The Ohio State University

# Project 4: Build-a-Planet

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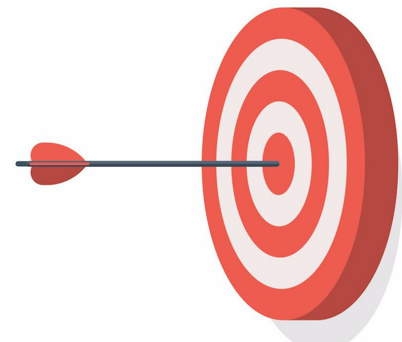
# Goals



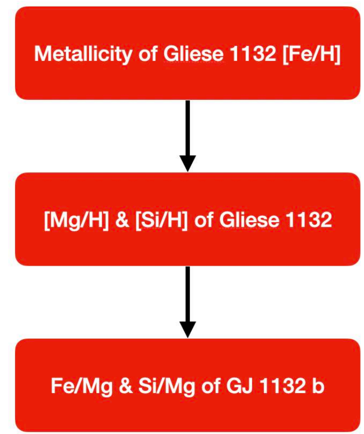
- Run code from a command line
- Predict a planet's mass from its radius
- Understand results in context of similar planets
- Understand how varying composition varies the mass and/or radius
- Compare to mineralogy to Earth

# GJ 1132b

- Orbits a red dwarf star
- Orbit ~ 1.6 days
- It is 39 light-years away
- Temperature = 450°F (232 °C)
- Likely rocky

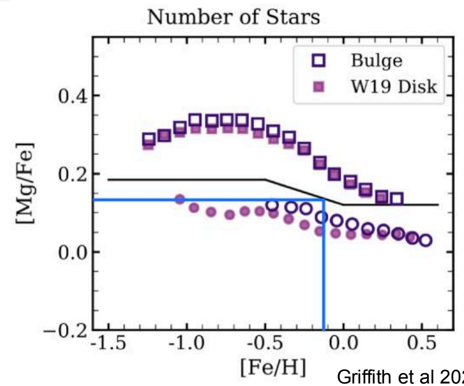
# What does the Stellar Composition tell us?

- The metallicity of Gliese 1132 can tell us the likely refractory composition of GJ 1132 b
- Unknown refractory ratios: Fe/Mg & Si/Mg



# Composition of Gliese 1132

- From NEA: [Fe/H] = -0.12
- [Mg/Fe] = 0.13 $\qquad$ $(Mg/Fe)_{sun}$ = 1.148
- [Mg/Fe] = $\log_{10}\left(\frac{Mg/Fe}{(Mg/Fe)_{sun}}\right)$ $\rightarrow$ Mg/Fe = 1.548
- $\frac{Mg}{H} = \frac{Mg}{Fe} * \frac{Fe}{H}$ $\rightarrow$ [Mg/H] = $\log_{10}\left(\frac{Mg/H}{(Mg/H)_{sun}}\right)$ = 0.01




Griffith et al 2021

| | | Solar photosphere | s.d. (dex) |
|---|---|---|---|
| 12 | Mg | 7.54 | 0.06 |
| 13 | Al | 6.47 | 0.07 |
| 14 | Si | 7.52 | 0.06 |
| 15 | P | 5.46 | 0.04 |
| 16 | S | 7.16 | 0.05 |
| 17 | Cl | 5.50 | 0.30 |
| 18 | Ar | 6.50 | 0.10 |
| 19 | K | 5.11 | 0.09 |
| 20 | Ca | 6.33 | 0.07 |
| 21 | Sc | 3.10 | 0.10 |
| 22 | Ti | 4.90 | 0.06 |
| 23 | V | 4.00 | 0.02 |
| 24 | Cr | 5.64 | 0.01 |
| 25 | Mn | 5.37 | 0.05 |
| 26 | Fe | 7.48 | 0.06 |

# Conversion

- $[Si/Mg] = -0.0462$ → $Si/Mg = 0.8585$
- $[Fe/Mg] = -0.1303$ → $Fe/Mg = 0.6453$

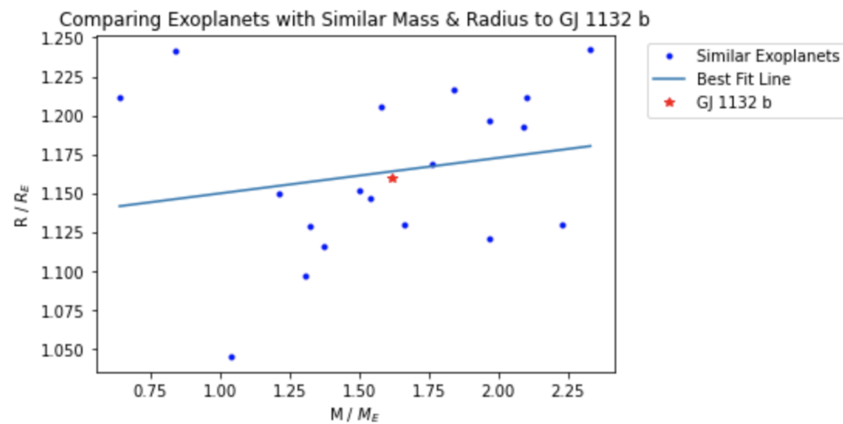
$$[X/Mg] = \alpha_{cc}[Mg/H] + \log\left[\frac{1 + R^X_{Ia}(A_{Ia}/A_{cc})10^{(\alpha_{Ia}-\alpha_{cc})[Mg/H]}}{1 + R^X_{Ia}}\right]$$

where $$\frac{A_{Ia}}{A_{cc}} = 10^{0.3-[Mg/Fe]} - 1$$

Griffith et al., 2020

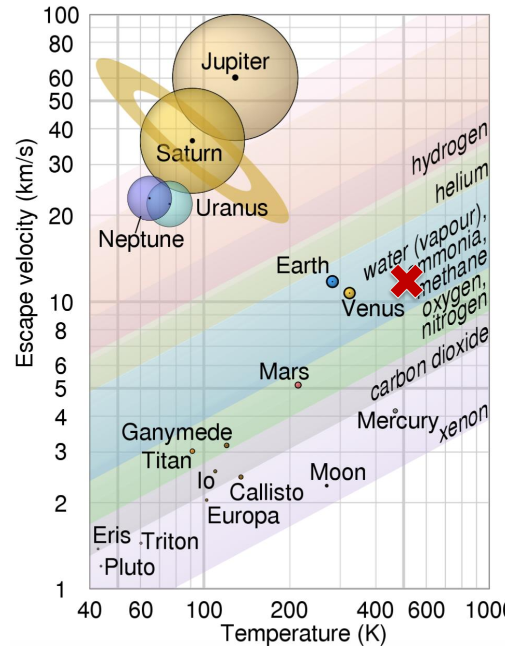
# Other Rocky Planets

- Planets with radii within 10% of our calculated value
- Below radius gap and orbits very close to star → no substantial atmosphere
- Follows R ~ M^0.28 (Chen & Kipping)

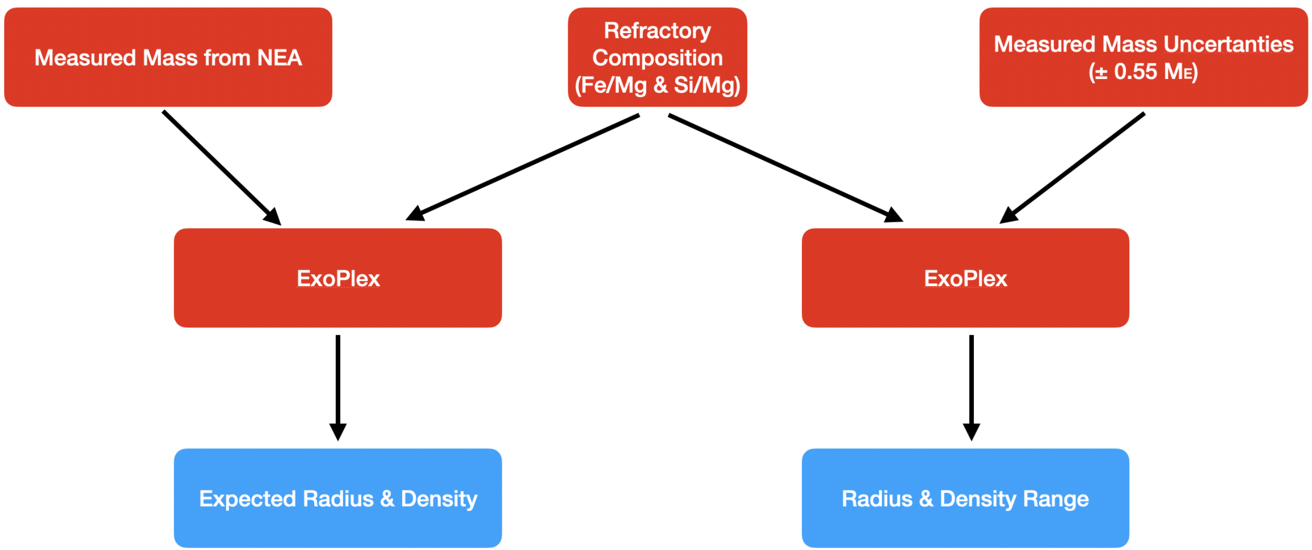


# Atmospheric Retention of GJ 1132 b

- Escape Velocity: $$V_e = \sqrt{\frac{2GM_P}{R_P}}$$
- $M_P = 1.62\ M_E$ $R_P = 1.16\ R_E$
- $T_{Eq} = 529\ K \pm 9$
- We can assume that our planet has some form of atmosphere, potentially due to volcanism



# Expected Range of Radius & Density

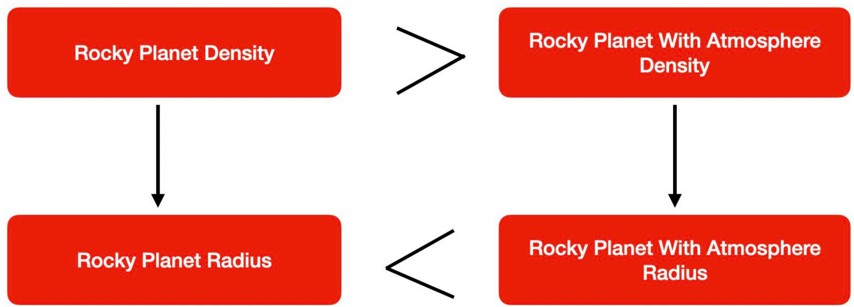


# Effects of Measured Mass Uncertainty

- Expected Radius & Density: $R_P = 1.159\ R_E$ $\rho_P = 5.737$ kg/m$^3$
- Lower Limit: $R_P = 1.036\ R_E$ $\rho_P = 5.305$ kg/m$^3$
- ExoPlex breaks at $M_P = 1.647$ when attempting to get the upper limit
- Break Limit: $R_P = 1.169\ R_E$ $\rho_P = 5.684$ kg/m$^3$

$$\rho_P = \frac{3M_P}{4\pi {R_P}^3}$$

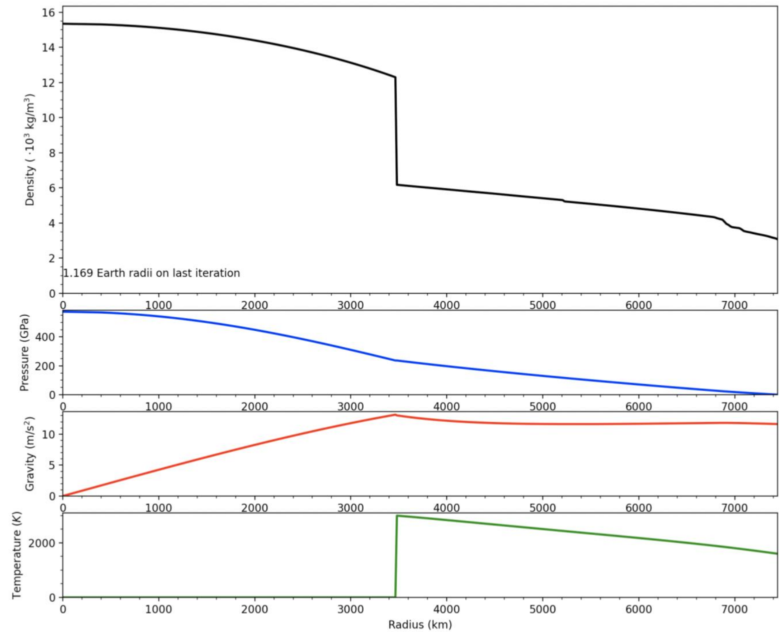
# Determining an Accurate Model for GJ 1132 b



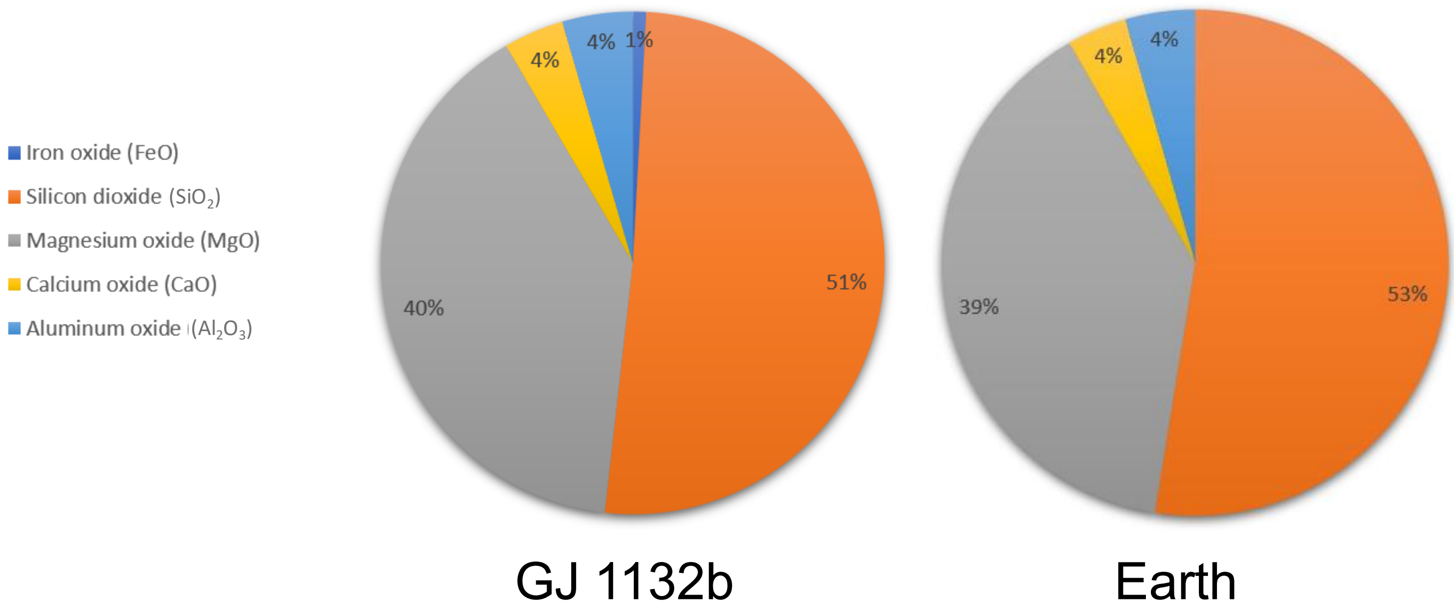

- Analyze how changing the FeO & FeMg affects the density of our planet

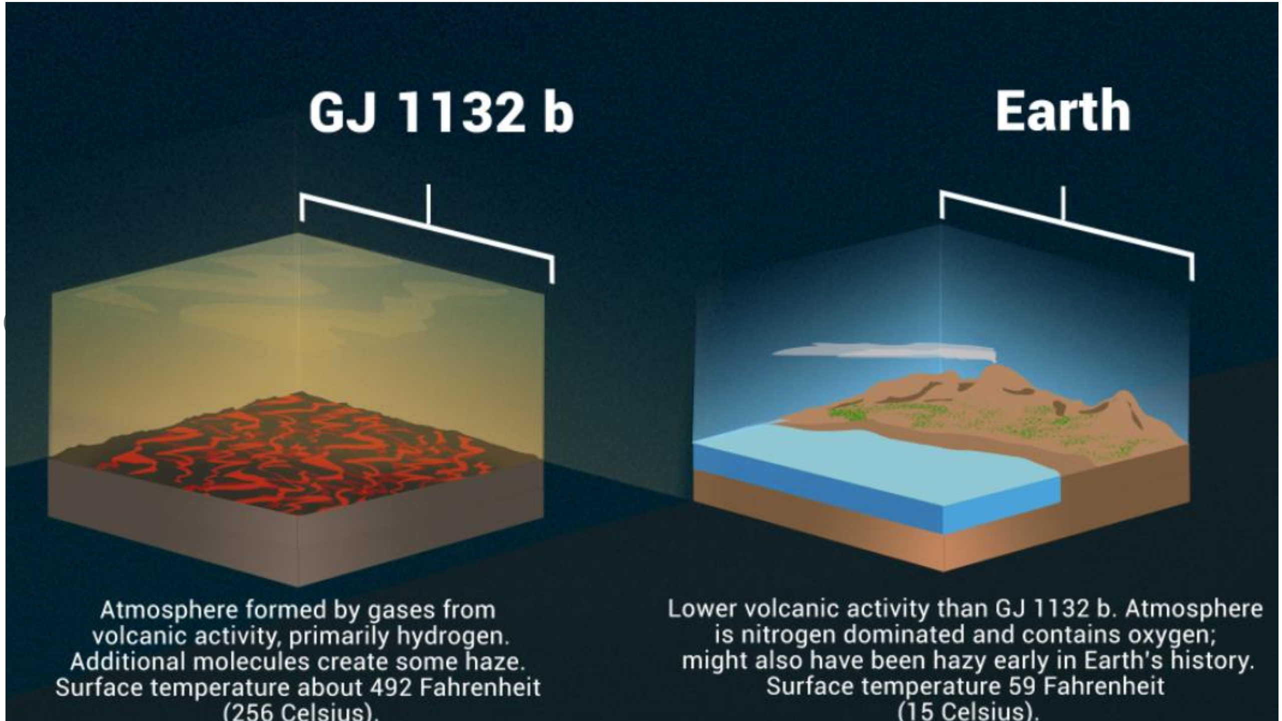
# Core & Mantle Structure

- Mass of the planet doesn't change
- RP = 1.169 RE
- FeMg = 0.6
- FeO = 0.02
- Accounts for the extended radius due to the atmosphere



# Mineralogy


Iron oxide (FeO)
Silicon dioxide ($SiO_2$)
Magnesium oxide (MgO)
Calcium oxide (CaO)
Aluminum oxide ($Al_2O_3$)
4%
1%
4%
51%
40%
4%
4%
53%
39%
GJ 1132b
Earth


GJ 1132 b
Earth
Atmosphere formed by gases from volcanic activity, primarily hydrogen. Additional molecules create some haze. Surface temperature about 492 Fahrenheit (256 Celsius).
Lower volcanic activity than GJ 1132 b. Atmosphere is nitrogen dominated and contains oxygen; might also have been hazy early in Earth's history. Surface temperature 59 Fahrenheit (15 Celsius).

# Conclusions

- Expected: $R_P$ = 1.159 $R_E$ and $M_P$ = 1.62 $M_E$ $\rho_P$ = 5.737 kg/$m^3$
- Accounting for atmosphere: $R_P$ = 1.169 $R_E$ $\rho_P$ = 5.591 kg/$m^3$
- Refractory composition: Si/Mg = 0.86 and Fe/Mg = 0.65
- No substantial atmosphere, but probably some due to volcanism
- Similar composition to Earth; some Fe in mantle

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Questions?

# Contributions

- Alex – Calculations, ppt
- Ashley – Calculations, ppt, report
- Mariana – Report, ppt
- Missie – Report
- Yuanhao – Coding, calculations