



Mirage Earths

*Extreme Water Loss and Abiotic O₂
Buildup in the Habitable Zones
of M Dwarfs*

Rodrigo Luger and **Rory Barnes**

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The Big Picture

M dwarfs: the best targets

Scalo et al. (2007), Ricker et al. (2010)



Terrestrial planets are easiest to detect around low-mass stars

Rapid planet formation

Raymond et al. (2007), Lissauer (2007)



Both *in situ* formation and disk-driven migration into the HZ occur in $\lesssim 10$ Myr

Extended pre-MS phase

Baraffe et al. (1998), Lissauer (2007)



M dwarfs can take up to ~ 1 Gyr to reach the main sequence

Long activity timescales

Scalo et al. (2007), West et al. (2008)

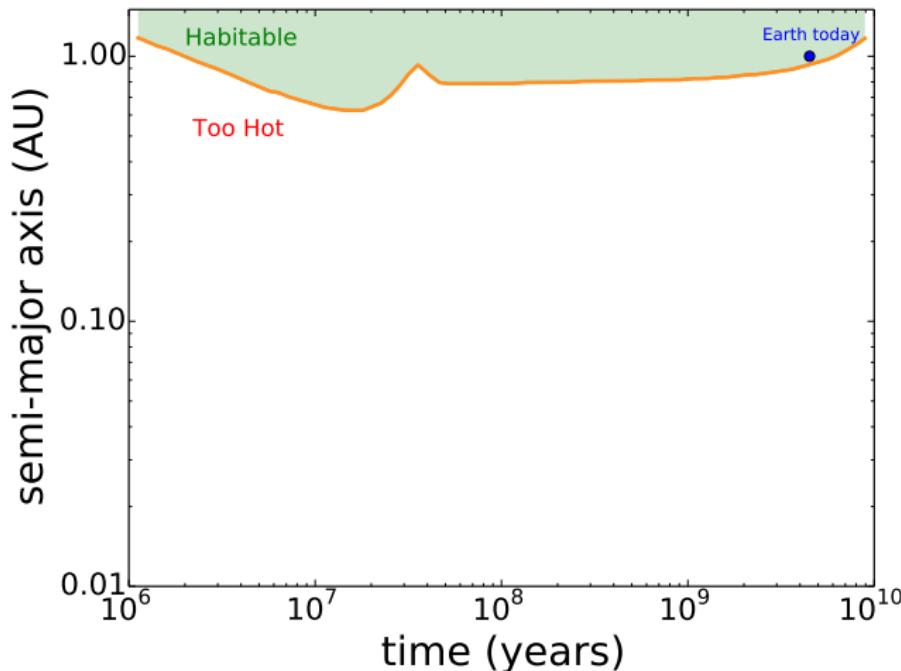


High X-ray/EUV fluxes in the HZ for up to a few Gyr



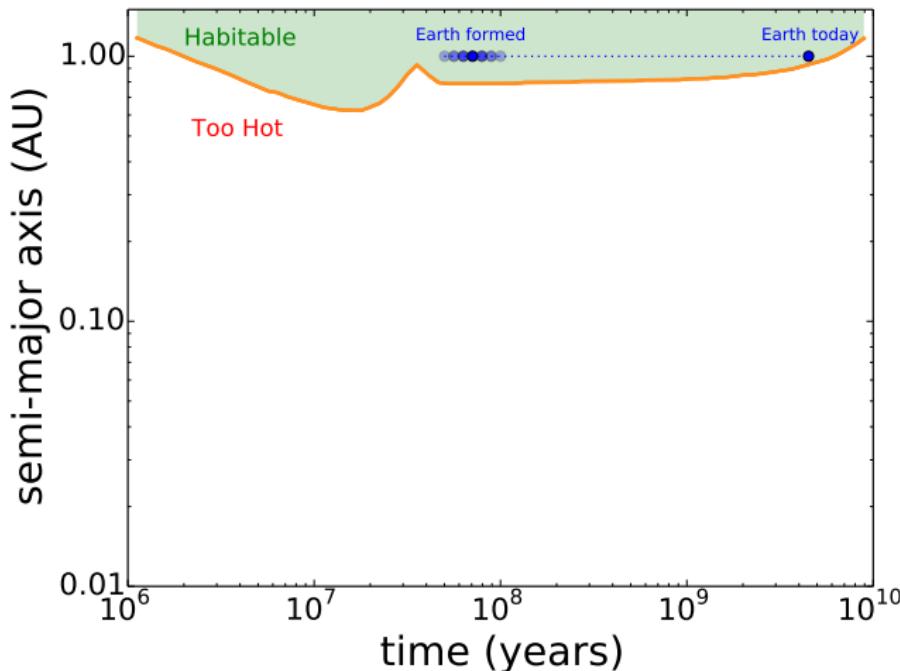
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Pre-Main Sequence Evolution



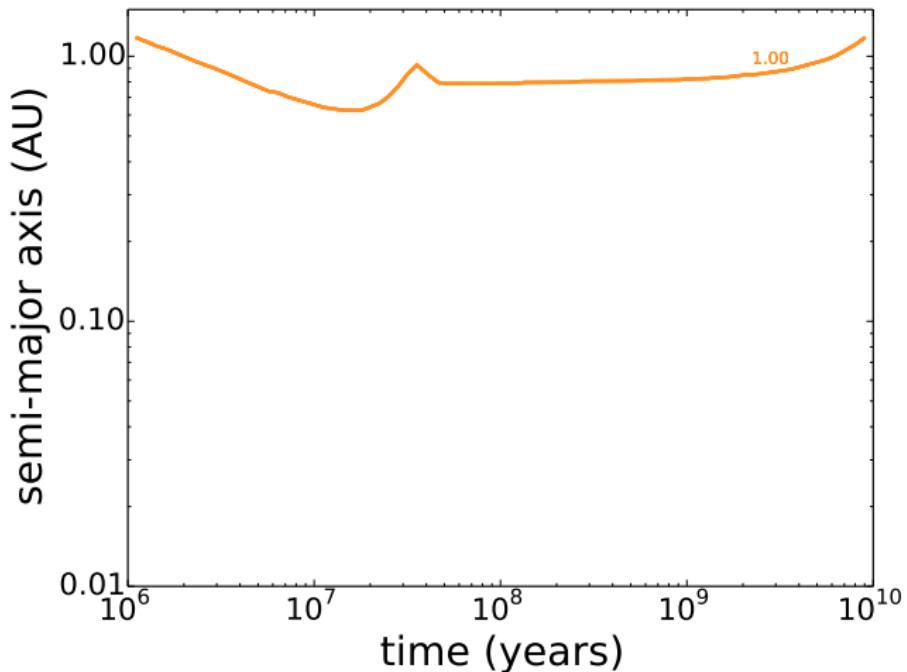
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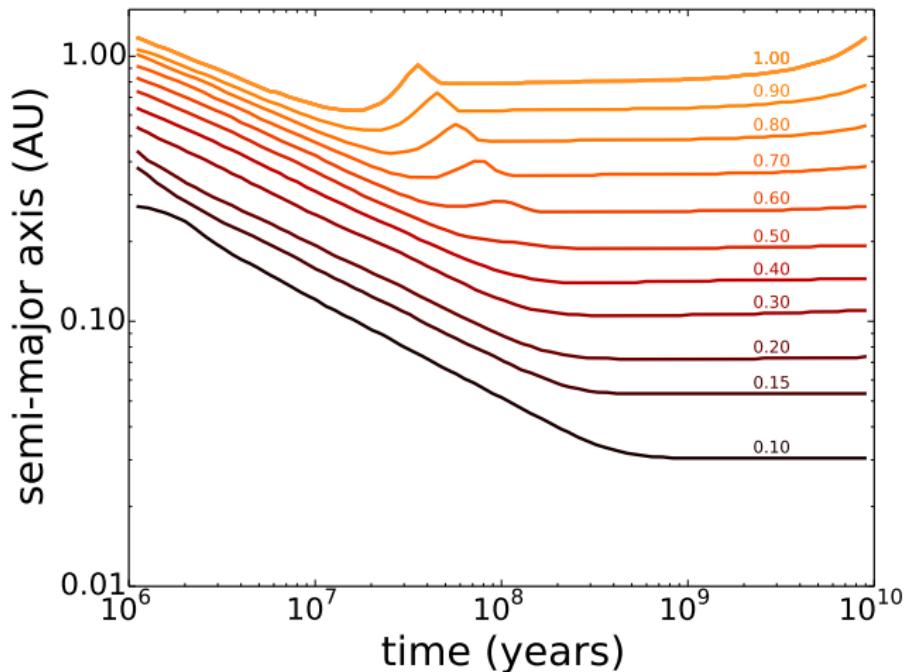
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Pre-Main Sequence Evolution



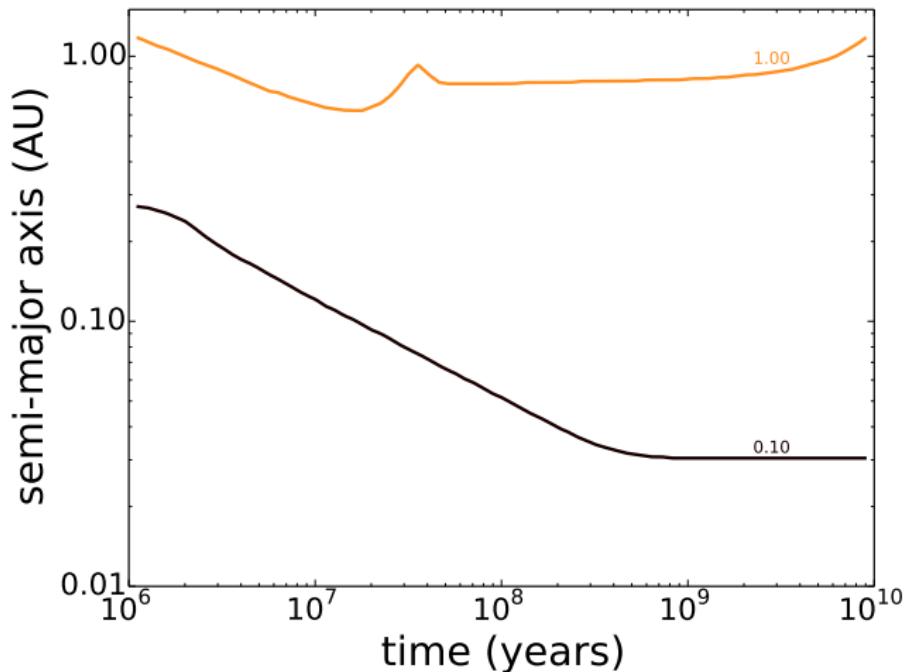
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Pre-Main Sequence Evolution



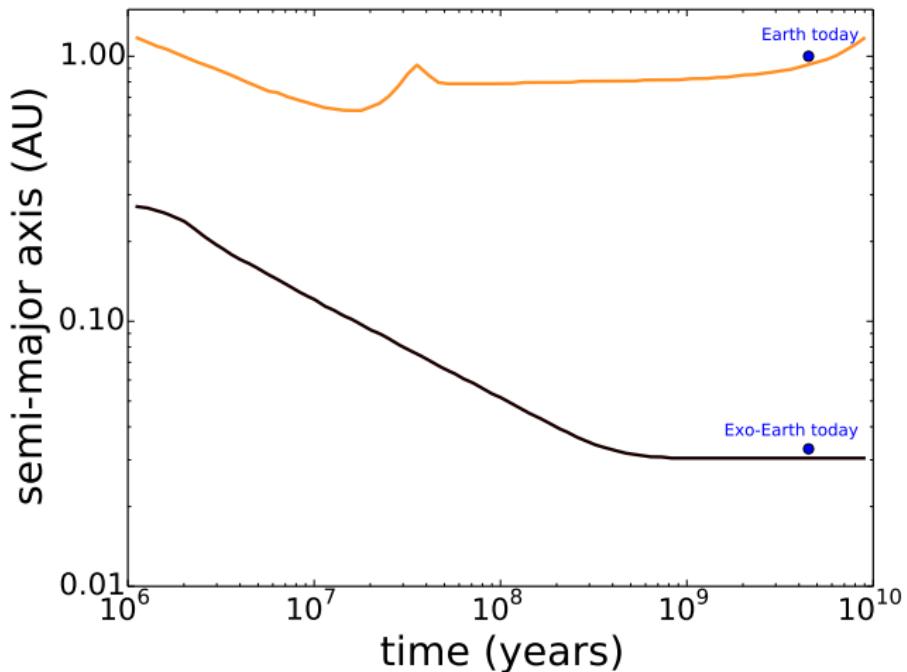
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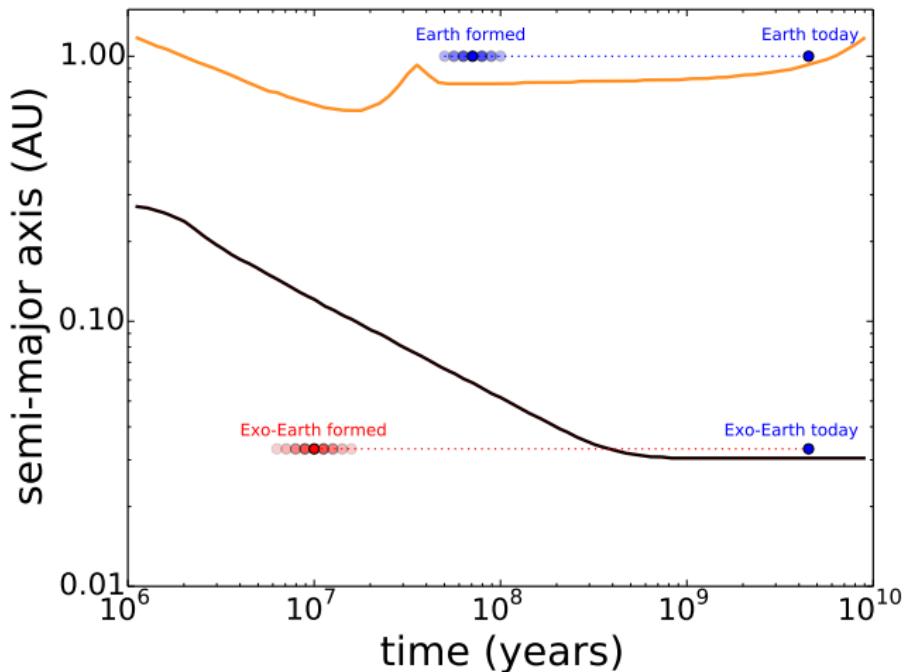
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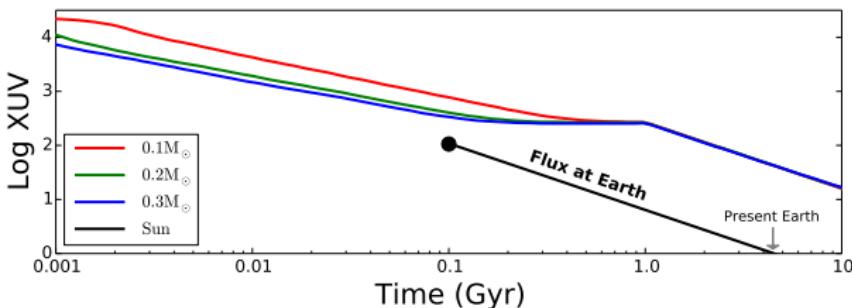


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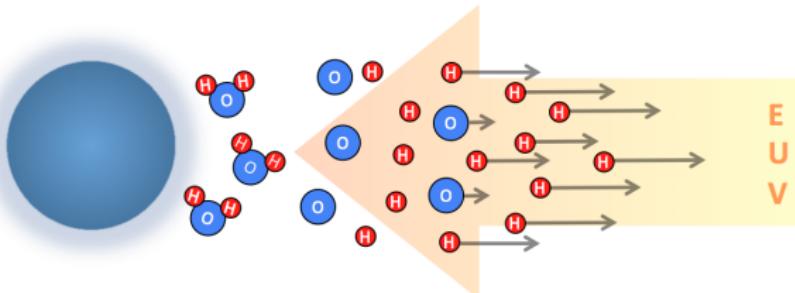


Atmospheric Escape Model

- XUV power law decline (Ribas et al. 2005)

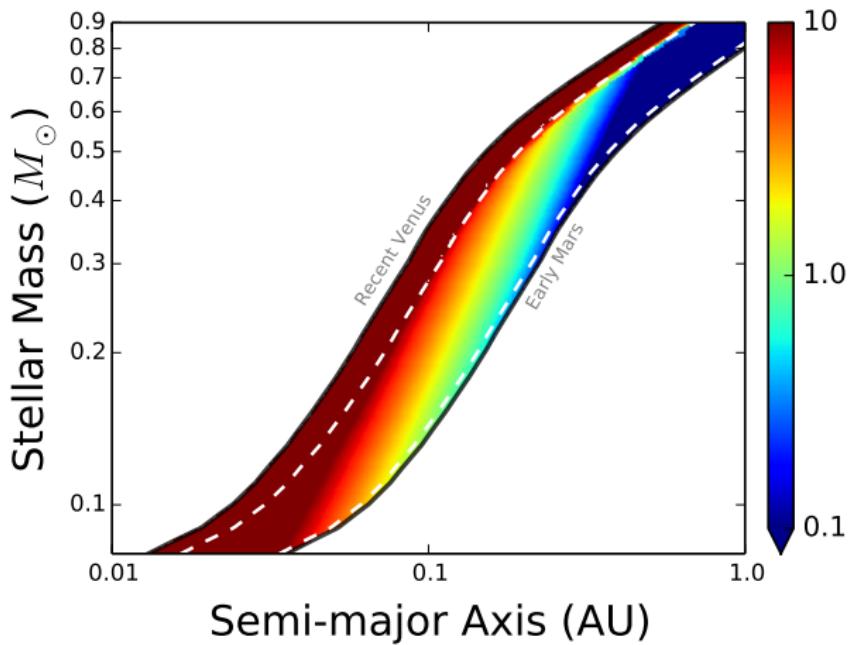


- XUV-driven energy-limited escape (Erkaev et al. 2007)
& hydrodynamic mass fractionation (Hunten et al. 1987)





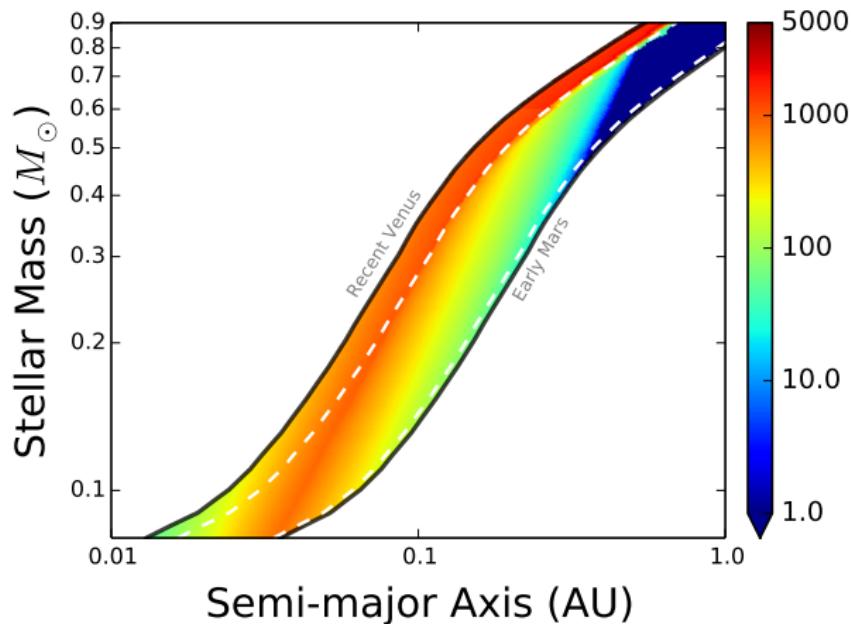
Water Loss (Oceans)



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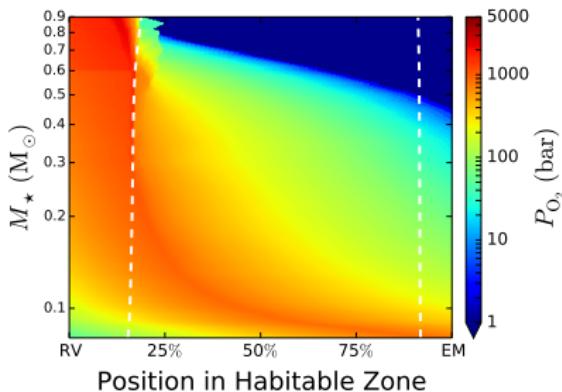
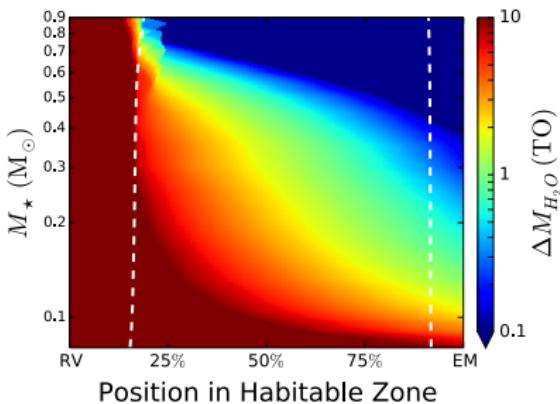


O₂ Buildup (bars)



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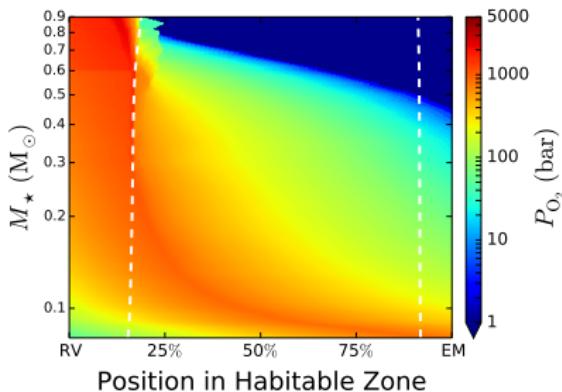
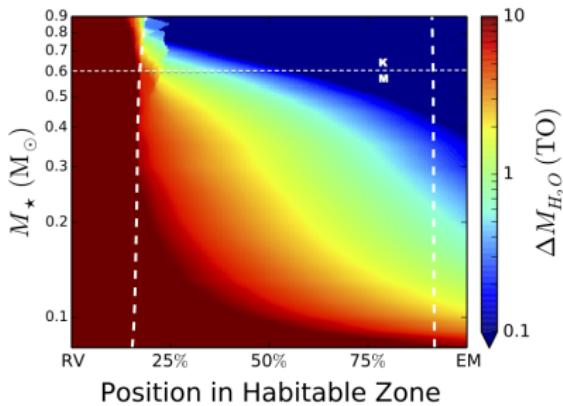
Water Loss & O₂ Buildup



A 1 M_\oplus planet can lose as many as 10 Earth oceans of water and build up several hundred of bars of O₂. Water loss is significant around all M dwarfs.

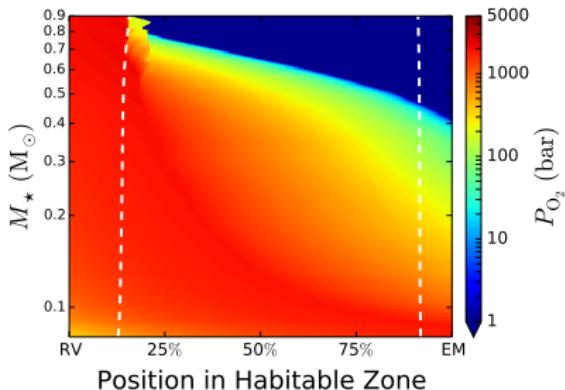
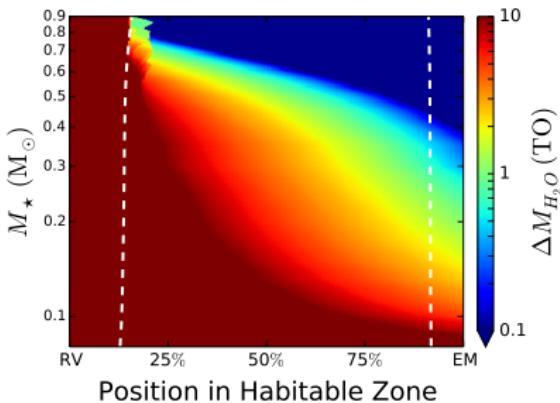


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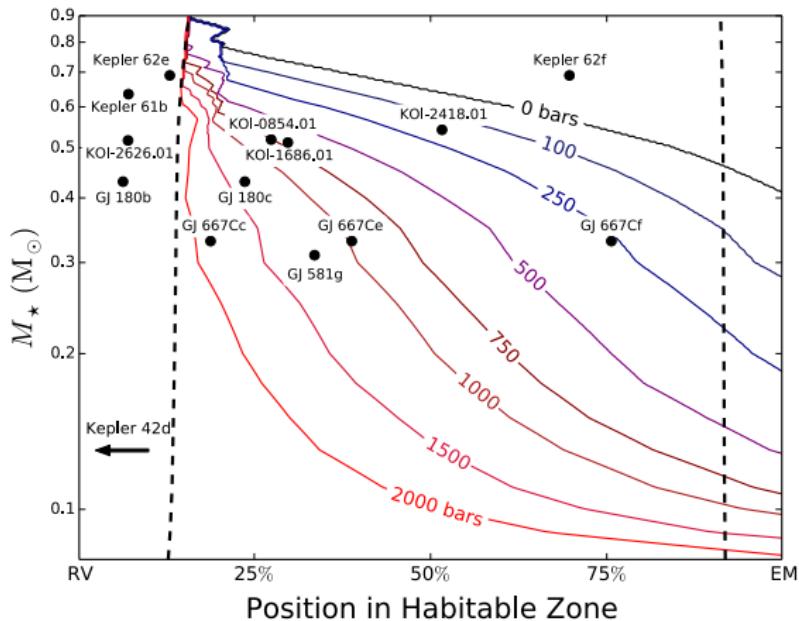
Water Loss & O₂ Buildup



A $5 M_\oplus$ super-Earth can lose up to a few **tens of Earth oceans** of water and build up **several thousands of bars** of O₂, particularly near the inner HZ of low-mass M dwarfs.



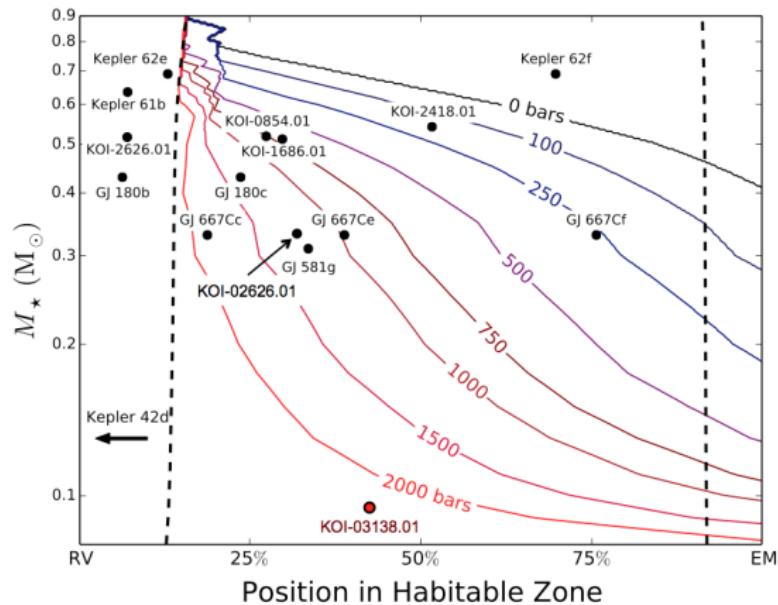
O₂ Buildup on Known Exoplanets



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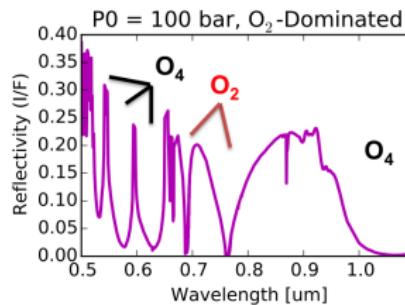
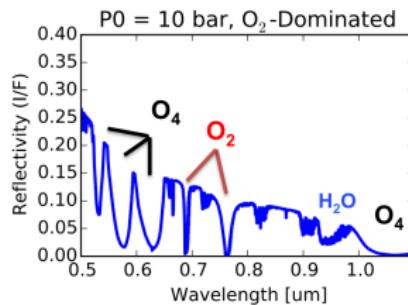
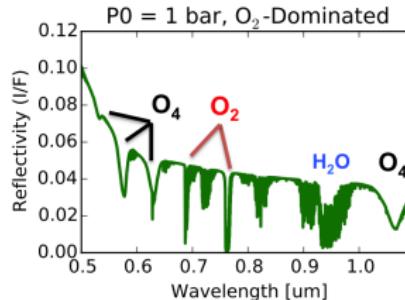
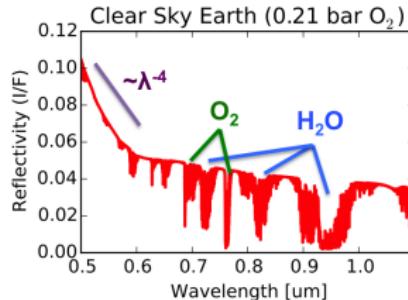


O₂ Buildup on Known Exoplanets





Detection of O₂-Rich Atmospheres



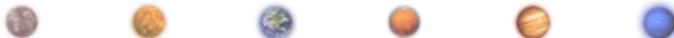
At high O₂ partial pressures, dimer (O₄) features can be used to constrain the O₂ abundance

Schwieterman, Luger et al.
(2015, in prep)

See presentation #7486 by
Eddie Schwieterman on
Thursday



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Summary & Conclusions

- Planets in the HZs of *all* M dwarfs can lose several Earth oceans of water and build up hundreds to thousands of bars of O₂. Both processes **threaten the habitability of many terrestrial planets**
- **Water loss scales with planet mass.** Super-Earths lose more water than Earths because of inhibited oxygen escape
- **O₂ buildup rates also scale with planet mass:** ~ 5 bars/Myr on Earths and ~ 25 bars/Myr on super-Earths. These rates are controlled by diffusion
- Fast O₂ production could overwhelm surface sinks, leading to detectable levels of atmospheric O₂ (Schwieterman et al. 2015). **O₂ may not be a reliable biosignature on M dwarf planets**



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Thank you



Luger and Barnes (2015)

online.liebertpub.com/doi/abs/10.1089/ast.2014.1231

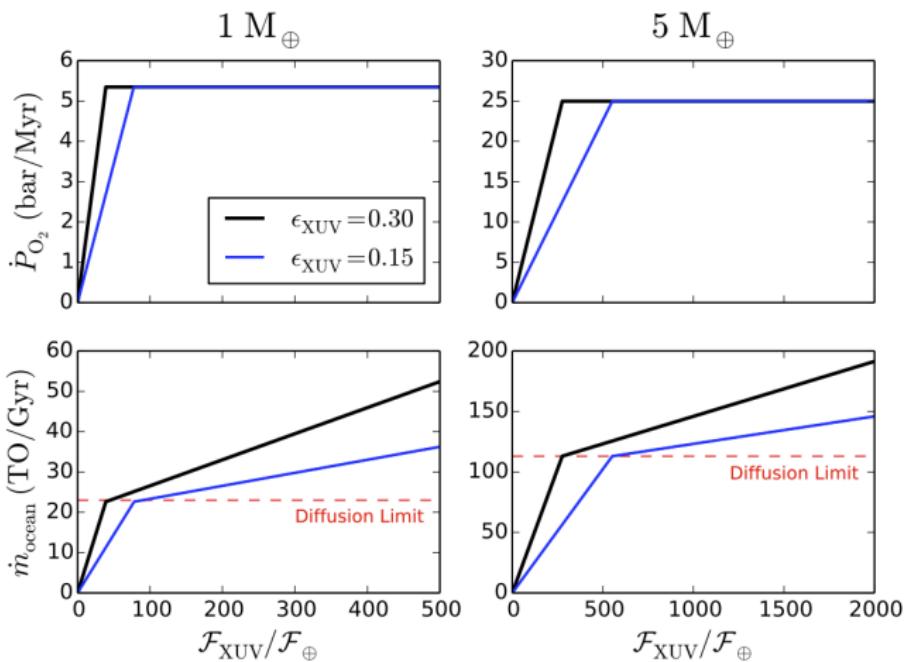


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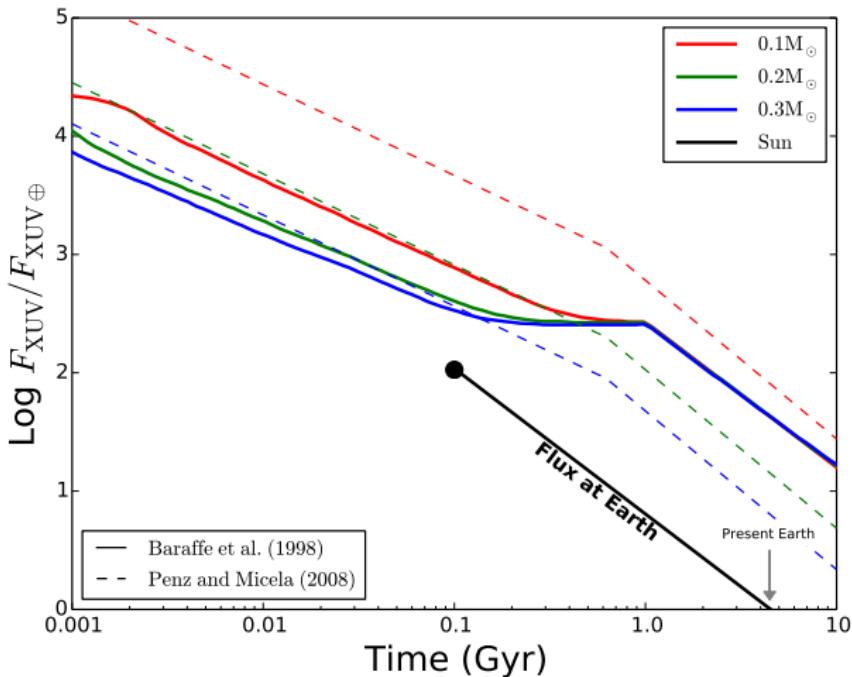
Atmospheric Escape Model



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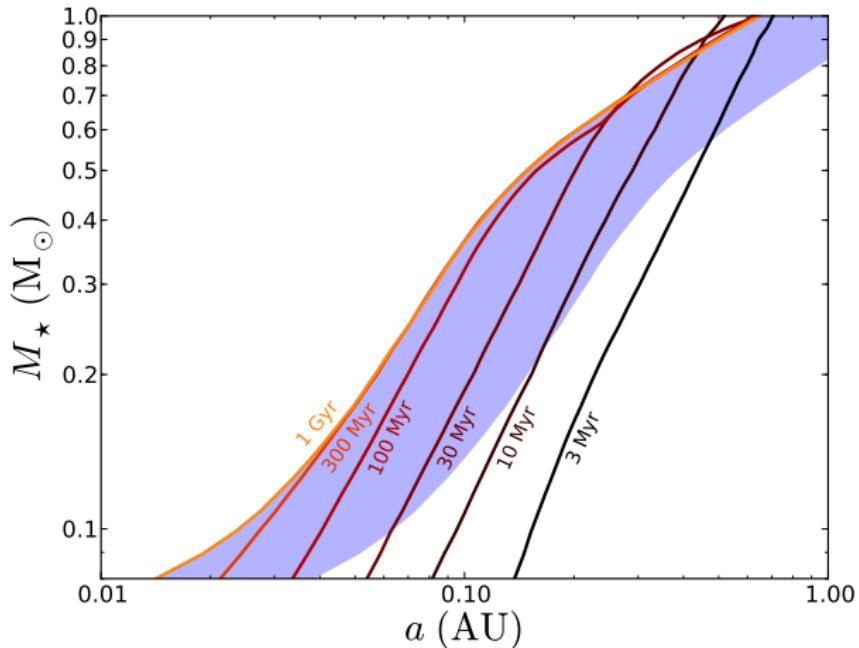
XUV Evolution



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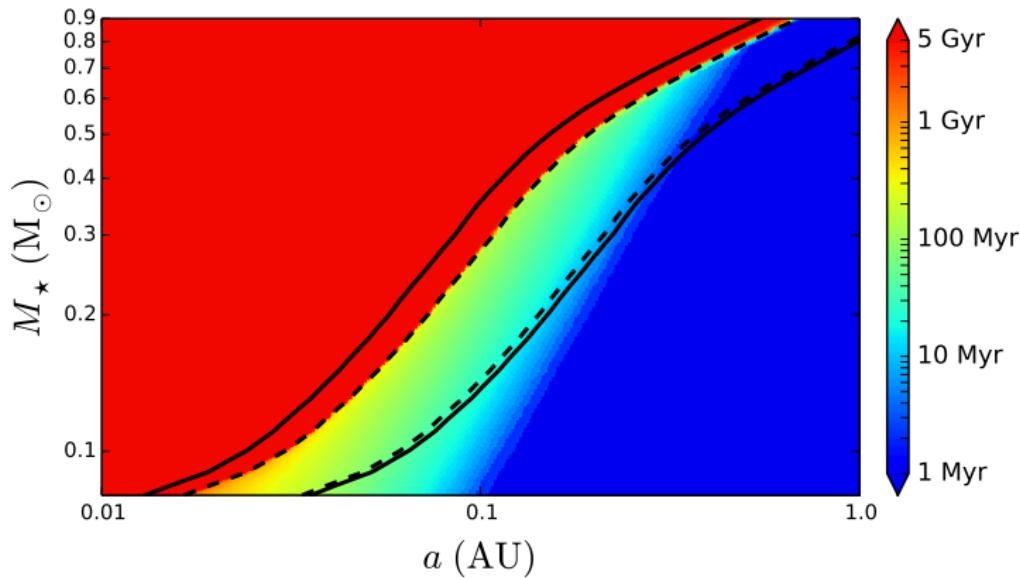
HZ Evolution



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Runaway Greenhouse Duration



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