Water as a Potential Sculptor of the M Dwarf Radius Valley

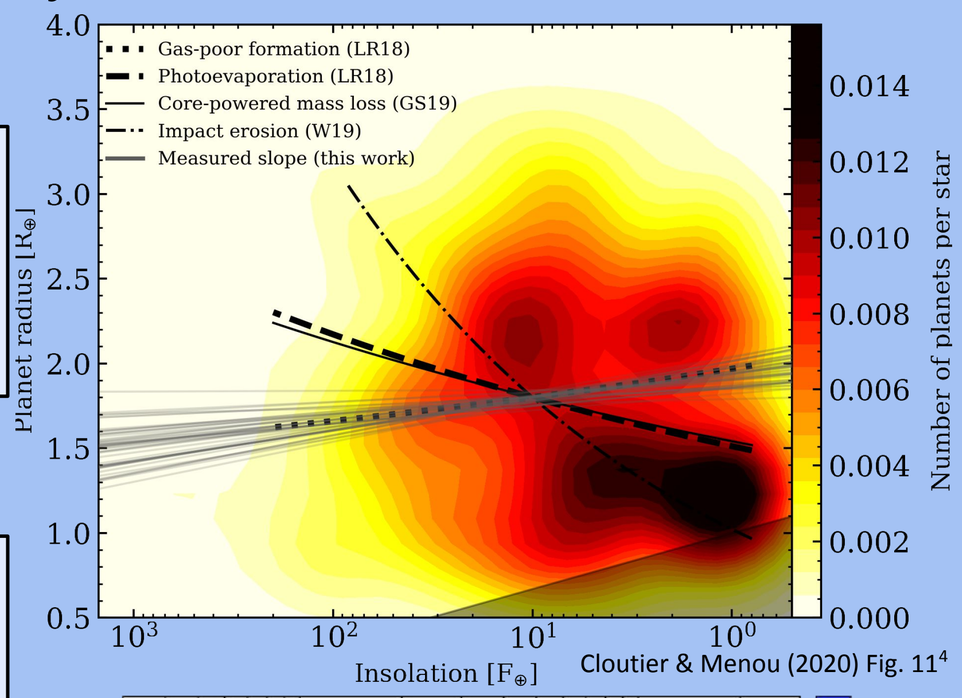
Bennett Skinner, Ralph Pudritz, and Ryan Cloutier

skinnb1@mcmaster.ca

https://tinyurl.com/Bennett-Skinner-CASCA2024

Background

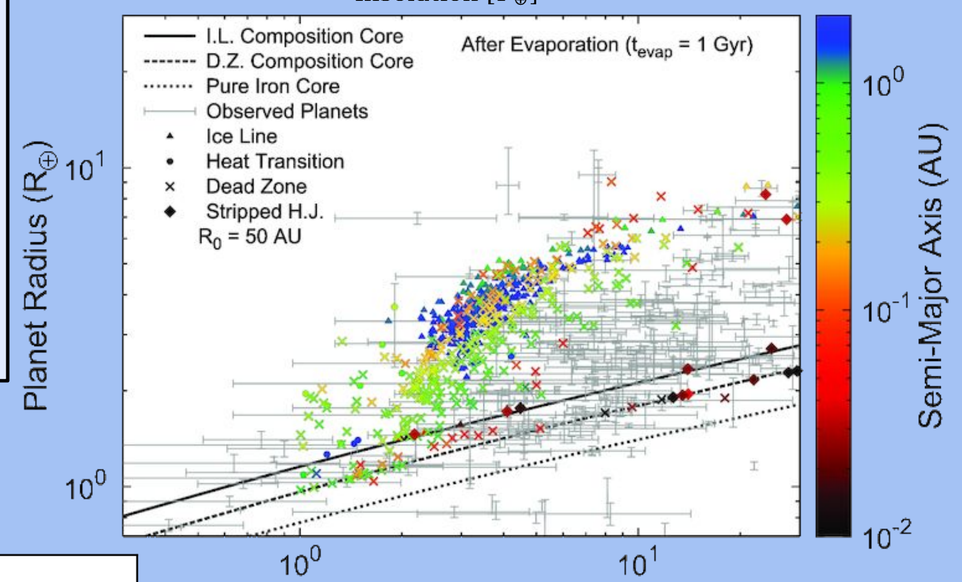
- Distribution of planetary radii is bimodal – "Radius Valley"[1]
  - Slope w/ instellation around FGK stars implies atmospheric escape[2,3]
- Slope different around M v. FGK stars[4]
  - Different formation mechanism? – Water worlds?[5]



Cloutier & Menou (2020) Fig. 11[4]

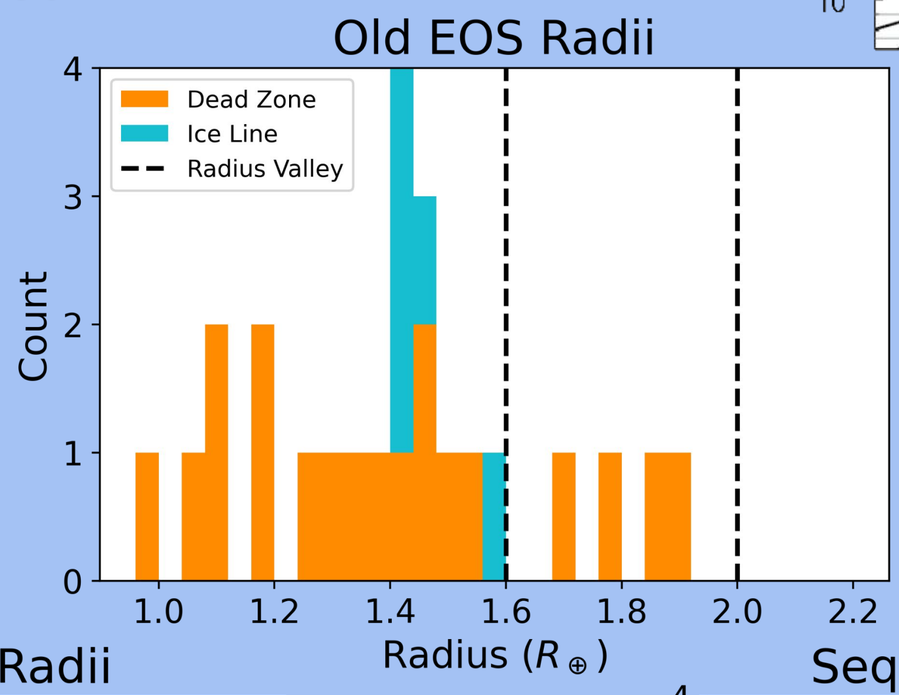
The Project

- McMaster Planet Population Synthesis model[6]
  - Planetesimal accretion in disk around FGK star
  - Planets form in planet traps at dead zone (dry) and ice line (wet)
  - Disks chemically evolve
- Recalculate planet radii w/ new advances
  - New Equations of State (EOS) for water[7], iron[8], silicates[9], opacities[10]
  - Sequestration of water into planetary interior[11]
- **Can radius valley be replicated solely w/ water?**



Alessi et al. (2020b) Fig. 7[6]

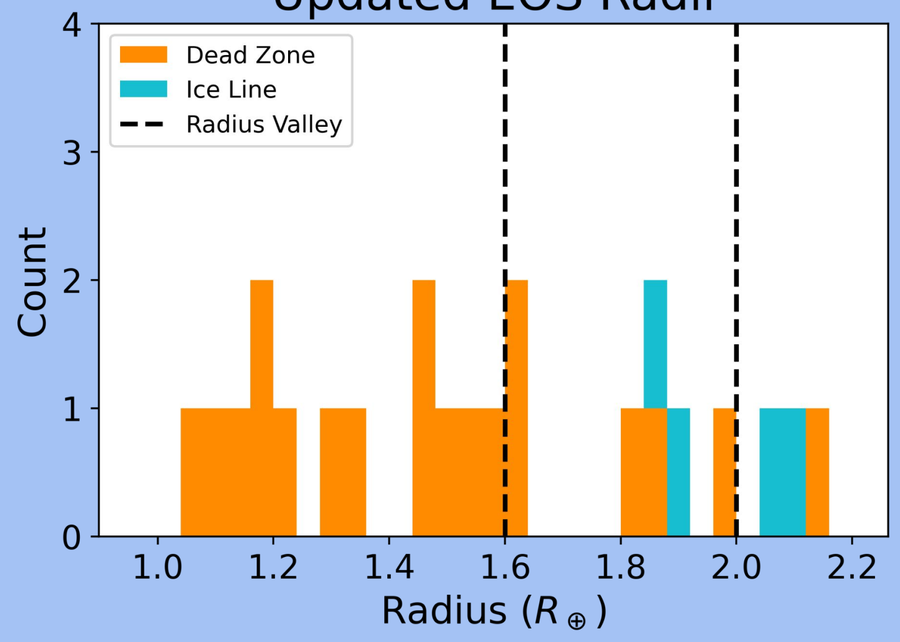
Data

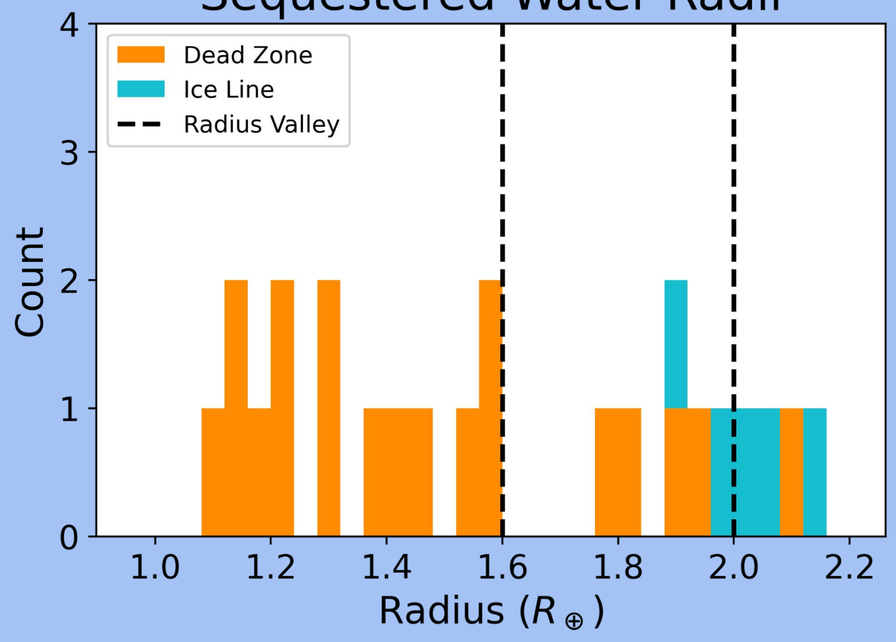


P < 100 days
H/He mass frac < 1e-3

Update EOS

Sequester Water





Results

- **Updated EOS and sequestration separate water and dry worlds**
  - Water does NOT solely replicate radius valley, but could contribute
  - Some water worlds in the valley

Future Work

- Update McMaster Planet Population Synthesis model for M stars
- Increase sample size by running more simulations
- Take advantage of disk chemistry tracking to improve mantle model

Acknowledgements & References

We would like to thank Caroline Dorn's ETH Zürich research group, particularly Komal Bali, for providing tabulated M-R relationships for planets with water sequestration.

[1]Fulton, B. J., Petigura, E. A., Howard, A. W., Isaacson, H., Marcy, G. W., Cargile, P. A., Hebb, L., Weiss, L. M., Johnson, J. A., Morton, T. D., Sinukoff, E., Crossfield, I. J. M., and Hirsch, L. A. (2017)
[2]Lopez, E. D. and Rice, K. (2018)
[3]Gupta, A. and Schlichting, H. E. (2019)
[4]Cloutier, R. and Menou, K. (2020)
[5]Burn, R., Mordasini, C., Mishra, L., Haldemann, J., Venturini, J., Emsenhuber, A., and Henning, T. (2024)
[6]Alessi, M., Inglis, J., and Pudritz, R. E. (2020)
[7]Haldemann, J., Alibert, Y., Mordasini, C., and Benz, W. (2020)
[8]Hakim, K., Rivoldini, A., Van Hoolst, T., Cottenier, S., Jaeken, J., Chust, T., and Steinle-Neumann, G. (2018)
[9]Sotin, C., Grasset, O., and Mocquet, A. (2007)
[10]Freedman, R. S., Lustig-Yaeger, J., Fortney, J. J., Lupu, R. E., Marley, M. S., and Lodders, K. (2014)
[11]Luo, H., Dorn, C., and Deng, J. (2024)