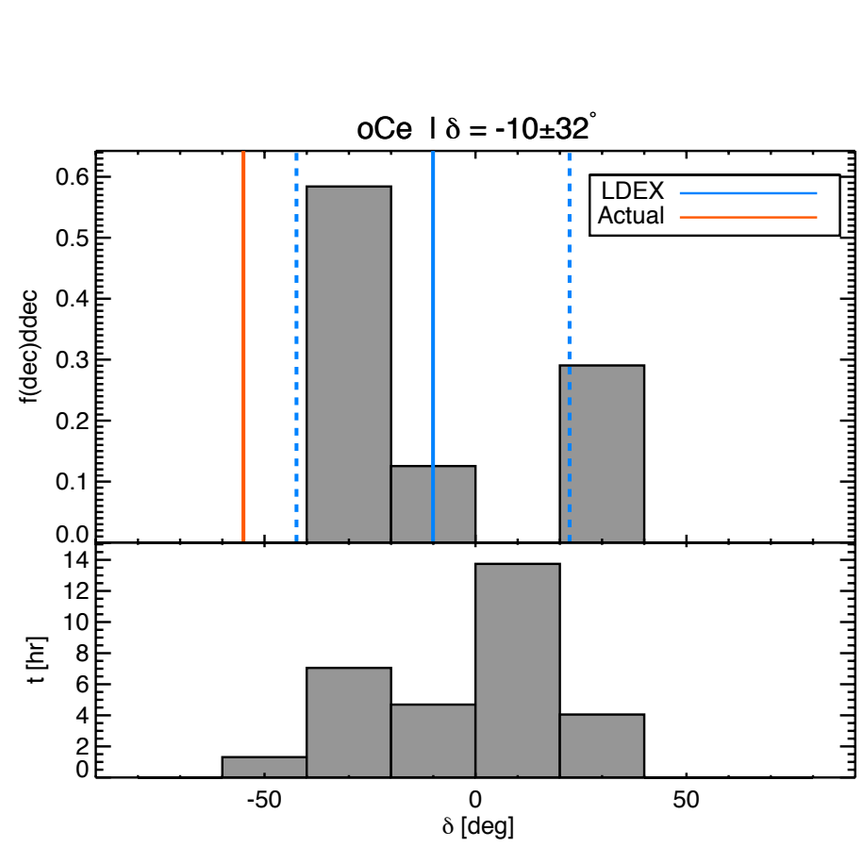


Omicron Centaurids

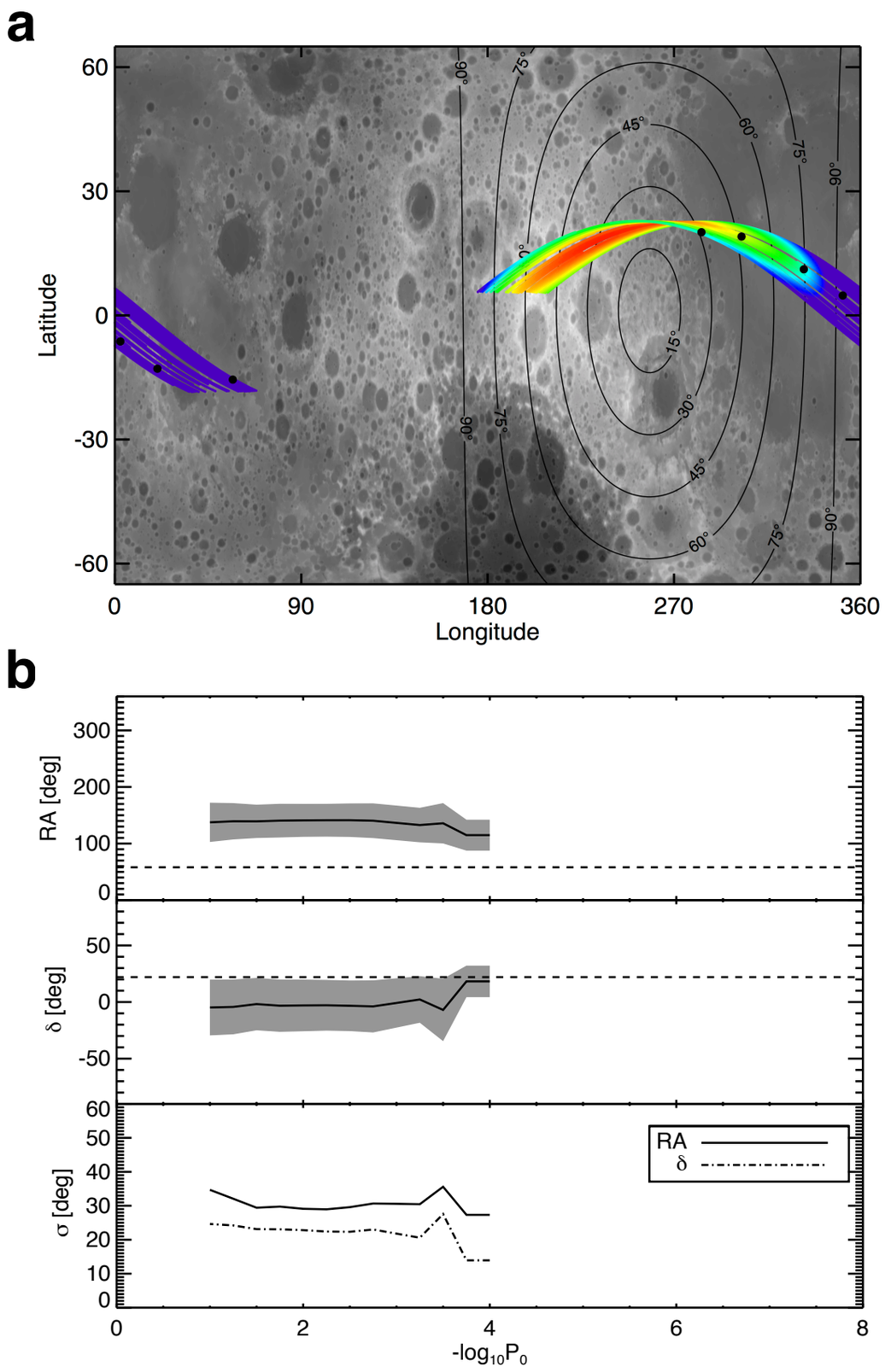


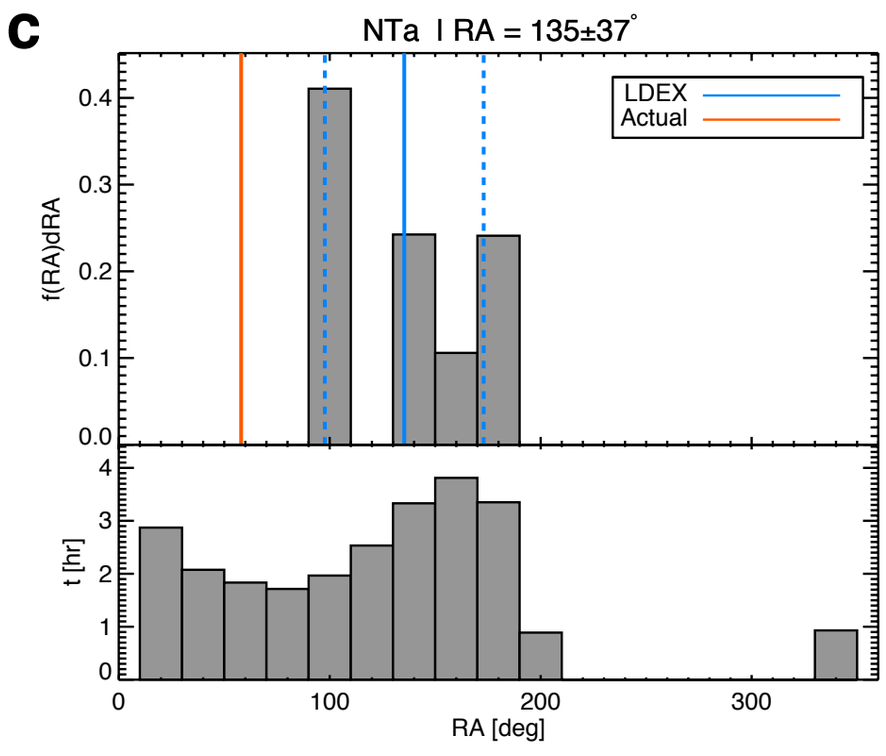


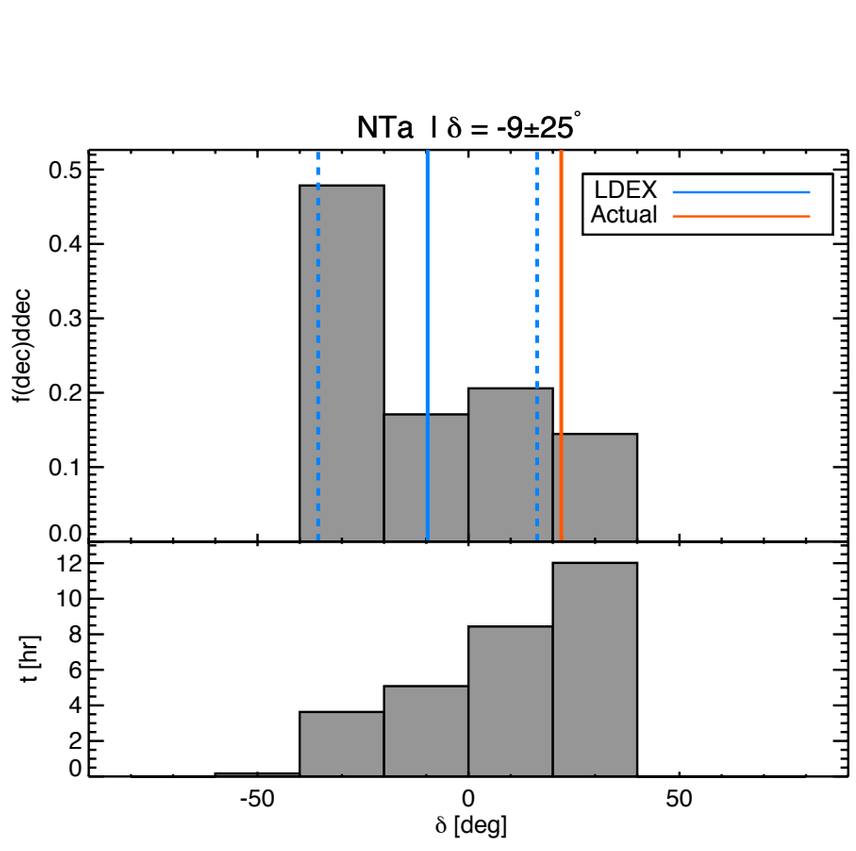
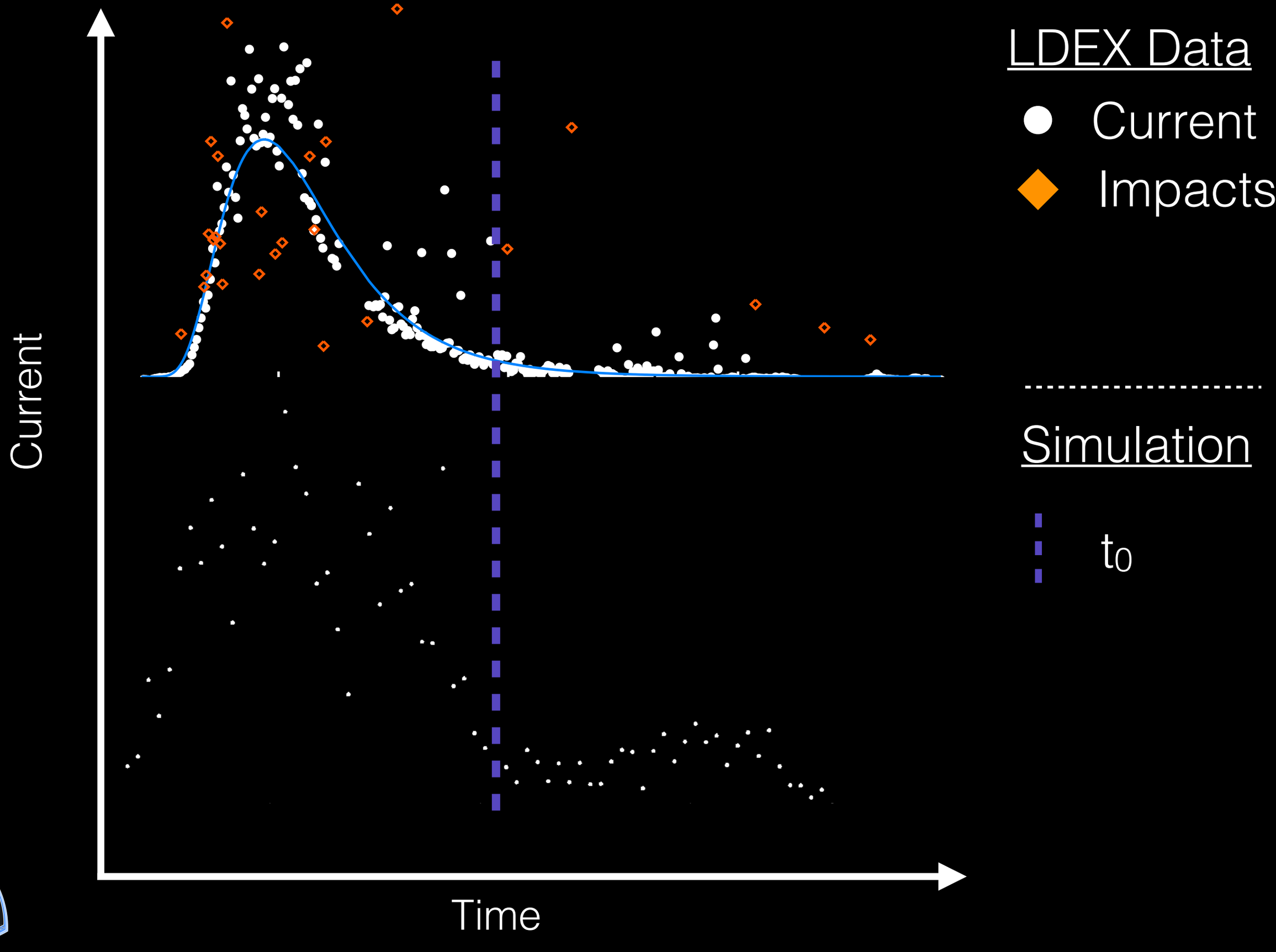




Northern Taurids







Comparison