The impact of Stellar Coronal Mass Ejection and Flare on the atmosphere of hot Jupiter HD189733b and its transit signature

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Context & Aim of Our Study

- Radiation coming from the host star ionizes planetary material and drives planetary outflow (Murray-Clay et al. 2009, Hazra et al. 2020).
- This evaporating planetary atmosphere is observed in hydrogen lines using transit spectroscopy.
- Lecavelier desEtangs et al. 2012 detected a temporal variation in the atmospheric evaporation from HD189733b during two transit events (April 2010 and September 2011).
- During transit event in September 2011, an enhancement in the evaporation rate was found and a flare was also detected 8h before the transit.
- These observations motivate us to study the possible reason for this enhanced evaporation. Is it because of a flare or a CME or an effect of Both?

Our 3D radiation hydrodynamic model

We solve 3D radiation hydrodynamics equations including photoionization, collisional ionization and radiative recombination and corresponding heating and cooling

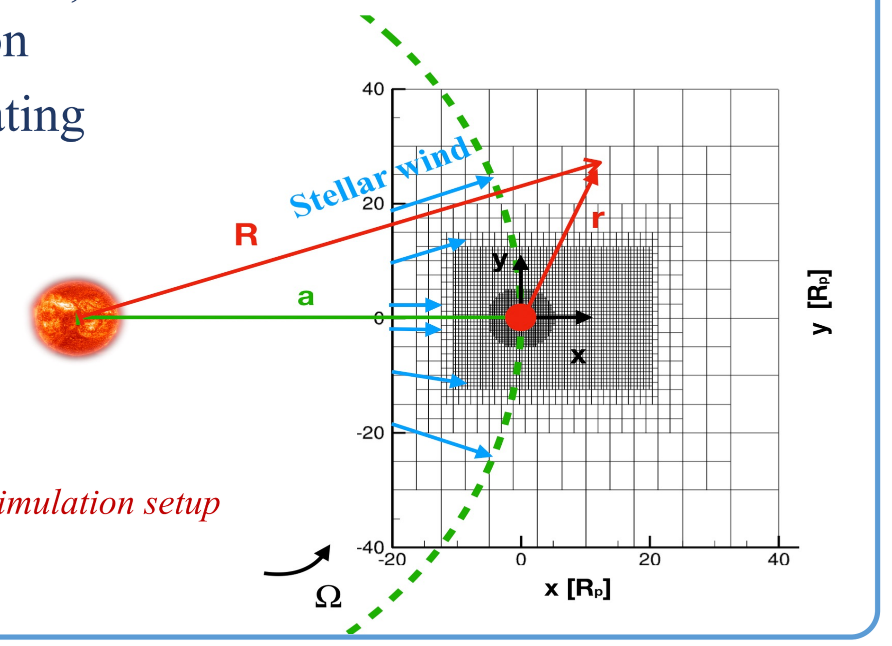
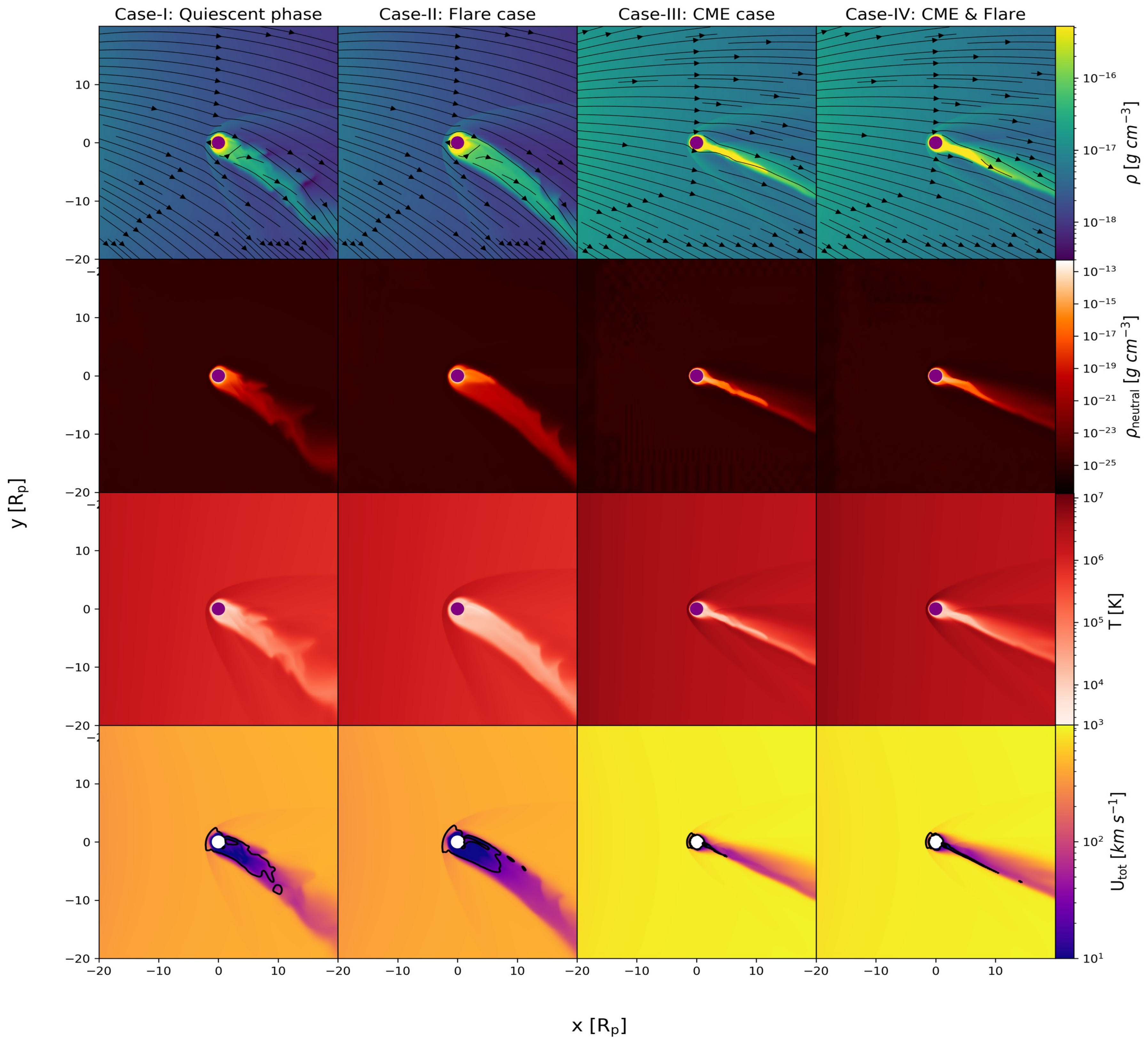


Fig1: Simulation setup

Effect of stellar transients on the planetary outflow

We study four cases to investigate the effect of stellar transients after planetary outflow self-consistently driven by stellar heating:

Case-I: Quiescent phase, Case-II: a Flare case, Case-III: a CME case and Case-IV: CME & Flare



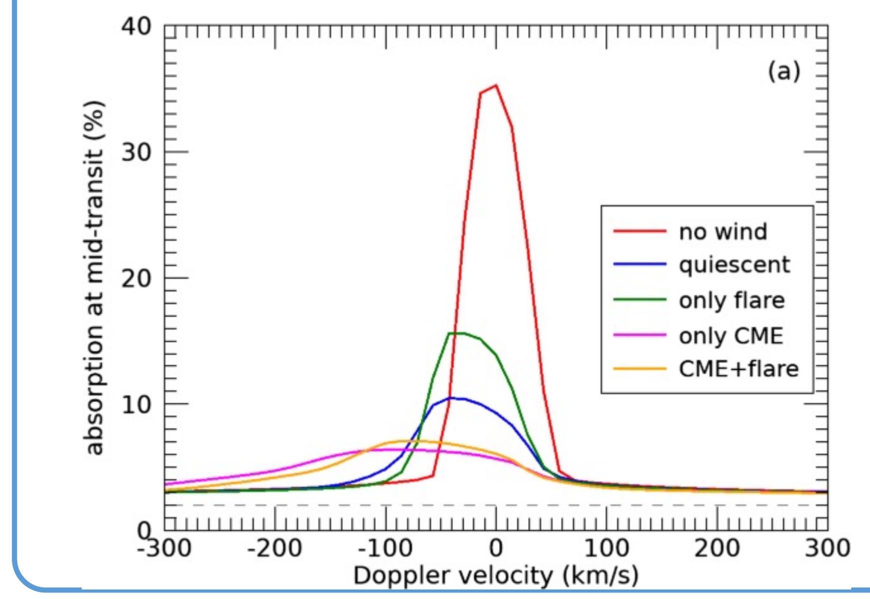
Different parameters (density and speed of stellar wind/CME) and Mass loss rate from the planet

Cases	L_{XUV} ($10^{-5} L_\odot$)	density (g cm^{-3})	speed (km s^{-1})	$\dot{M}_p$ (10^{11} g s^{-1})
Planetary outflow only	3.4	–	–	0.6
I Quiescent phase	3.4	5.3×10^{-18}	315	0.8
II Flare case	11	5.3×10^{-18}	315	1.0
III CME case	3.4	2.1×10^{-17}	755	3.2
IV CME & Flare	11	2.1×10^{-17}	755	4.0

Fig2:Total density, neutral density, temperature and total velocity in the orbital plane of the planet

- The CME & flare case has a mass loss rate which is almost one order of magnitude larger than quiescent phase of the star
- We use the neutral density, velocity and temperature from our simulation to calculate transit spectra for our four cases.

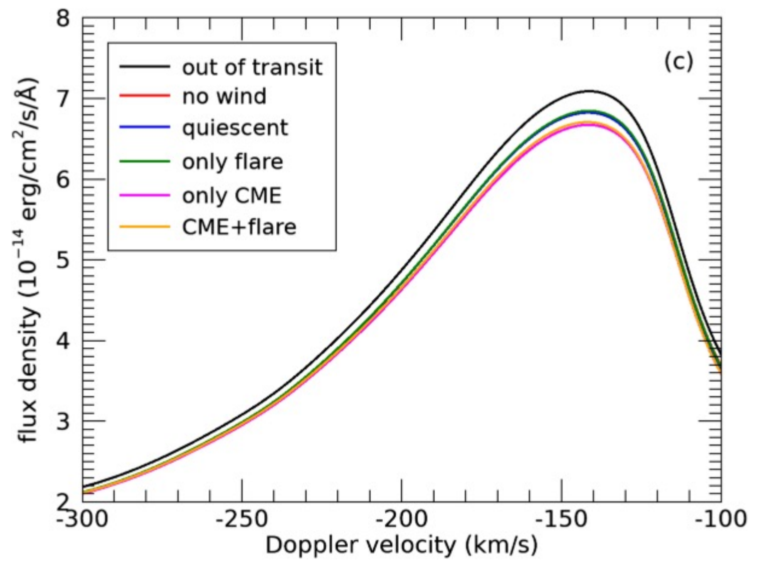
Synthetic Transit Observation: Ly-alpha line



Synthetic Transit spectra as a function of doppler velocities for four cases considered here. We include a no stellar wind case to compare with the four cases.

Predicted line profile, convolved with the line spread function of the G140Mgrating mode in the blue wing.

CME case shows the largest absorption in the blue wing among all cases.



Conclusions

- **We have developed a self-consistent radiation driven planetary outflow model with photoionization, where we can track protons and neutrals separately.**
- **Four cases are considered to study the impact of stellar transient events: quiescent case, a flare case, a CME case and CME + flare both.**
- **We find that a flare followed by a CME is most effective to remove the planetary material with highest mass loss rate of 4.0 x 10^11 g/s**
- **The observed blue wing absorption for HD189733b is closely reproduced in our model when we consider only the effect of CME**

References

1. **Murray-Clay R. A., Chiang E. I., Murray N., 2009, ApJ, 693, 23**
2. **Lecavelier des Etangs A., et al., 2012, A&A, 543, L4**
3. **Hazra G., Vidotto A. A., D'Angelo C. V., 2020, MNRAS, 496, 4017**
4. **Hazra G., Vidotto A. A., Carolan, S., D'Angelo C. V., Manchester, W, 2021,, MNRAS, 509 (4), 5858-5871**

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