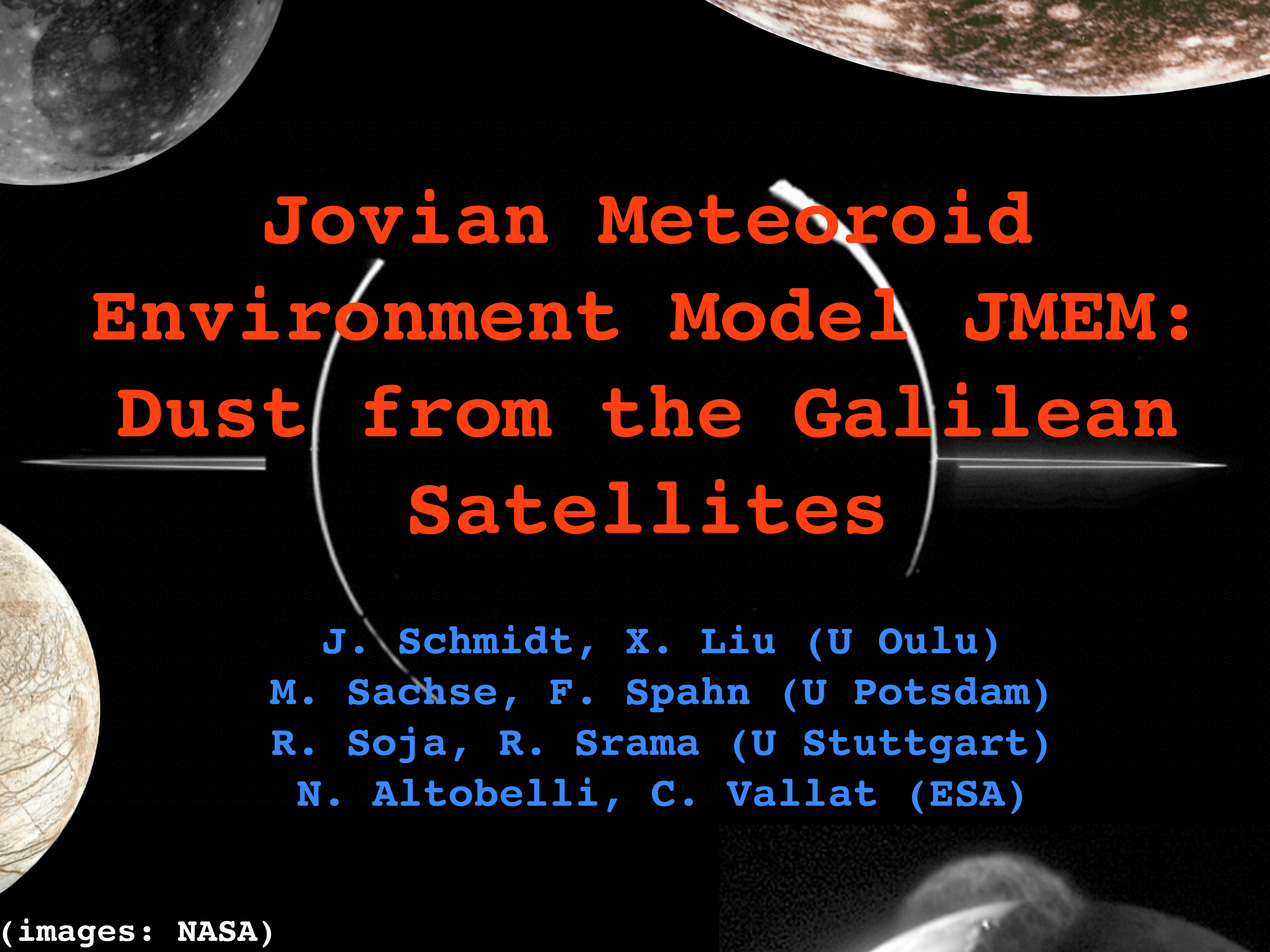


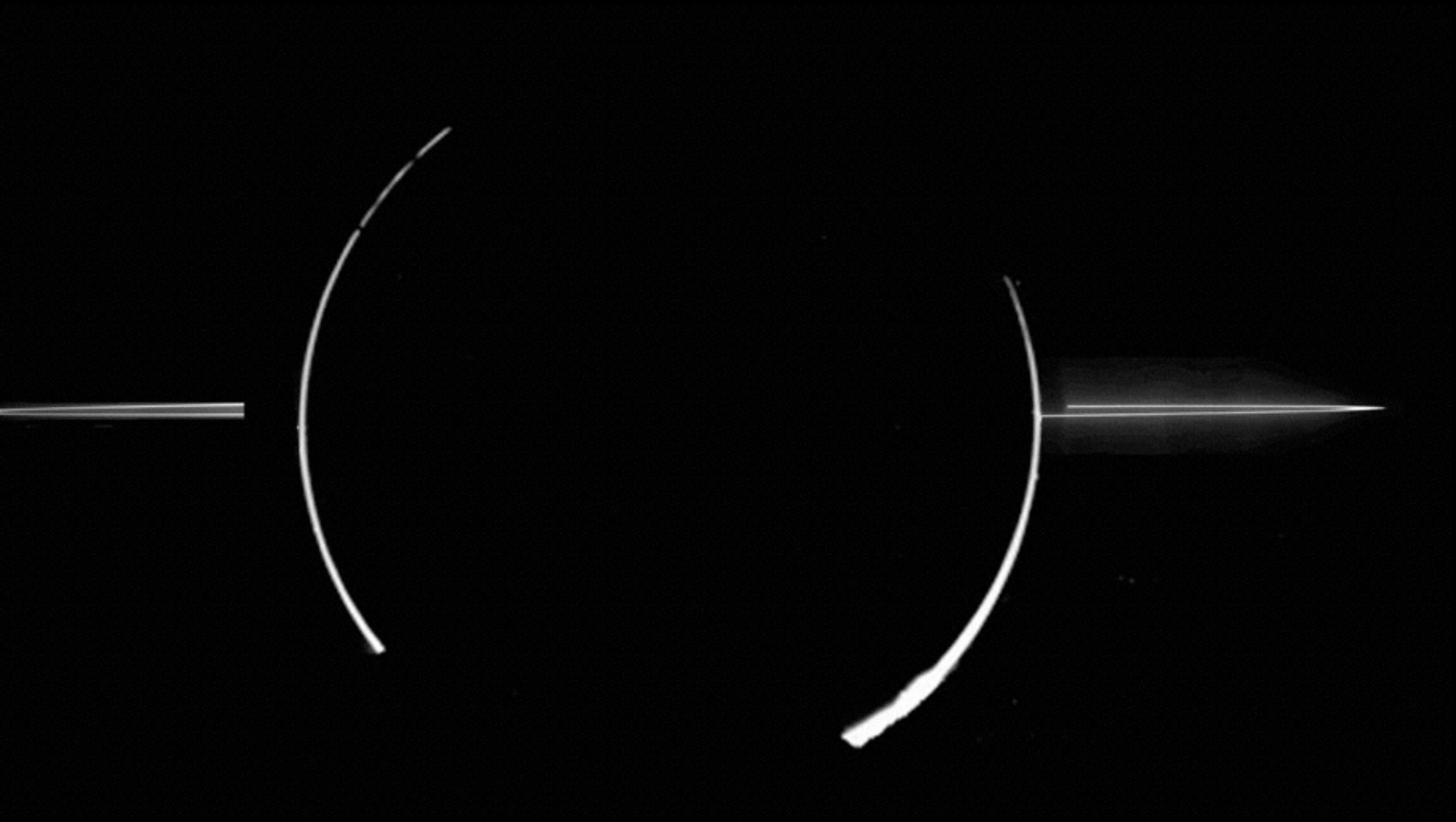
Jovian Meteoroid Environment Model JMEM: Dust from the Galilean Satellites

J. Schmidt, X. Liu (U Oulu)
M. Sachse, F. Spahn (U Potsdam)
R. Soja, R. Srama (U Stuttgart)
N. Altobelli, C. Vallat (ESA)

(images: NASA)

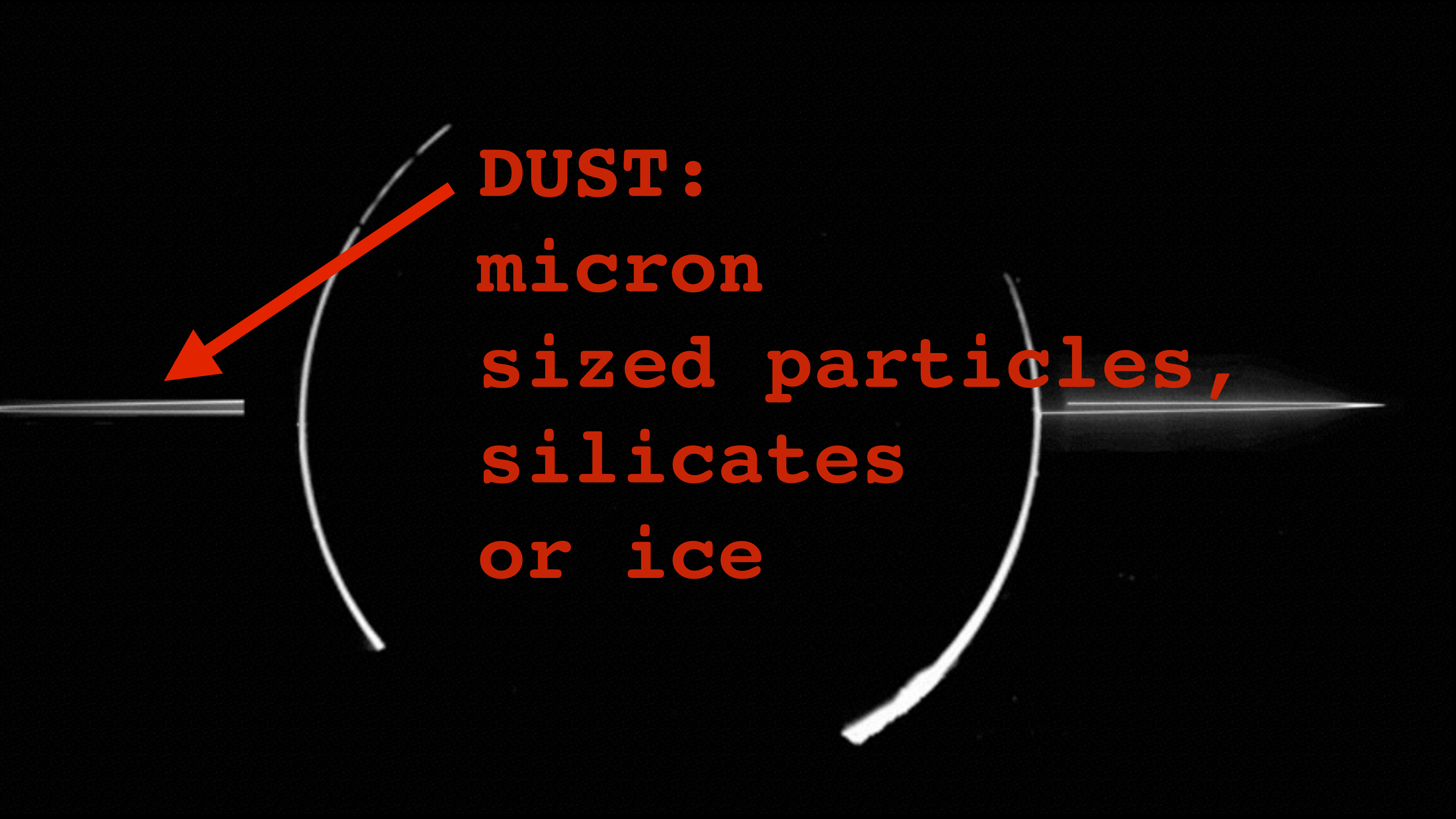
Background

Jupiter's ring system and ring moons



(images: NASA)

Jupiter's ring system and ring moons

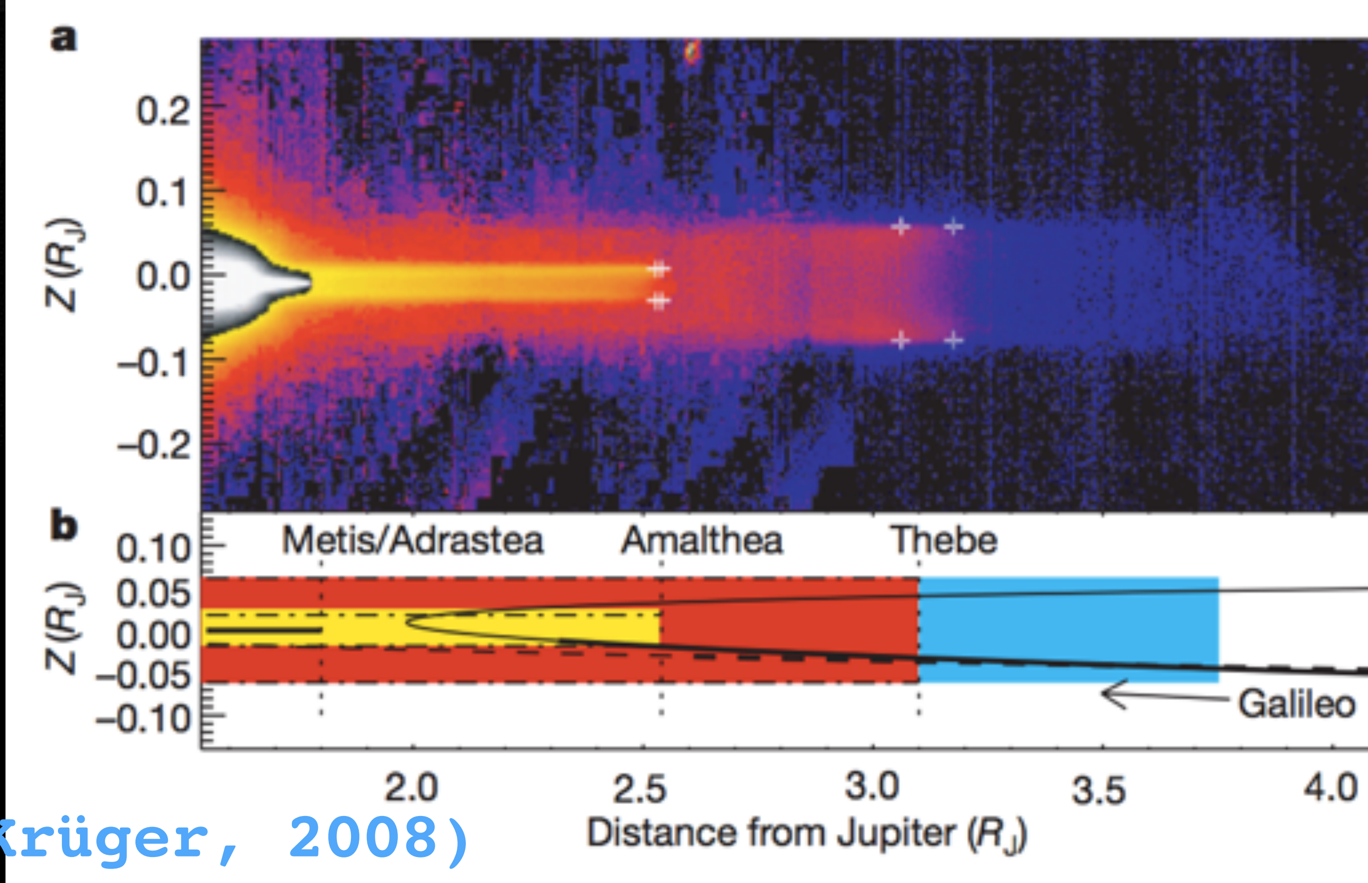


DUST:
micron
sized particles,
silicates
or ice

(images: NASA)

Jupiter's ring system and ring moons

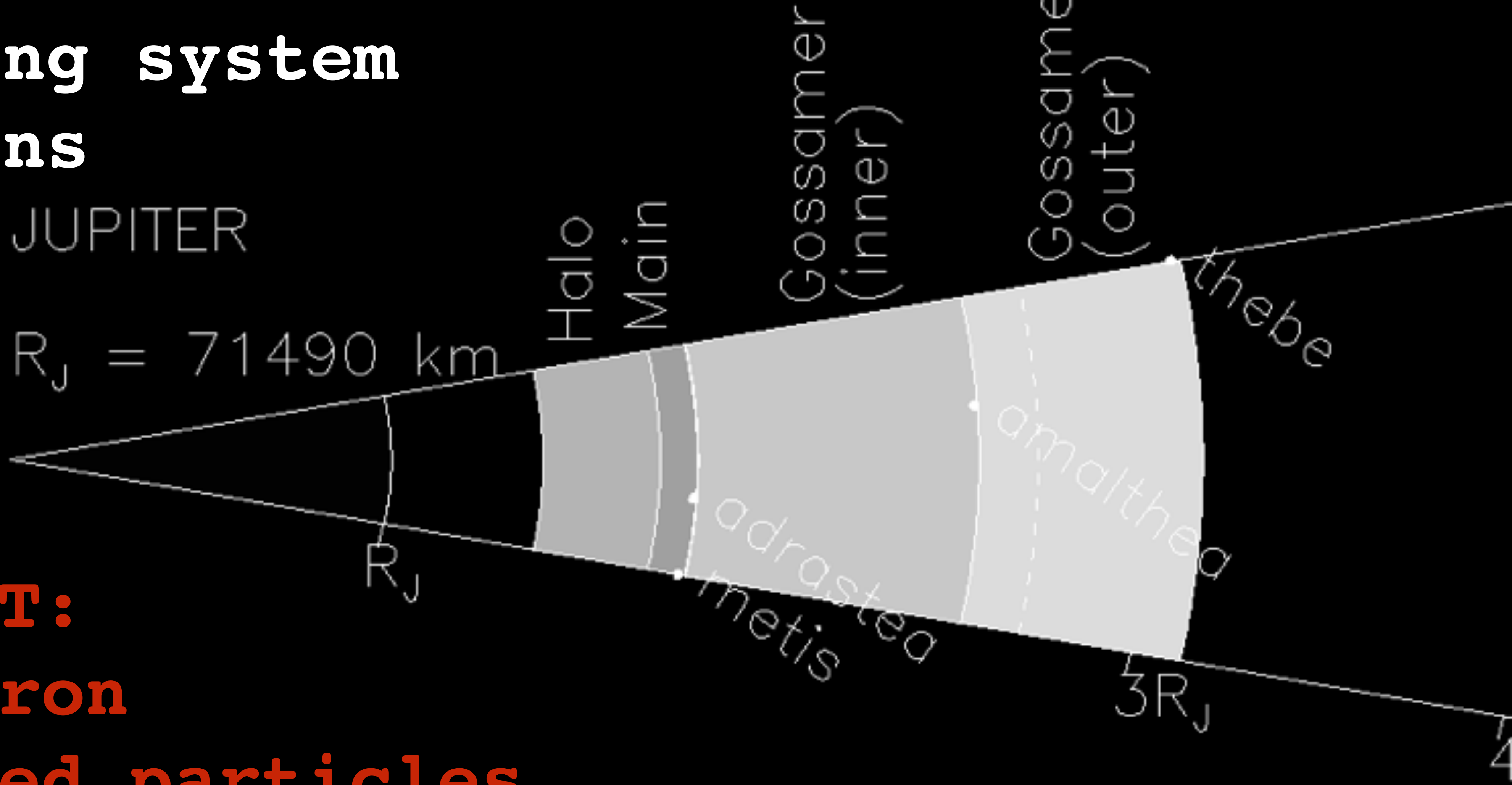
DUST:
micron sized particles,
silicates
or ice



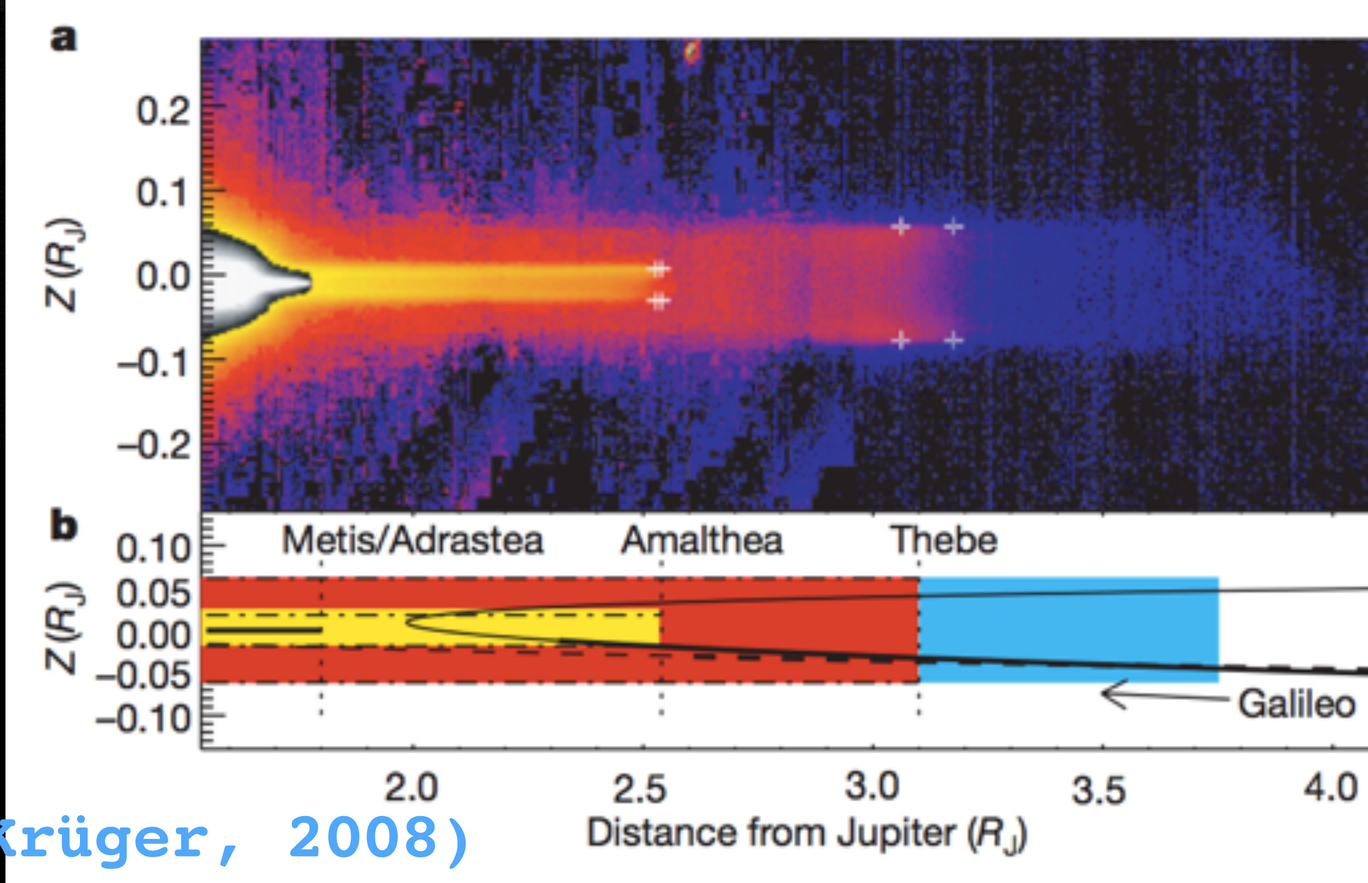
(Hamilton&Krüger, 2008)

(images: NASA)

Jupiter's ring system and ring moons



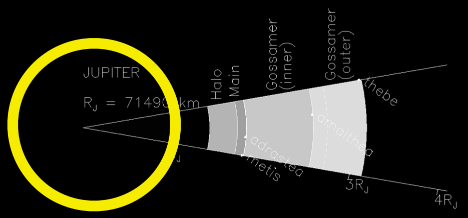
DUST: micron sized particles, silicates or ice



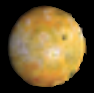
(Hamilton&Krüger, 2008)

(images: NASA)

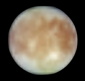
four large moons



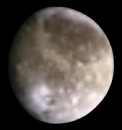
rings



Io

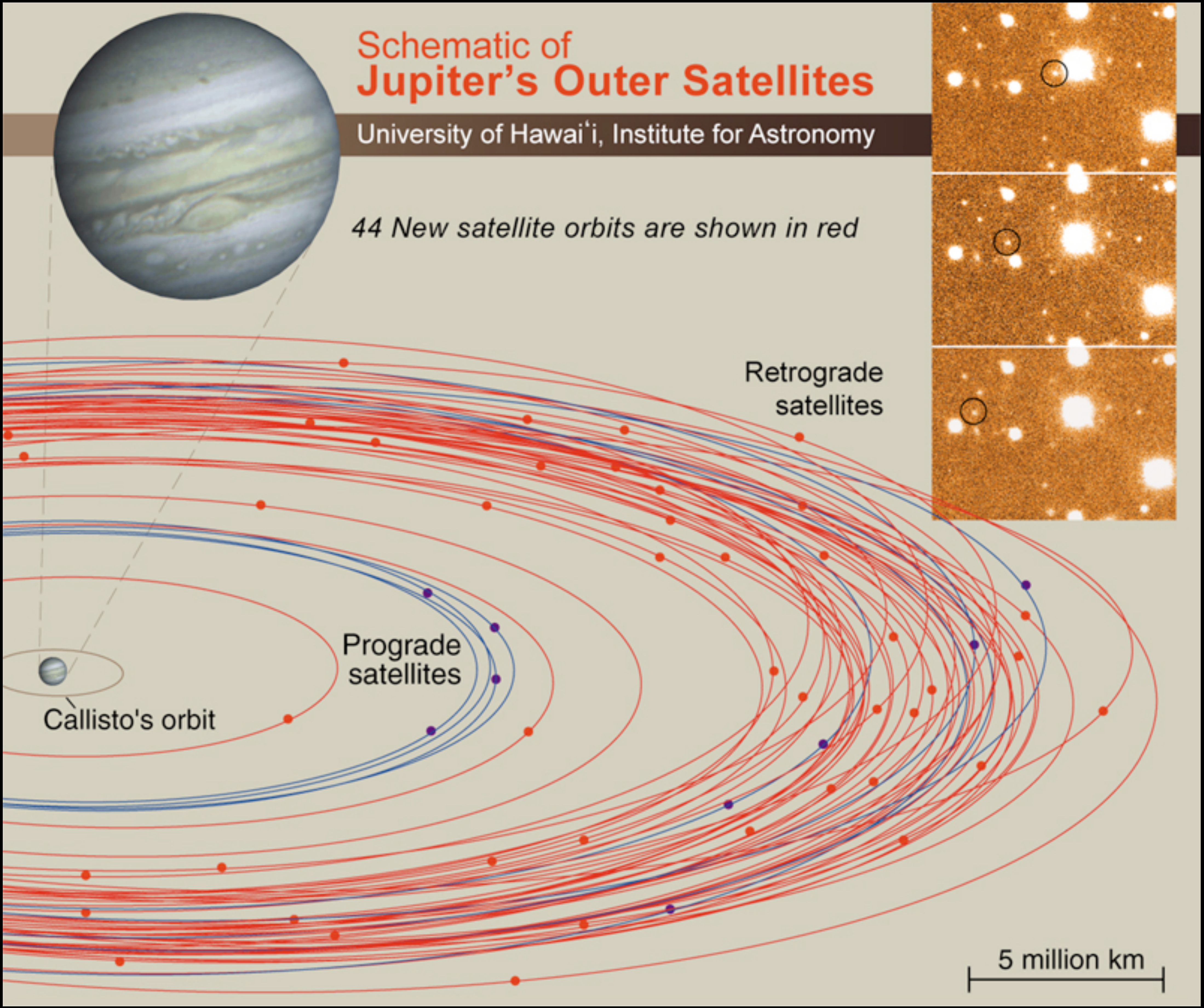


Europa



Ganymede

Callisto



Schematic of Jupiter's Outer Satellites

University of Hawaiʻi, Institute for Astronomy

44 New satellite orbits are shown in red

Dust is all over the place:

(images: NASA)

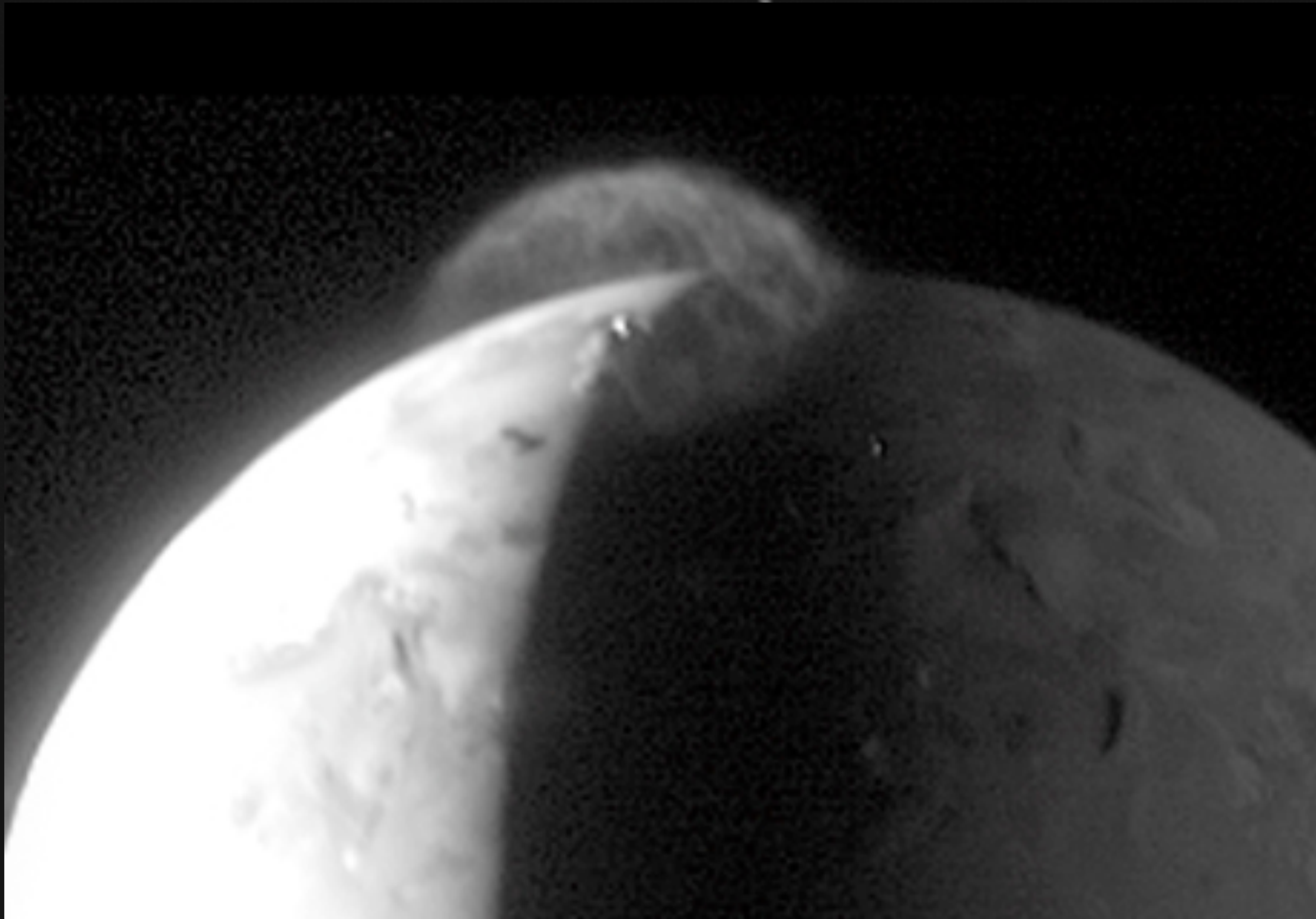
Dust is all over the place:

* main rings, halo & gossamer ring

(images: NASA)

Dust is all over the place:

- main rings, halo & gossamer ring
- stream particles from Io's volcanoes



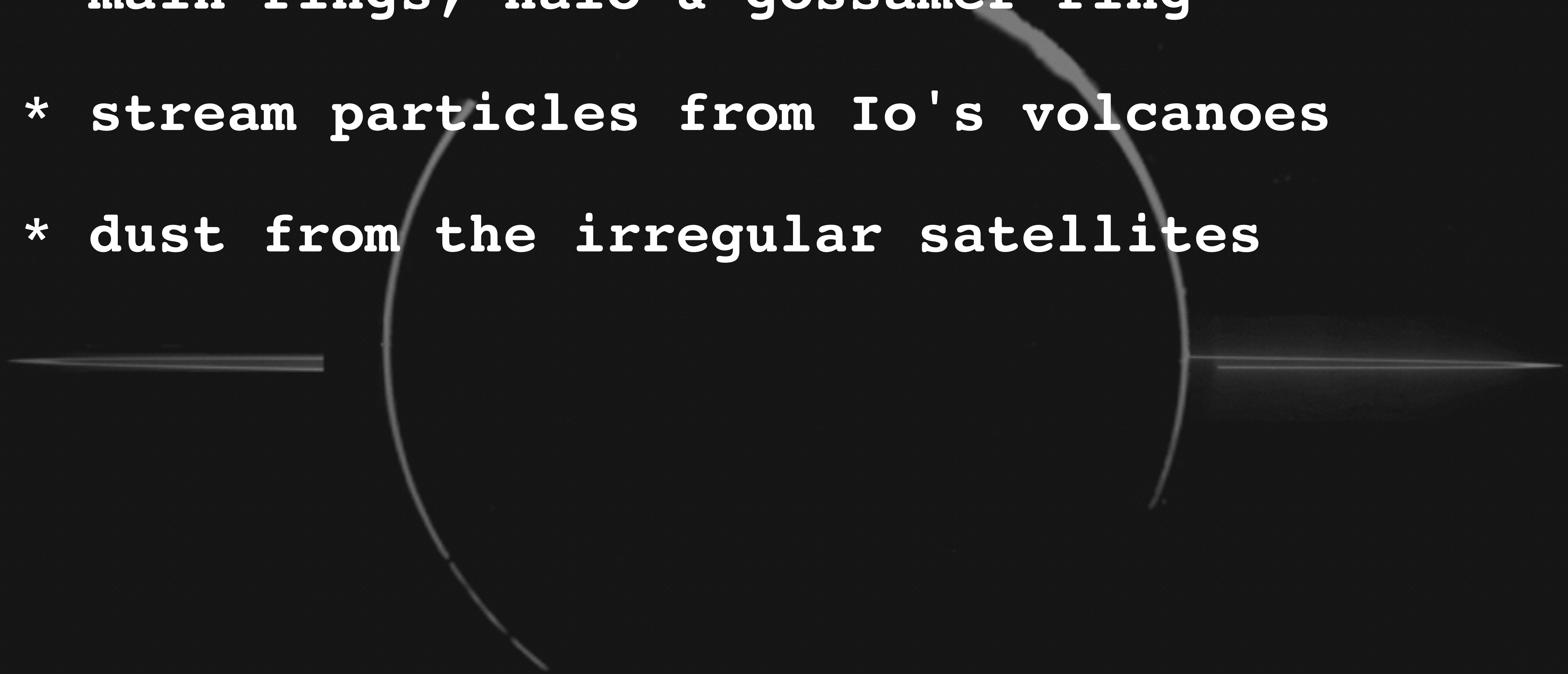
(images: NASA)

Dust is all over the place:

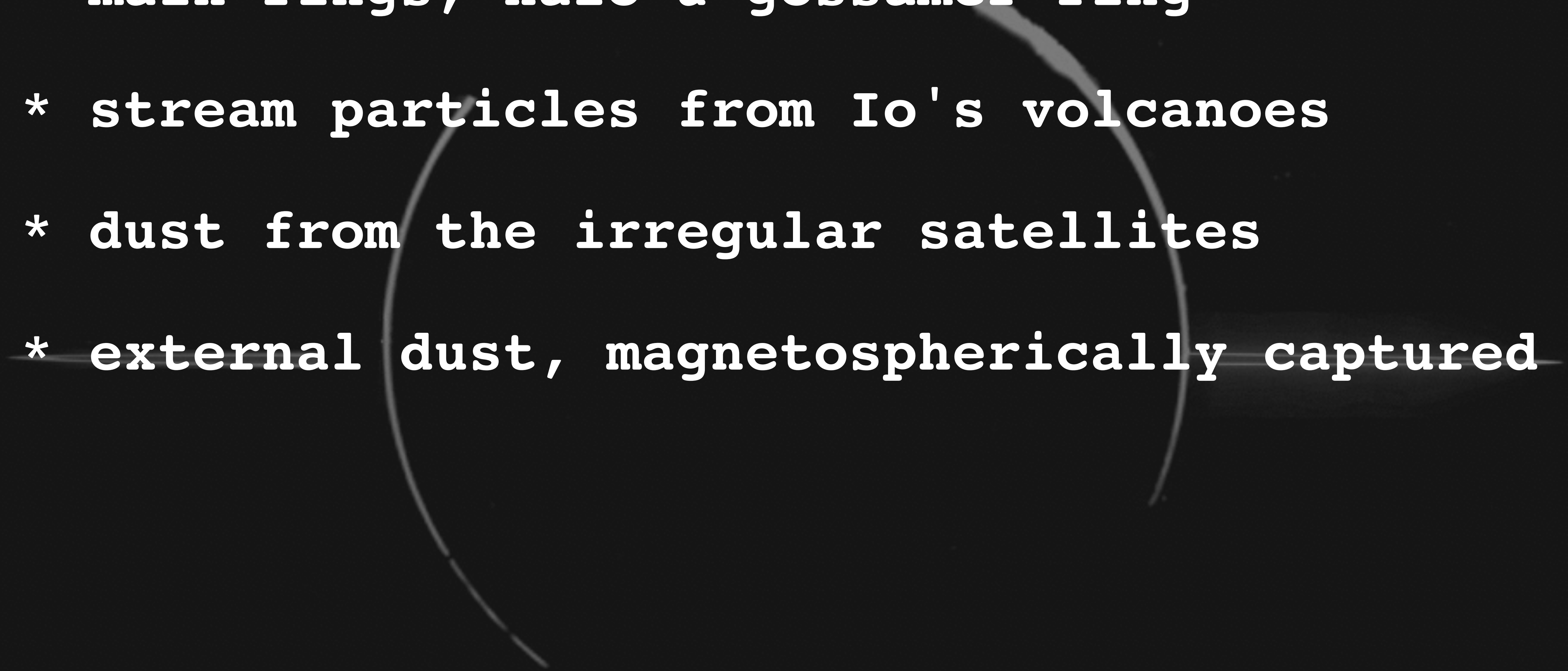
* main rings, halo & gossamer ring

* stream particles from Io's volcanoes

* dust from the irregular satellites



(images: NASA)



Dust is all over the place:

* main rings, halo & gossamer ring

* stream particles from Io's volcanoes

* dust from the irregular satellites

* external dust, magnetospherically captured

(images: NASA)

Dust is all over the place:

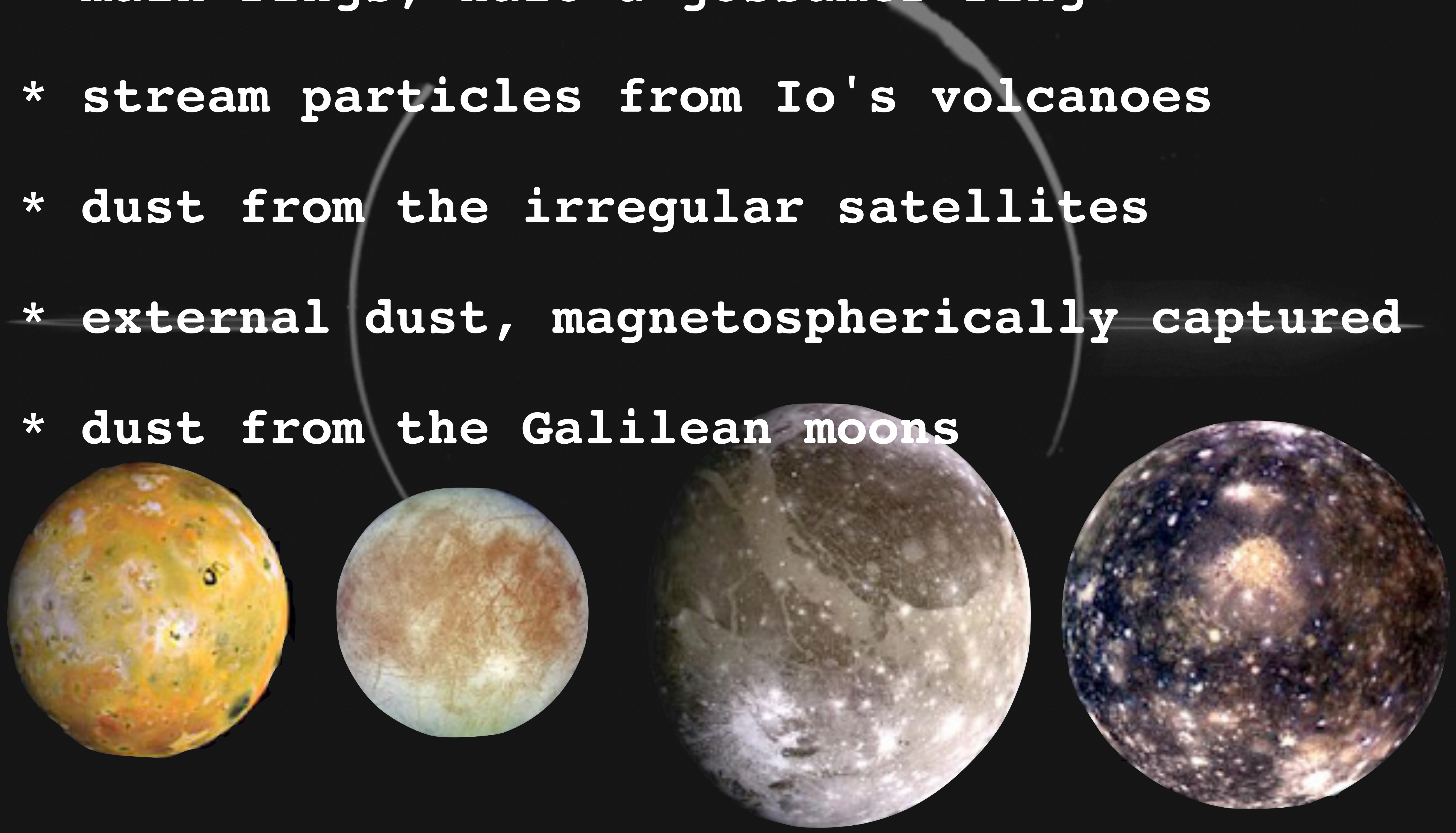
* main rings, halo & gossamer ring

* stream particles from Io's volcanoes

* dust from the irregular satellites

* external dust, magnetospherically captured

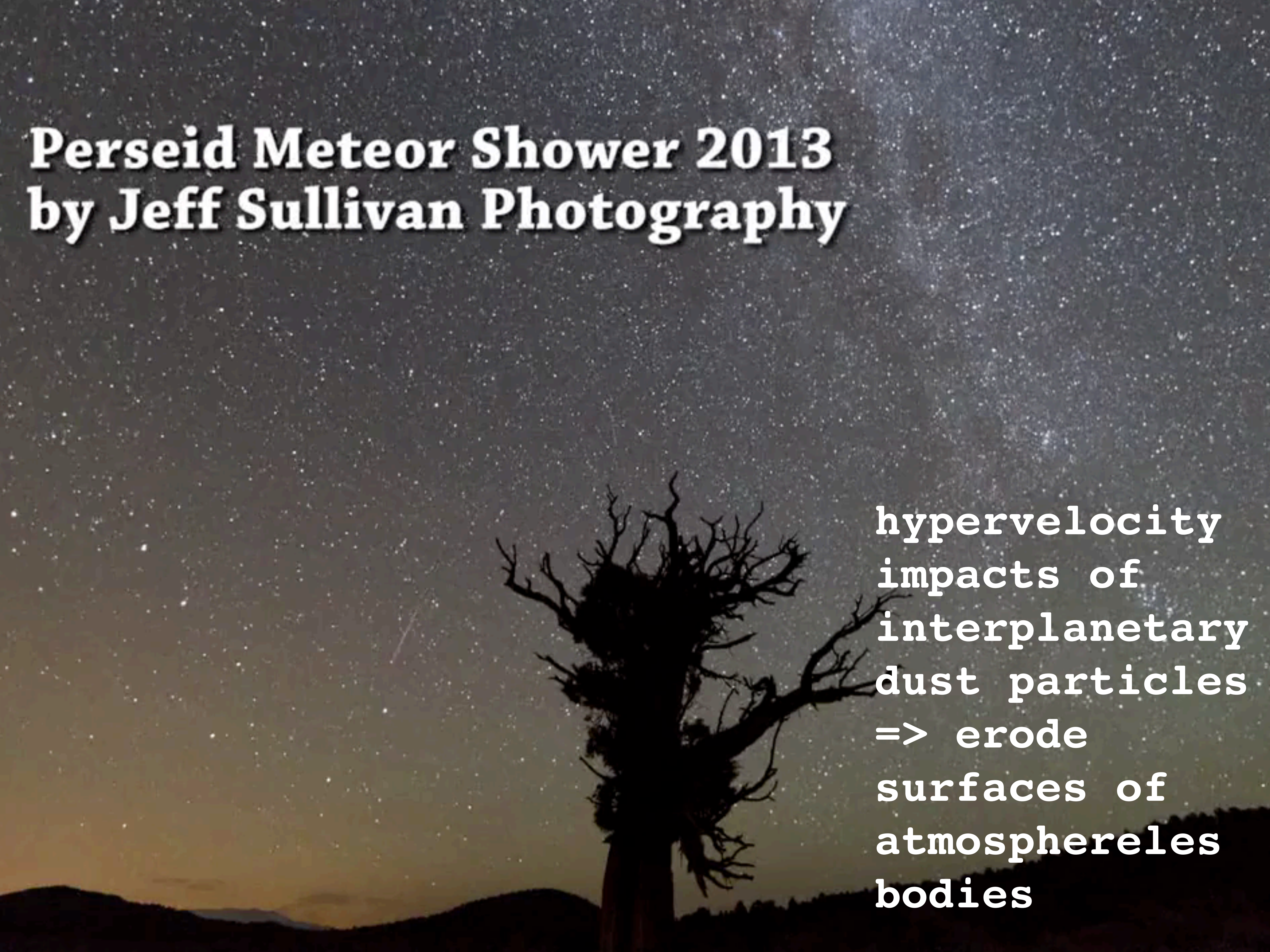
* dust from the Galilean moons



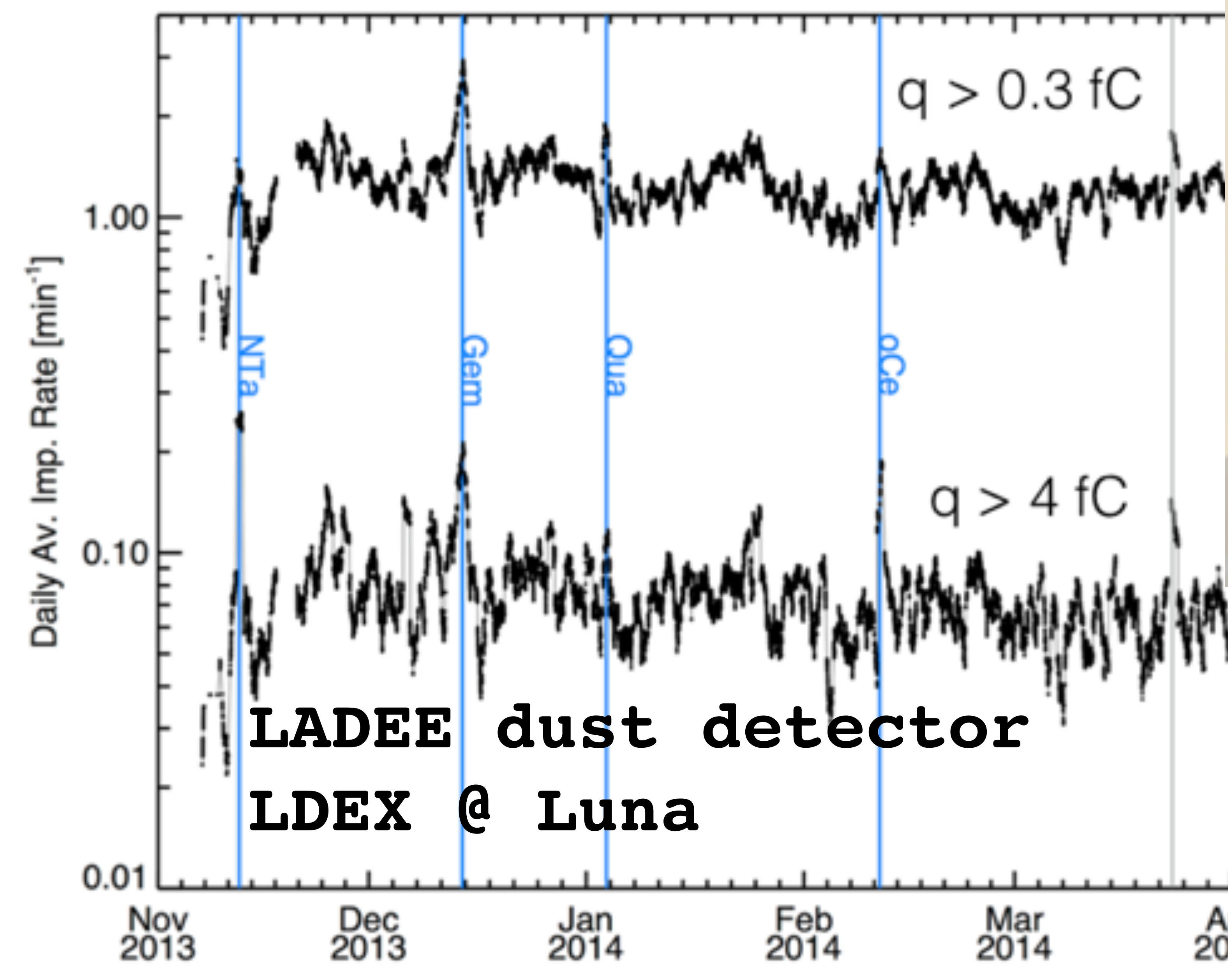
(images: NASA)

Perseid Meteor Shower 2013
by Jeff Sullivan Photography

Perseid Meteor Shower 2013
by Jeff Sullivan Photography

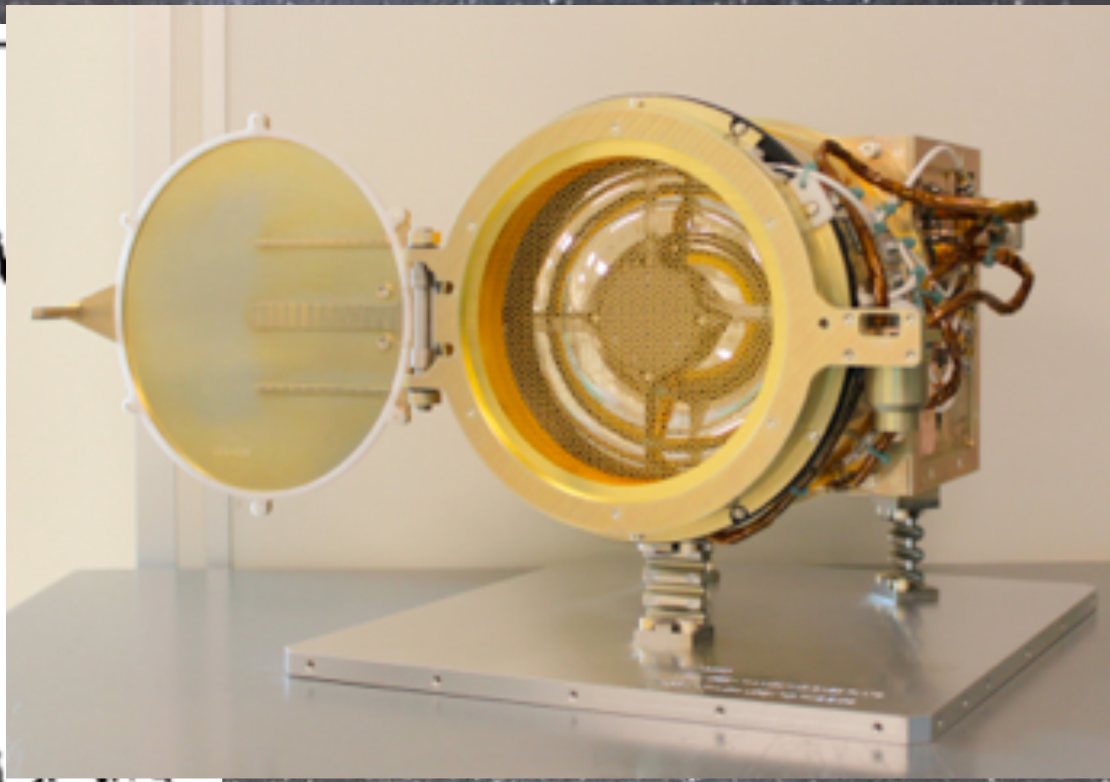


hypervelocity impacts of interplanetary dust particles => erode surfaces of atmosphereles bodies



LADEE dust detector
LDEX @ Luna

(Horanyi et al,Nature, 2015)



(LASP/CU Boulder)

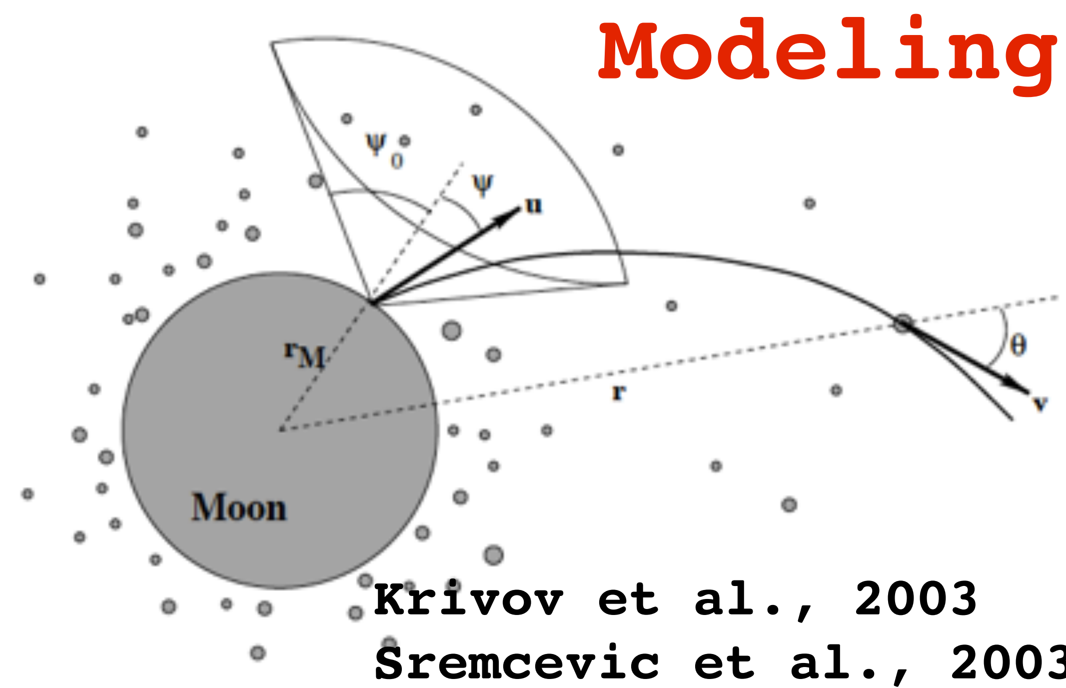
hypervelocity impacts of interplanetary dust particles => erode surfaces of atmosphereles bodies

Dust from the Galilean moons:

-> dust exospheres

(Krüger, 1999, Nature)

replenish cirumplanetary dust environment



Modeling

Krivov et al., 2003
Sremcevic et al., 2003

Dust from the Galilean moons:

-> dust exospheres

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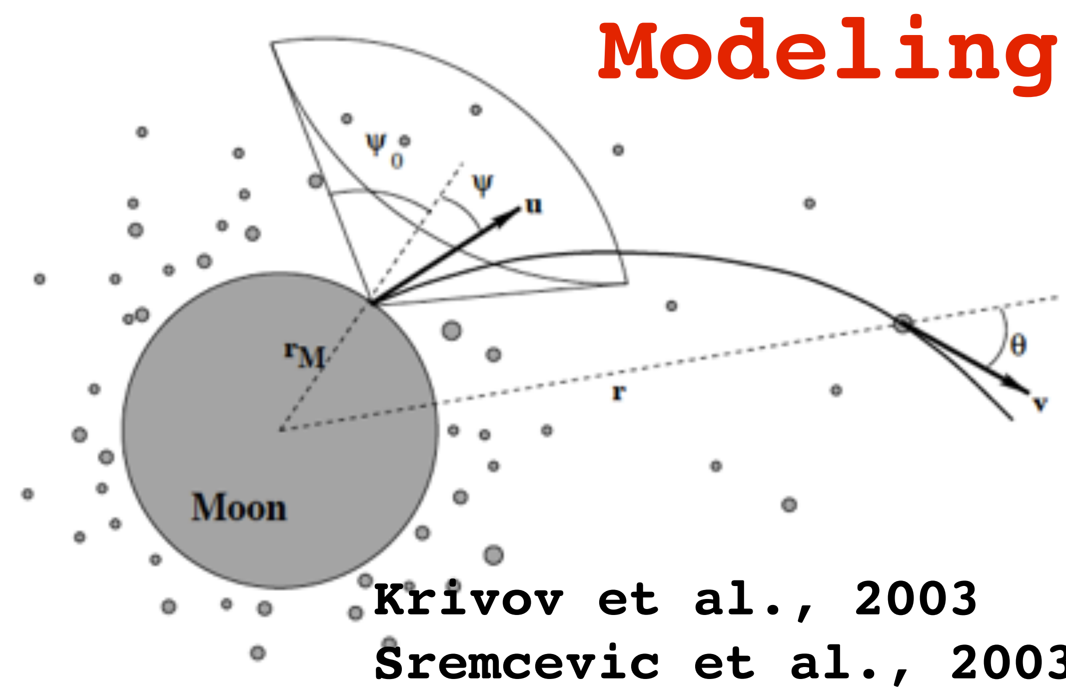
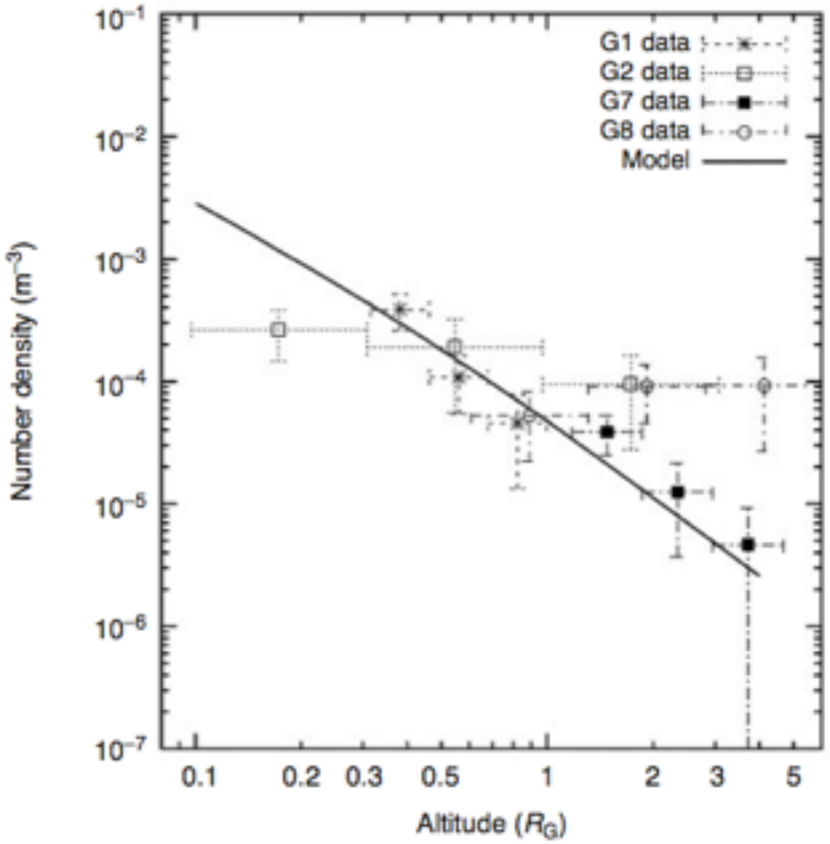
replenish cirumplanetary dust environment

Modeling

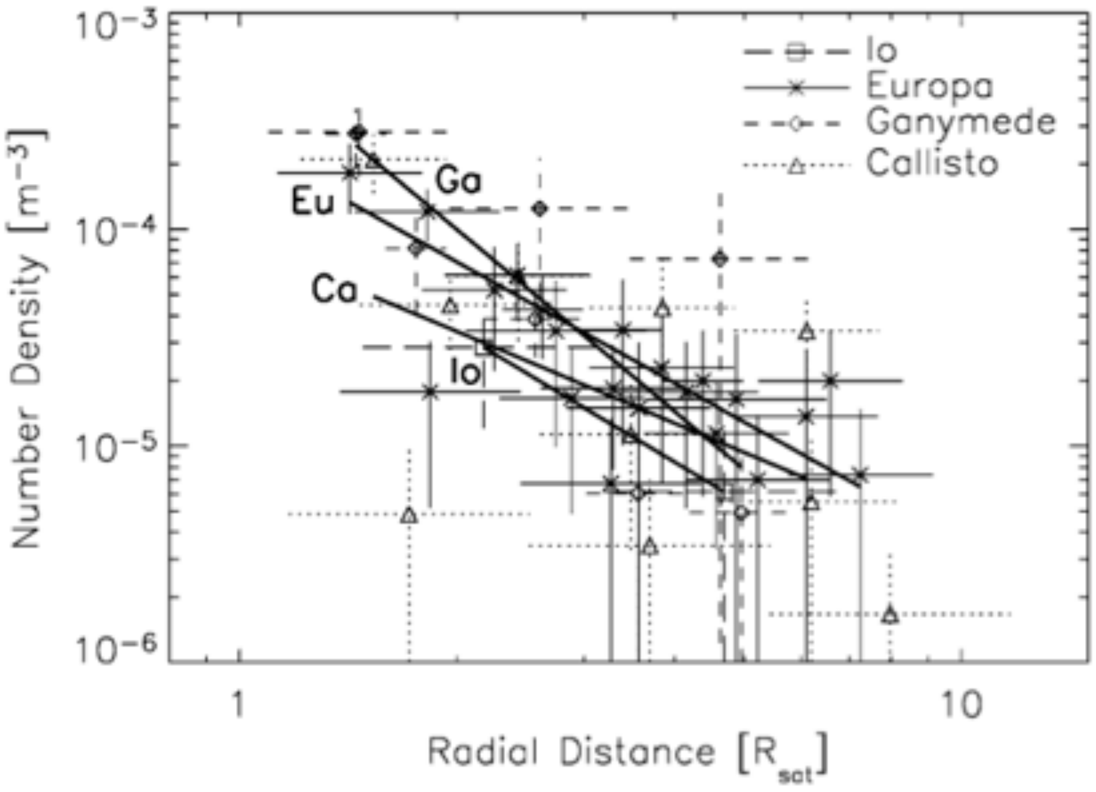


Krivov et al., 2003
Sremcevic et al., 2003

Galileo DDS data:



(Krüger et al, 1999, Nature)



(Krüger et al, 2003, Icarus)

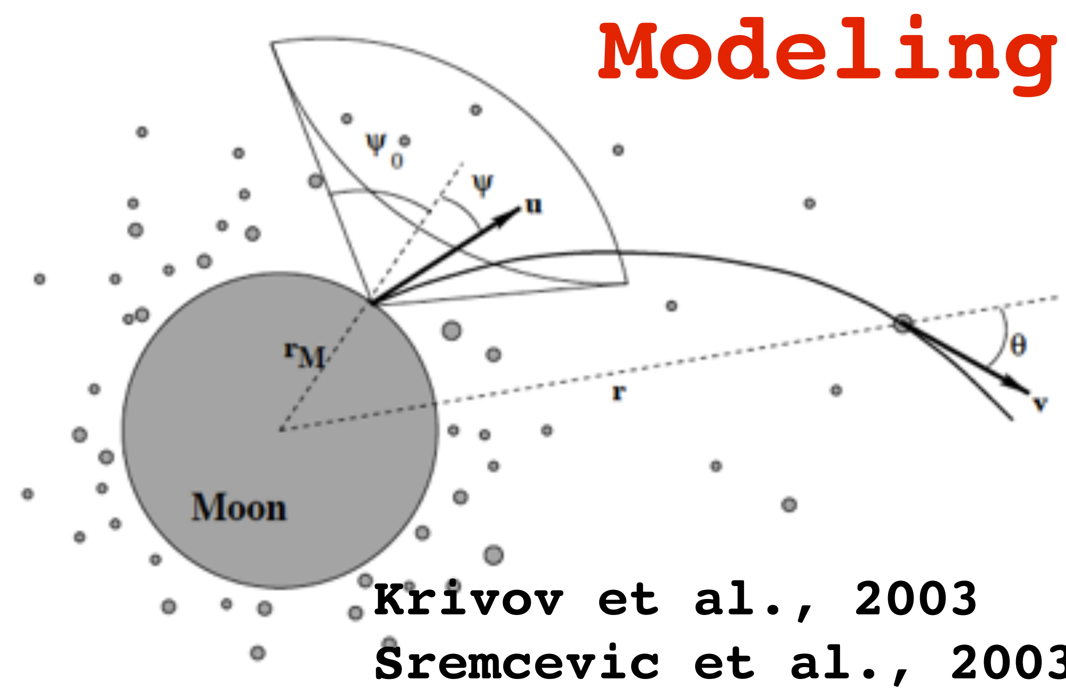
Dust from the Galilean moons:

-> dust exospheres

(Krüger, 1999, Nature)

replenish cirumplanetary dust environment

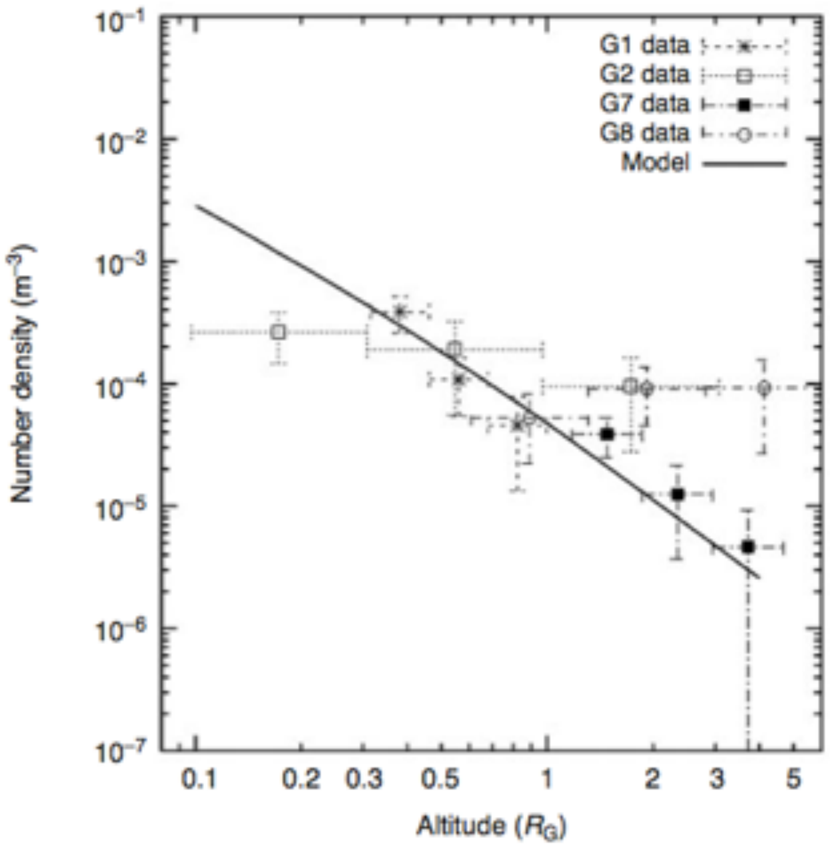
-> relevant for JUICE dust hazard



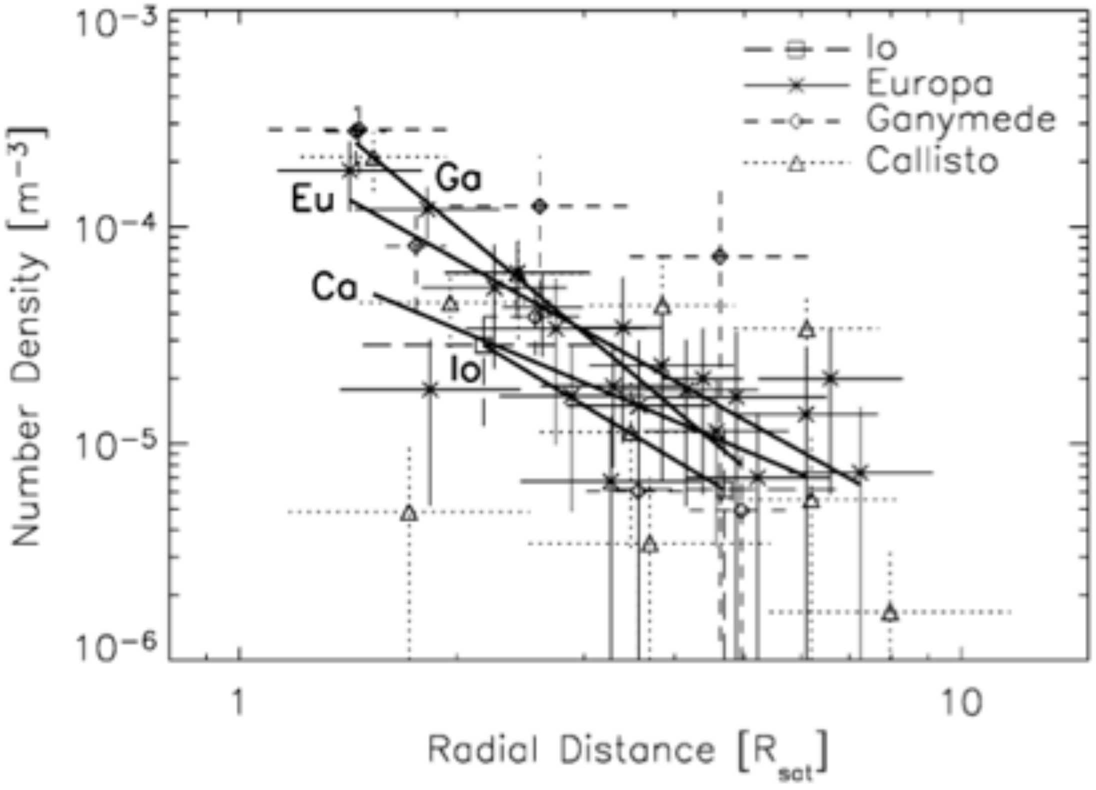
Modeling

Krivov et al., 2003
Sremcevic et al., 2003

Galileo DDS data:



(Krüger et al, 1999, Nature)



(Krüger et al, 2003, Icarus)

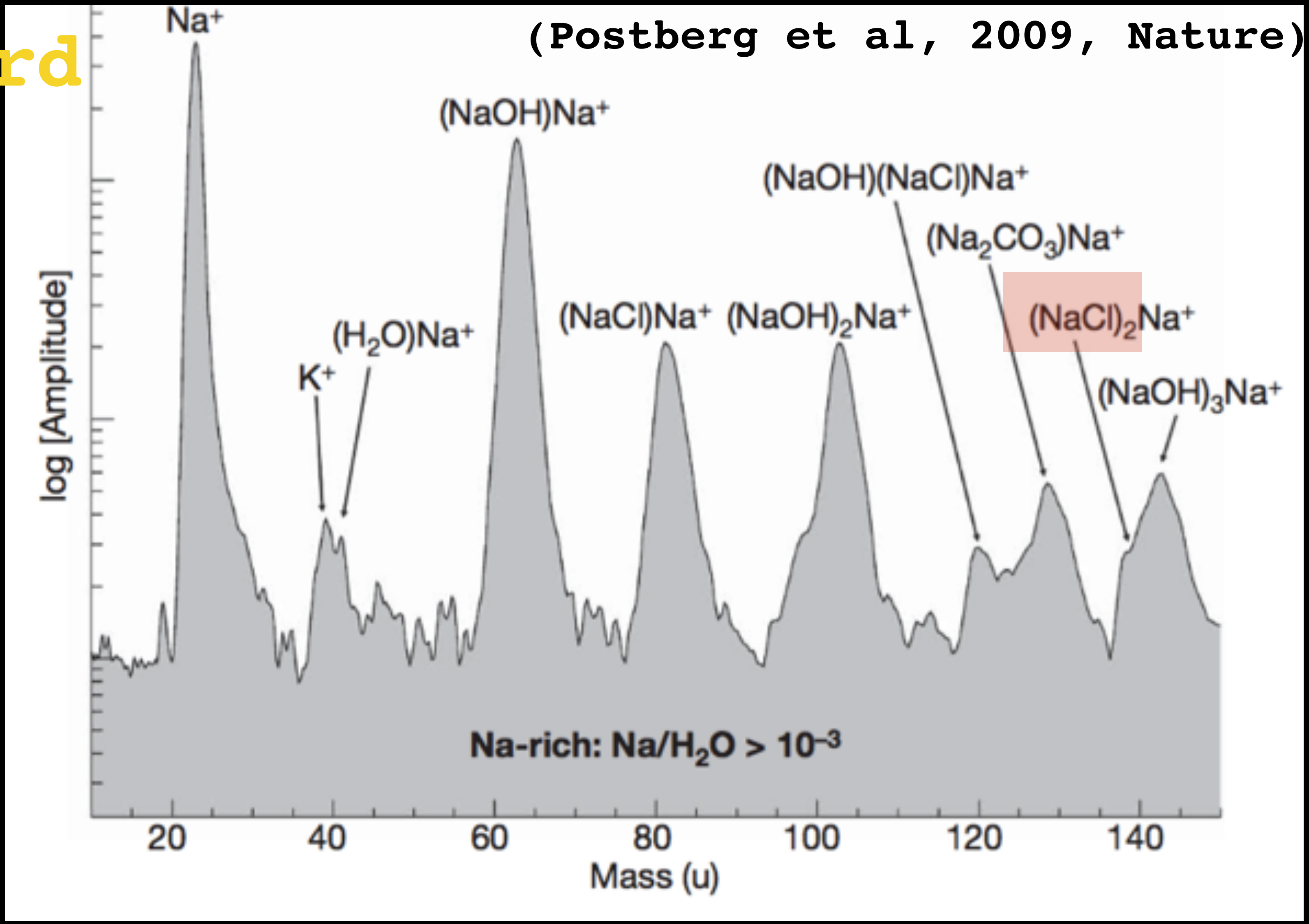
Dust from the Galilean moons:

-> ejecta from impacts of interplanetary dust: fill region of Galilean moons

-> relevant for JUICE dust hazard

-> S/C with dust spectrometer: analyse grain composition
  * Cassini CDA@Enceladus

NaCl -> water



(Postberg et al, 2009, Nature)

Dust from the Galilean moons:

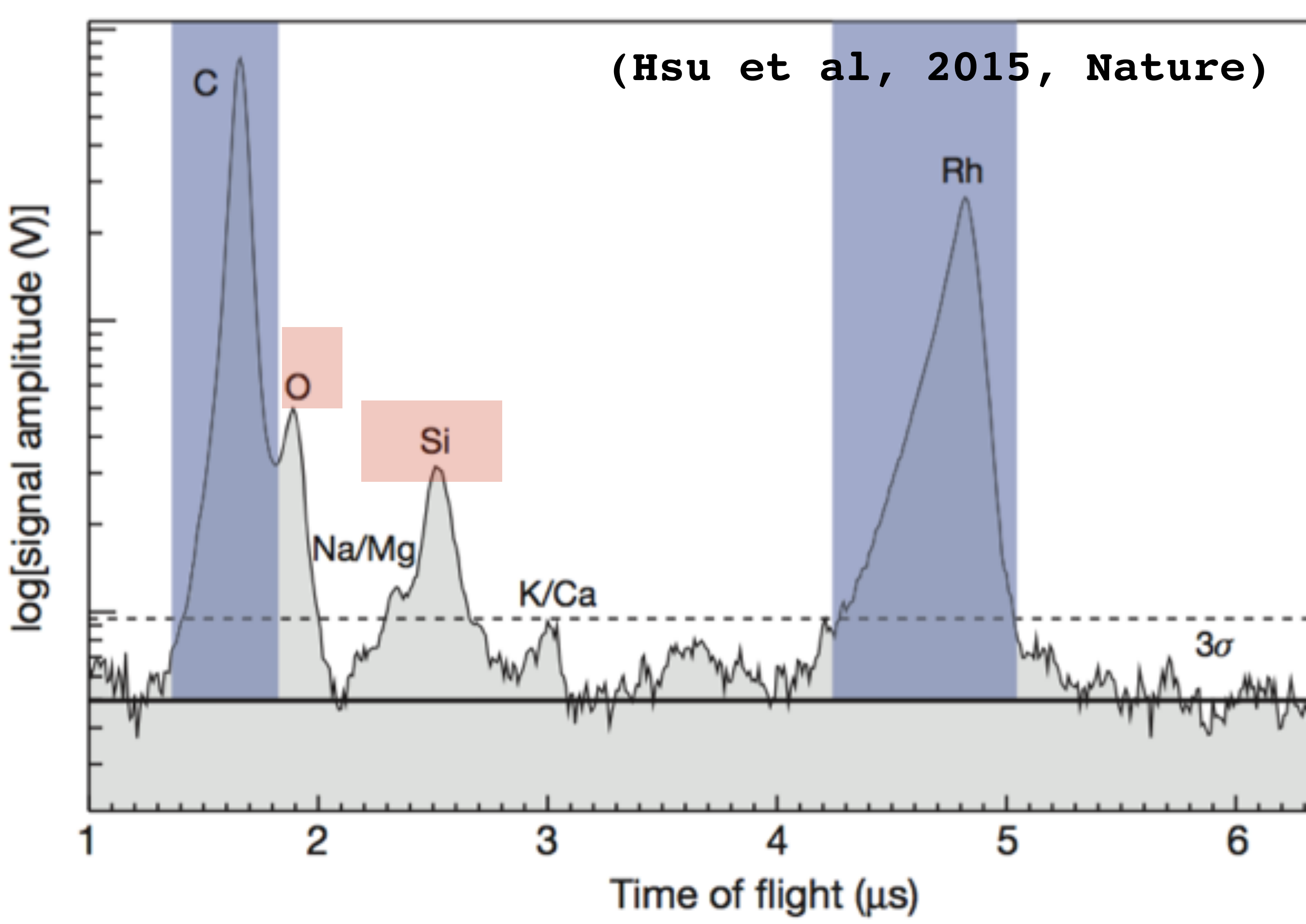
-> ejecta from impacts of interplanetary dust: fill region of Galilean moons

-> relevant for JUICE dust hazard

-> S/C with dust spectrometer: analyse grain composition
  * Cassini CDA@Enceladus

nano-silica

-> hydrothermal activity



(Hsu et al, 2015, Nature)

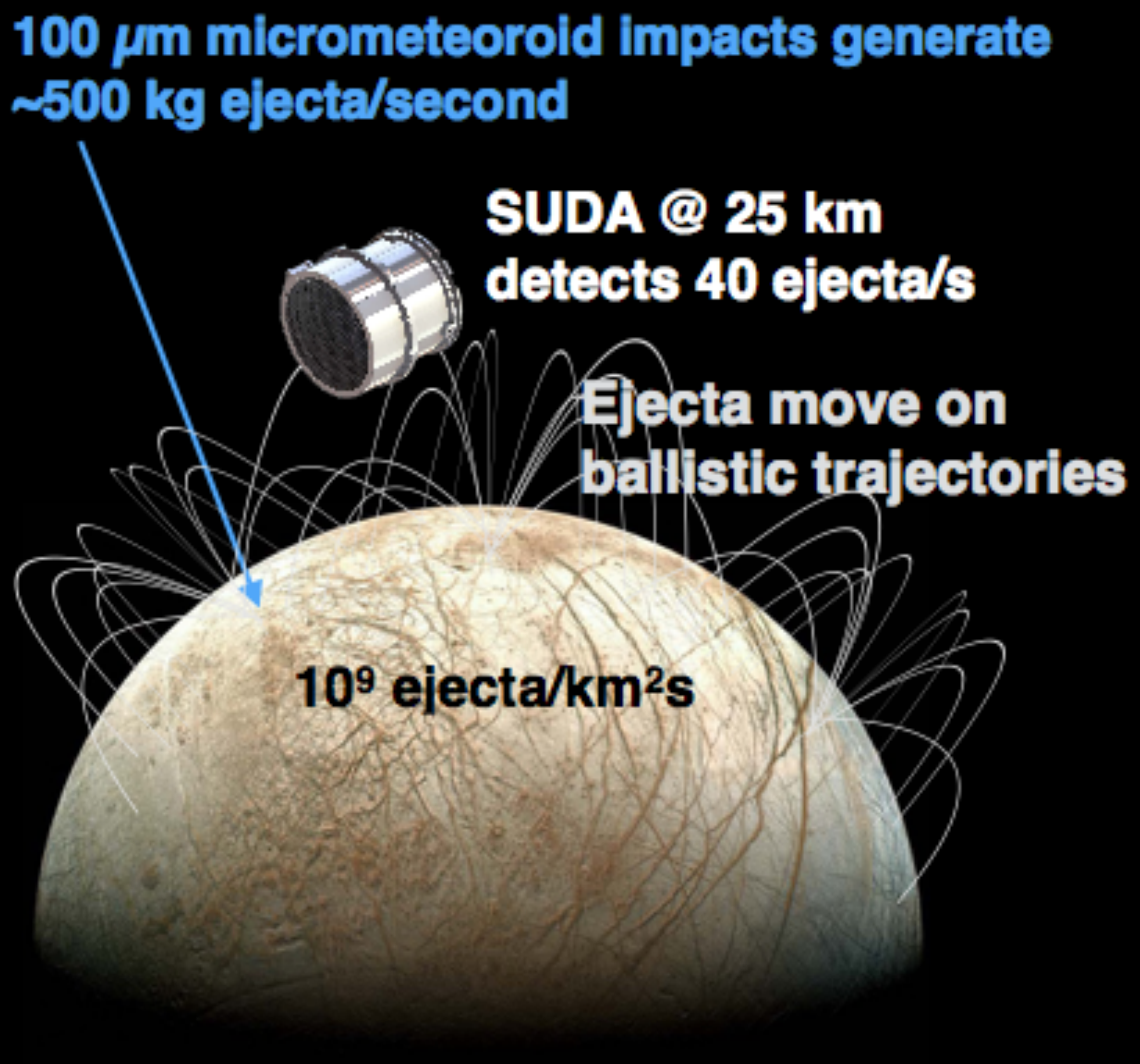
Dust from the Galilean moons:

-> ejecta from impacts of interplanetary dust: fill region of Galilean moons

-> relevant for JUICE dust hazard

-> S/C with dust spectrometer: analyse grain composition

- Cassini CDA@Enceladus
- Europa Clipper SUDA@Europa



Mass Yield ~ 4000

Koschny & Grün, Icarus, 2001; Krivov et al., Icarus, 2003

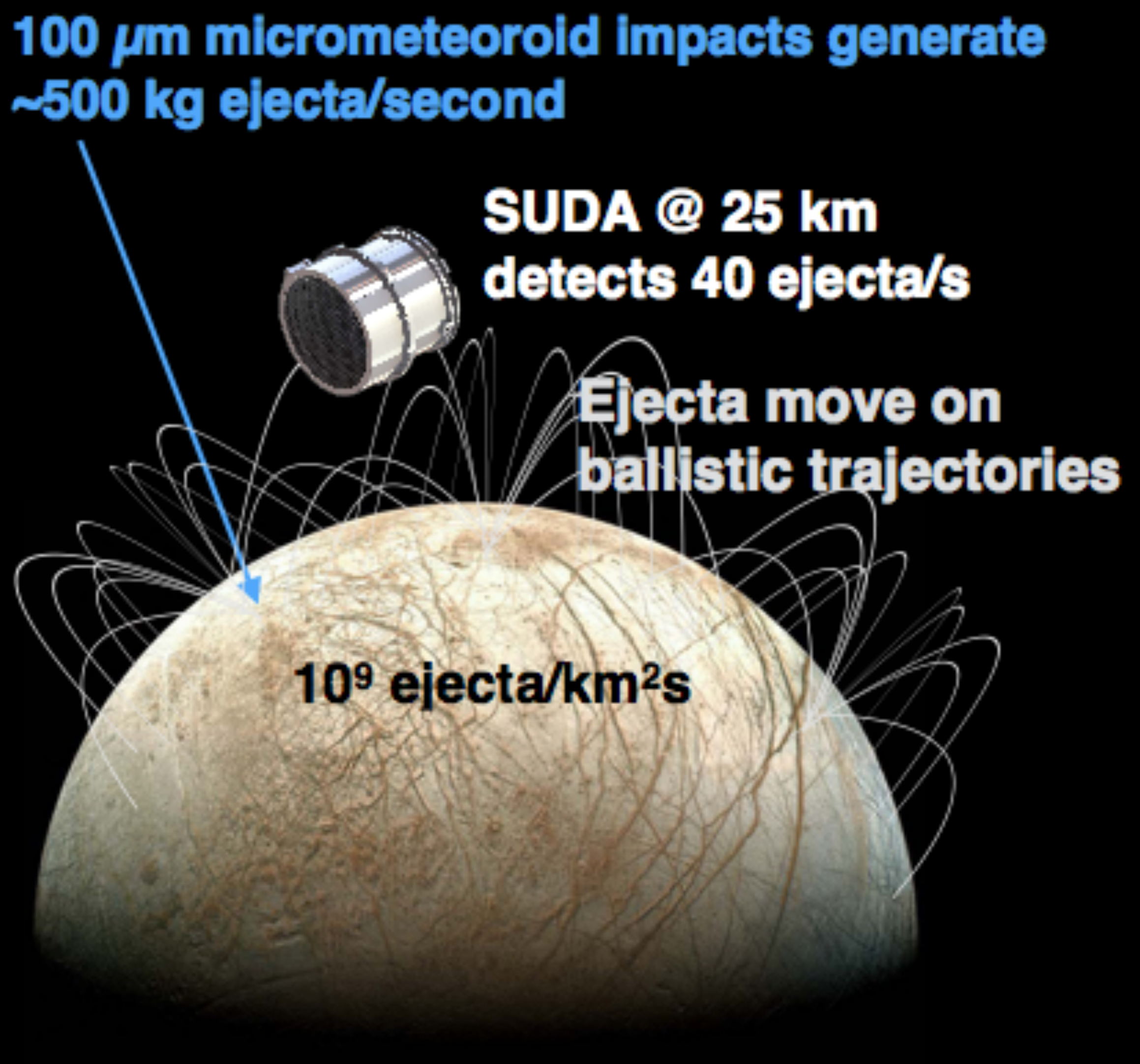
Dust from the Galilean moons:

-> ejecta from impacts of interplanetary dust: fill region of Galilean moons

-> habitability: non-ice composition exchange processes

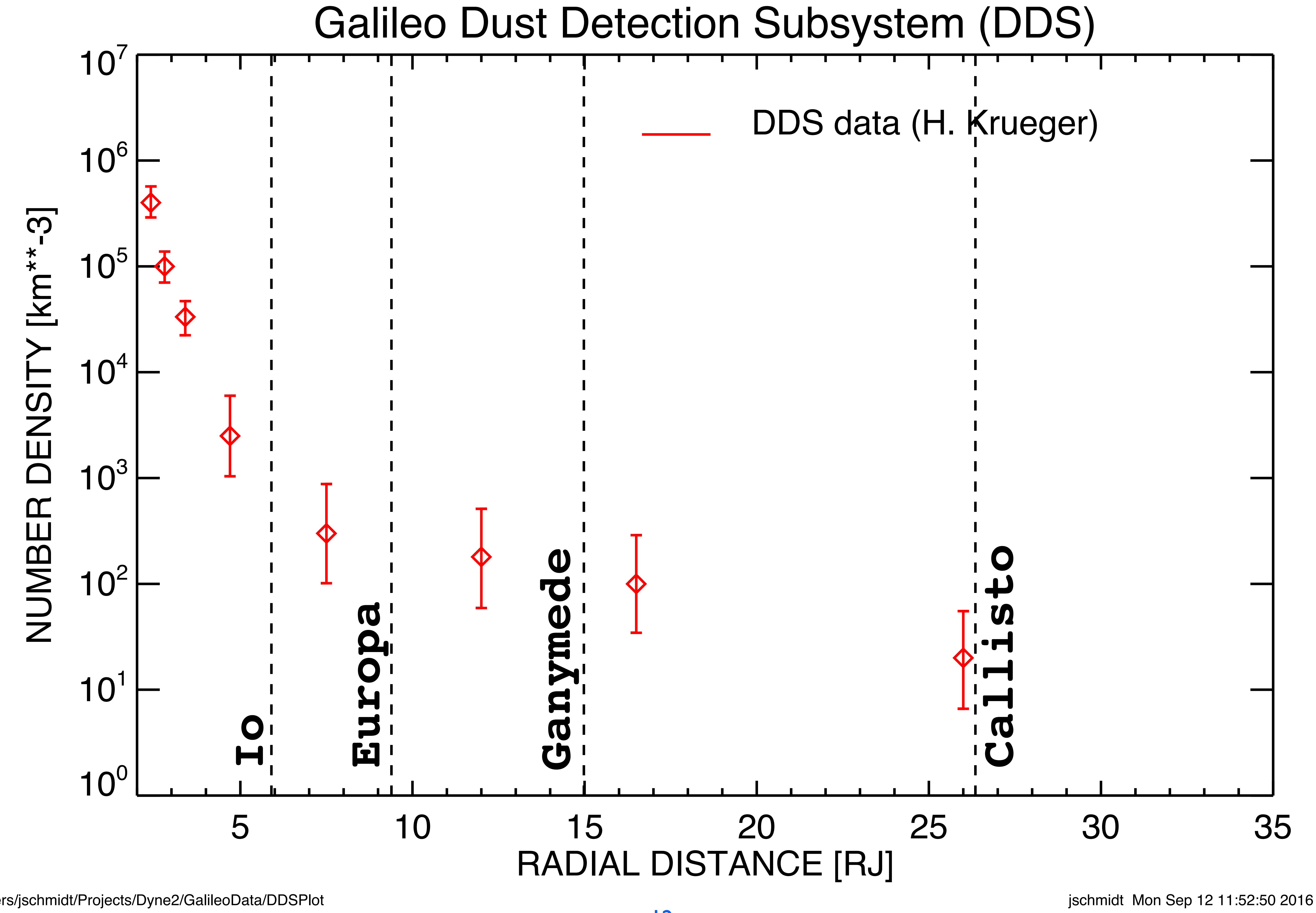
-> relevant for JUICE dust hazard

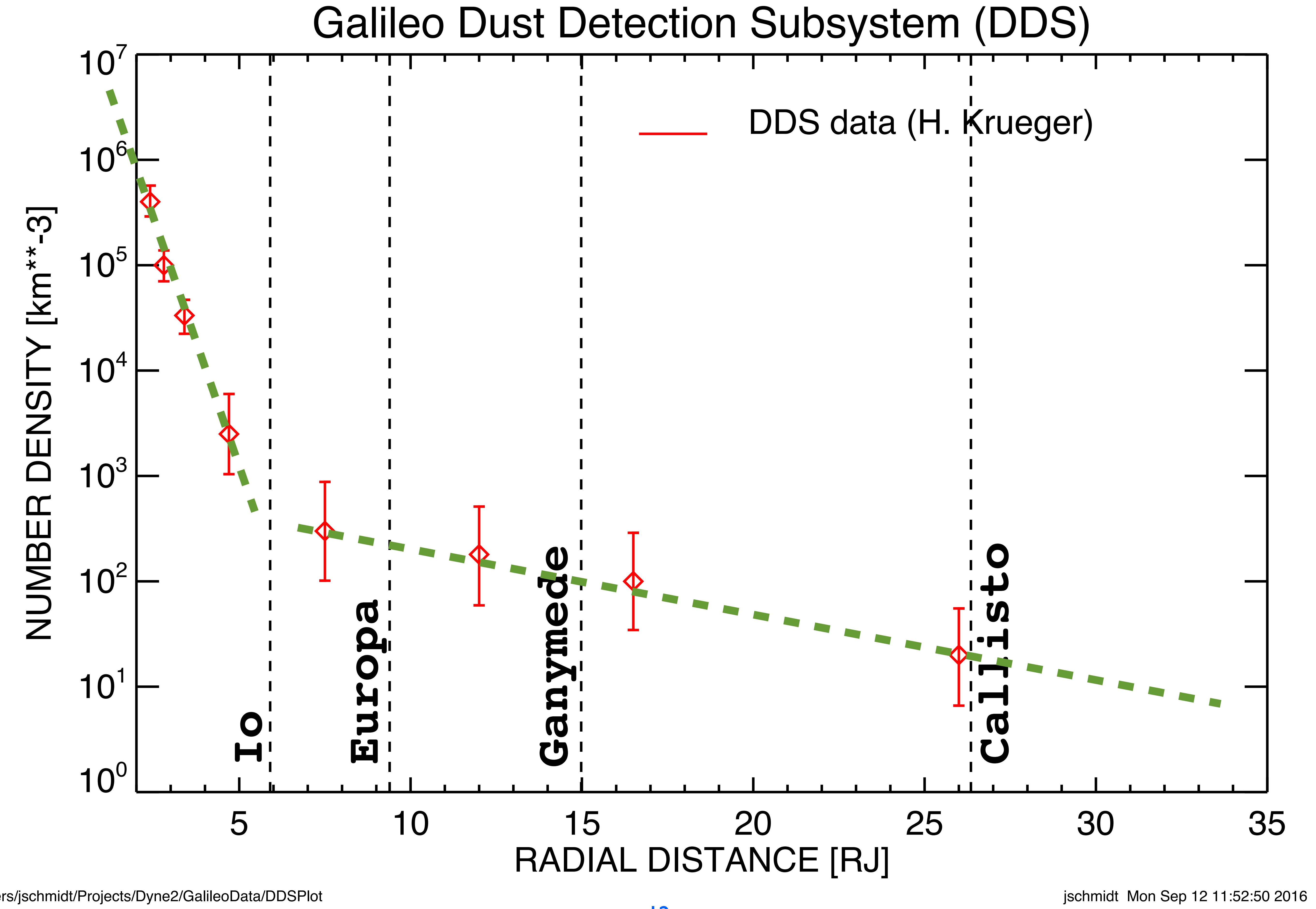
-> S/C with dust spectrometer: analyse grain composition
  * Cassini CDA@Enceladus
  * Europa Clipper SUDA@Europa



Mass Yield ~ 4000

Koschny & Grün, Icarus, 2001; Krivov et al., Icarus, 2003


Galileo Dust Detection Subsystem (DDS)
DDS data (H. Krueger)
NUMBER DENSITY [km**-3]
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
5
10
15
20
25
30
35
RADIAL DISTANCE [RJ]
Io
Europa
Ganymede
Callisto
ers/jschmidt/Projects/Dyne2/GalileoData/DDSPlot
jschmidt Mon Sep 12 11:52:50 2016


Galileo Dust Detection Subsystem (DDS)
DDS data (H. Krueger)
NUMBER DENSITY [km**-3]
10^7
10^6
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Europa
Ganymede
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5
10
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20
25
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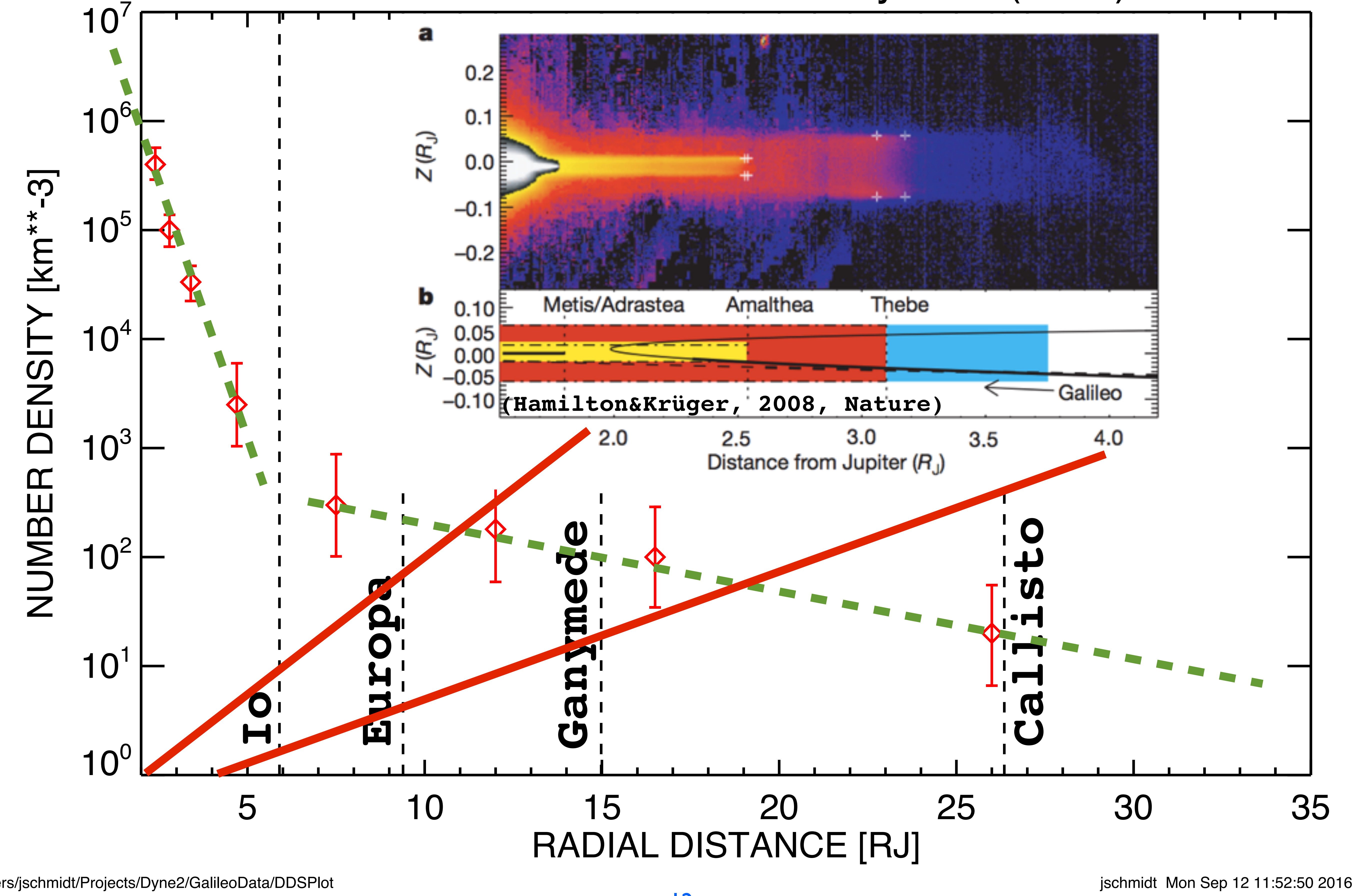
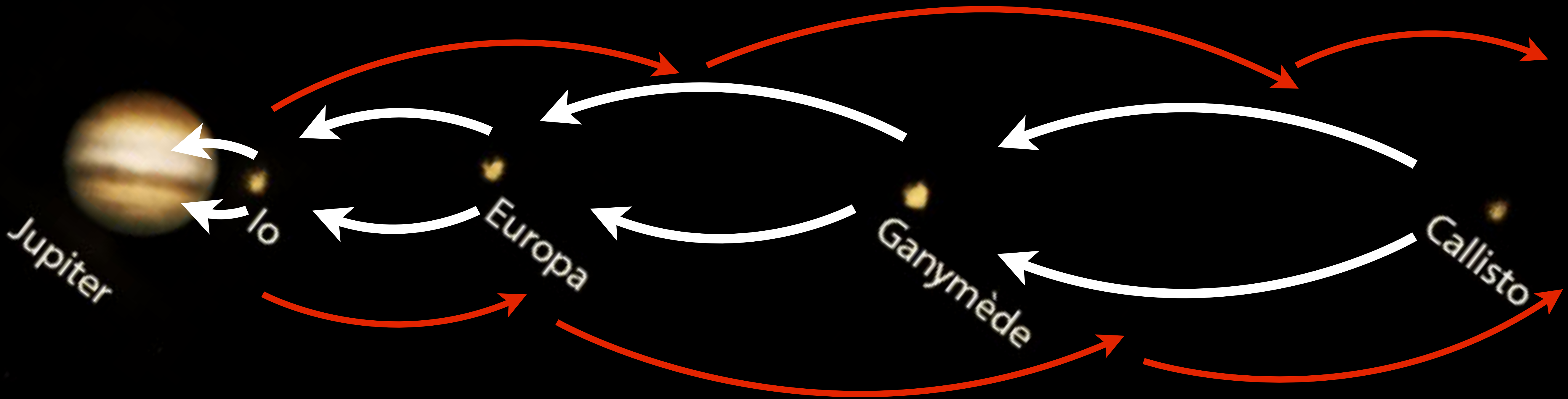
35
RADIAL DISTANCE [RJ]
ers/jschmidt/Projects/Dyne2/GalileoData/DDSPlot
jschmidt Mon Sep 12 11:52:50 2016

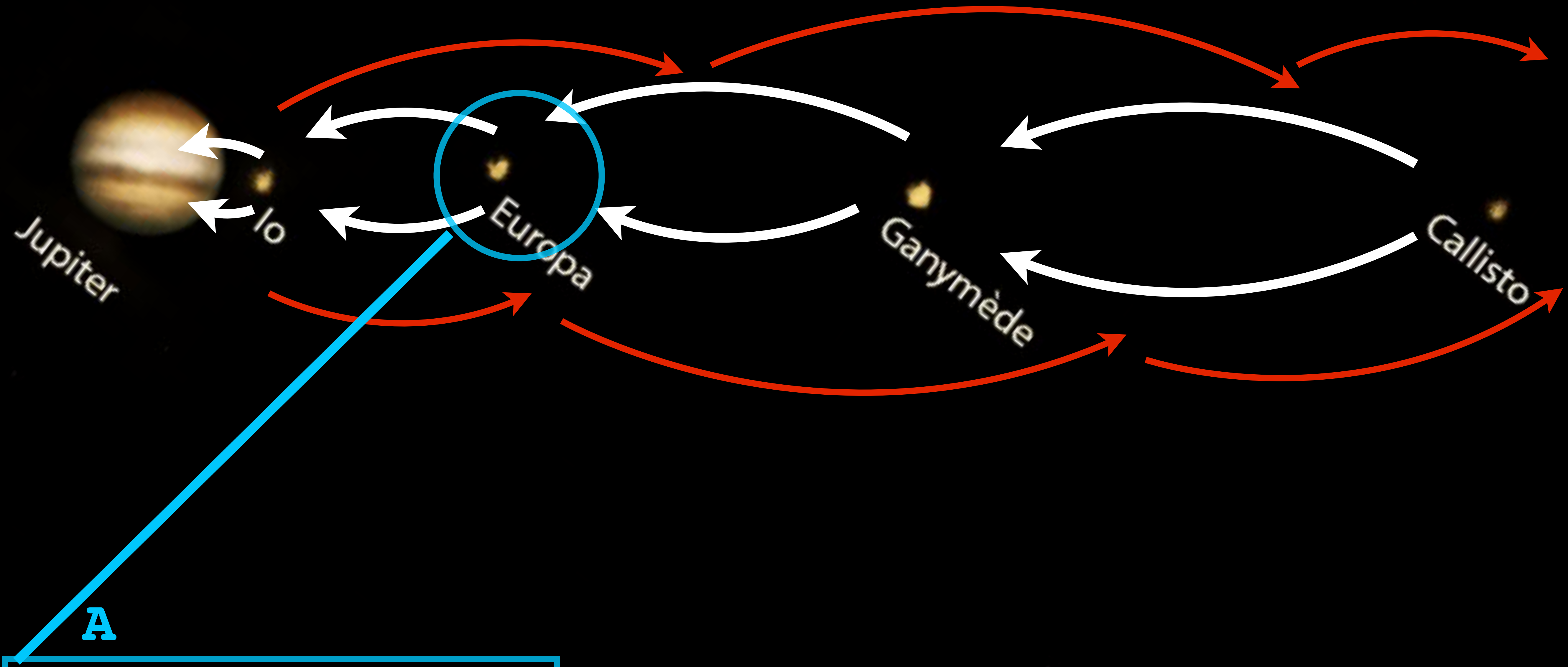
Galileo Dust Detection Subsystem (DDS)



Dust Model for the Galilean Satellites: JMEM



(Liu et al, JGR, 2016)

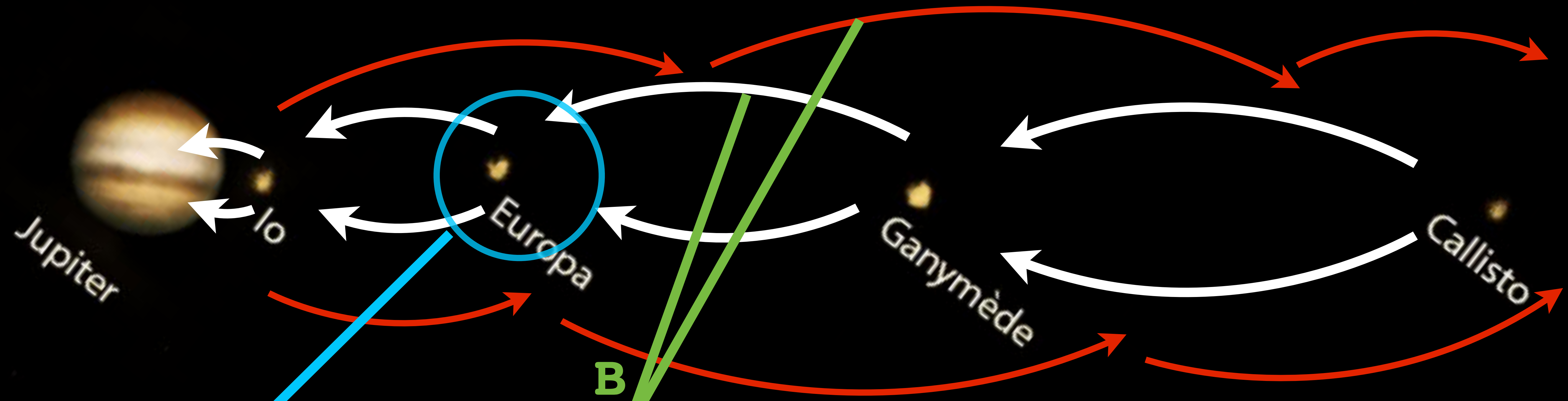


dust creation,
launch to orbit:

-> want to test effect of different starting distributions?

-> dynamics through Hill-sphere (nearly) generic

(Liu et al, JGR, 2016)



long term orbital evolution:

-> CPU expensive. Want to re-use individual trajectories

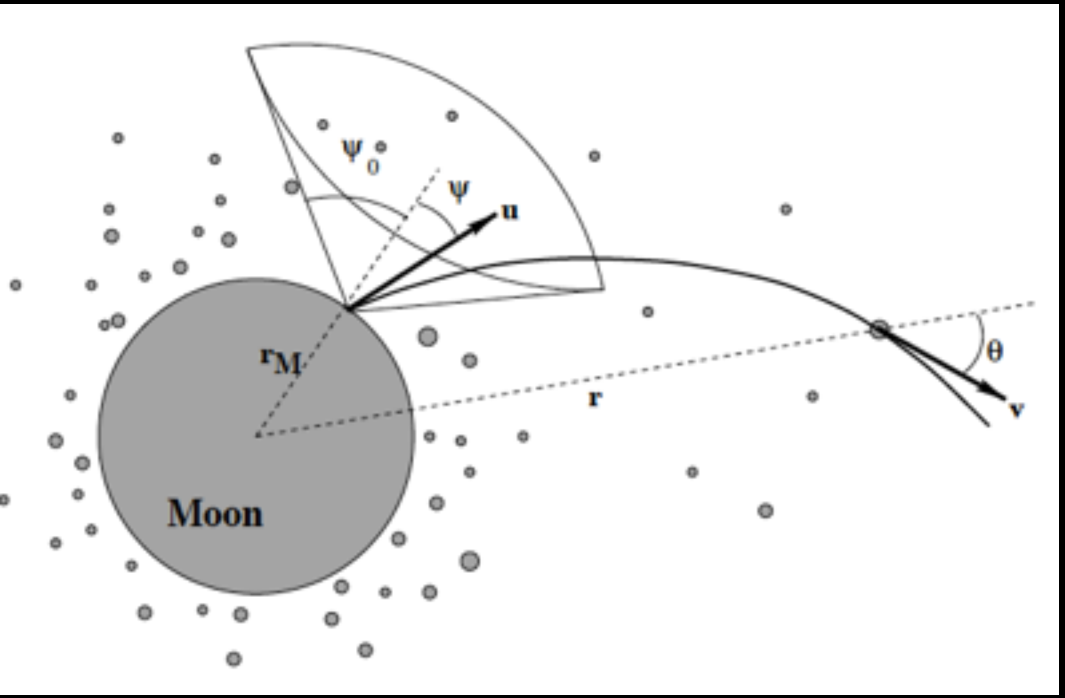
-> statistical weighting with probabilities from A

dust creation, launch to orbit:

-> want to test effect of different starting distributions?

-> dynamics through Hill-sphere (nearly) generic

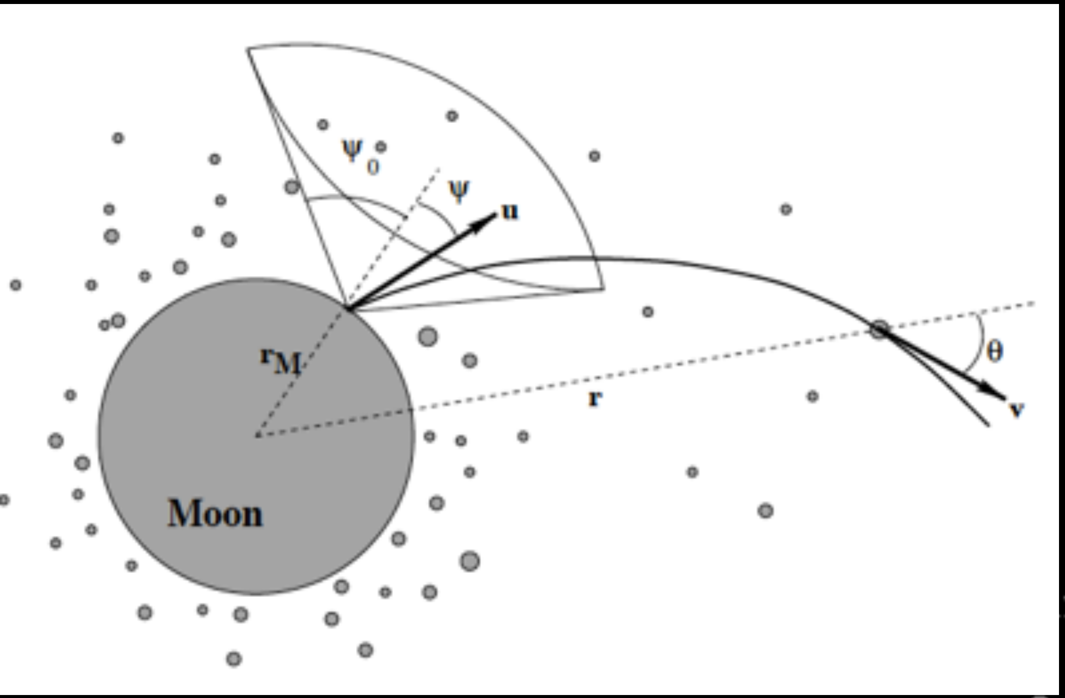
(Liu et al, JGR, 2016)



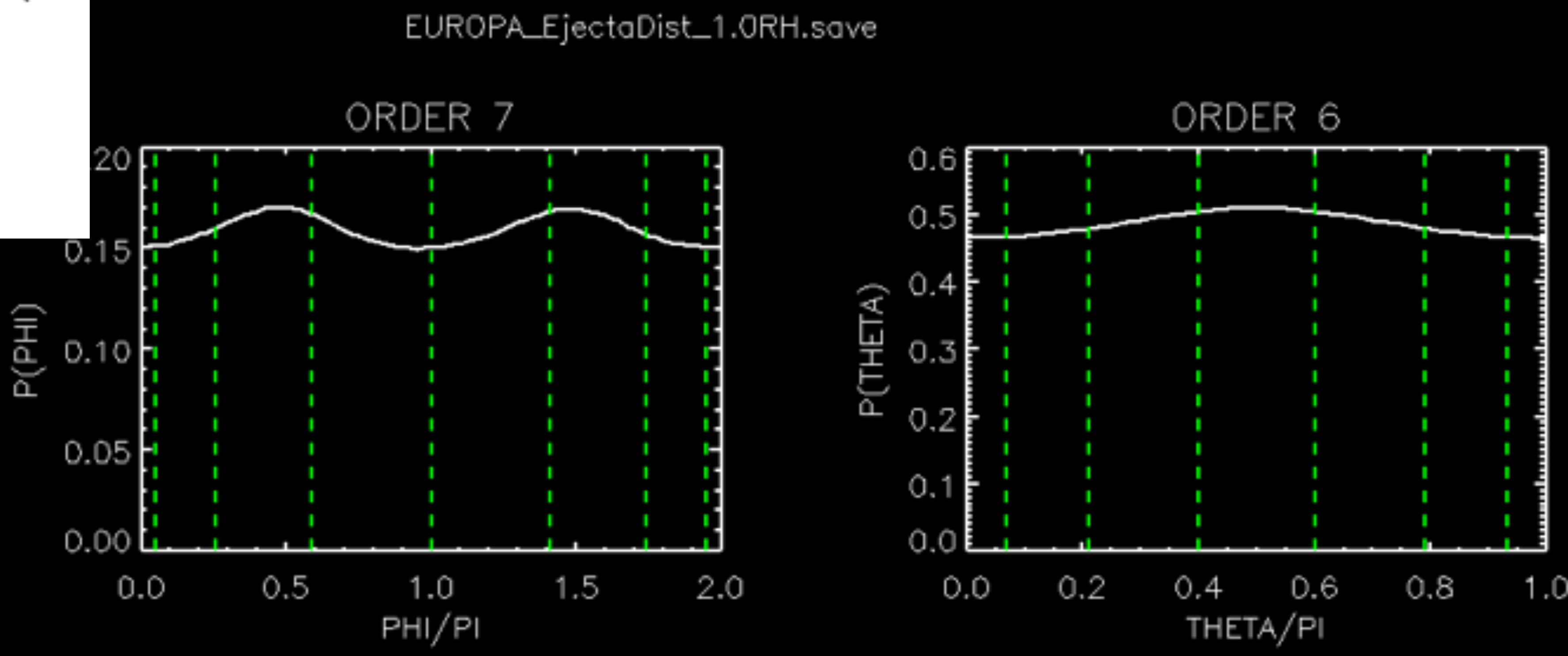
1st step:

~10^6 particles
from surface
-> tabulate phase
space density @
Hill sphere

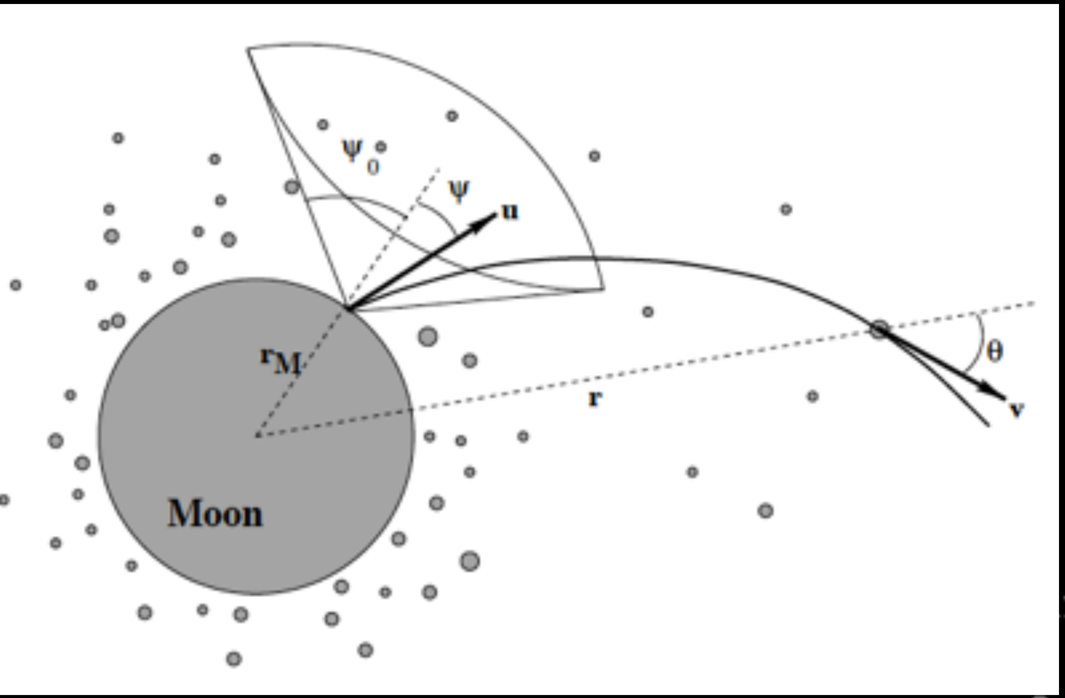
(Liu et al, JGR, 2016)



1st step:
$\sim 10^6$ particles from surface -> tabulate phase space density @ Hill sphere



(Liu et al, JGR, 2016)



1st step:

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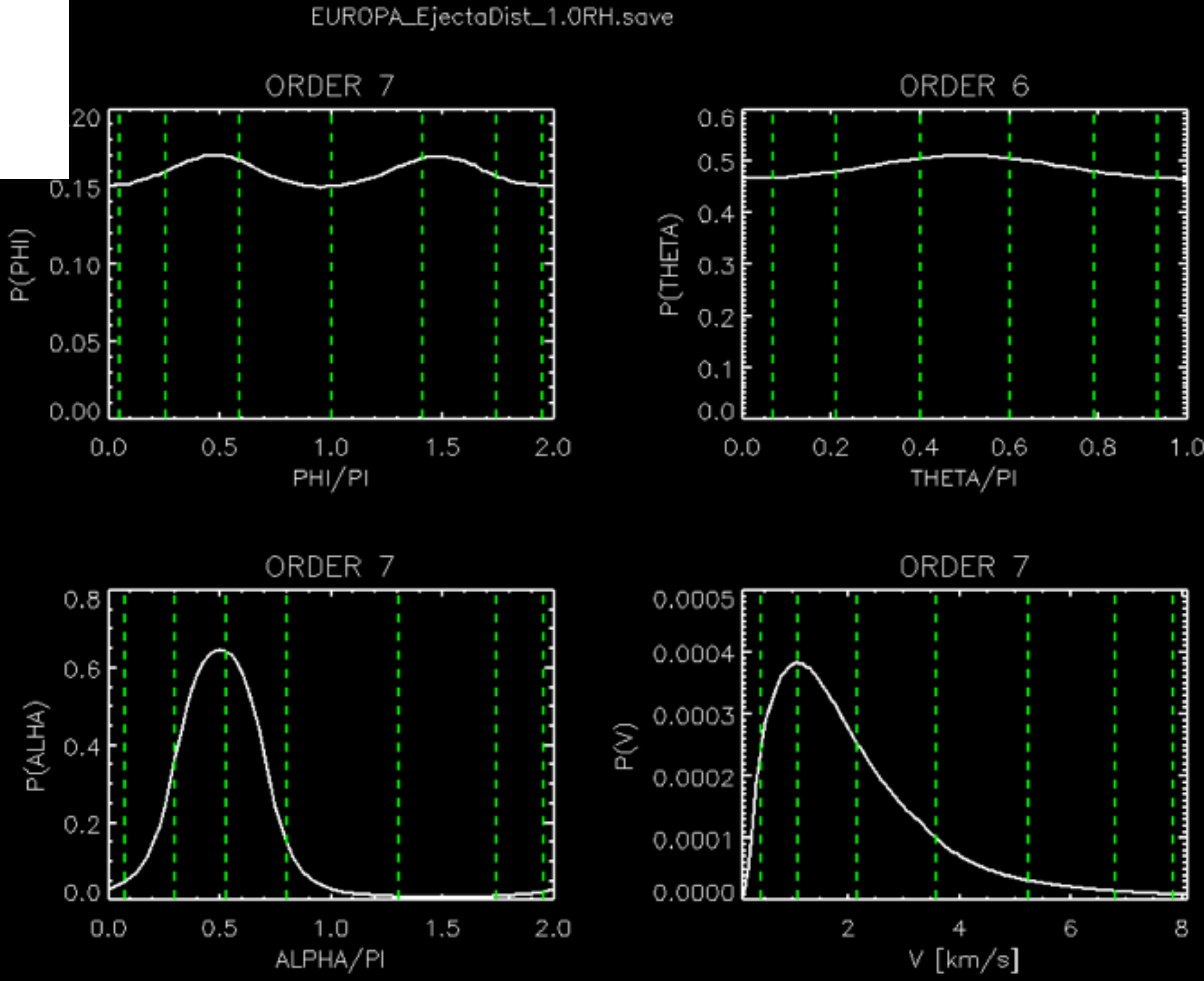
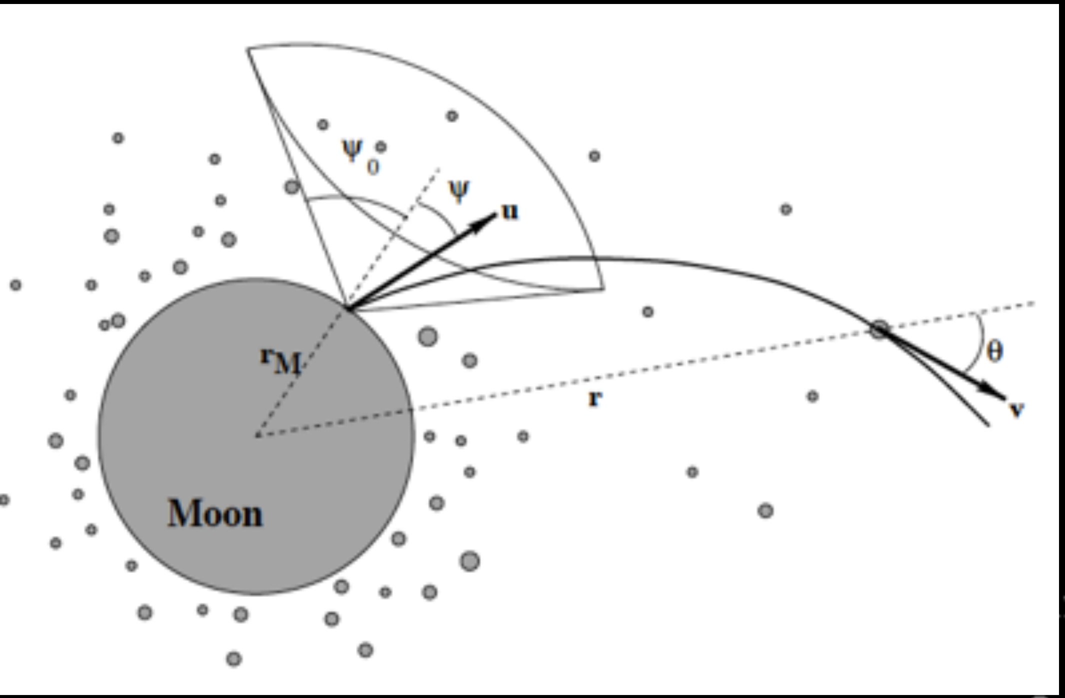


(Liu et al, JGR, 2016)



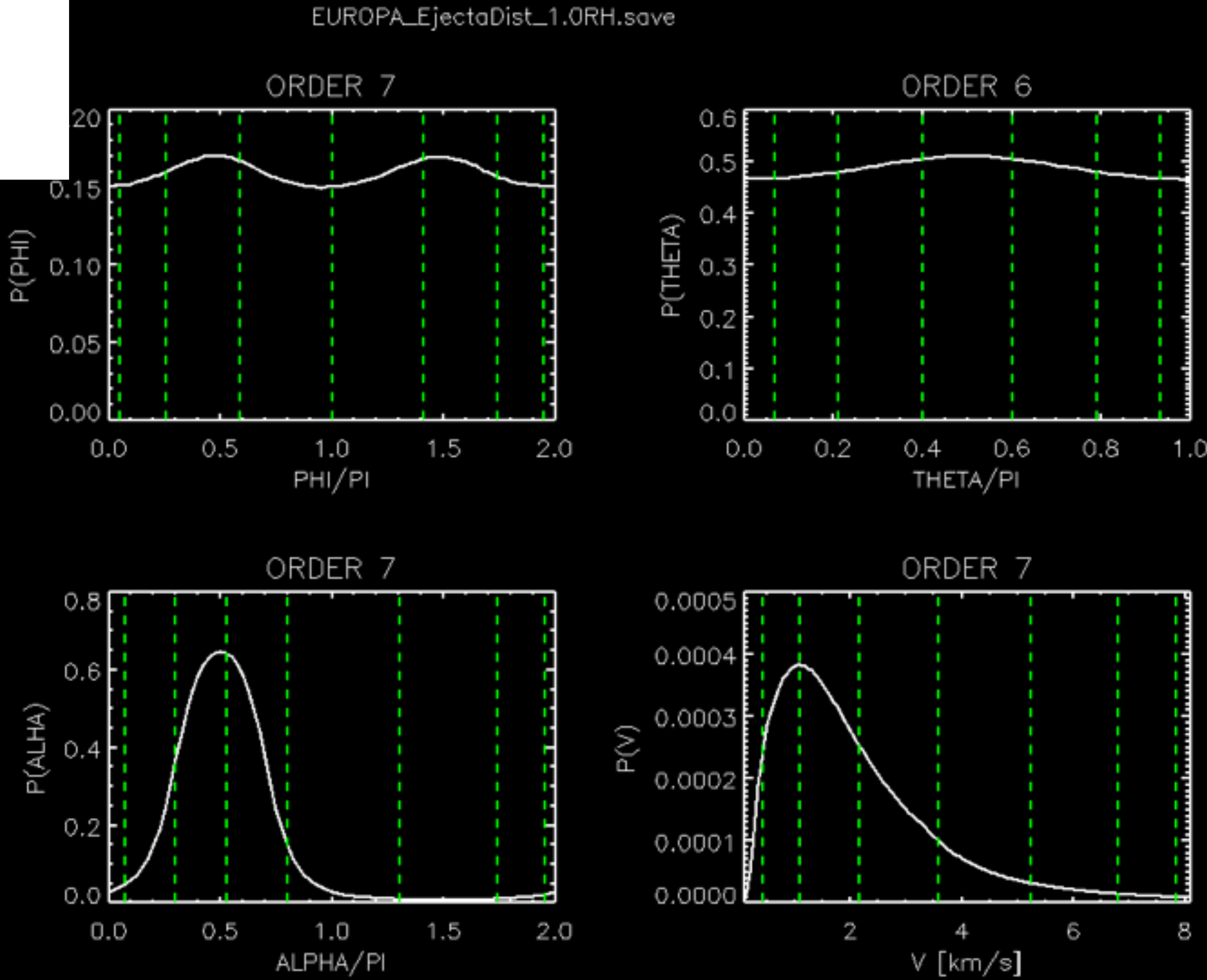
**-> for each Galilean moon
~10 CPU hours**

-> repeat for various starting distributions, if wanted

1st step:

~10^6 particles from surface

-> tabulate phase space density @ Hill sphere



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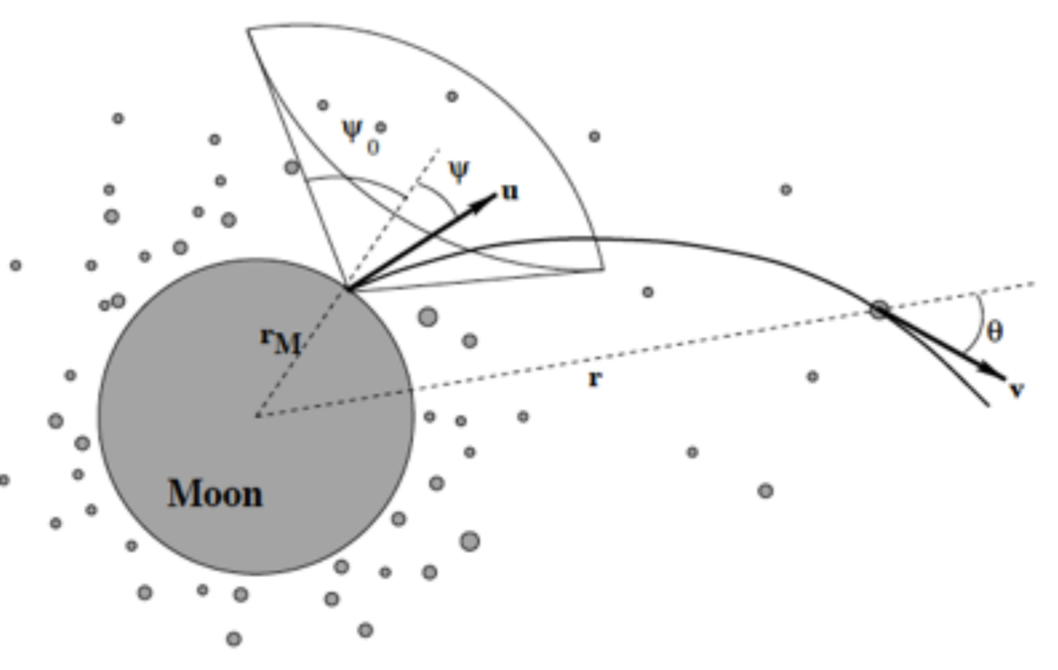


-> for each Galilean moon ~10 CPU hours

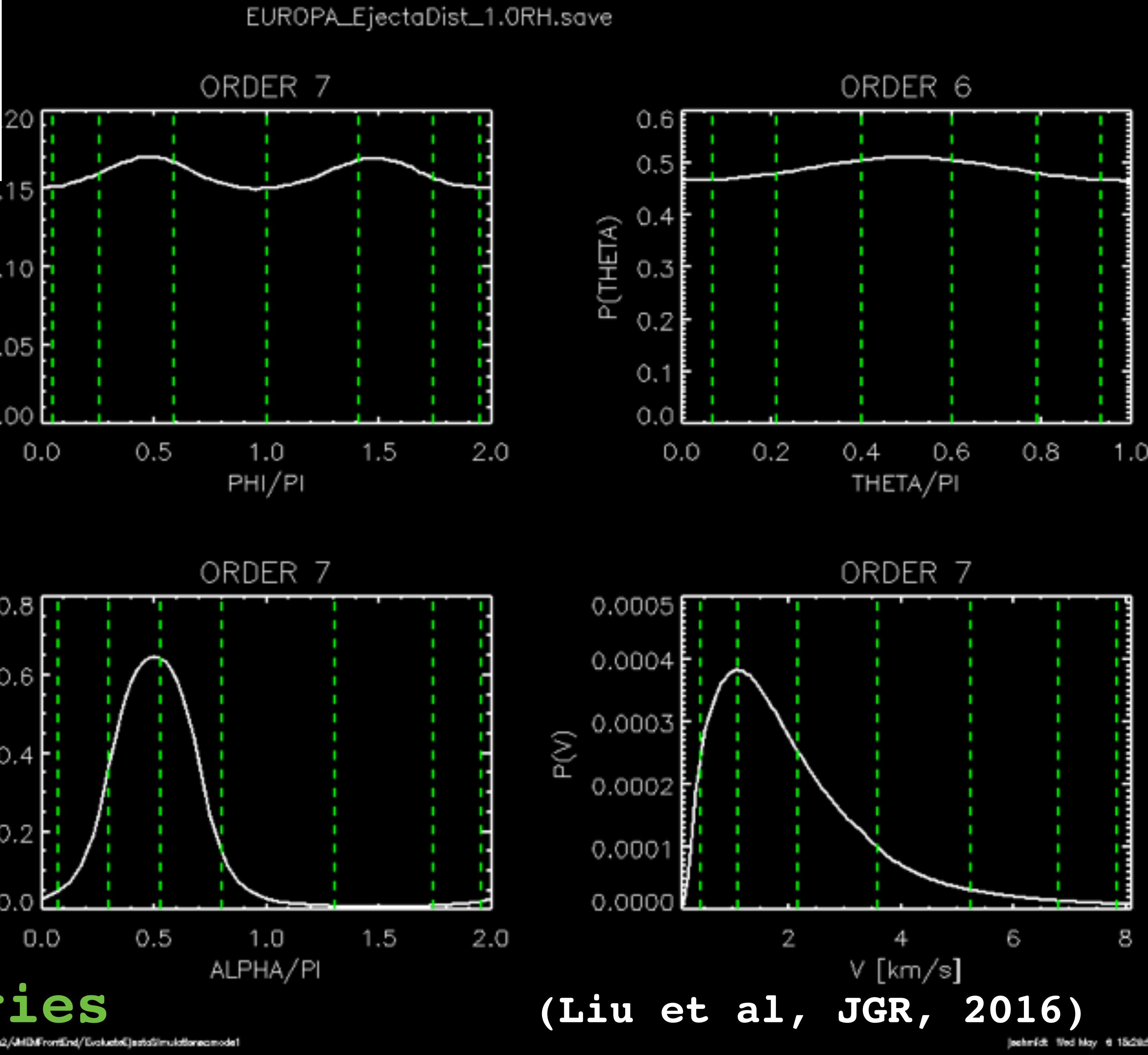
-> repeat for various starting distributions, if wanted

1st step:

~10^6 particles from surface

-> tabulate phase space density @ Hill sphere

-> determine abscissas and weights for Gauss integration = weighting of particle trajectories



(Liu et al, JGR, 2016)

$$\ddot{\vec{r}} = \ddot{\vec{r}}\Big|_{\mathrm{JUP}} + \ddot{\vec{r}}\Big|_{\mathrm{EM}} + \ddot{\vec{r}}\Big|_{\mathrm{RP}} + \ddot{\vec{r}}\Big|_{\mathrm{DRAG}} + \ddot{\vec{r}}\Big|_{\mathrm{MOONS}} + \ddot{\vec{r}}\Big|_{\mathrm{SOLG}}$$

2nd step: for given moon do

-> long-term integrations (using abscissa values of Gaussian weighting as starting conditions)

(Liu et al, JGR, 2016)

$$\ddot{\vec{r}} = \ddot{\vec{r}}\Big|_{\mathrm{JUP}} + \ddot{\vec{r}}\Big|_{\mathrm{EM}} + \ddot{\vec{r}}\Big|_{\mathrm{RP}} + \ddot{\vec{r}}\Big|_{\mathrm{DRAG}} + \ddot{\vec{r}}\Big|_{\mathrm{MOONS}} + \ddot{\vec{r}}\Big|_{\mathrm{SOLG}}$$

planet, inc. higher moments

2nd step: for given moon do

-> long-term integrations (using abscissa values of Gaussian weighting as starting conditions)

(Liu et al, JGR, 2016)

$$\ddot{\vec{r}} = \ddot{\vec{r}}\Big|_{\mathrm{JUP}} + \ddot{\vec{r}}\Big|_{\mathrm{EM}} + \ddot{\vec{r}}\Big|_{\mathrm{RP}} + \ddot{\vec{r}}\Big|_{\mathrm{DRAG}} + \ddot{\vec{r}}\Big|_{\mathrm{MOONS}} + \ddot{\vec{r}}\Big|_{\mathrm{SOLG}}$$

↑

planetary magnetic field
+ corotational E field

2nd step: for given moon do

-> long-term integrations (using abscissa values of Gaussian weighting as starting conditions)

(Liu et al, JGR, 2016)

$$\ddot{\vec{r}} = \ddot{\vec{r}}\Big|_{\mathrm{JUP}} + \ddot{\vec{r}}\Big|_{\mathrm{EM}} + \ddot{\vec{r}}\Big|_{\mathrm{RP}} + \ddot{\vec{r}}\Big|_{\mathrm{DRAG}} + \ddot{\vec{r}}\Big|_{\mathrm{MOONS}} + \ddot{\vec{r}}\Big|_{\mathrm{SOLG}}$$

↑

radiation pressure
and Poynting-Robertson drag

2nd step: for given moon do

-> long-term integrations (using abscissa values of Gaussian weighting as starting conditions)

(Liu et al, JGR, 2016)

$$\ddot{\vec{r}} = \ddot{\vec{r}}\Big|_{\mathrm{JUP}} + \ddot{\vec{r}}\Big|_{\mathrm{EM}} + \ddot{\vec{r}}\Big|_{\mathrm{RP}} + \ddot{\vec{r}}\Big|_{\mathrm{DRAG}} + \ddot{\vec{r}}\Big|_{\mathrm{MOONS}} + \ddot{\vec{r}}\Big|_{\mathrm{SOLG}}$$

↑

plasma drag

2nd step: for given moon do

-> long-term integrations (using abscissa values of Gaussian weighting as starting conditions)

(Liu et al, JGR, 2016)

$$\ddot{\vec{r}} = \ddot{\vec{r}}\Big|_{\mathrm{JUP}} + \ddot{\vec{r}}\Big|_{\mathrm{EM}} + \ddot{\vec{r}}\Big|_{\mathrm{RP}} + \ddot{\vec{r}}\Big|_{\mathrm{DRAG}} + \ddot{\vec{r}}\Big|_{\mathrm{MOONS}} + \ddot{\vec{r}}\Big|_{\mathrm{SOLG}}$$

gravity of satellites

2nd step: for given moon do

-> long-term integrations (using abscissa values of Gaussian weighting as starting conditions)

(Liu et al, JGR, 2016)

$$\ddot{\vec{r}} = \ddot{\vec{r}}\Big|_{\mathrm{JUP}} + \ddot{\vec{r}}\Big|_{\mathrm{EM}} + \ddot{\vec{r}}\Big|_{\mathrm{RP}} + \ddot{\vec{r}}\Big|_{\mathrm{DRAG}} + \ddot{\vec{r}}\Big|_{\mathrm{MOONS}} + \ddot{\vec{r}}\Big|_{\mathrm{SOLG}}$$

$\uparrow$

solar gravity

2nd step: for given moon do

-> long-term integrations (using abscissa values of Gaussian weighting as starting conditions)

(Liu et al, JGR, 2016)

$$\ddot{\vec{r}} = \ddot{\vec{r}}\Big|_{\mathrm{JUP}} + \ddot{\vec{r}}\Big|_{\mathrm{EM}} + \ddot{\vec{r}}\Big|_{\mathrm{RP}} + \ddot{\vec{r}}\Big|_{\mathrm{DRAG}} + \ddot{\vec{r}}\Big|_{\mathrm{MOONS}} + \ddot{\vec{r}}\Big|_{\mathrm{SOLG}}$$

↑ solar gravity

2nd step: for given moon do

-> long-term integrations (using abscissa values of Gaussian weighting as starting conditions)

-> do this for 10 particle sizes from 0.05 micron to 1cm

-> integrate until the particle hits a sink: planet, moons, escape from the system

-> repeat for each moon: 60,000 CPU hours on large cluster (CSC Espoo)

(Liu et al, JGR, 2016)

$$\ddot{\vec{r}} = \ddot{\vec{r}}\Big|_{\mathrm{JUP}} + \ddot{\vec{r}}\Big|_{\mathrm{EM}} + \ddot{\vec{r}}\Big|_{\mathrm{RP}} + \ddot{\vec{r}}\Big|_{\mathrm{DRAG}} + \ddot{\vec{r}}\Big|_{\mathrm{MOONS}} + \ddot{\vec{r}}\Big|_{\mathrm{SOLG}}$$

solar gravity

2nd step: for given moon do

-> long-term integrations (using abscissa values of Gaussian weighting as starting conditions)

-> do this for 10 particle sizes from 0.05 micron to 1cm

-> integrate until the particle hits a sink: planet, moons, escape from the system

-> repeat for each moon: 60,000 CPU hours on large cluster (CSC Espoo)

storage:

save (osculating) orbital elements

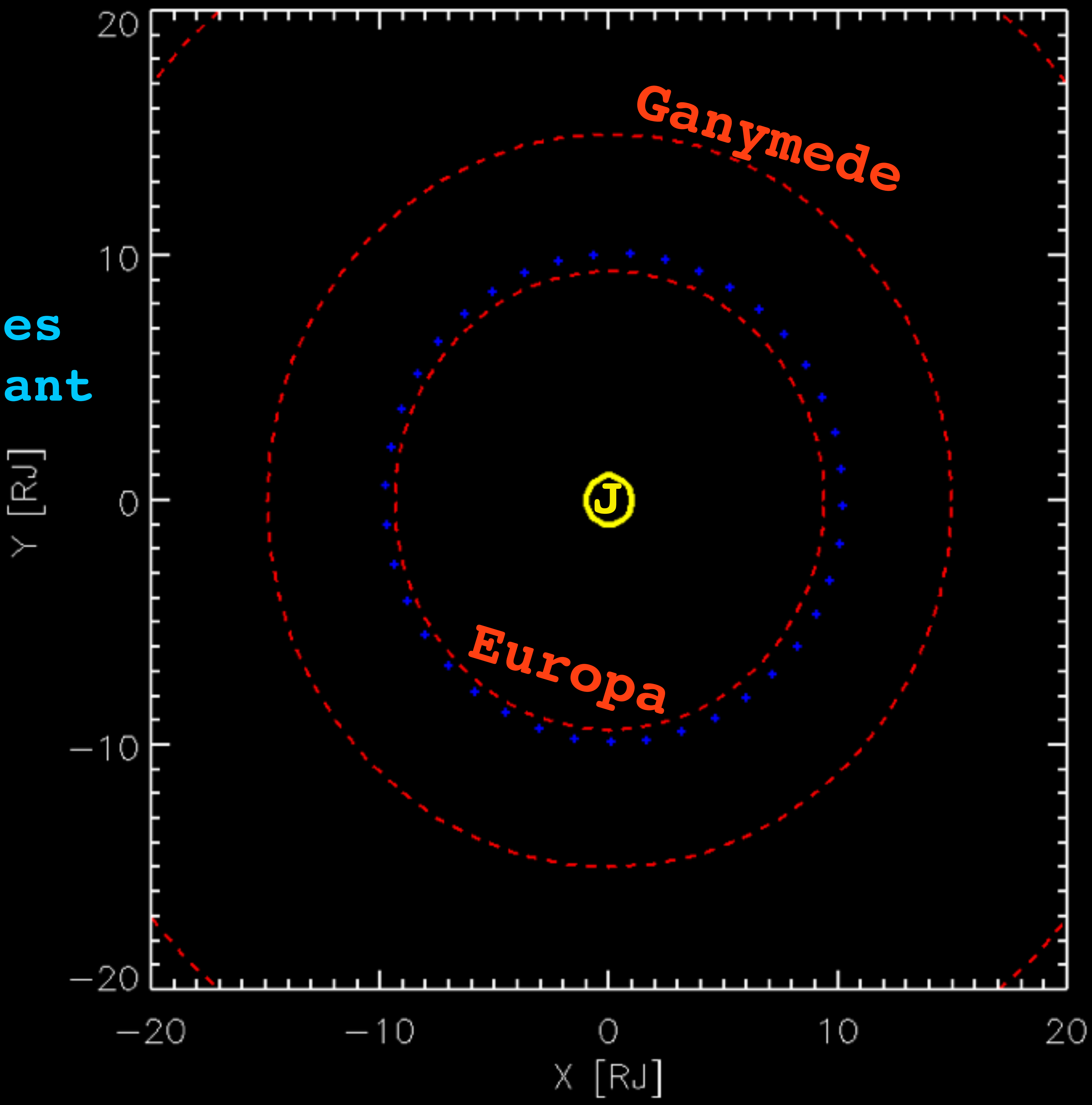
~ once per orbit

(Liu et al, JGR, 2016)

3rd step: populate cylindrical grid

from elements:

positions &velocities @equidistant times



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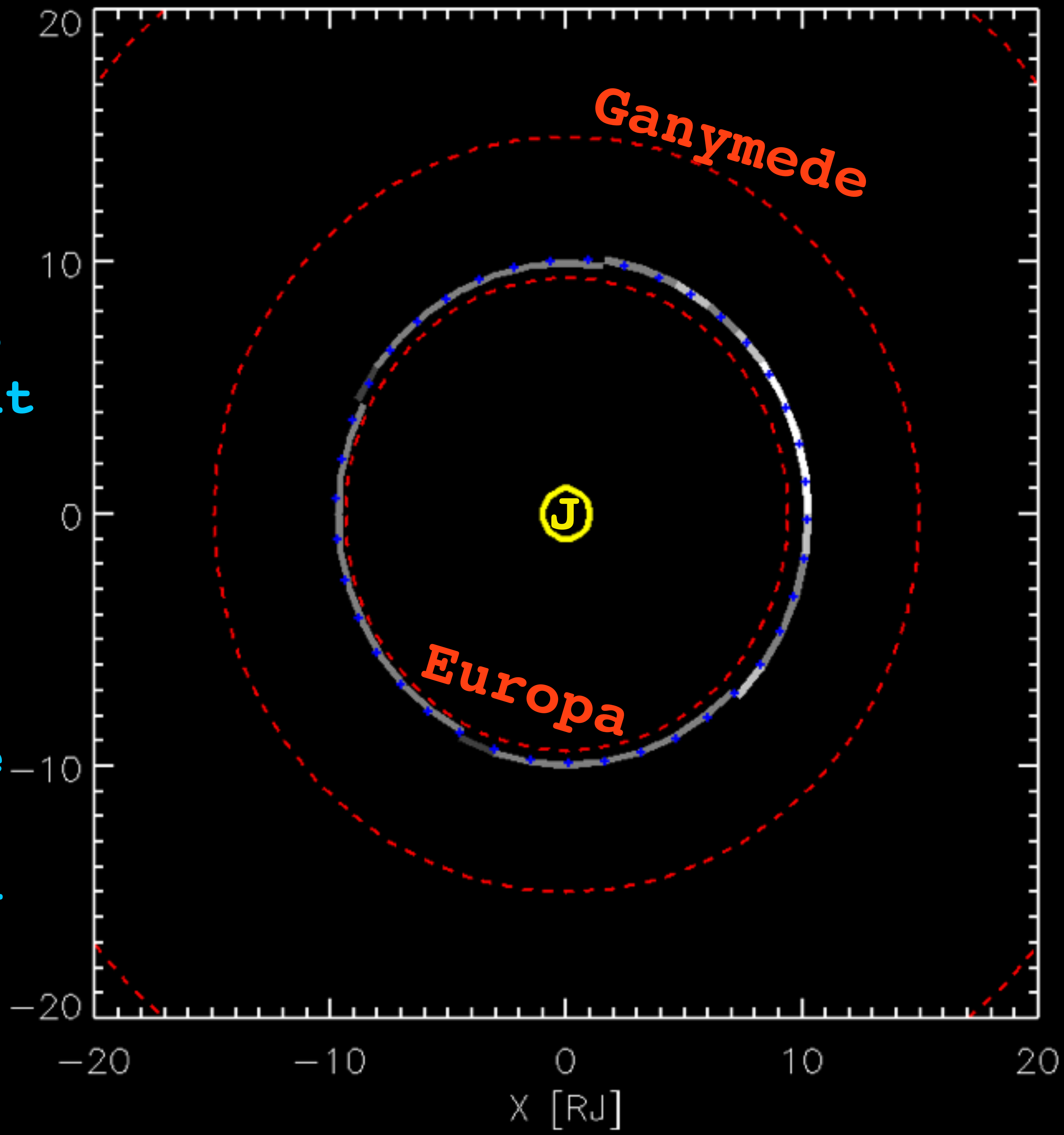
increment counters @respective location in the grid



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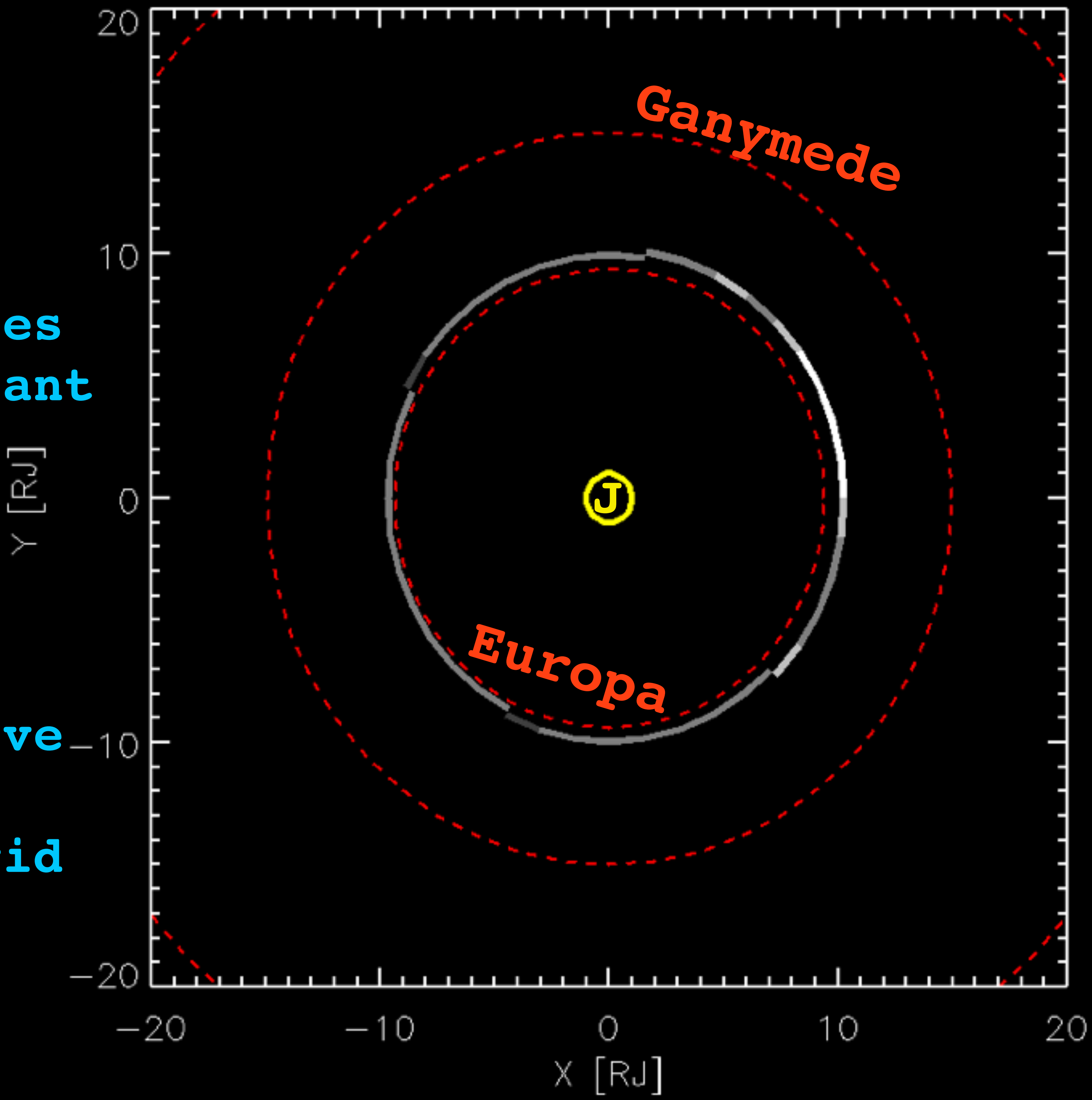

4th step: co-adding and calibration

number density for grains of size r in cell i,j,k of grid

4th step: co-adding and calibration

$$\tilde{n}_{moon}(i,j,k;r)\mathrm{d}r = \mathrm{d}r \int \mathrm{d}\xi \, P_{moon}(\xi) \, \frac{N_{moon}(\xi;i,j,k;r)}{V_{cell}(i,j,k)}$$

$$\text{where} \quad \xi = \{\phi, \theta, \alpha, \beta, v\}$$

number density for grains of size r in cell i,j,k of grid

4th step:
co-adding
and
calibration

A) distributions of
starting conditions
1st step

$$\tilde{n}_{moon}(i,j,k;r)\mathrm{d}r = \mathrm{d}r \int \mathrm{d}\xi \, P_{moon}(\xi) \, \frac{N_{moon}(\xi;i,j,k;r)}{V_{cell}(i,j,k)}$$

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pos and direction
of velocity starting
vector

**number density for
grains of size r
in cell i,j,k
of grid**

4th step:
co-adding
and
calibration

A) distributions of
starting conditions
1st step

B) grid from
2nd step

$$\tilde{n}_{moon}(i,j,k;r)\mathrm{d}r = \mathrm{d}r \int \mathrm{d}\xi \, P_{moon}(\xi) \, \frac{N_{moon}(\xi;i,j,k;r)}{V_{cell}(i,j,k)}$$

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$$\text{where} \quad \xi = \underbrace{\{\phi,\theta,\alpha,\beta,v\}}_{\text{pos and direction of velocity starting vector}}$$

number density for grains of size r in cell i,j,k of grid

numerical integration: use Gaussian weights

4th step: co-adding and calibration

A) distributions of starting conditions 1st step

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$$\tilde{n}_{moon}(i,j,k;r)\mathrm{d}r = \mathrm{d}r \int \mathrm{d}\xi \, P_{moon}(\xi) \, \frac{N_{moon}(\xi;i,j,k;r)}{V_{cell}(i,j,k)}$$

where $\xi = \underbrace{\{\phi, \theta, \alpha, \beta, v\}}$

pos and direction of velocity starting vector

number density for grains of size r in cell i,j,k of grid

numerical integration: use Gaussian weights

$$n_{total}(i,j,k;>r) = \sum_{moons} c_{moon} \int_r^\infty \mathrm{d}r' \, f(r') \, \tilde{n}_{moon}(i,j,k;r')$$

4th step: co-adding and calibration

A) distributions of starting conditions 1st step

B) grid from 2nd step

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plausible power law: e.g. $r^{-3.7}$

4th step: co-adding and calibration

A) distributions of starting conditions 1st step

B) grid from 2nd step

$$\tilde{n}_{moon}(i,j,k;r)\mathrm{d}r = \mathrm{d}r \int \mathrm{d}\xi \, P_{moon}(\xi) \, \frac{N_{moon}(\xi;i,j,k;r)}{V_{cell}(i,j,k)}$$

where $\xi = \underbrace{\{\phi, \theta, \alpha, \beta, v\}}$

pos and direction of velocity starting vector

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normalization from Galileo DDS

plausible power law: e.g. $r^{-3.7}$

4th step: co-adding and calibration

- do the same for the velocity in a given grid cell

$$\vec{v}_{total}(i,j,k;>r) = \sum_{moons} \underset{\uparrow}{c_{moon}} \int_r^\infty \mathrm{d}r' \, \underset{\uparrow}{f(r')} \, \tilde{\vec{v}}_{moon}(i,j,k;r')$$

normalization from Galileo DDS

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4th step: co-adding and calibration

- do the same for the velocity in a given grid cell
- to reconstruct the flux on a user specified surface: also store moments for $<v^2>$ and $<v^3>$

$$\vec{v}_{total}(i,j,k;>r) = \sum_{moons} \underset{\uparrow}{c_{moon}} \int_r^\infty \mathrm{d}r' \, \underset{\uparrow}{f}(r') \, \tilde{\vec{v}}_{moon}(i,j,k;r')$$

normalization from Galileo DDS

plausible power law: e.g. $r^{-3.7}$

4th step: co-adding and calibration

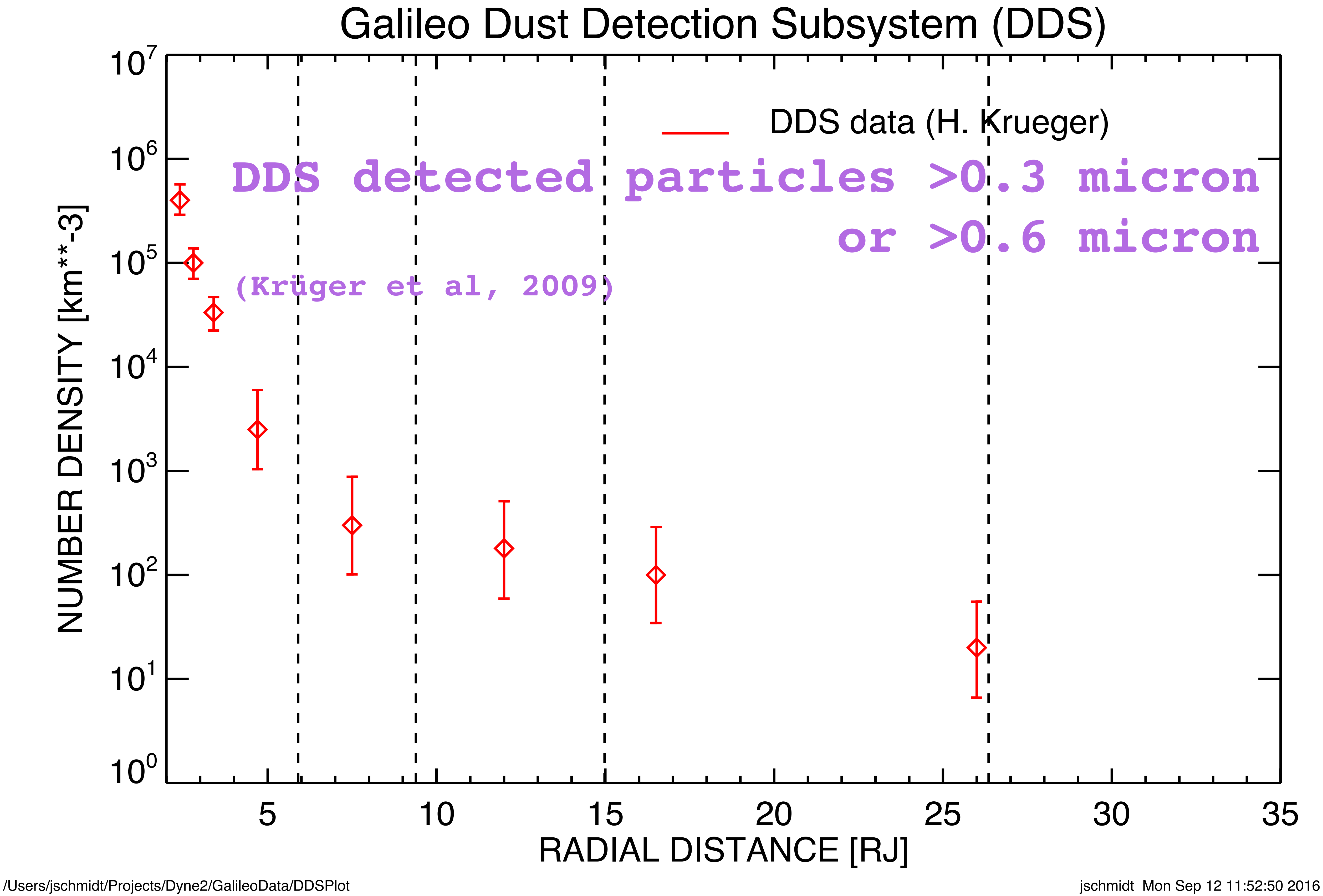
* do the same for the velocity in a given grid cell
* to reconstruct the flux on a user specified surface: also store moments for $<v^2>$ and $<v^3>$
* populating the grid cells takes about 2 CPU hours for all moons, grain sizes

$$\vec{v}_{total}(i,j,k;>r) = \sum_{moons} c_{moon} \int_r^\infty \mathrm{d}r' \, f(r') \, \tilde{\vec{v}}_{moon}(i,j,k;r')$$

normalization from Galileo DDS

plausible power law: e.g. $r^{-3.7}$

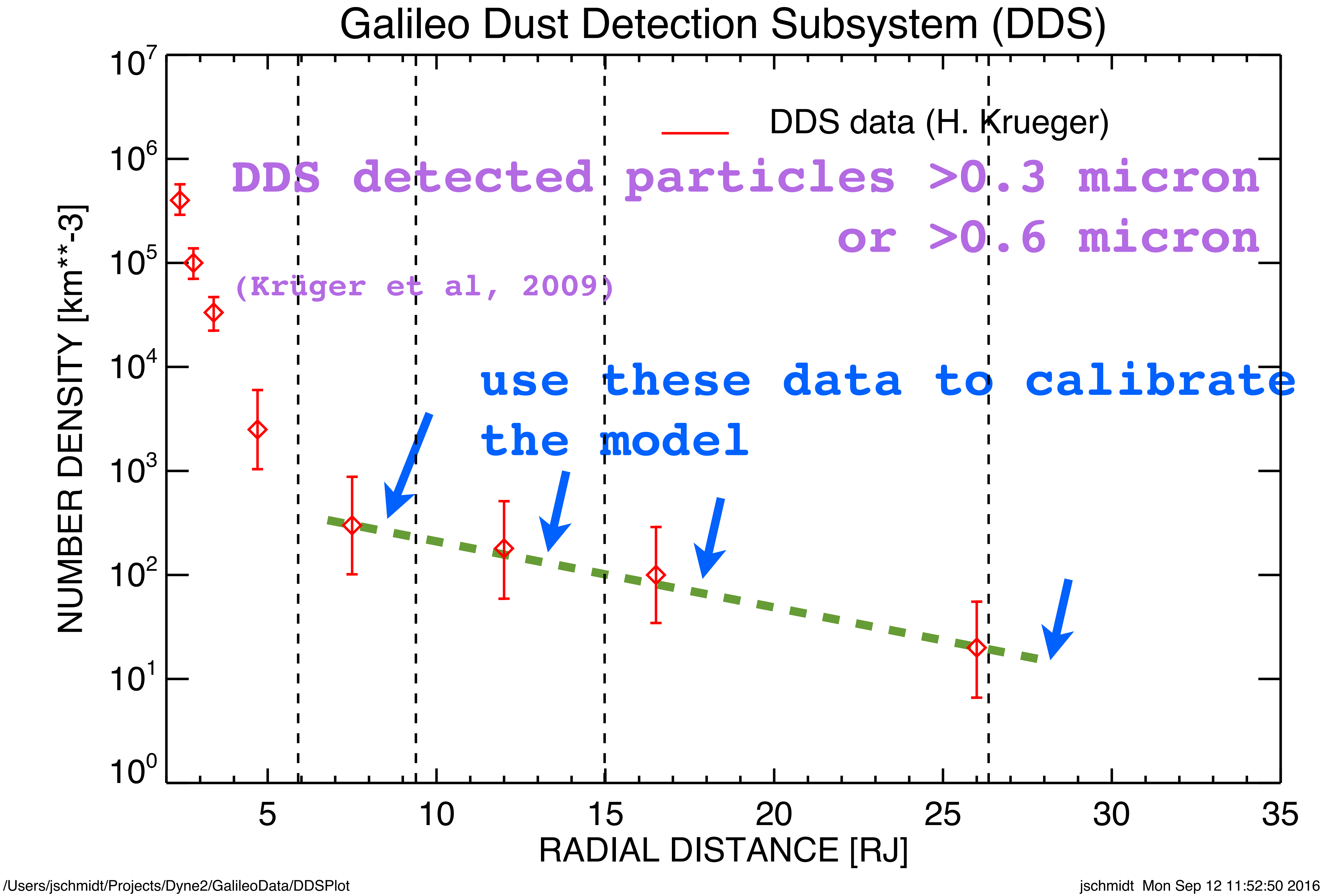
Calibration, in practice



DDS detected particles >0.3 micron
or >0.6 micron

(Krüger et al, 2009)

Calibration, in practice

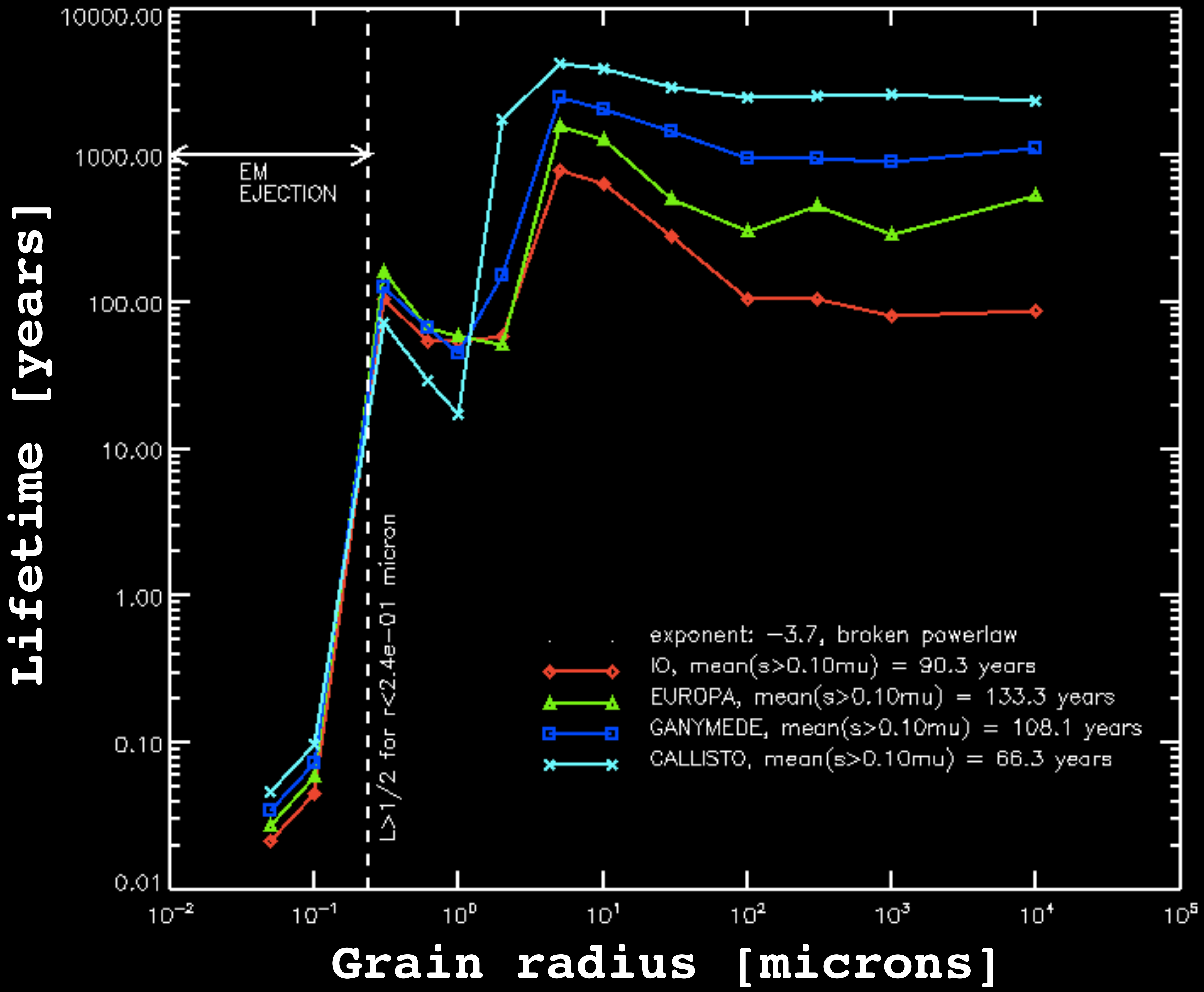


DDS detected particles >0.3 micron
or >0.6 micron

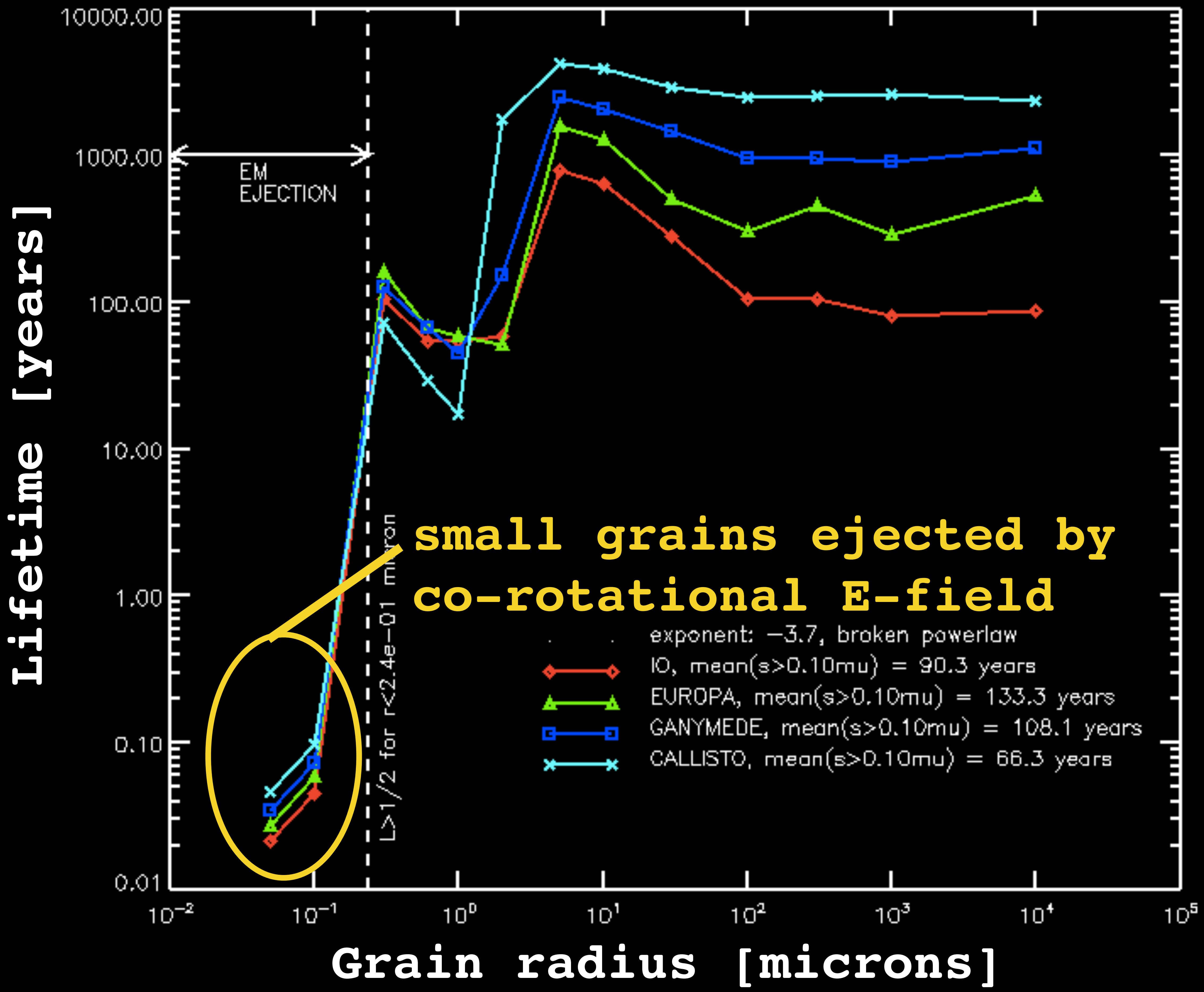
(Krüger et al, 2009)

use these data to calibrate the model

Grain lifetimes

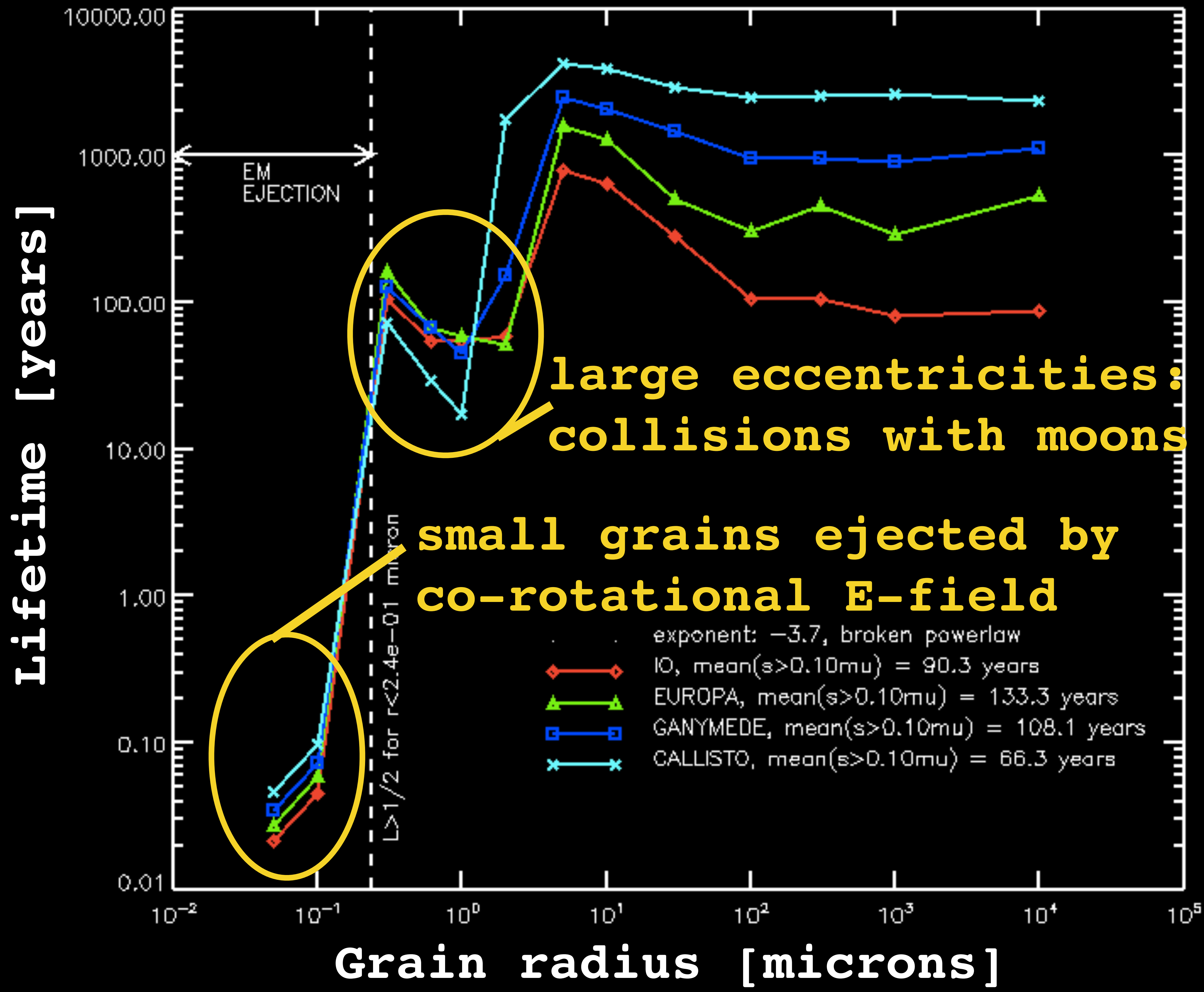


Grain lifetimes



small grains ejected by co-rotational E-field

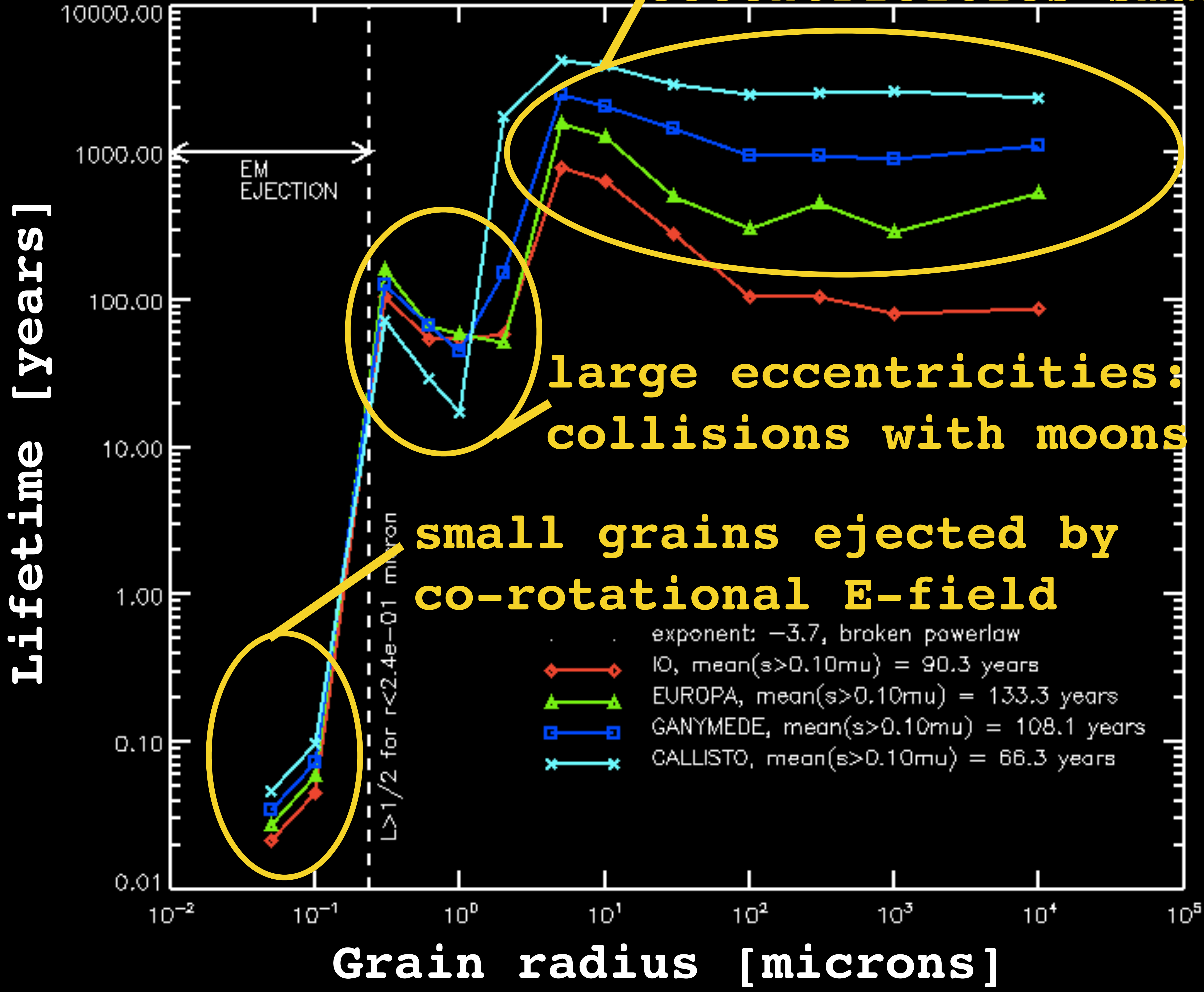
Grain lifetimes



large eccentricities: collisions with moons

small grains ejected by co-rotational E-field

Grain lifetimes



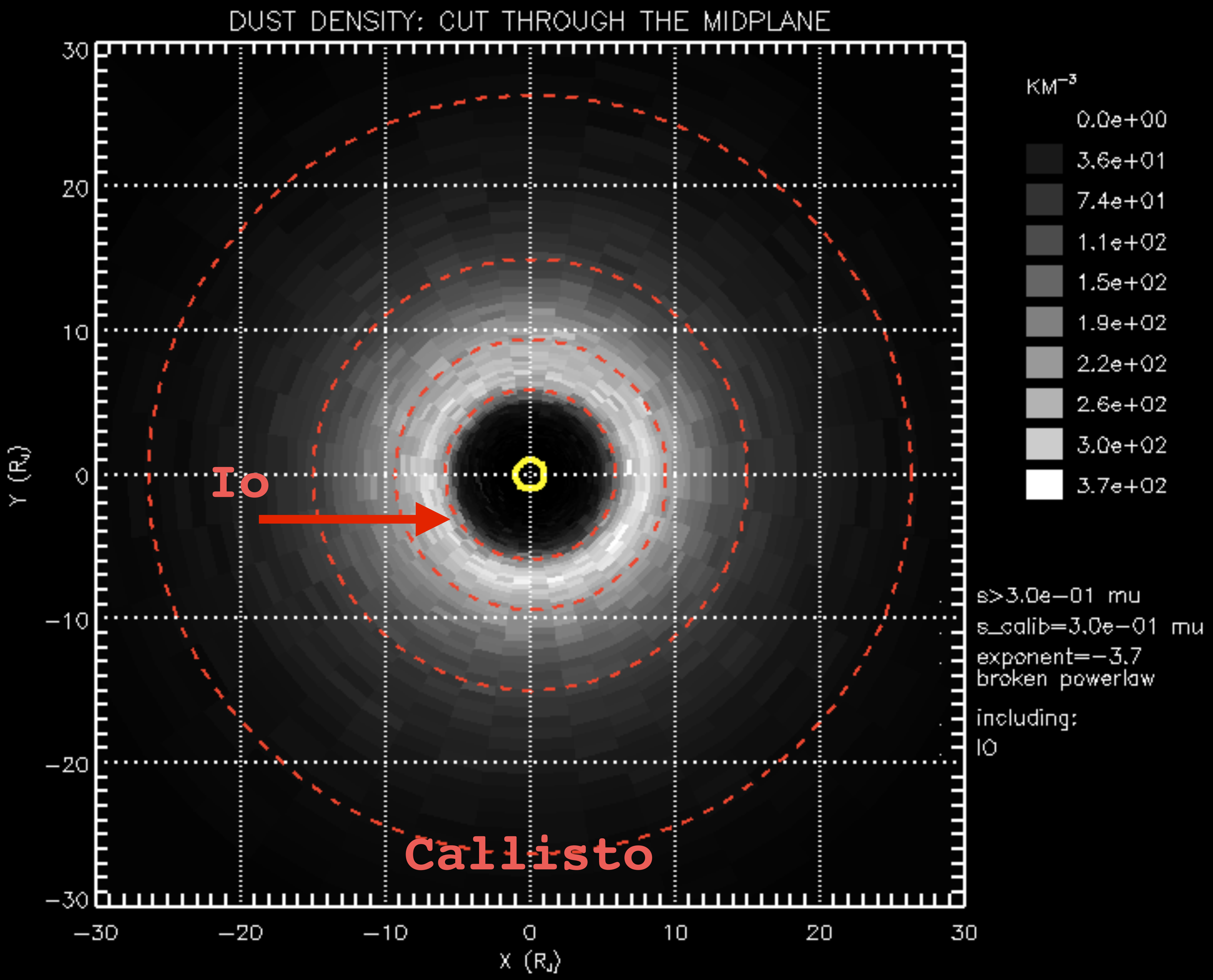
eccentricities small

large eccentricities: collisions with moons

small grains ejected by co-rotational E-field

Model: Grains from Io only

inertial frame

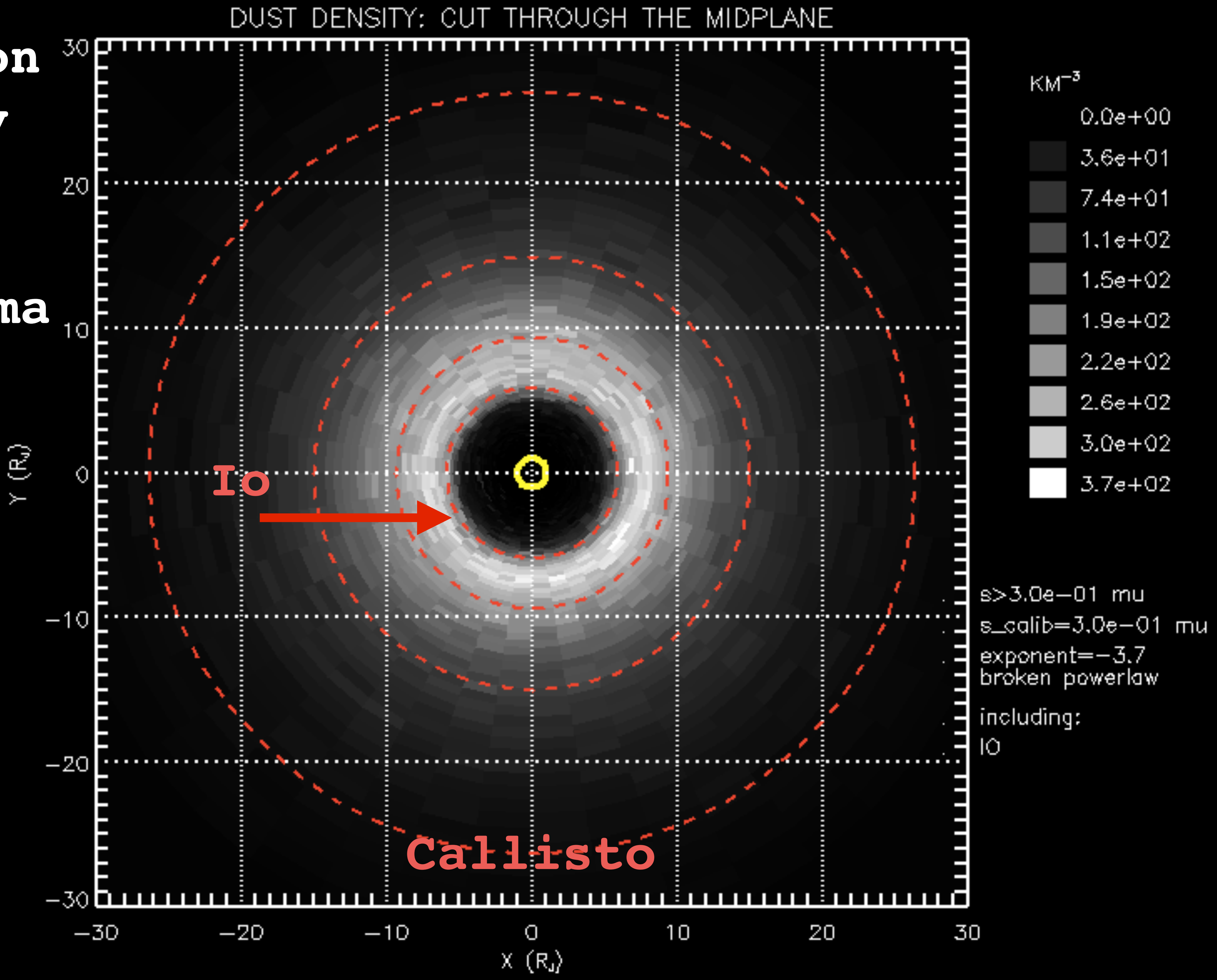


Model: Grains from Io only **inertial frame**

evolution radially outward:

$\dot{a} > 0$

-> plasma drag



Model: Grains from Io only inertial frame

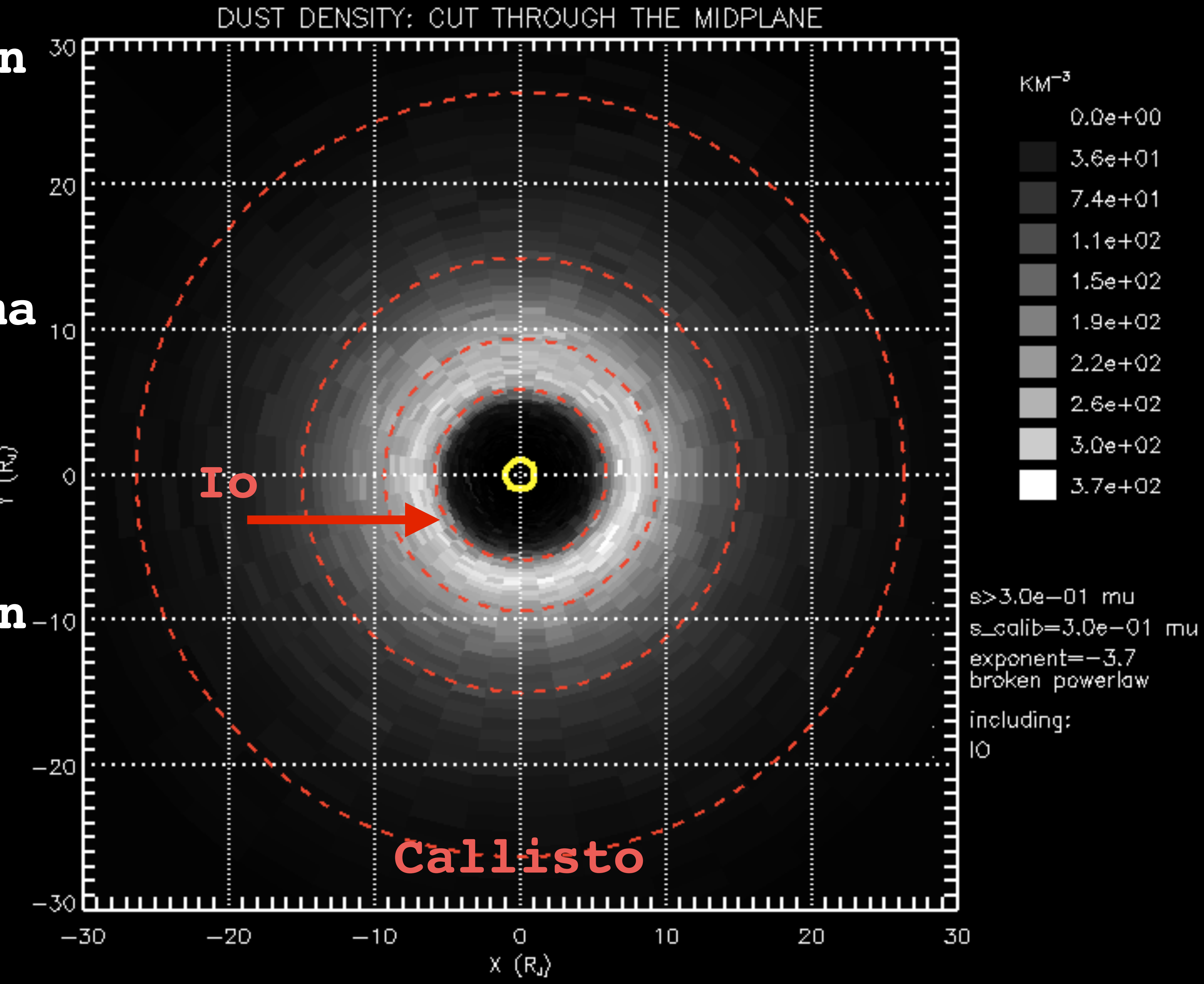
evolution radially outward:

$\dot{a} > 0$

-> plasma drag

$\dot{e} > 0$

-> solar radiation



Model: Grains from Io only **inertial frame**

evolution radially outward:

$\dot{a} > 0$

-> plasma drag

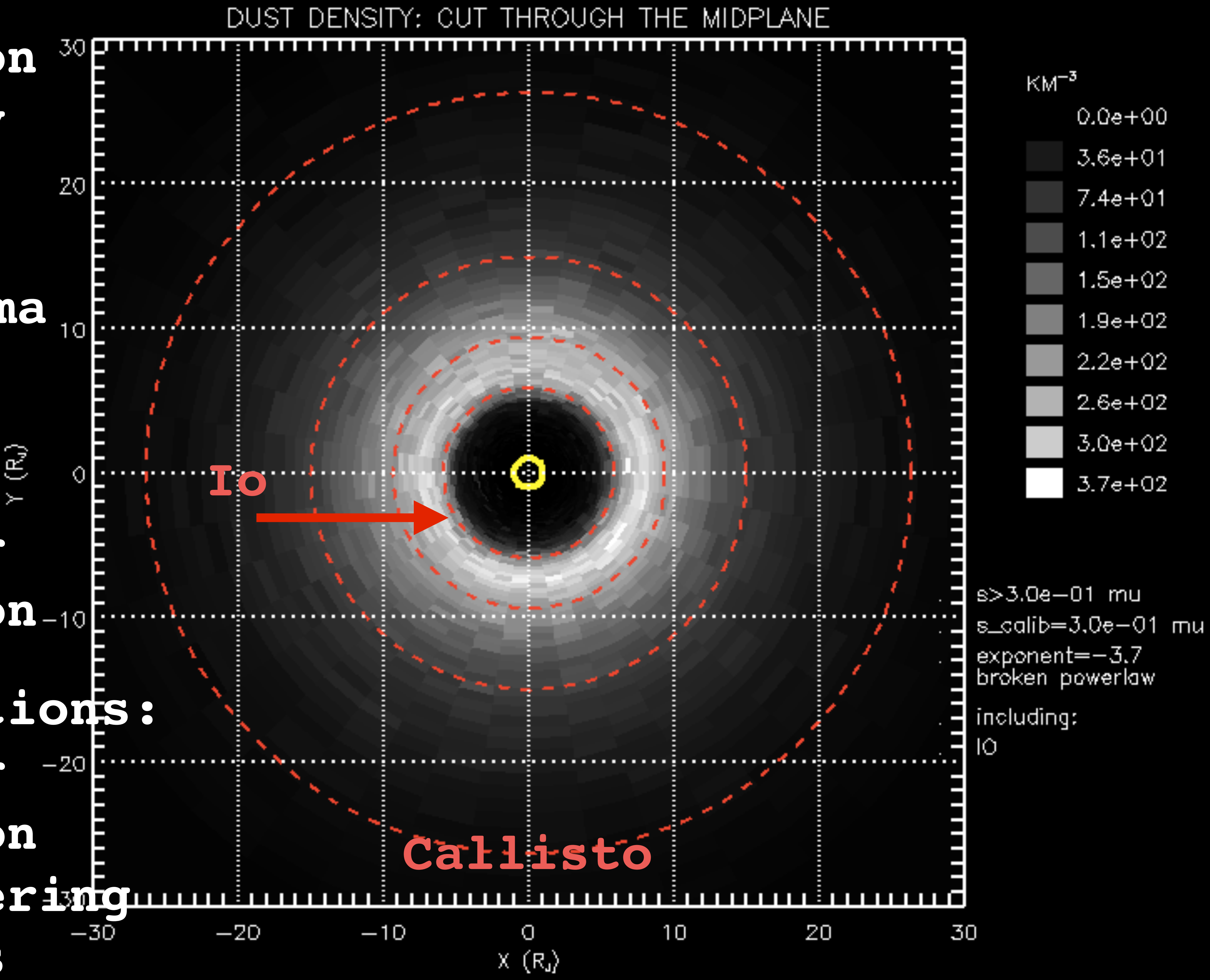
$\dot{e} > 0$

-> solar radiation

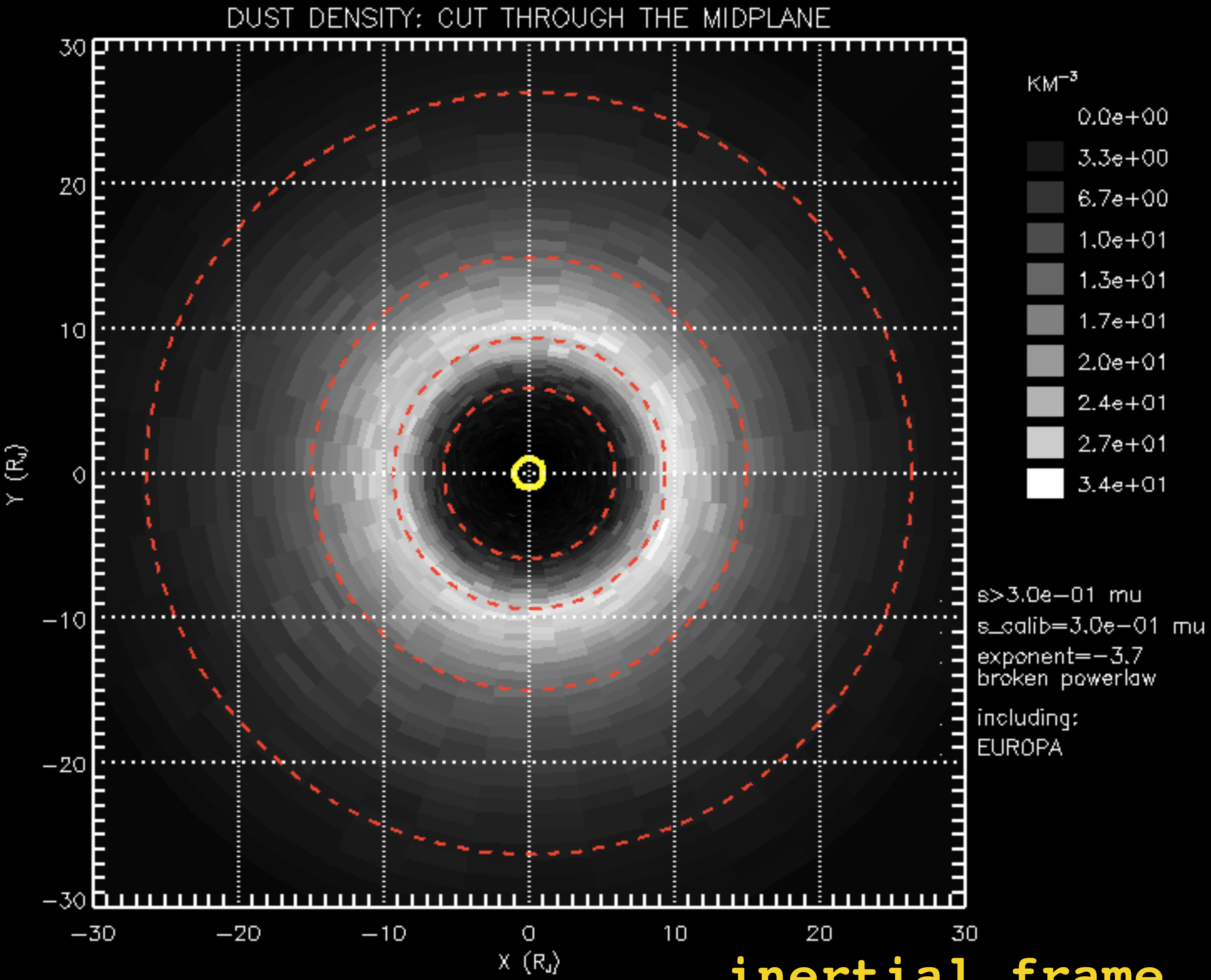
inclinations:

-> solar radiation

+ scattering by moons

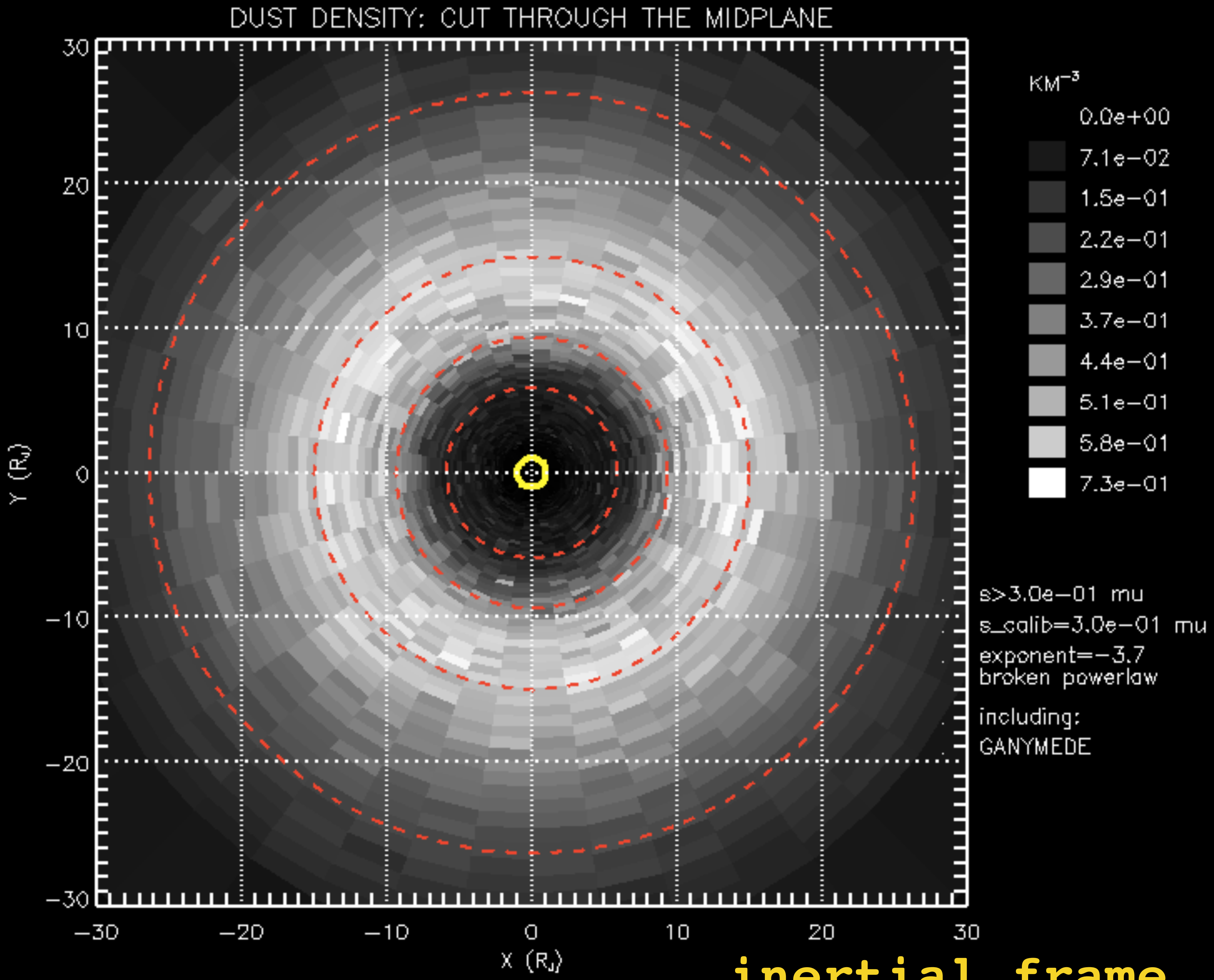


Model: Grains from Europa only



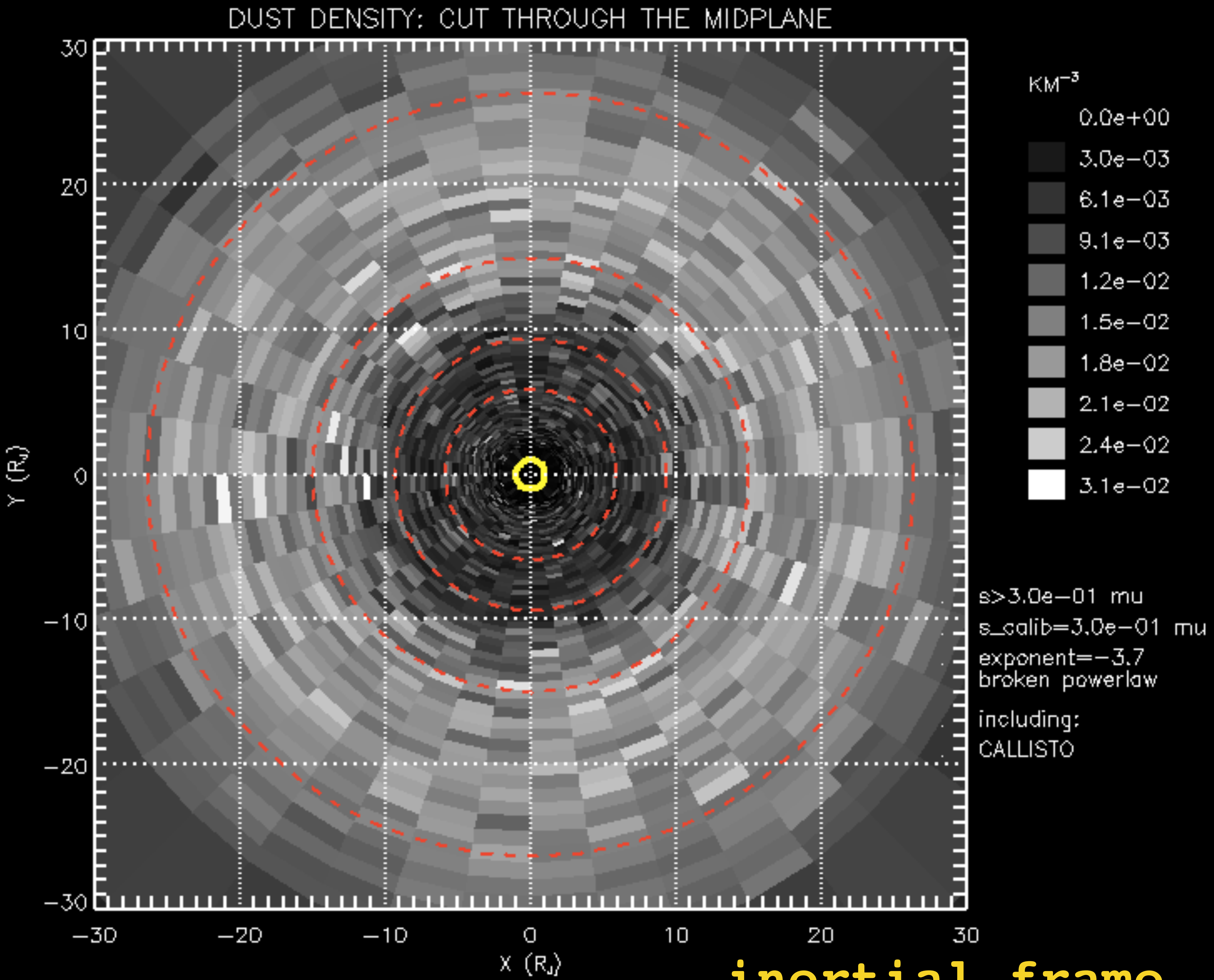
inertial frame

Model: Grains from Ganymede only



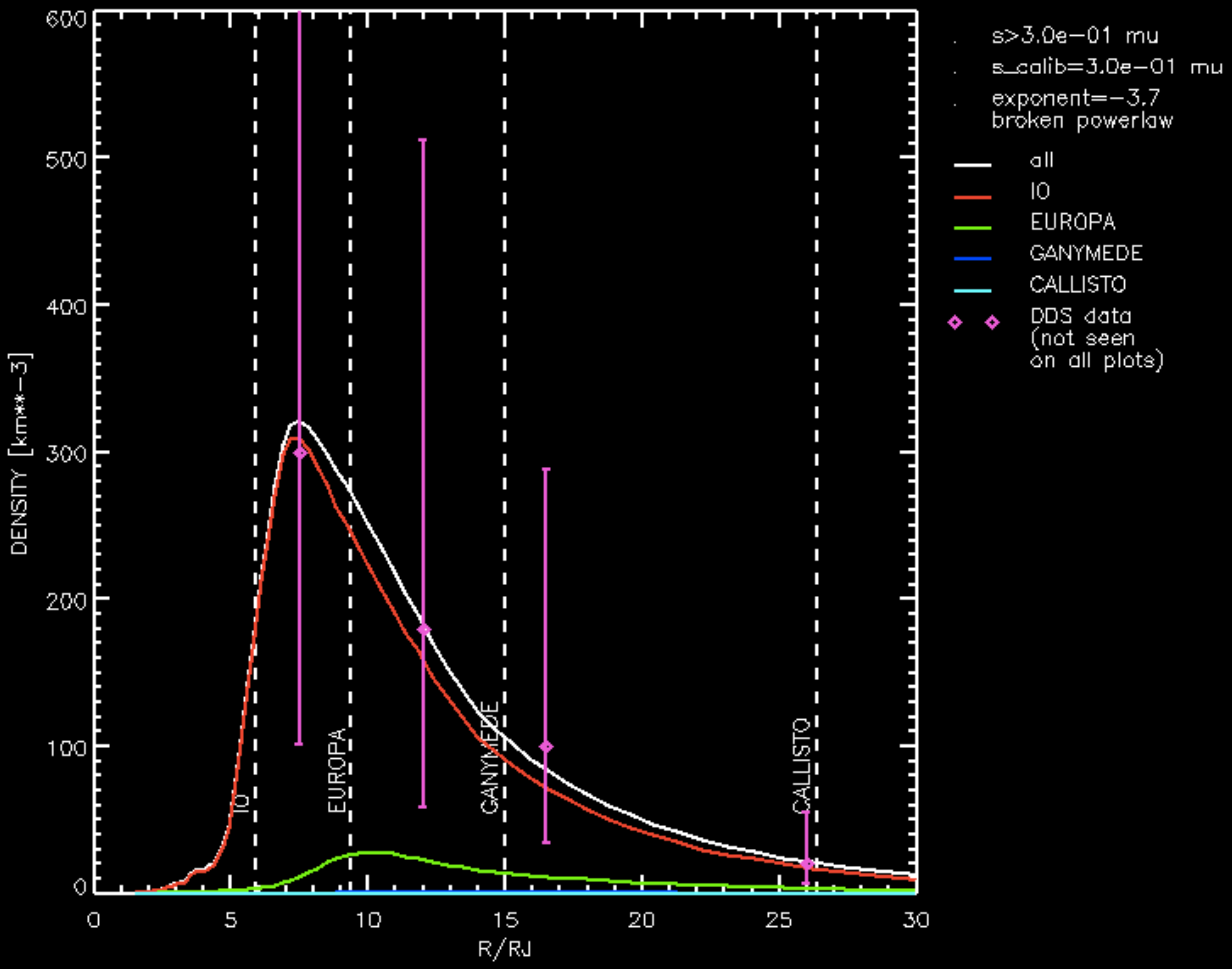
inertial frame

Model: Grains from Callisto only

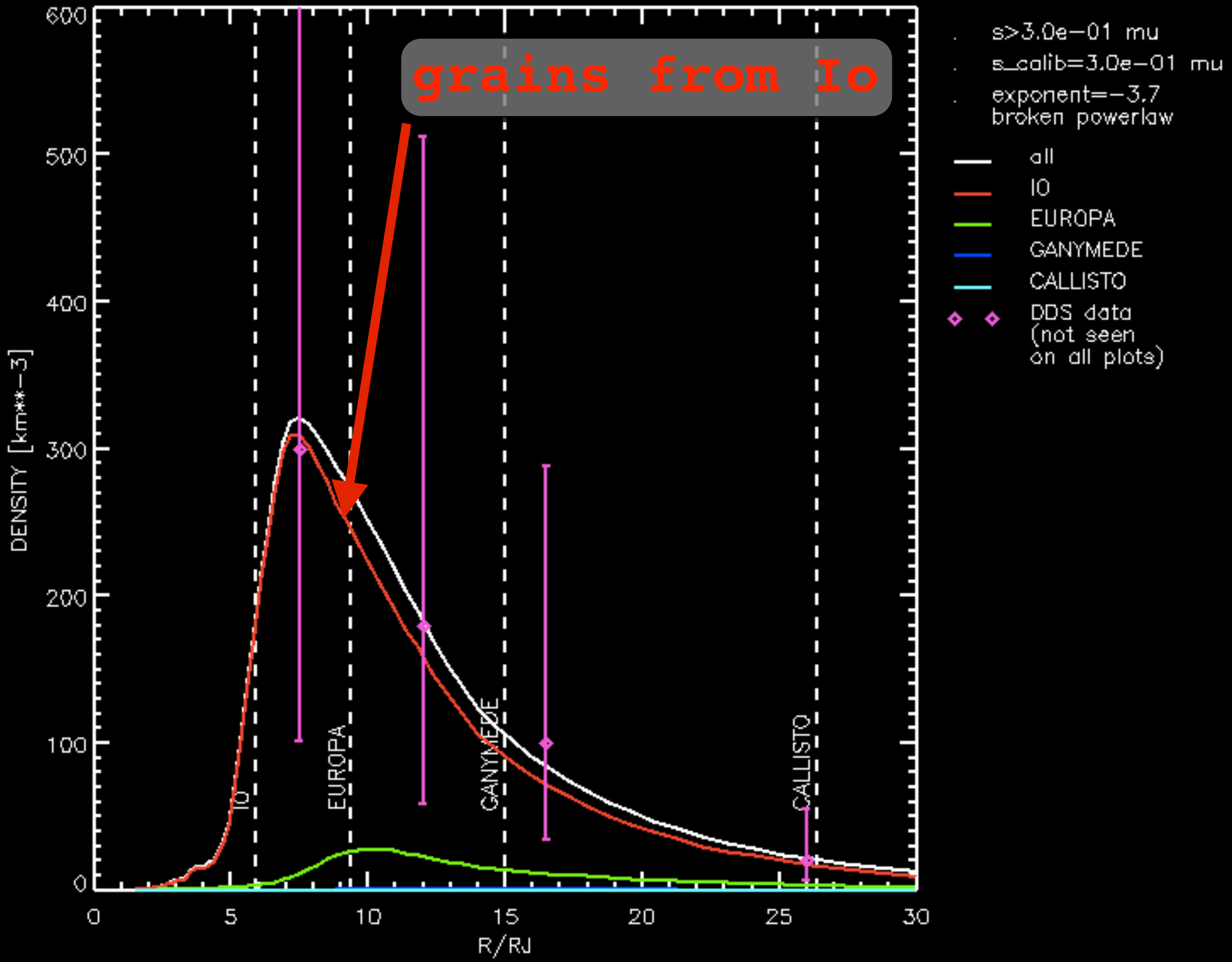


inertial frame

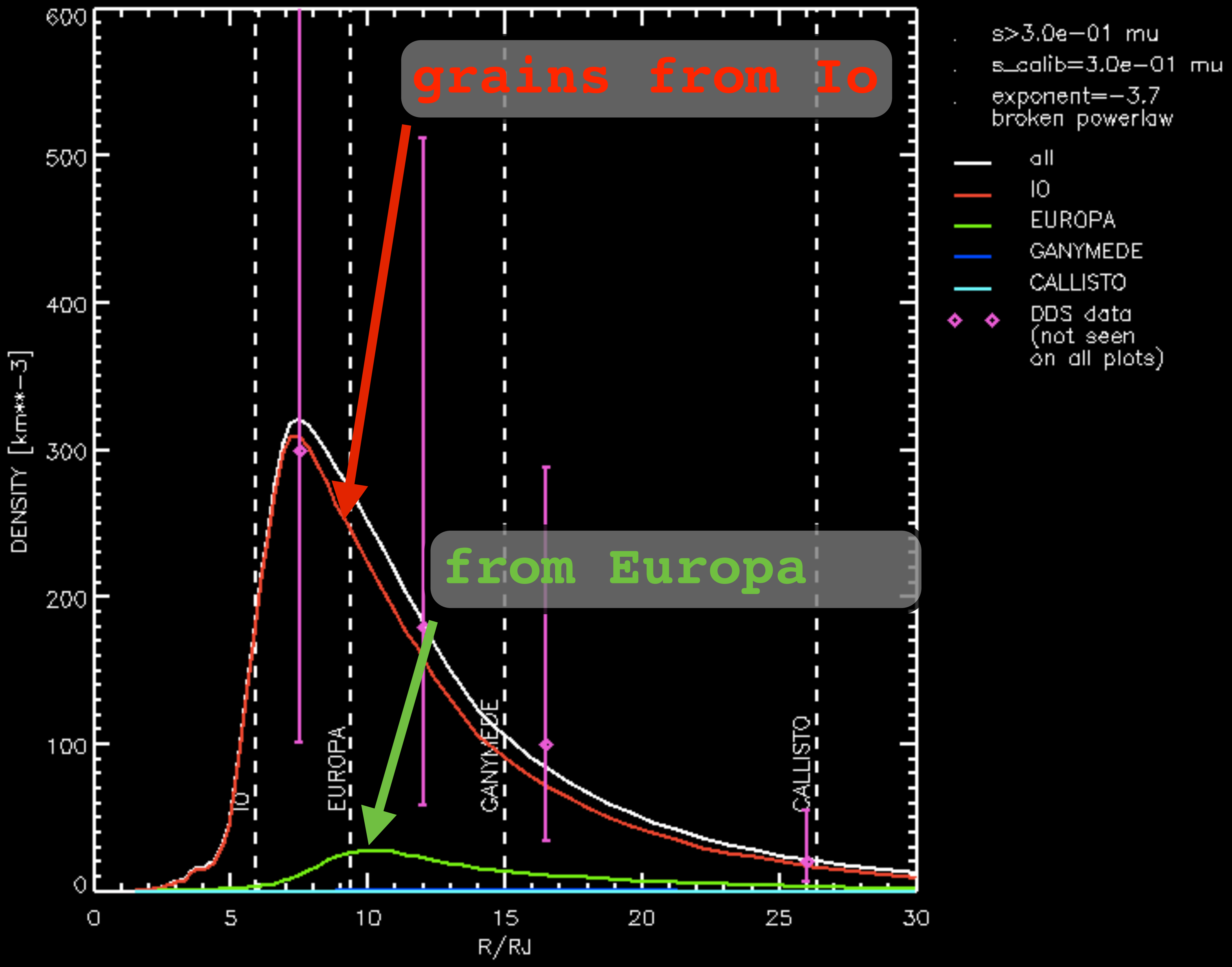
Calibration of the model with Galileo DDS:



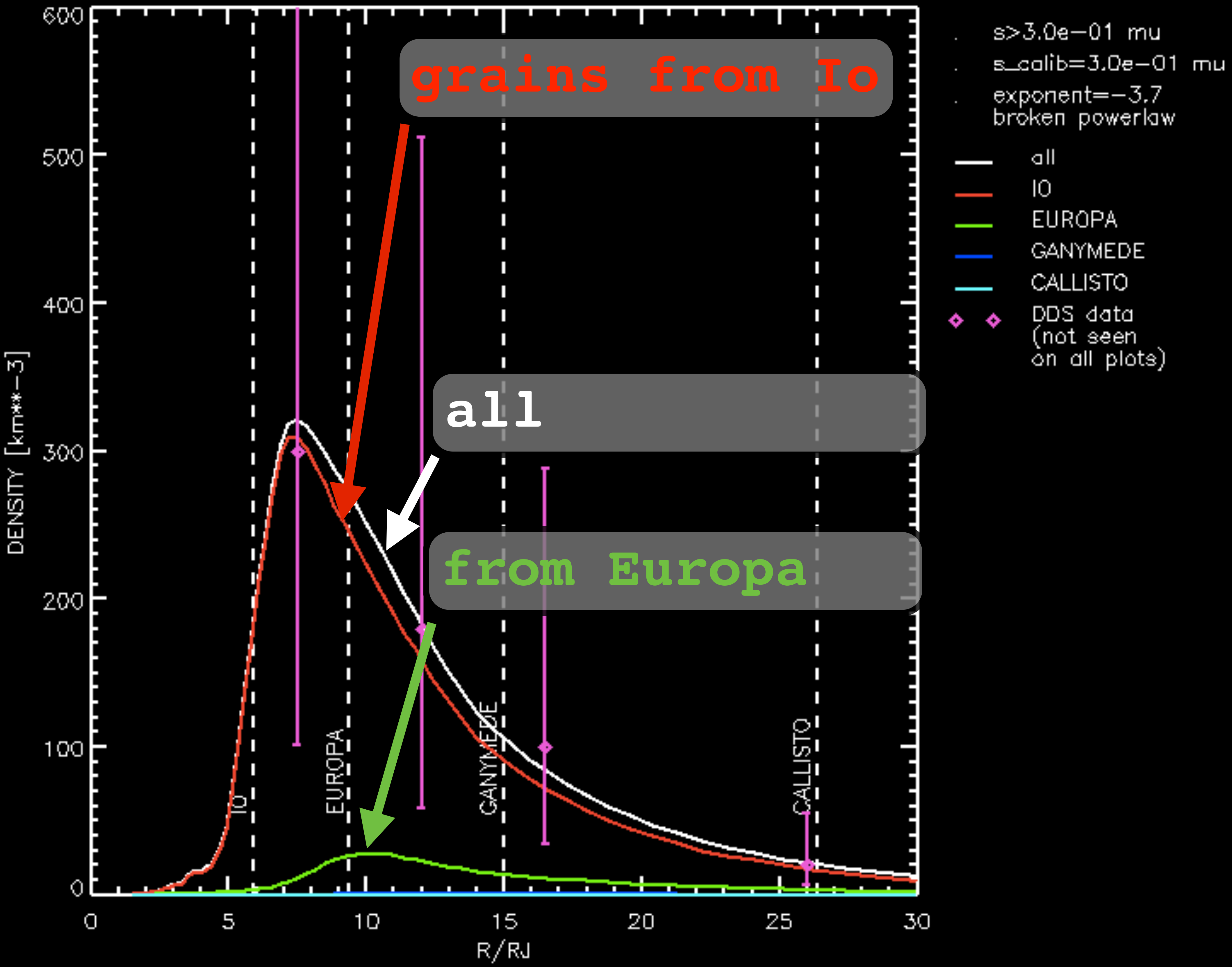
Calibration of the model with Galileo DDS:



Calibration of the model with Galileo DDS:



Calibration of the model with Galileo DDS:

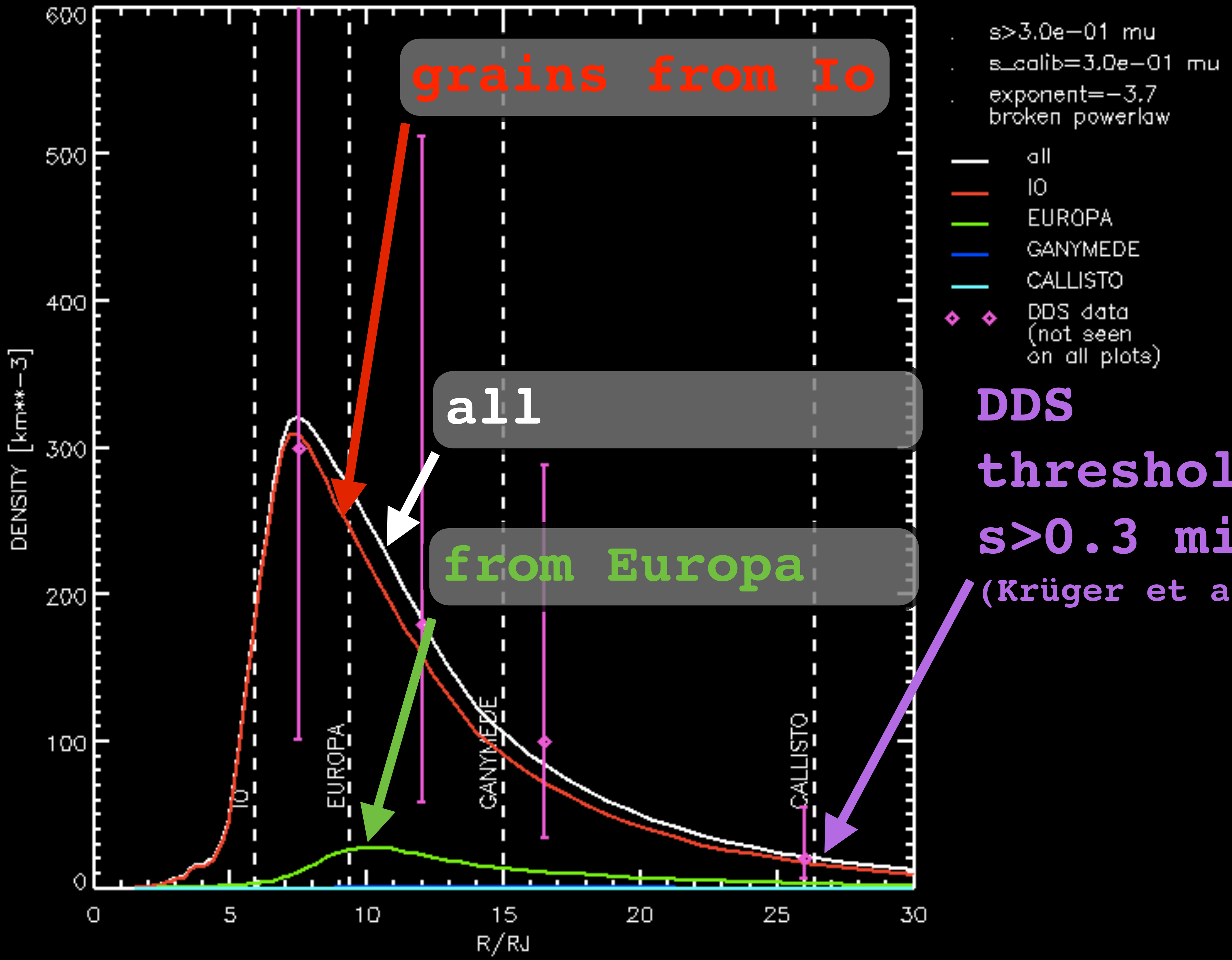


grains from Io

all

from Europa

Calibration of the model with Galileo DDS:



grains from Io

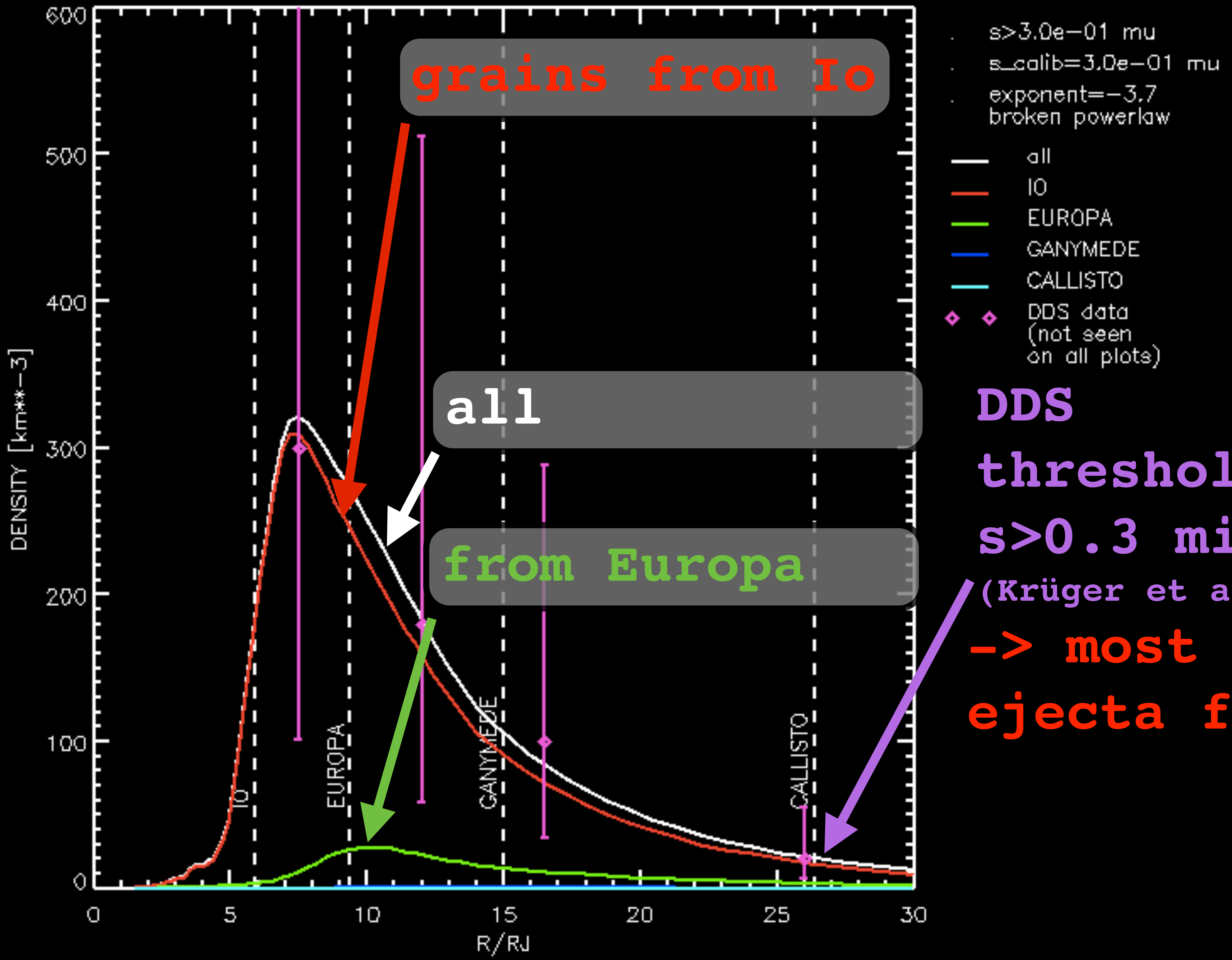
all

from Europa

DDS threshold s>0.3 micron

(Krüger et al, 2009)

Calibration of the model with Galileo DDS:



grains from Io

all

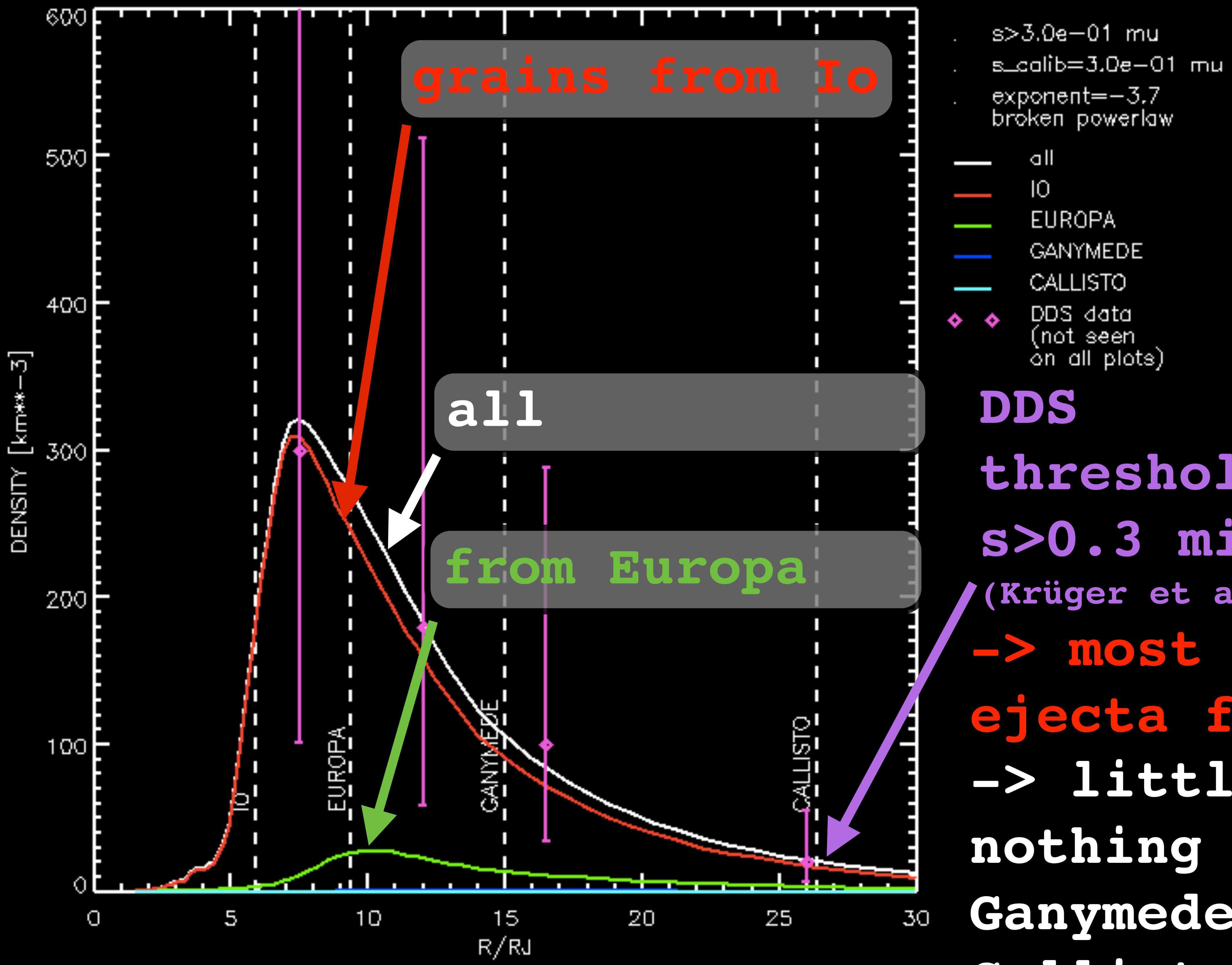
from Europa

DDS threshold s>0.3 micron

(Krüger et al, 2009)

-> most are ejecta from Io

Calibration of the model with Galileo DDS:



grains from Io

all

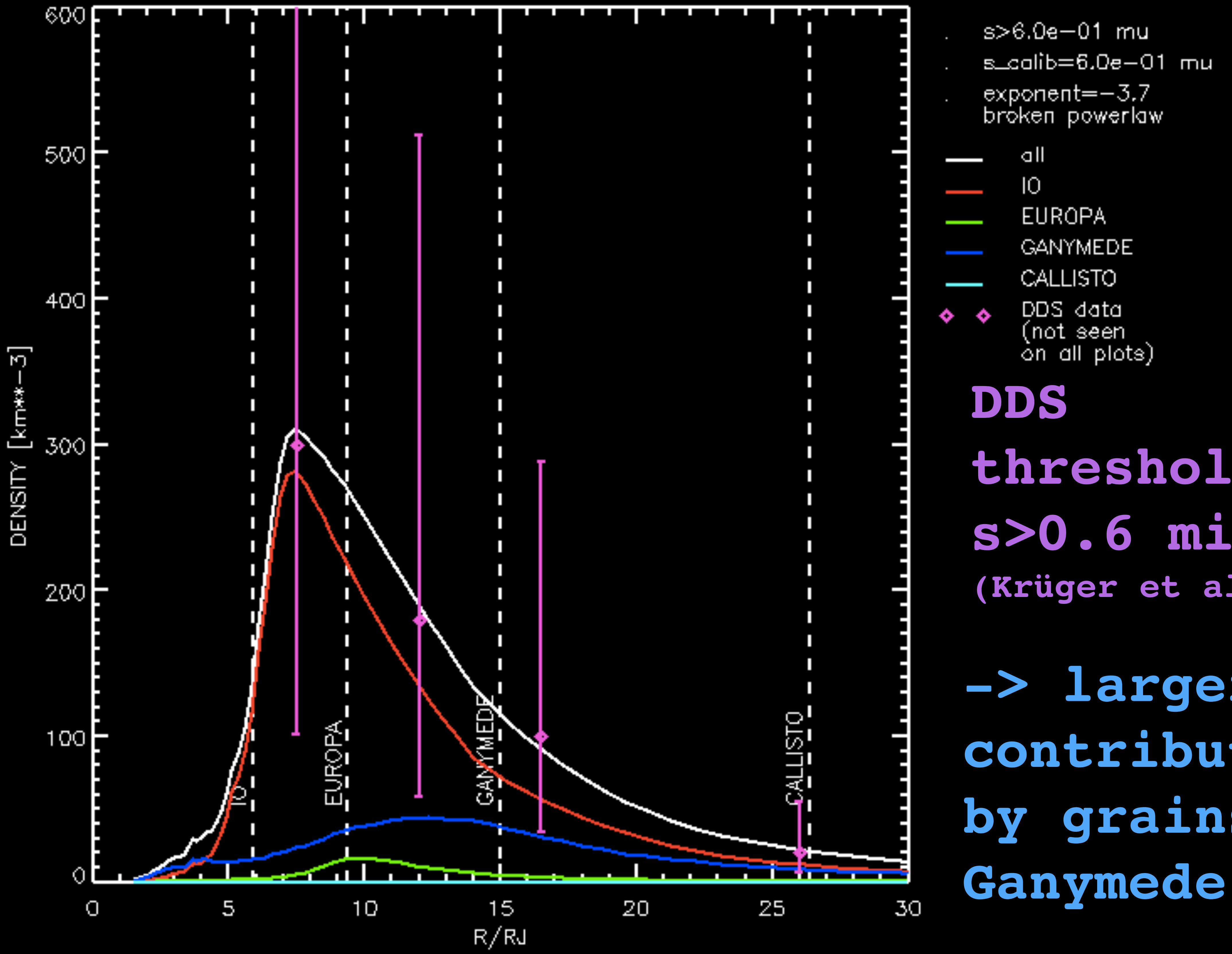
from Europa

DDS threshold s>0.3 micron
(Krüger et al, 2009)

-> most are ejecta from Io

-> little or nothing from Ganymede/ Callisto

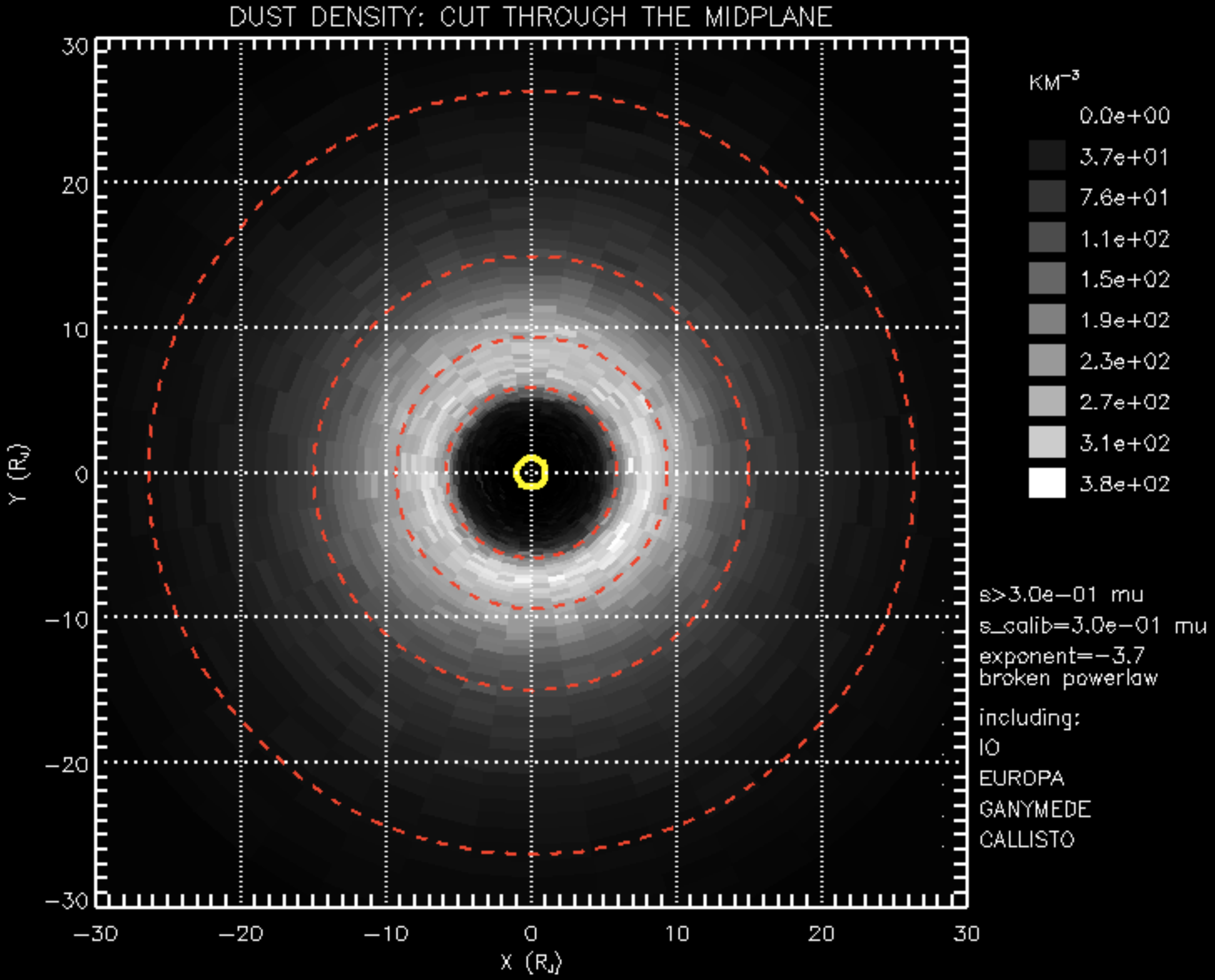
Calibration of the model with Galileo DDS:



DDS threshold s>0.6 micron
(Krüger et al, 2009)

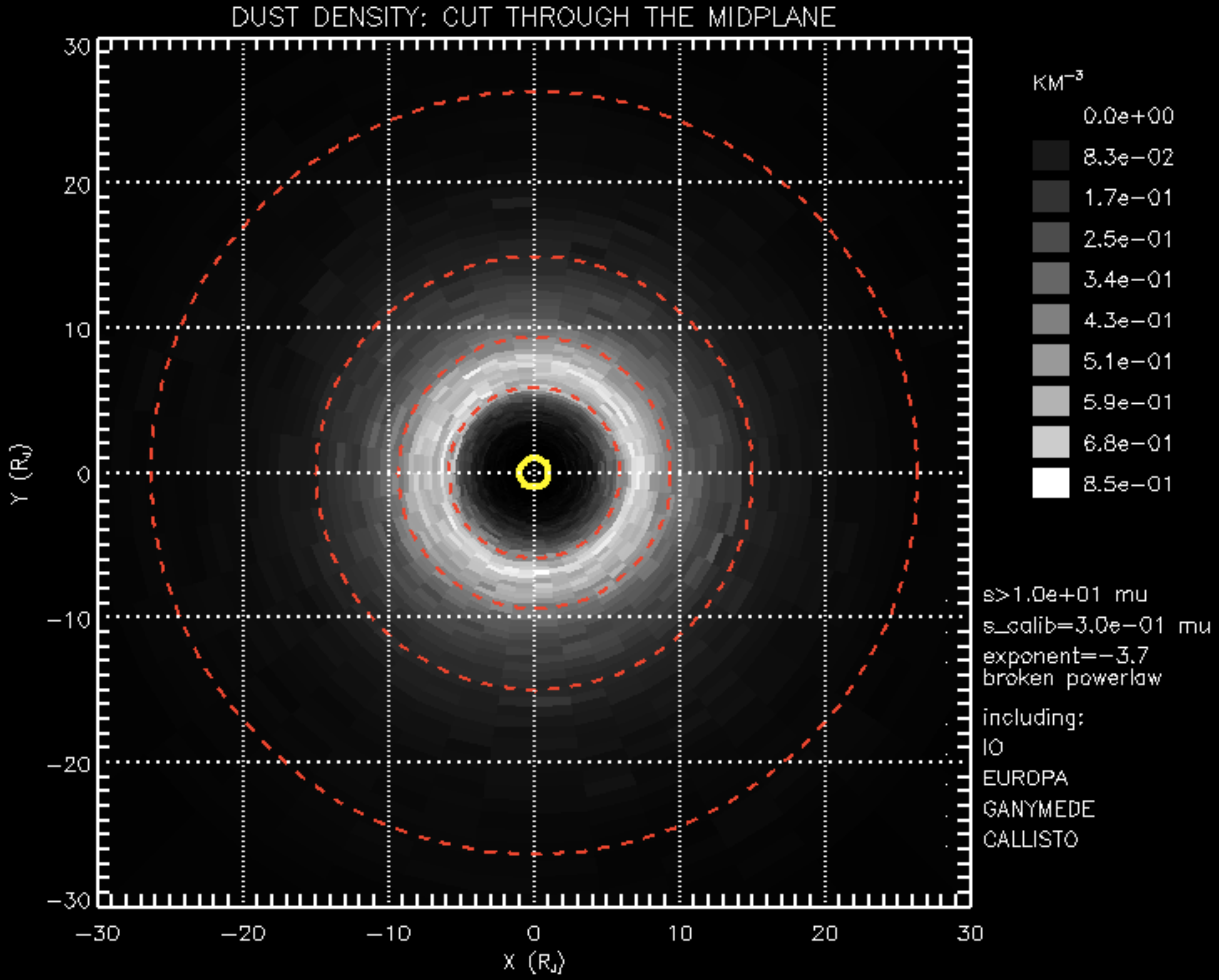
-> larger contribution by grains from Ganymede

All moons:



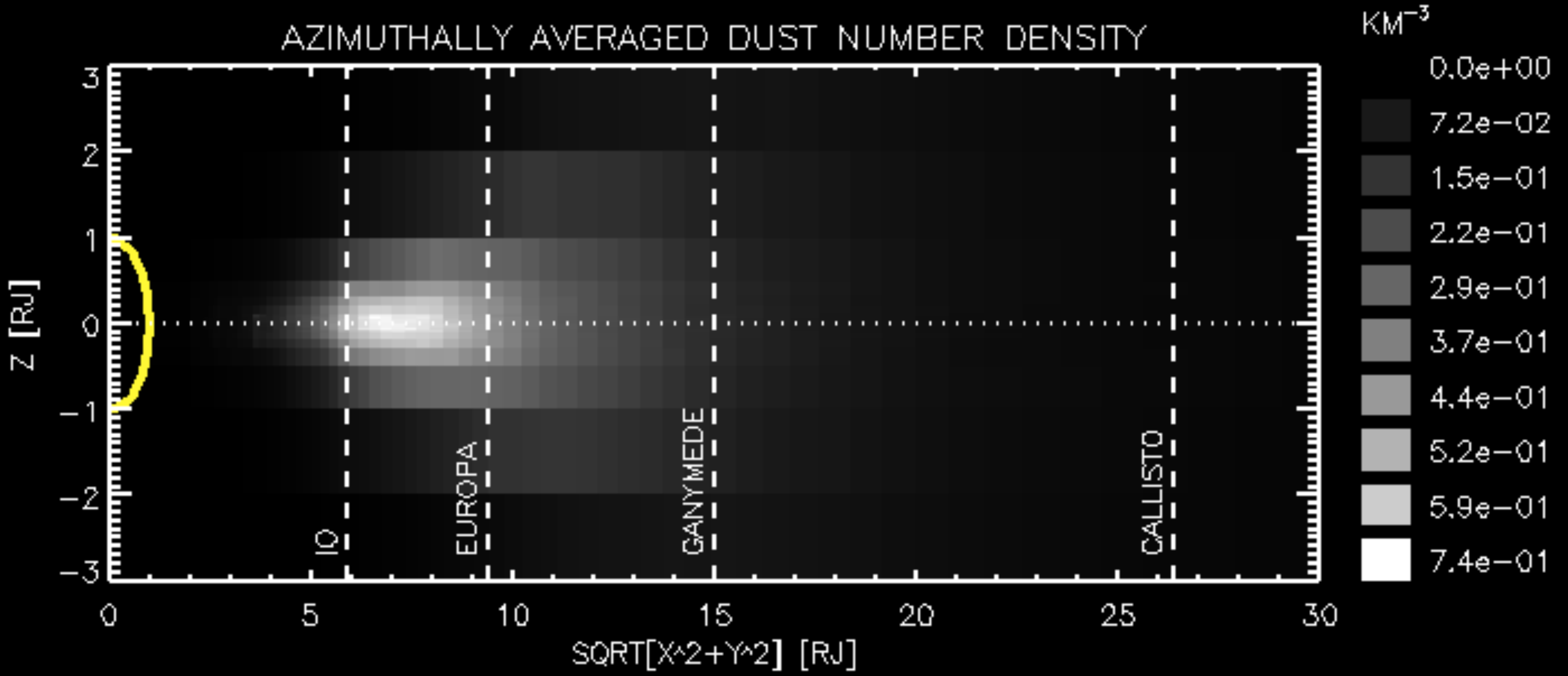
inertial frame

Grains > 10 micron



inertial frame

Vertical cut



s>1.0e+01 mu

s_calib=3.0e−01 mu

exponent=−3.7
broken powerlaw

including:

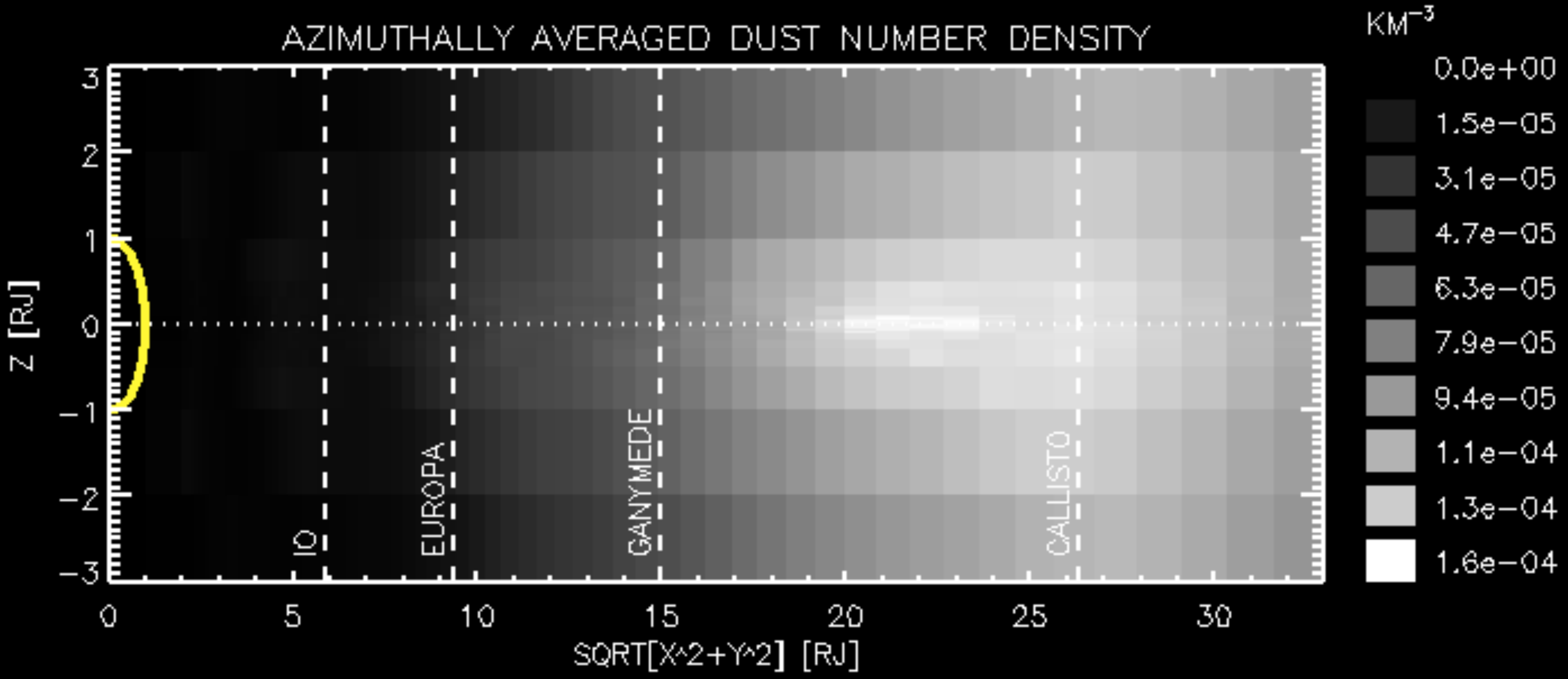
IO

EUROPA

GANYMEDE

CALLISTO

Only grains from Callisto:



s>1.0e+01 mu

s_calib=3.0e−01 mu

exponent=−3.7
broken powerlaw

including:

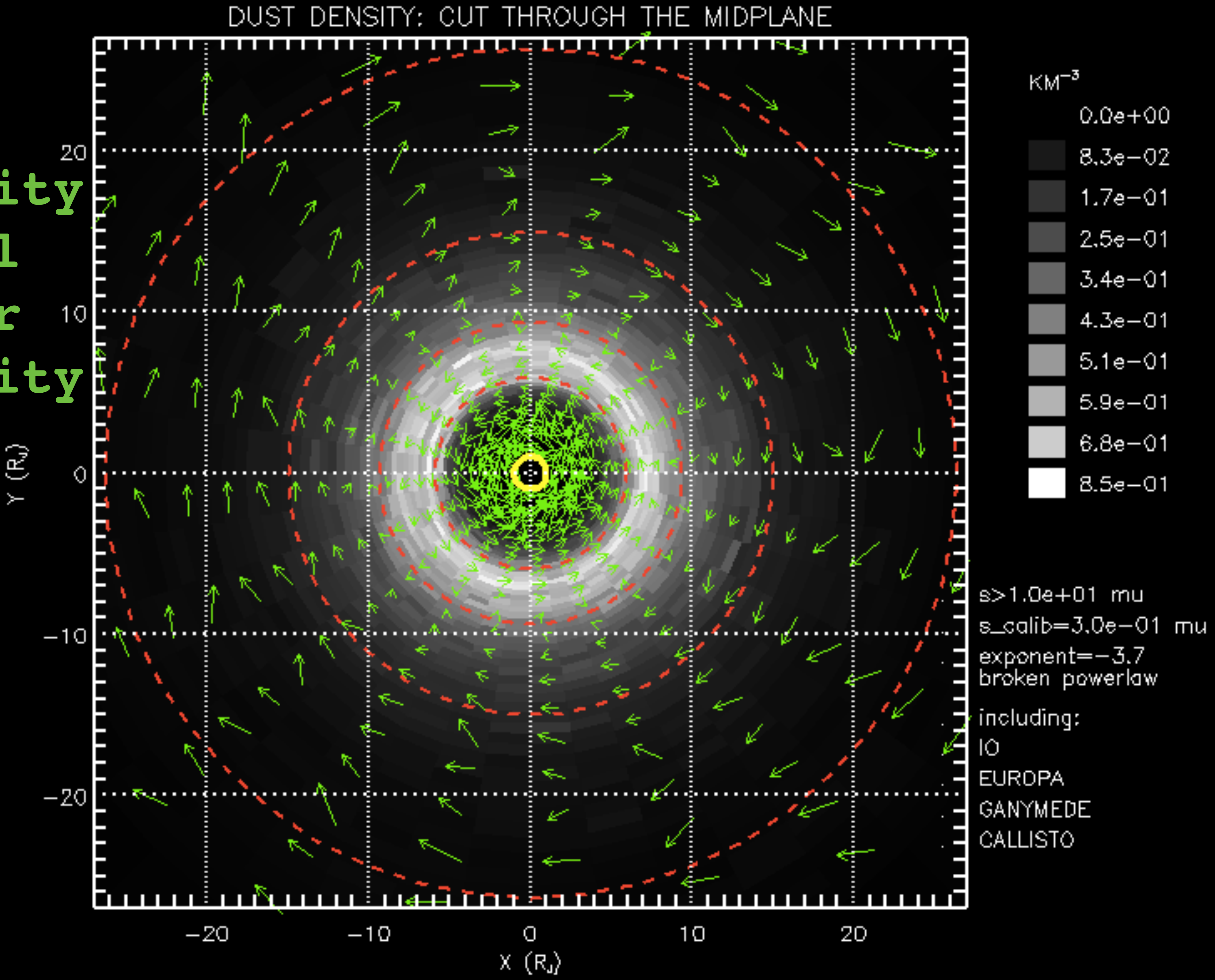
CALLISTO

-> very low density

-> larger vertical spread

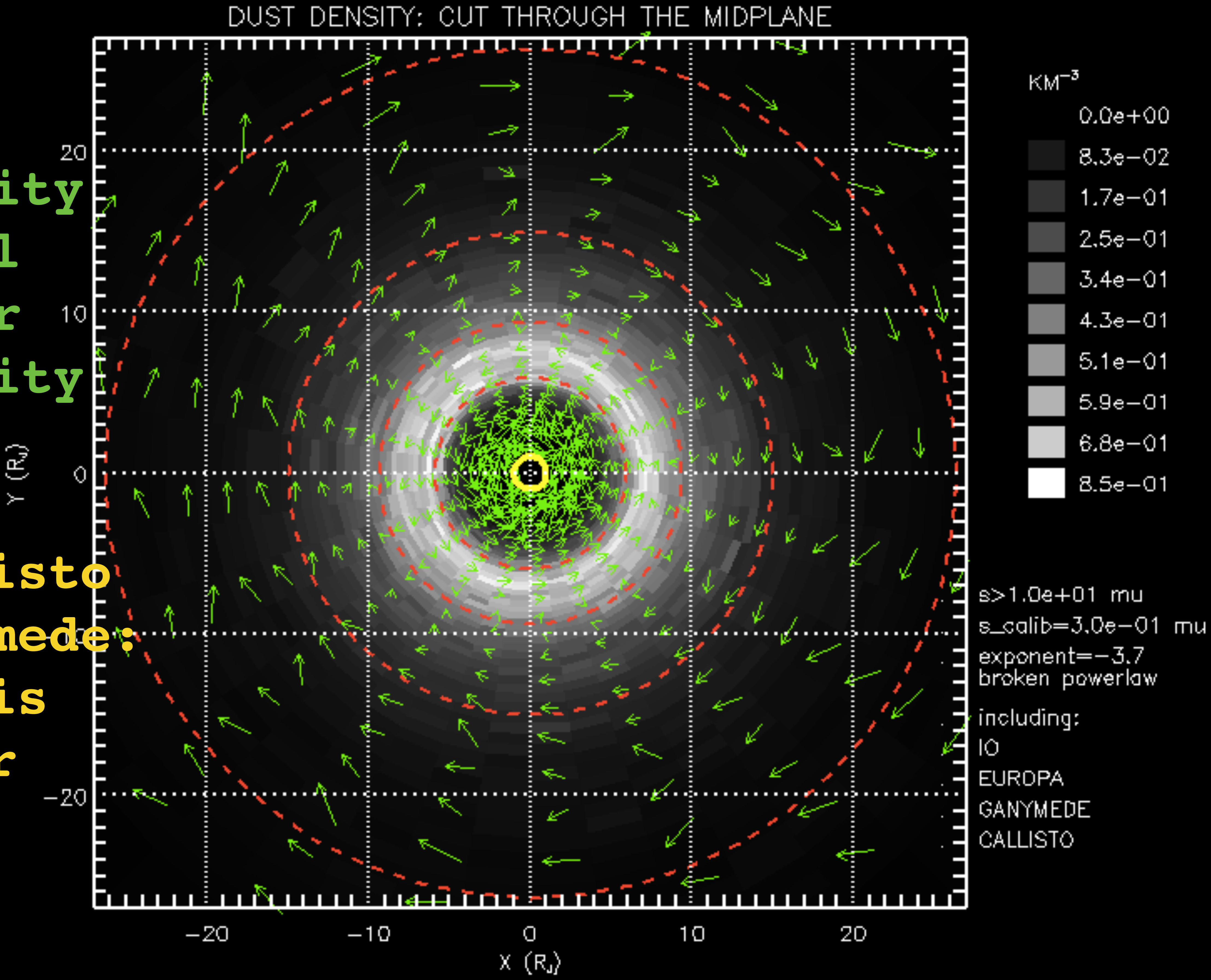
Systematic velocities

dust velocity -local kepler velocity



Systematic velocities

dust velocity -local kepler velocity

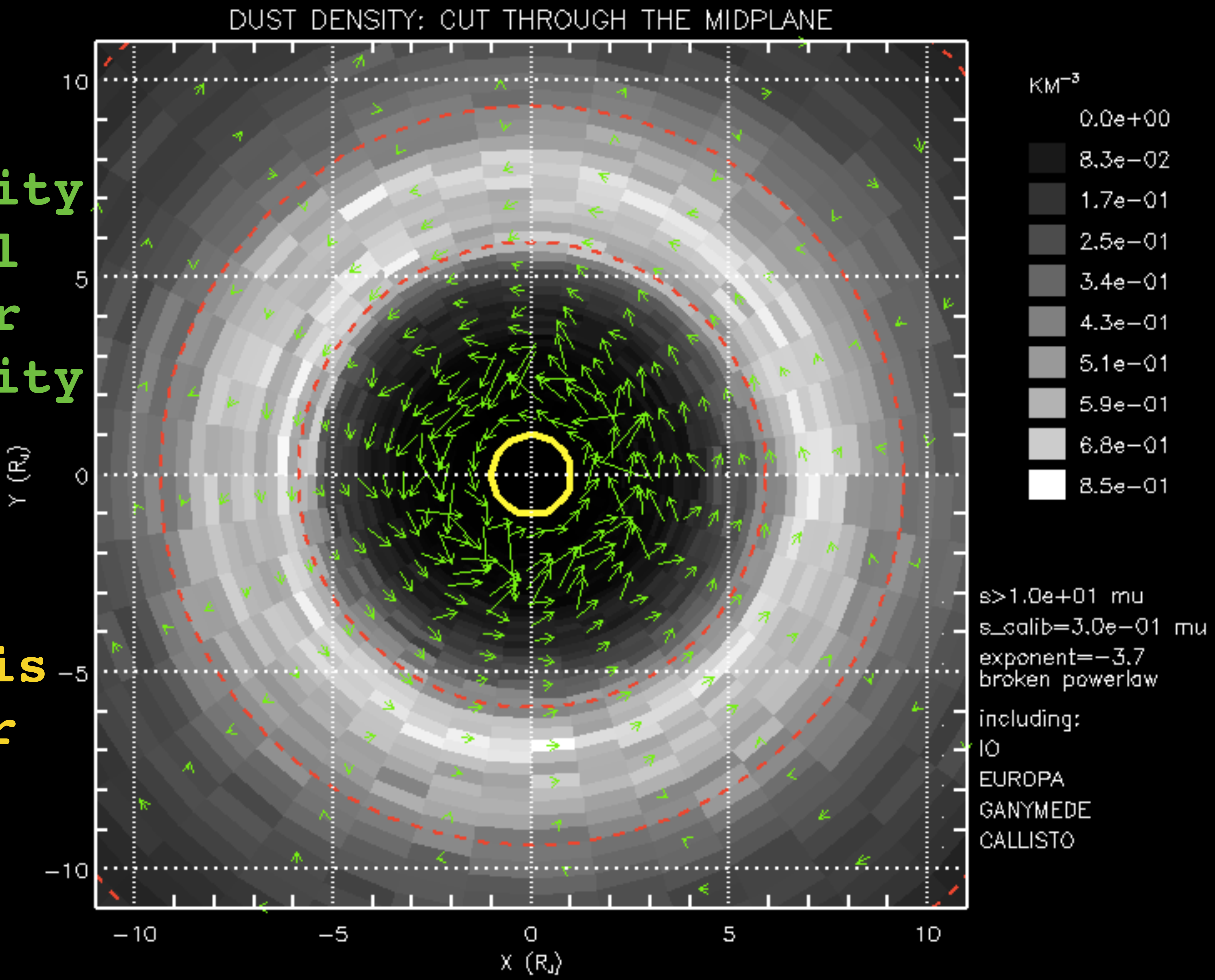


@Callisto +Ganymede: dust is slower than moons

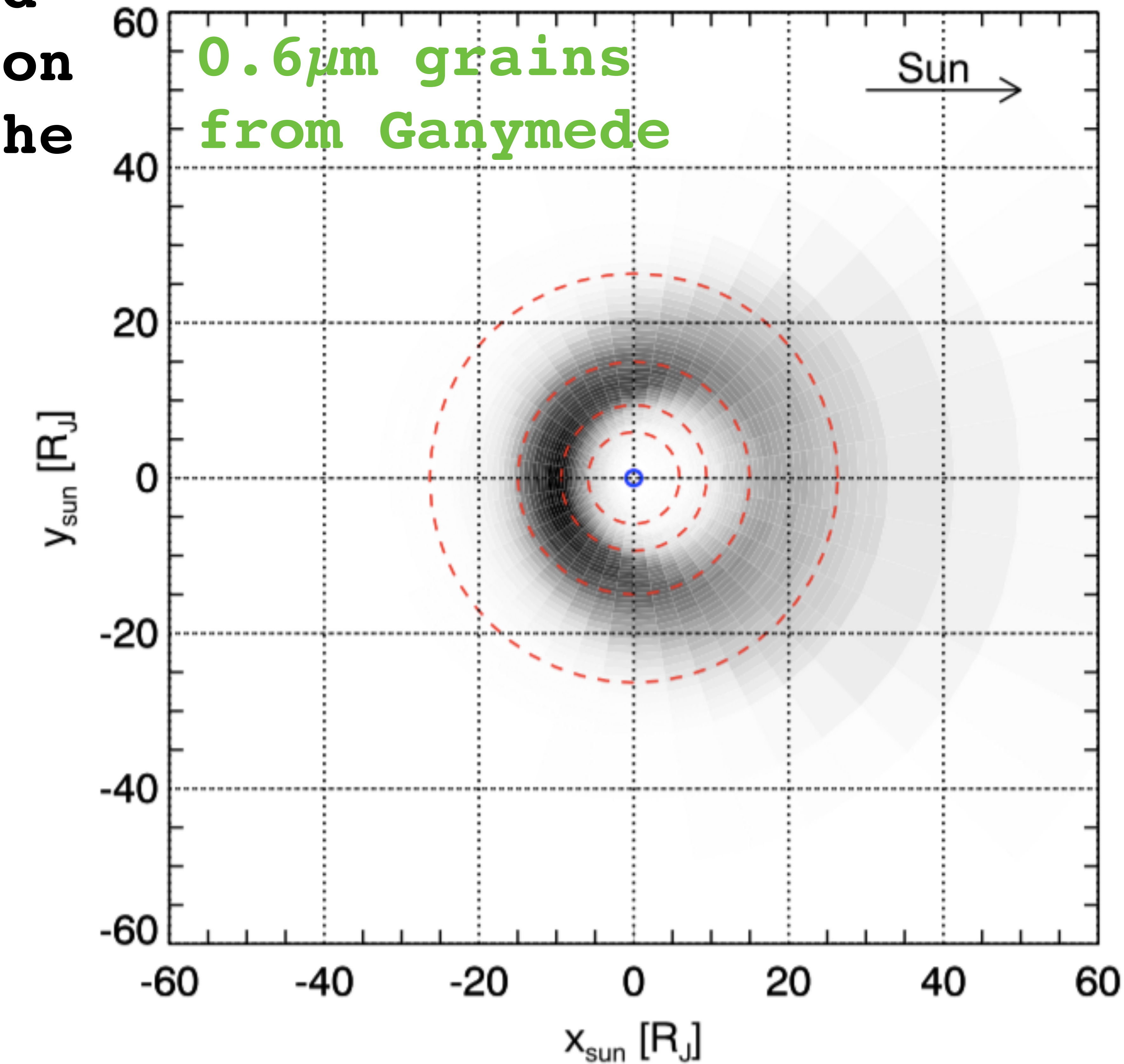
Systematic velocities

dust velocity -local kepler velocity

@Io: dust is faster than moon

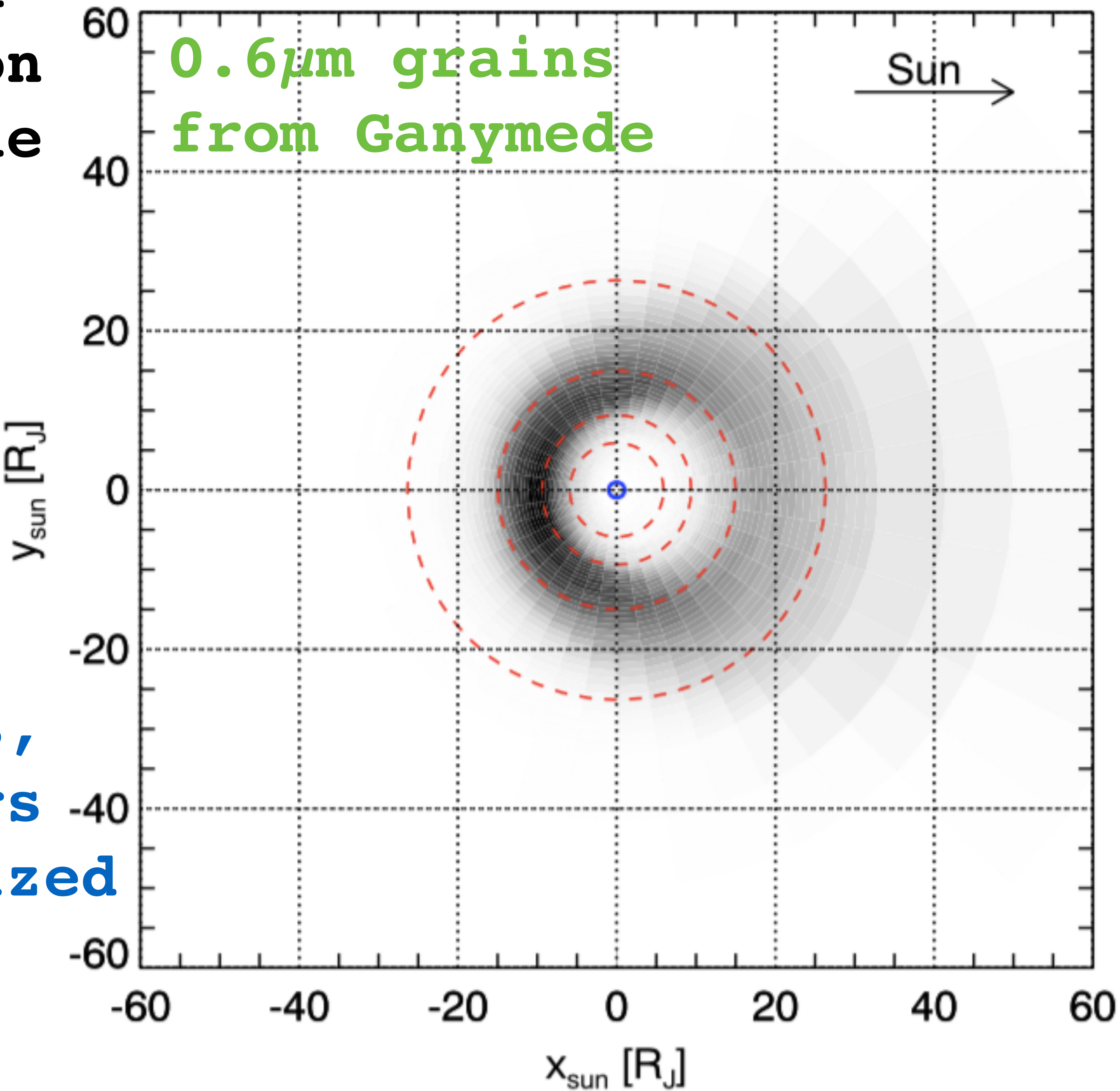


In a frame with fixed orientation towards the Sun:



(Liu et al, JGR, 2016)

In a frame with fixed orientation towards the Sun:


0.6μm grains from Ganymede

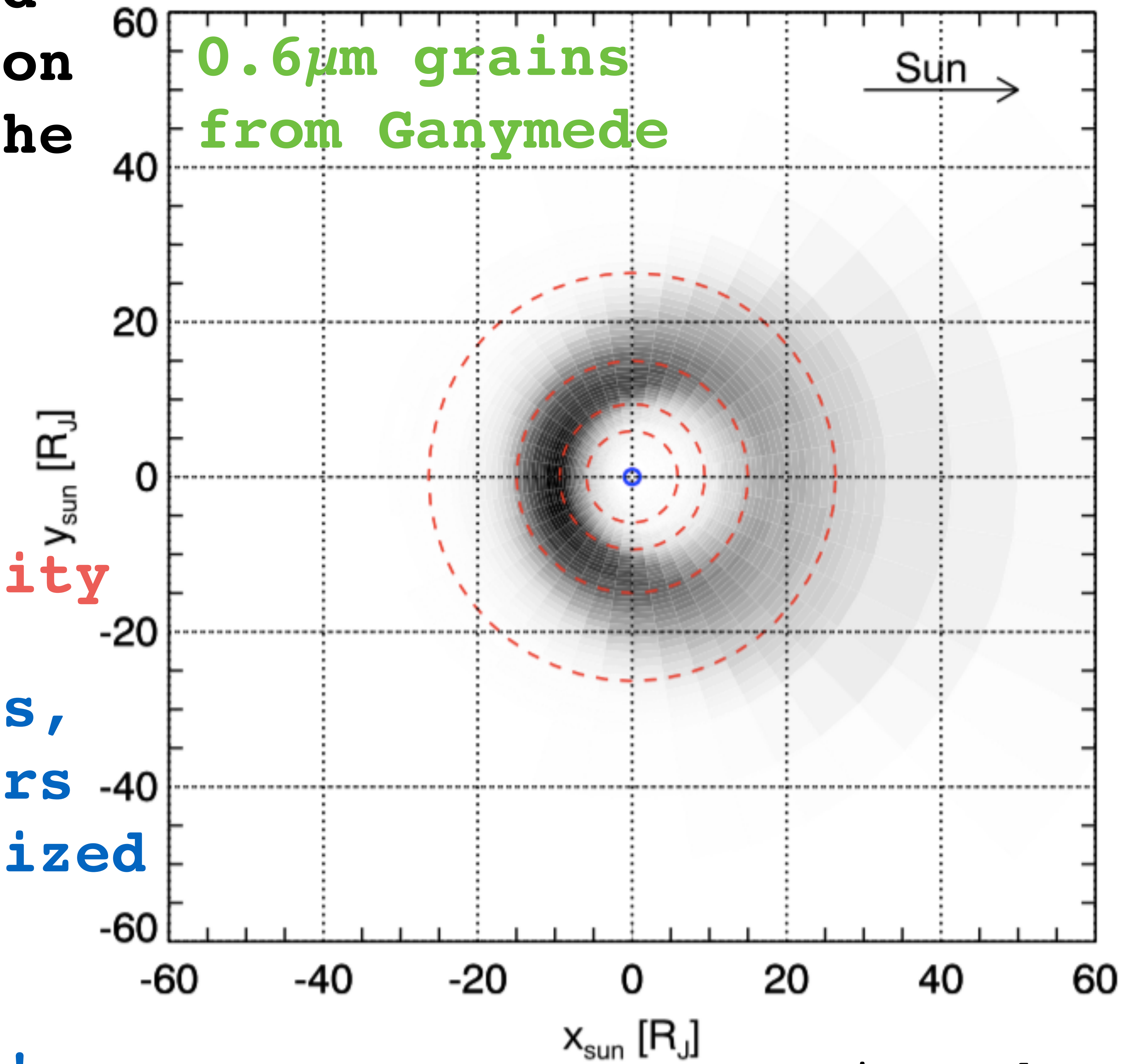
apocenters, pericenters get organized wrto subsolar longitude!

(Liu et al, JGR, 2016)

In a frame with fixed orientation towards the Sun:

radiation pressure pumps eccentricity

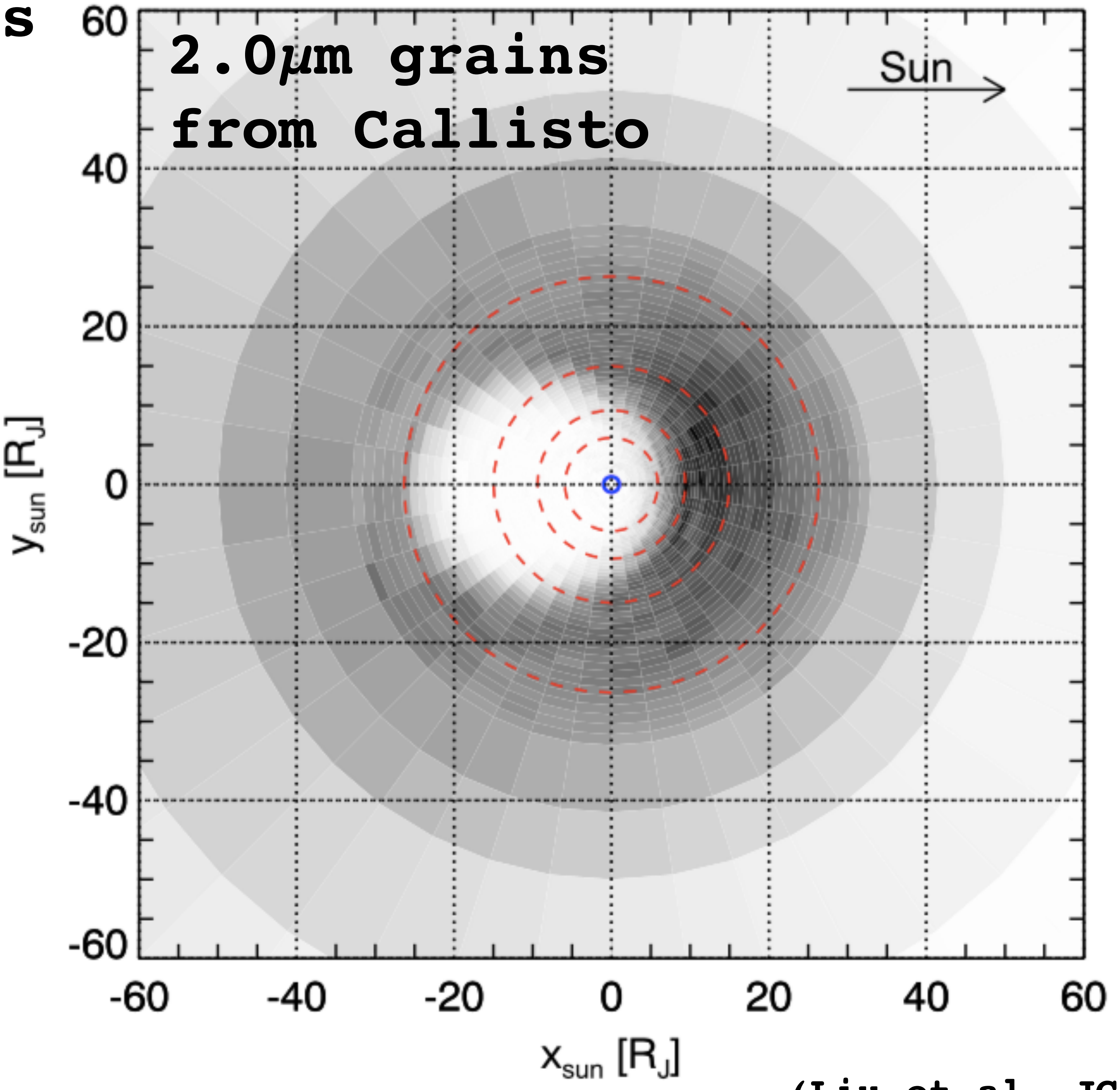
apocenters, pericenters get organized wrto subsolar longitude!



0.6μm grains from Ganymede

(Liu et al, JGR, 2016)

`heliotropic'
dust rings



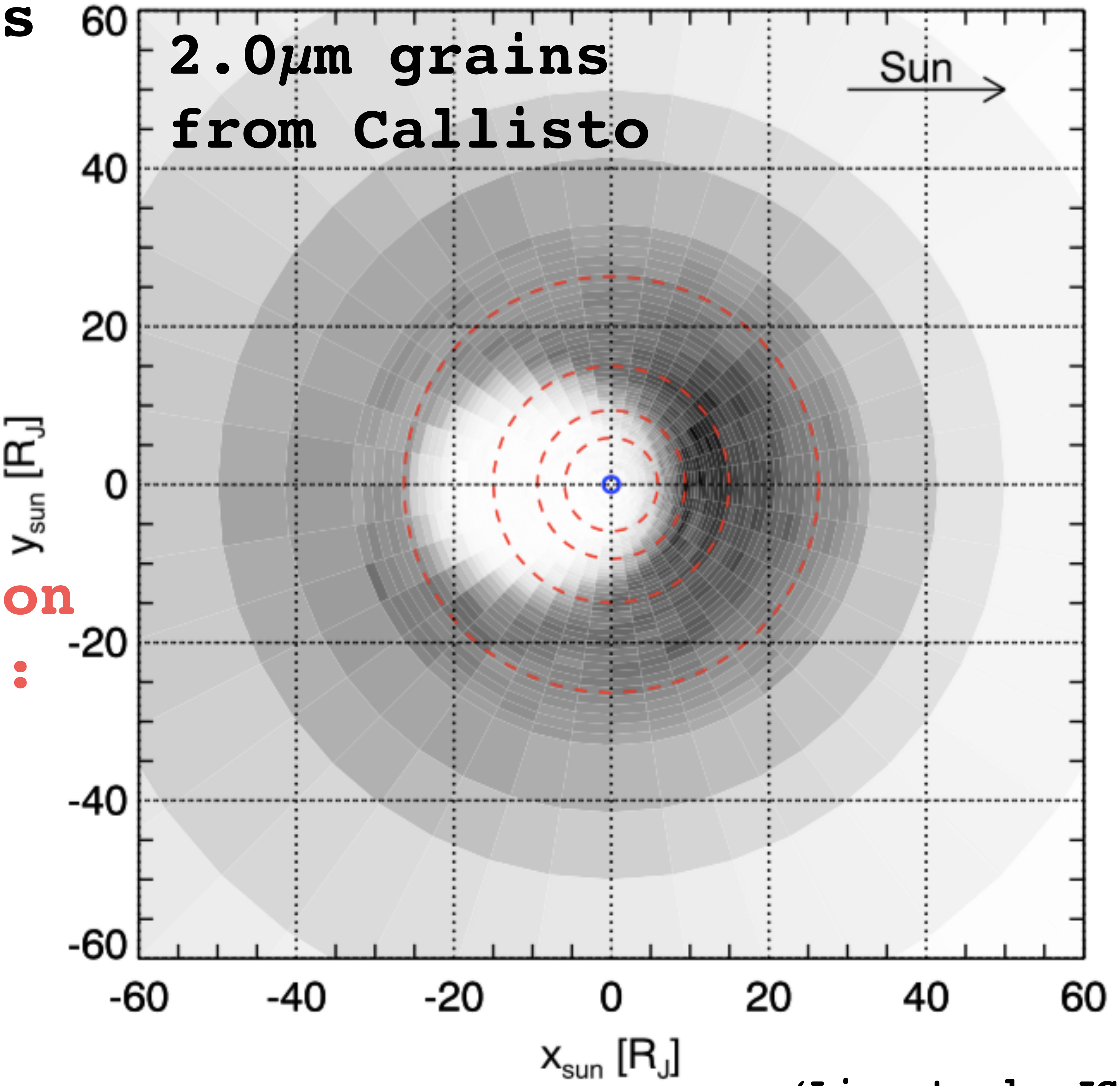
2.0μm grains
from Callisto

(Liu et al, JGR, 2016)

`heliotropic'
dust rings

point towards or away from Sun, depending on grain size:

$\dot{\varpi}$ changes sign



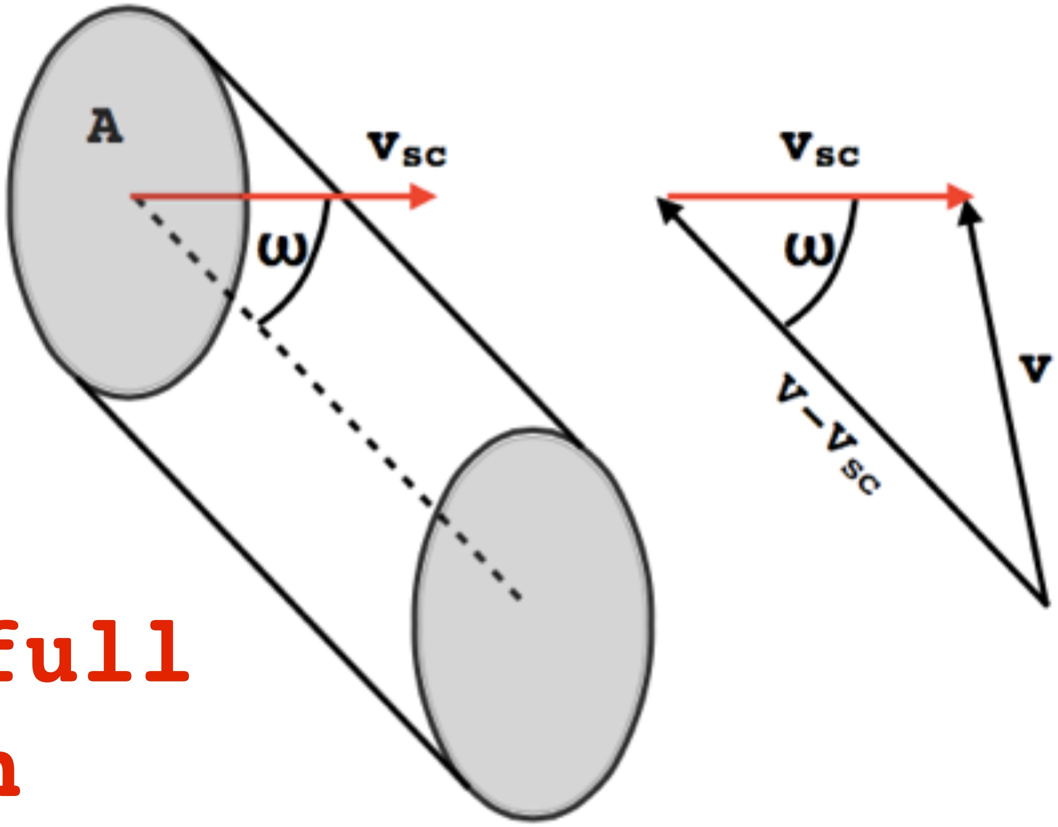
(Liu et al, JGR, 2016)

Calculation of fluxes:

$$J = \int \mathrm{d}^3 v \, f(\vec{v}) \, |\vec{v}_{sc} - \vec{v}| \, \Theta_H(\cos\omega)$$

$\uparrow$

we cannot store the full velocity distribution function in each grid point!



Calculation of fluxes:

$$J = \int \mathrm{d}^3 v\, f(\vec{v})\, |\vec{v}_{sc} - \vec{v}|\, \Theta_H(\cos\omega)$$

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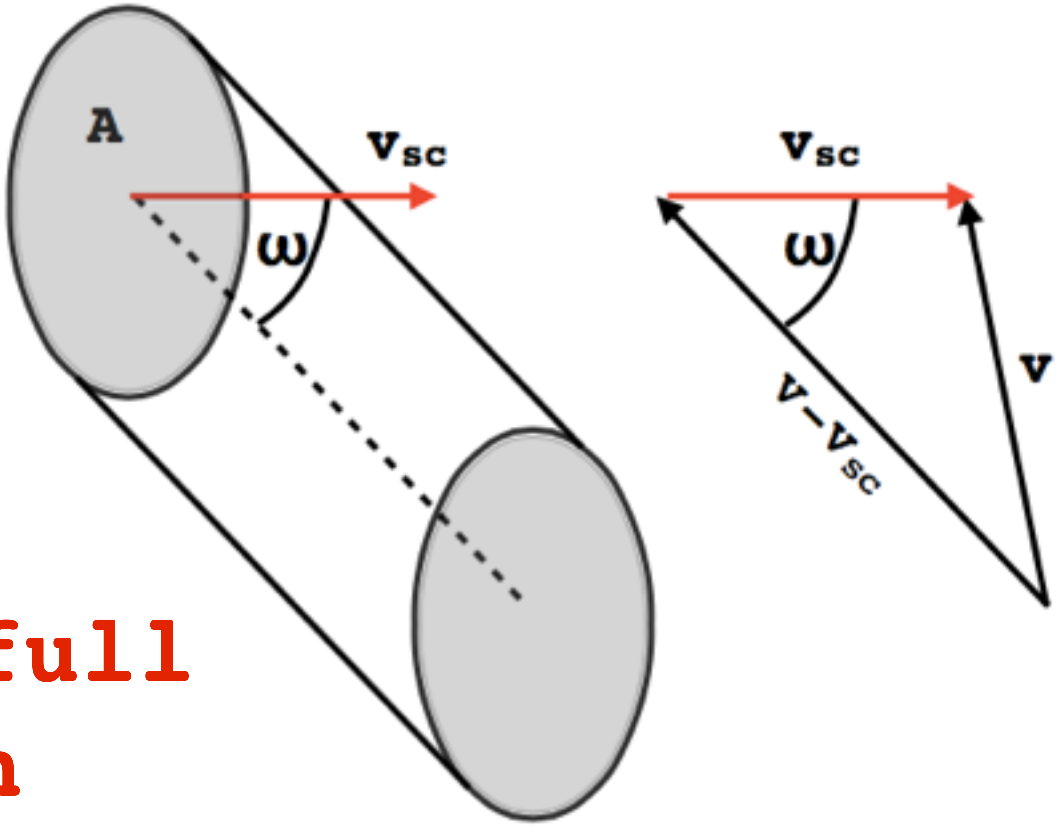
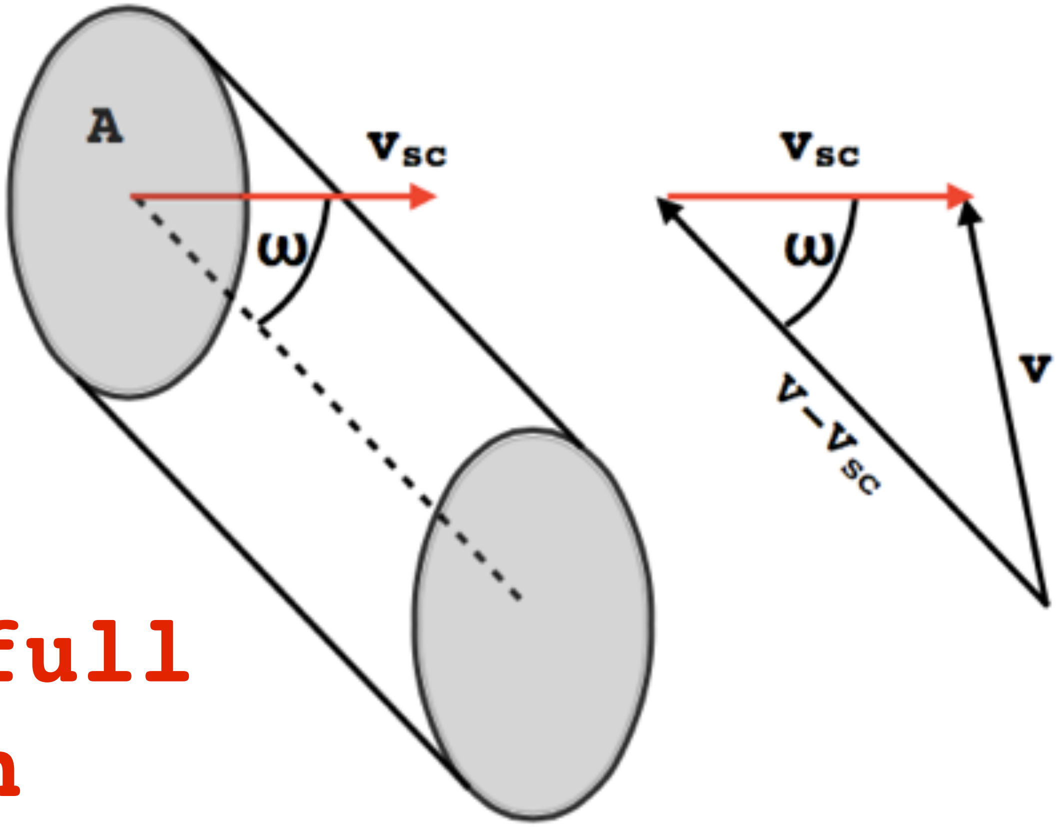


and:

approximation $J = nv$ does NOT hold in many cases!

Calculation of fluxes:



$$J = \int \mathrm{d}^3 v \, f(\vec{v}) \, |\vec{v}_{sc} - \vec{v}| \, \Theta_H(\cos\omega)$$

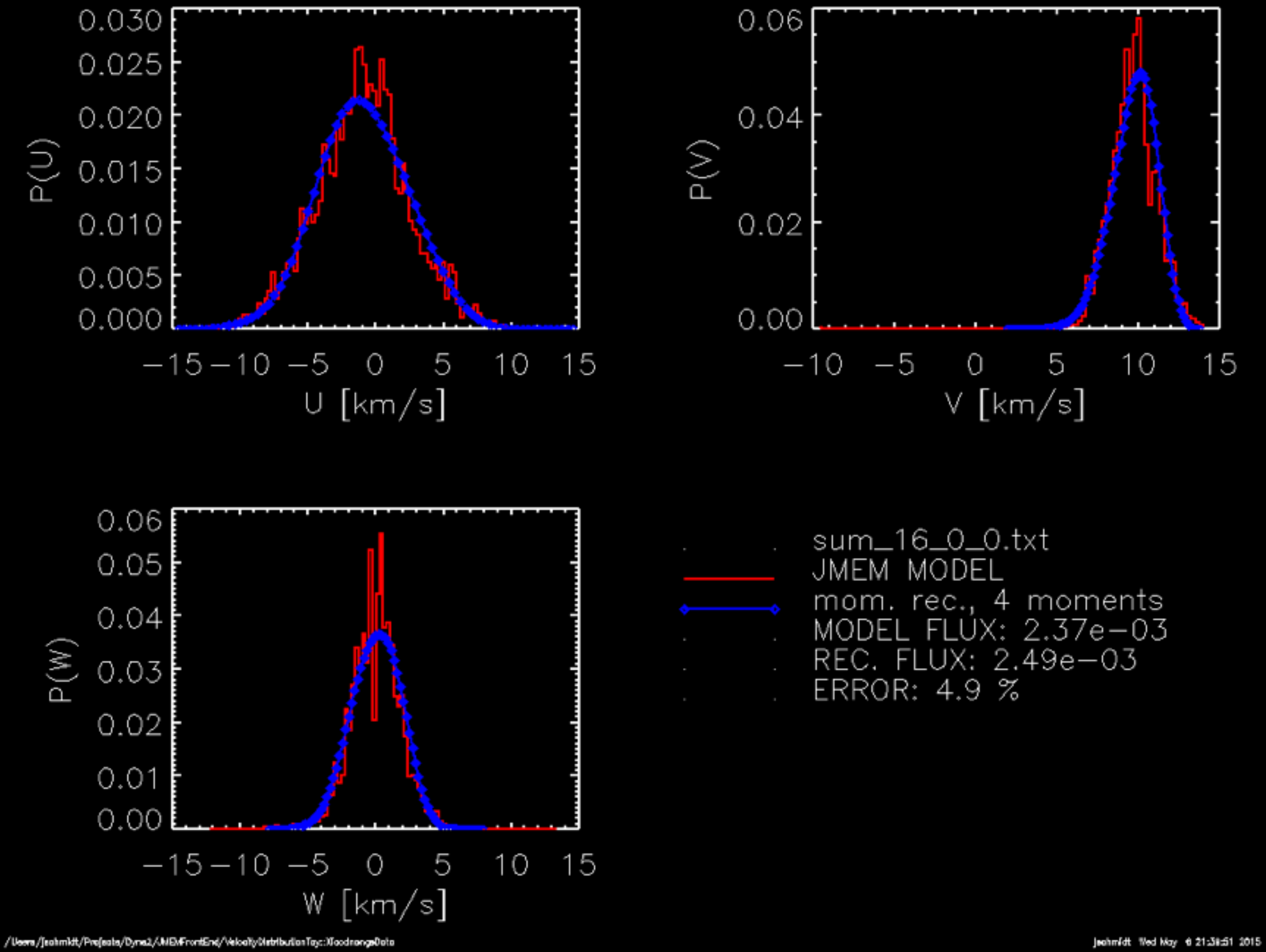
↑ we cannot store the full velocity distribution function in each grid point!

and:

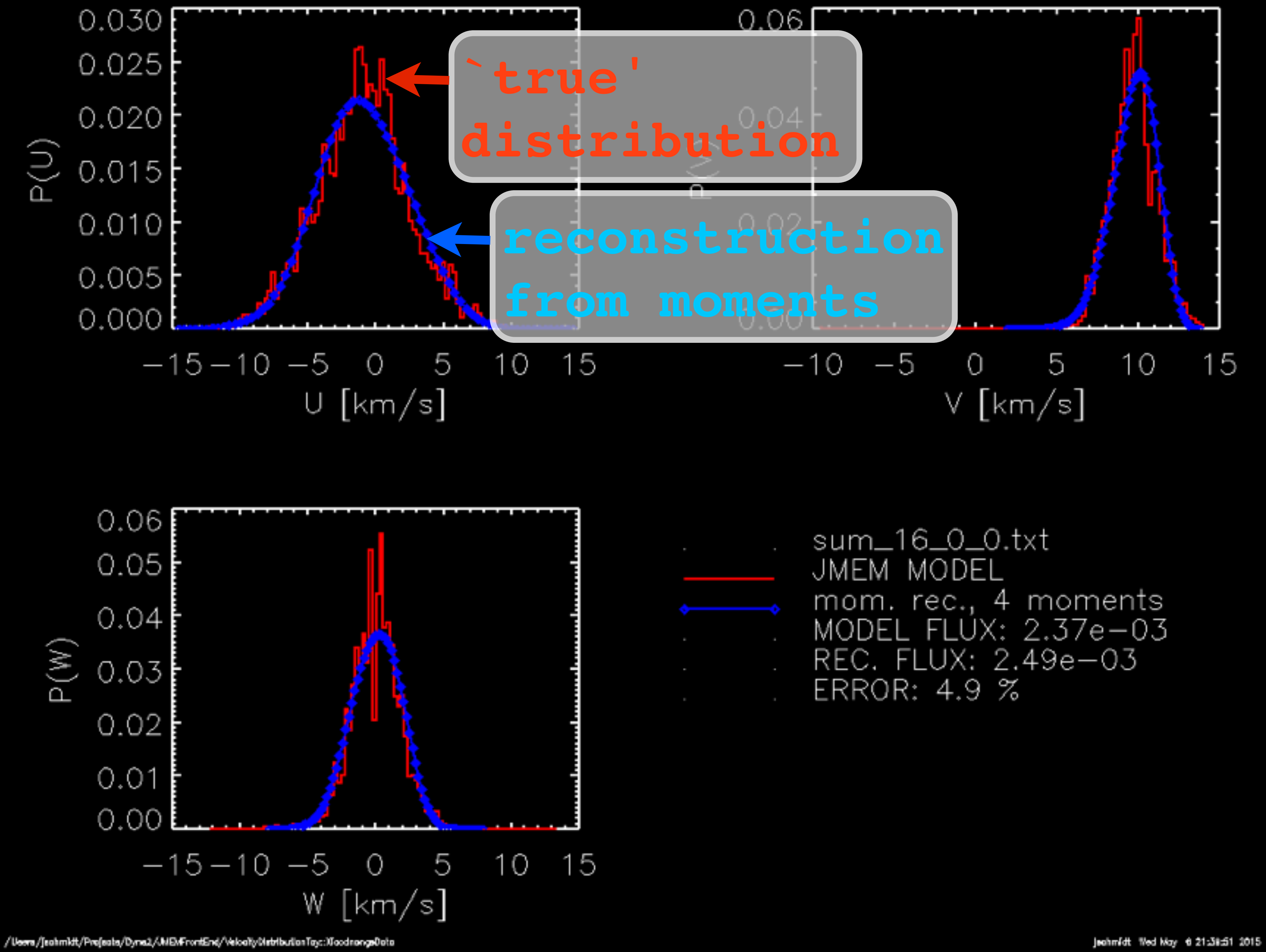
approximation $J = nv$ does NOT hold in many cases!

=> save 4 moments of the velocity components and use known algorithm to reconstruct the distribution from the moments

Calculation of the flux: Example



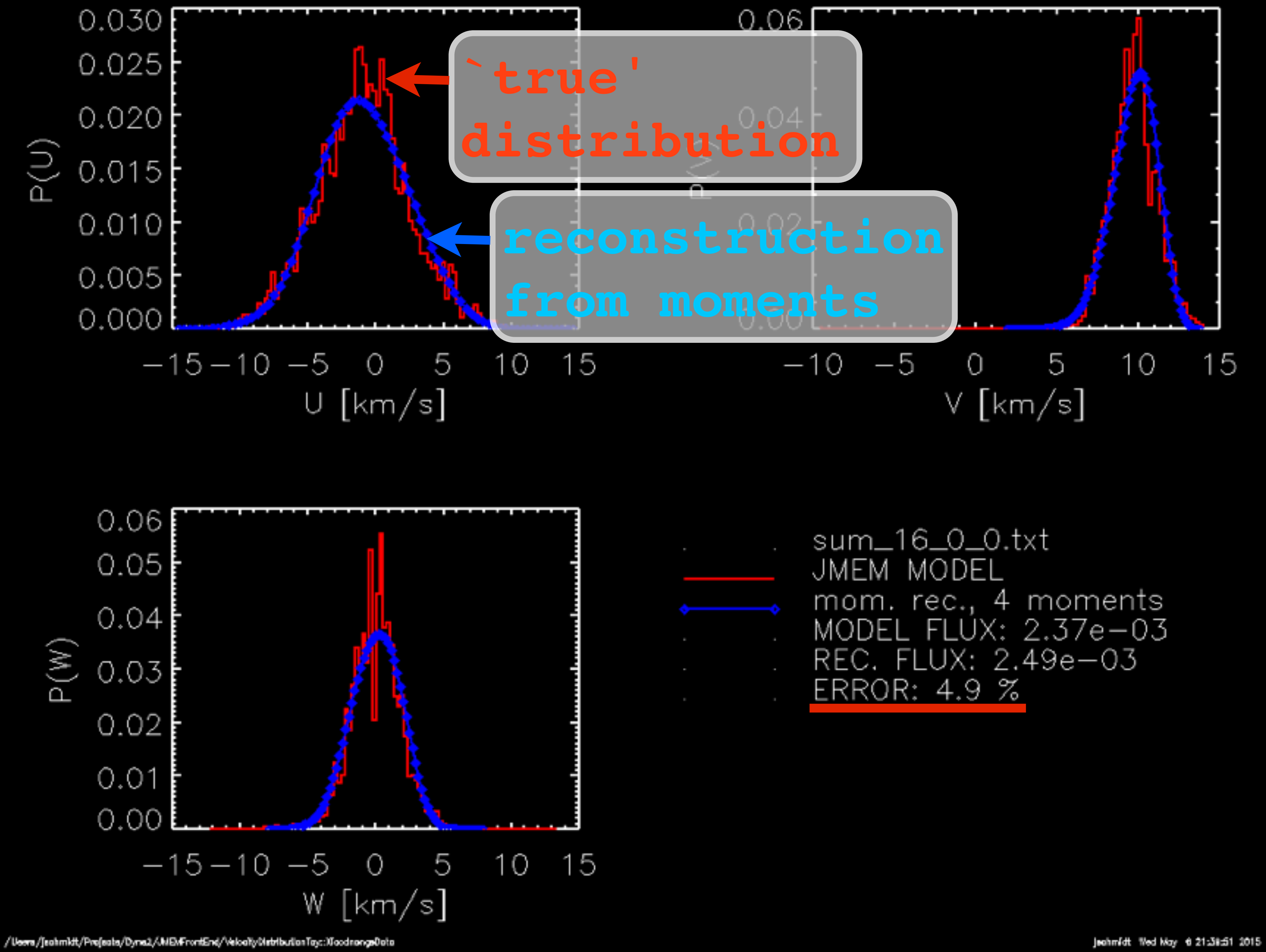
Calculation of the flux: Example



`true' distribution

reconstruction from moments

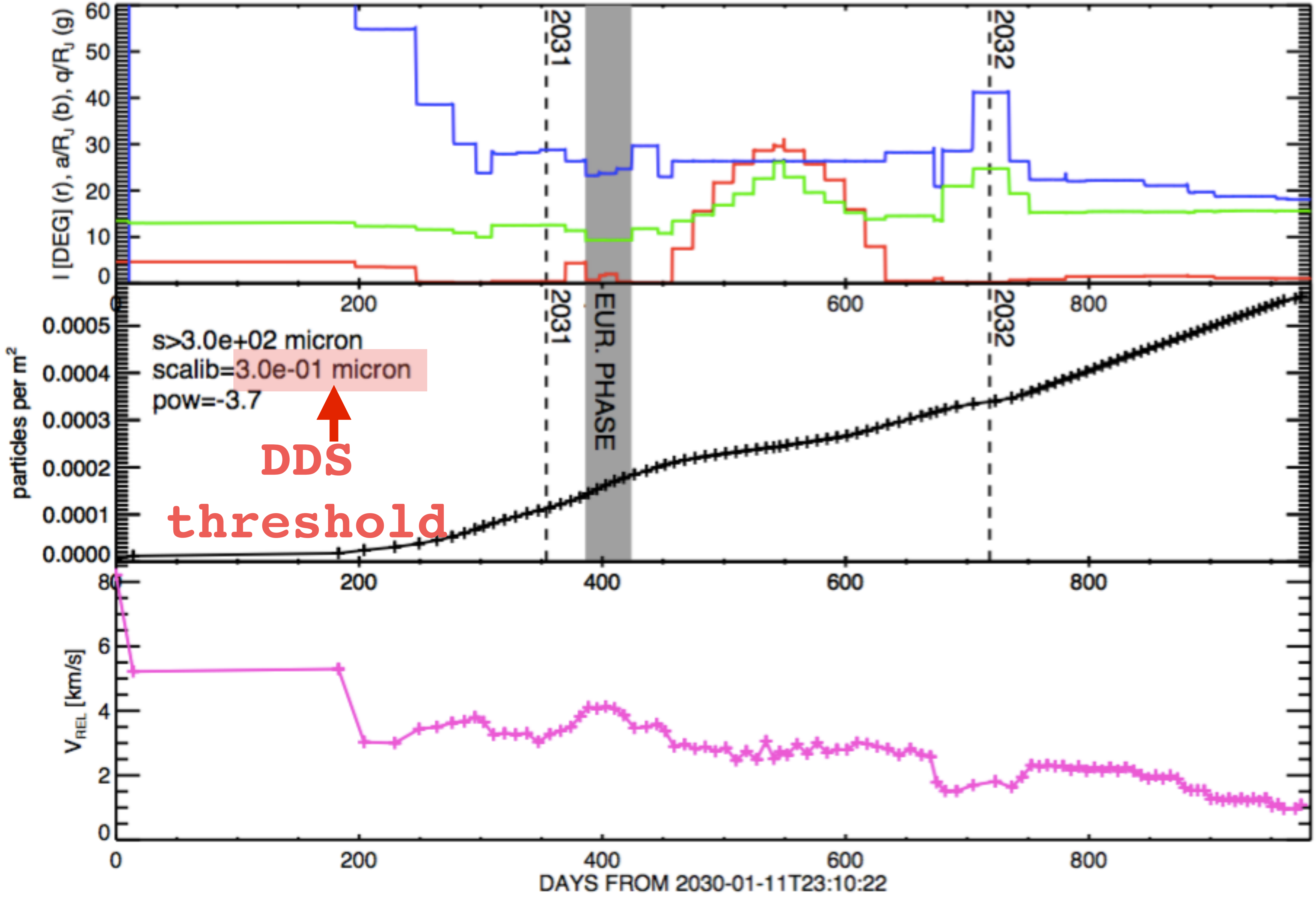
Calculation of the flux: Example



`true' distribution

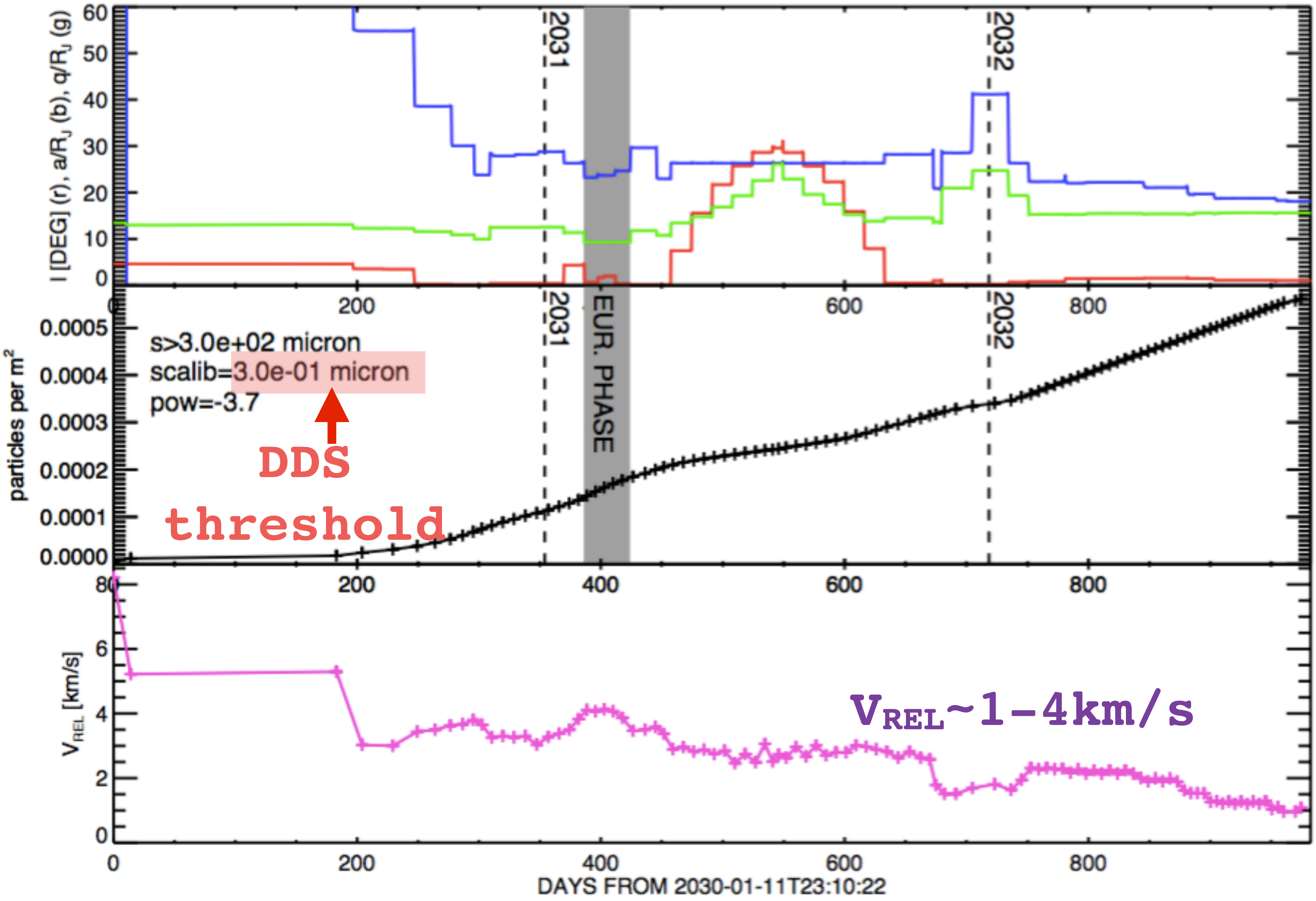
reconstruction from moments

e.g. particles >300μm accumulated by JUICE:



DDS threshold

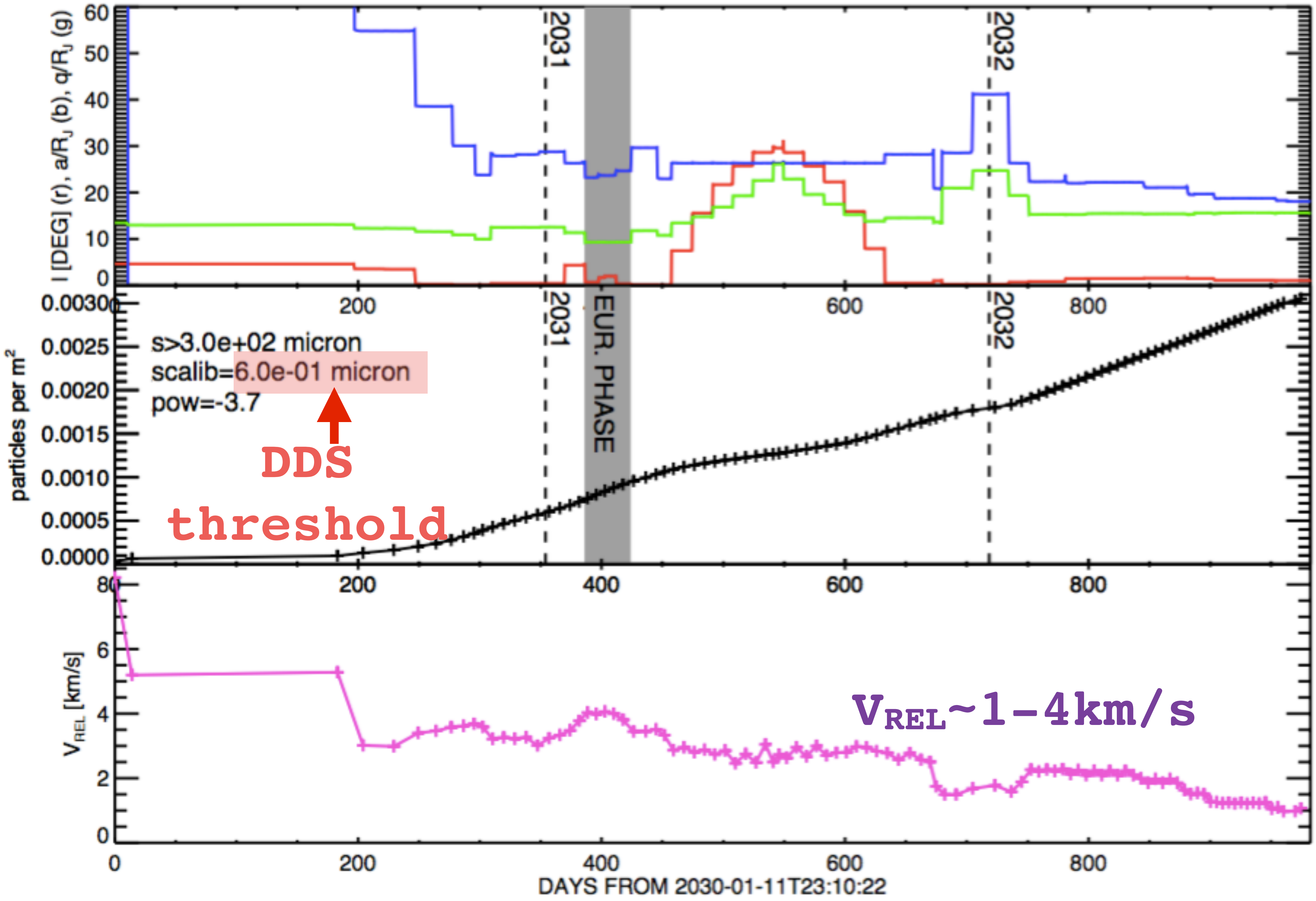
e.g. particles >300μm accumulated by JUICE:



DDS threshold

V_{REL}~1-4km/s

e.g. particles >300μm accumulated by JUICE:



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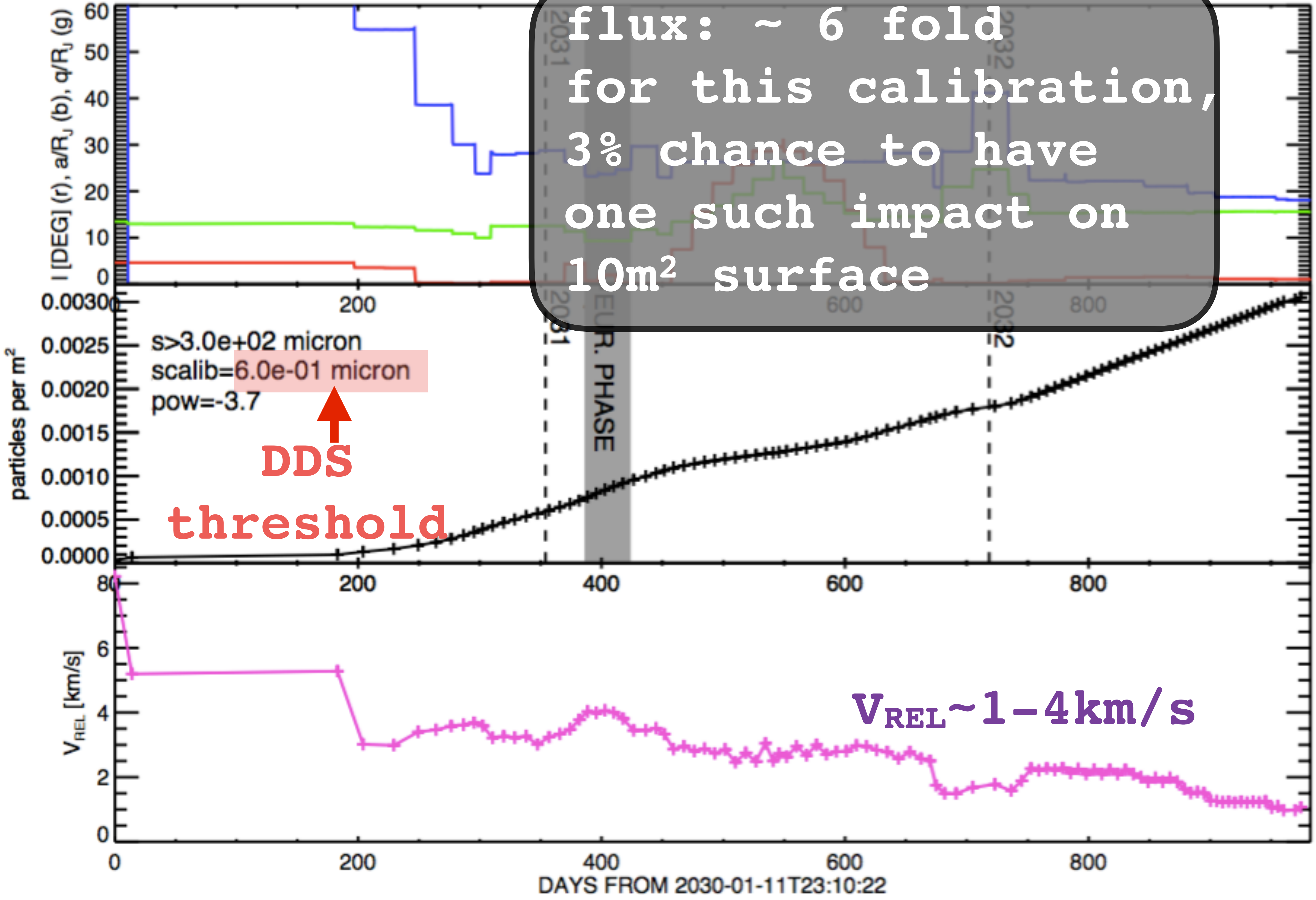

flux: ~ 6 fold for this calibration, 3% chance to have one such impact on 10m^2 surface

DDS threshold

V$_{REL}$~1-4km/s

Fluxes onto the surfaces of the moons: space weathering, chemical alteration

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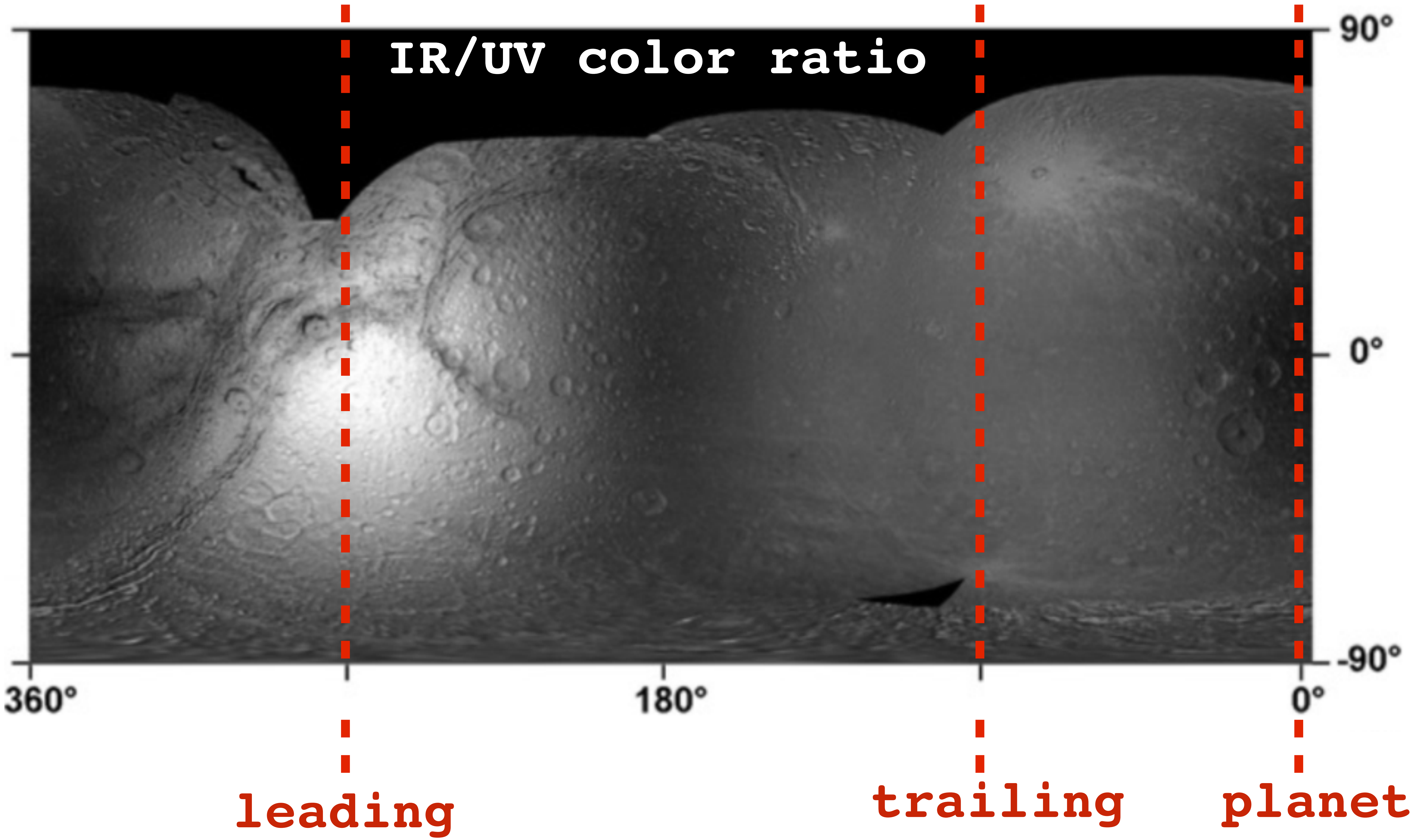
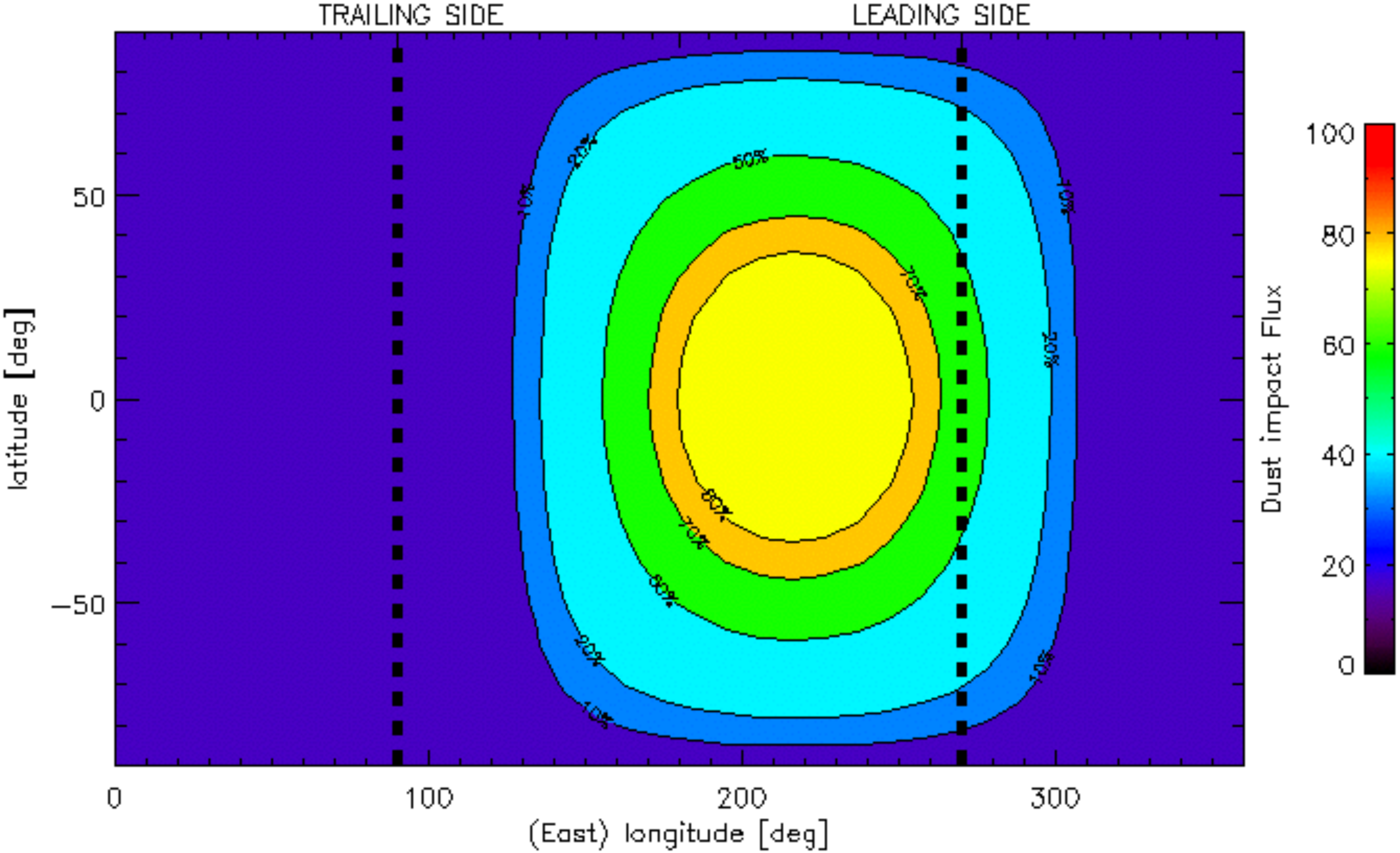


Saturn's moon Dione (Schenk et al, 2010)

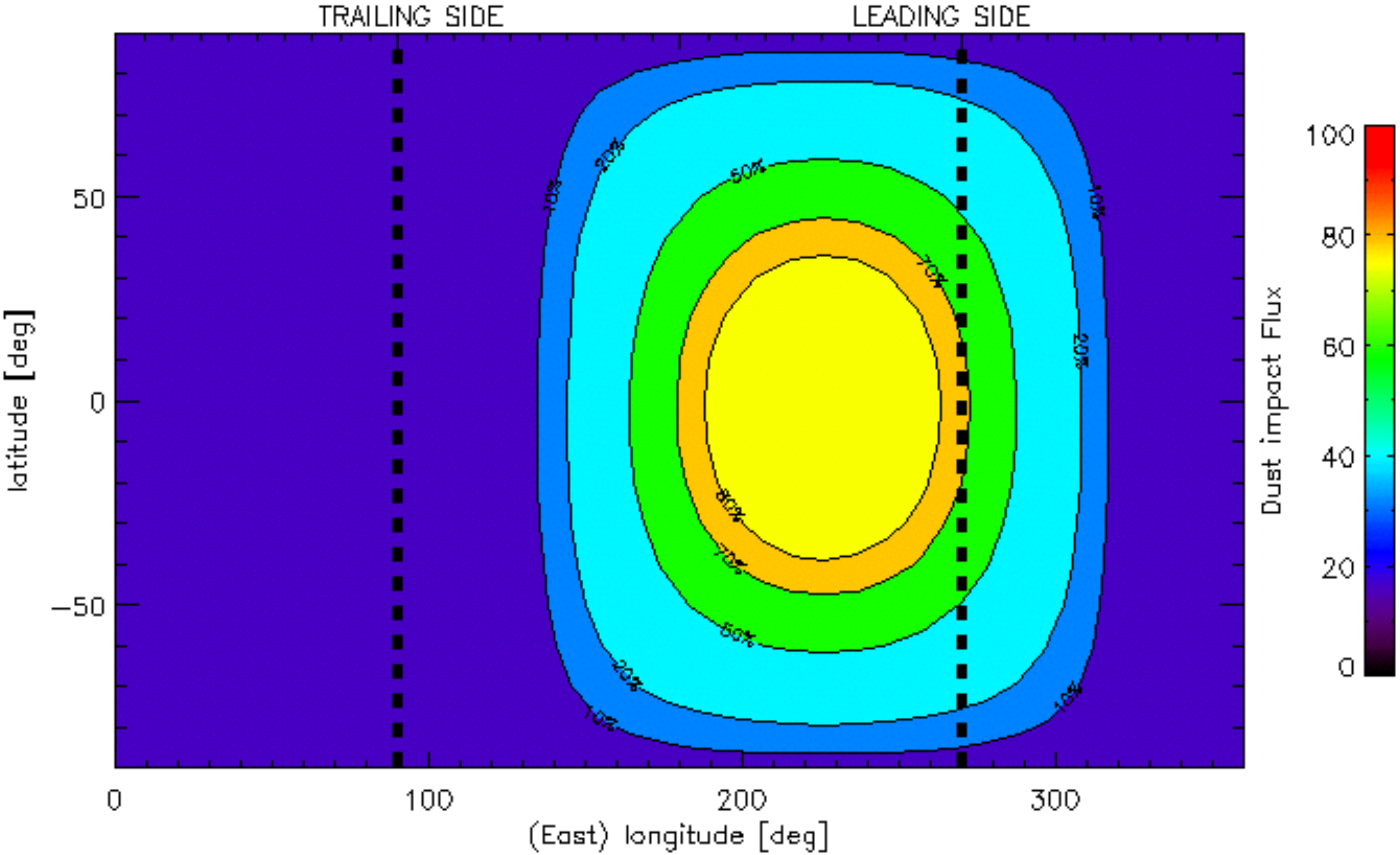
Fluxes onto the surfaces of the moons: space weathering, chemical alteration

EUROPA



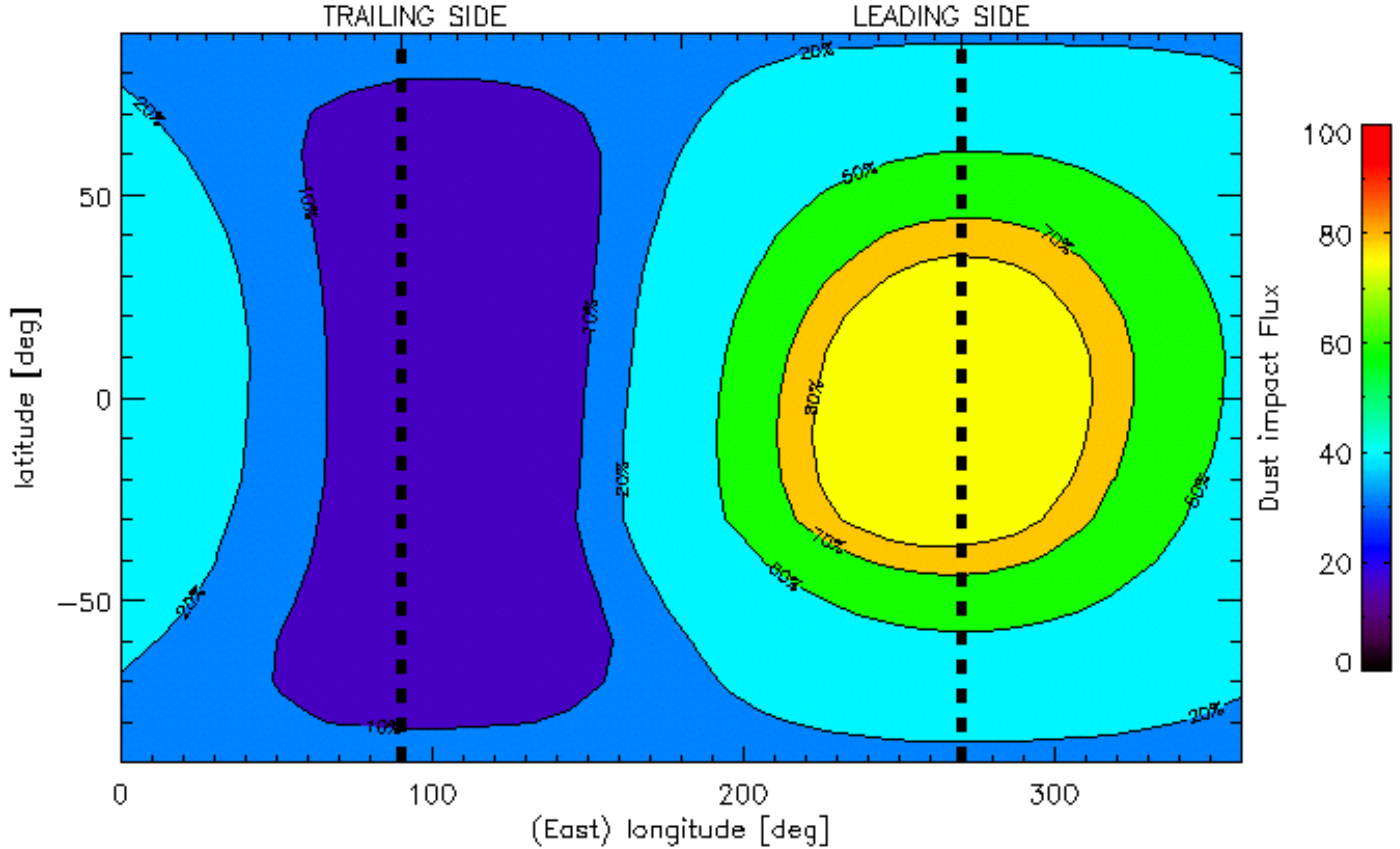
Fluxes onto the surfaces of the moons: space weathering, chemical alteration

Ganymede



Fluxes onto the surfaces of the moons: space weathering, chemical alteration

Callisto



Summary

* new model/code to simulate dust environment of Jupiter

* size-resolved number densities and fluxes

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* size-resolved number densities and fluxes

* applications:

-> dust hazard, degradation of SC hardware

-> pointing information for instruments
on future missions:
JUICE (PEP-JoEE, RPWI)
Europa Clipper (SUDA)

-> characterize external inflow of dust
on surfaces, e.g. Io dust on Europa

-> space weathering

Summary

* **TBD:**
  Sputtering, variable charging processes, different materials (e.g. silicates)

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Thank You!

spare slides

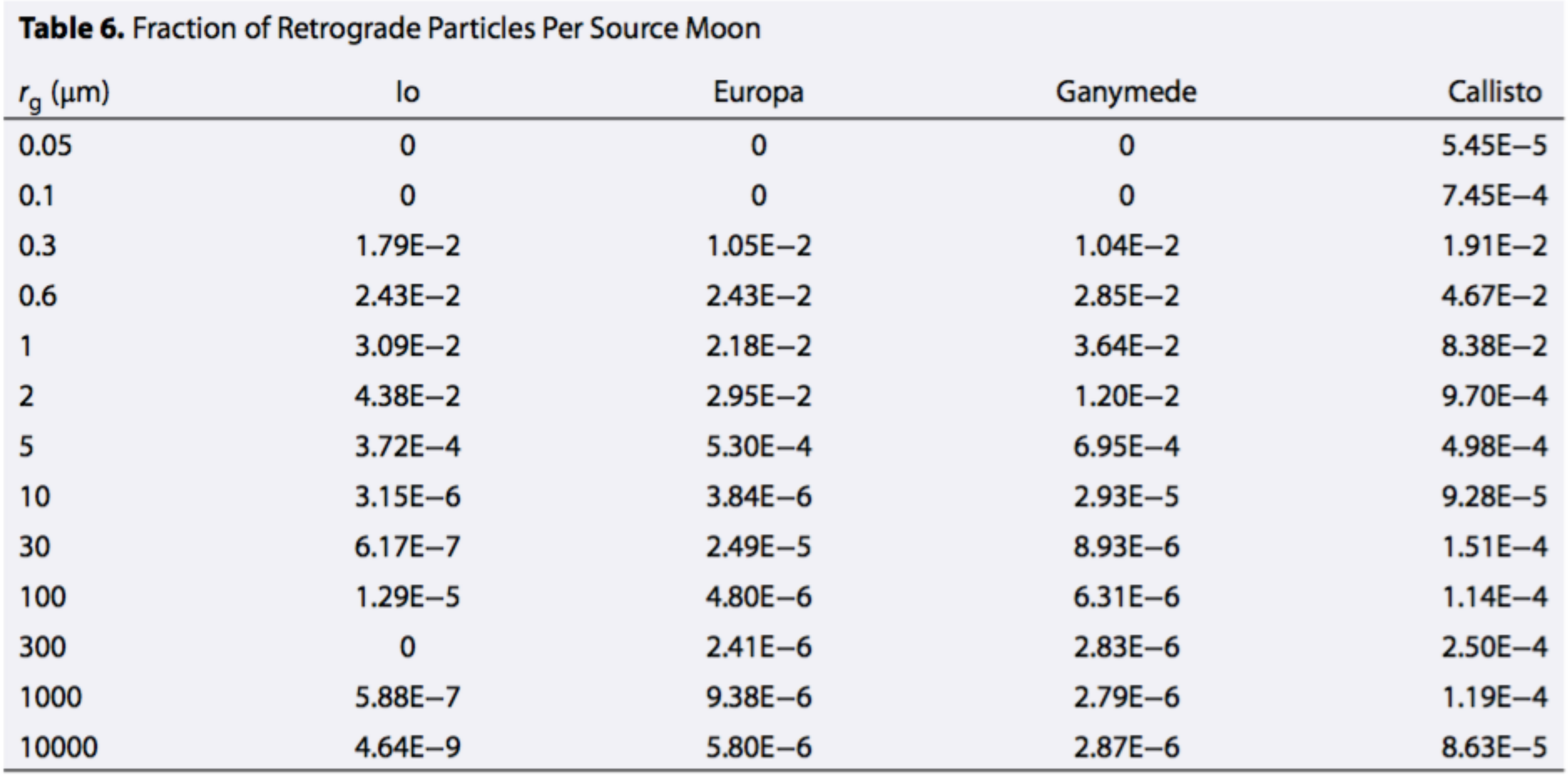
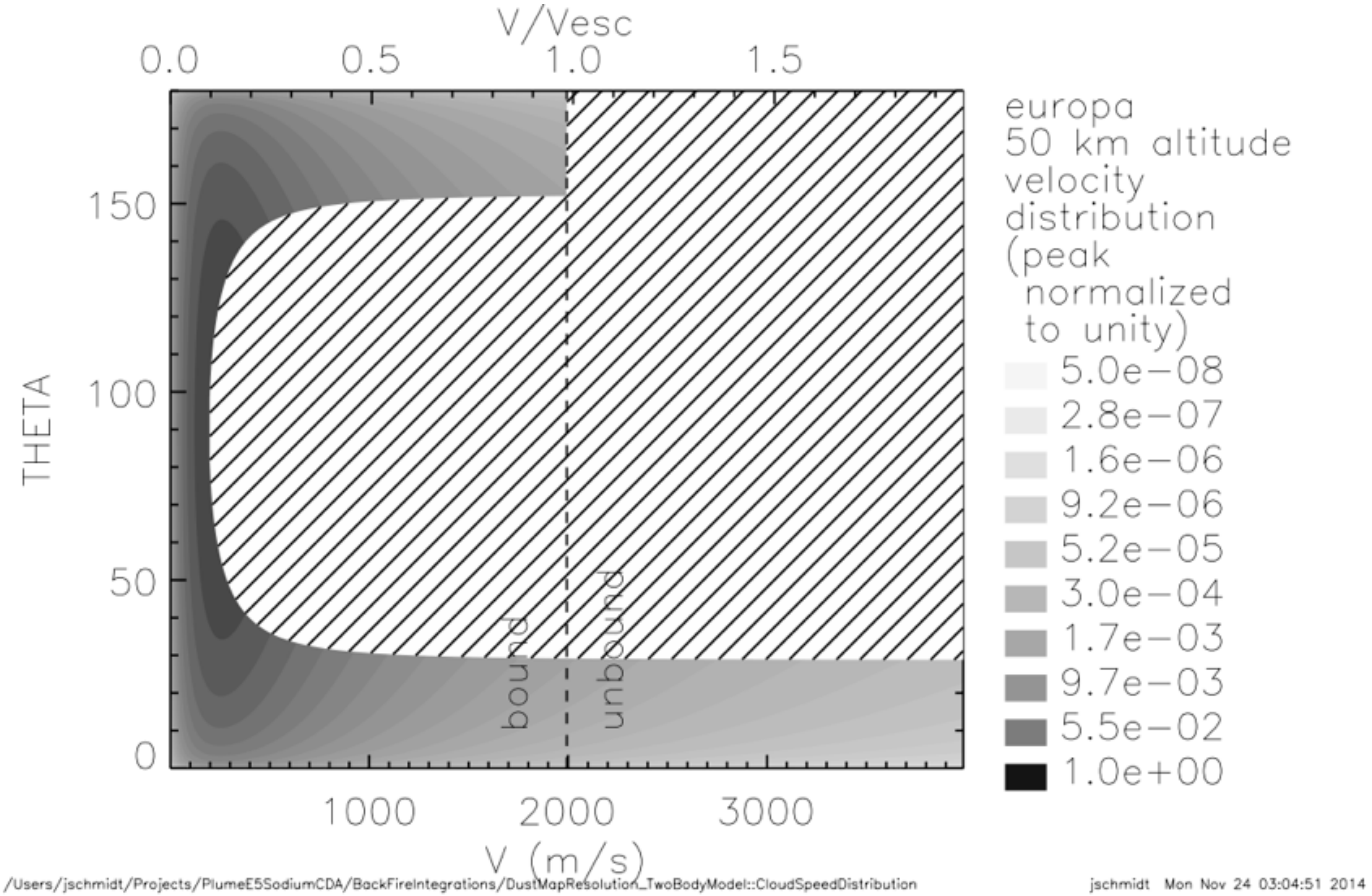
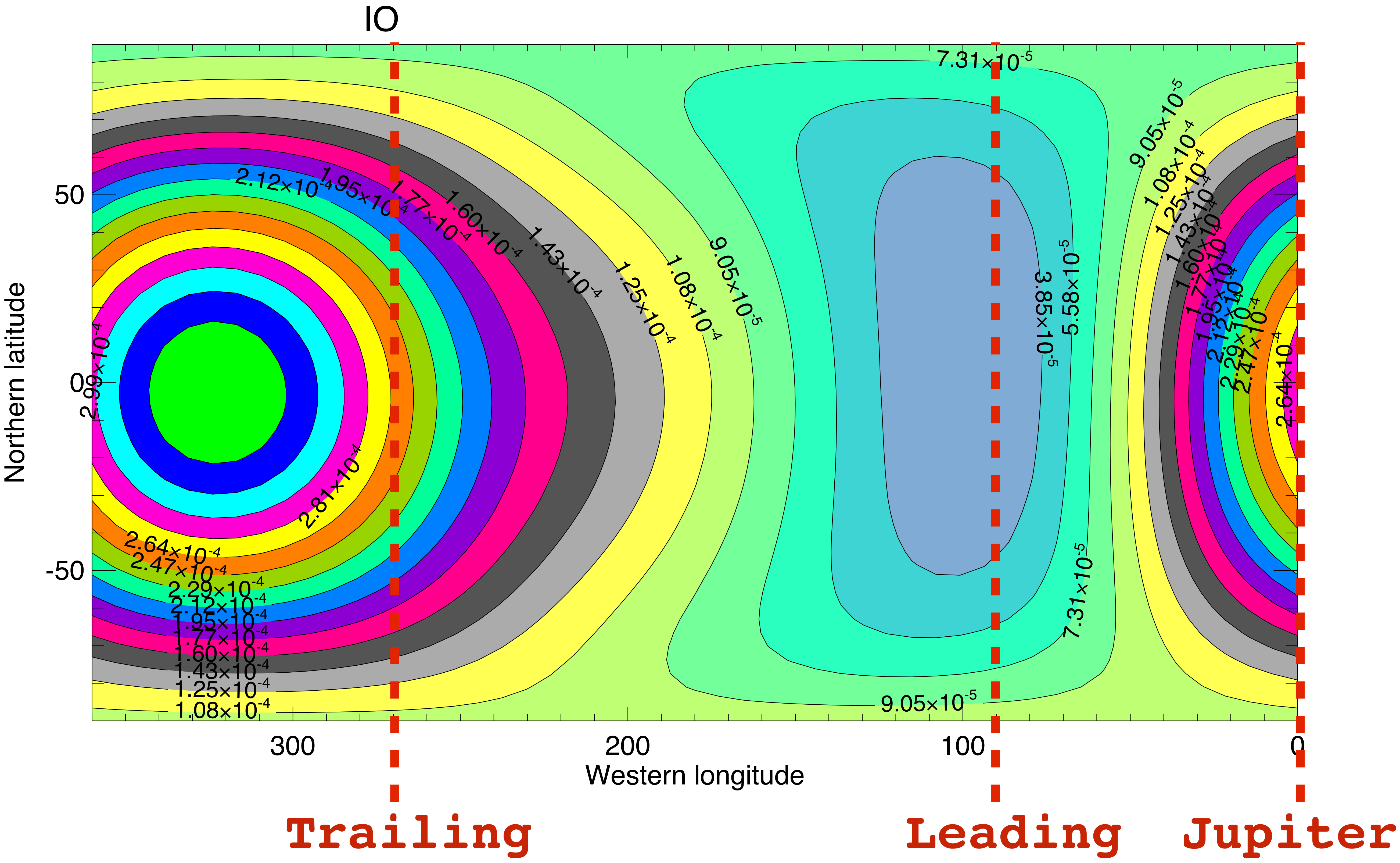


Table 6. Fraction of Retrograde Particles Per Source Moon

r_g (μm)	Io	Europa	Ganymede	Callisto
0.05	0	0	0	5.45E−5
0.1	0	0	0	7.45E−4
0.3	1.79E−2	1.05E−2	1.04E−2	1.91E−2
0.6	2.43E−2	2.43E−2	2.85E−2	4.67E−2
1	3.09E−2	2.18E−2	3.64E−2	8.38E−2
2	4.38E−2	2.95E−2	1.20E−2	9.70E−4
5	3.72E−4	5.30E−4	6.95E−4	4.98E−4
10	3.15E−6	3.84E−6	2.93E−5	9.28E−5
30	6.17E−7	2.49E−5	8.93E−6	1.51E−4
100	1.29E−5	4.80E−6	6.31E−6	1.14E−4
300	0	2.41E−6	2.83E−6	2.50E−4
1000	5.88E−7	9.38E−6	2.79E−6	1.19E−4
10000	4.64E−9	5.80E−6	2.87E−6	8.63E−5

(Liu et al, JGR, 2016)


V/Vesc
0.0
0.5
1.0
1.5
THETA
150
100
50
0
1000
2000
3000
V (m/s)
bound
unbound
europa
50 km altitude
velocity
distribution
(peak
normalized
to unity)
5.0e−08
2.8e−07
1.6e−06
9.2e−06
5.2e−05
3.0e−04
1.7e−03
9.7e−03
5.5e−02
1.0e+00
/Users/jschmidt/Projects/PlumeE5SodiumCDA/BackFireIntegrations/DustMapResolution_TwoBodyModel::CloudSpeedDistribution
jschmidt Mon Nov 24 03:04:51 2014


IO
Northern latitude
Western longitude
50
0
-50
300
200
100
0
2.99×10-4
2.81×10-4
2.64×10-4
2.47×10-4
2.29×10-4
2.12×10-4
1.95×10-4
1.77×10-4
1.60×10-4
1.43×10-4
1.25×10-4
1.08×10-4
9.05×10-5
7.31×10-5
5.58×10-5
3.85×10-5
Trailing
Leading
Jupiter