INVESTIGATING **CORE INDUCTION EFFECT** ON **ATMOSPHERIC ESCAPE** AND IMPLICATIONS FOR **HABITABILITY**

Laura Chin[1] Chuanfei Dong[1] Yuxi Chen[2]

lrchin@bu.edu

[1] Department of Astronomy, Boston University, Boston, MA
[2] Center for Space Environment Modeling, University of Michigan, Ann Arbor, MI

BACKGROUND

A rocky planet is considered habitable if it can retain an atmosphere capable of sustaining liquid water on its surface over long timescales. However, atmospheric ions in the upper atmosphere are susceptible to non-thermal escape processes, particularly during periods of intense stellar activity. An intrinsic planetary magnetic field may mitigate this loss by shielding the upper atmosphere from direct interaction with the stellar wind, thereby enhancing atmospheric retention and improving the planet's prospects for long-term habitability.

In the process of magnetized stellar wind-planet interaction, the **core induction effect** allows a planet's conducting core to generate additional magnetic fields. This effect has been studied at Mercury [1,2], which possesses a large conducting core (~80% of the planetary radius). Could the core induction effect protect the atmospheres of close-in rocky exoplanets with large conducting cores?

METHODS + MODEL SETUP

MODEL

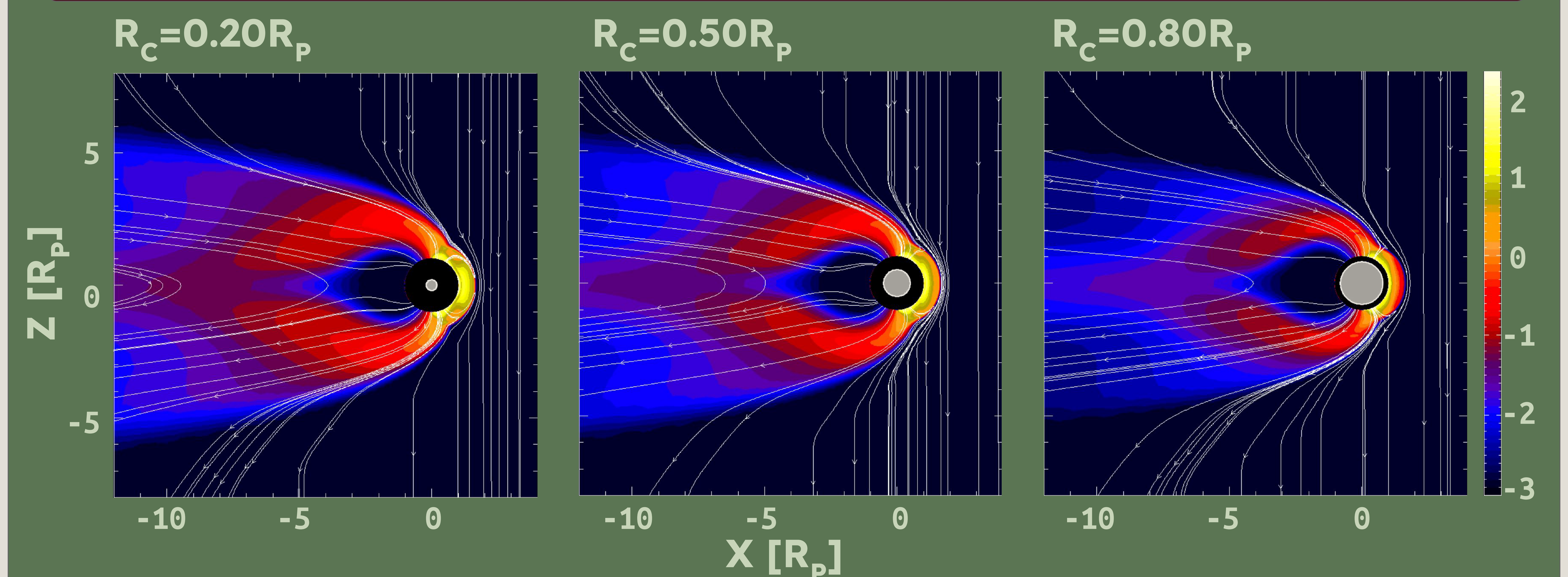
We use the **BATS-R-US** multispecies MHD code [3,4], which has been extensively applied to studies of solar system planets (e.g. Venus, Earth, and Mars) and rocky exoplanets [5], including Proxima Centauri b (PCb) [6].

PARAMETERS

		(Exo)Planet Analog
Stellar Wind	$n = 4245\ cm^{-3}$ $T = 10.0e5\ K$ $v = (-1937.5, 6.7, -13.0)\ km/s$ $B = (0,23.\ 0, -194.3)\ nT$	Early (~4 Gya) Solar CME event with 10x higher density
Mass*	$M \sim 1.27\ M_{Earth}$	PCb
Radius	$R \sim 1.1\ R_{Earth}$	Earth, Venus, PCb
Core	$R_C = 0.20, 0.50, 0.80\ R_P$ Dipole = ½ Earth (15000 nT)	Moon, Earth, Mercury Early (~4 Gya) Earth
Atmosphere	Scale height = $0.85H_{Venus}$ Composition = CO_2-dominated	PCb Venus

[PRELIMINARY] ESCAPE RATES

O^+ LOG-SCALE CONTOUR PLOTS

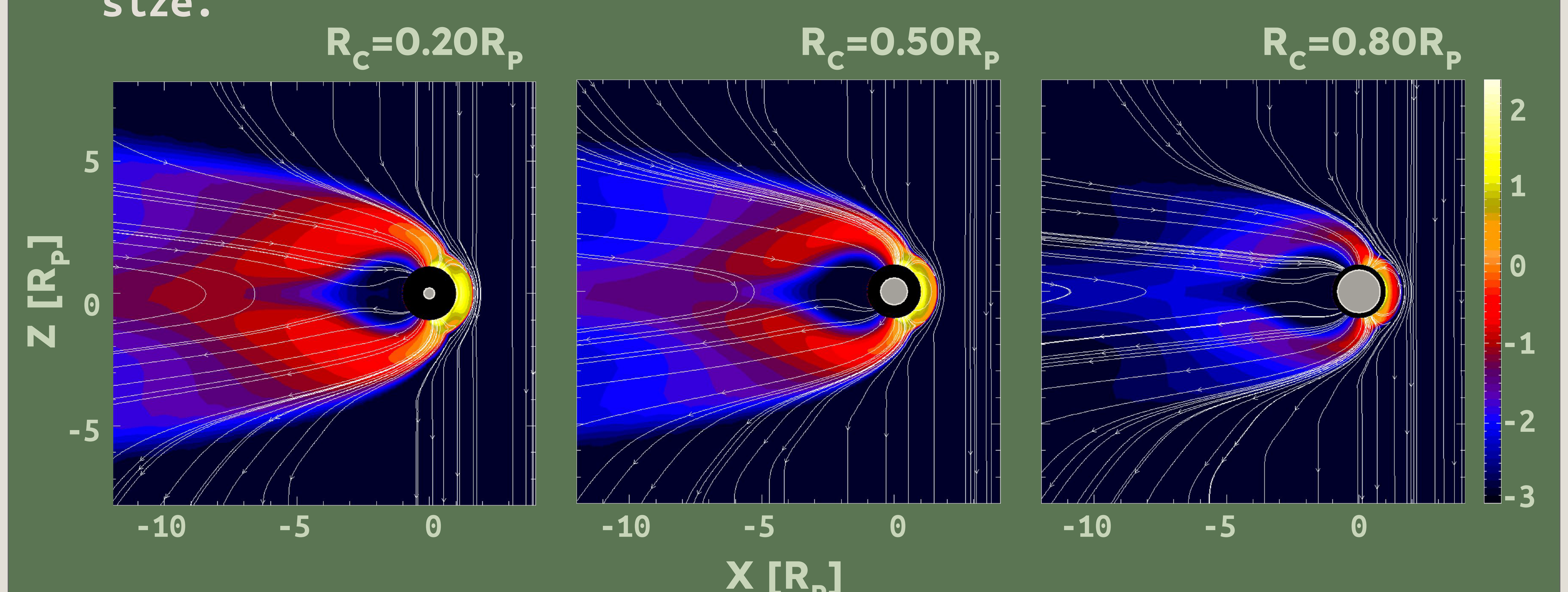


▲ **Induction effect only:** planets all have the same mass and scale height.

Total ion escape rate ~2x lower for planet with largest core compared to smallest

▼ ***Gravity + induction effect:** planet mass and atmospheric scale height calculated more self-consistently with core size.

Even more significant difference in total ion escape rate: ~5x lower for planet with largest core vs smallest



DISCUSSION + NEXT STEPS

Preliminary results indicate that the planet with the largest conducting core exhibits the lowest atmospheric ion escape rate. This result signifies that planets with larger conducting cores may have better prospects for habitability.

Beyond the core induction effect, planets with larger cores are also more **massive** than planets with the same radius and smaller cores. Planetary mass positively correlates with escape velocity—the heavier the planet, the higher its escape velocity. Combined with the core induction effect, this relationship **amplifies** the trend between core size and ion escape rate.

Going forward, we will continue running the simulations to ensure they have reached a steady state.

ACKNOWLEDGEMENTS

This work is supported by the Clare Boothe Luce Fellowship and NASA grant 80NSSC23K1115. Computational resources provided by the NASA High-End Computing (HEC) Program. The Space Weather Modeling Framework (SWMF) that comprises BATS-R-US is publicly available: https://github.com/SWMFsoftware/BATSRUS

REFERENCES

[1] Jia, X., Slavin, J.A., Gombosi, T.I., et al. 2015, JGR: Space Physics, 120, 4763-4775.
[2] Dong, C., Wang, L. Hakim, A., et al. 2019, GRL, 46, 11584-11596
[3] Ma, Y.J., Nagy, A.F., Russell, C.T., et al. 2013, JGR: Space Physics, 118, 321
[4] Tóth, G., van der Holst, B. Solkolov, I.V., et al. 2012, JCP, 231(3), 870-903
[5] Chin, L., Dong, C., Lingam, M. 2024, ApJL, 963, L20
[6] Dong, C., Lingam, M., Ma, Y., Cohen, O. 2017, ApJL, 837(2), L26