STELLAR WIND EFFECT ON ATMOSPHERIC ESCAPE

Hiroto Mitani (UTAP)

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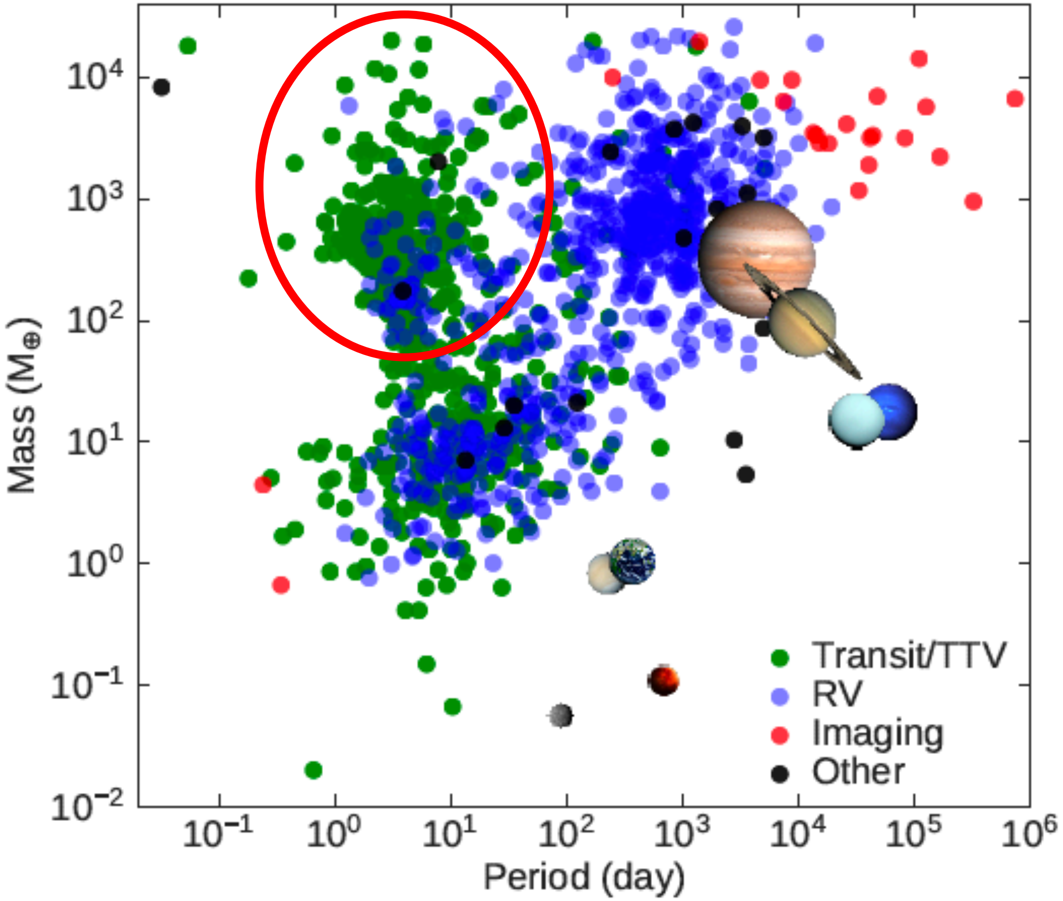
INTRODUCTION: HOT JUPITERS

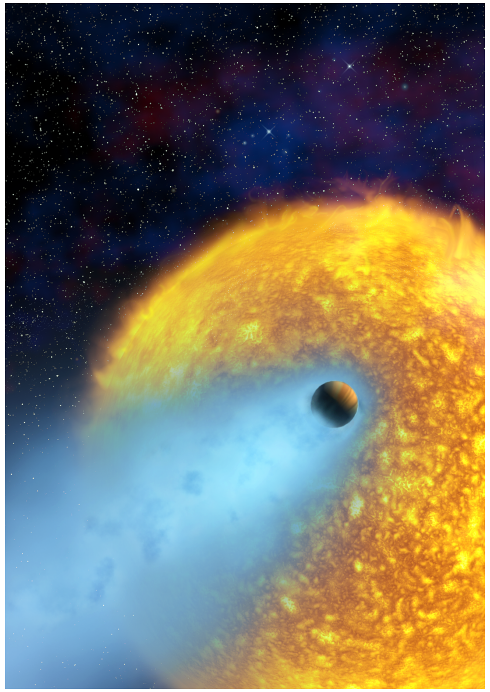


Vardan Adibekyan et al. 2019

- About 4000 exoplanets have been discovered
- Many exoplanets are different from planets in our solar system (Hot Jupiters, Super earth, …)
- Formation and evolution mechanisms are not clear

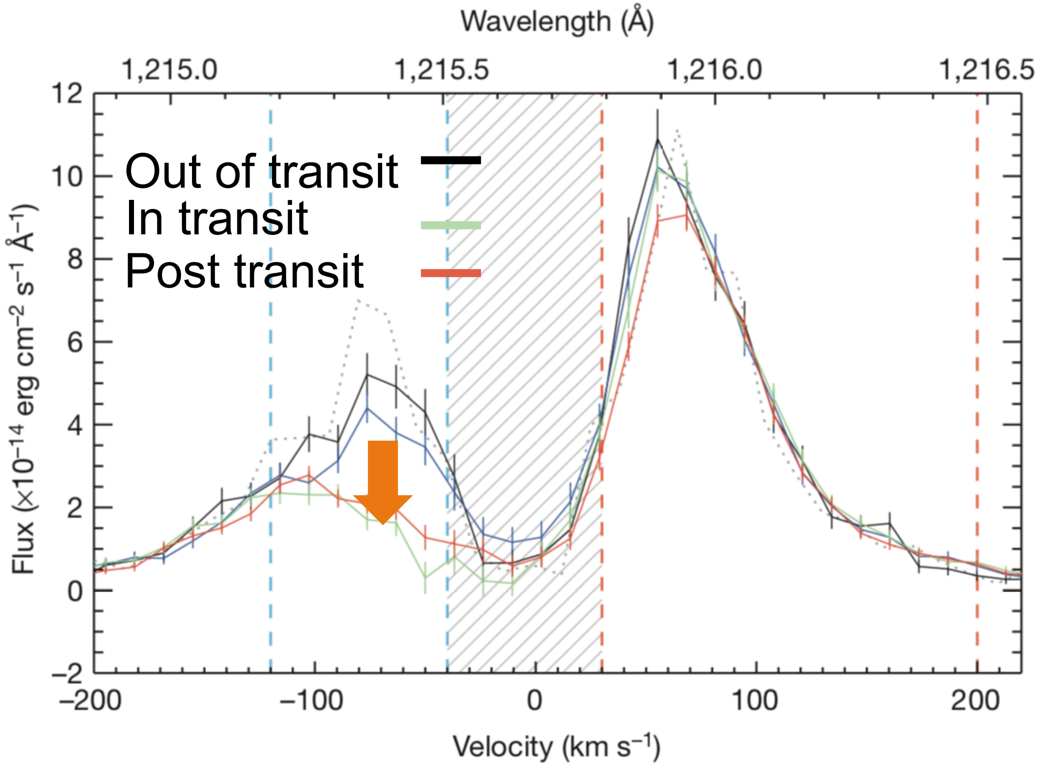
OBSERVATIONS OF ATMOSPHERIC ESCAPE

Artistic image of atmospheric escape



NASA/European Space Agency/Alfred Vidal-Madjar
(Institut d'Astrophysique de Paris, CNRS)

Lyα Transit observation

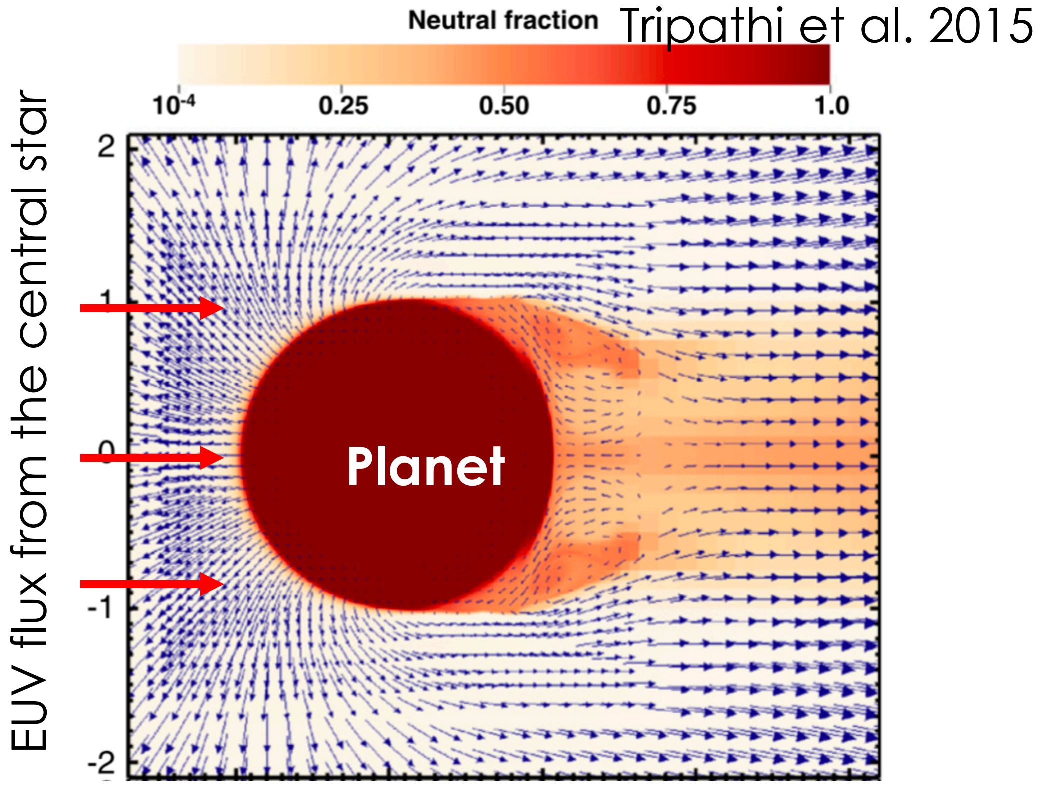


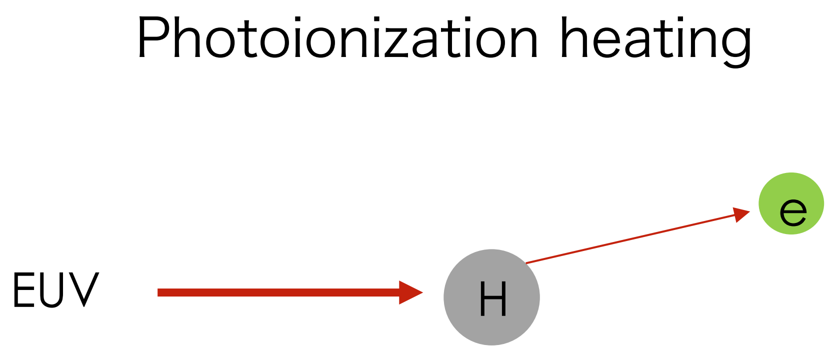
Ehrenreich et al. 2015

- The atmosphere heated by Extreme-Ultraviolet (EUV; >13.6eV) radiation from the central star **hydrodynamically escape**
- Atmospheric escape have been observed by the transit of close-in planets

EUV PHOTOIONIZATION HEATING

Simulation of the escaping atmosphere



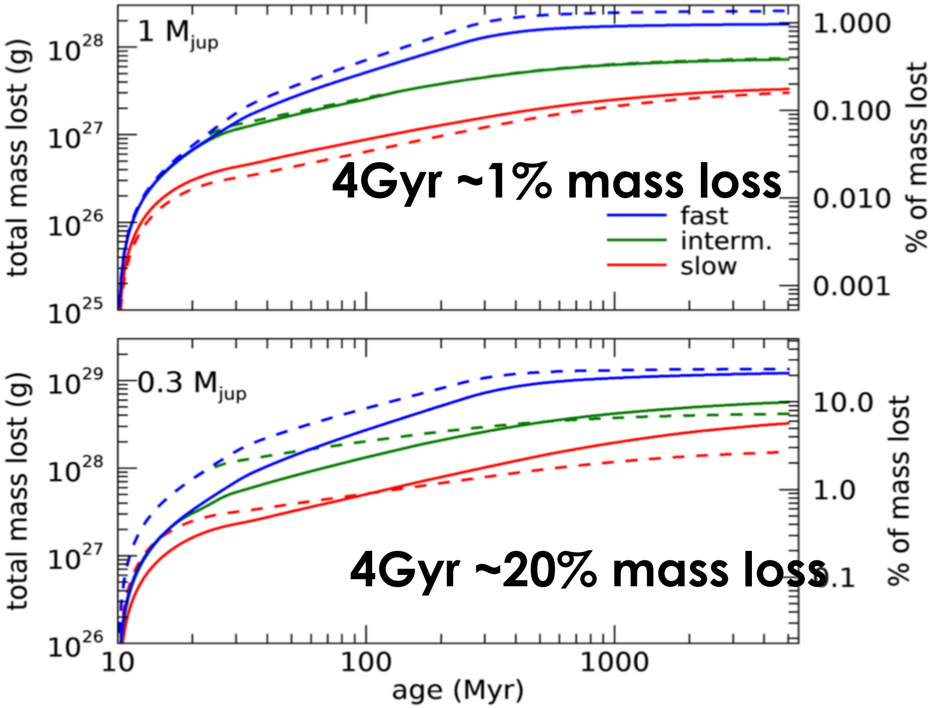


- Theoretical simulation including **Extreme UV(EUV; >13.6 eV) photoionization heating**
- $\dot{M} \sim 10^{9-12} g/s$, Typical hot Jupiters can survive ($t_{esc} \sim 10^{12} yr$)

ATMOSPHERIC ESCAPE AND PLANETARY EVOLUTION

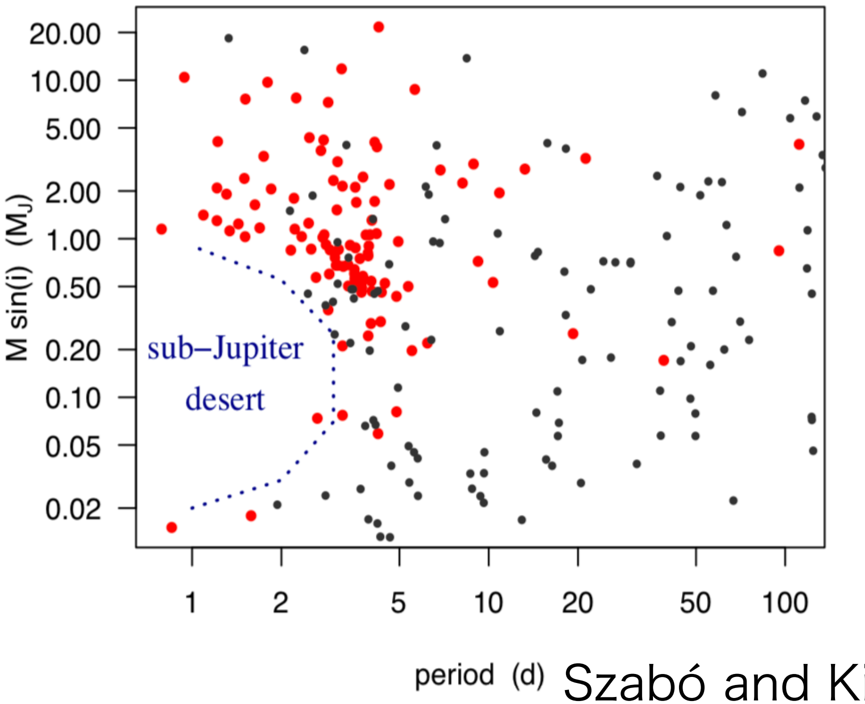
Total mass loss due to escape

Allan & Vidotto 2019



The light planets lose a lot of their mass

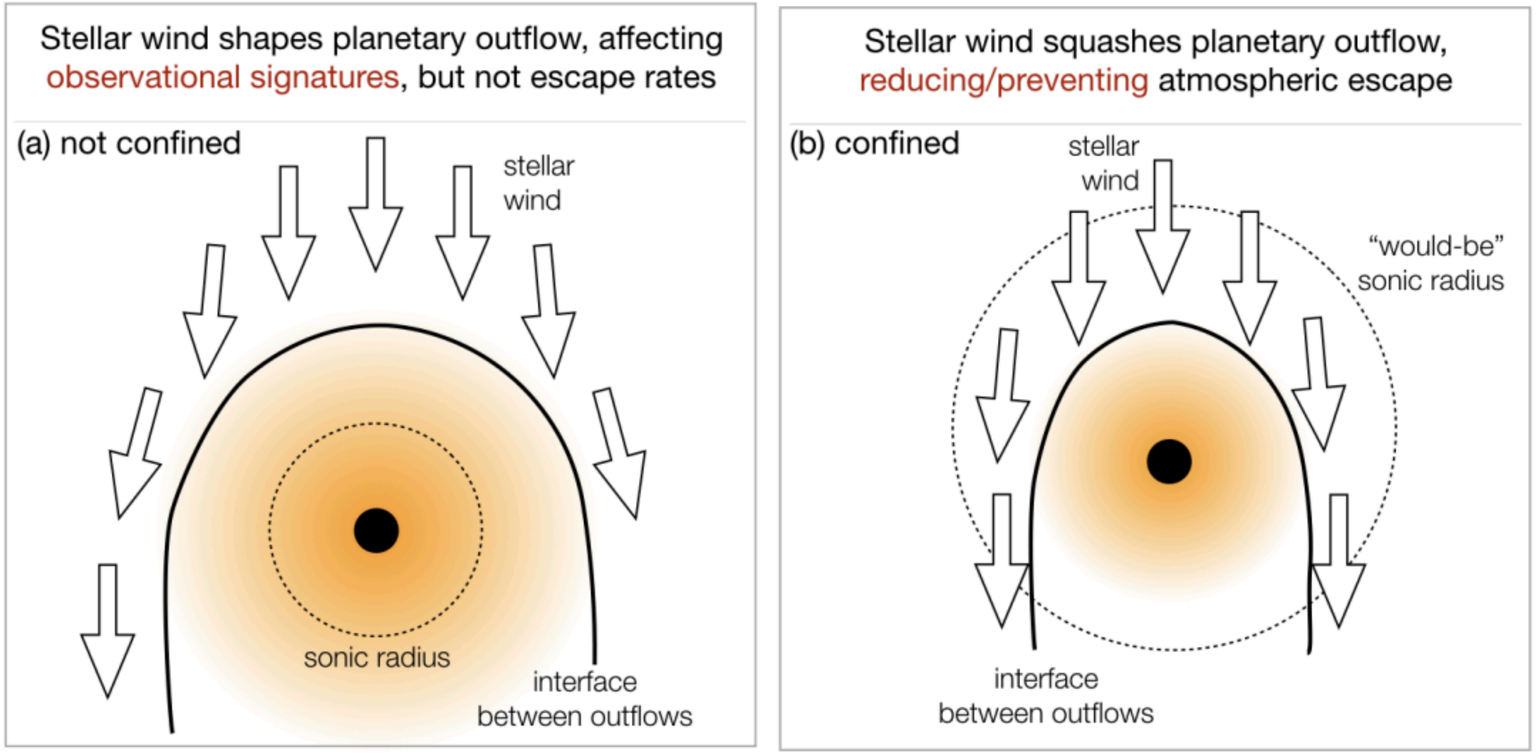
Sub-Jupiter desert



Szabó and Kiss 2011

The small number of light close-in planets

STELLAR WIND AND ATMOSPHERIC ESCAPE



- Stellar wind can confine the atmosphere and reduce the mass-loss rates
- 1D simulation suggests that the wind can be important for some close-in planets around active star

Vidotto & Cleary 2020

Self-consistent simulations in multiple dimensions can be important in explaining observations

METHOD: HYDRODYNAMIC SIMULATION WITH RADIATIVE TRANSFER

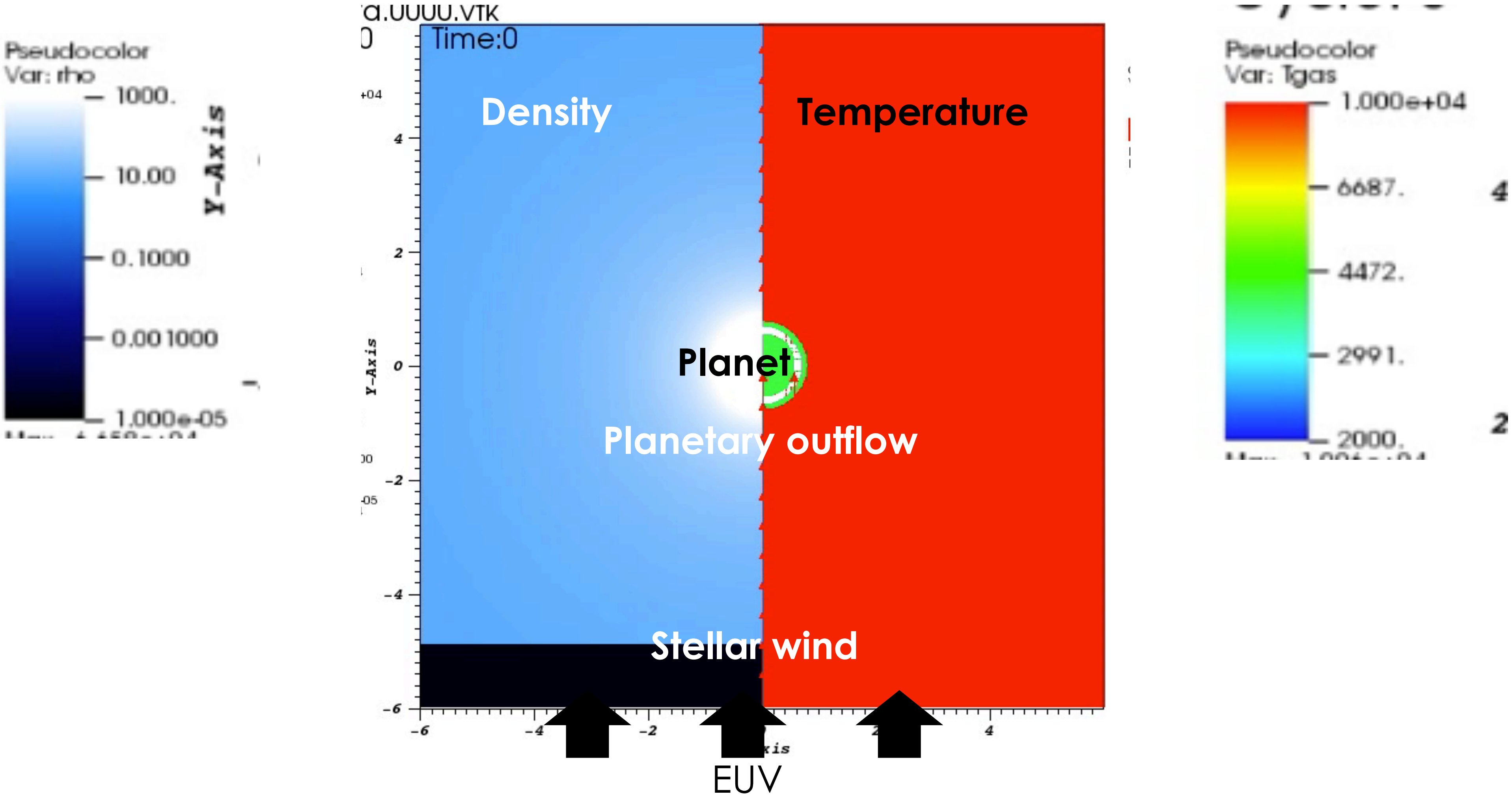
- 2D Hydrodynamics + Radiative Transfer (Nakatani et al. 2018a, Nakatani & Yoshida 2019) + gravity from the planet and the star + centrifugal force
- Light gas giants around 6000K star in Sub-Jupiter desert
- Initial conditions :Upper atmosphere 10000K and lower atmosphere 4000K（Murray-Clay et al. 2009）

Fiducial parameters

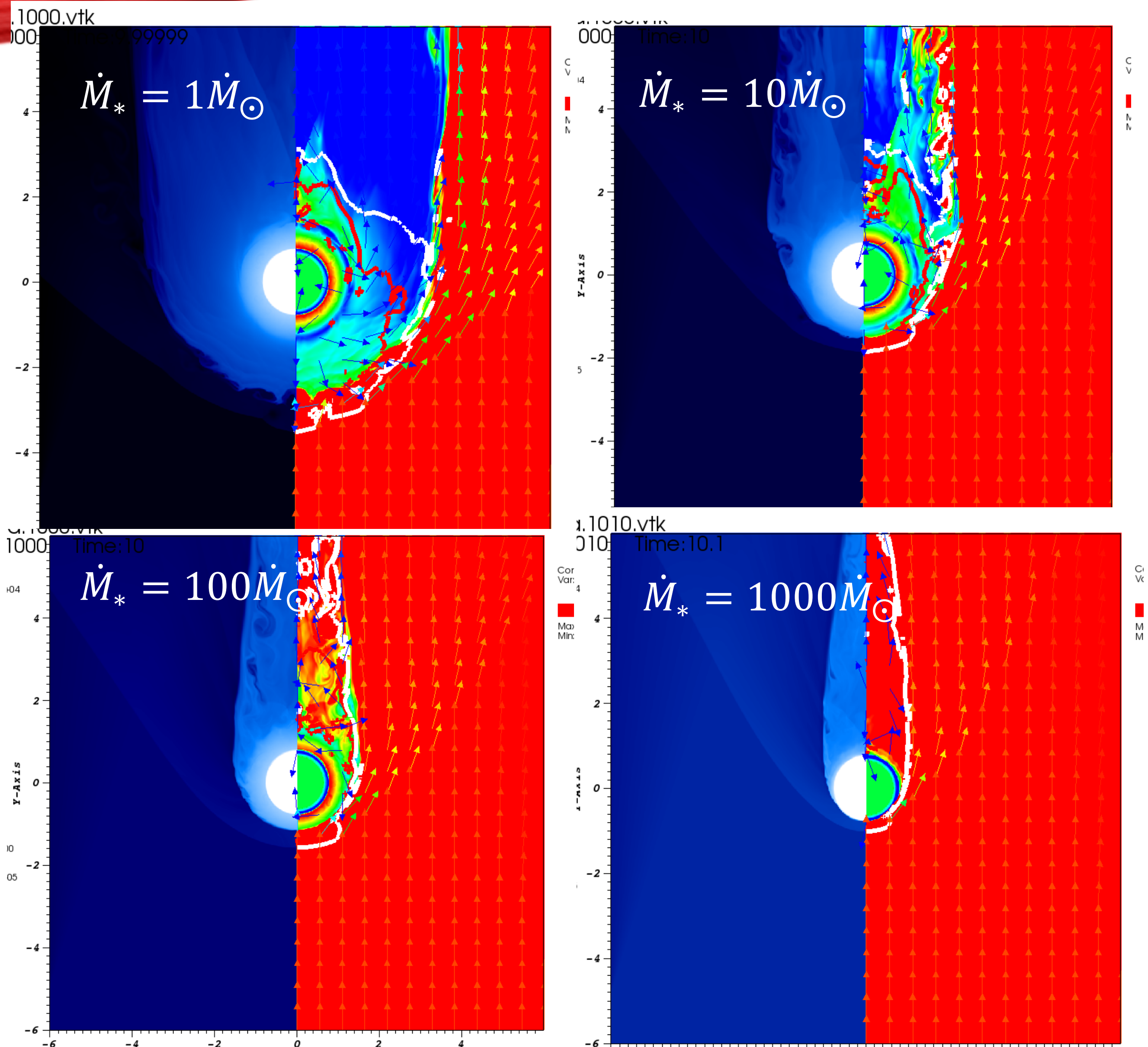
Star mass	$1M_{\odot}$
Star Radius	$1R_{\odot}$
EUV	1.4×10^{38} photons/s
Wind velocity	540km/s
Wind density	$2.5\times10^{3}\ cm^{-3}$
Wind temperature	2MK

planet mass	$0.3M_J$
planet radius	$1R_J$
Semi-major axis	$0.045\ AU$

ATMOSPHERIC ESCAPE WITH STELLAR WIND



STELLAR WIND STRENGTH

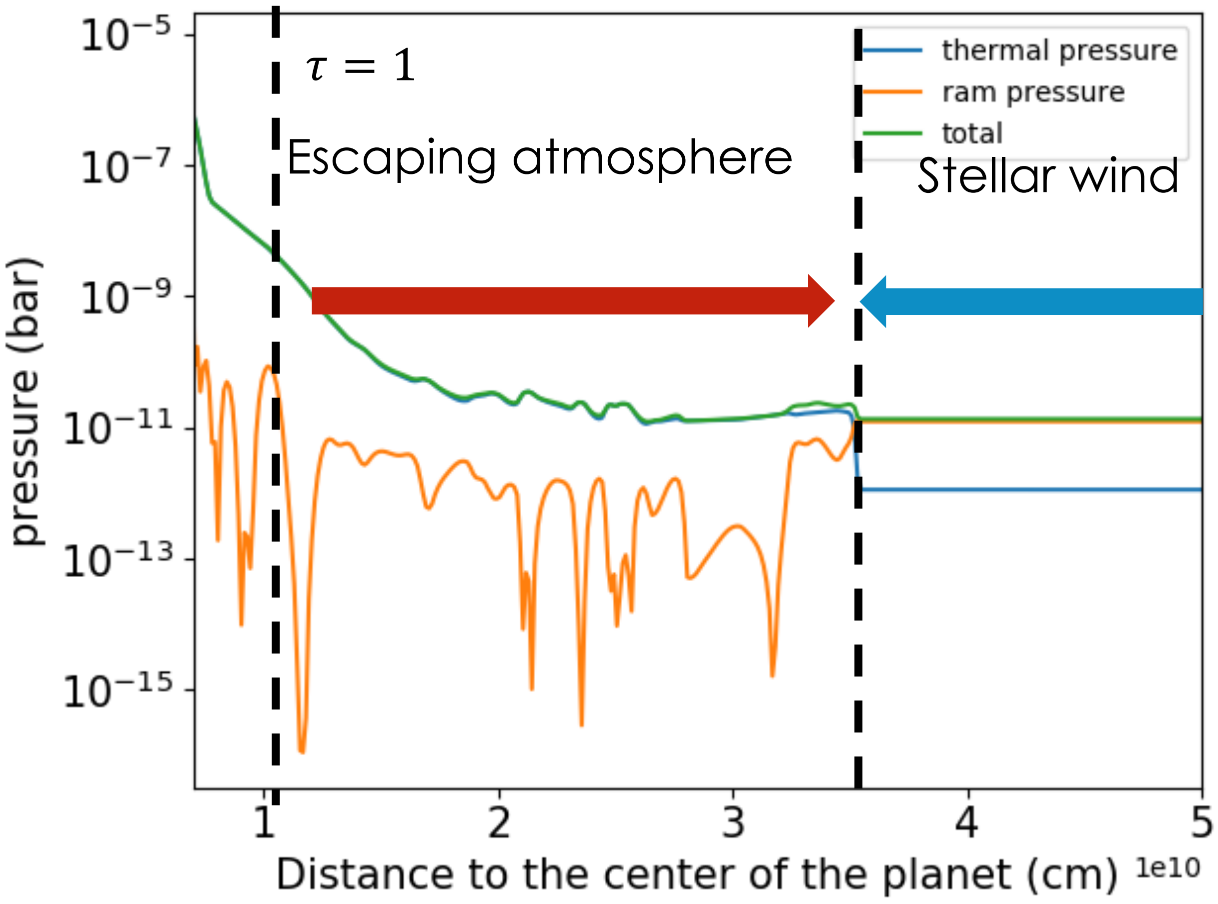


- Strong stellar wind can confine planetary atmosphere
- Escaping atmosphere exists ~5Rp in solar wind case, ~3Rp in 10 solar case, ~2Rp in 100 solar case
  → Reduce the Lya transit radius

$$\dot{M}_\odot = 2\times10^{-14} M_\odot/yr$$

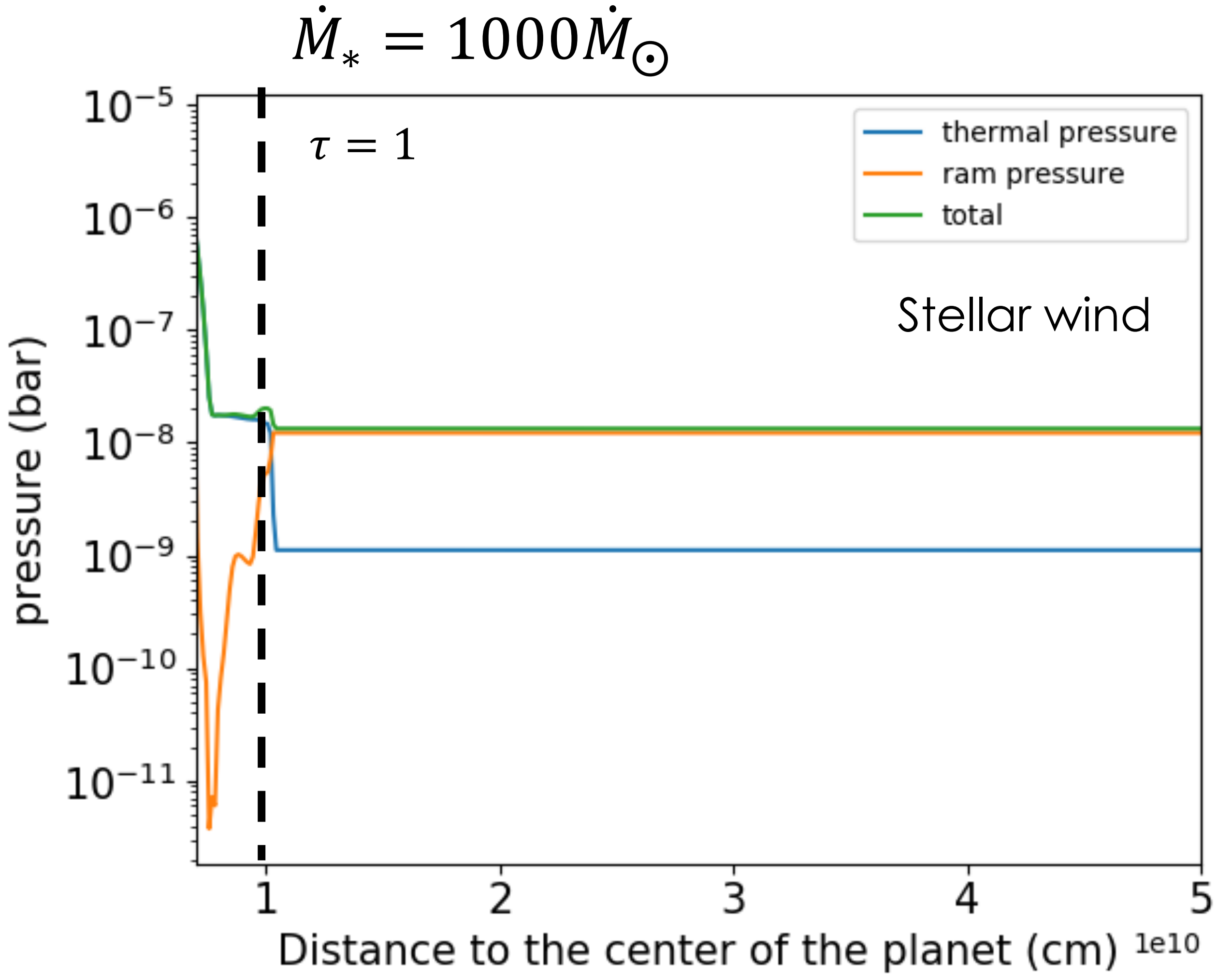
PRESSURE PROFILES

$\dot{M}_* = 1\dot{M}_\odot$



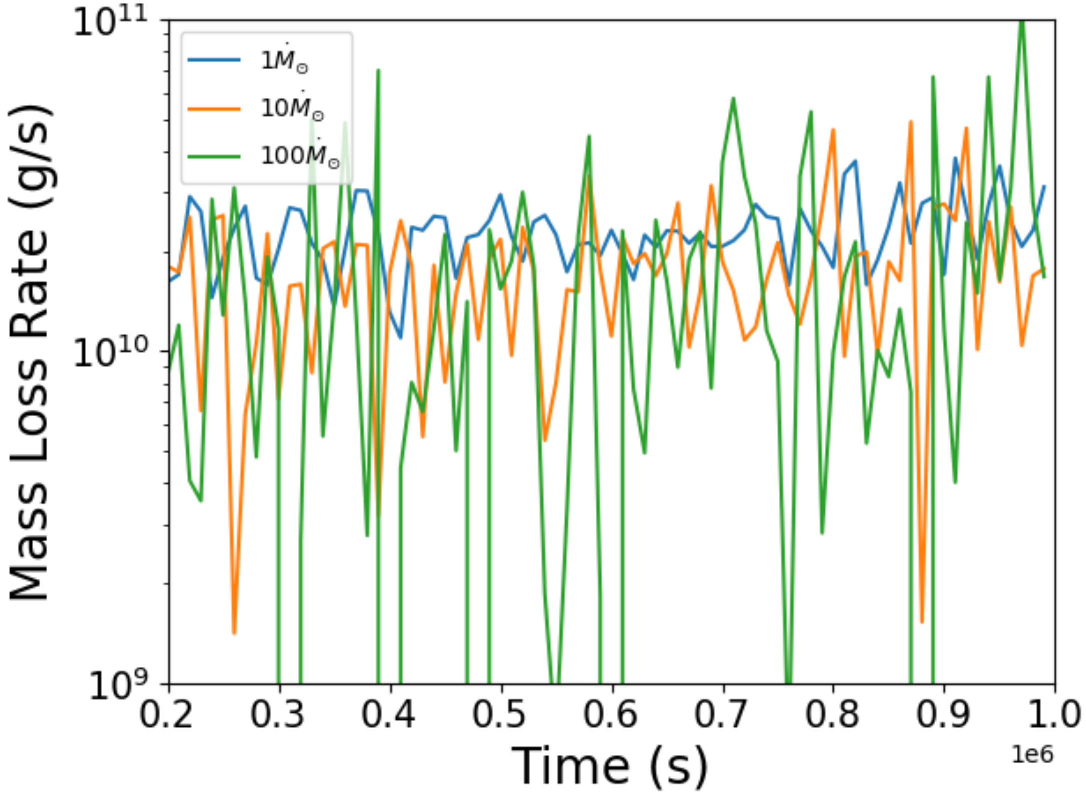
The escaping atmosphere extends to where the ram pressure and thermal pressure are balanced

PRESSURE PROFILES



The escaping atmosphere extends to where the ram pressure and thermal pressure are balanced

STELLAR WIND EFFECT ON PLANETARY EVOLUTION



- The mass-loss rates are independent of the strength of the wind
- $\dot{M}_* = 1000\dot{M}_\odot$: the mass-loss rate becomes small

When the atmosphere is escaping, the rate may not be affected by stellar wind, but when the stellar wind is too strong the rate becomes small because the atmosphere is compressed to the point where EUV can reach

The wind can change the planetary evolution around active star

SUMMARY

- Many close-in giant planets (Hot Jupiters)are detected by recent observation
- Atmosphere of some hot Jupiters escapes due to the heating of EUV radiation from the host star
- Stellar wind from the host star can confine the escaping atmosphere and reduce the transit radius and the radius may determined by the balance of the ram pressure and thermal pressure
- It may not change the planetary evolution unless the stellar wind is extremely strong but can change the observational signature ?

STRONG EUV RADIATION CAN EXTEND ATMOSPHERE AGAINST THE WIND