Solar Orbiter First Results (Cruise Phase) Special issue

First dust measurements with the Solar Orbiter Radio and Plasma Wave instrument

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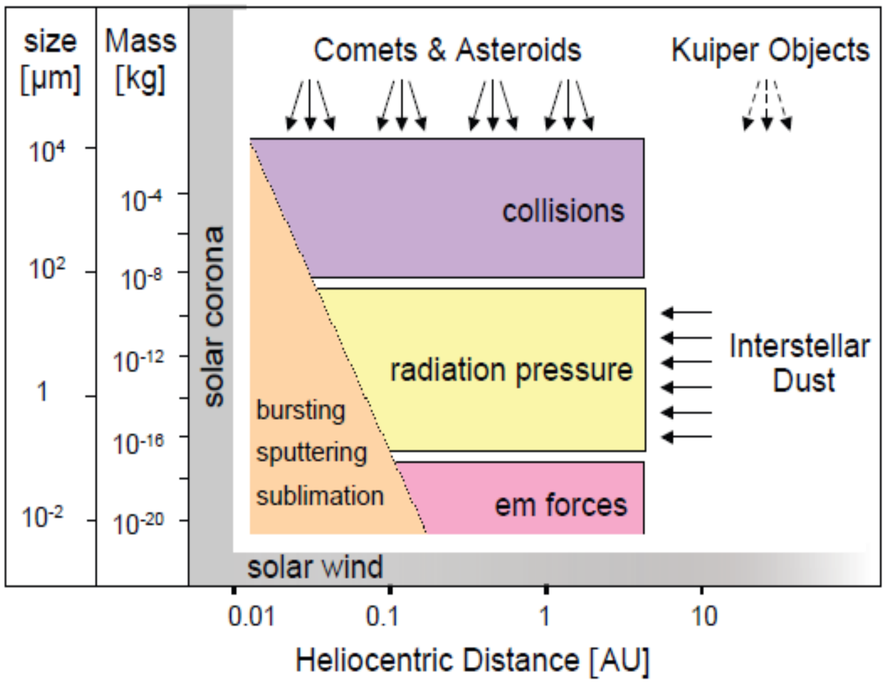
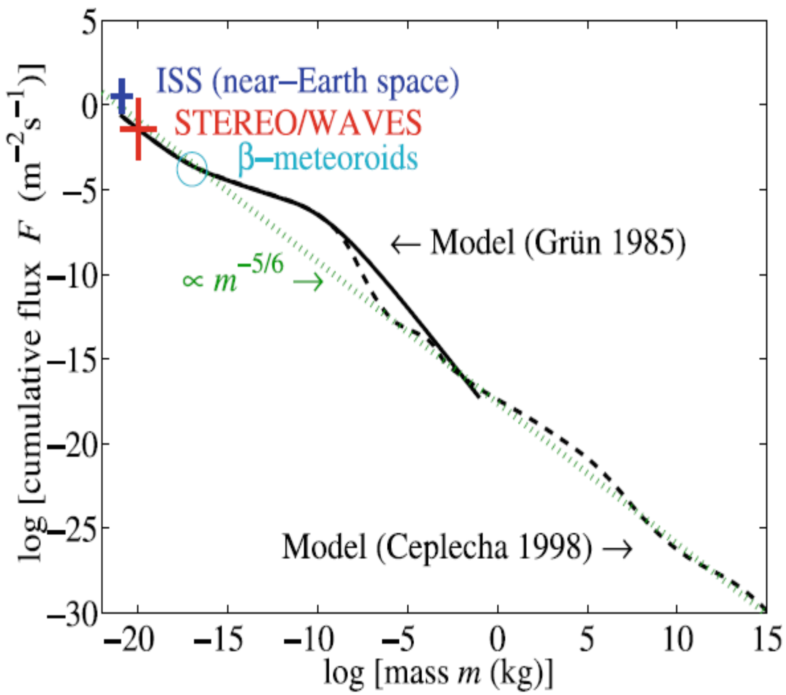
Solar system dust : the physical picture





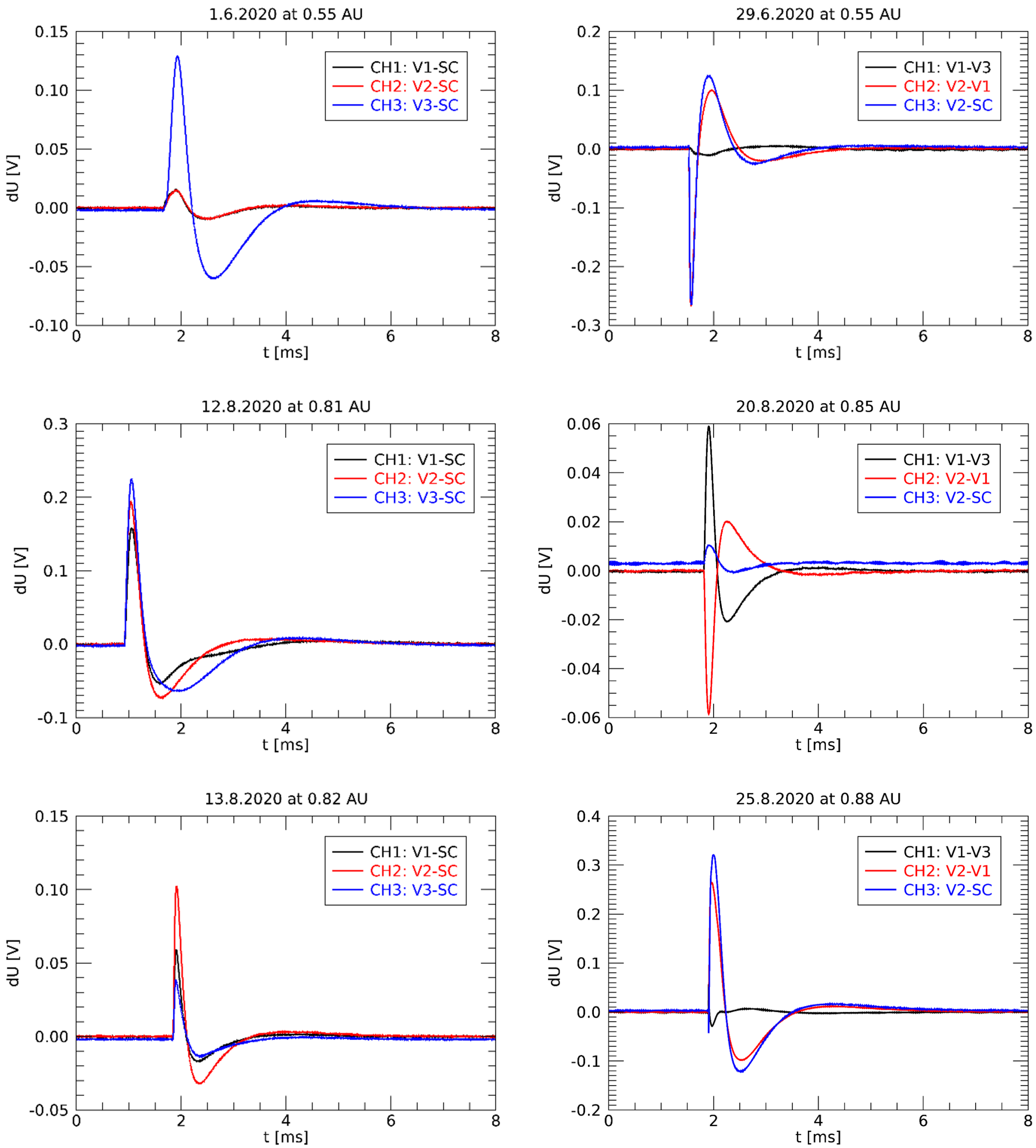
<u>Sources :</u>

- Planets, comets, asteroids
- Interstellar medium

<u>Sinks :</u>

- Fragmentation to small size
- Sublimation

<u>Mass Flux essentially controlled by fragmentation : F ~ m^-5/6</u>



monopole

dipole

Examples of RPW TDS snapshots

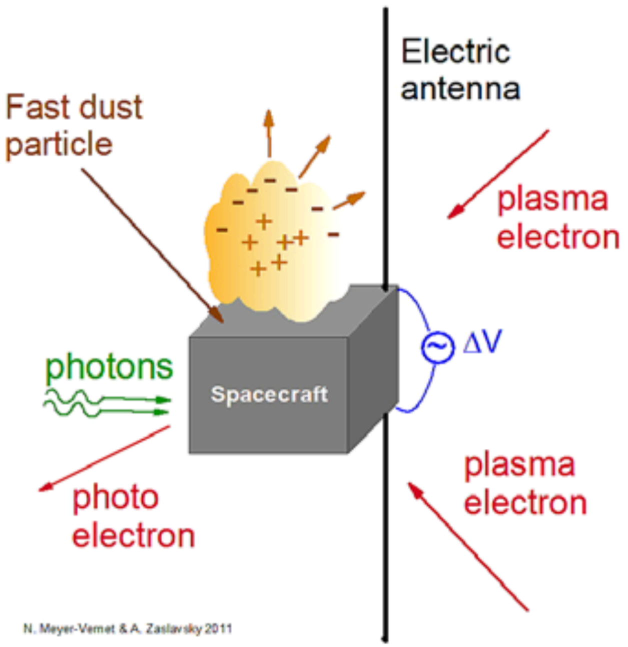
Interpretation for monopole signals (s/c potential variation)

$$Q(m,v) \simeq \frac{C_{sc} V_{peak}}{\Gamma}.$$

Dipoles/additional to s/c potential variation

$$Q(m,v) \sim \frac{4\pi\epsilon_0 L_{ant} V_{peak,dipole}}{\Gamma},$$

Interpretation



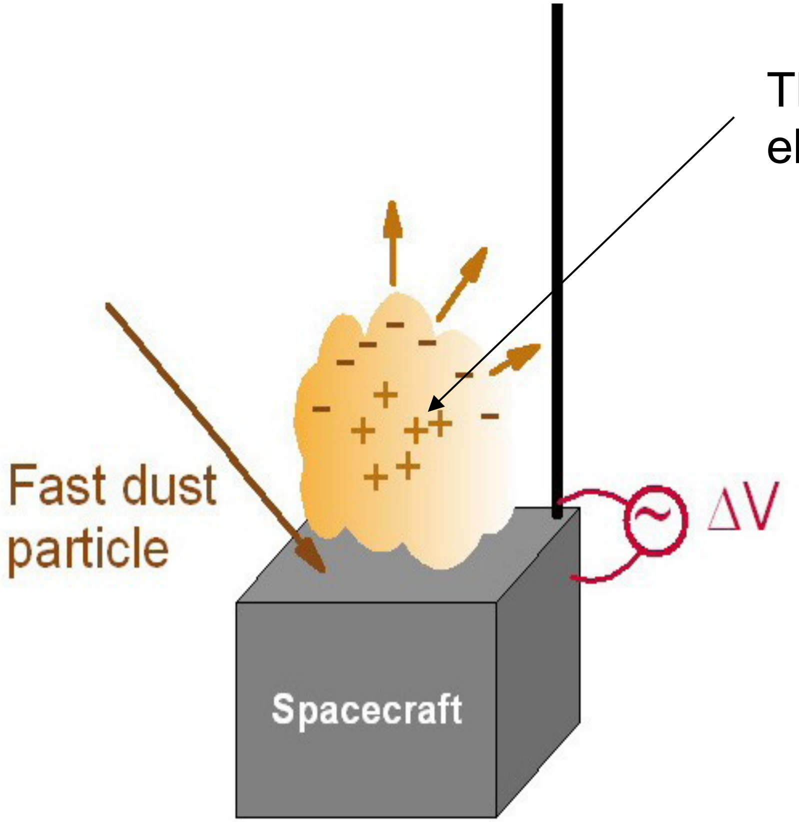
The potential of the s/c is floating due to its collection of various currents

The impact of a dust particle on the s/c produces charges that are collected, and produce a perturbation current.

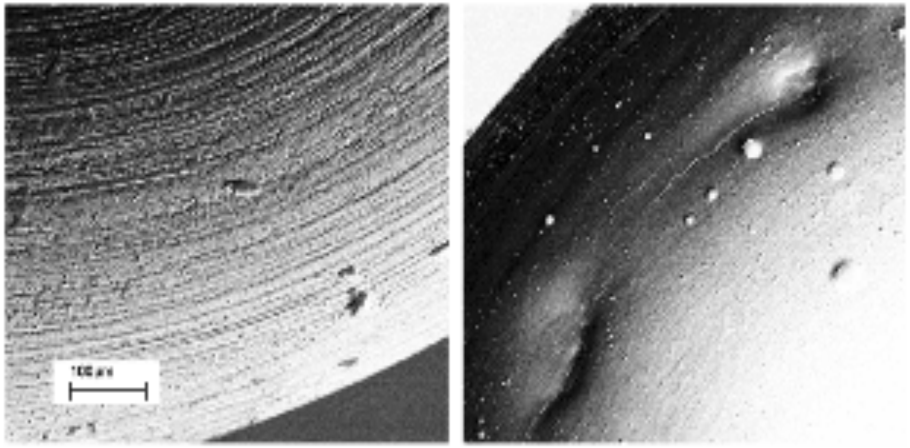
$$\varphi(t) = \varphi_{eq} + \delta\varphi(t) \qquad \frac{d}{dt}\delta\varphi + \frac{1}{\tau}\delta\varphi = \frac{I_{dust}(t)}{C} \quad \Rightarrow \quad \delta\varphi_{max} \sim \frac{Q}{C}$$

Effect of electrostatic influence also to be taken into account (cf presentation of K. Rackovic on Thursday)

Linking the mass to the charge



The electric charges necessary to produce an electric signal are generated by impact ionization

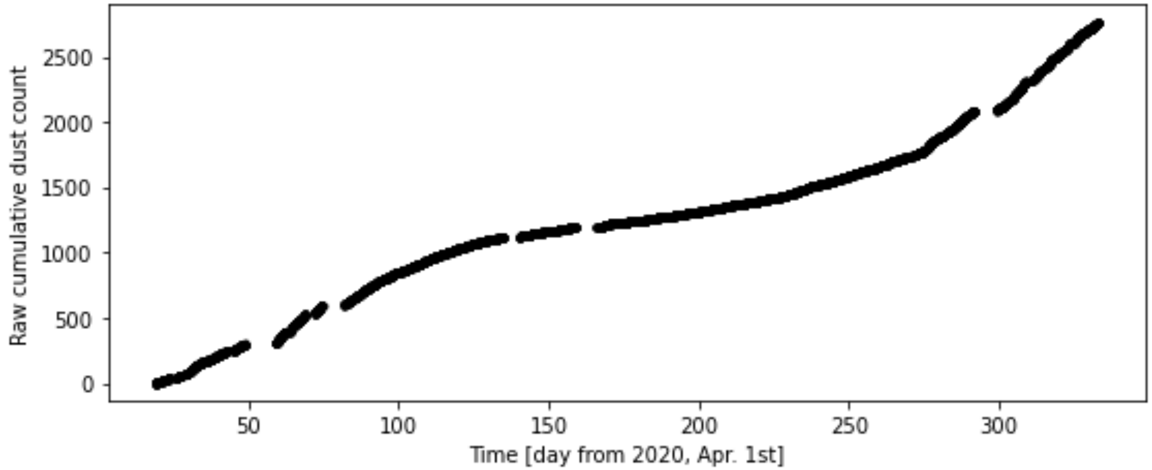


Dust impact craters (right) reproduced from [Castaldo et al., 2007]

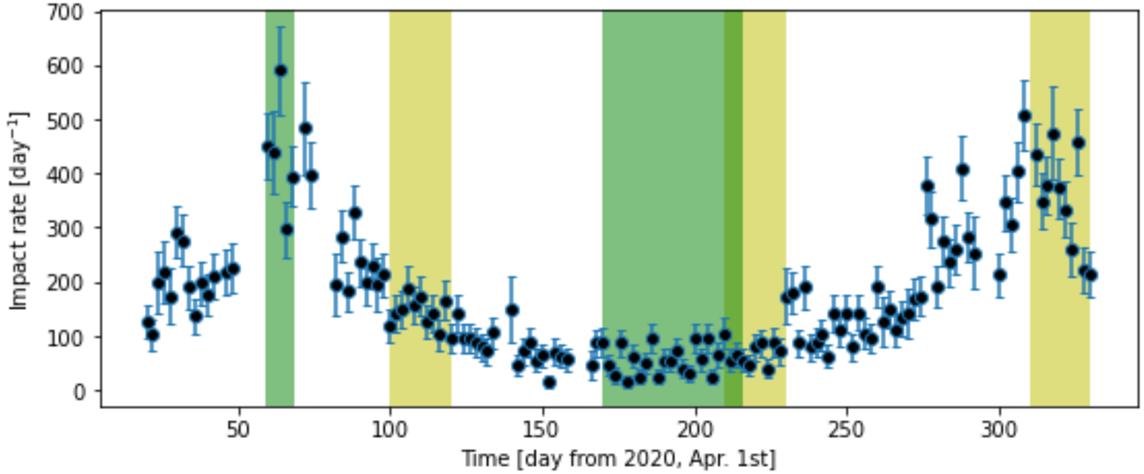
The charge generated during the impact is dependant on the mass and the velocity of the impacting particle (as well as the chemical properties of the impacted)

$$Q \simeq 0.7 m^{1.02} v^{3.48}$$

[McBride and McDonnell, 1999]

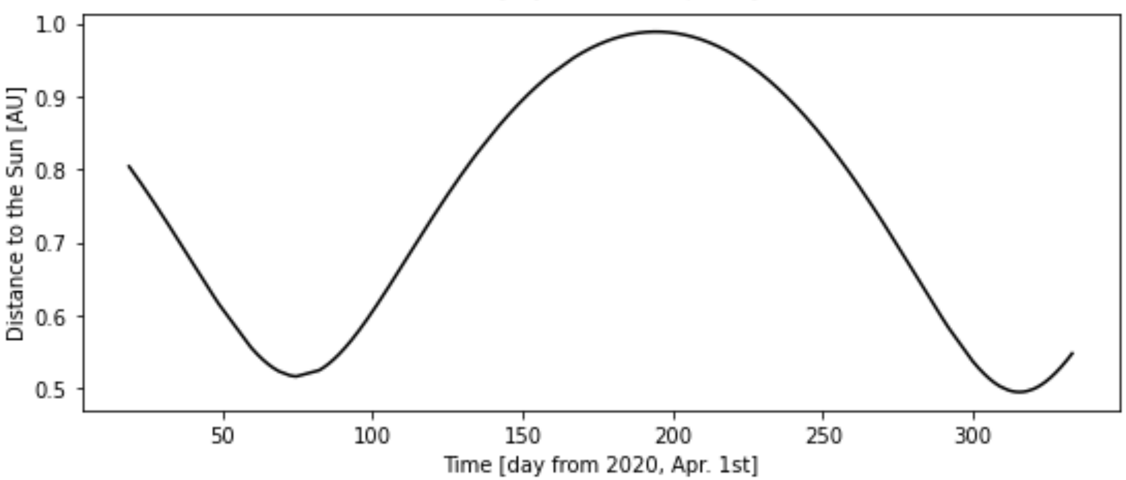


Raw cumulative nb of counts



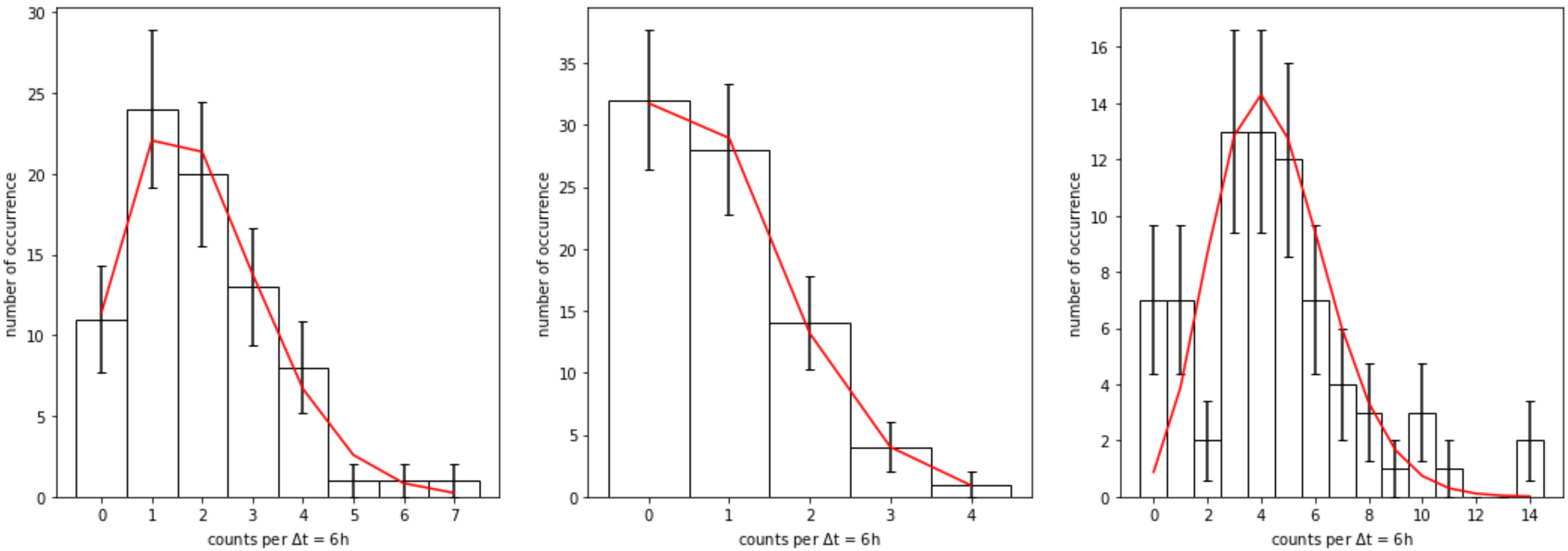
Impact rate:

$$R = N_{impact}/(N_{snapshots}\Delta t).$$



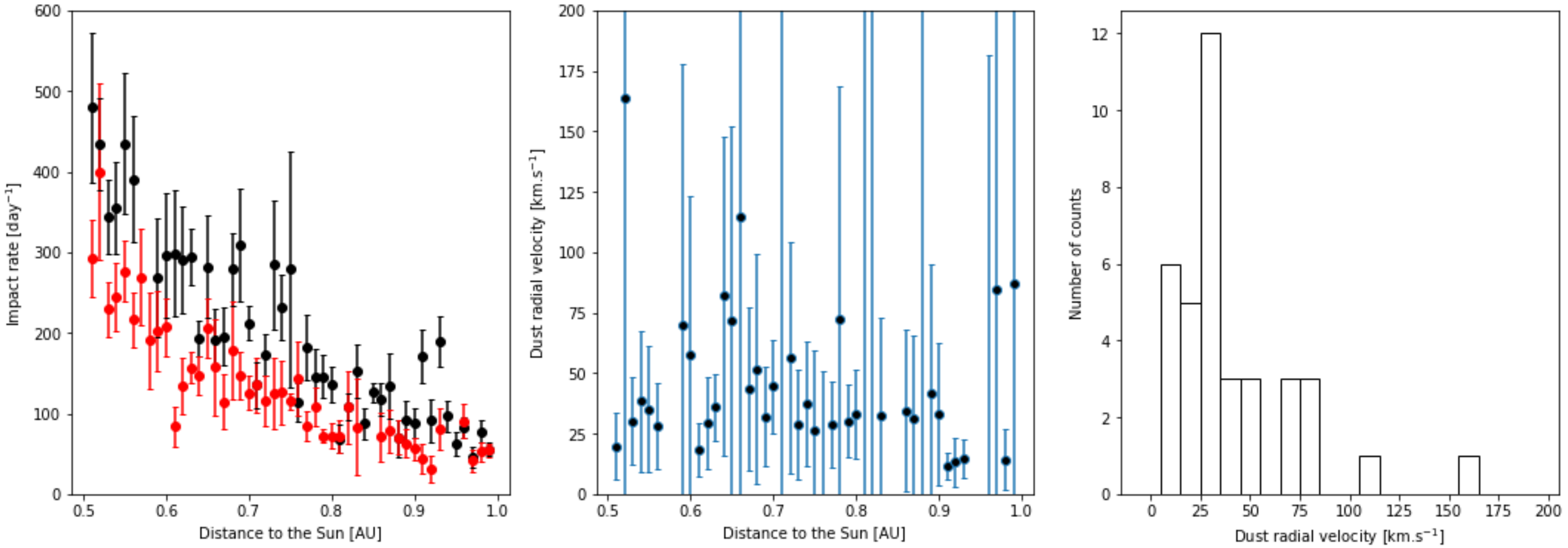
Distance to the Sun

Histograms of (raw) number of impacts recorded per 6h



In red Poisson distribution for the corresponding flux

Estimation of impactors velocity:



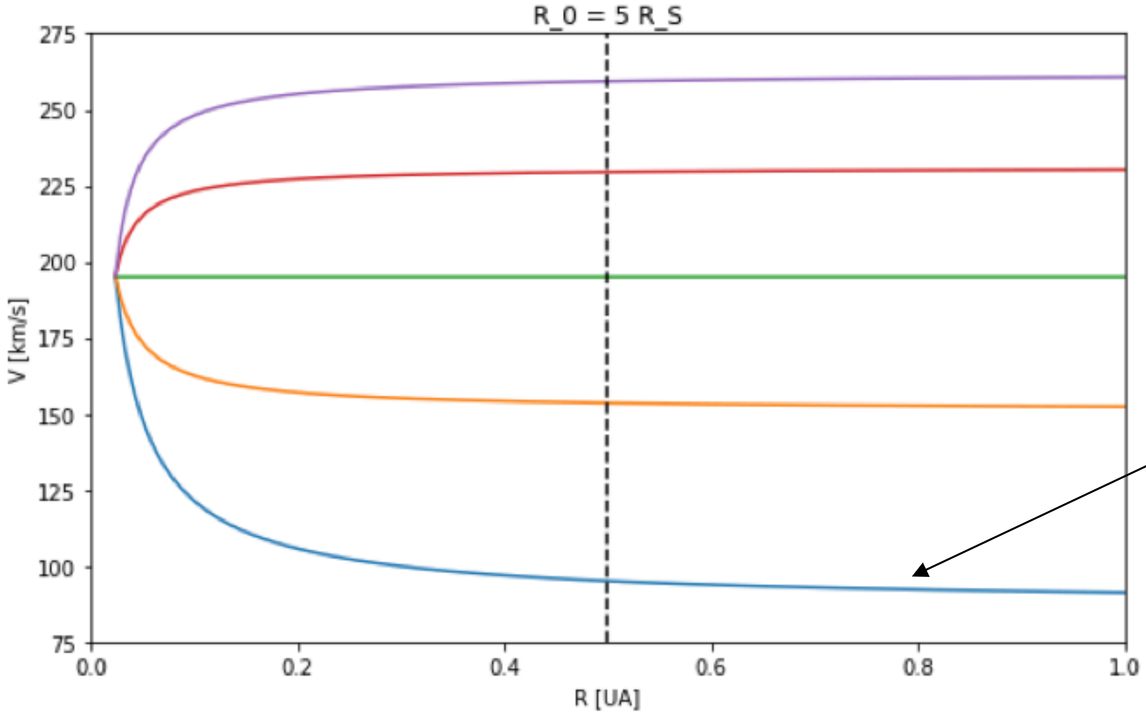
$$v_{r,dust} \sim \frac{R_{in} + R_{out}}{R_{in} - R_{out}} \left| v_{r,sc} \right|$$

Max of the histogram 30 km/s
Average around 50 km/s

Fluxes

Assumption : beta-meteoroids & interstellar dust

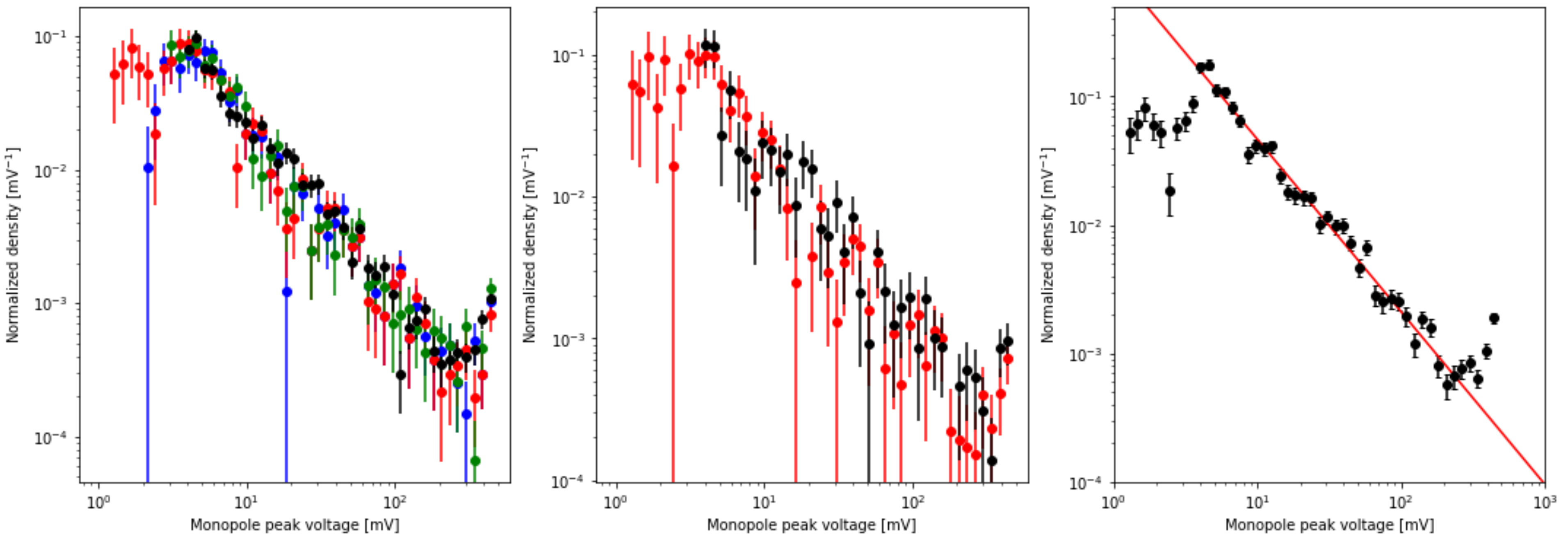
Velocity model for beta :



beta = 0.6

$V_r(1AU) = 80$ km/s

Monopole peak voltage distributions



Power law behaviour in the observed voltage range

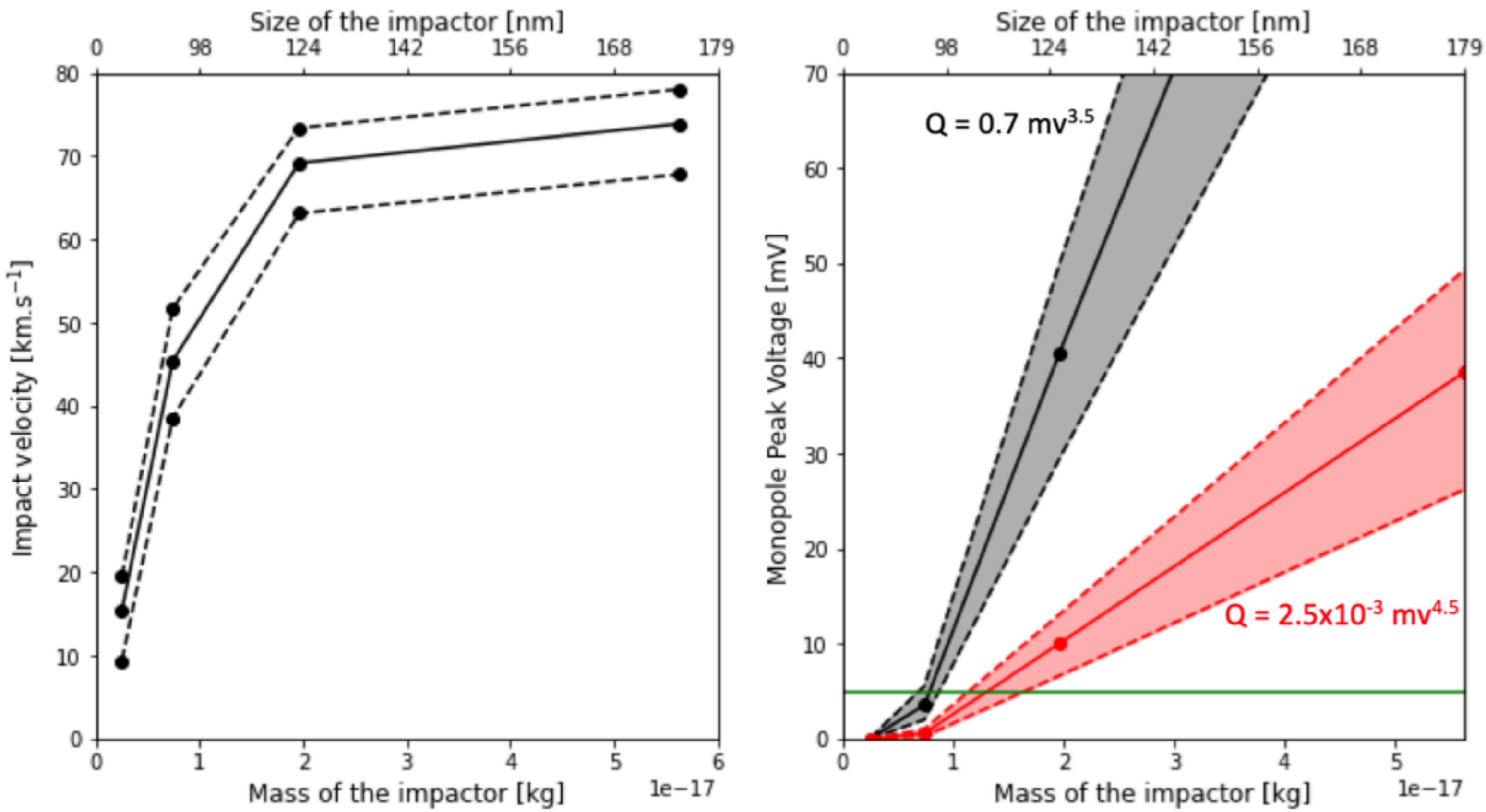
Monopole peak voltage distributions

Monopole	Time interval	Number of events	Power-law index
V1 (SE1 mode)	Apr. 1st – Nov. 31st	328	-1.34 ± 0.14
V2 (SE1 mode)	Apr. 1st – Nov. 31st	328	-1.34 ± 0.14
V2 (XLD1 mode)	Apr. 1st – Nov. 31st	934	-1.37 ± 0.10
V3 (SE1 mode)	Apr. 1st – Nov. 31st	328	-1.36 ± 0.11
V2 (SE1 mode)	May 30th – Jun. 8th (Perihelion)	185	-1.37 ± 0.19
V2 (XLD1 mode)	Sep. 17th – Nov. 2nd (Aphelion)	161	-1.20 ± 0.17
V2 (SE1 and XLD1 modes)	Apr. 1st – Nov. 31st	1262	-1.34 ± 0.07

Should correspond to power law index of the cumulative mass flux, if the velocity of the dust does not vary too much on the observed interval

If the velocity increases on the observed interval then power law index of voltages is an underestimation of the cumulative mass flux power-law

Mass of the smallest impactors



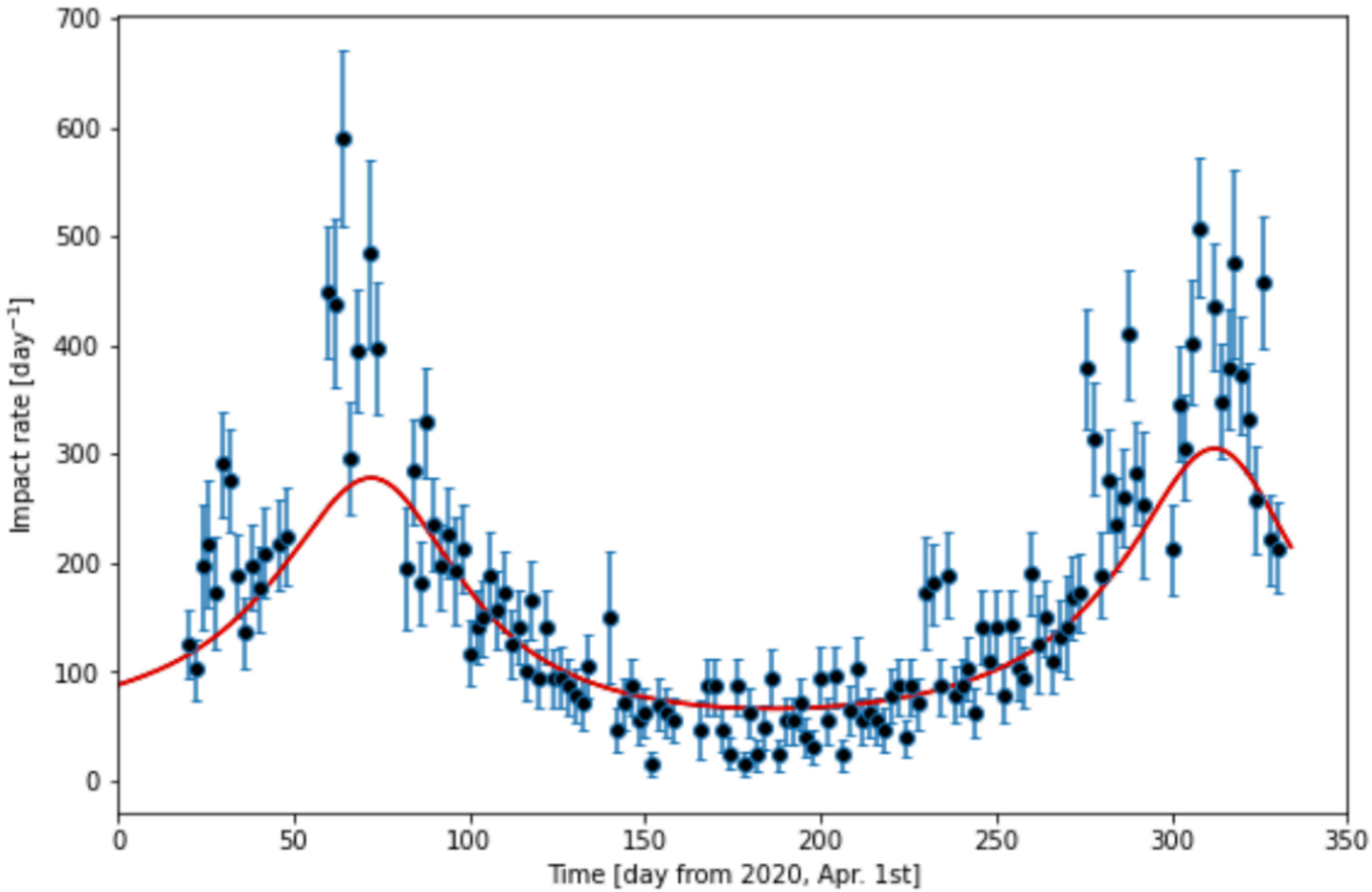
Velocity from numerical simulations

Monopole peak voltage for two charge yields
High : 0.7mv^3.5
Low : 2.5e-3mv^4.5

Size around 100nm

Impact rate vs simple model

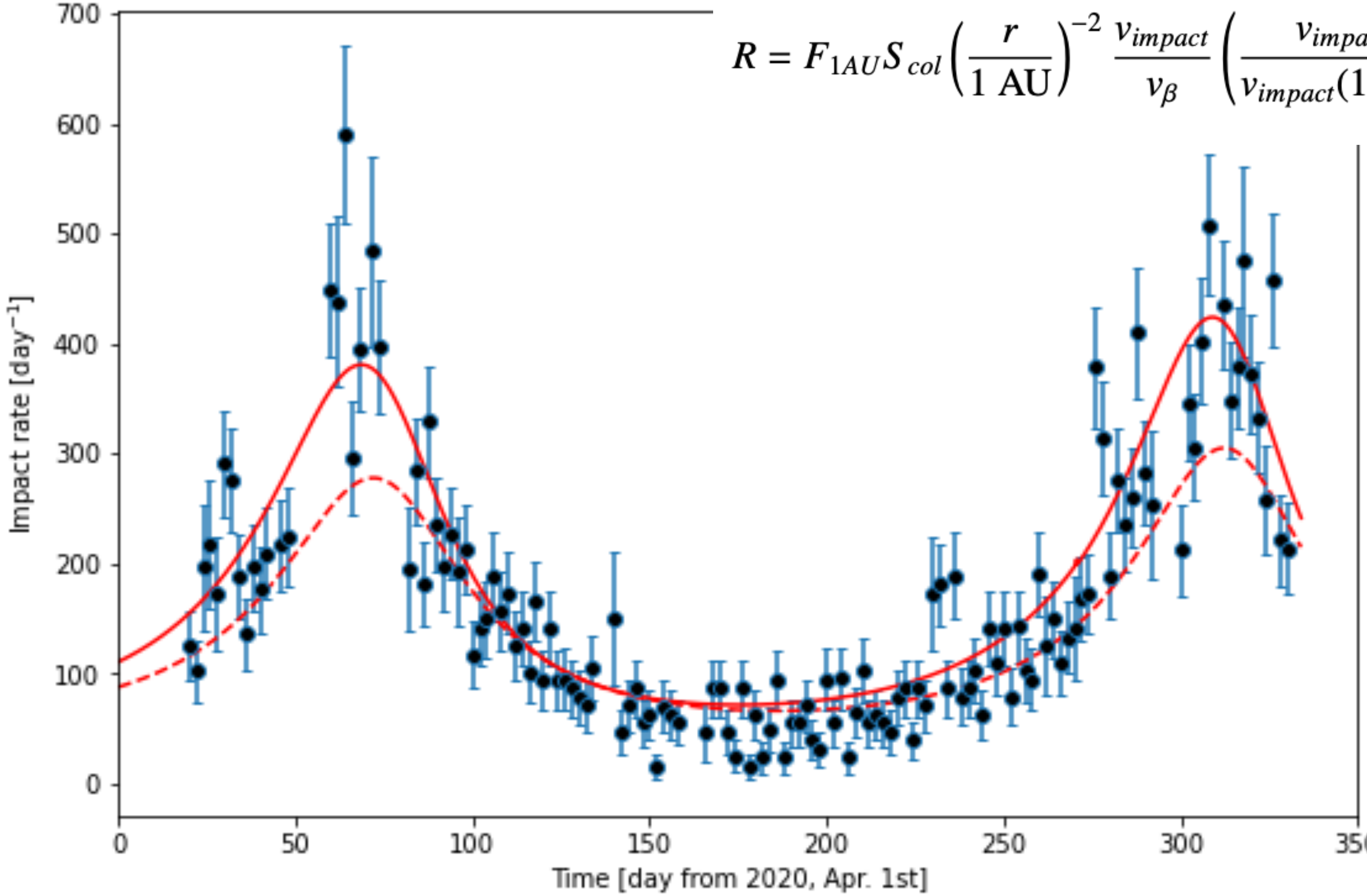
$$R = F_{1AU} S_{col} \left(\frac{r}{1\ \text{AU}}\right)^{-2} \frac{v_{impact}}{v_\beta}$$



Systematic underestimation of rates at the perihelion

Assuming the smallest mass detected is velocity dependent

$$R = F_{1AU} S_{col} \left(\frac{r}{1\ \text{AU}}\right)^{-2} \frac{v_{impact}}{v_\beta} \left(\frac{v_{impact}}{v_{impact}(1\ \text{AU})}\right)^{\alpha\delta}$$

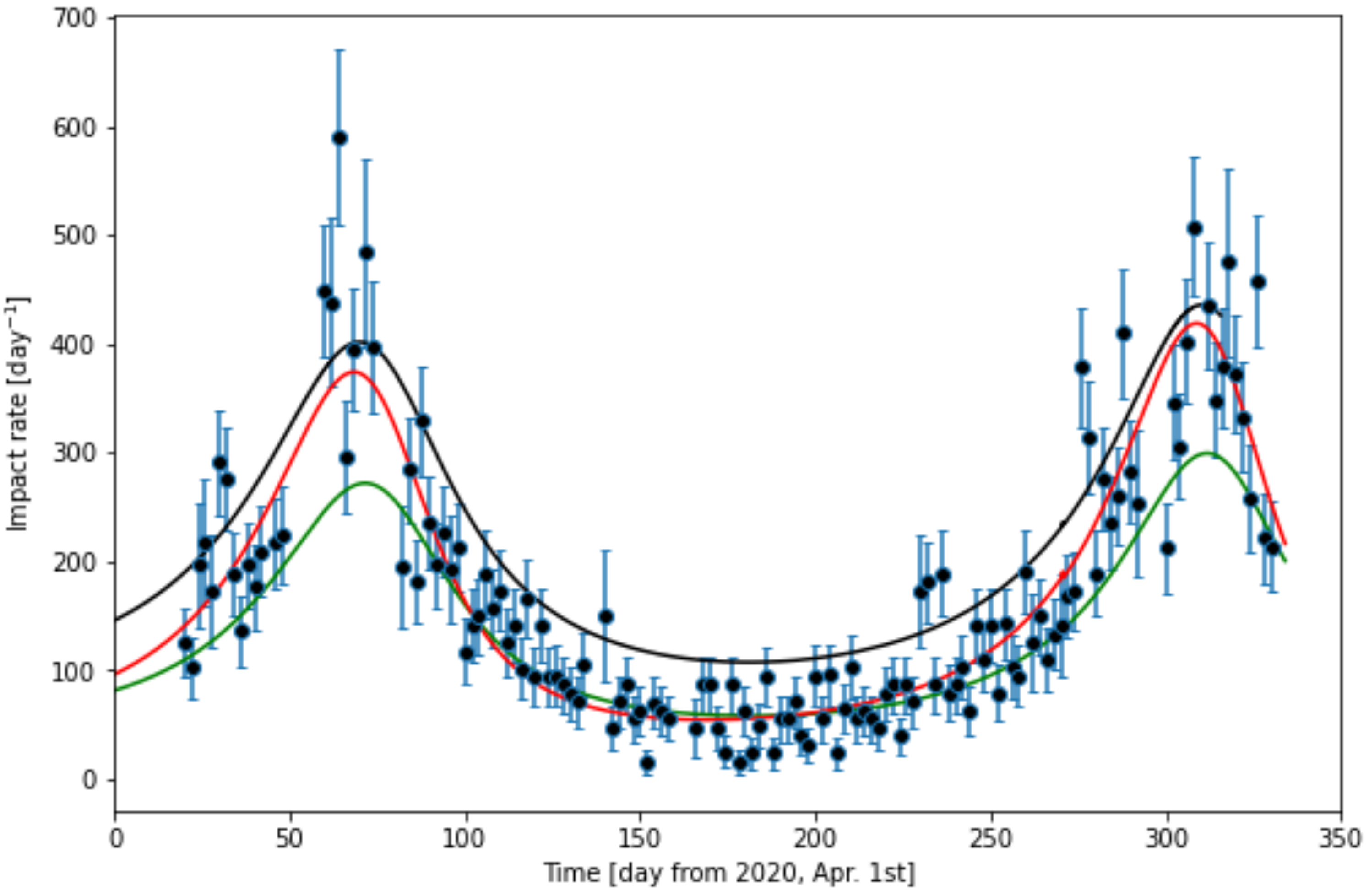


$Q = A.mv^{\alpha}$

$F = F.m^{-\delta}$

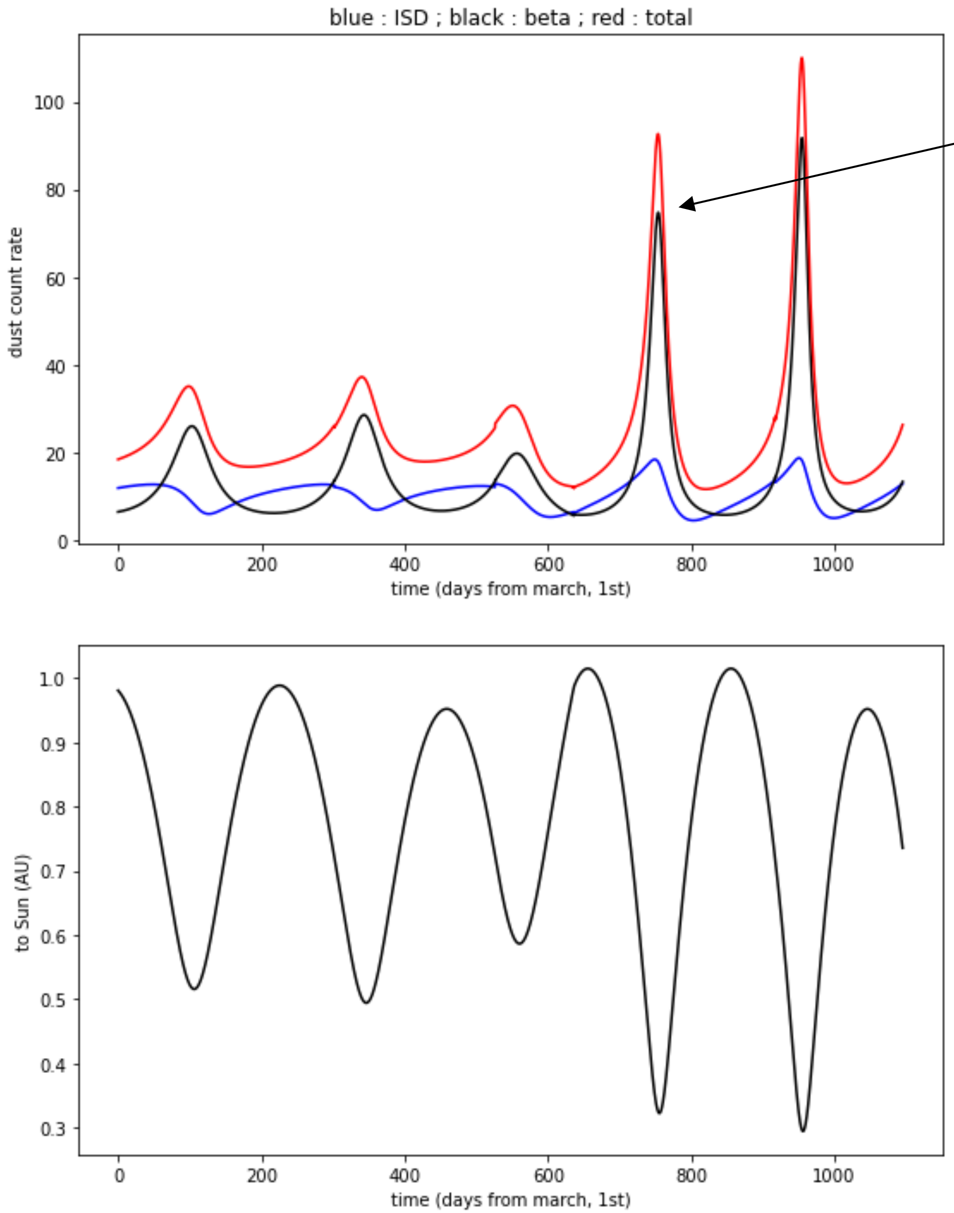
Here $\alpha\delta = 1.35 \Rightarrow \delta = 0.29 - 0.37.$ (Or alpha = 3.9)

Comparison to numerical simulation



Black curve : simulated impact rate for 100 nm < r < 200 nm

Future



Spring 2022

Estimate of fluxes up to march 2023

Conclusions

- Particles of size >= 100 nm
- Radial velocity of the impactors around 50 km/s
- Cumulative flux of particles larger than around 3. 10^{-18} kg at 1 AU of 8.10^{-5} m^2s^{-1}
- We can determin the power law index of the cumulative mass flux by two different methods
- Direct observation of voltages (assuming mass indepedent of velocity) gives δ=0.33 +/- 0.08)
- Impact rate vs impact velocity model gives δ = 0.3 – 0.4 (depending on value taken for alpha)