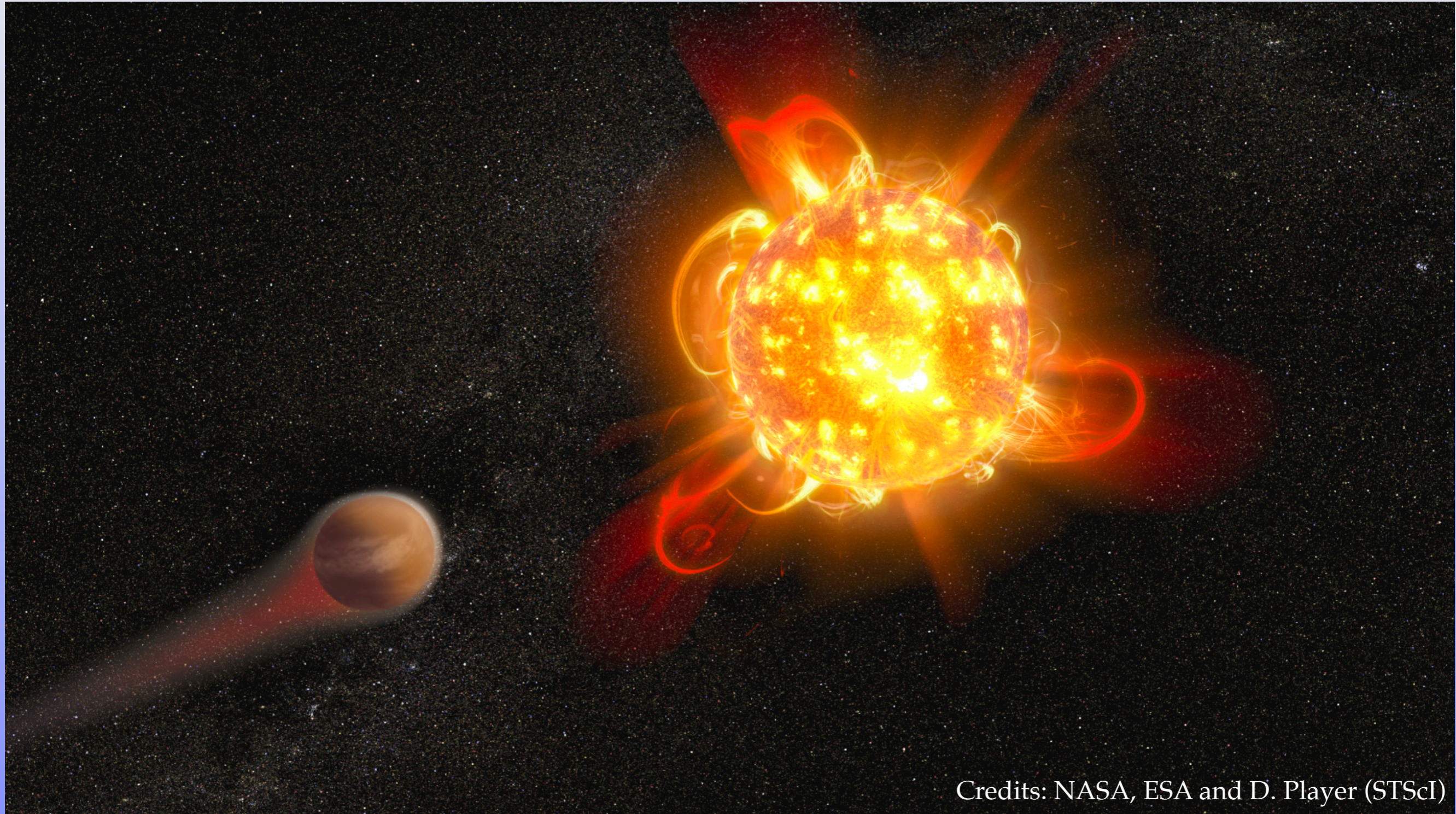


Star-planet Interaction in close-in exoplanets



Credits: NASA, ESA and D. Player (STScI)

Ofer Cohen

Unsolved Problems in Astrophysics and Cosmology
The Hebrew University of Jerusalem - December 2022

ExoPAG 27

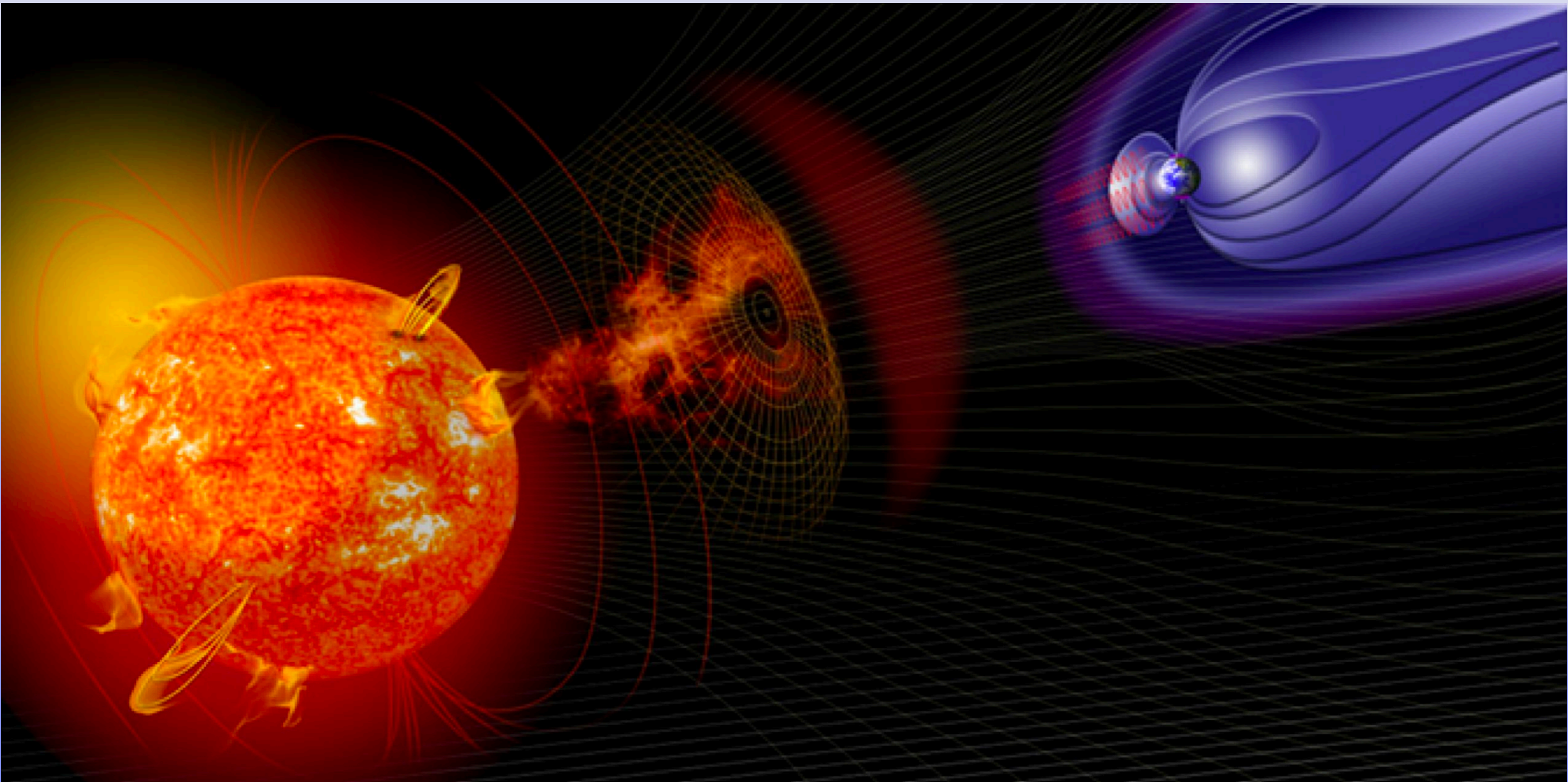
Date: January 7, 2023 - January 8, 2023

Location: Seattle, WA (AAS meeting)

<https://exoplanets.nasa.gov/exep/events/388/exopag-27/>

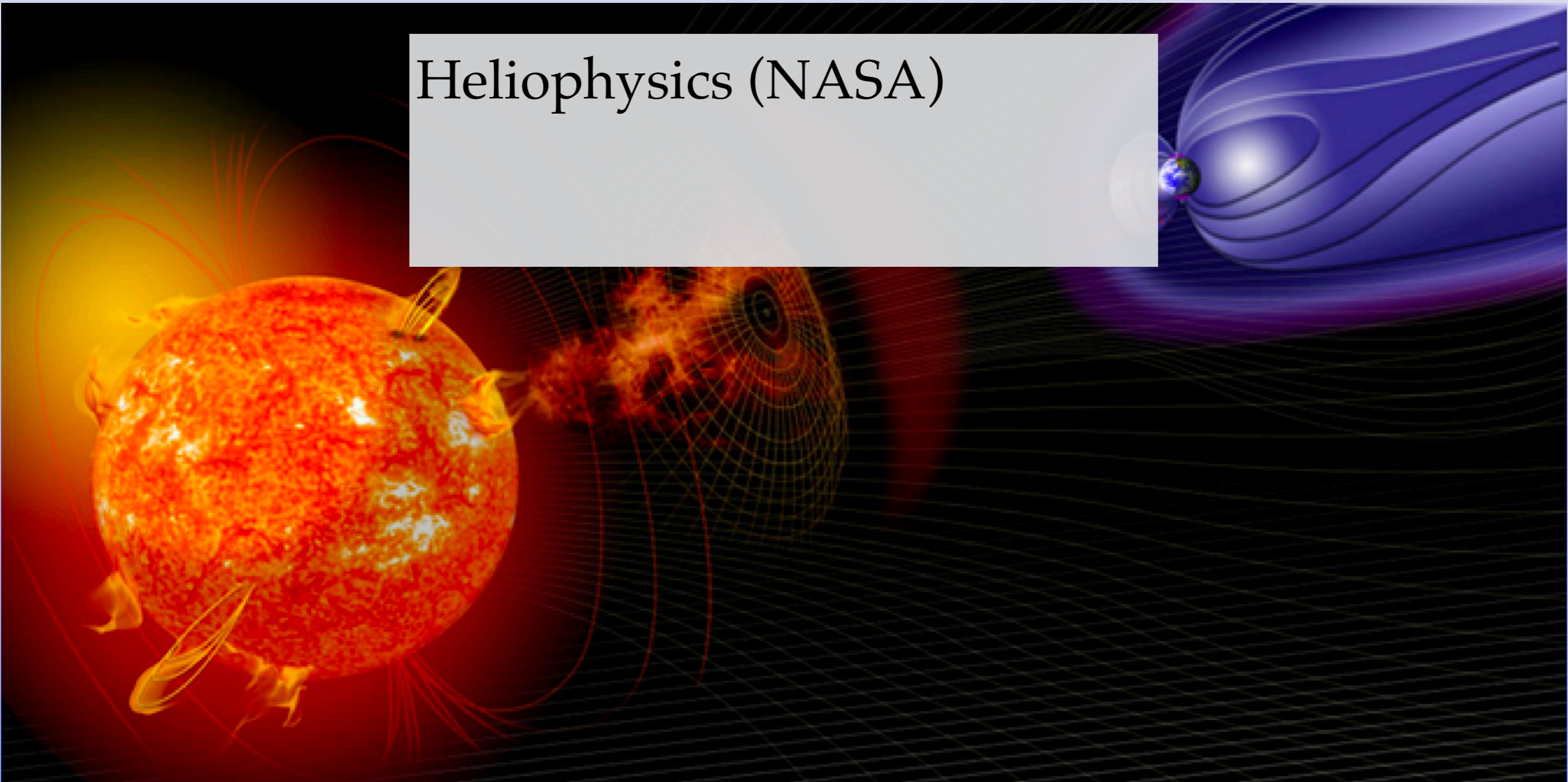
NASA's Exoplanet Exploration Program Analysis Group (ExoPAG) will hold its twenty seventh meeting January 7th through the 8th, 2023 immediately preceeding the 241st AAS meeting in Seattle, WA. This will be a hybrid meeting. The agenda will include programmatic updates of relevance for the ExoPAG community, science updates and descriptions of exciting new capabilities, updates from SIGs and SAGs, as well as our regular business meeting.

Interaction between planets and the stellar environment:



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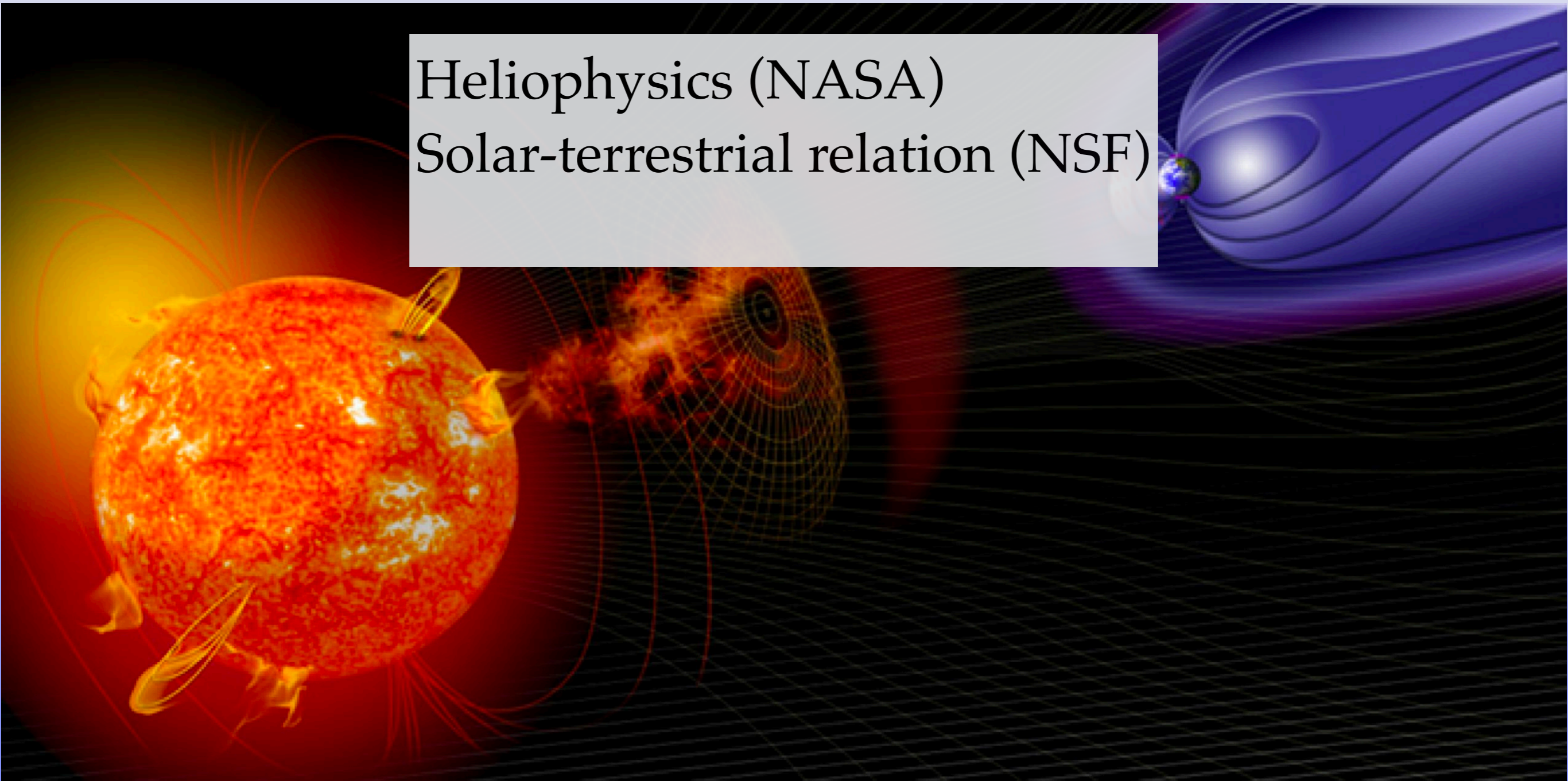
Heliophysics (NASA)



Interaction between planets and the stellar environment:

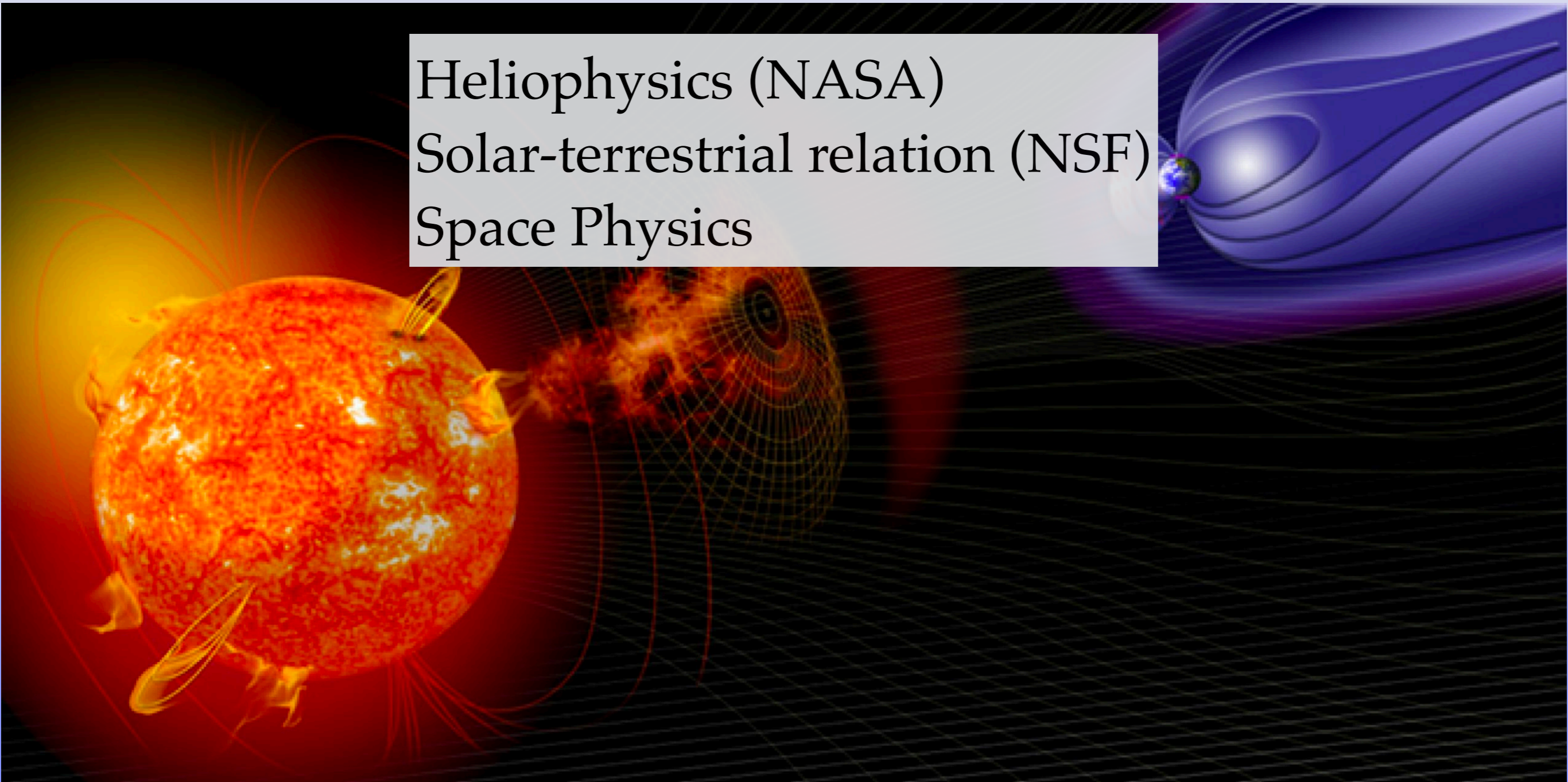
Heliophysics (NASA)

Solar-terrestrial relation (NSF)

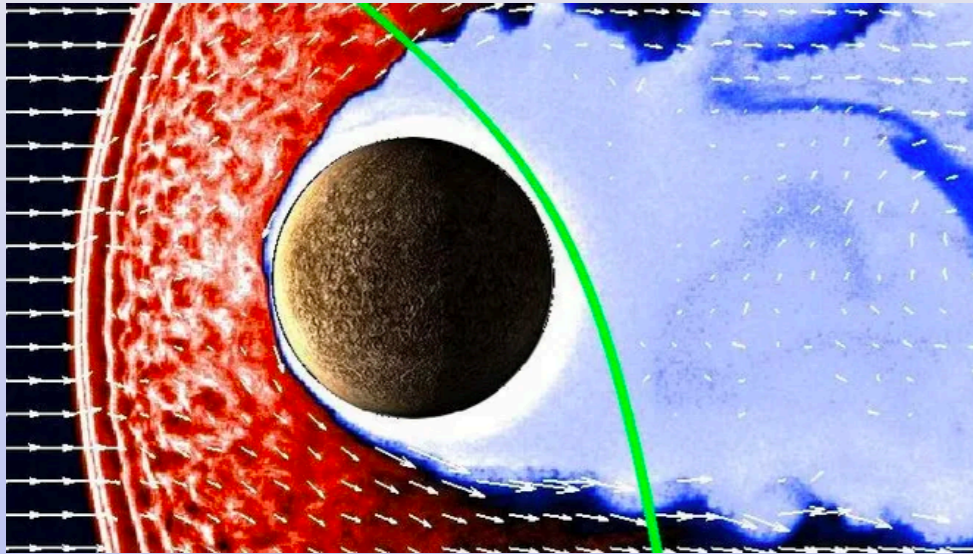


Interaction between planets and the stellar environment:

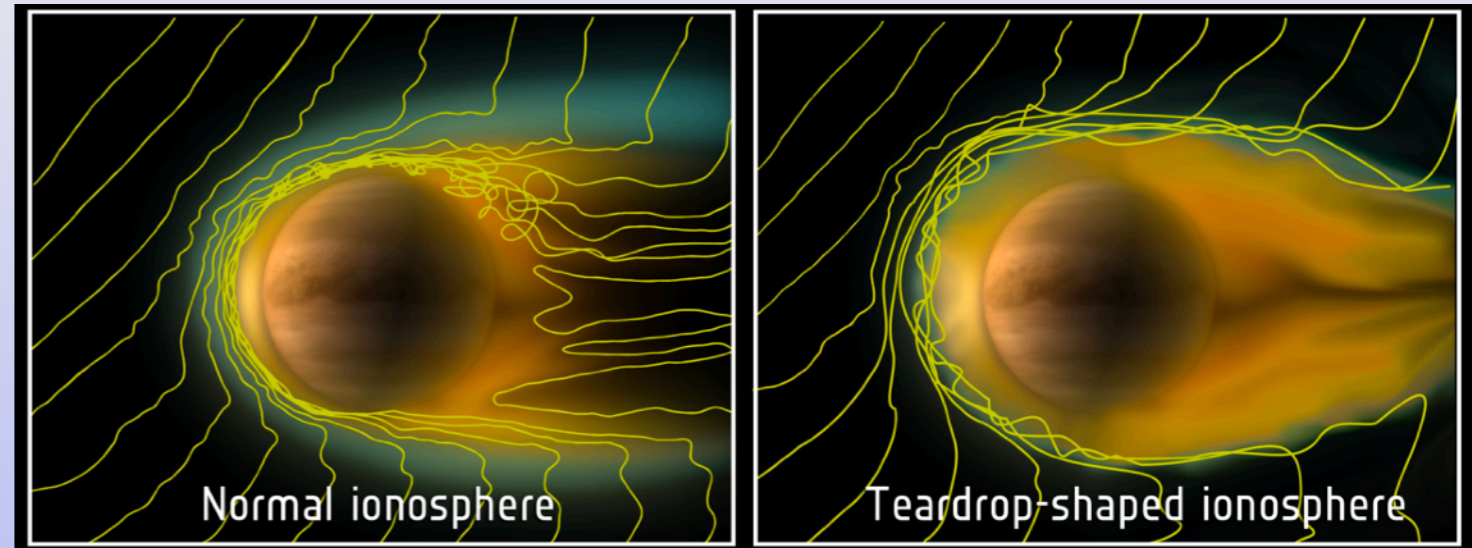
Heliophysics (NASA)
Solar-terrestrial relation (NSF)
Space Physics



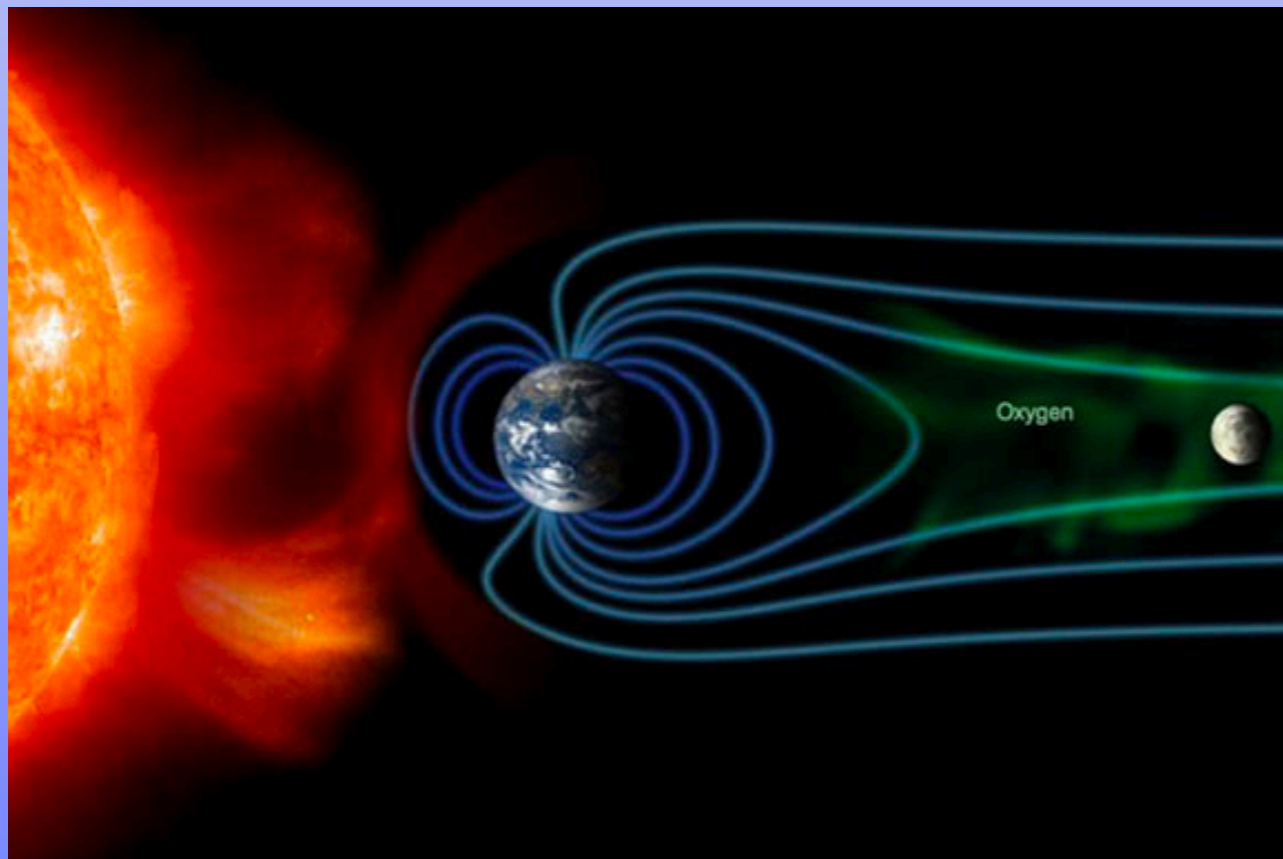
The interaction of the solar wind with solar system planets:



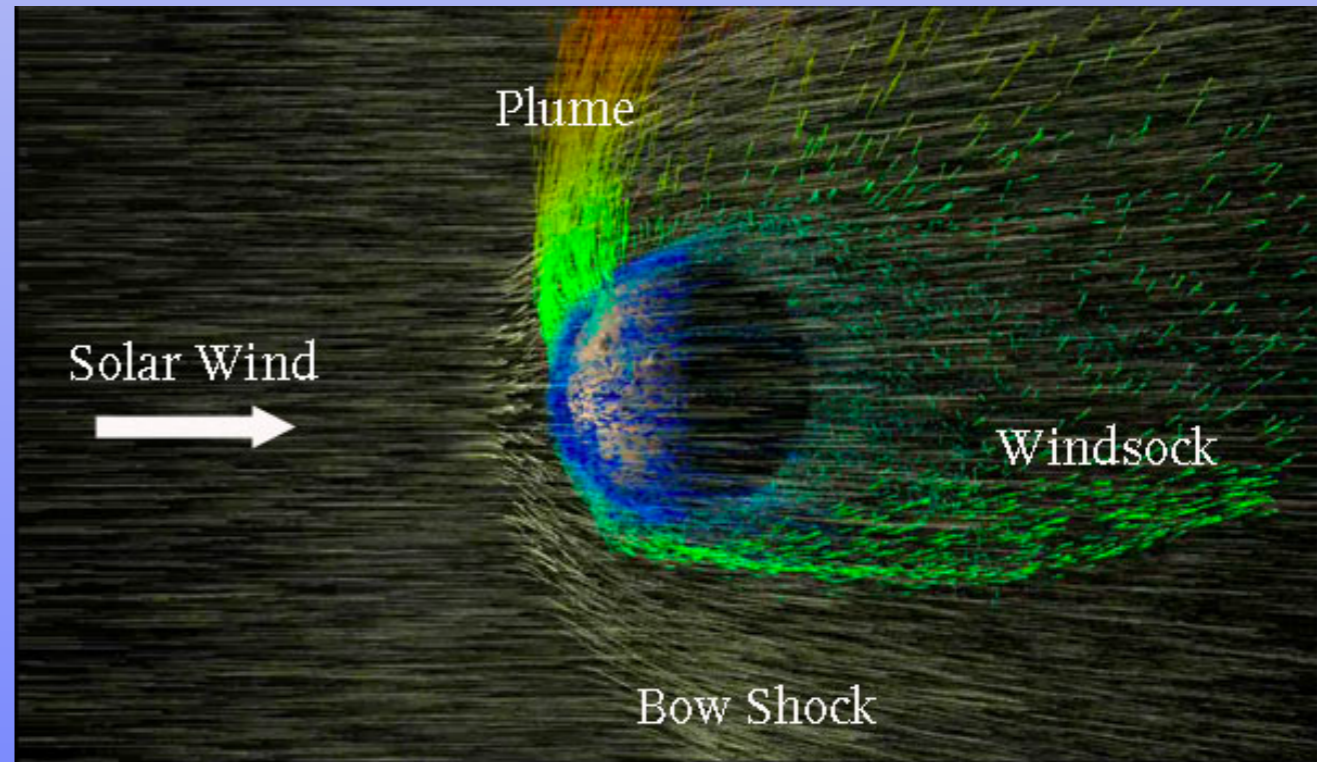
Mercury



Venus

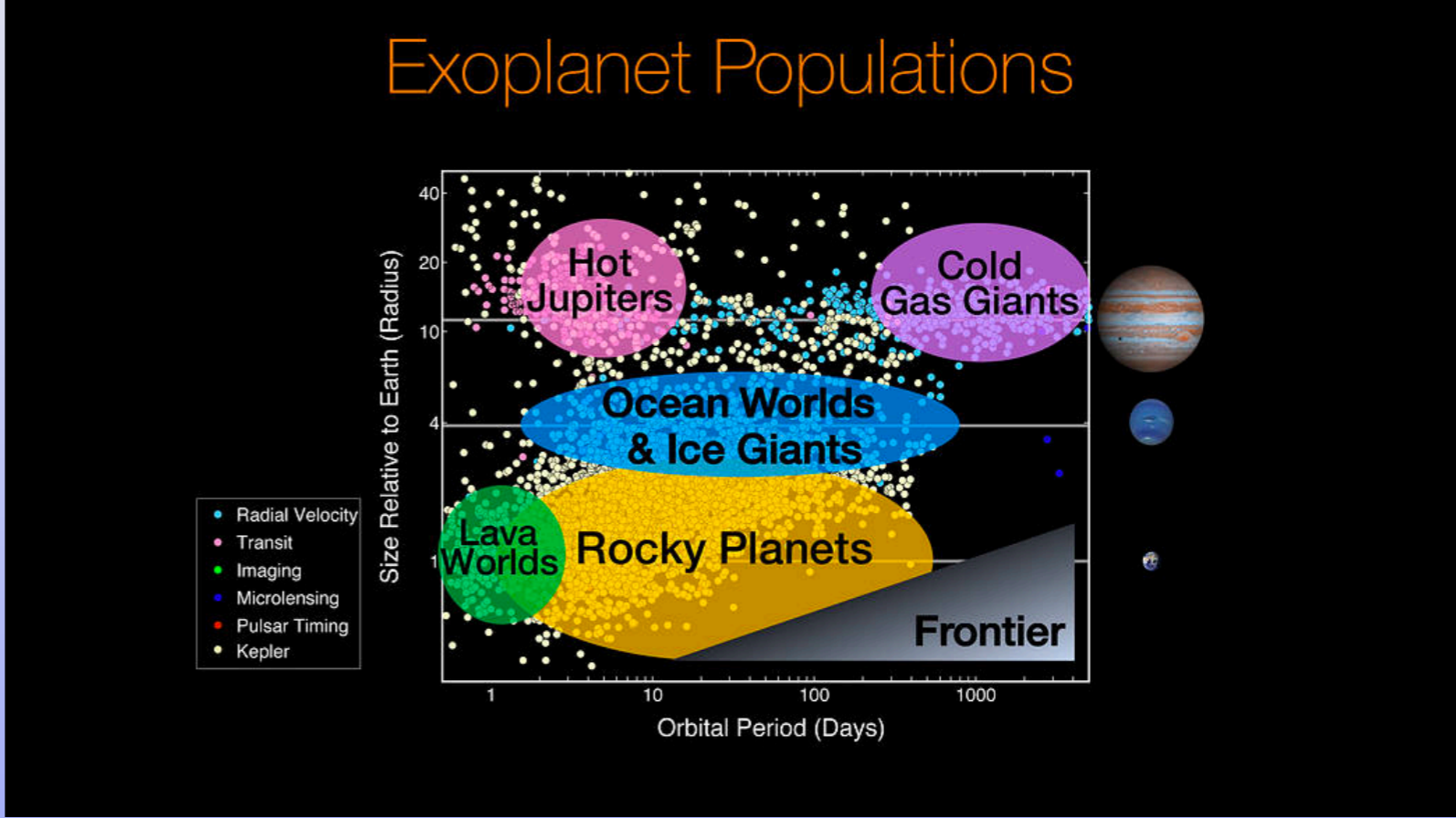
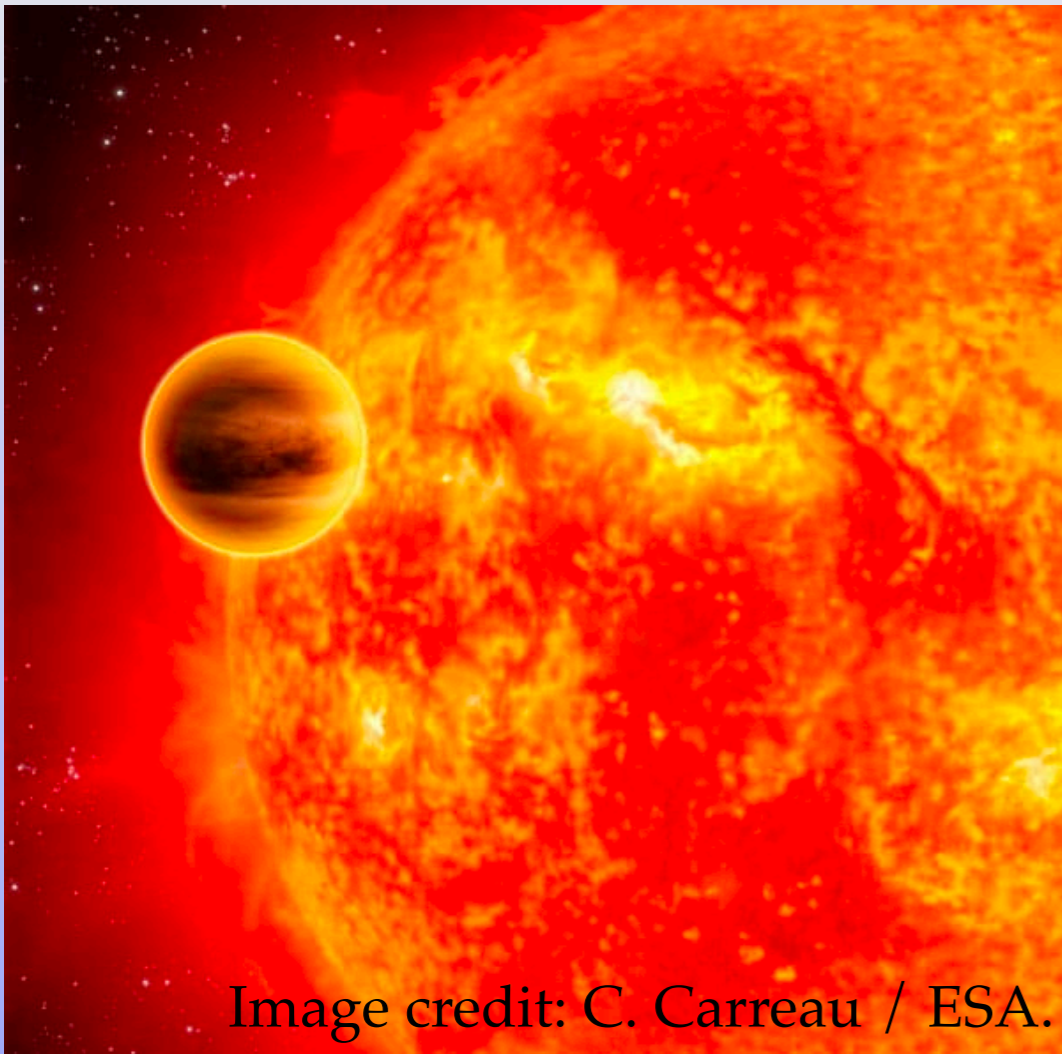


Earth

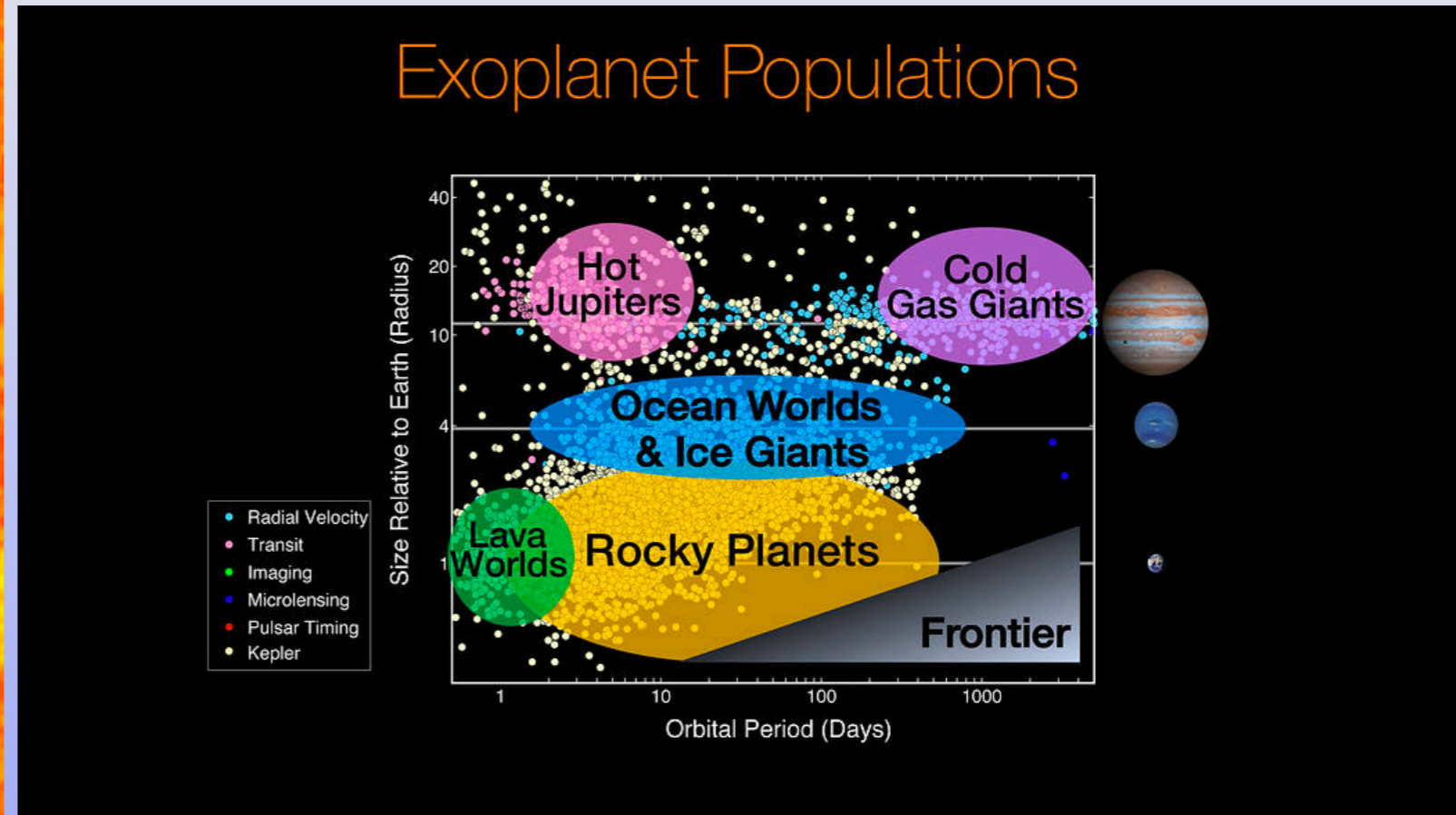
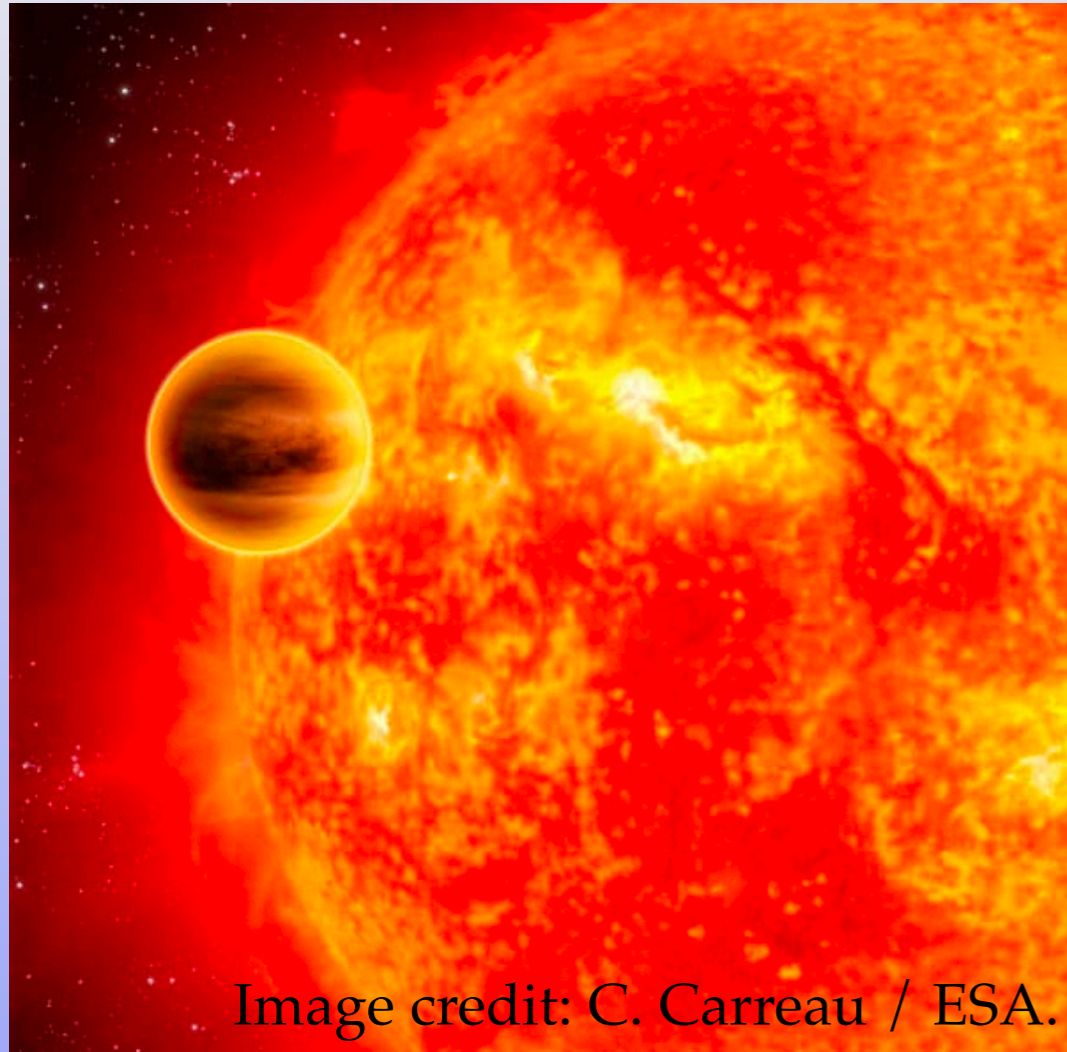


Mars

The unique case of short-orbit exoplanets:

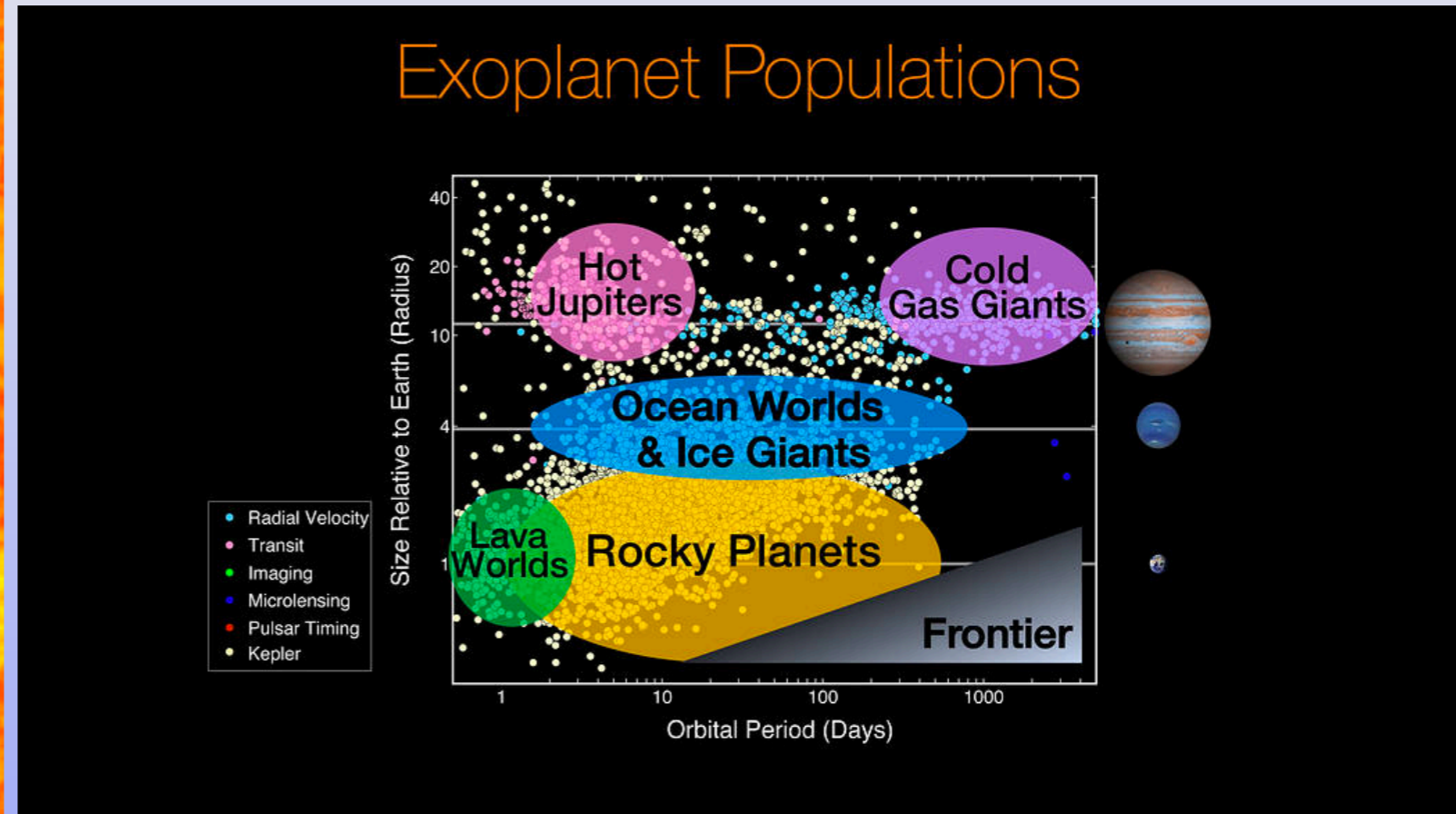
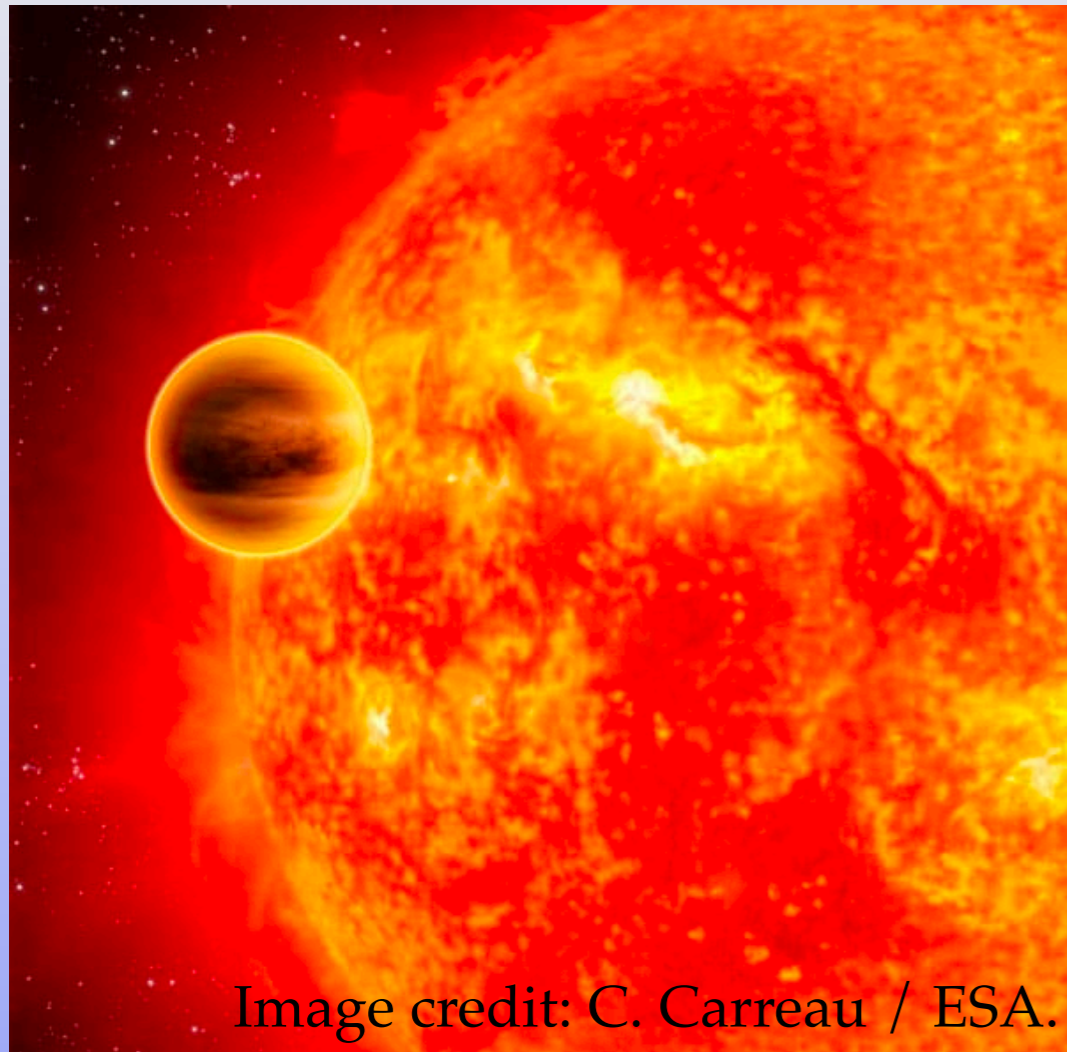


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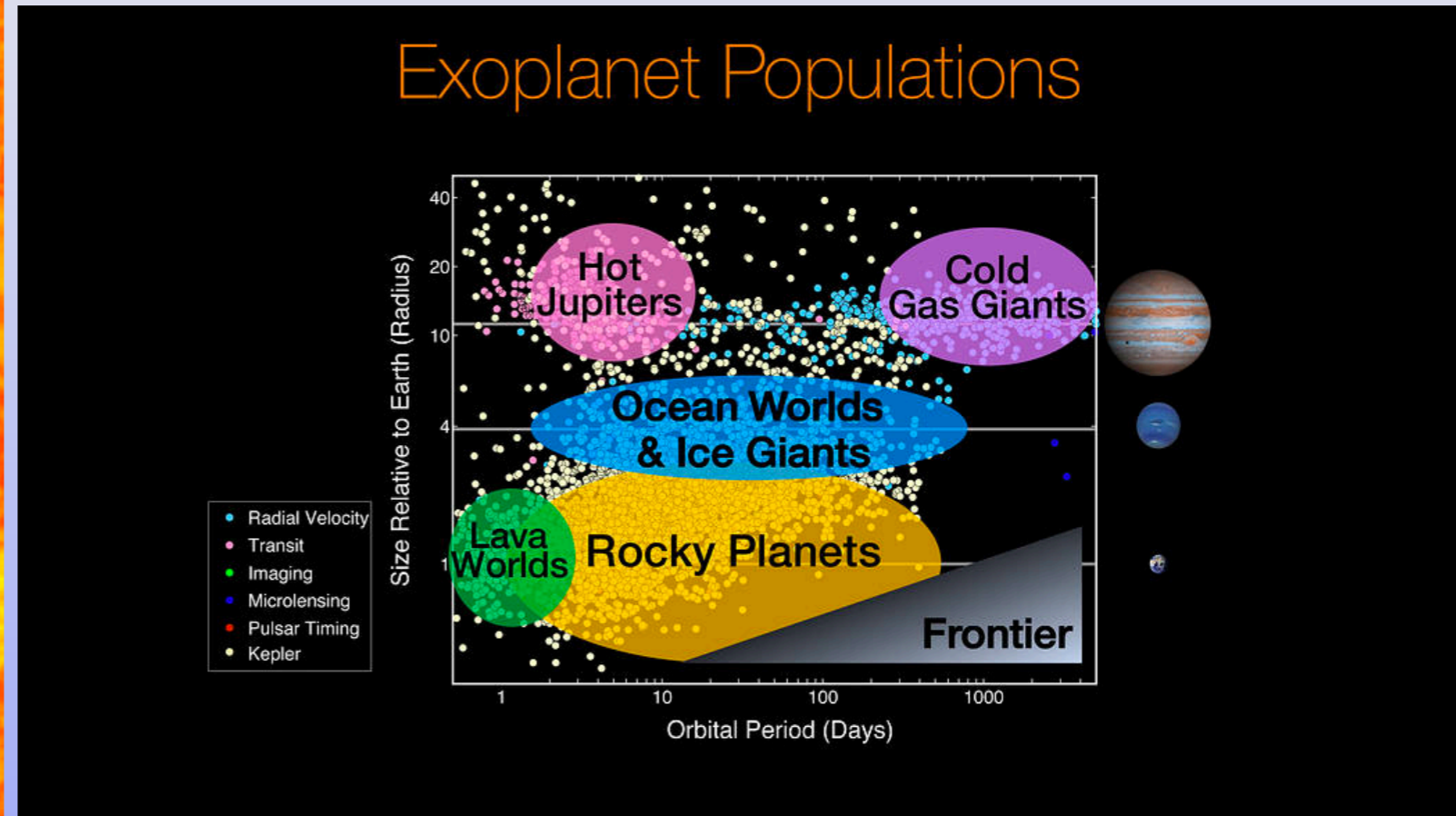
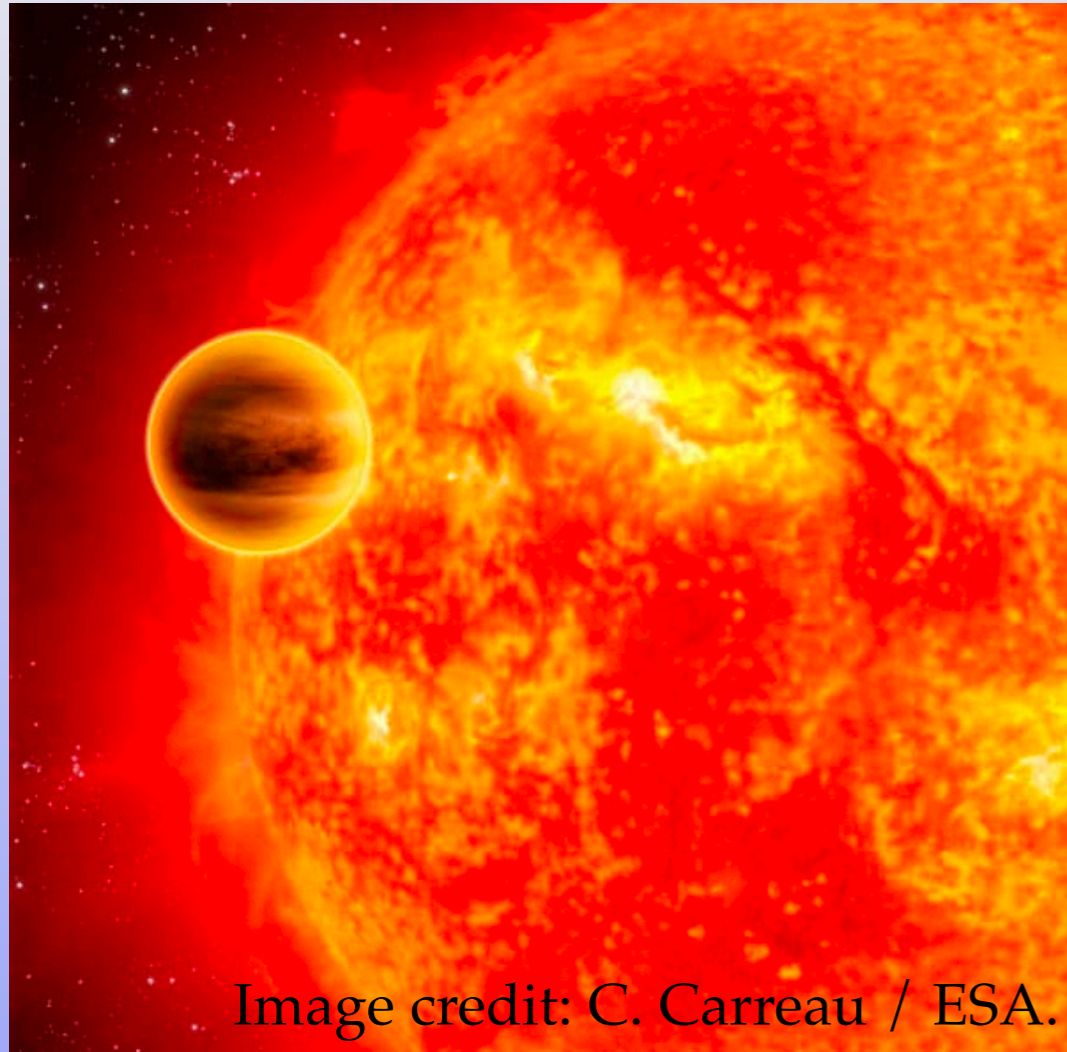
A strong Star-planet Interaction (SPI)

The unique case of short-orbit exoplanets:



A strong Star-planet Interaction (SPI)
A feedback from the planet on the star

The unique case of short-orbit exoplanets:



A strong Star-planet Interaction (SPI)
A feedback from the planet on the star
SPI observed signatures

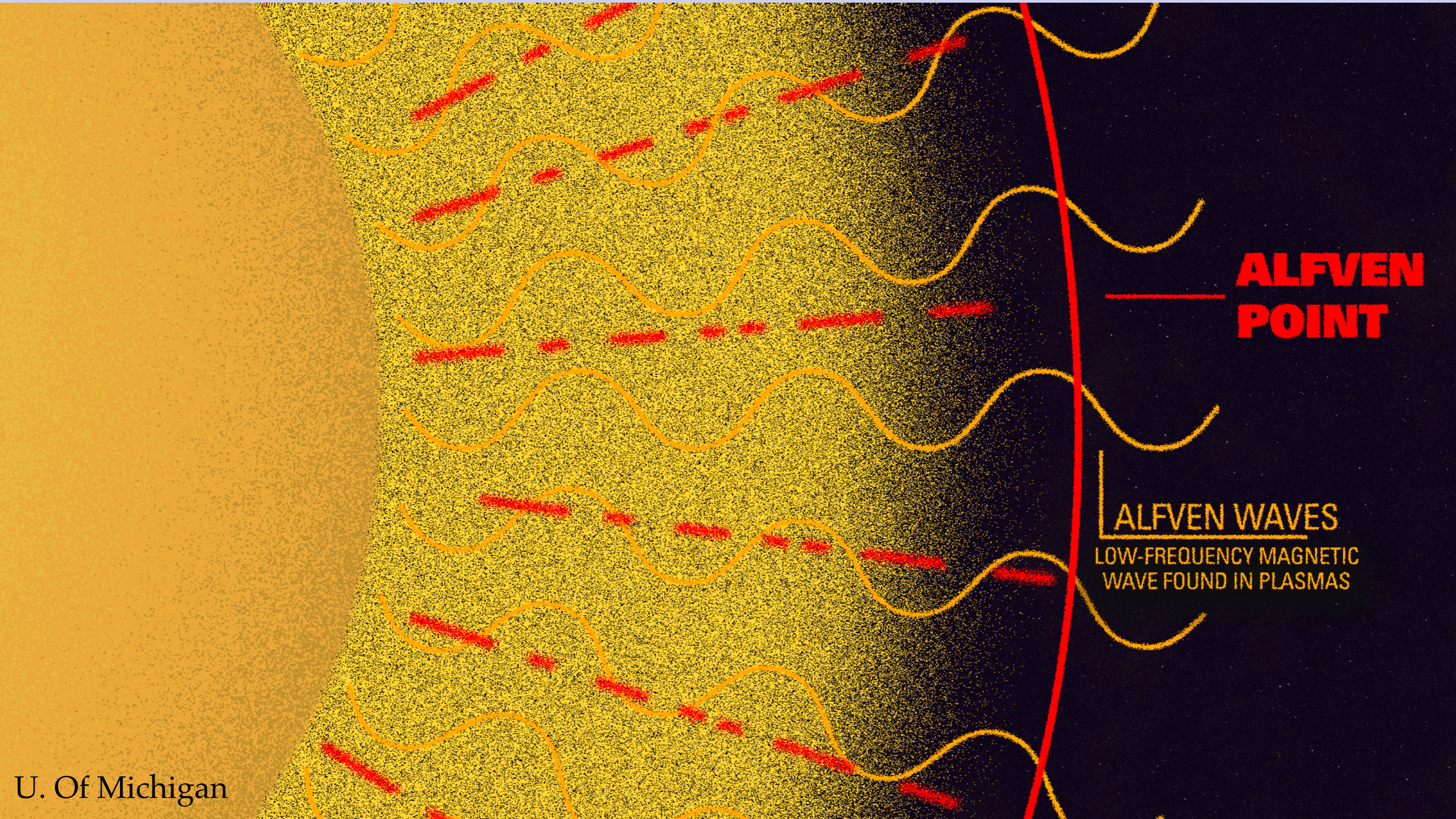
Gravitational / tidal Interaction

Gravitational / tidal Interaction

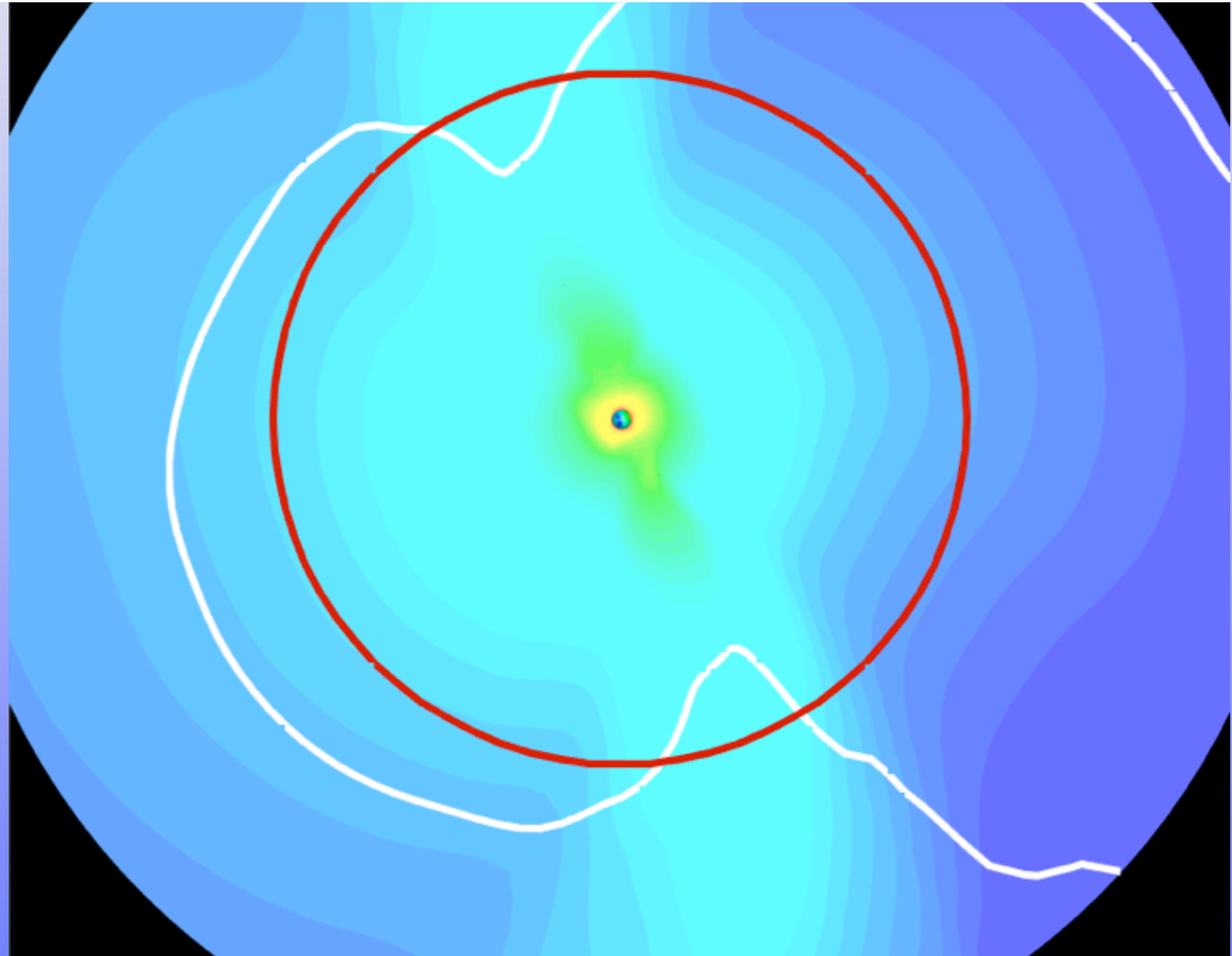
(Electro-)magnetic interaction

Gravitational / tidal Interaction

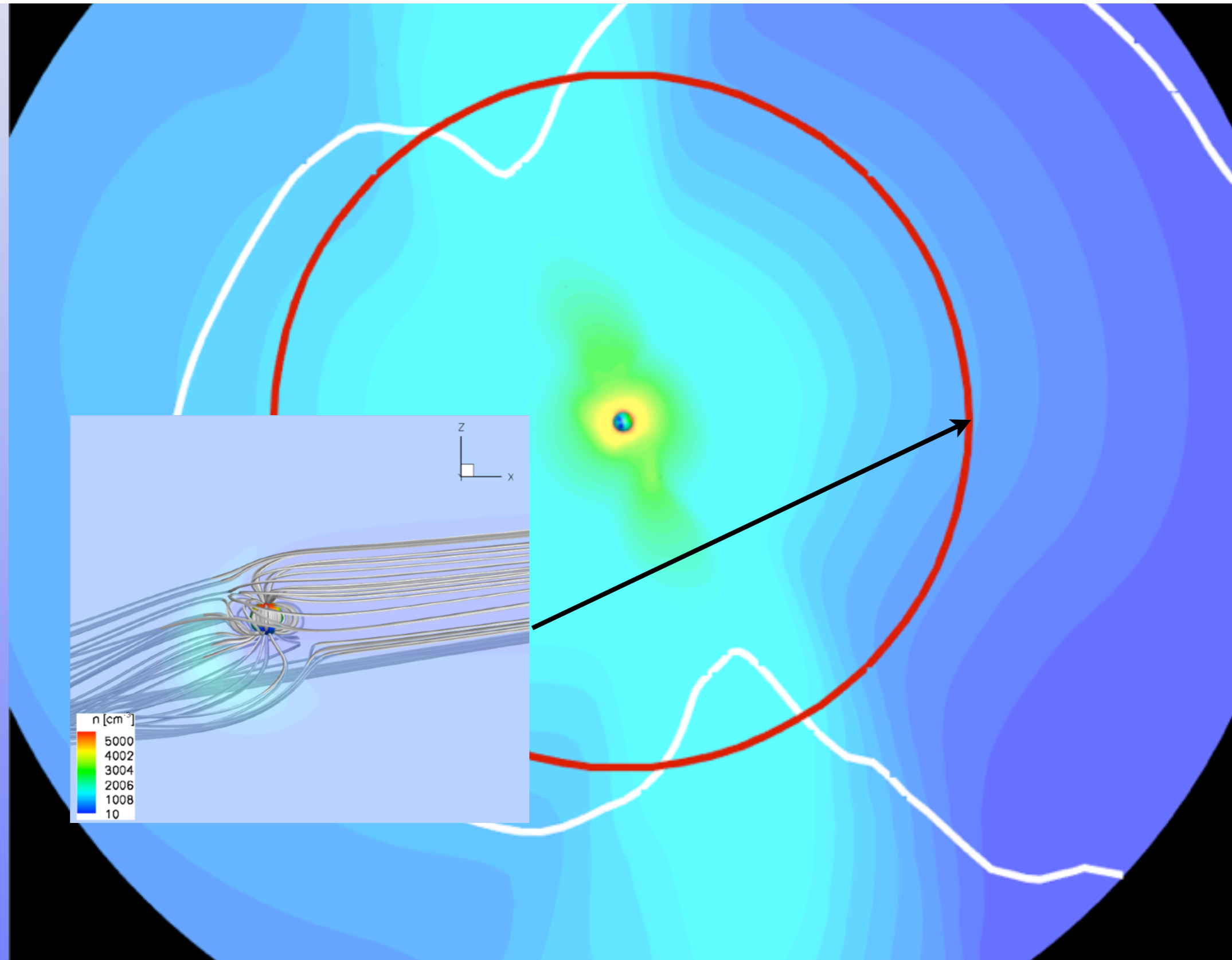
(Electro-)magnetic interaction



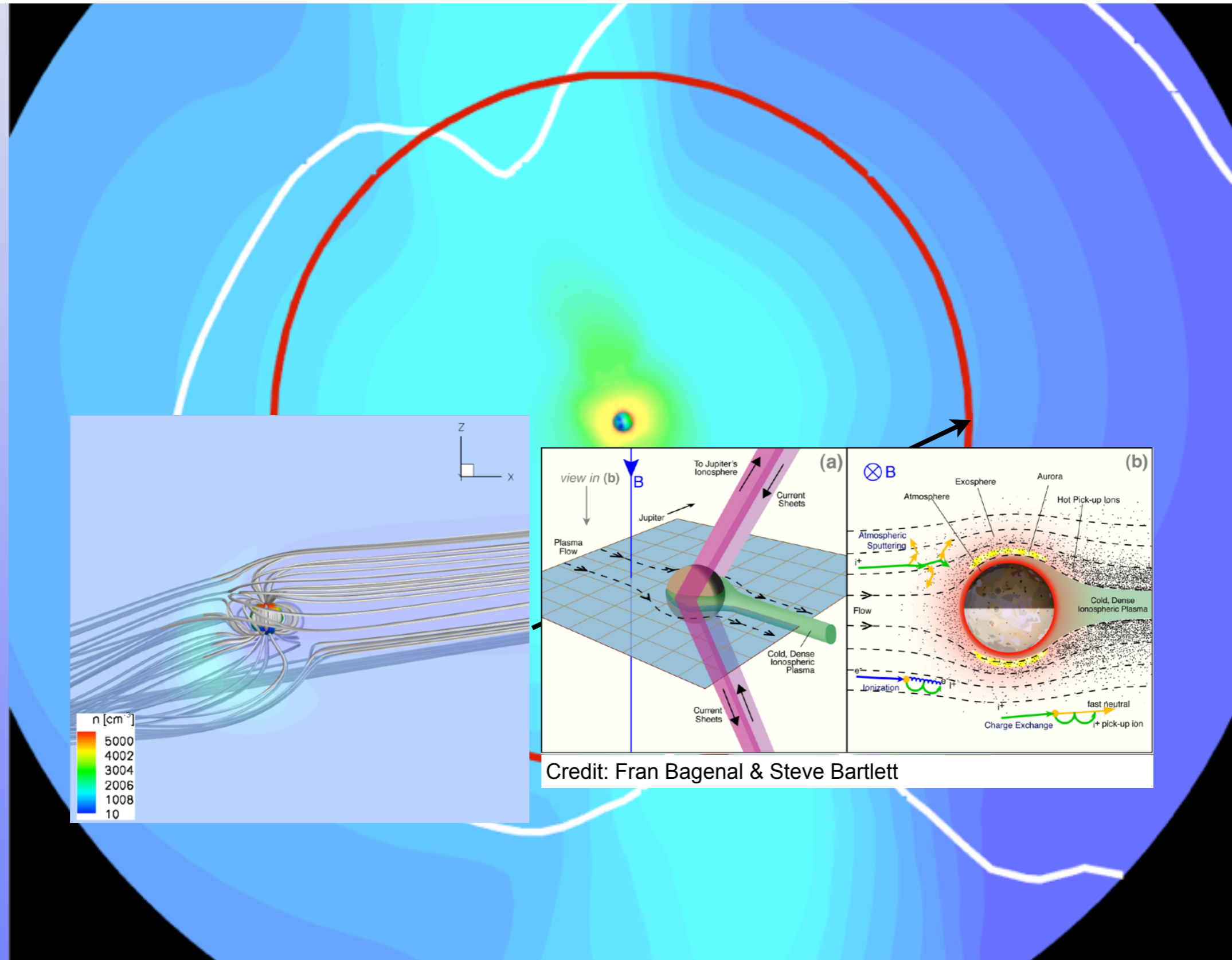
Possible unique conditions in a nearly sub-Alfvénic stellar wind regime:



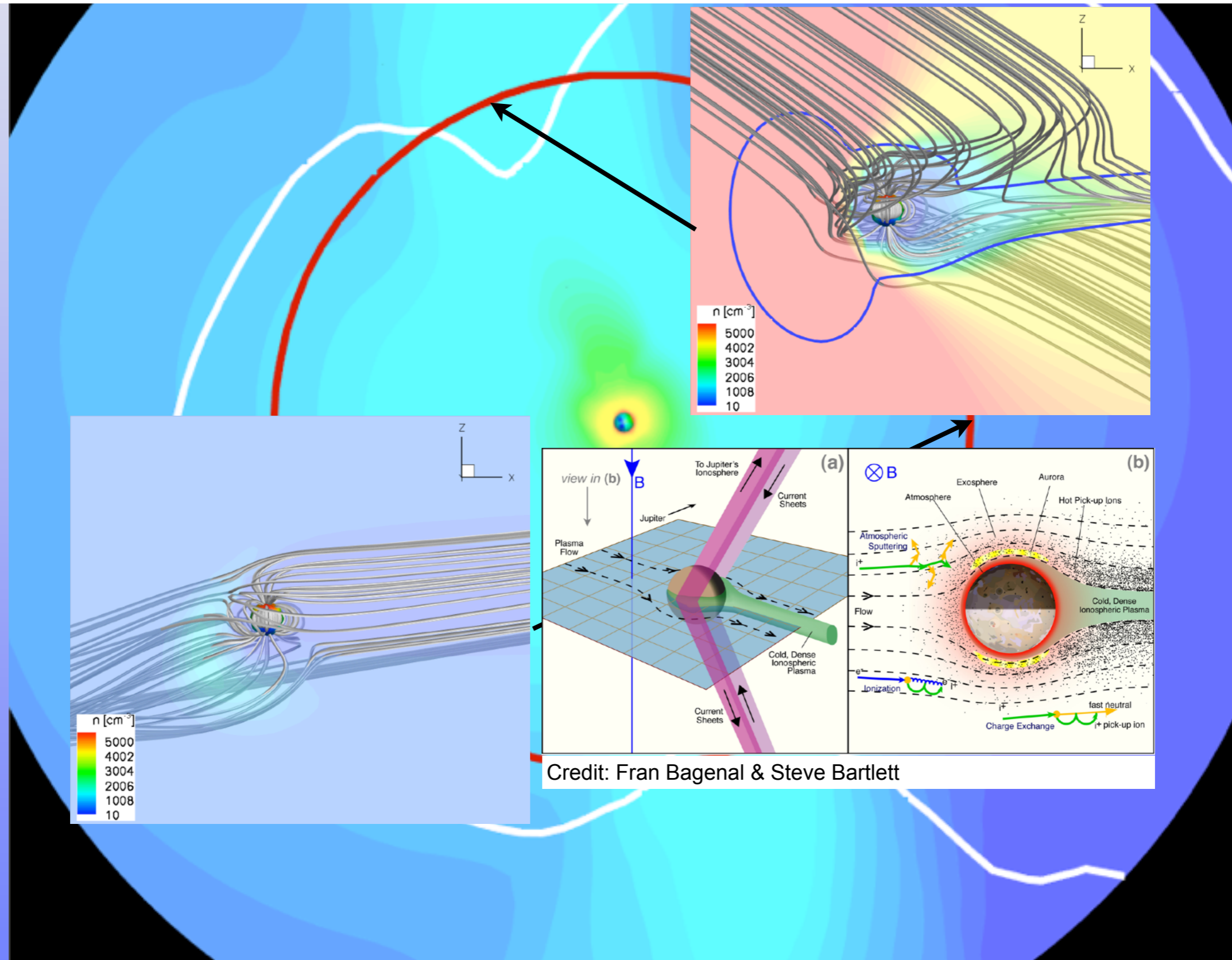
Possible unique conditions in a nearly sub-Alfvenic stellar wind regime:



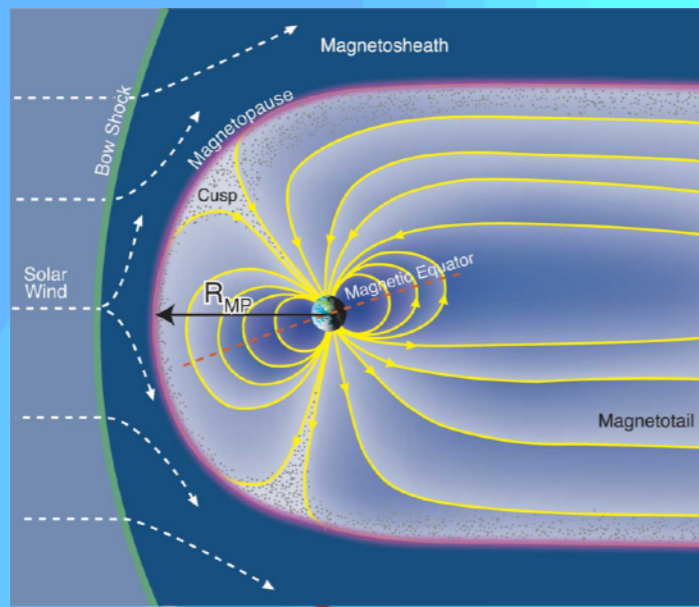
Possible unique conditions in a nearly sub-Alfvénic stellar wind regime:



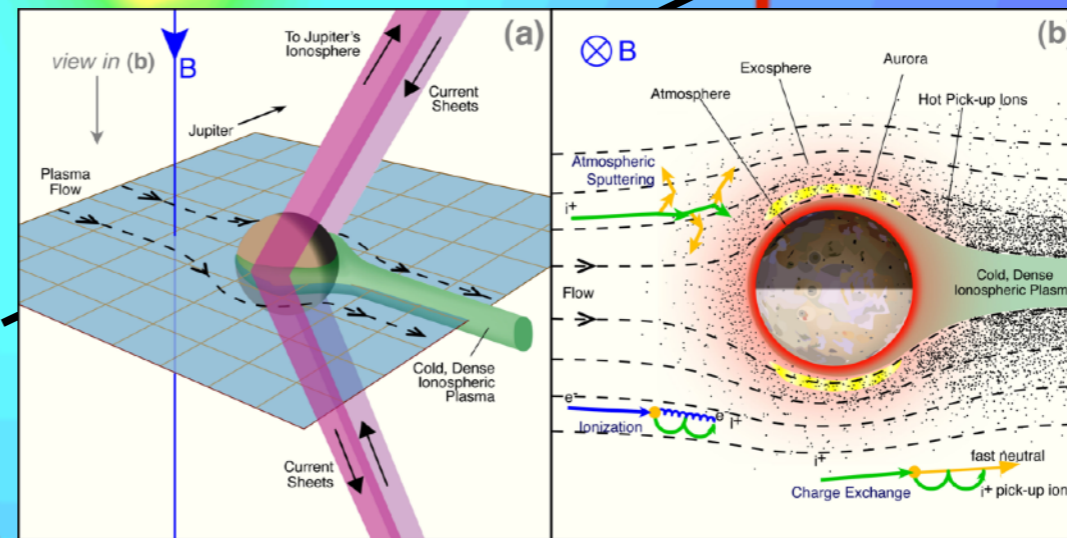
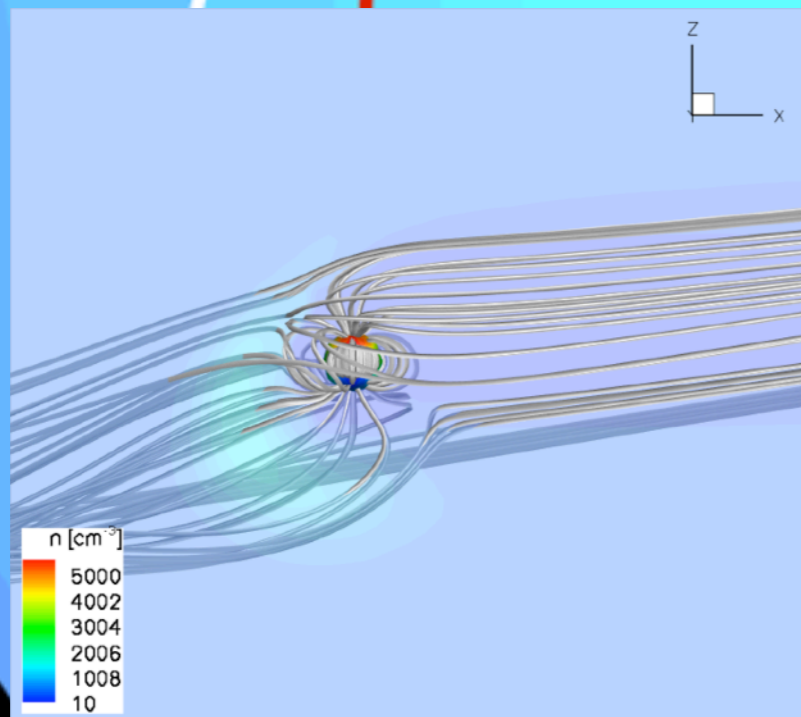
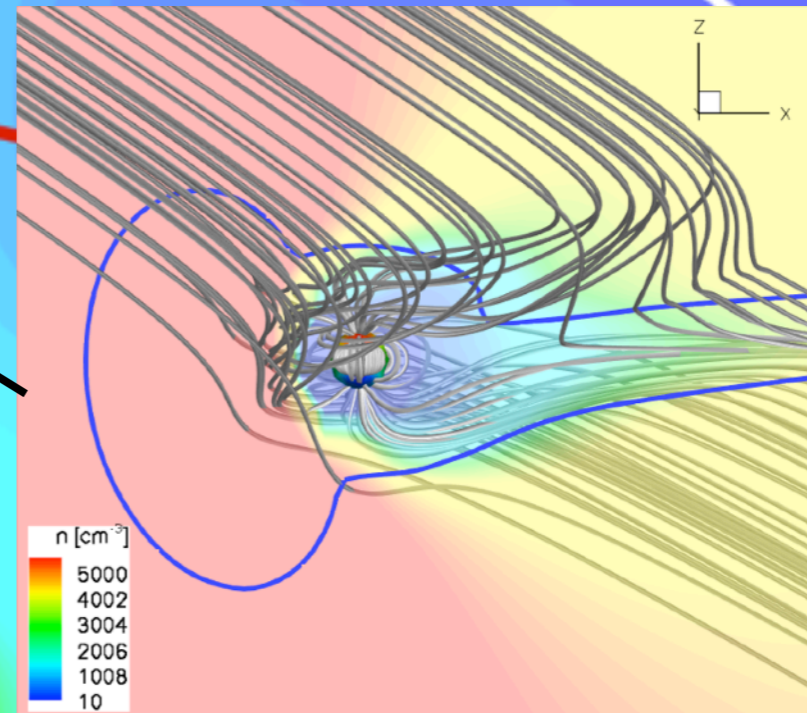
Possible unique conditions in a nearly sub-Alfvénic stellar wind regime:



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Credit: Fran Bagenal & Steve Bartlett

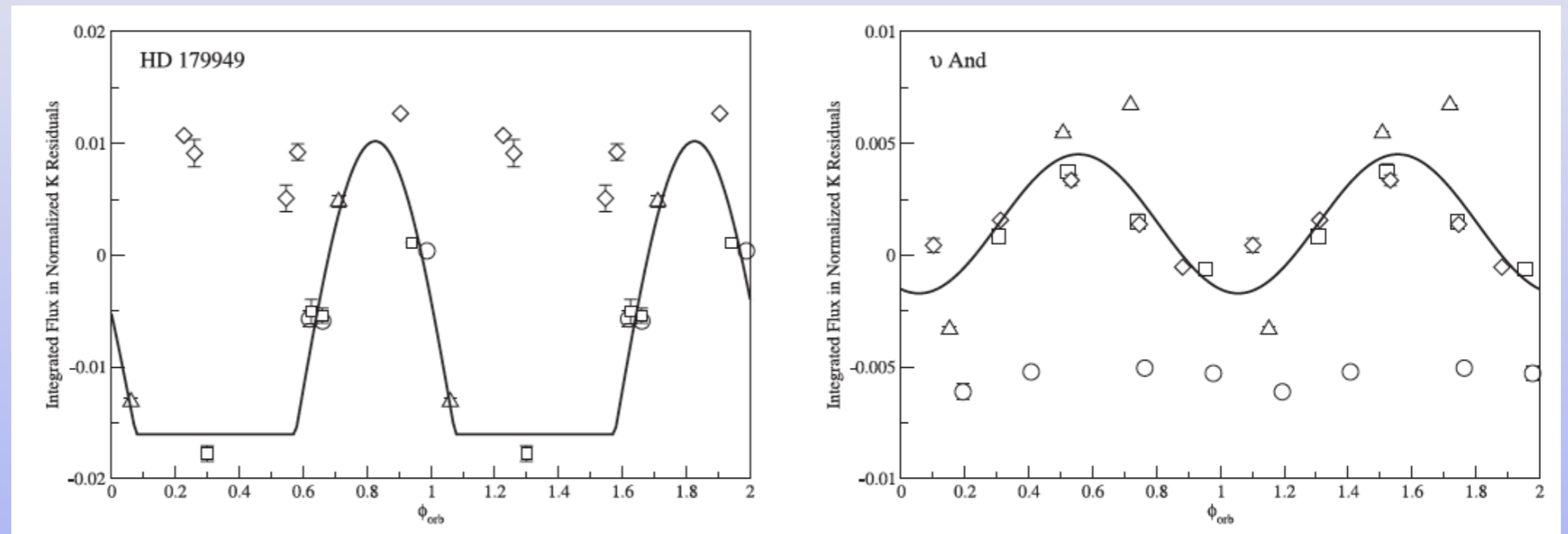


Credit: Fran Bagenal & Steve Bartlett

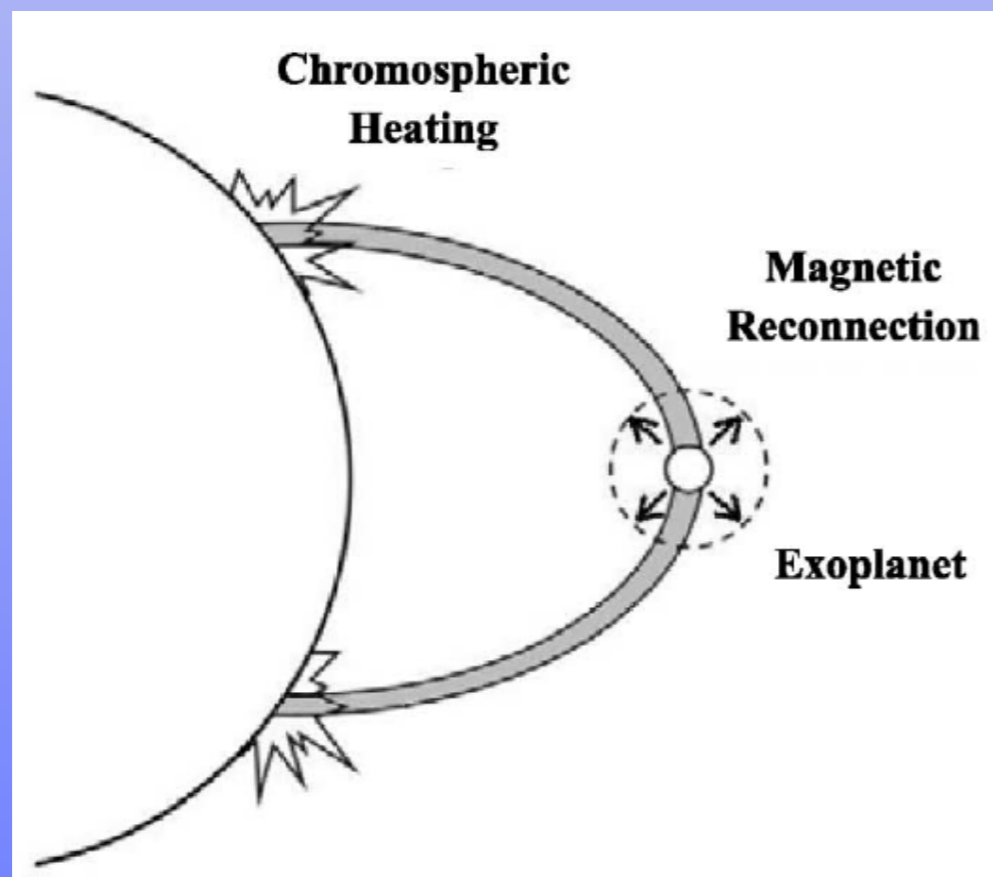
Induced stellar activity by a close-in magnetized planet:

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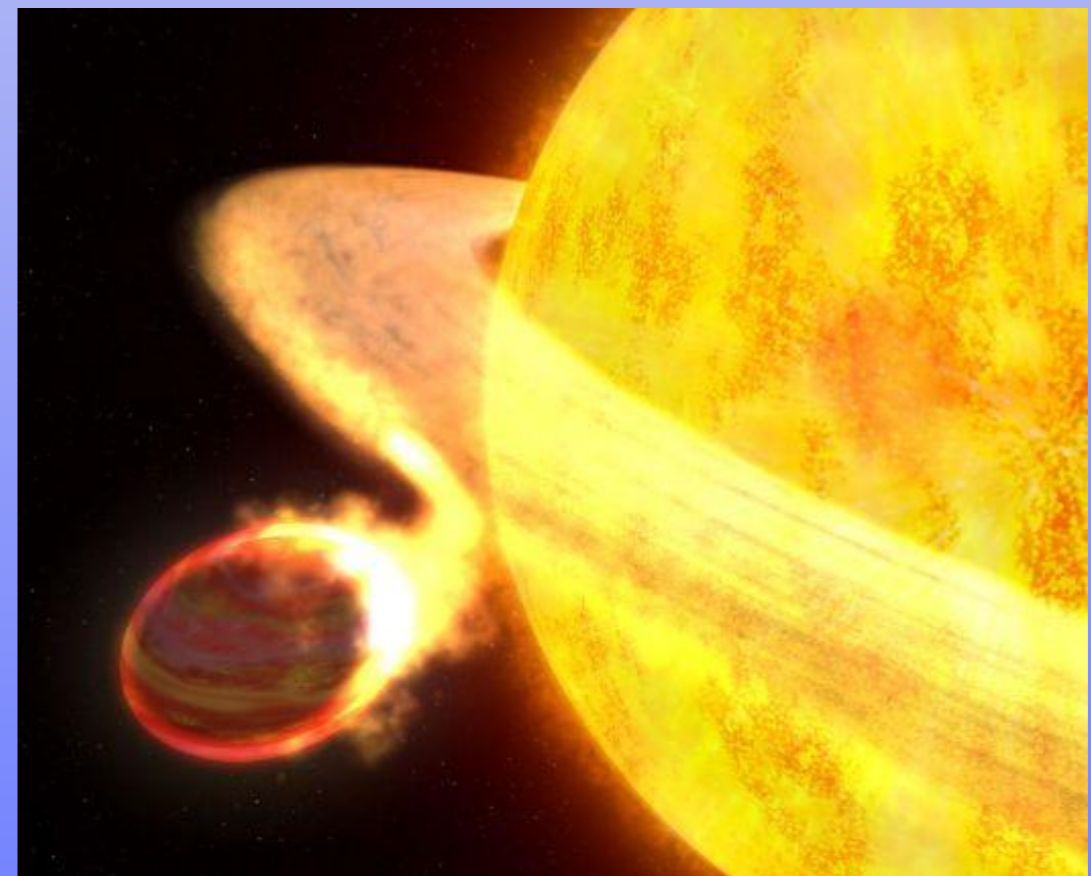
Integrated
Ca II H and
K flux Vs.
orbital phase

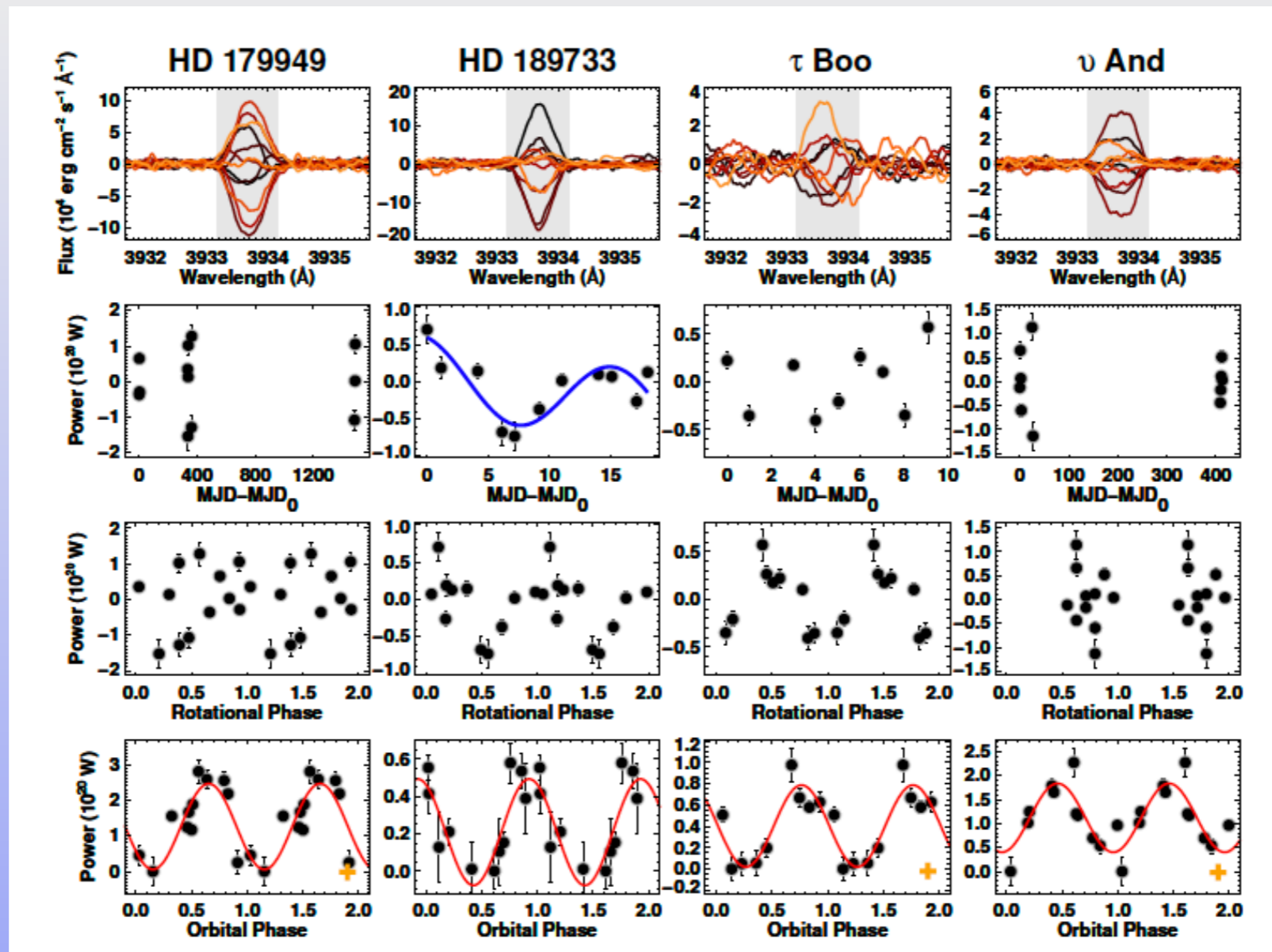


Shkolnik et. al 2005



Ip, Kopp, & Hu, 2004

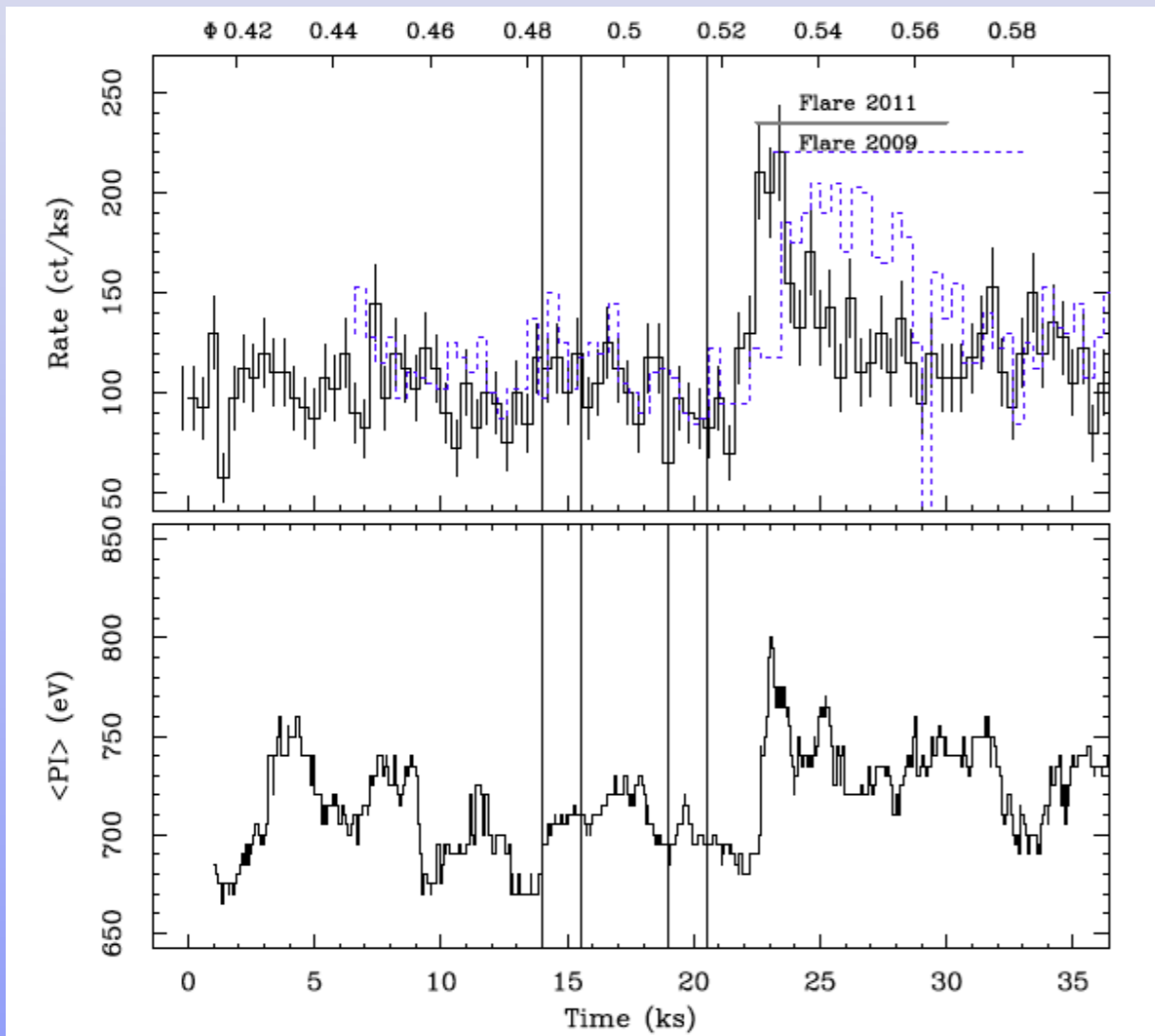




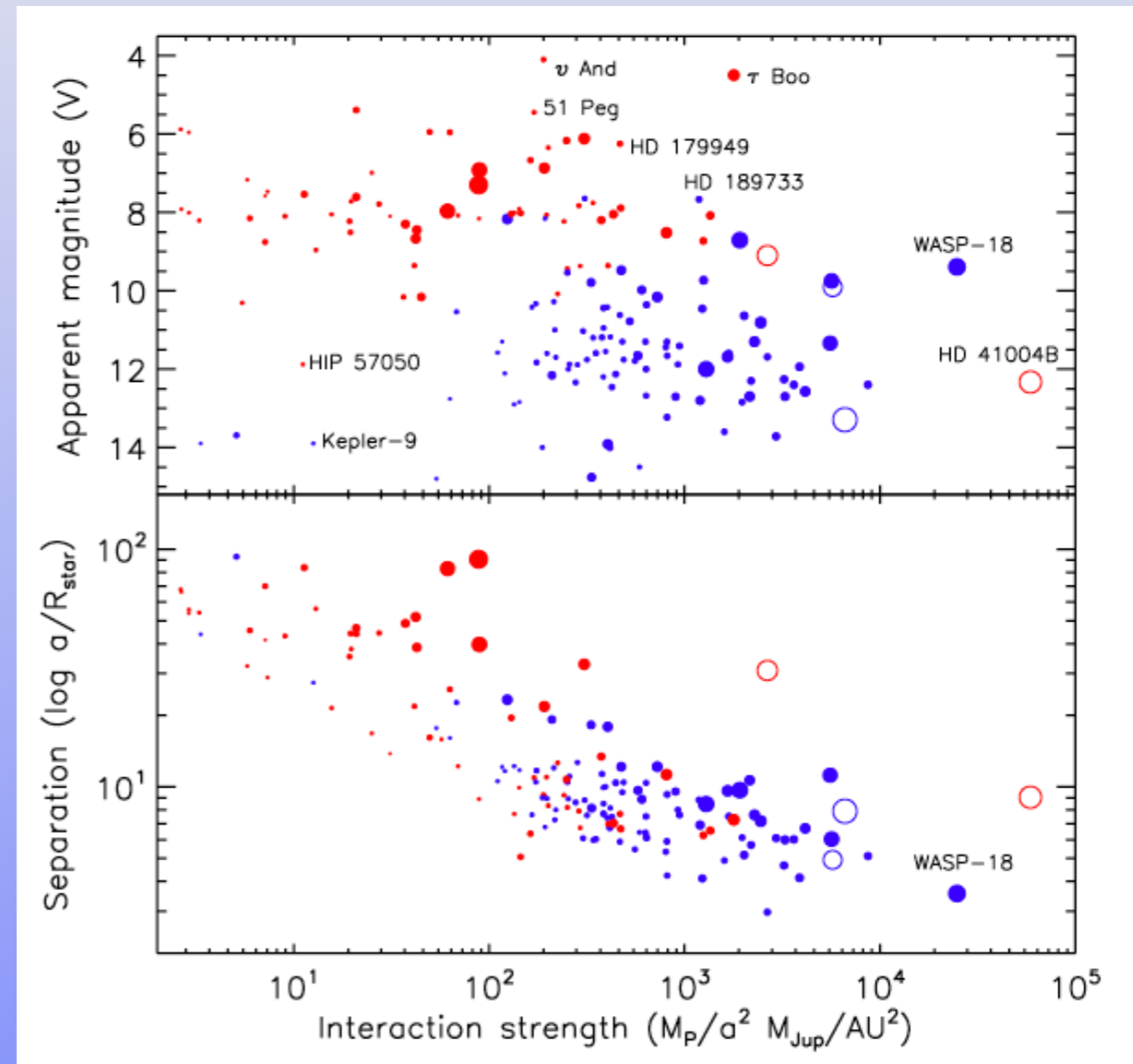
Cauley et. al 2019

$$P = \gamma \frac{\pi}{\mu} R_p^2 B_*^{4/3} B_{p0}^{2/3} v_{\text{rel}}$$

SPI in the X-ray band



Pillitteri et. al 2011



Miller et. al, ApJ, 2012

“star-planet interaction as a robust method of estimating exoplanet magnetic field strengths may be limited.”

Estimating planetary magnetic field using SPI:

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- Observed signal - uncertain

Estimating planetary magnetic field using SPI:

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- Knowledge about the stellar magnetic field - not a single value

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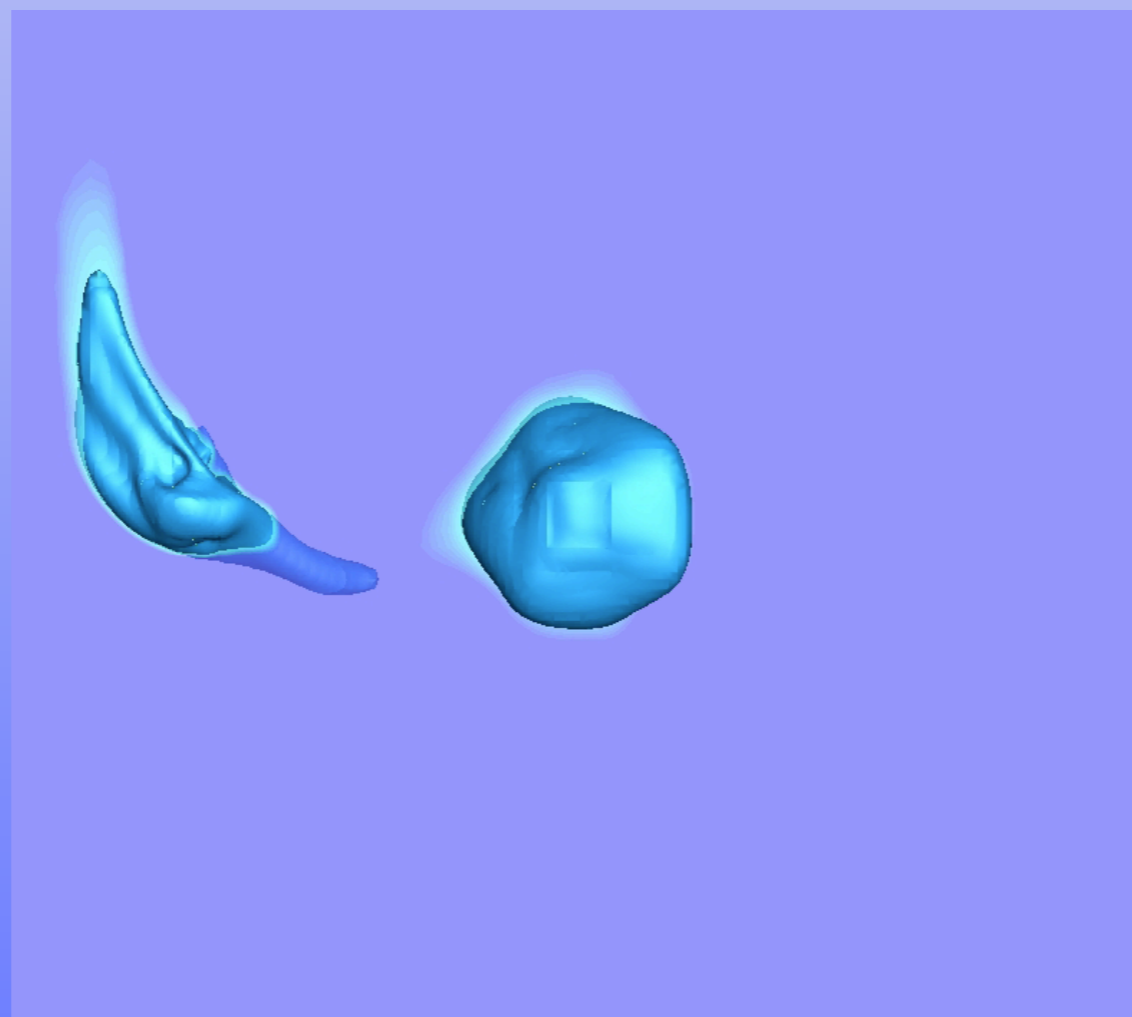
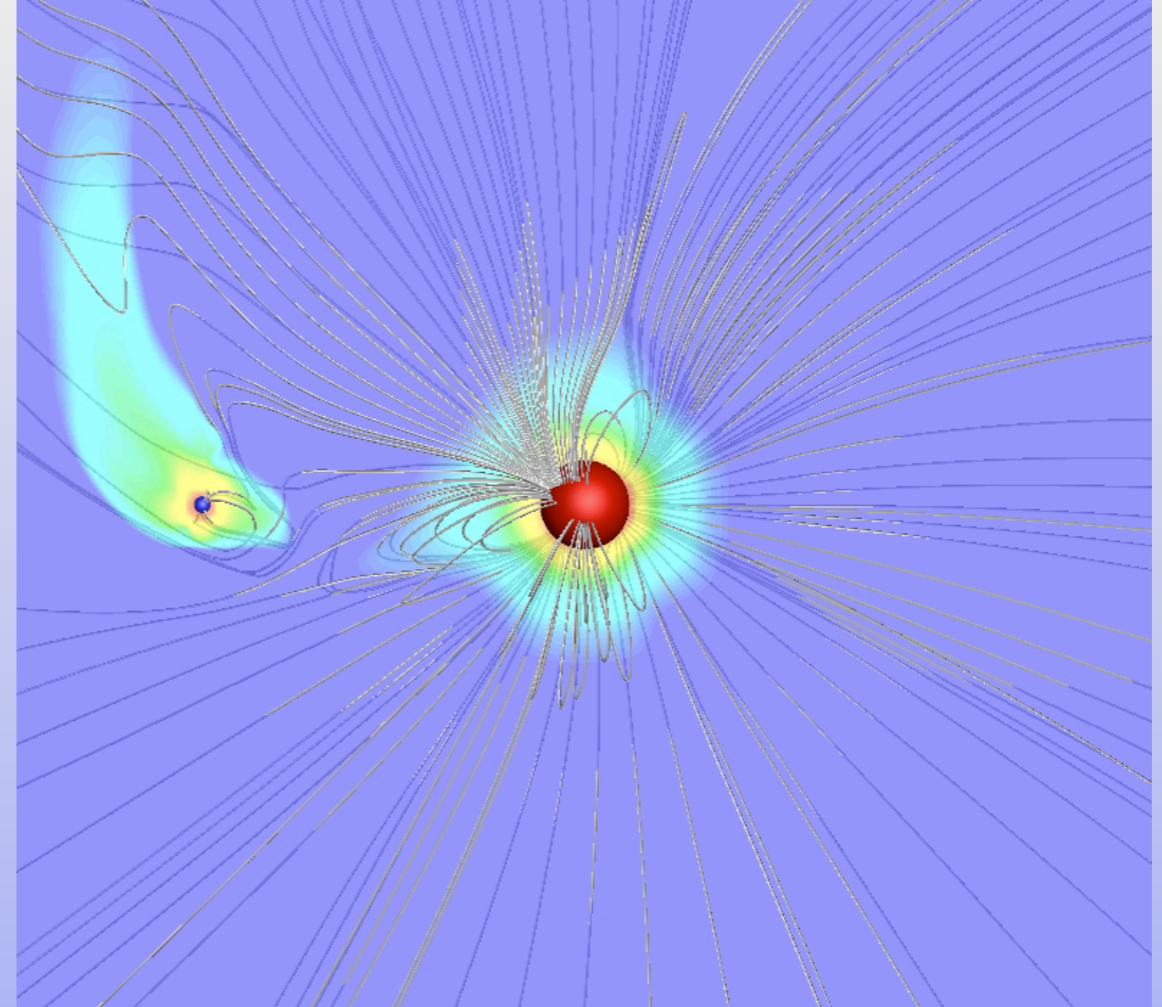
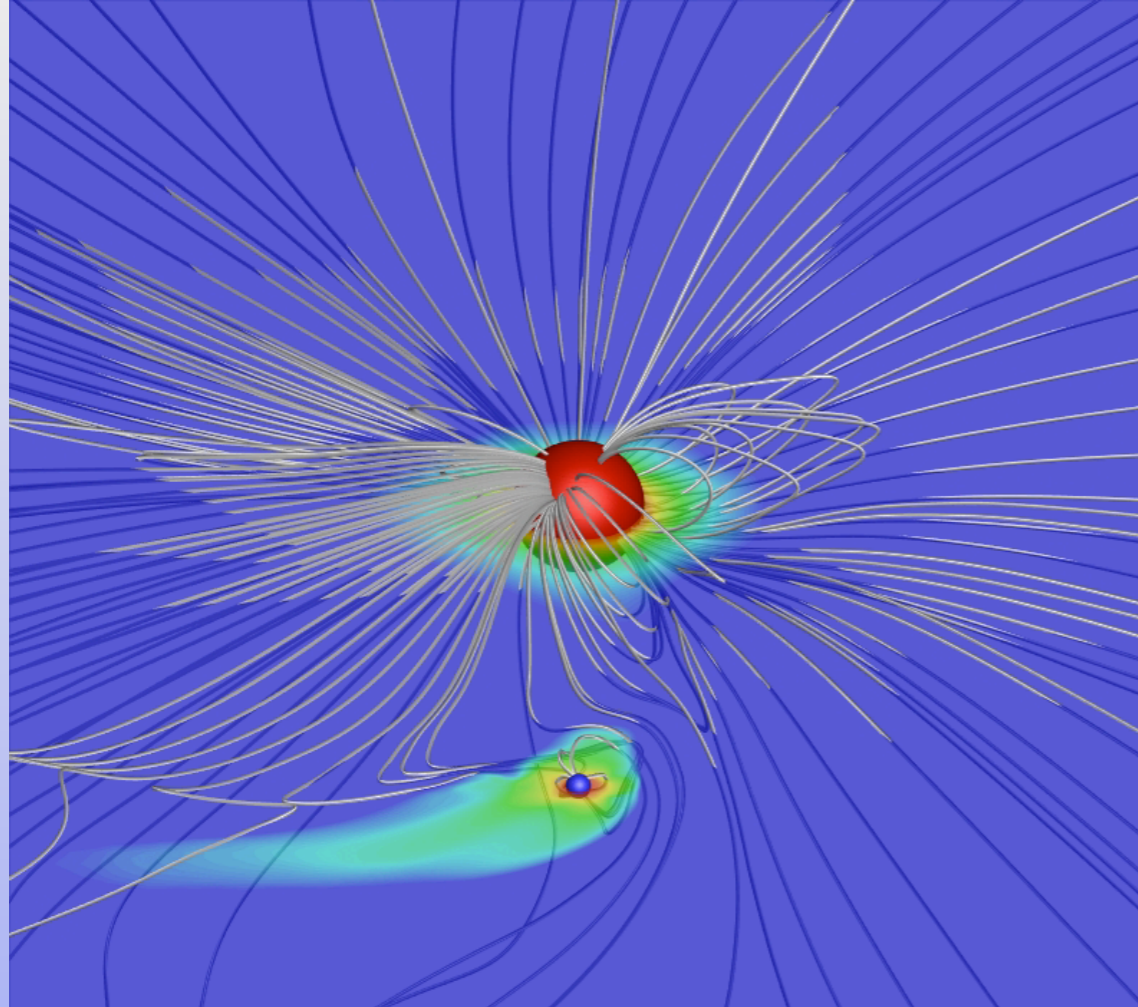
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- Knowledge about the stellar wind conditions

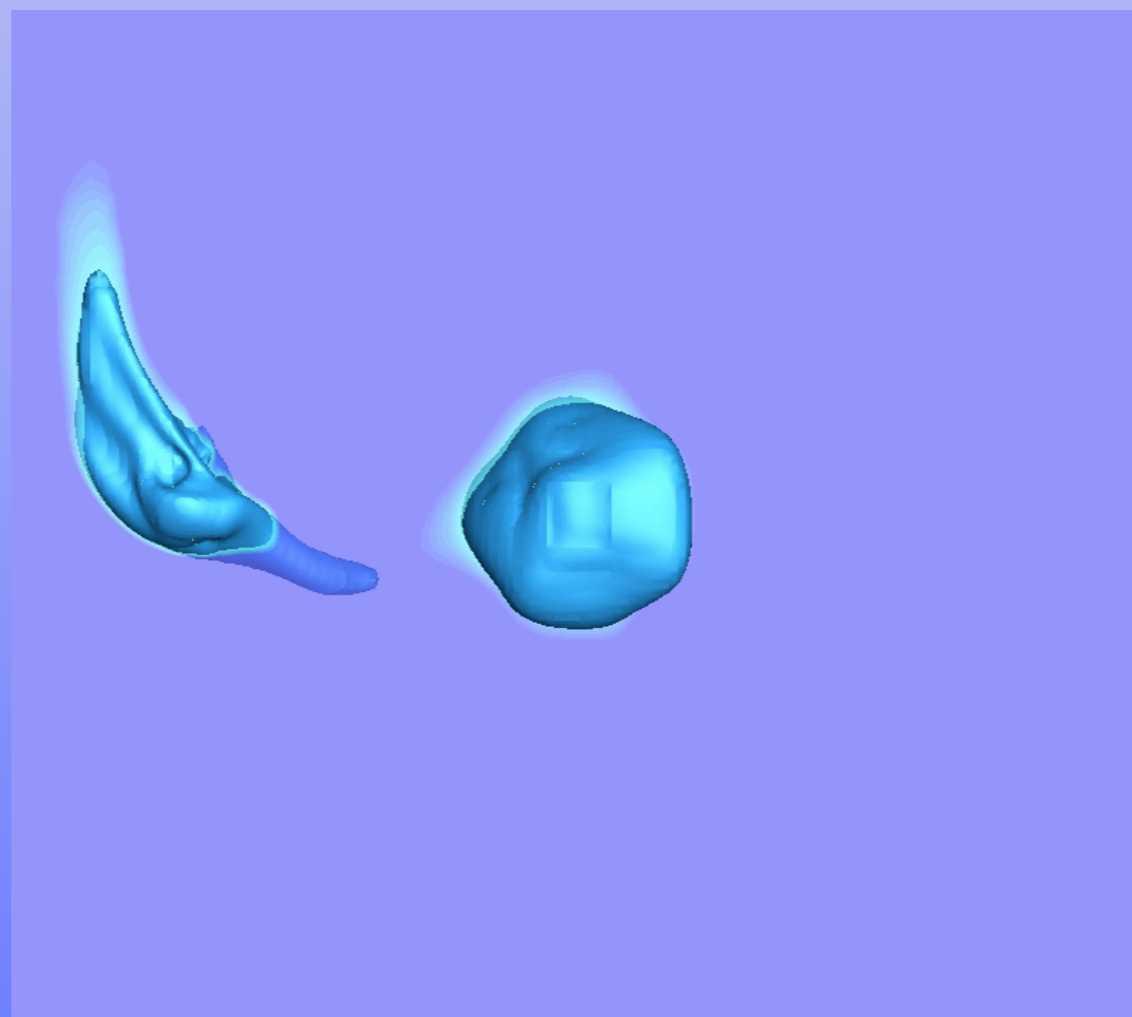
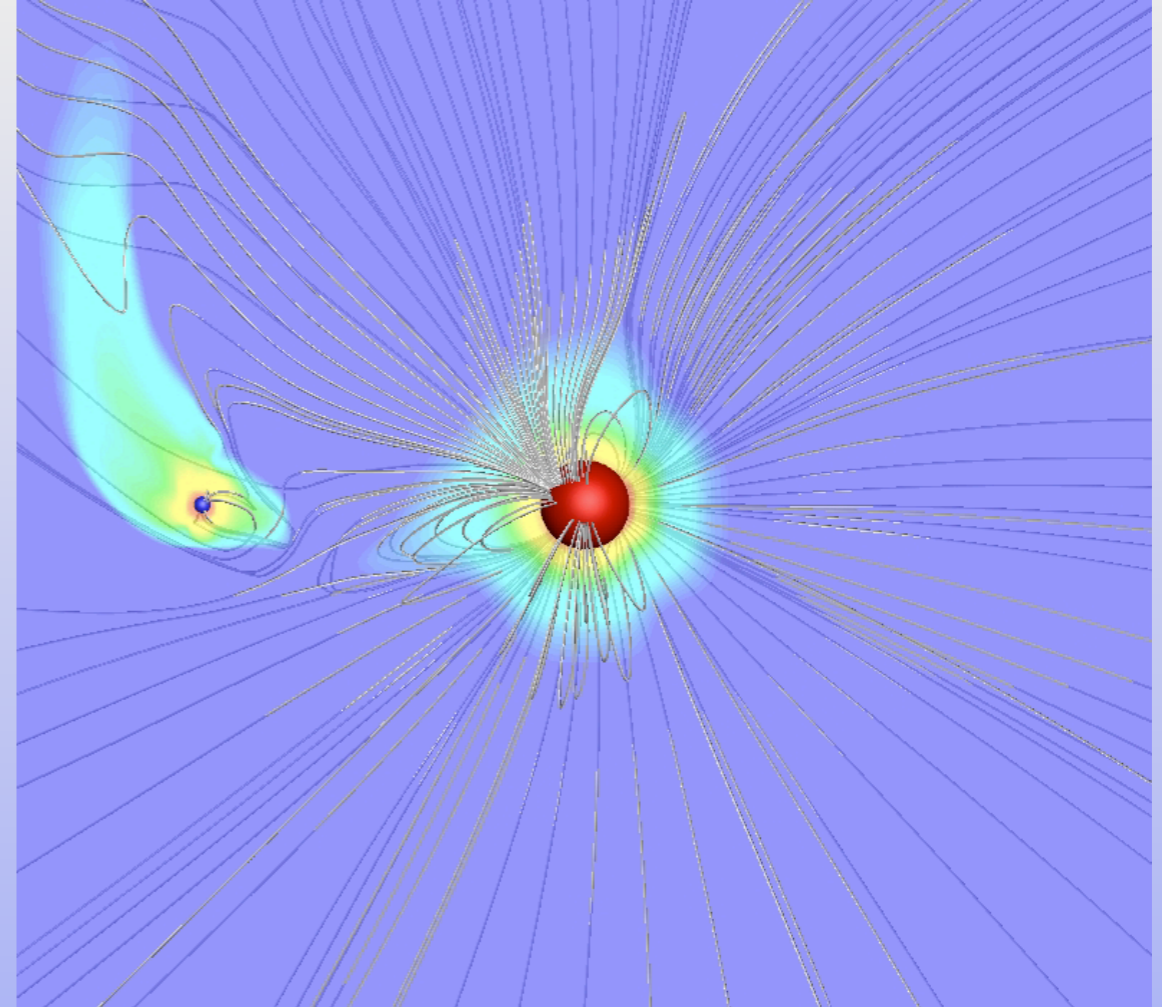
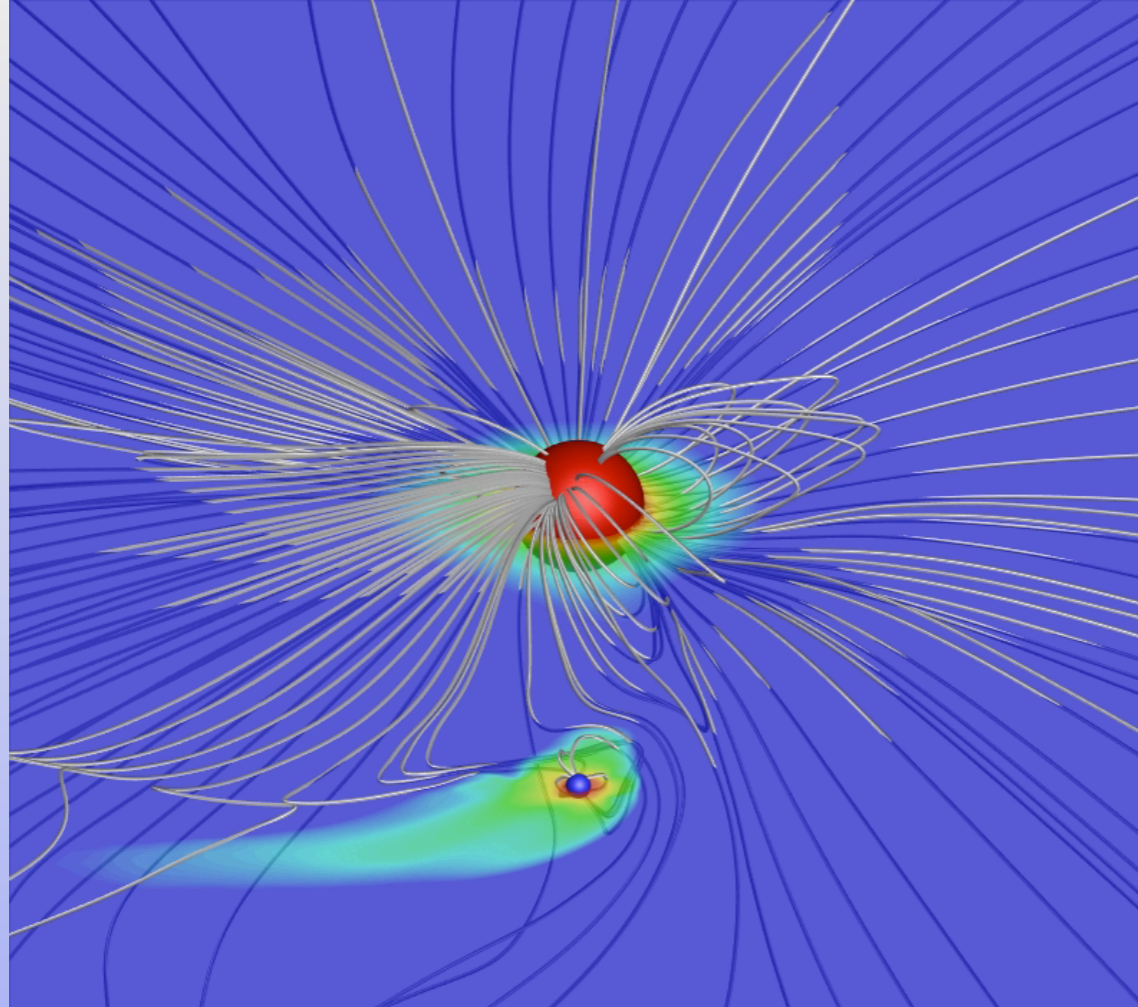
Estimating planetary magnetic field using SPI:

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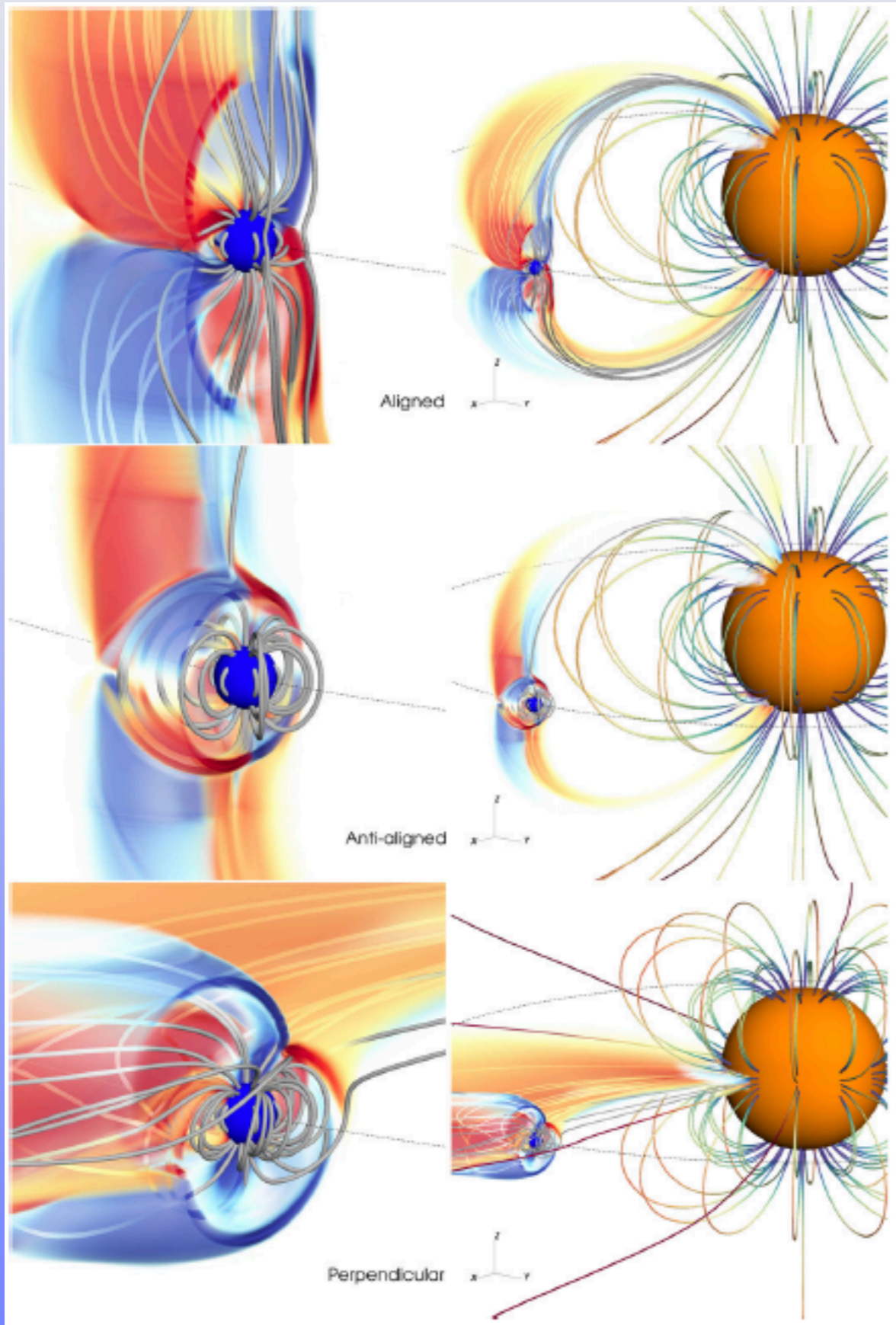
- Observed signal - uncertain
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- Knowledge about the stellar wind conditions
- Uncertainty in the efficiency factor
- SPI events may be very short and local





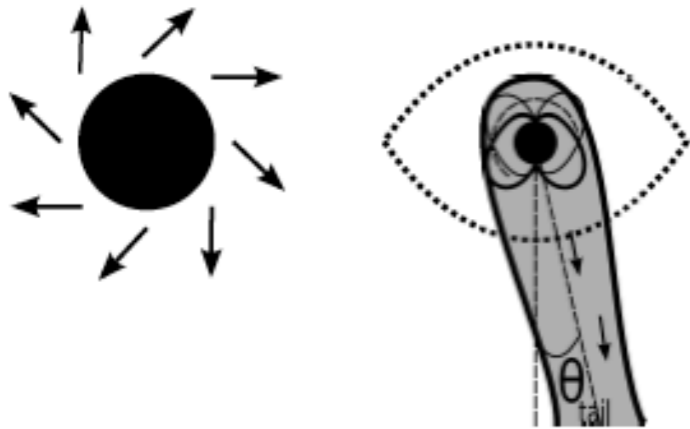
Angular momentum transfer:

Magnetic torques could be comparable to tidal torques, leading to planet migration with time scales of 10-100 thousand years.

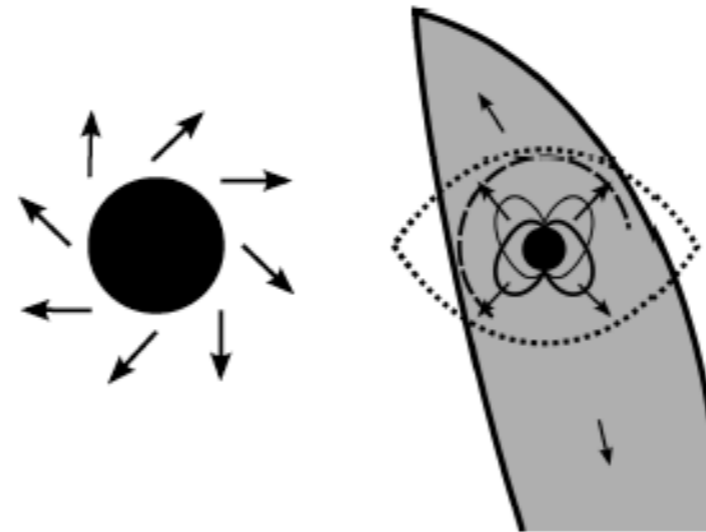


SPI classification:

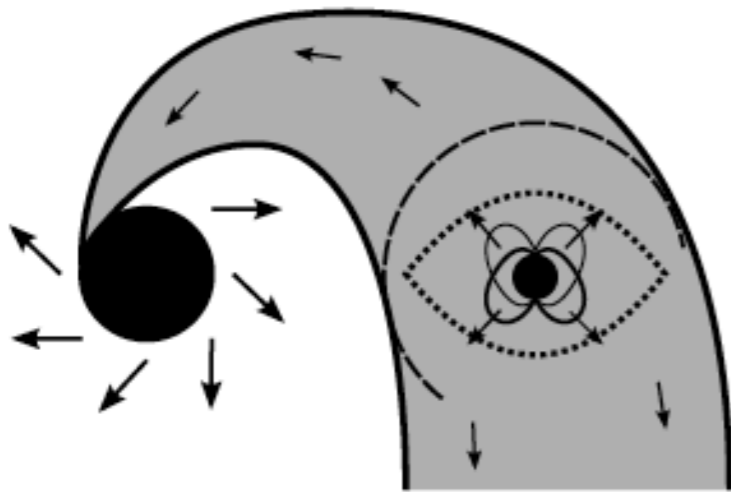
Type I: bowshock and thin tail



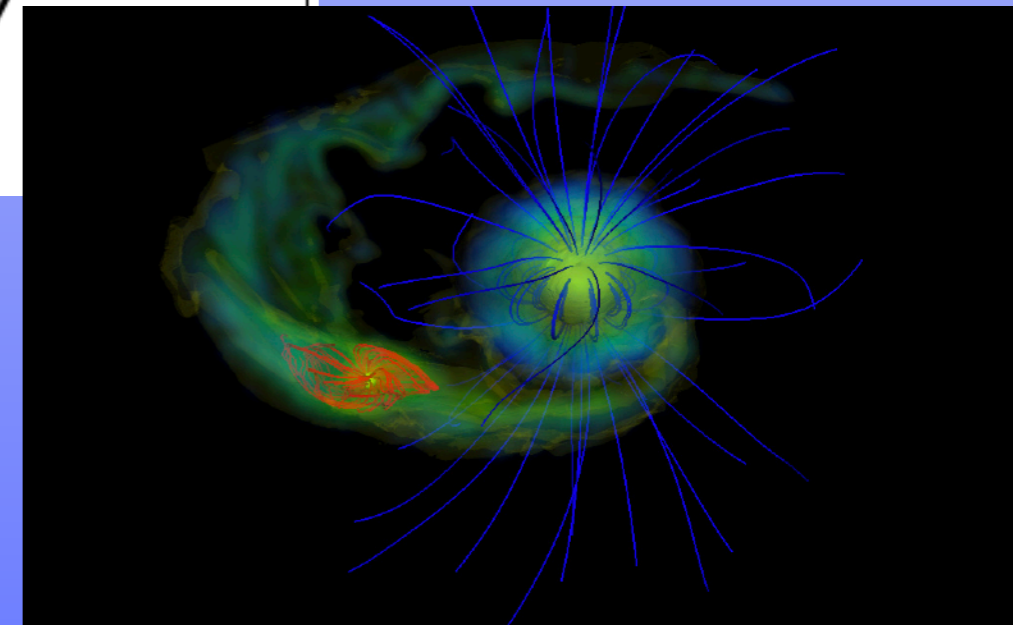
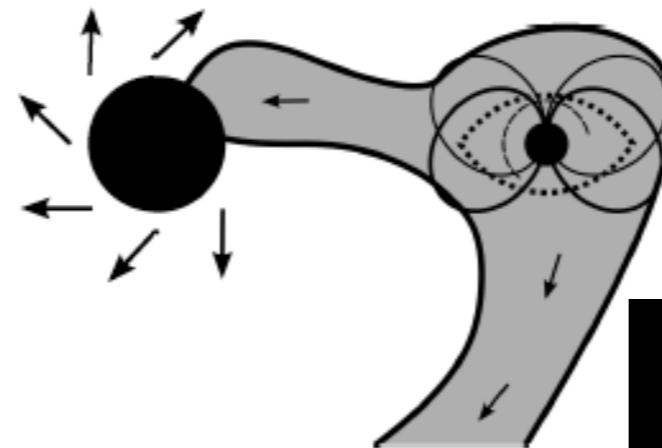
Type II: colliding winds and tail



Type III: strong planetary-wind, accretion and tail



Type IV: Roche-lobe overflow, accretion and tail



Radio signatures of SPI

Radio signatures of SPI

Auroral emissions from exoplanets - the planet is the source of radio emission.

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Stellar wind conditions are still required

$$P_k \simeq \rho(\Delta u)^3 \pi r_M^2$$



$$P_{\text{radio}} = C * P_k$$

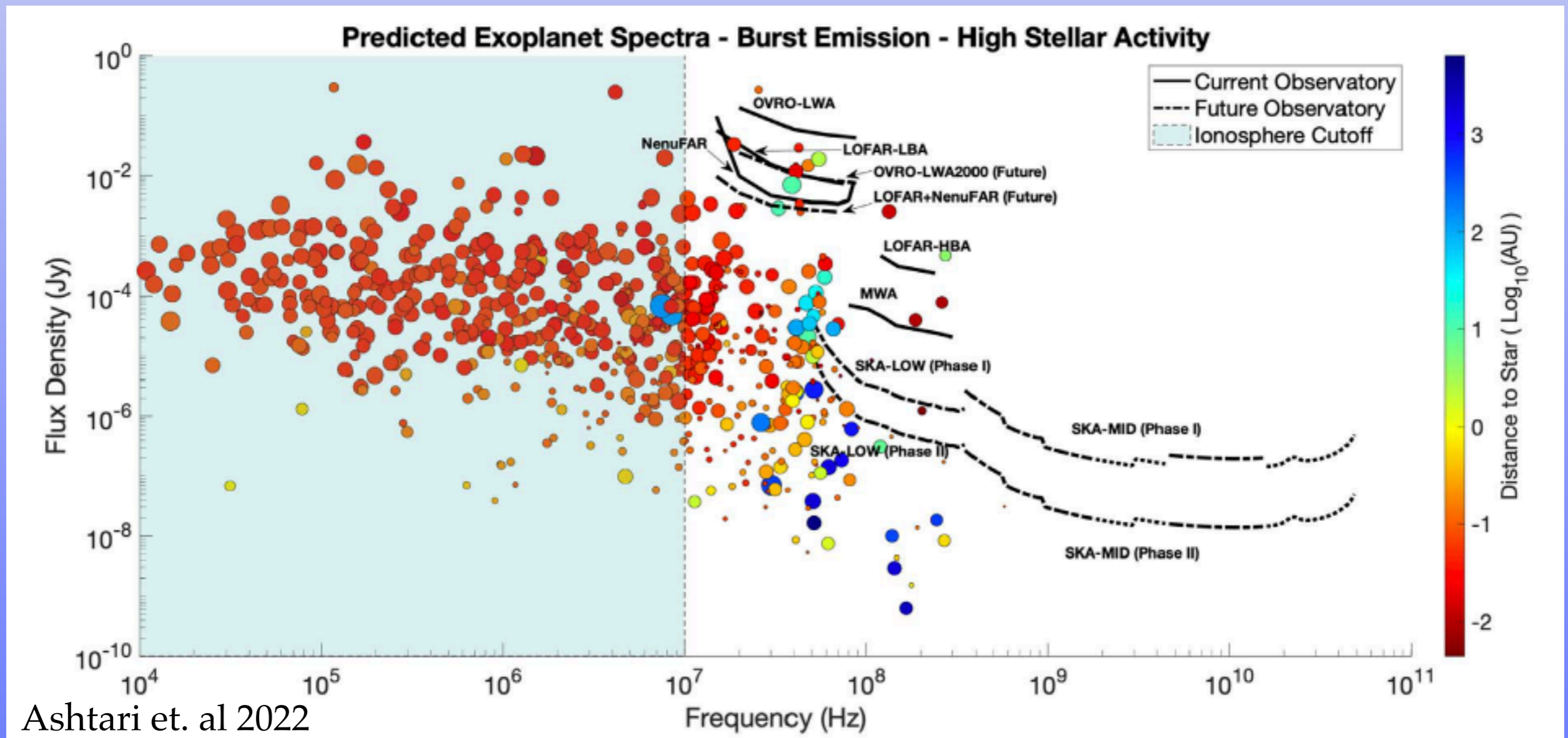
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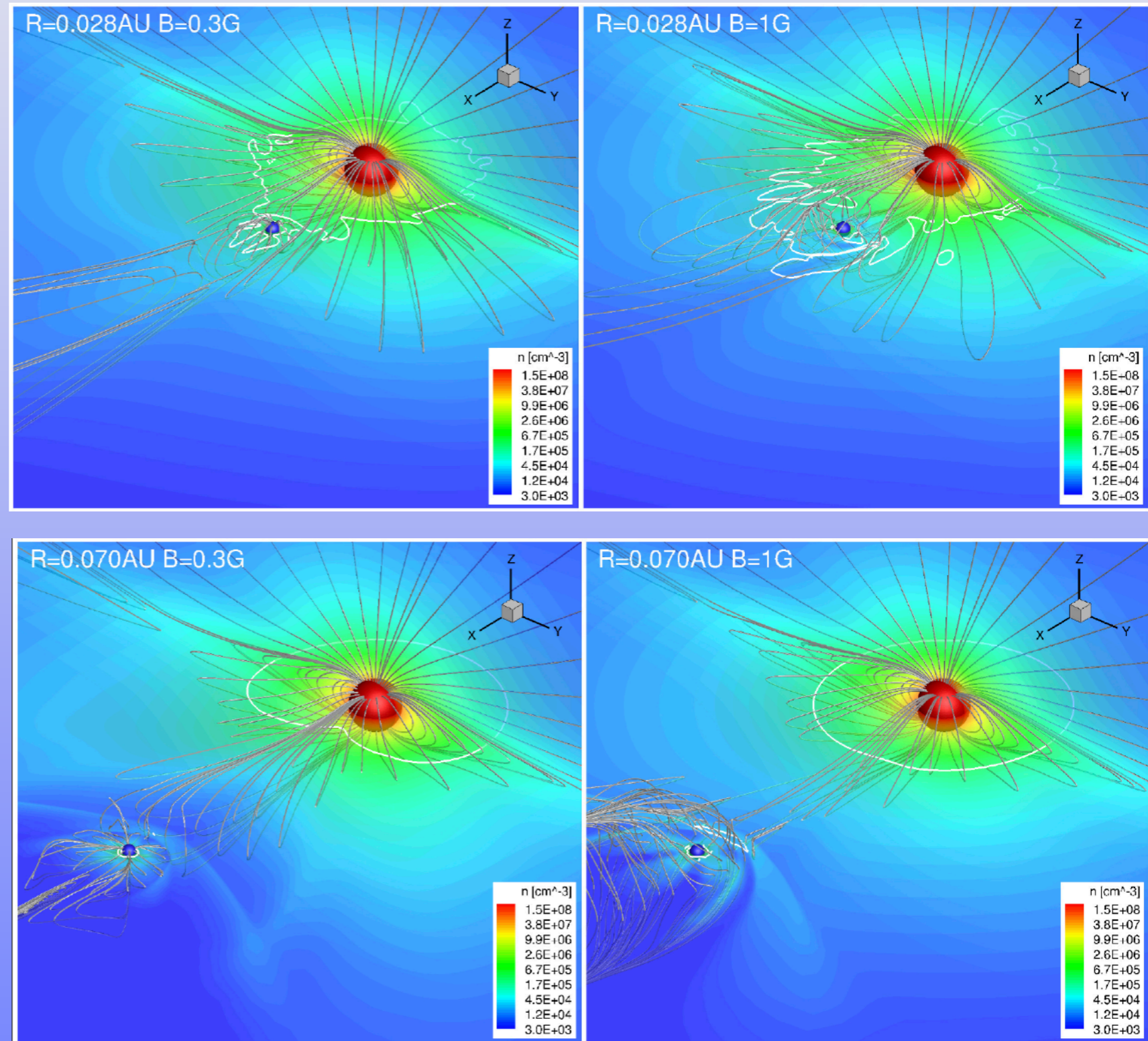
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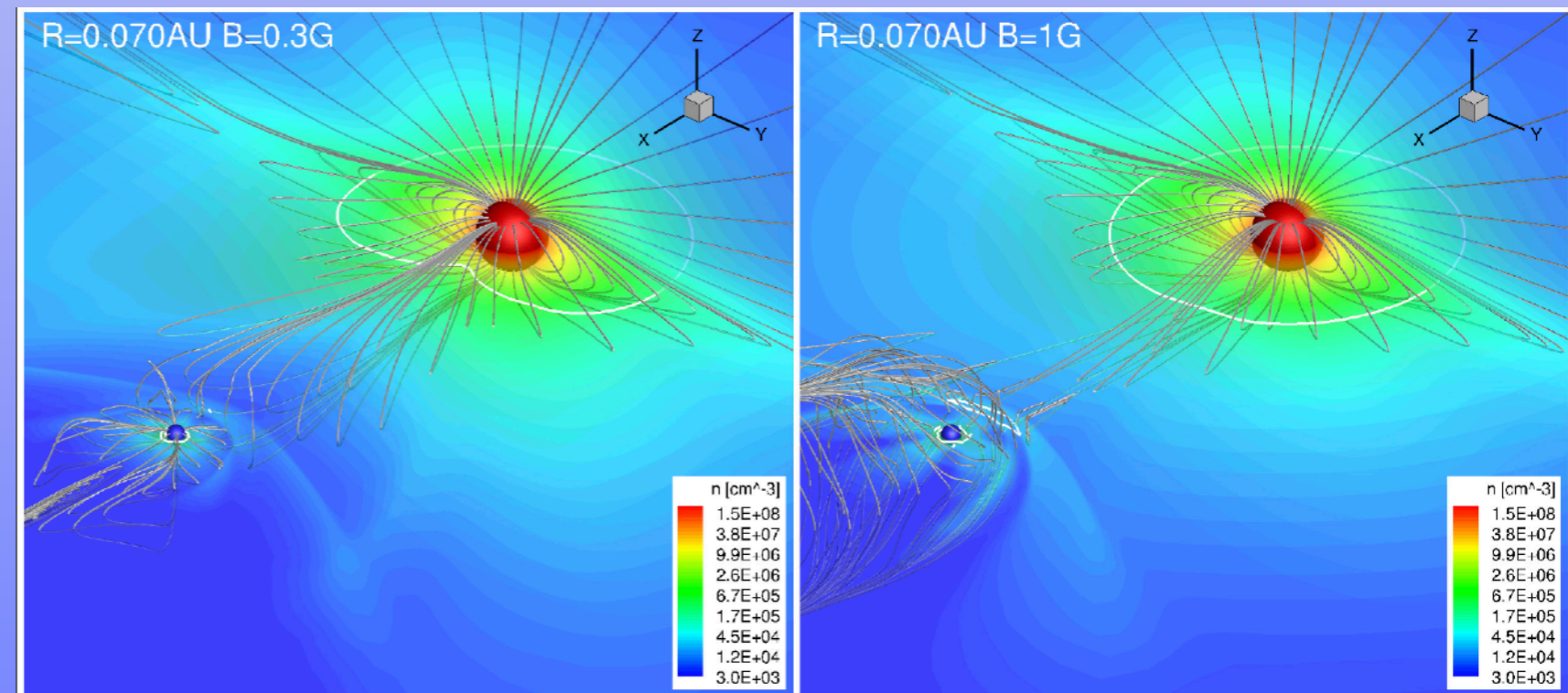
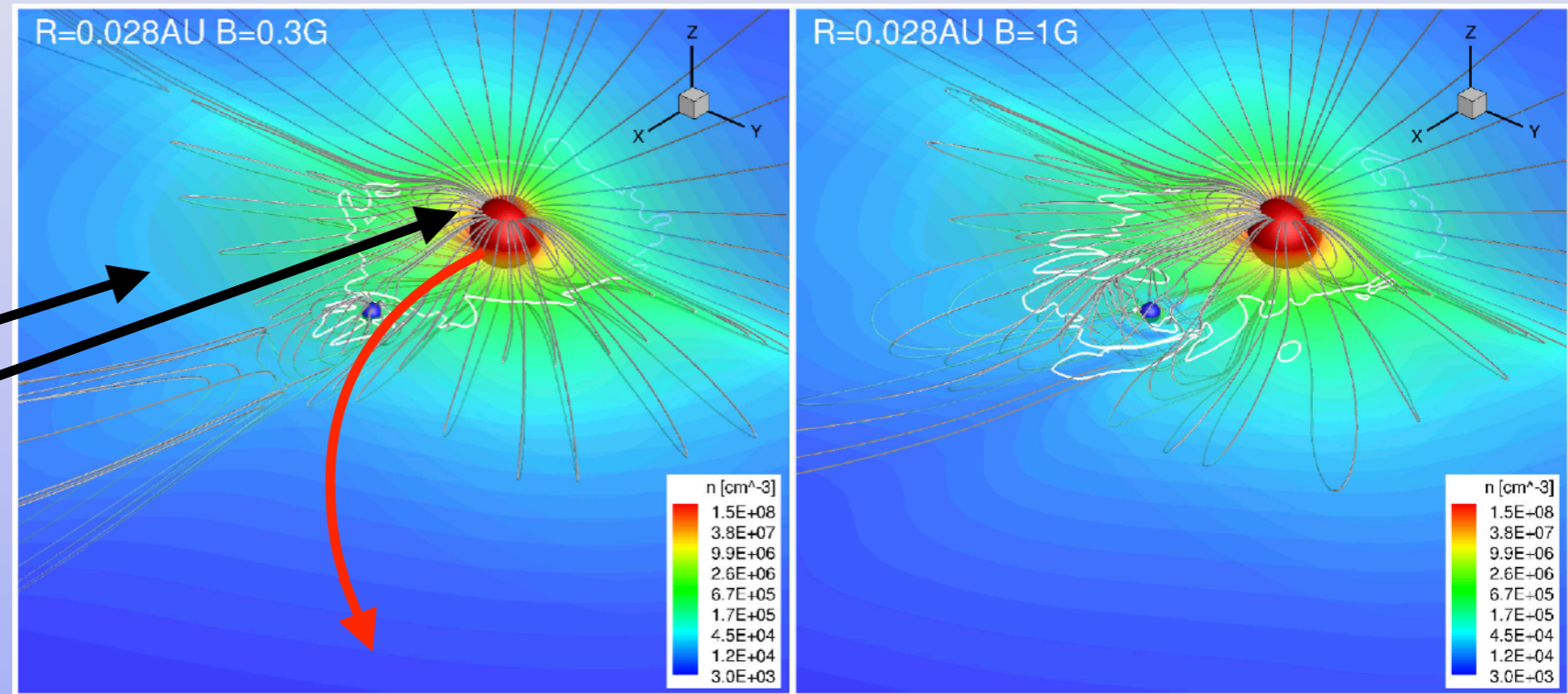


Simulating radio transits of exoplanets - modulations of the coronal emissions by the planet



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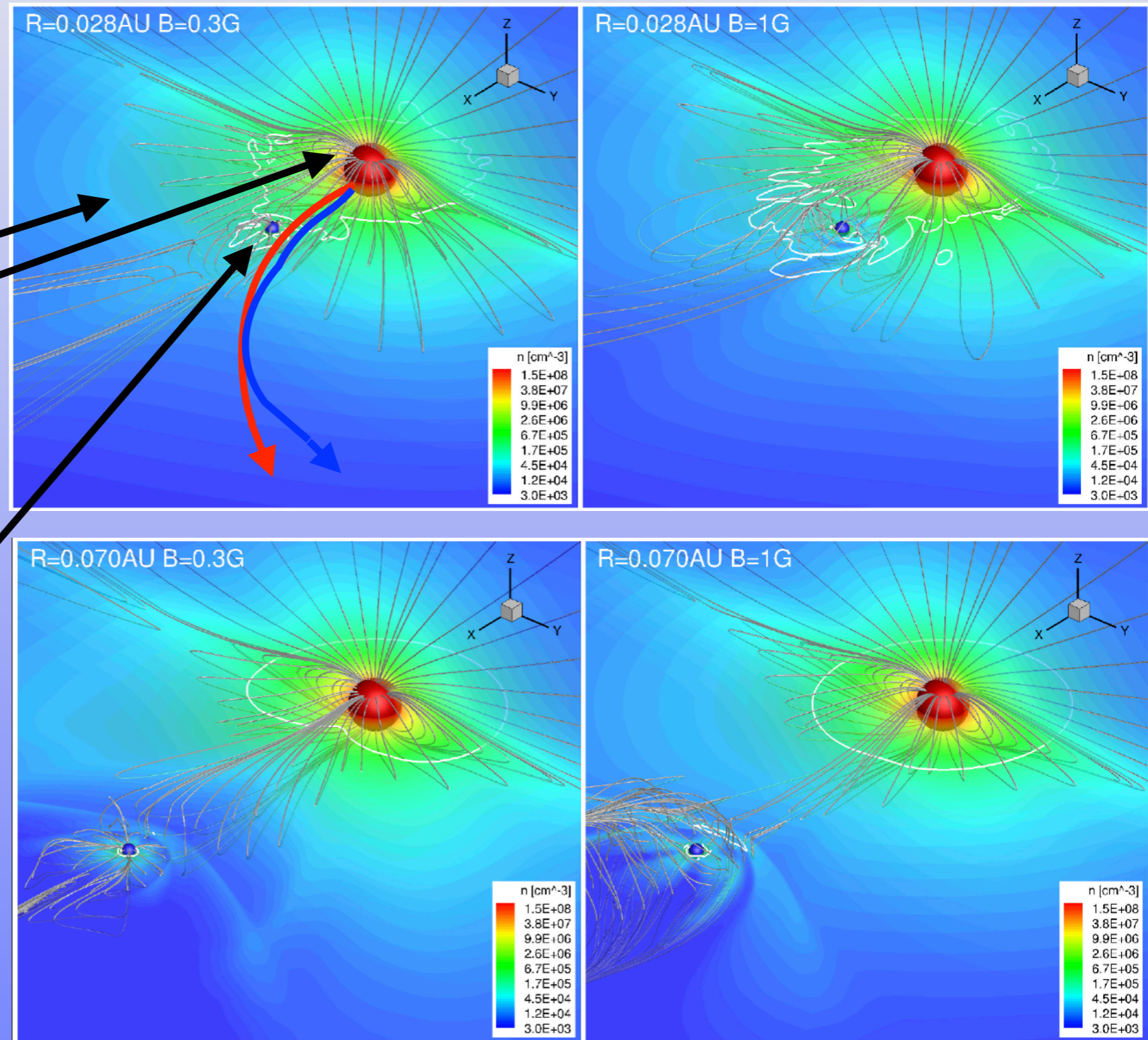
Plasma density
plasma frequency
radio wave path



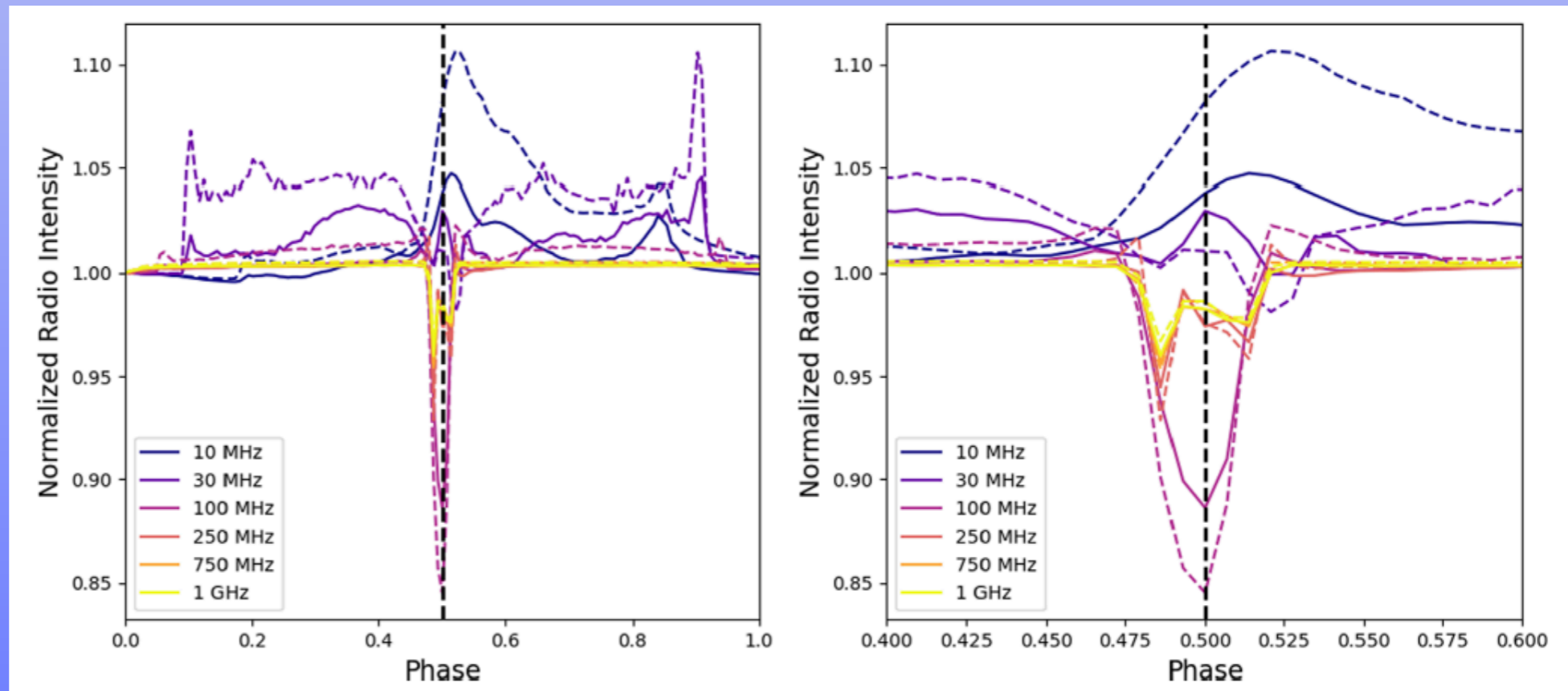
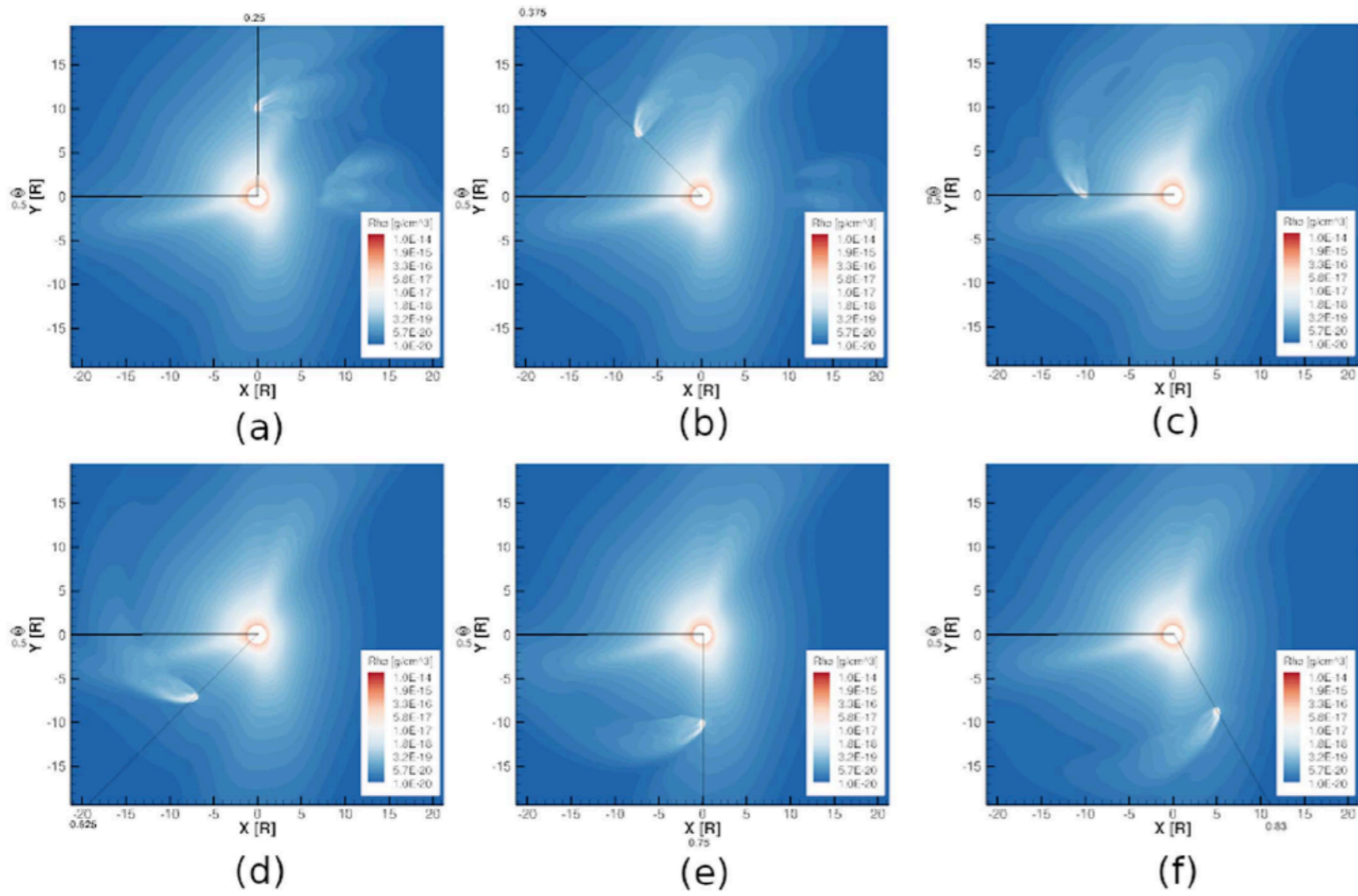
Simulating radio transits of exoplanets - modulations of the coronal emissions by the planet

Plasma density
plasma frequency
radio wave path

The planet modulates
the plasma density
and the radio wave
path



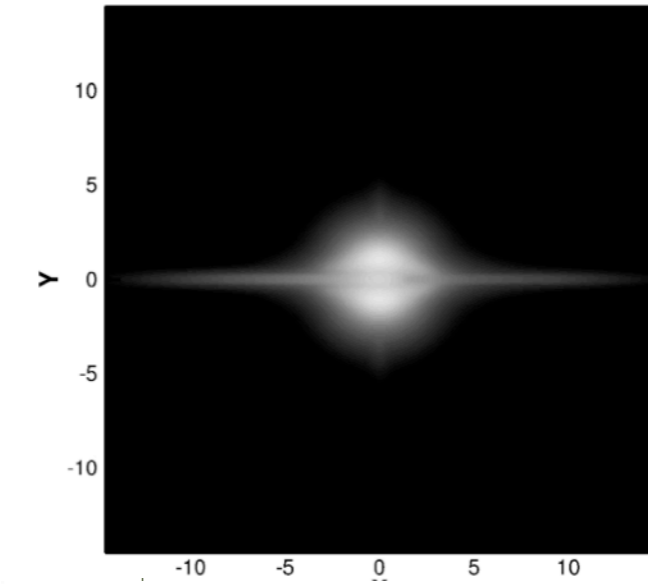
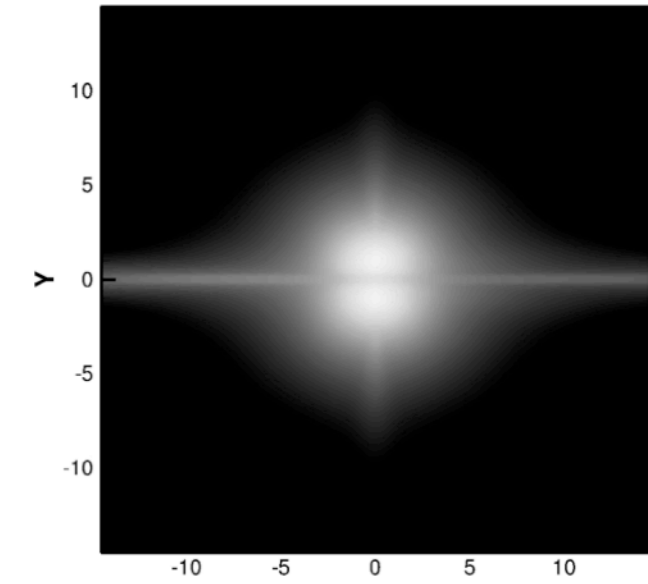
Radio transit in HD189733



R=0.028AU, Bp=0.3G

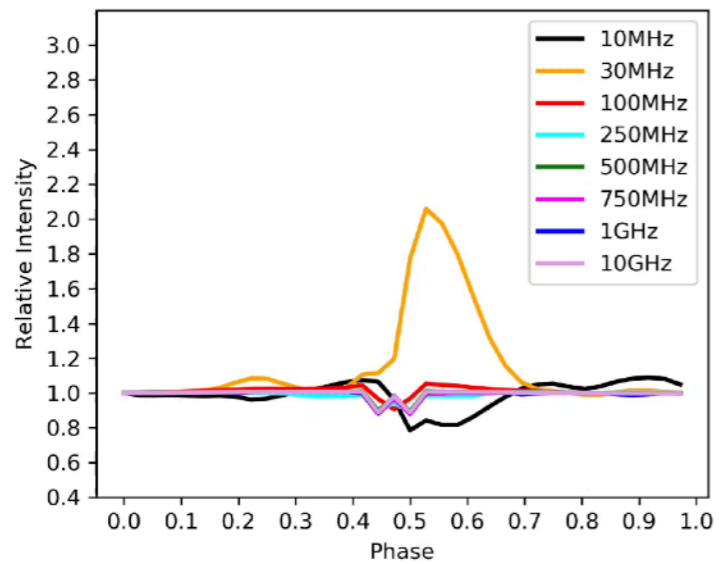
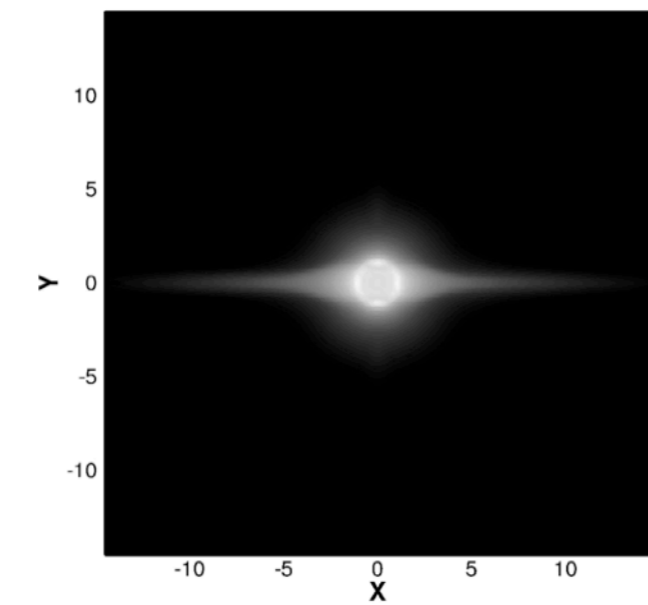
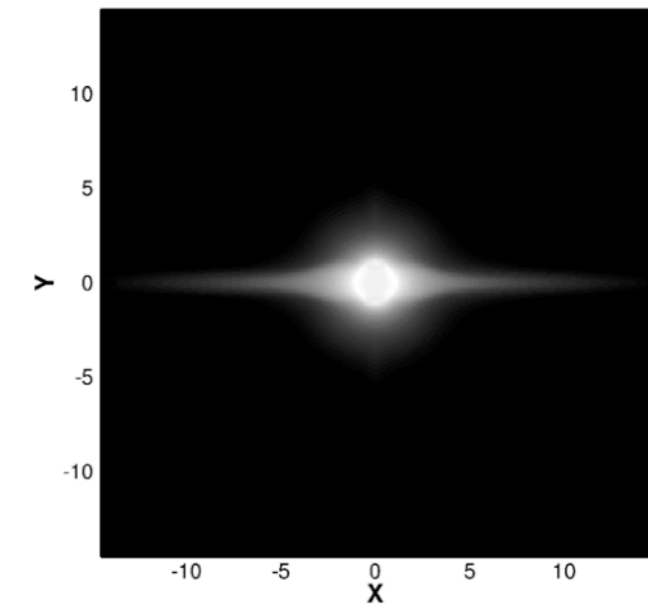
10 MHz

30 MHz



250 MHz

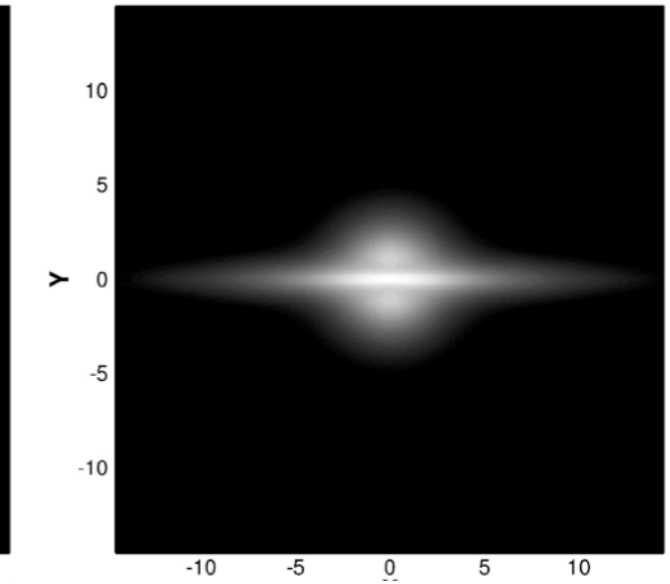
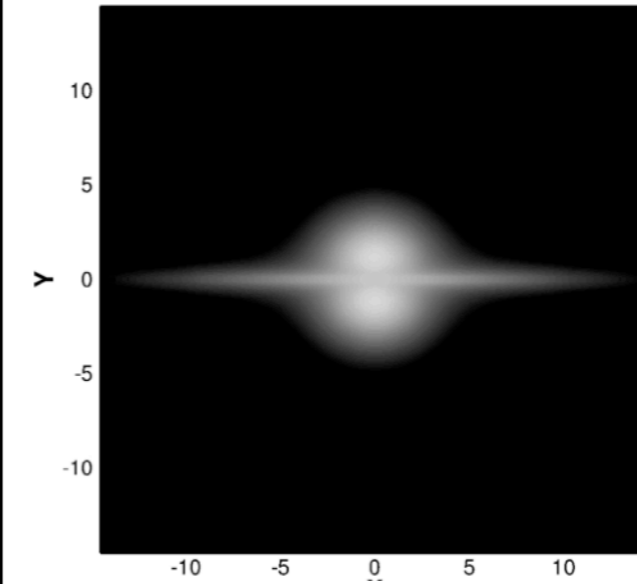
1 GHz



R=0.070AU, Bp=1G

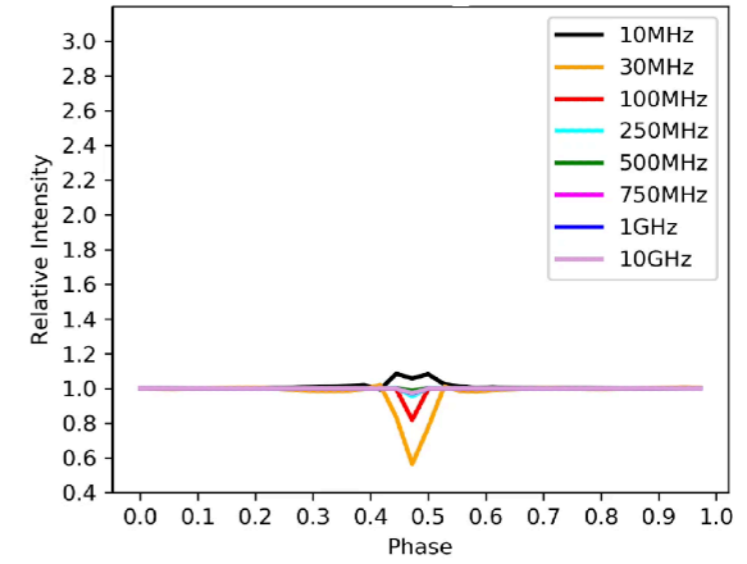
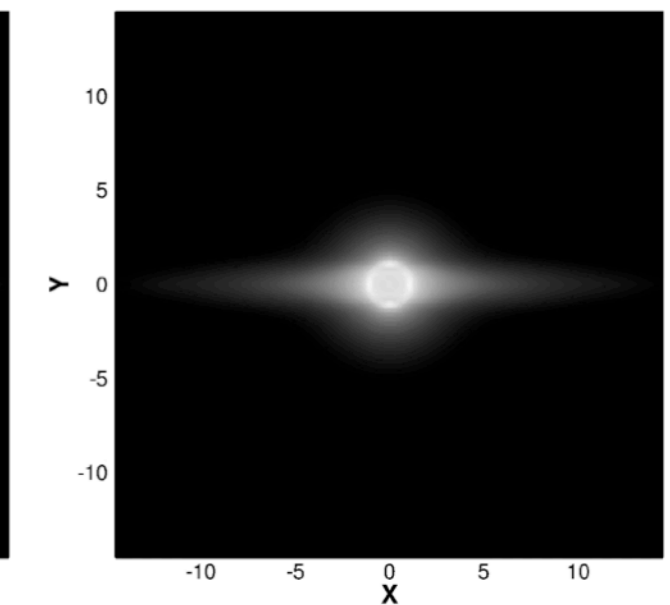
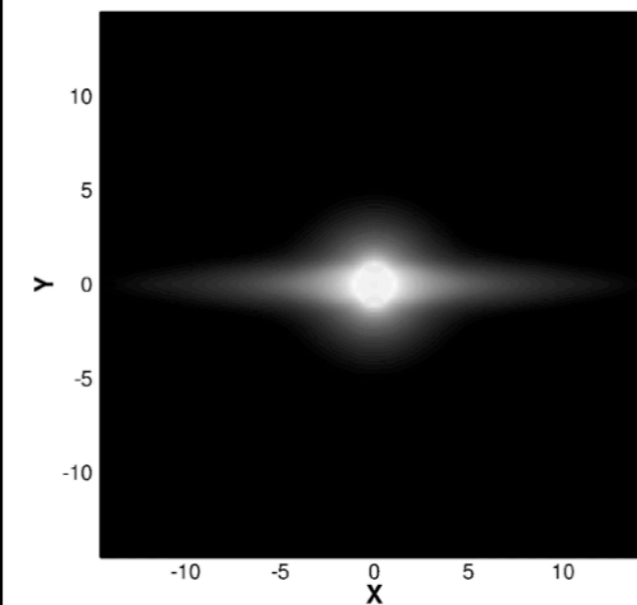
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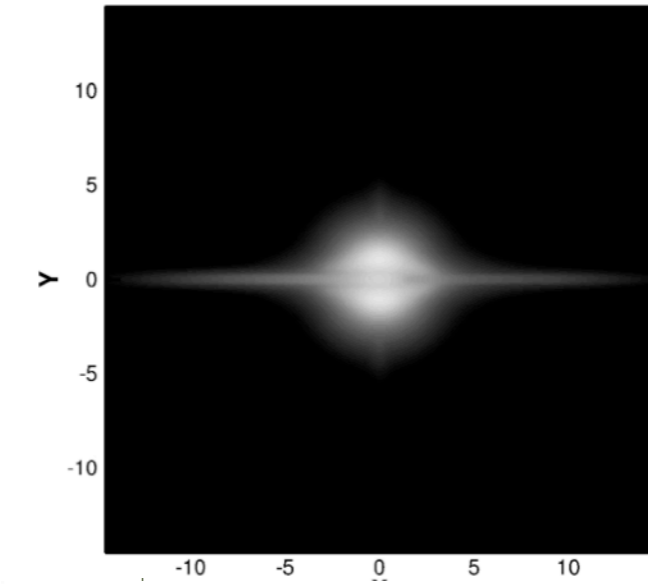
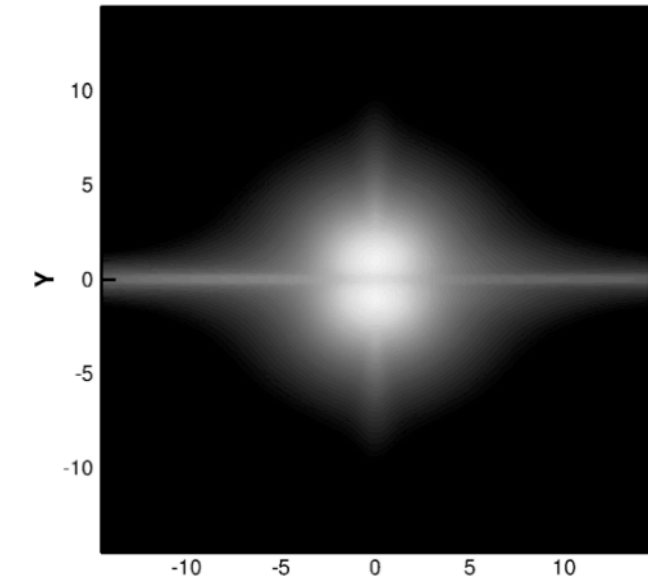
1 GHz



R=0.028AU, Bp=0.3G

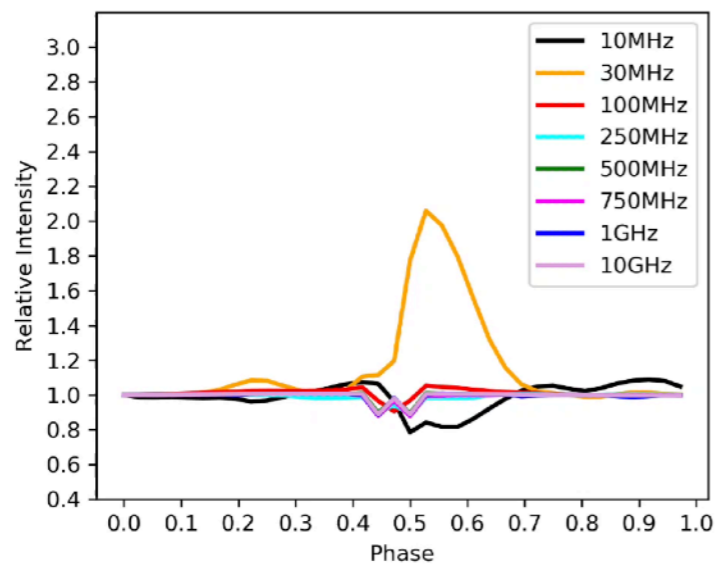
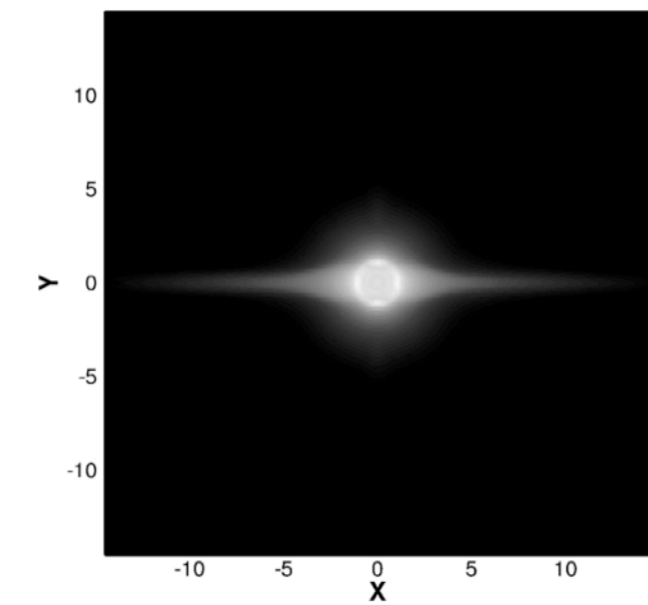
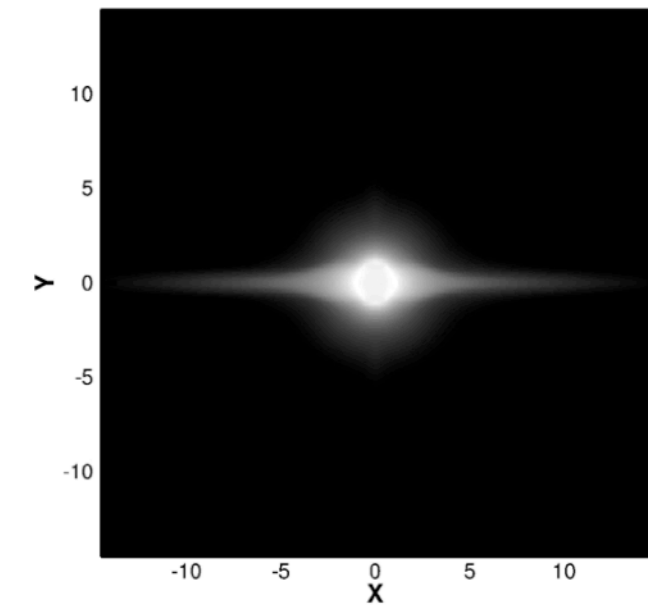
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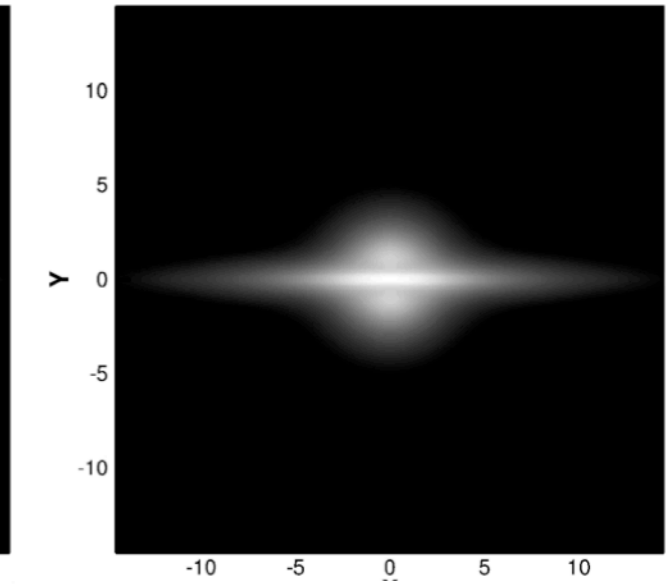
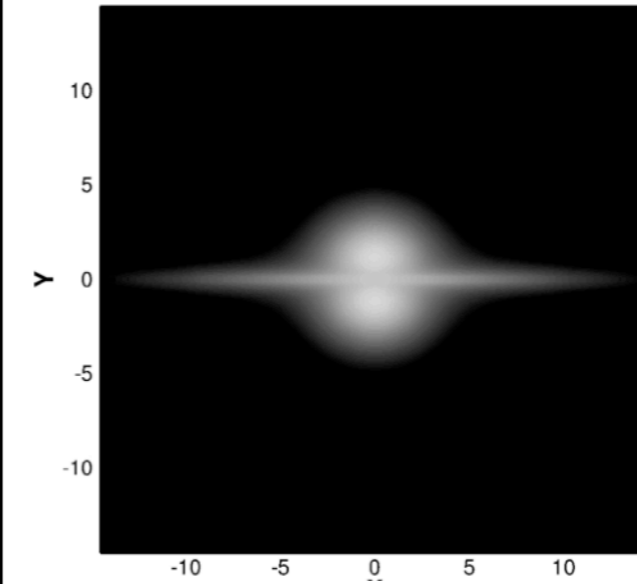
1 GHz



R=0.070AU, Bp=1G

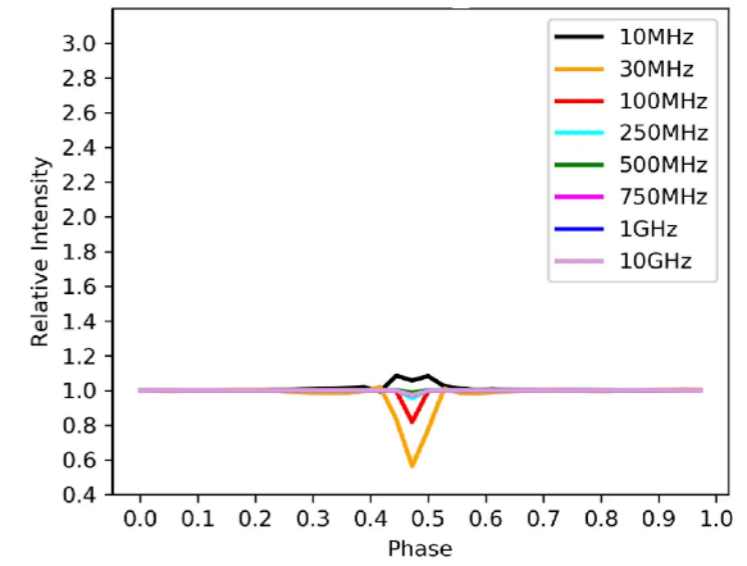
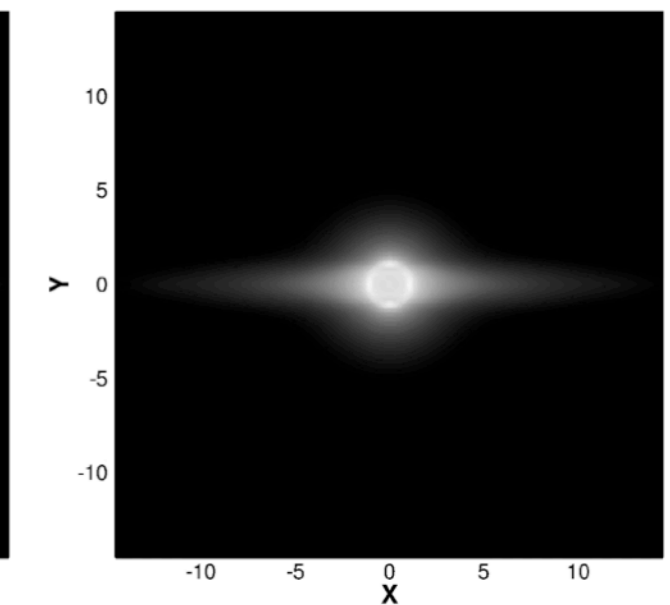
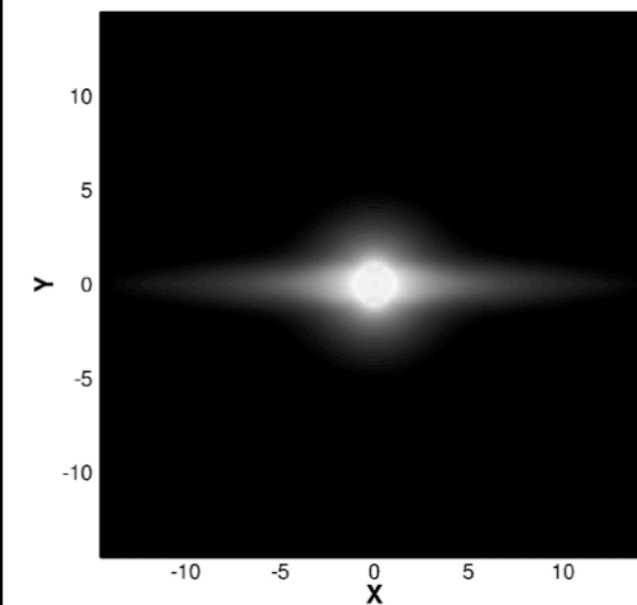
10 MHz

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250 MHz

1 GHz



Take away points

- Strong SPI is expected in short-orbit exoplanets, especially when the planets are in a sub-Alfvénic region
- Observed signatures could provide information about the planetary magnetic field
- Requires knowledge about the stellar field and stellar wind
- Can we improve SPI observations?
- Can we detect radio signatures of SPI/transit?