

Exo-Io Simulations of Toroidal Exospheres in Alkali Spectroscopy

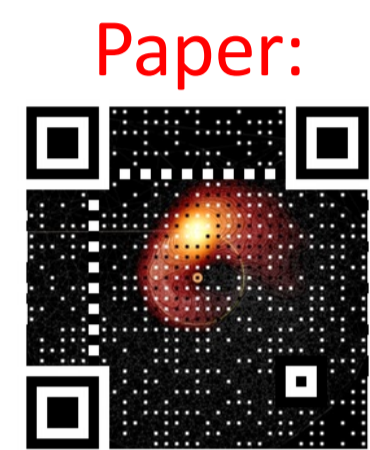
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Summary

- Although **exomoons**, natural satellites beyond our solar system, are still undetectable in direct searches with state-of-the-art instruments, their existence has been hypothesized to explain various **inconsistencies in exoplanetary spectra**.
- We develop a **3D test-particle Monte Carlo simulation** module called **SERPENS** and simulate the **neutral outgassing and evolution of a satellite** at multiple candidate exoplanet-exomoon systems to provide a **number density** and a **line-of-sight column density** map of the evolving particle environment.
- Our results demonstrate how exomoons similar to Io, referred to as **exo-Ios**, can affect line-of-sight column densities depending on the phase of the exomoon at the time of observation. Thus, it is possible to **model time-variable spectra by taking into account the phase of the exomoon**.



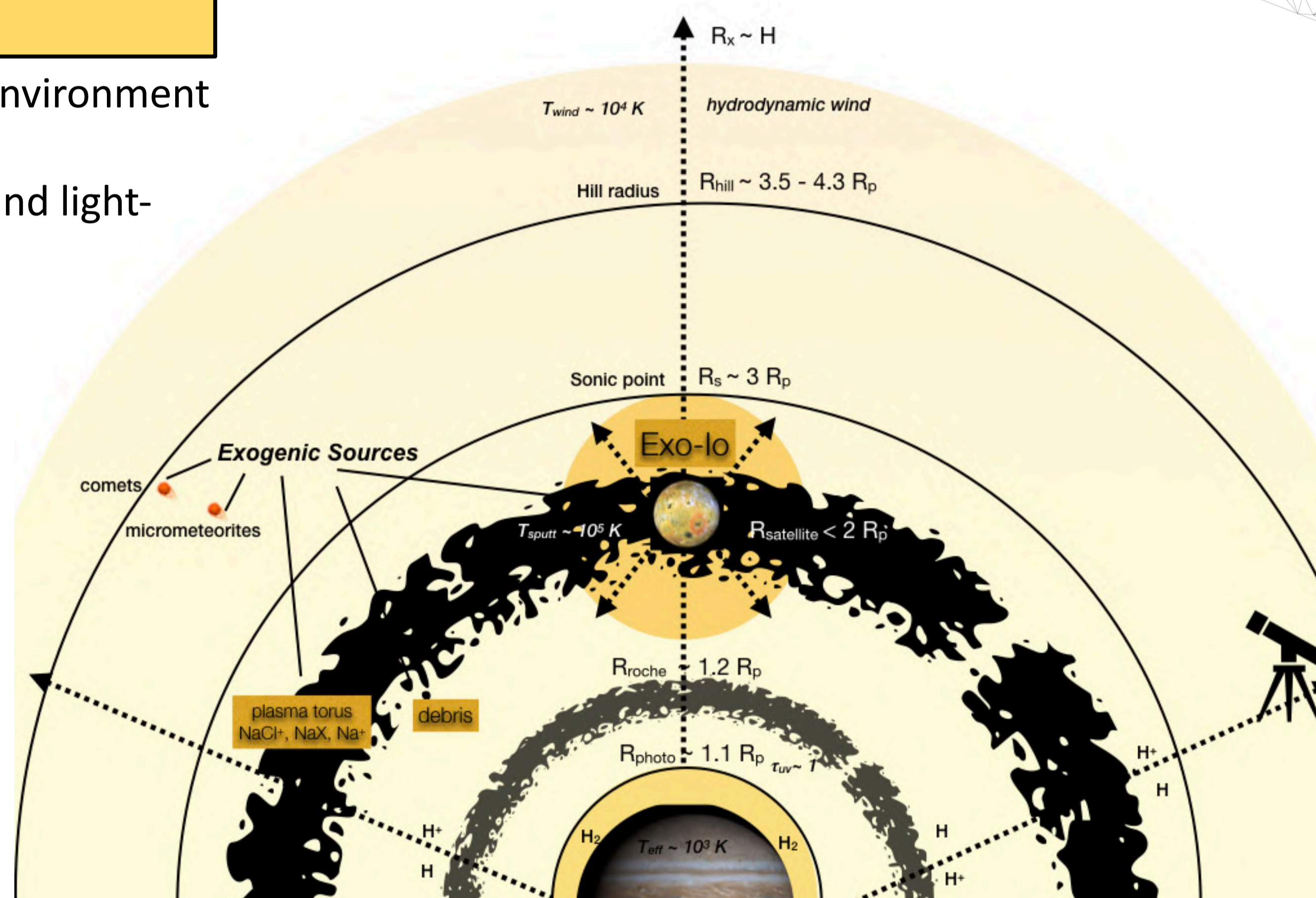
Paper:

Introduction & Goals

- Rocky exomoons are very small, so an **active** environment is needed to indicate their presence
→ Signatures in transiting exoplanet spectra and light-curves
- Tidal heating keeps orbit stable
- Predictions for future **high-resolution spectroscopy** by simulating particle evolution

What is an exo-Io ?

- Extreme **volcanism** because of **tidal heating**
→ Alkaline **atmosphere**
→ **Sputtering** as mass-loss mechanism
→ Emergence of a **particle torus**



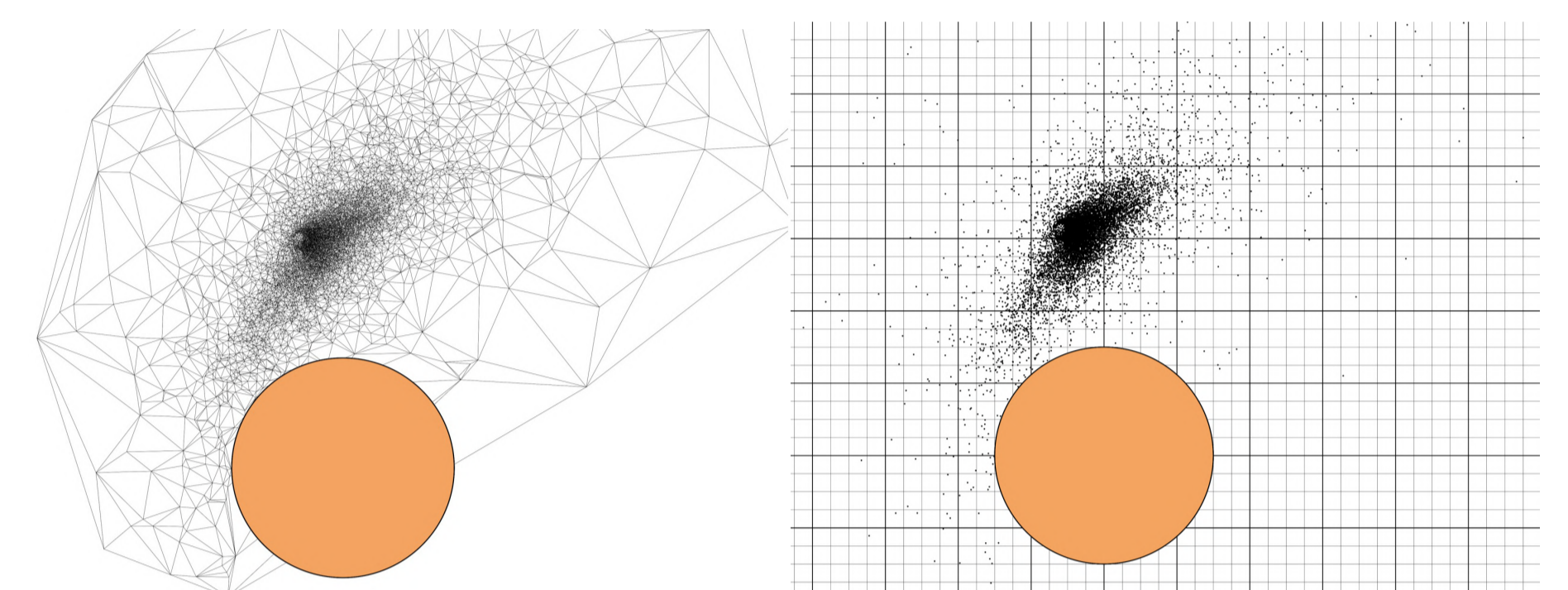
Methods

SERPENS

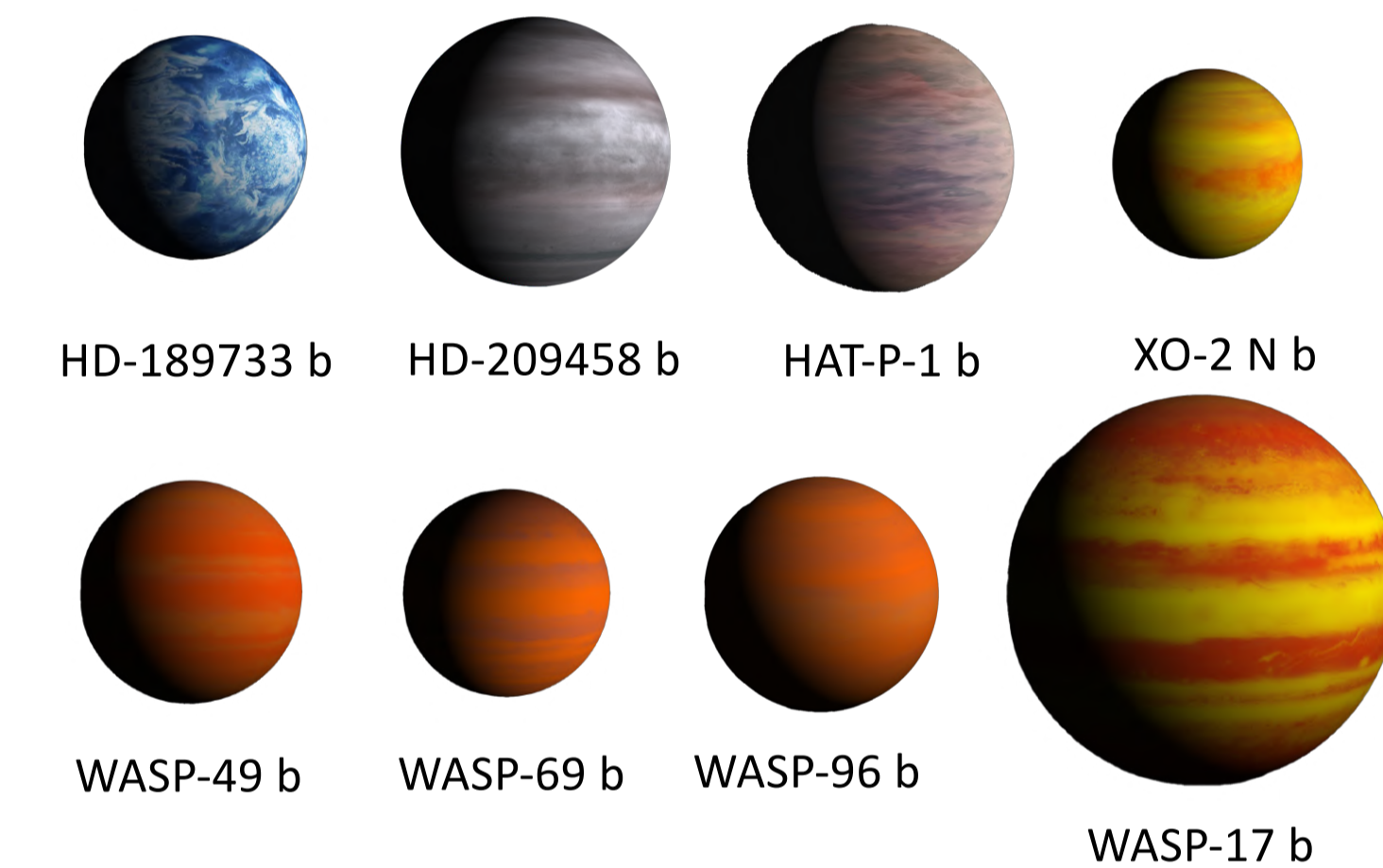
Simulating the Evolution of Ring Particles Emergent from Natural Satellites

- Test-particle Monte-Carlo simulation
- Open-Source & highly adaptive (<https://github.com/momzw/SERPENS>)
- Focused on neutral particles
- Inclusion of radiation pressure

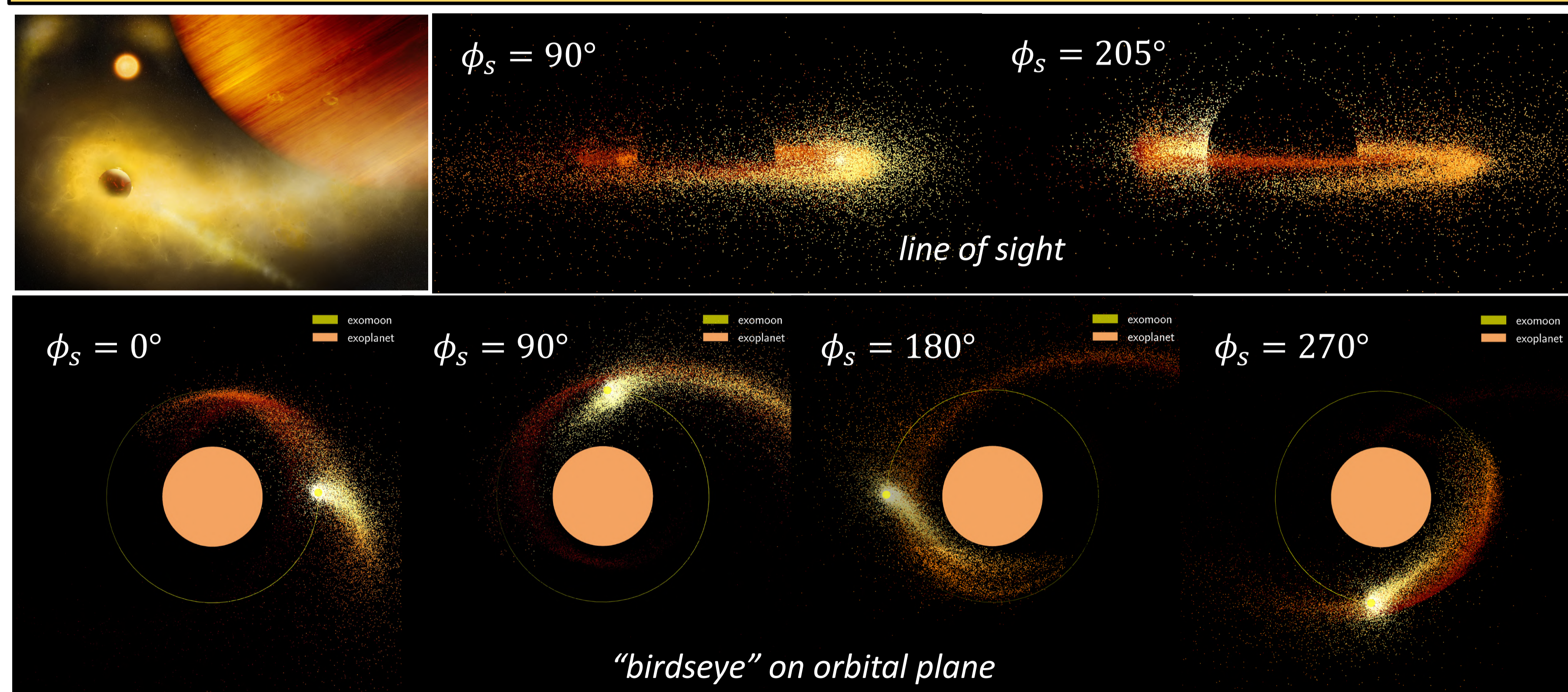
New Approach to Density Calculation:
The Delaunay Tessellation Field Density Estimation



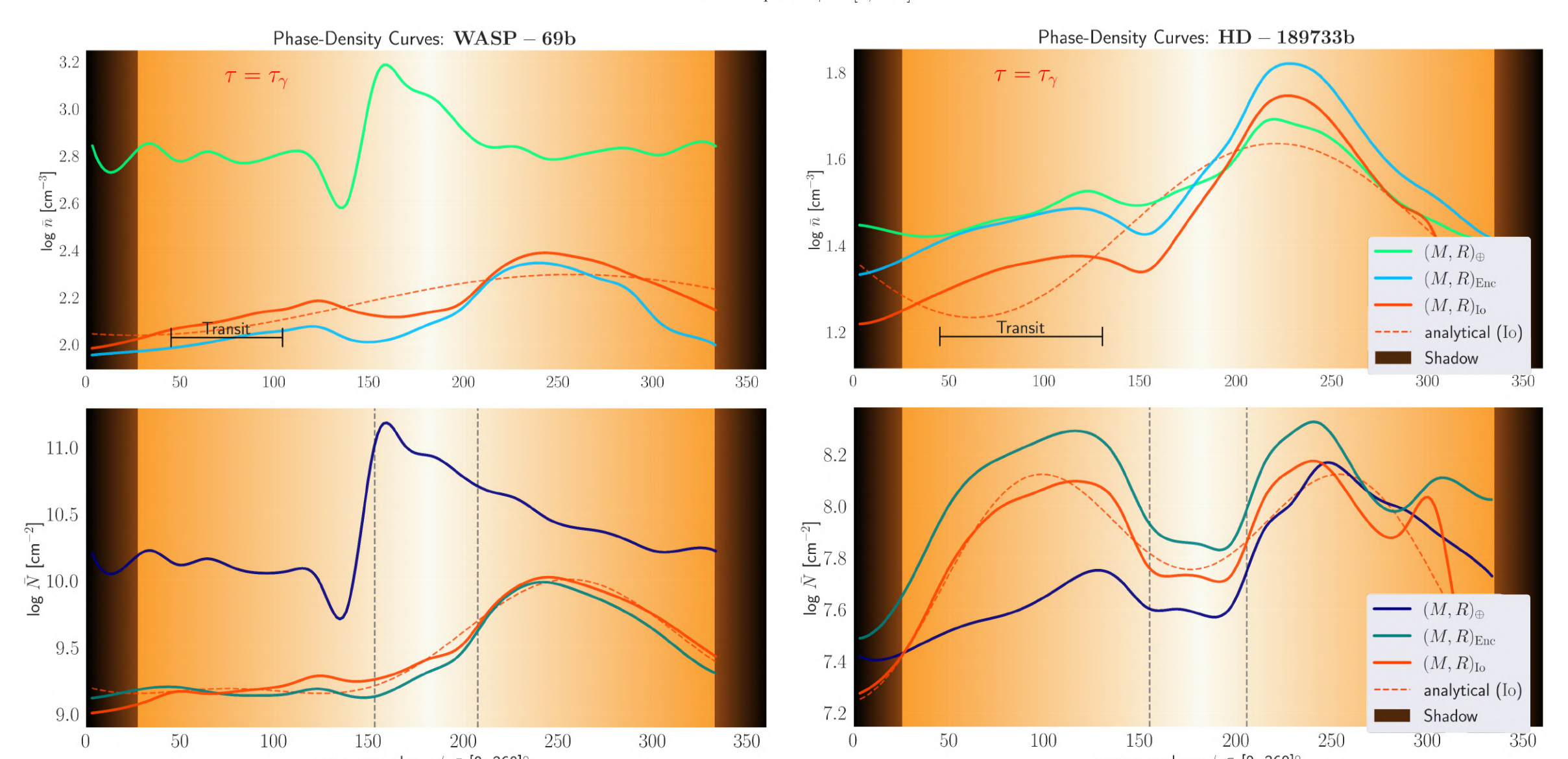
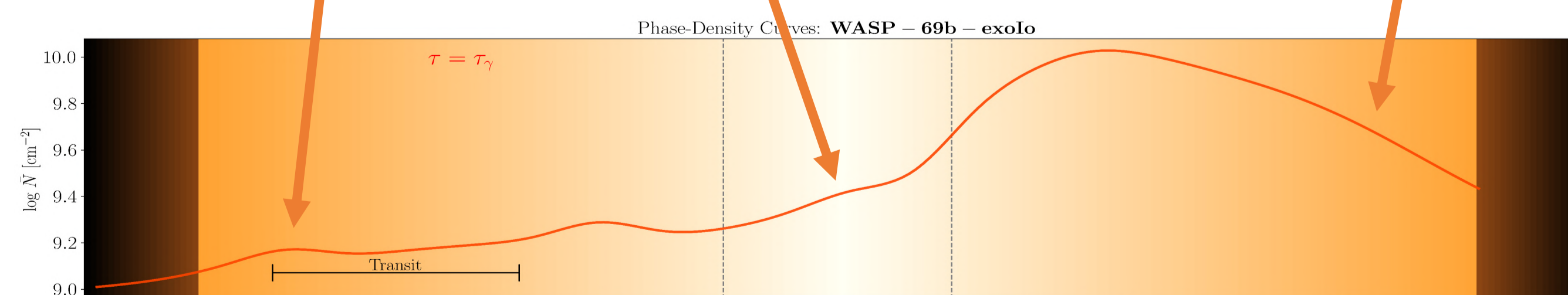
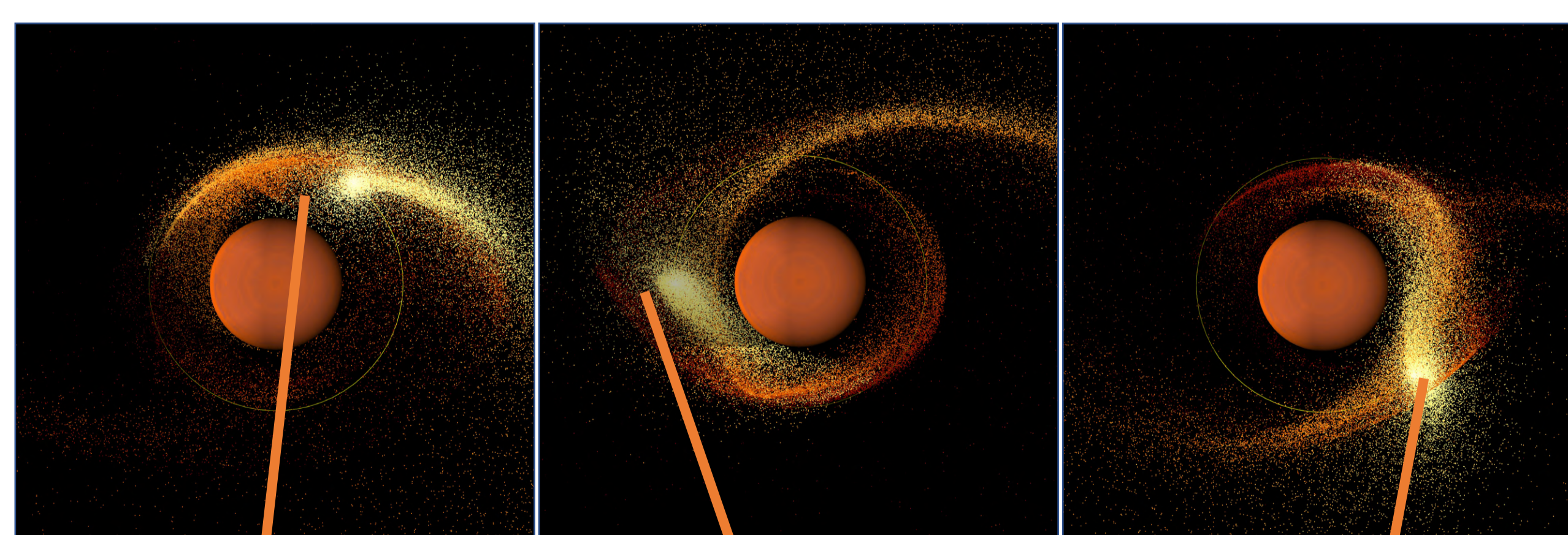
Candidate Systems



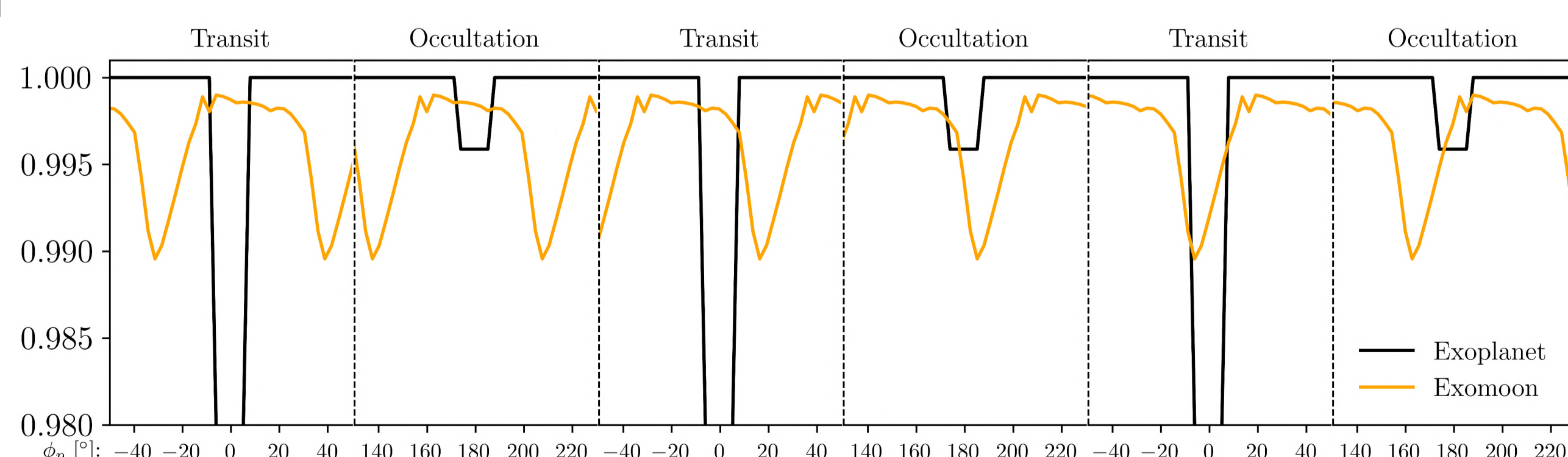
Results



- Toroidal structures emerge if lifetimes of species are long enough or exomoon mass-loss rates are large.
- Continuous evaporation is necessary when intense radiative forces are present.
- Spectral depth variations in transit spectra might be explainable by evaporating exomoons.



Watch our simulations on **YouTube!**



References

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