LOW-SPEED EJECTION MECHANISMS IN THE DART EXPERIMENT

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Following the impact of the NASA-DART space probe against the asteroid Dimorphos, several thousand tons of material were ejected at a wide range of velocities. Several groups have used close observations of LICIACube, as well as long-range long-range tracking from HST and the ground, to infer the spatial and velocity distribution of ejecta (Li et. al. 2022). From images taken by LICIACUbe's camera LUKE during the fly-by with a wide range of viewing angles, it was concluded that the ejecta cone had a wide angle of ~145º. In addition, **the tip of the ejecta cone does not appear to have been located at the surface, as would be expected from a point source cratering event. The ejecta was released from a wide area covering almost the entire impacted hemisphere (half of the Dimorphos surface centered on the impact point).**

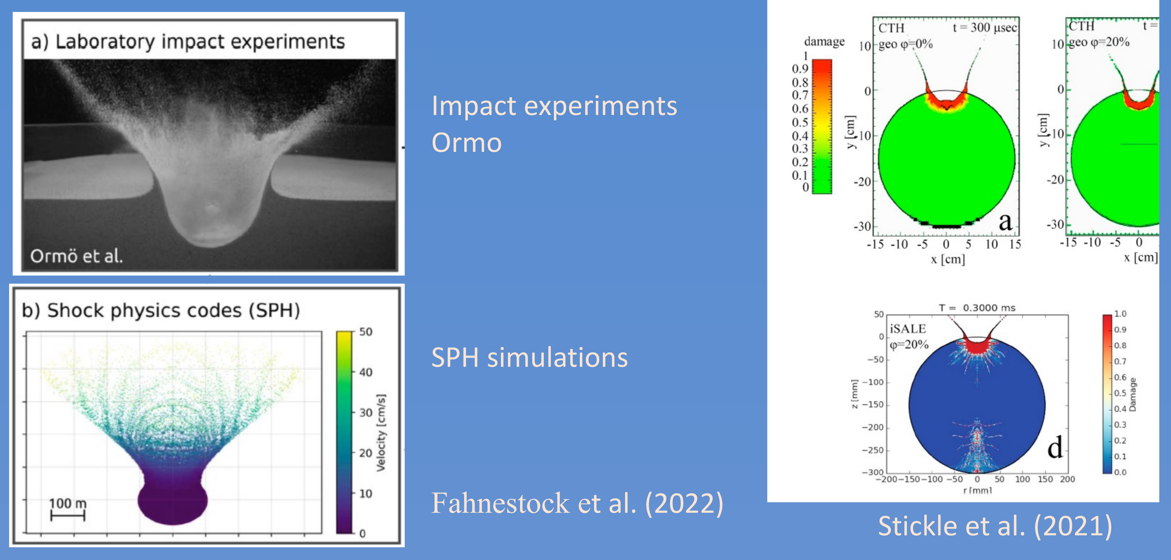
The ejected material can be broadly classified into three different regimes: the very-high-speed ejecta (with speeds tens m/s); the highspeed ejecta (a few m/s); and the low-speed ejecta (below 1 m/s). **The radial extension of the cone and the darkened ring just above the surface observed in a side view are in correspondence with the fact that most of the material was ejected at very low velocities.**

Moreno et al. (2022) and Tancredi et al. (2022) presented models similar to those used to study the evolution of Active Asteroids to predict coma brightness and the formation of a long-lived tail after impact. They dubbed the DART experiment as the creation of the first artificial Active Asteroid. The inversion of this model is used by Moreno et al. (this conference) to infer the ejecta distribution in mass and velocities, concluding that most of the material was released at velocities comparable to the escape velocity from Dimorphos' surface (i.e. 0.09 m/s).

What are the physical mechanisms that could explain the wide ejecta cone, the large ejection zone (~one hemisphere) and low velocities of the material?
Tancredi et al. (2022) predicted that the seismic shaking generated by the impact, and the so-called "cocoa effect" (lofting of small particles from the top of a dust layer when shaking it off), are the mechanism behind these observations. Other groups have been working on other interpretations.

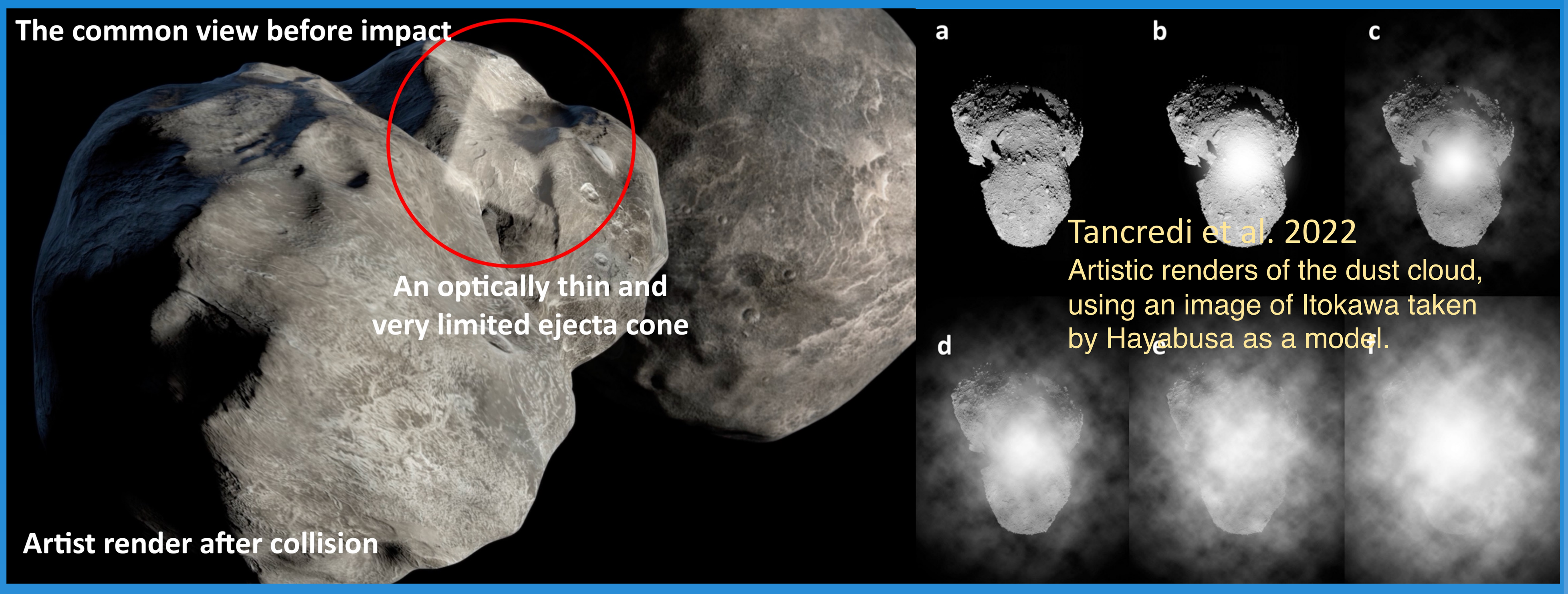
What do laboratory experiences and simulations tell us?

Experiments in granular material and SPH simulations showed an ejecta cone limited to a small area.

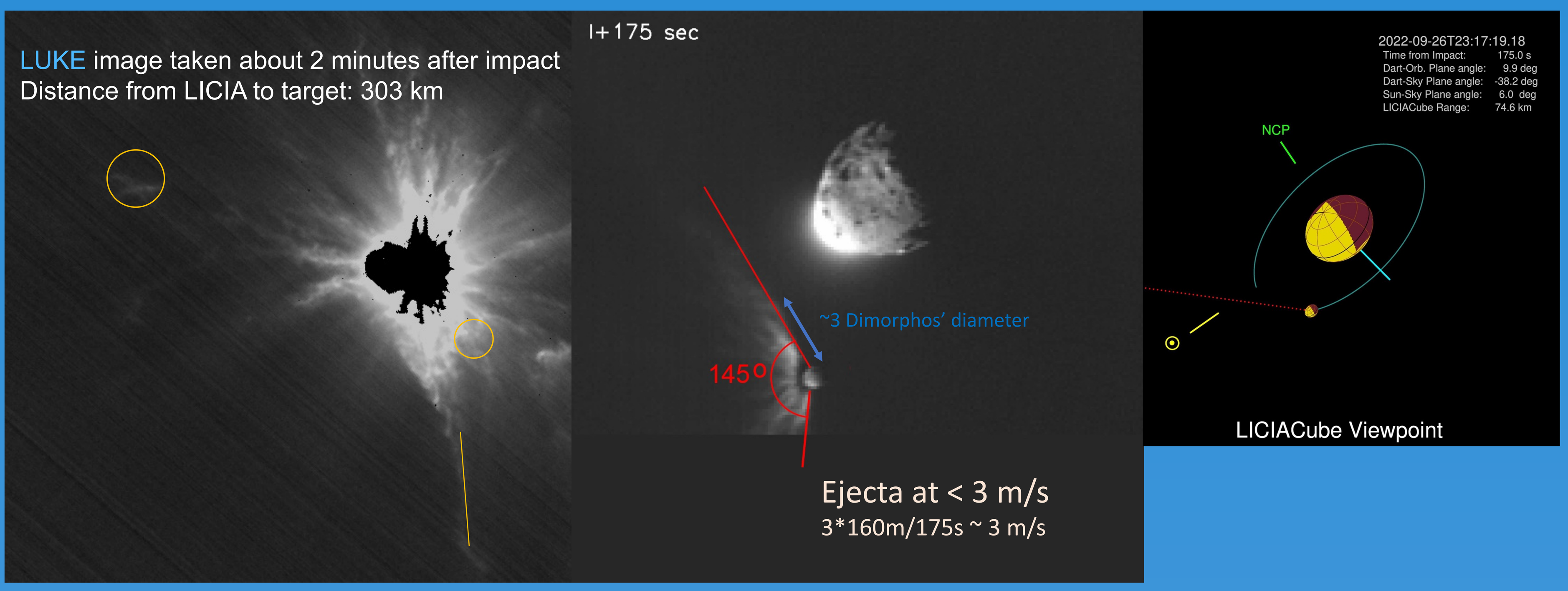


These results are not in agreement with the observations.

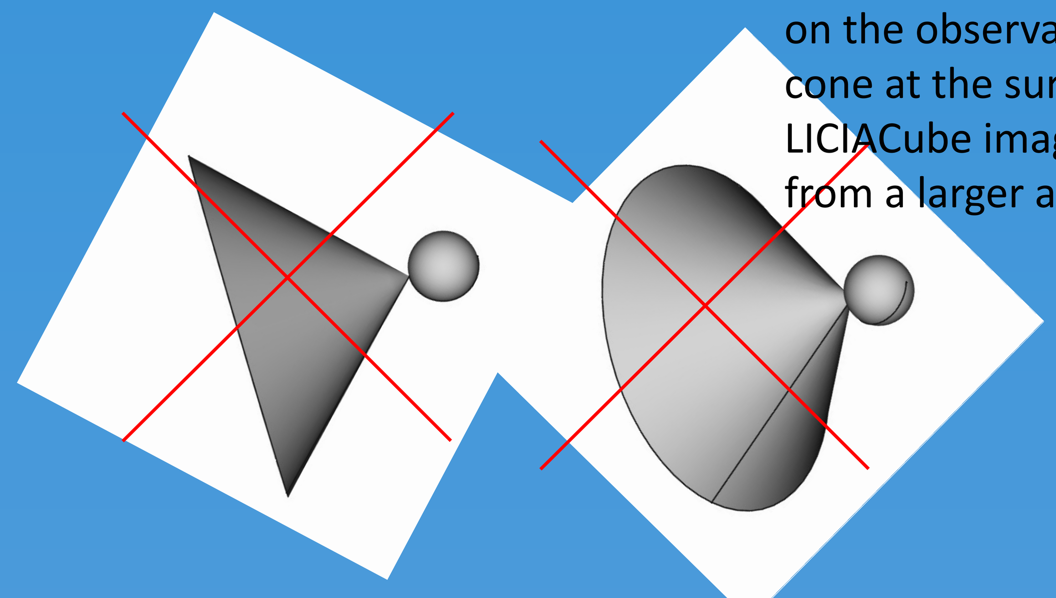
Predictions before impact

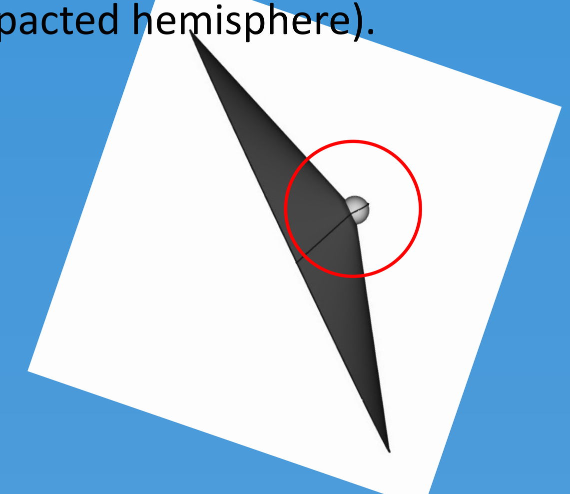


Observations after impact of the Ejecta cone



Up to now, most of the models for the ejecta cone based on the observations, are asumming the vertex of the cone at the surface. But, from the side view in the LICIACube images, the material appears to be released from a larger area (the entire impacted hemisphere).



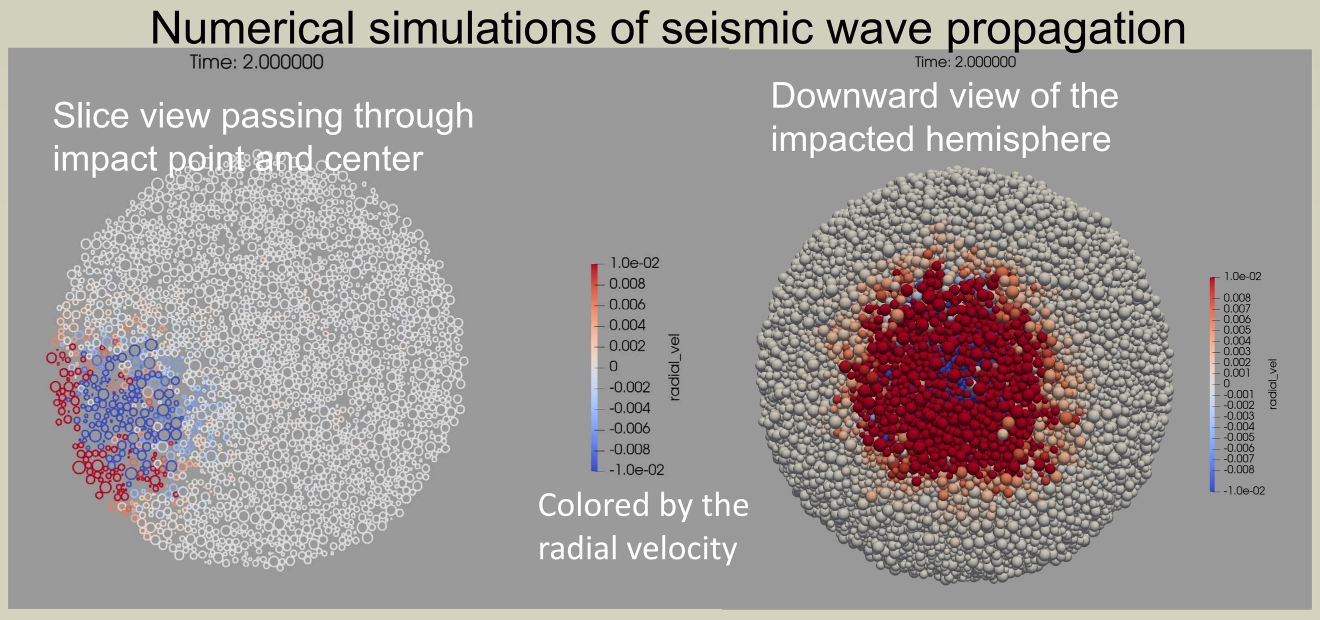


Lofting of material at low speed as a consequence of the generation of seismic waves (Tancredi et al., 2022)

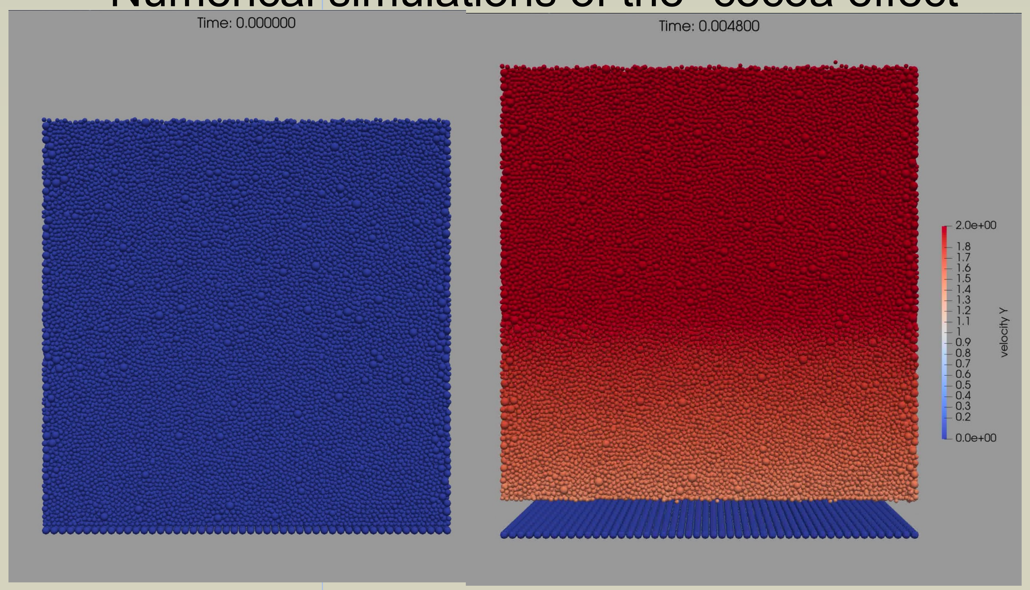
We divide the process into the following steps:

i) generation of impact-induced seismic waves and propagation into the body interior;
ii) arrival of these waves at points located far from the impact point, producing a shaking effect on the ground;
iii) lofting of particles due to shaking and ejection at low speed (comparable to the escape velocity): the "cocoa effect".

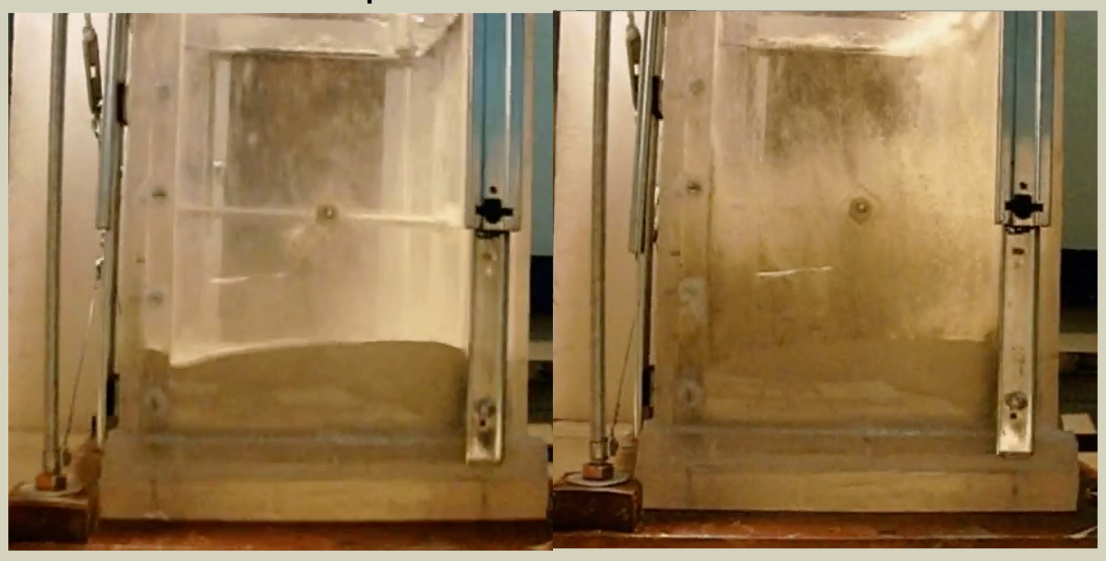
Numerical simulations of seismic wave propagation



Numerical simulations of the "cocoa effect"



Lab experiments of the "cocoa effect"



The combination of the seismic wave propagation affecting a large area and the "cocoa effect" could explain the shape of the low-velocity ejecta cone.

Conclusions

- The cone has an open angle of ~145º.
- The dust particles in the densest part of the cone have speeds < 3m/s.
- A cone with a tip on the surface looks incompatible with the observations.
- A broad outflow cone coming from a large surface area is required.
- Cratering experiments and SPH models produce ejecta plume with a conical shape with a tip on the surface, in contradiction with observations.
- Other models are required to explain a broad outflow cone, e.g. seismic shaking + "cocoa effect"

Numerical simulations were done using the DEM package ESyS-Particle (https://launchpad.net/esys-particle) and later improvements that include self-gravity (ESyS-Gravity, Rocchetti et al. 2021).

References:

- Li et al (2023) "Ejecta from the DART-produced active asteroid Dimorphos" (2022).; Nature DOI: 10.1038/s41586-023-05811-4
- Moreno et al. (2022), "Ground-based observability of Dimorphos DART impact ejecta: Photometric predictions"; MNRAS,515,2,2178–2187; https://doi.org/10.1093/mnras/stac1849
- Rocchetti et al. "High performance computing simulations of self-gravity in astronomical agglomerates" (2021) Simulation. DOI: 10.1177/0037549721998766
- Tancredi et al. (2022), "Lofting of low speed ejecta produced in the DART experiment and production of a dust cloud" (2022) ; MNRAS; https://doi.org/10.1093/mnras/stac3258