

Stellar space weather effects on habitable-zone planets



@AlineVidotto

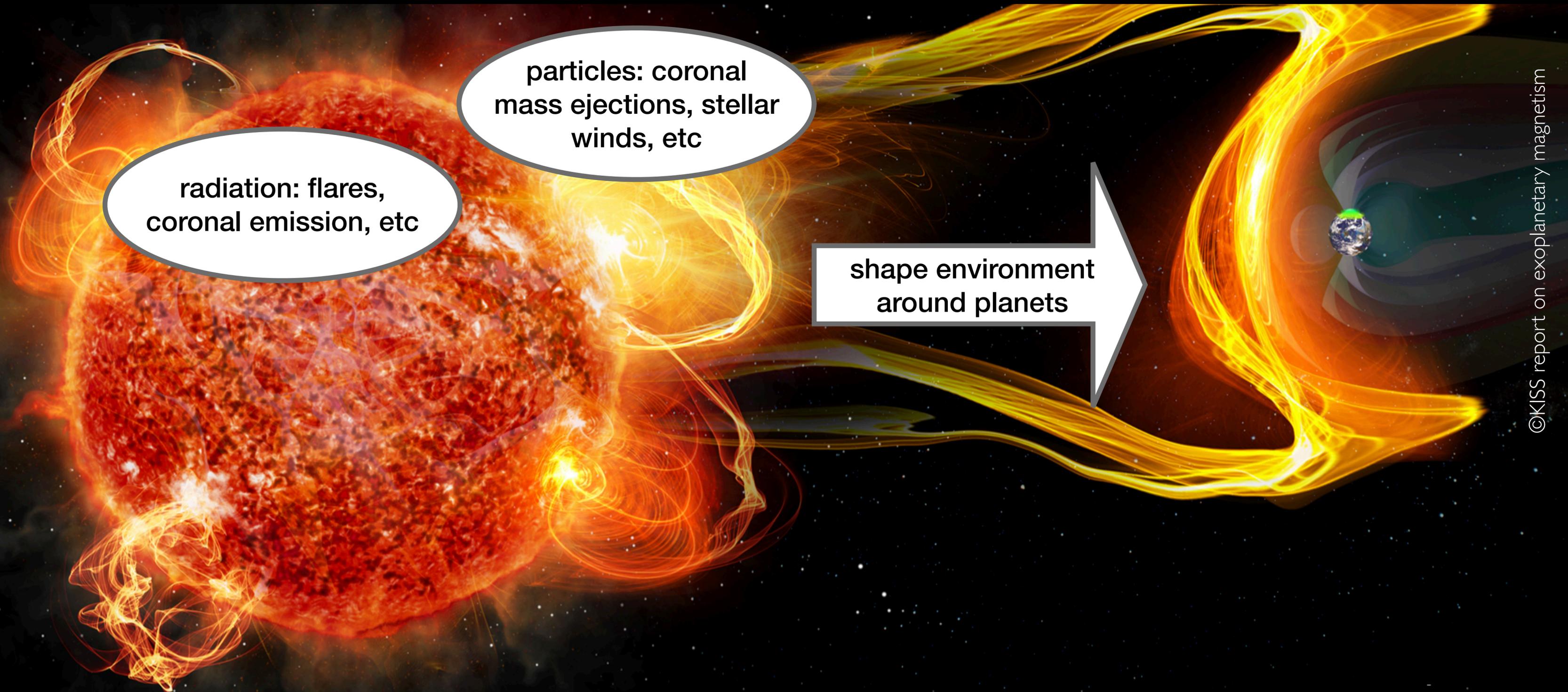


Thanks to: O Fionnagain, Kavanagh, Rodgers-Lee, Mesquita, Carolan, Hazra, Kubyshkina, Villarreal D'Angelo



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Stellar space weather effects on habitable-zone planets



radiation: flares,
coronal emission, etc

particles: coronal
mass ejections, stellar
winds, etc

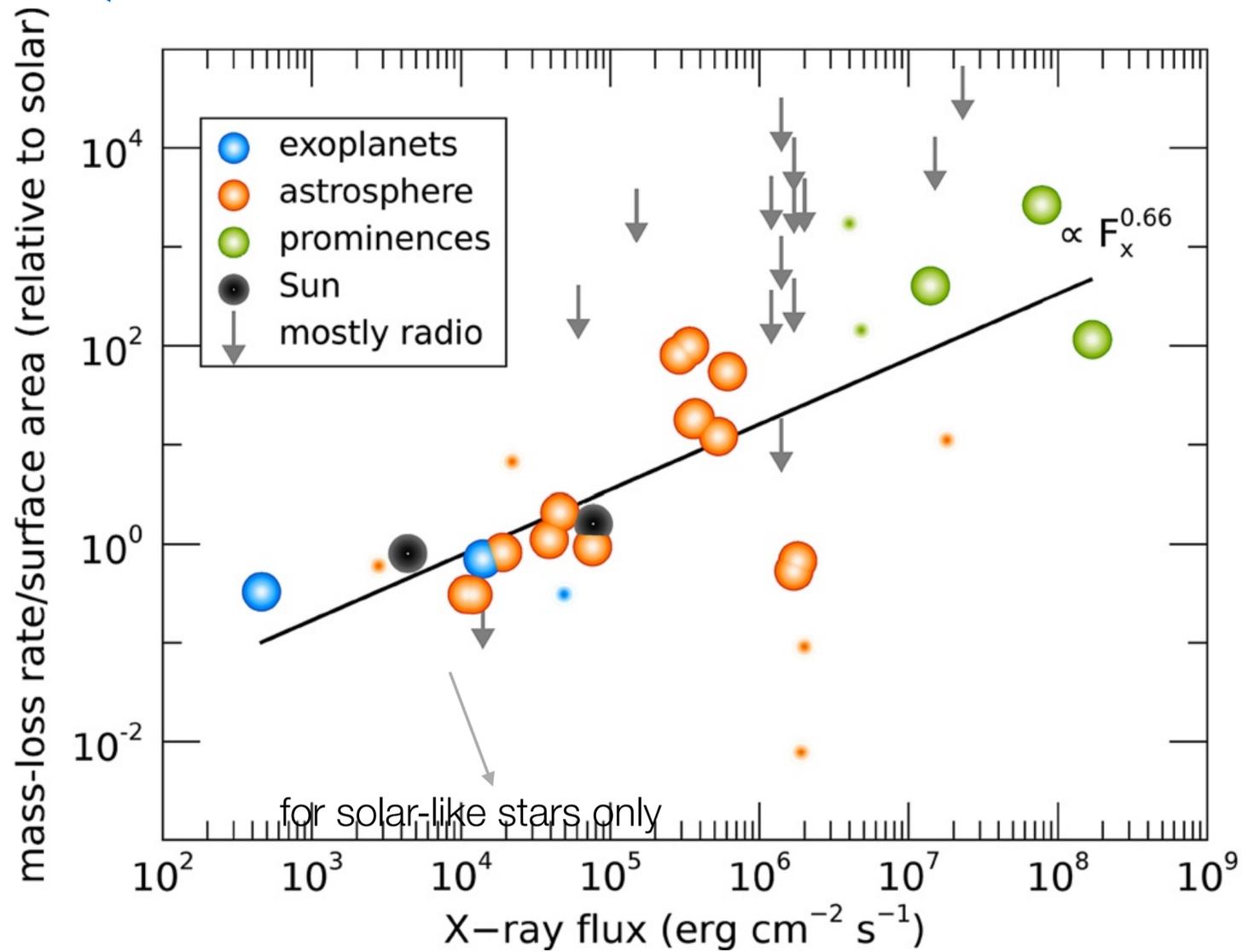
shape environment
around planets

How do winds, activity & planets evolve?

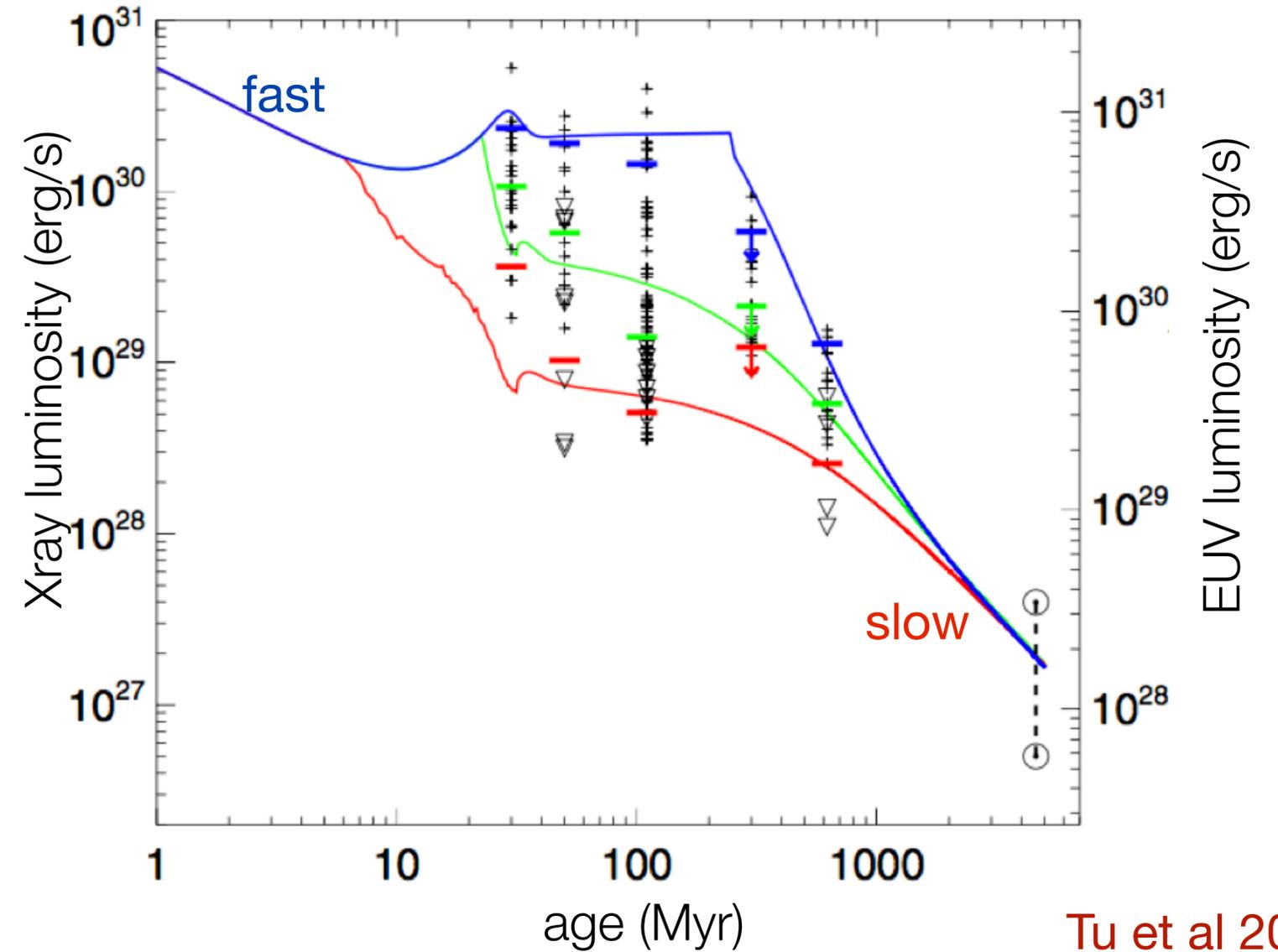
old stars
(less active,
slower rotation)

age

young stars
(more active,
faster rotation)



Vidotto 2021, Living Reviews in Solar Physics



Tu et al 2015

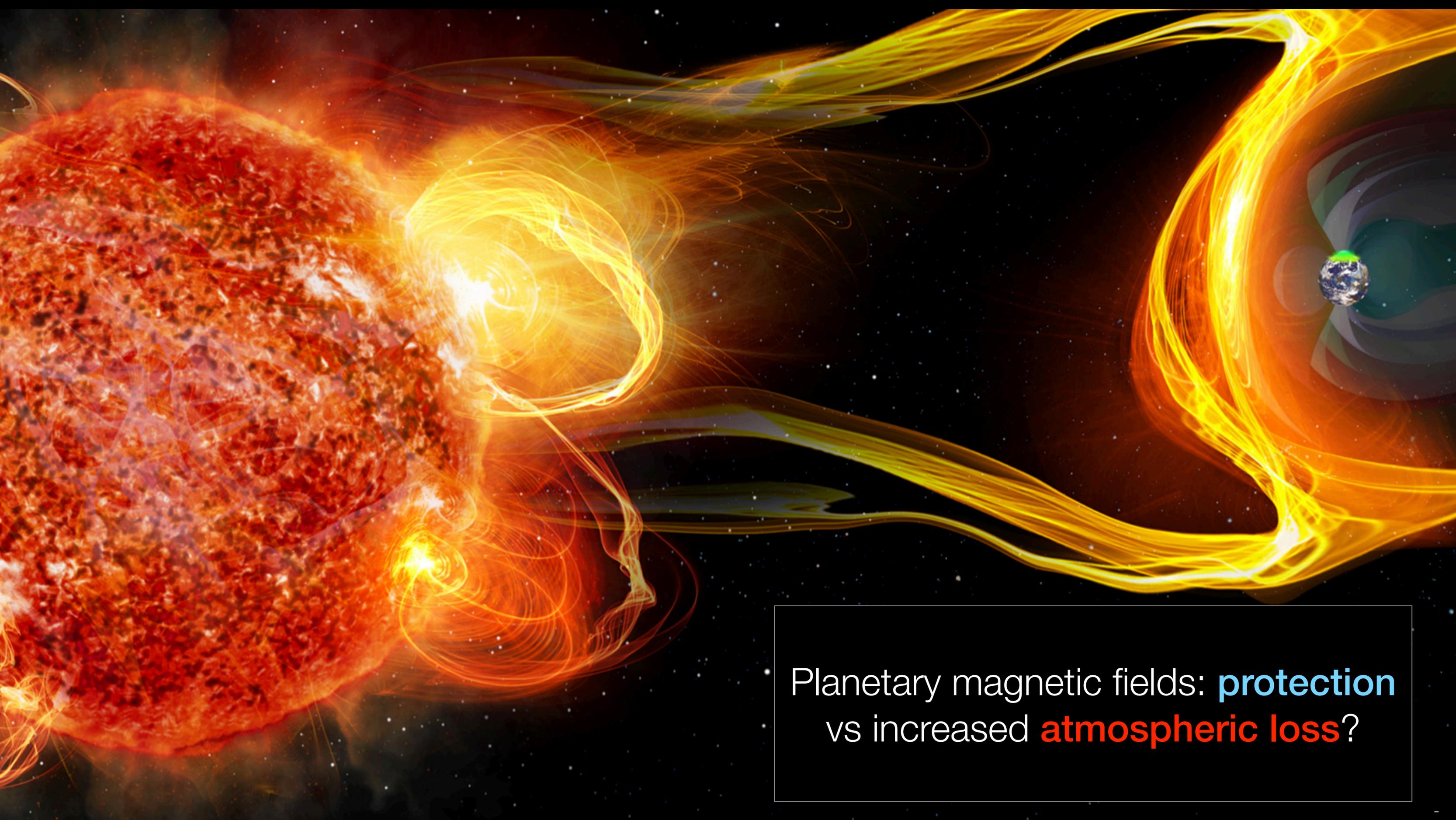
Outline

1

“Particle side”: how stellar winds affect magnetospheres and filters galactic cosmic rays

2

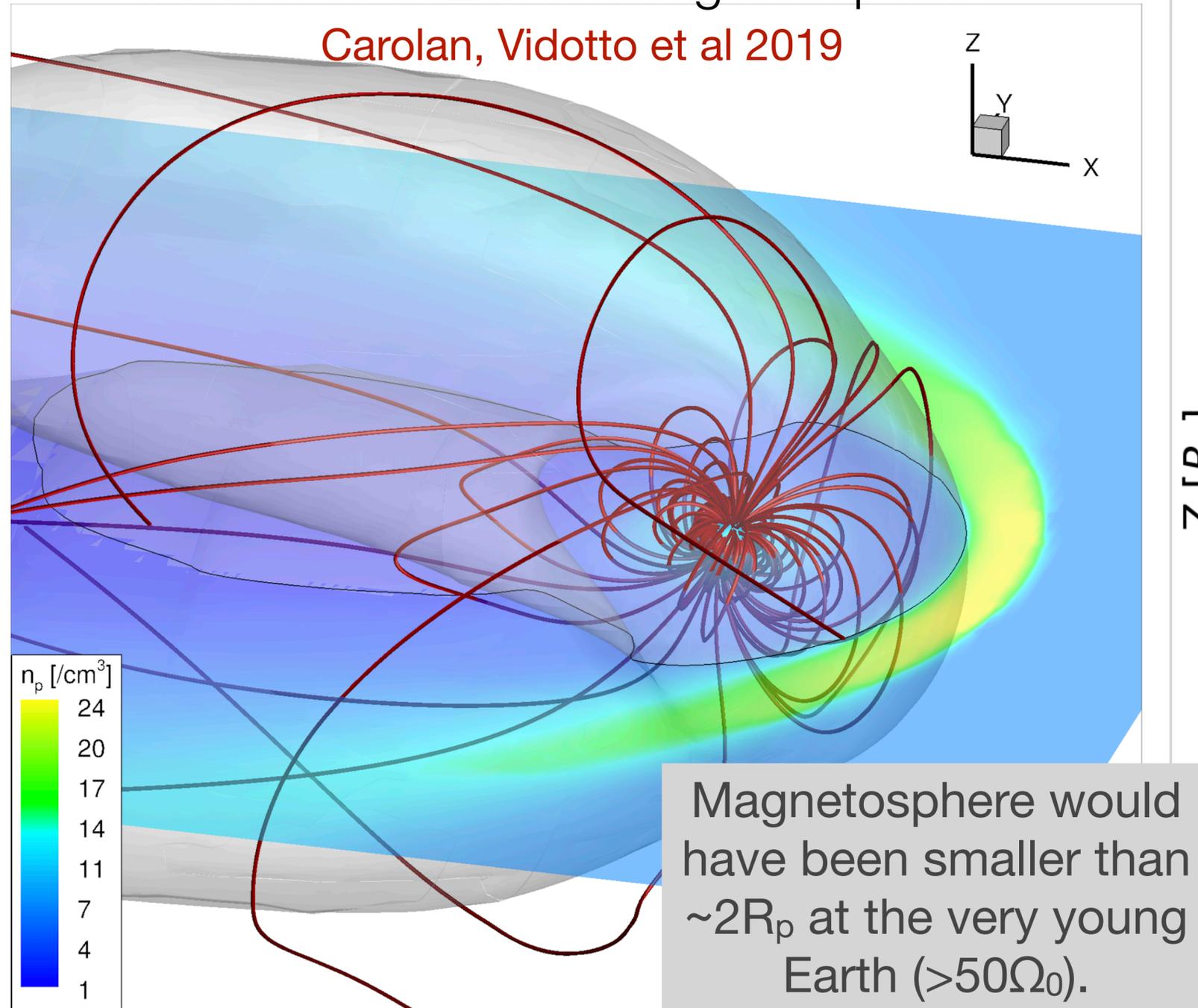
“Radiation side”: how high-energy stellar radiation & flares affect planetary evaporation



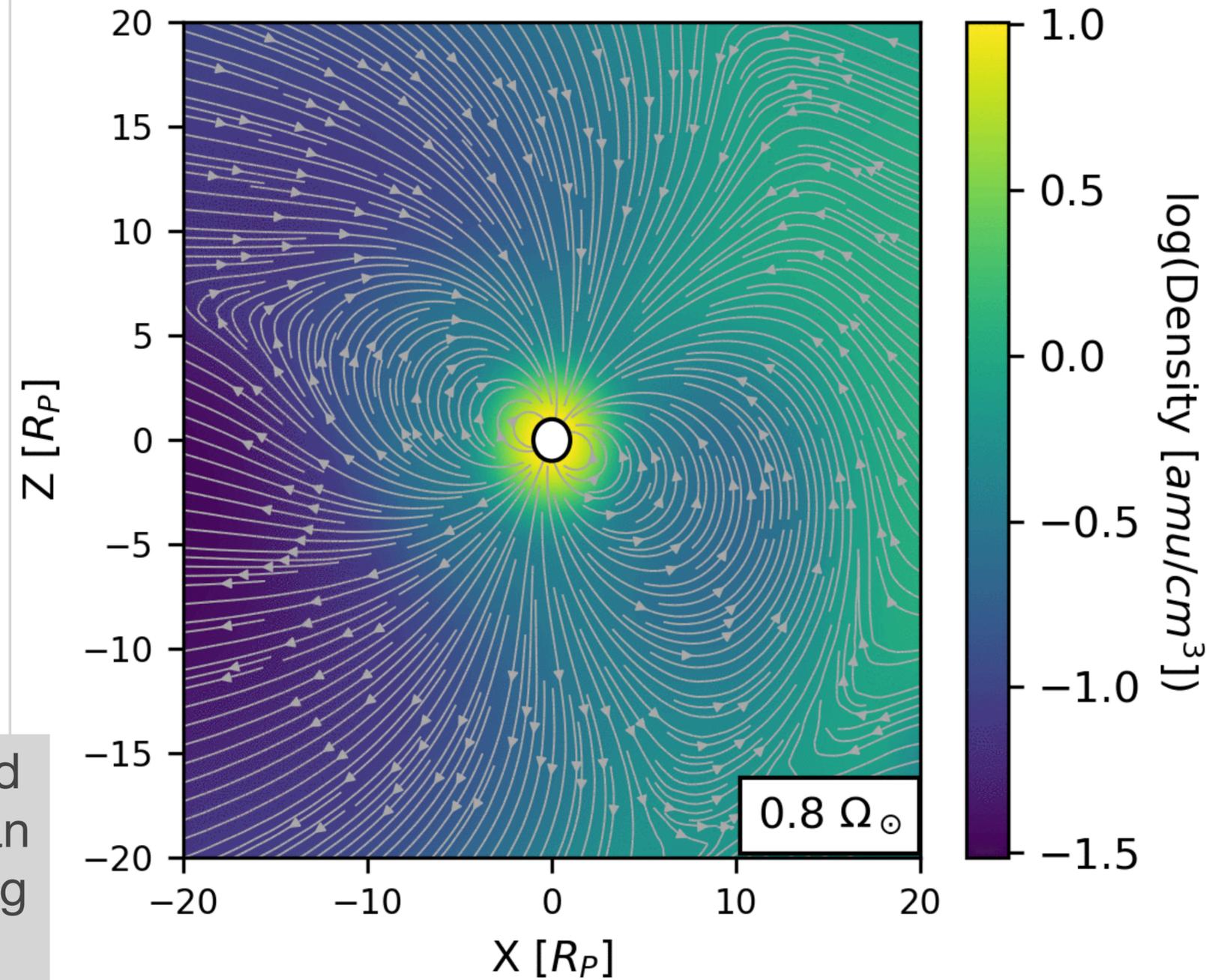
Planetary magnetic fields: **protection**
vs increased **atmospheric loss**?

The evolution of Earth's magnetosphere during the solar main sequence

3D models of the interaction between the solar wind and Earth's magnetosphere

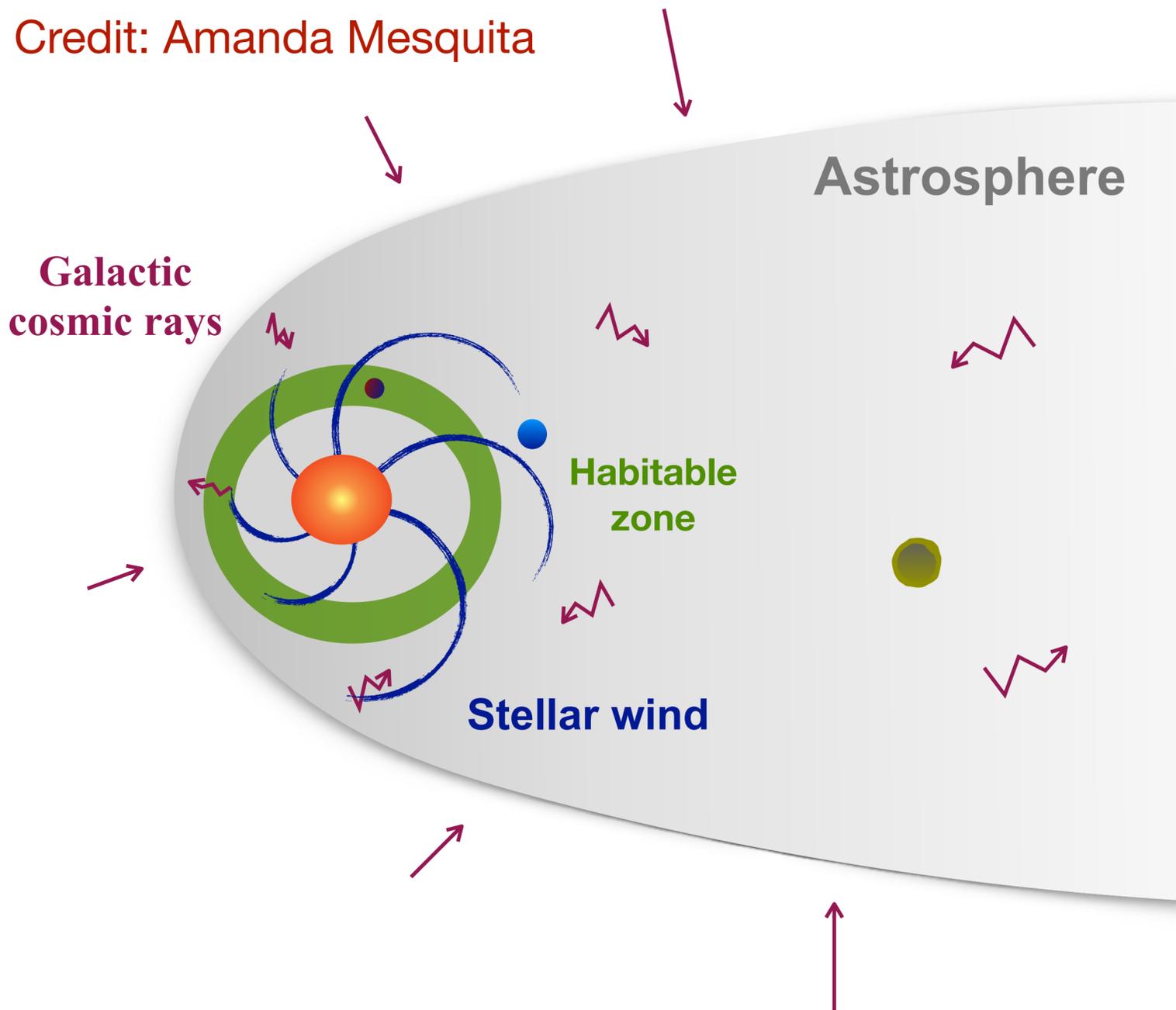


Increasing the strength of the solar wind as we look back in time



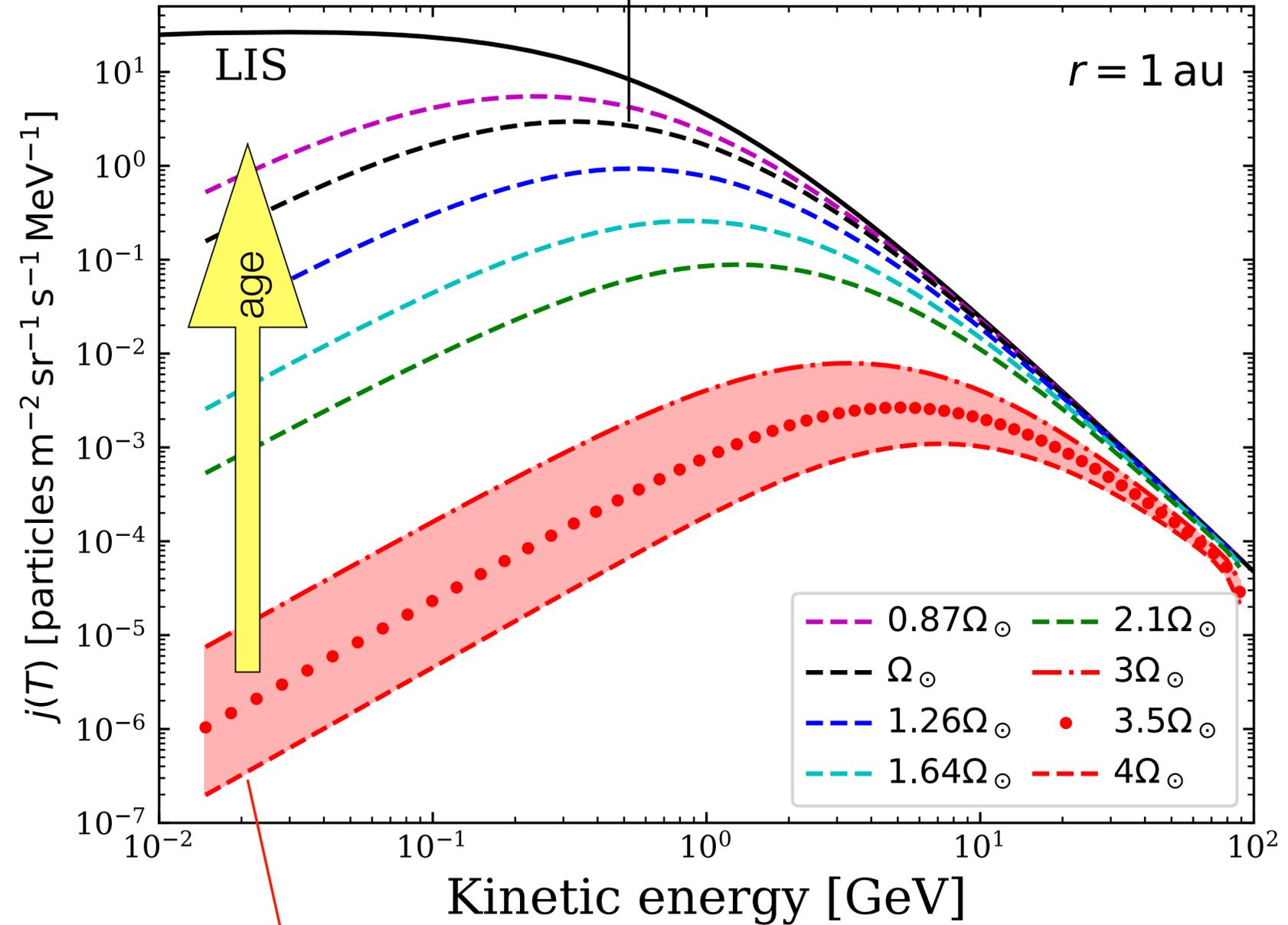
Less Galactic cosmic rays when the Sun was young

Credit: Amanda Mesquita



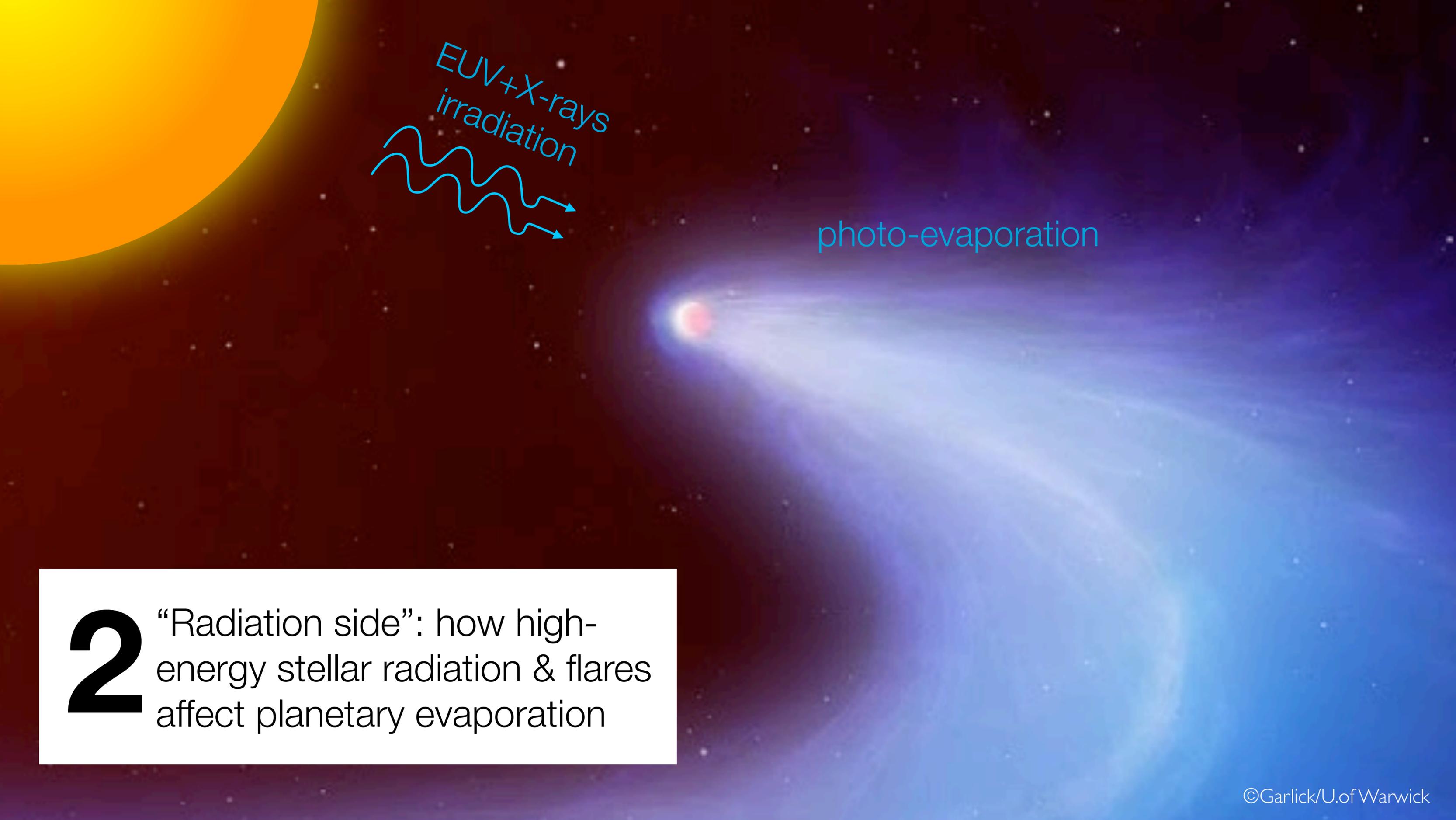
Present-day values

Rodgers-Lee et al 2020



Baby Sun

also: Mesquita et al 2021a, 2021b
Rodgers-Lee et al 2020, 2021a, 2021b

The image shows a large orange star in the top-left corner. Blue wavy arrows labeled 'EUV+X-rays irradiation' point from the star towards a smaller red star in the center. From this red star, a large, diffuse blue cloud of gas extends to the right, labeled 'photo-evaporation'. The background is a dark space filled with small white stars.

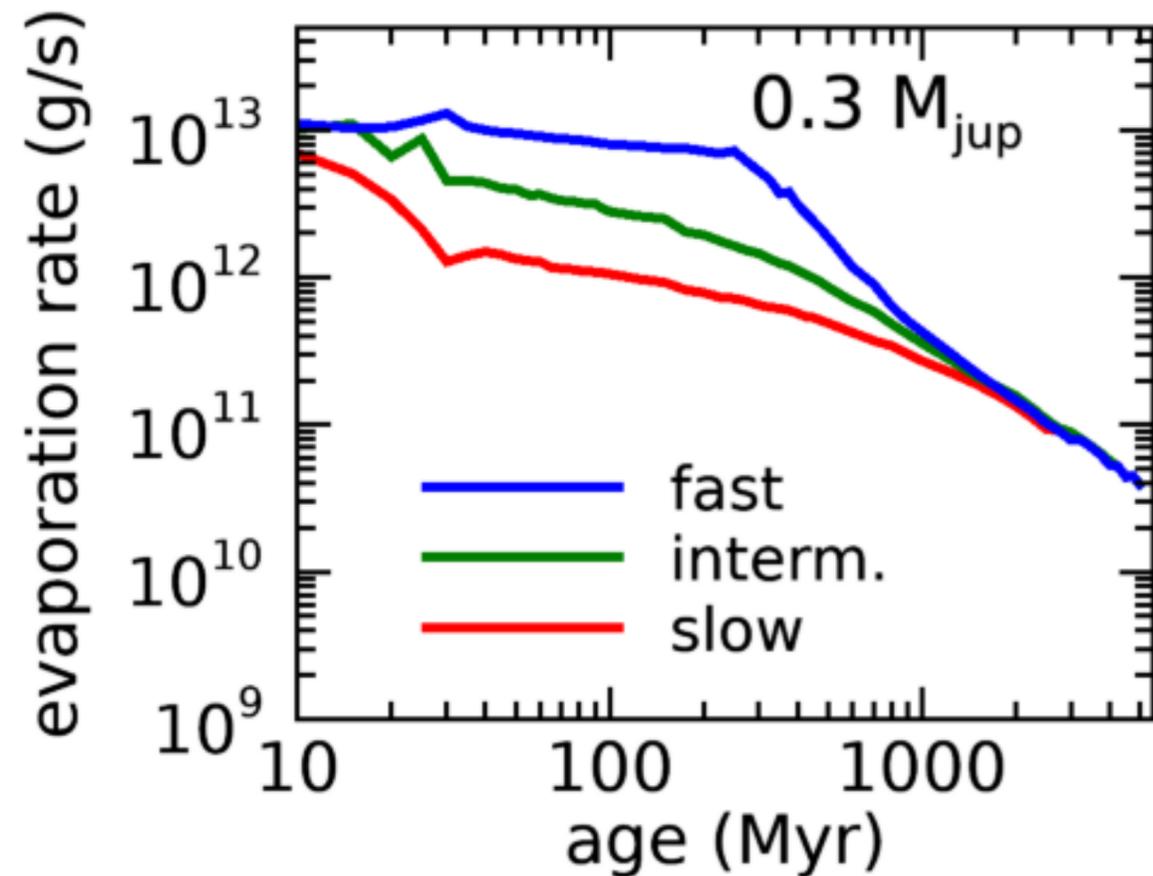
EUV+X-rays
irradiation

photo-evaporation

2 “Radiation side”: how high-energy stellar radiation & flares affect planetary evaporation

Effects of stellar radiation on atmospheric escape (close-in planets)

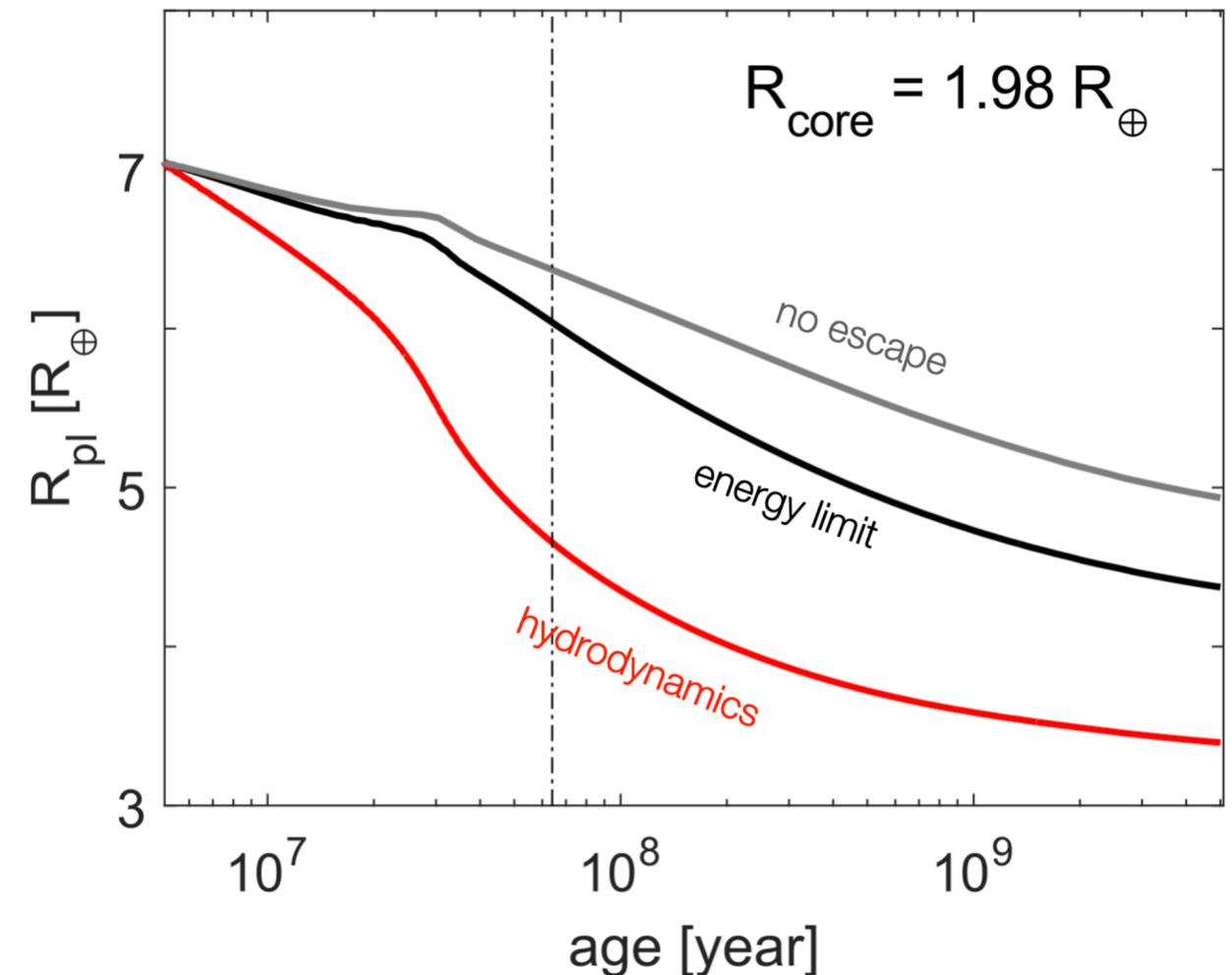
Survival of atmospheres depends on EUV history of host star



~20% mass lost through evolution

Allan & Vidotto 2019

Escape affects the internal structure of the planet



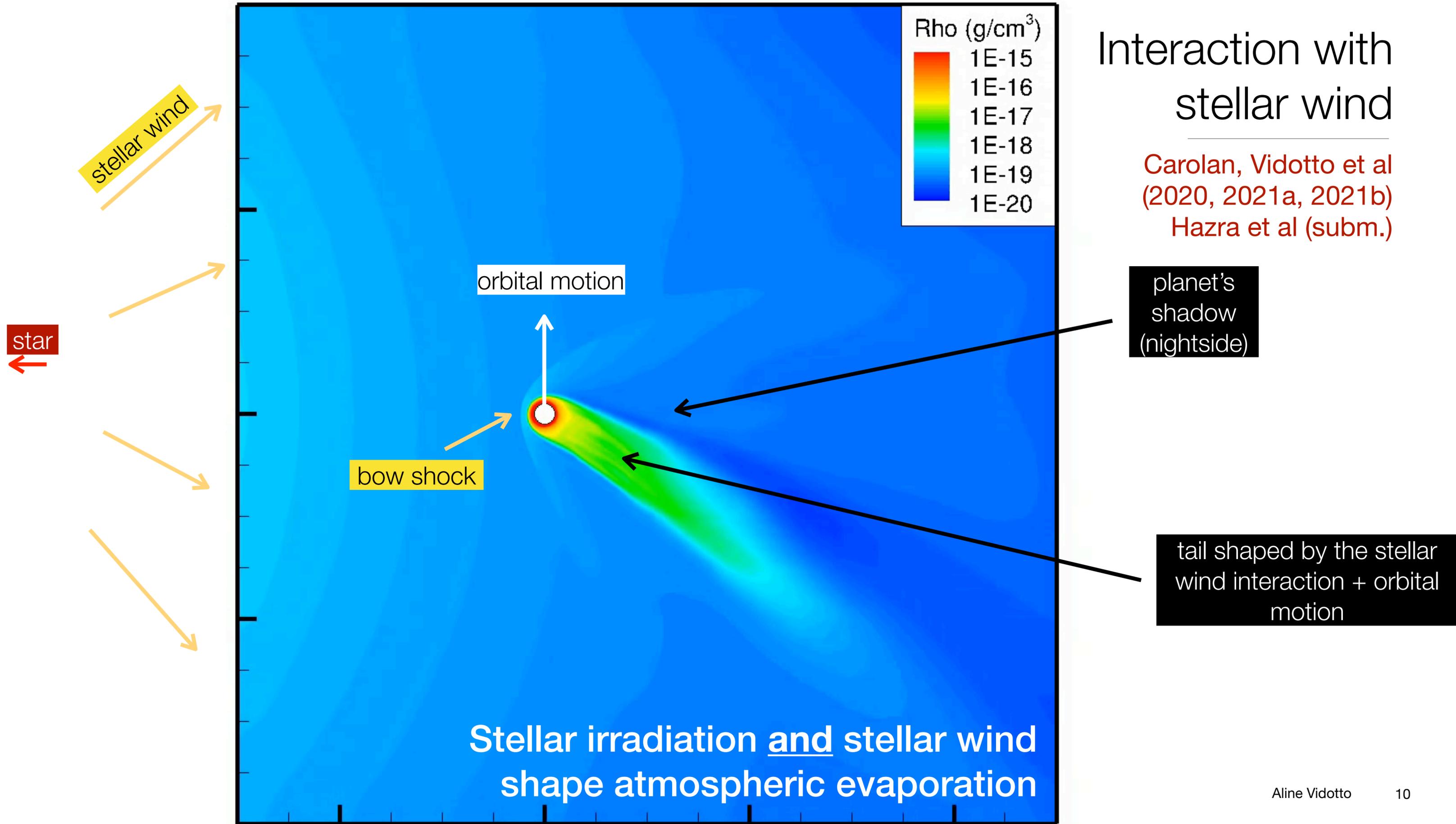
Kubyshkina et al 2020,
Kubyshkina & Vidotto 2021

planetary evolution with MESA

* Run your own model! inlists publicly available
<https://doi.org/10.5281/zenodo.4022393>

Interaction with stellar wind

Carolan, Vidotto et al (2020, 2021a, 2021b)
Hazra et al (subm.)

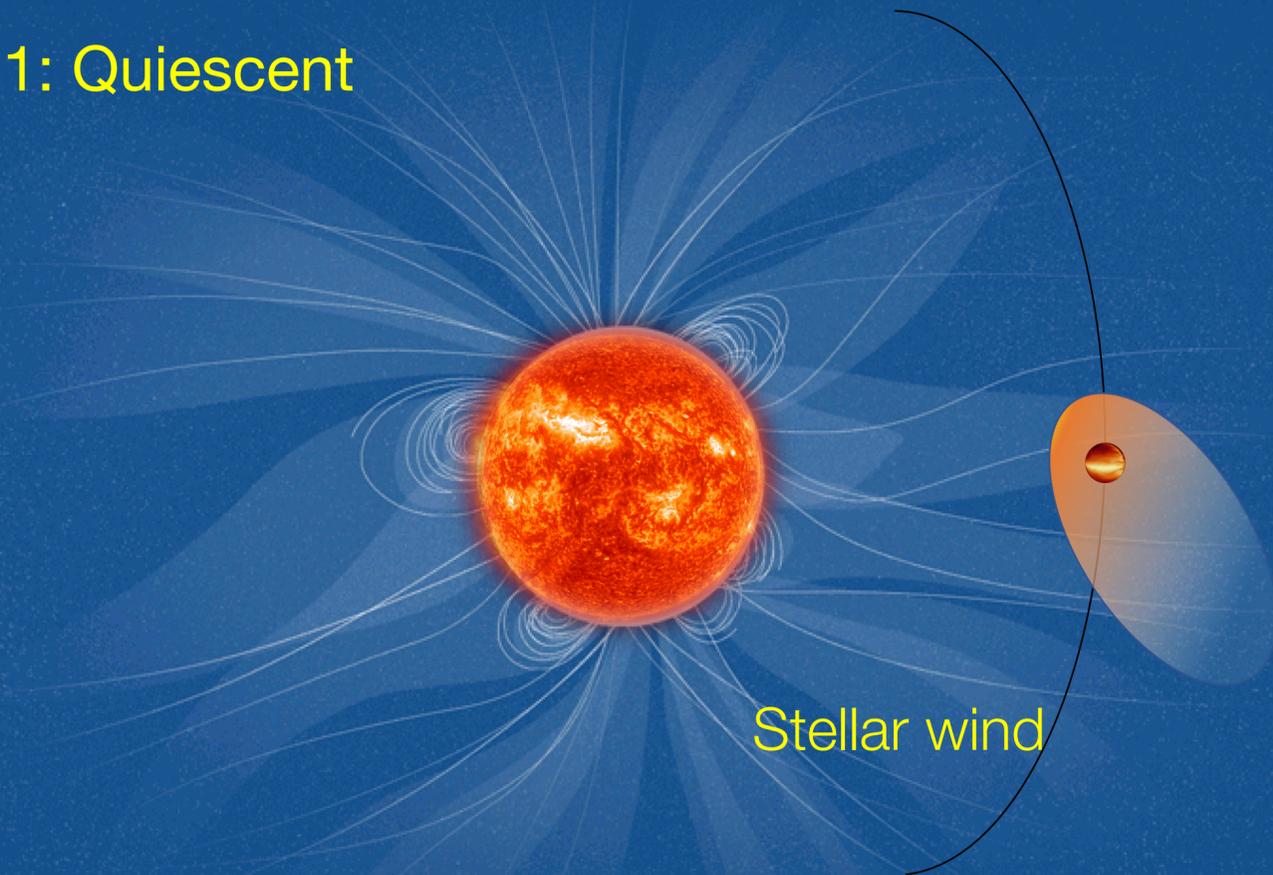


Effects of stellar activity (flares & CMEs) on planetary escape

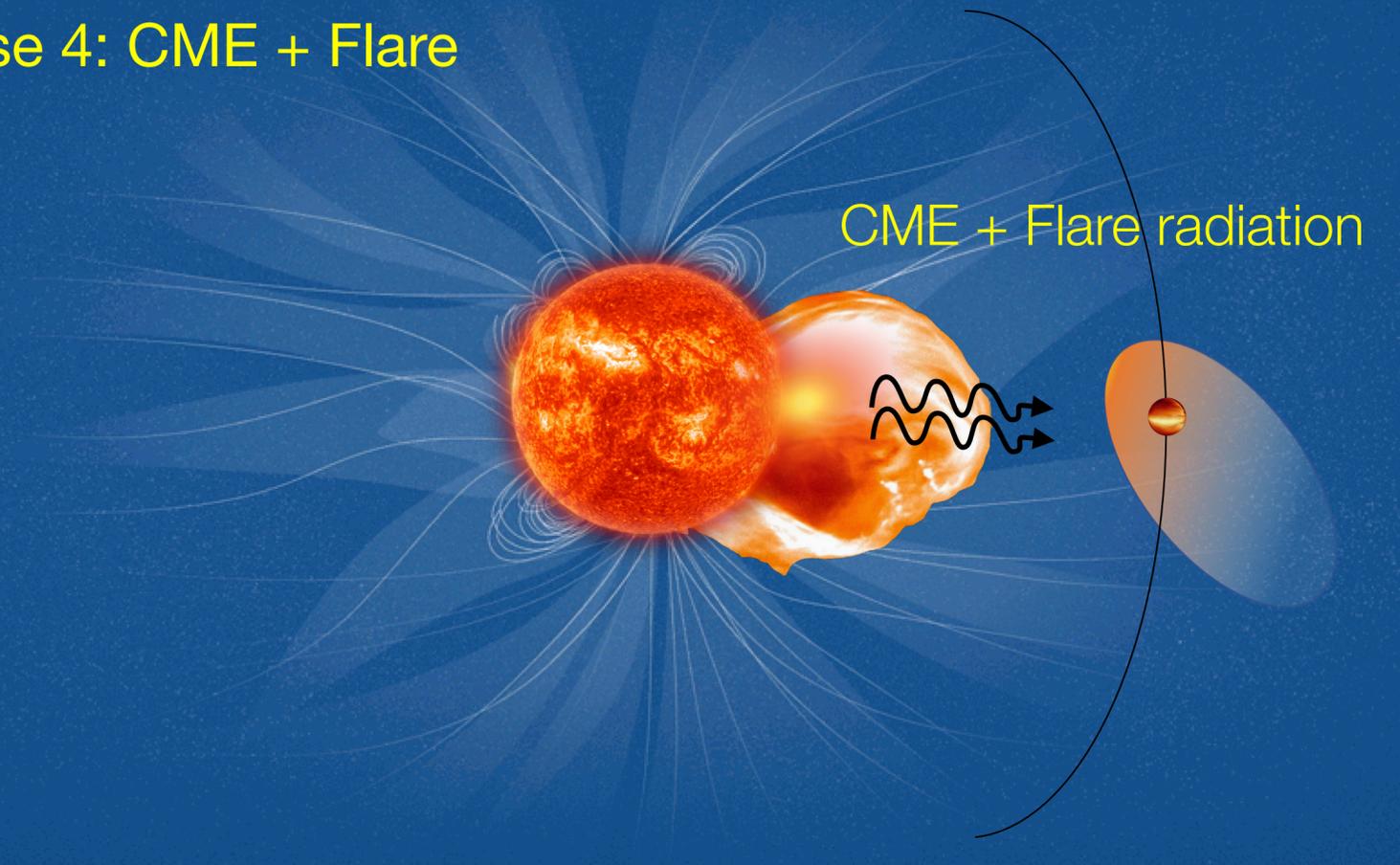
Scenarios simulated in 3D

Hazra, Vidotto et al submitted

Case 1: Quiescent



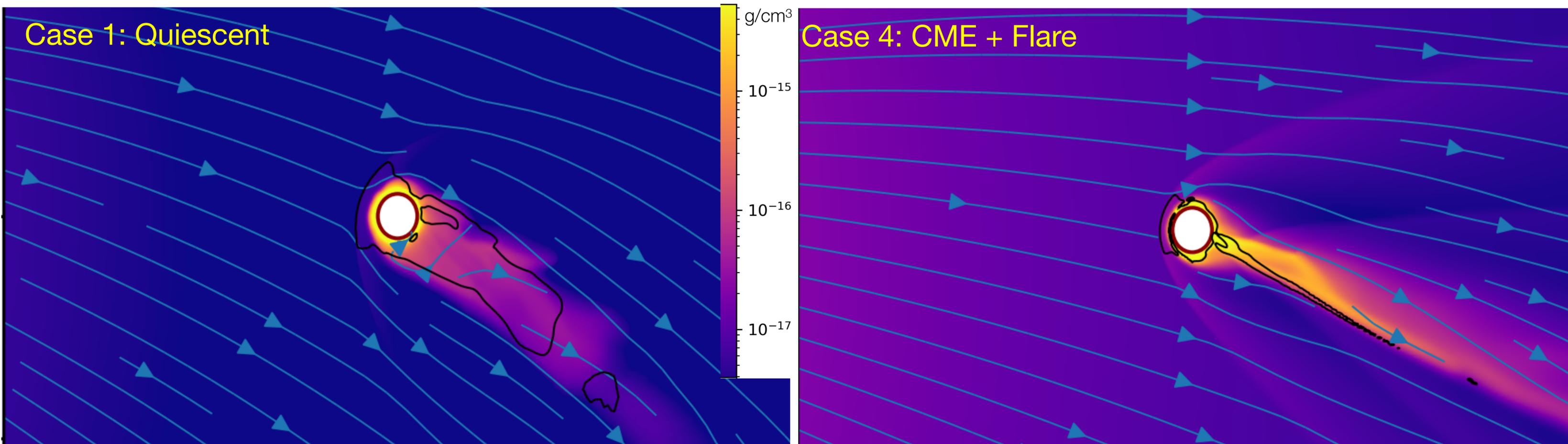
Case 4: CME + Flare



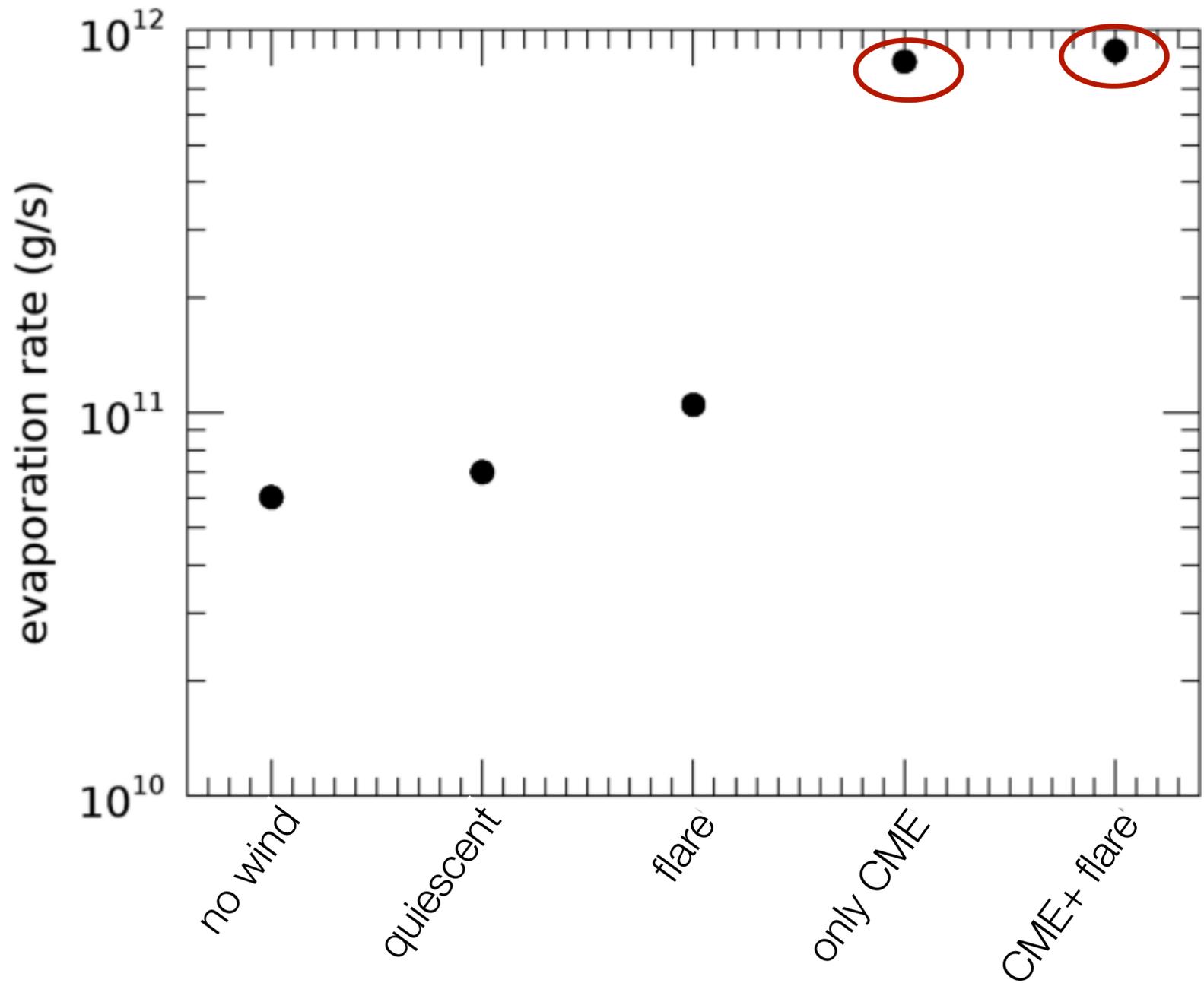
Effects of stellar activity (flares & CMEs) on planetary escape

Hazra, Vidotto et al submitted

Density profiles (cut at the orbital plane)



Does stellar activity (flares & CMEs) affect planetary escape?



Hazra, Vidotto et al submitted

- Yes, but..
 - ▶ Flare alone does not change evaporation significantly
 - ▶ CMEs are **more effective** at removing planetary material **momentarily**
- CMEs are expected to be more frequent at younger age → include them in evaporation models at younger ages

Conclusions

Younger solar-like stars have stronger winds, are more active and likely have more frequent coronal mass ejections.

The evolution of stellar irradiation **and** stellar wind shapes atmospheric evaporation.

Stellar CMEs (particle) seem to play a bigger role in planetary evaporation than the stellar flare (radiation) itself.