ASTR/GEOL-2040: Search for life in the Universe: Lecture 37

- planet's radius vs mass
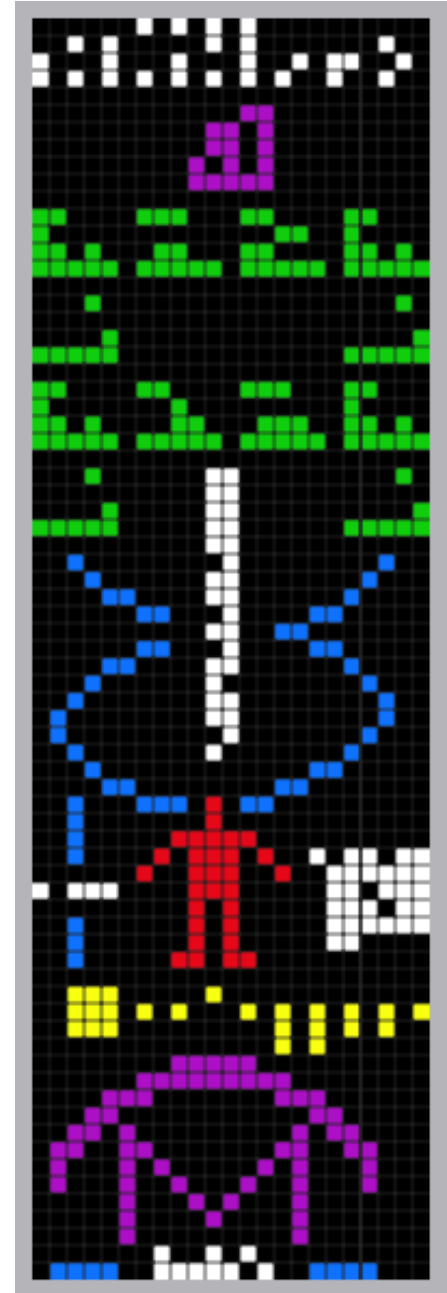- life around M dwarfs
- starshot

Axel Brandenburg
(Office hours: Mondays 2:30 – 3:30 in X590
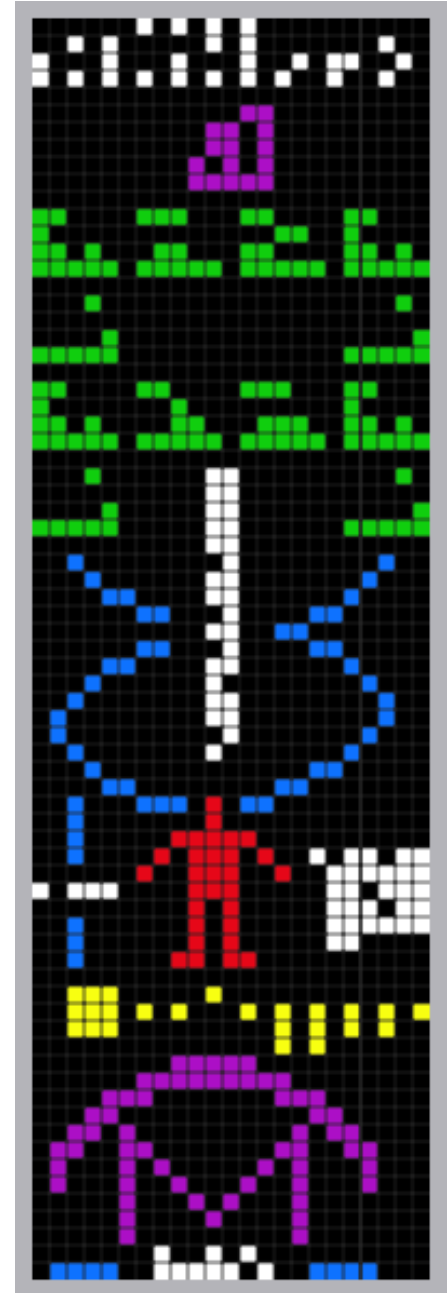and Wednesdays 11-12 in D230)

Decoding the signal

- Easy decoding?

- Sending back our own TV transmissions?

- Image 1679 = 23 x 73

- 1974 Arecibo message

but 1679 just example

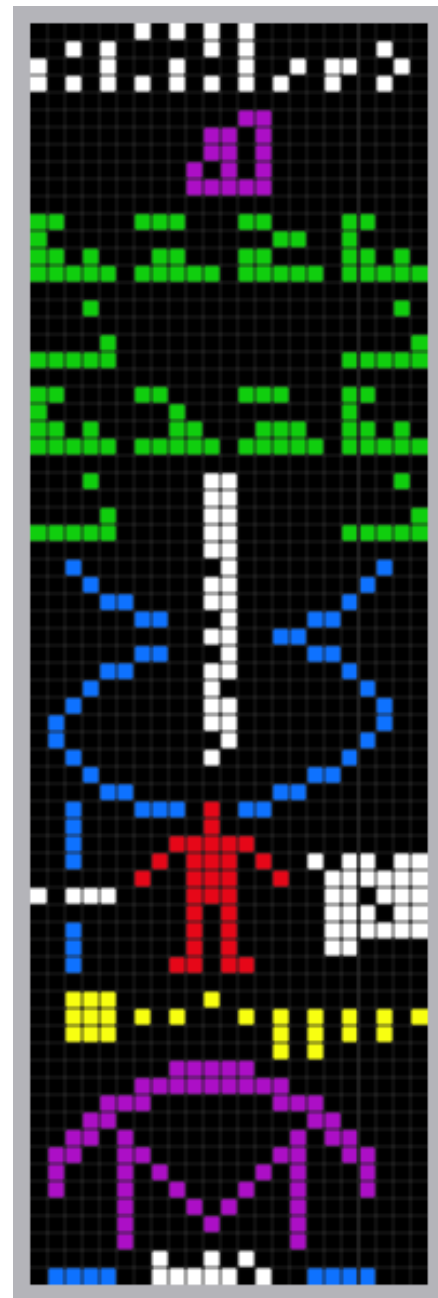- Arecibo: 1679 = 23 x 73
- Why not: 23 x 11 = 253
- Or: 5 x 11 = 55?

A. Product of odd numbers

B. Product of prime numbers

C. Product of even numbers

but 1679 just example

- Arecibo: $1679 = 23 \times 73$
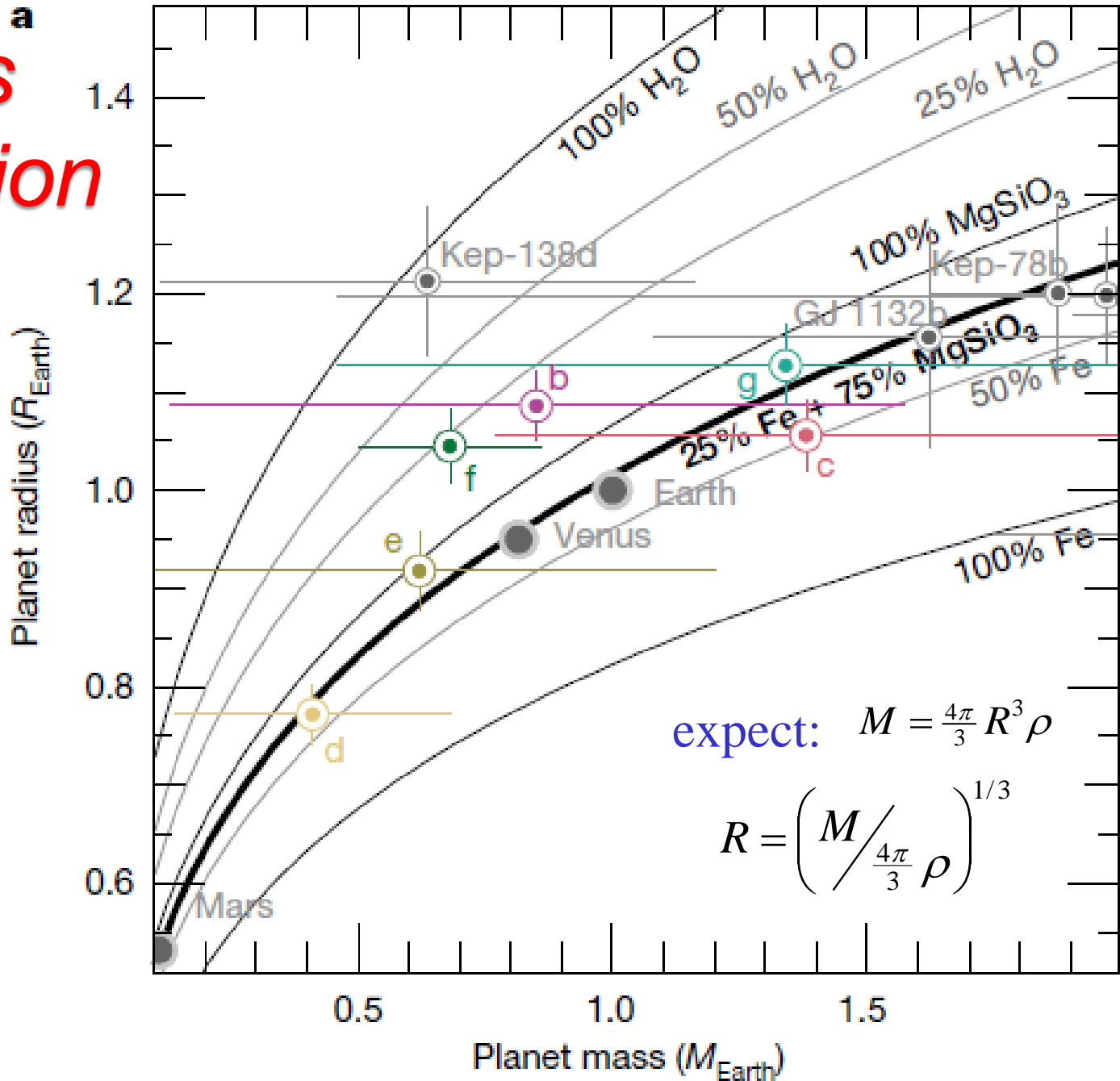- Why not: $23 \times 11 = 253$
- Or: $5 \times 11 = 55$?

A. Product of odd numbers

B. Product of prime numbers

C. Product of even numbers

Planets composition

…from the fast lecture

- Real terrestrial planets!

- Similar to Earth!

a

100% H$_2$O 50% H$_2$O 25% H$_2$O

Kep-138d

100% MgSiO$_3$

Kep-78b

Gd 1132b

MgSiO$_3$

b

g

f 25% Fe + 75% MgSiO$_3$

50% Fe

c

Earth

e Venus

100% Fe

d

Mars

Planet radius (R_{Earth})

Planet mass (M_{Earth})

expect: $M = \frac{4\pi}{3} R^3 \rho$

$$R = \left(M \middle/ \frac{4\pi}{3} \rho \right)^{1/3}$$

Planets composition

M	R
0.1	
0.2	
0.5	0.84
1.0	
2.0	

a

Mass–radius diagram of planets. X-axis: Planet mass (M_{Earth}) from 0.5 to 1.5. Y-axis: Planet radius (R_{Earth}) from 0.6 to 1.4. Composition curves labeled: 100% H_2O, 50% H_2O, 25% H_2O, 100% $MgSiO_3$, 25% Fe + 75% $MgSiO_3$, 50% Fe, 100% Fe. Planets plotted: Kep-138d, Kep-78b, Gd 1132b, Earth, Venus, Mars, and lettered points b, c, d, e, f, g.

Planets composition

M	R
0.1	
0.2	
0.5	0.84
1.0	1.01
2.0	
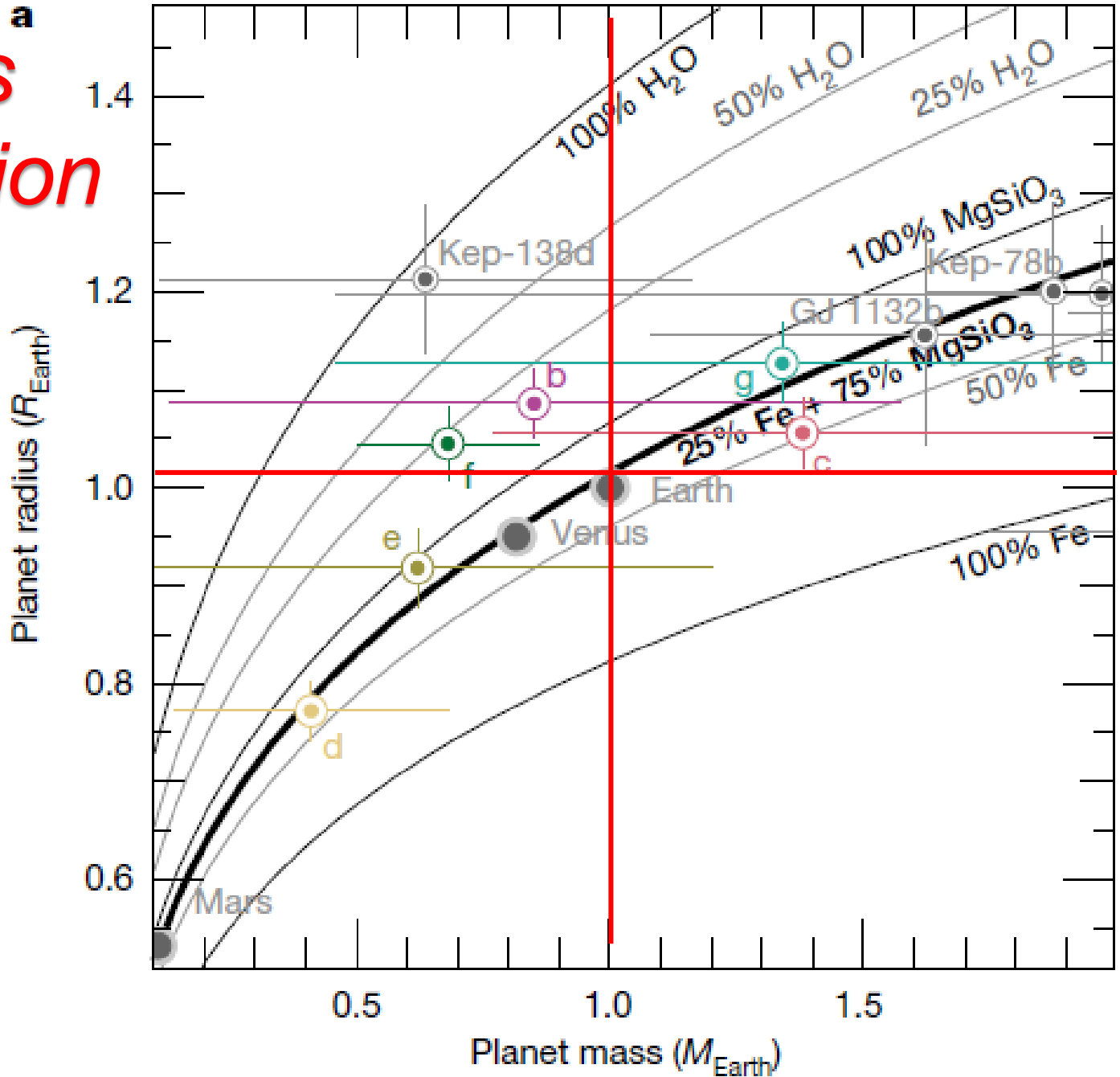
Planets composition

M	R
0.1	
0.2	
0.5	0.84
1.0	1.01
2.0	1.23
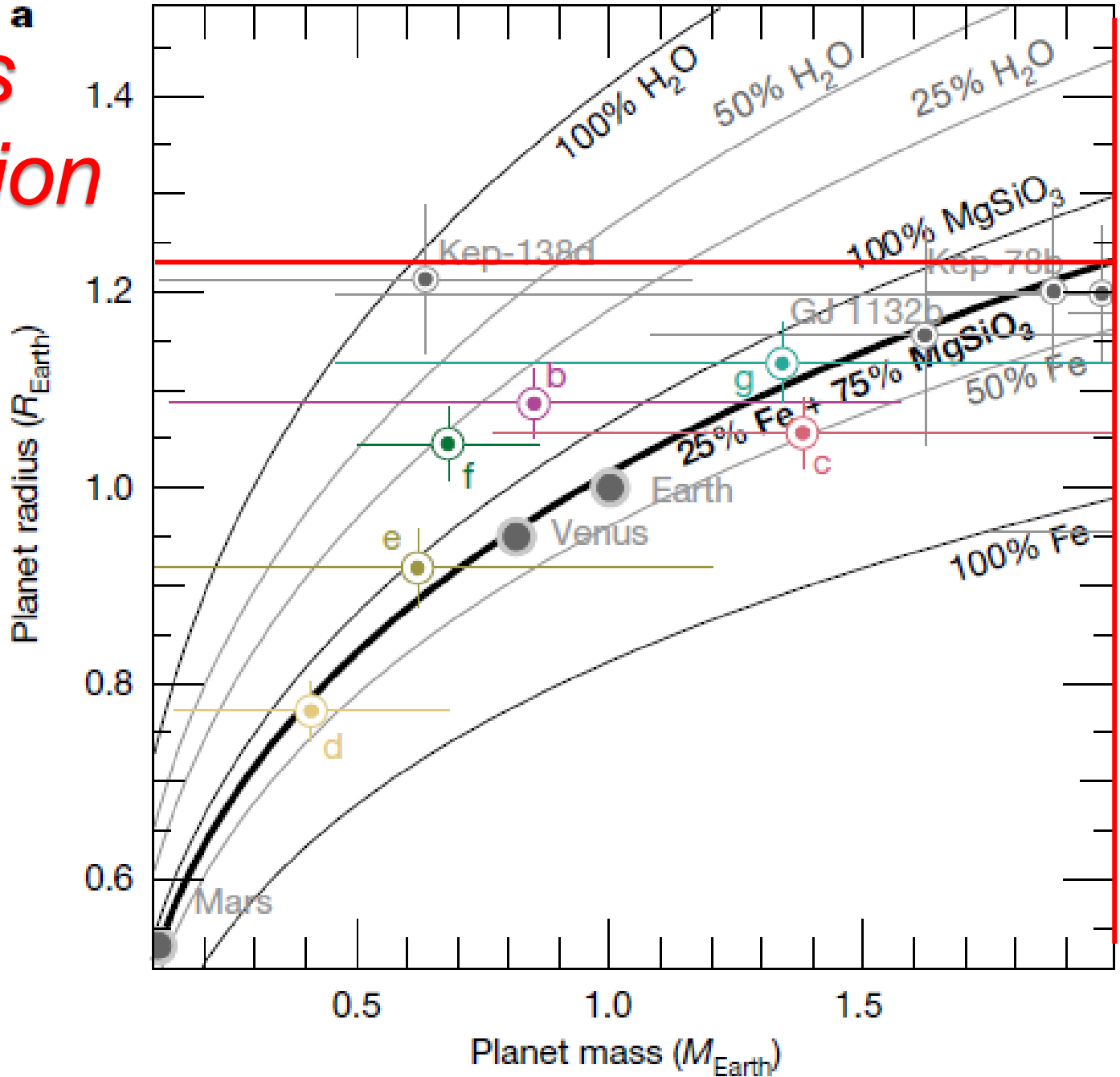
Planets composition

M	R
0.1	
0.2	0.64
0.5	0.84
1.0	1.01
2.0	1.23
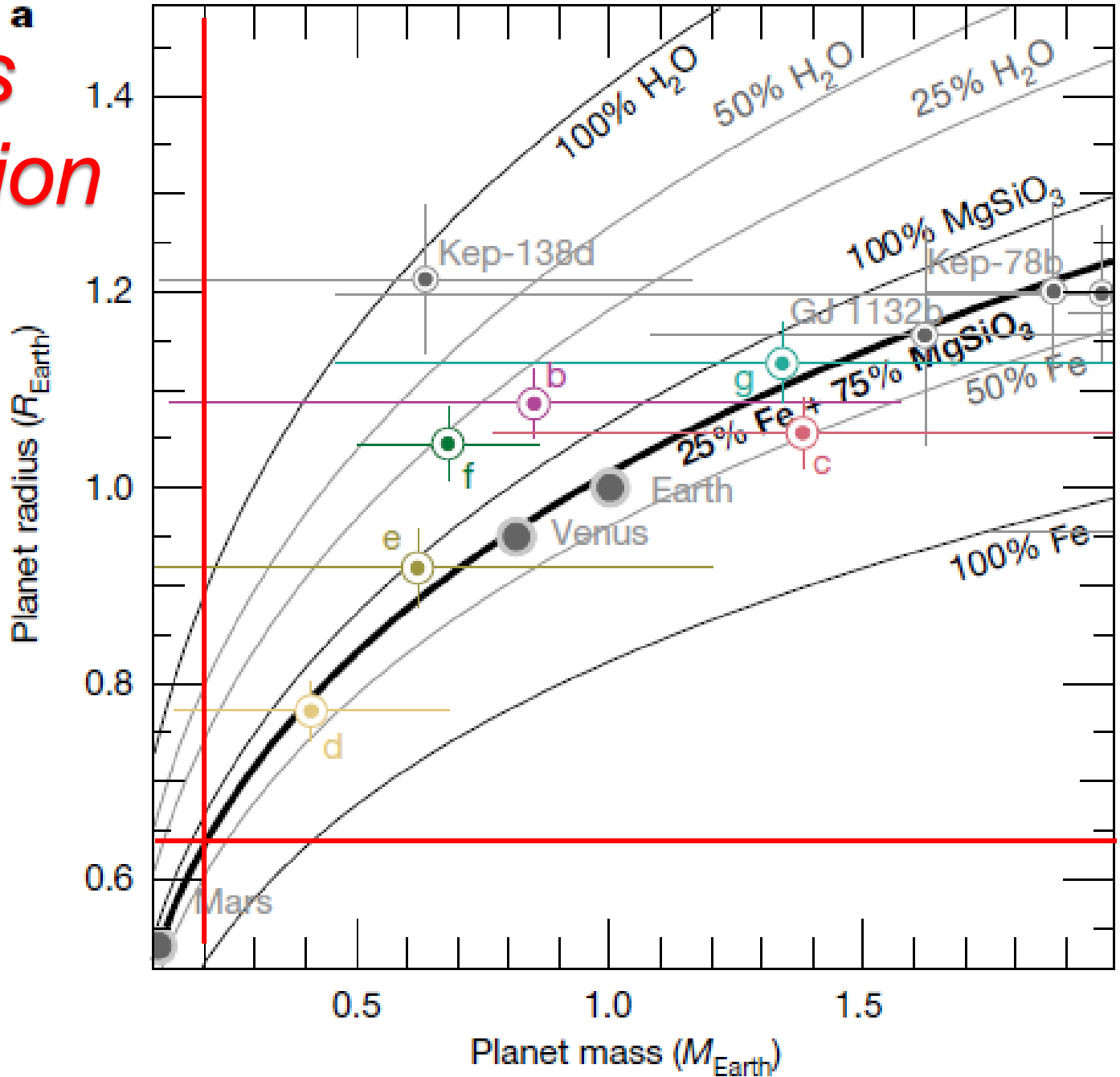
Planets composition

M	R
0.1	0.54
0.2	0.64
0.5	0.84
1.0	1.01
2.0	1.23

a

Planet radius (R_{Earth}) vs Planet mass (M_{Earth})

Composition curves: 100% H_2O, 50% H_2O, 25% H_2O, 100% $MgSiO_3$, 25% Fe + 75% $MgSiO_3$, 50% Fe, 100% Fe

Labeled planets: Kep-138d, Kep-78b, Gd 1132b, Earth, Venus, Mars, b, c, d, e, f, g

Planets composition

M	R
0.1	0.54
0.2	0.64
0.5	0.84
1.0	1.01
2.0	1.23

11

Planets composition

M	R
0.1	0.54
0.2	0.64
0.5	0.84
1.0	1.01
2.0	1.23
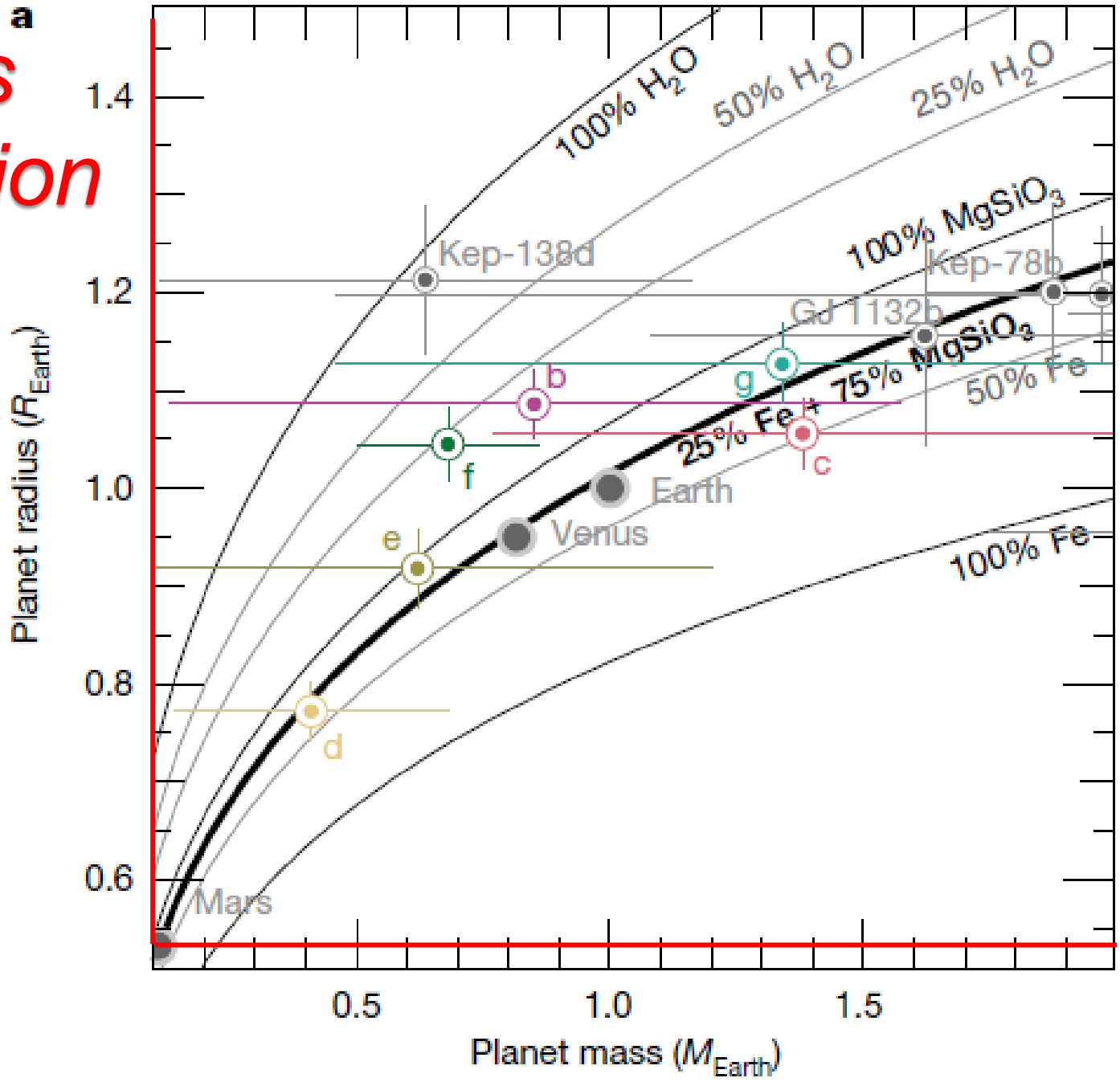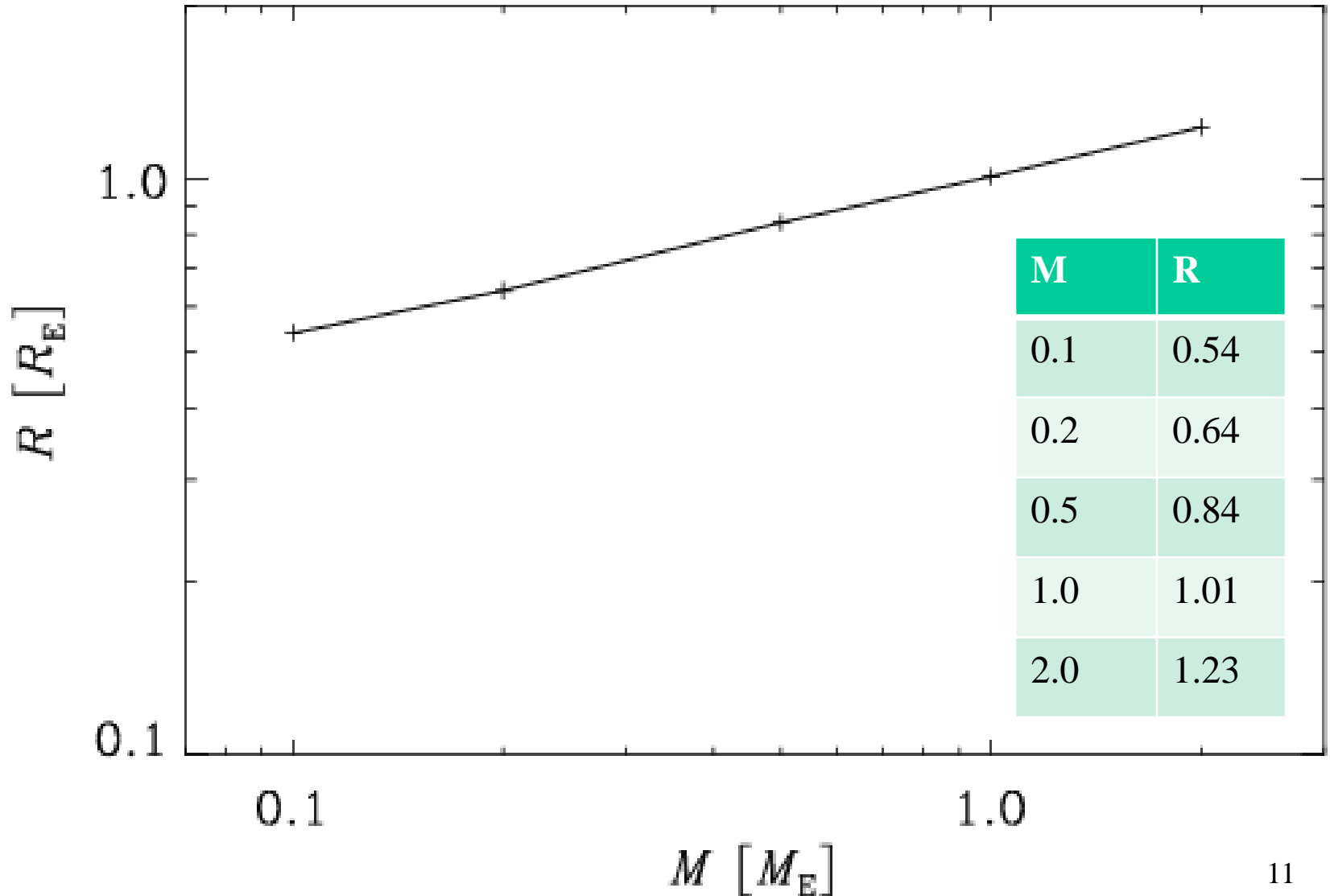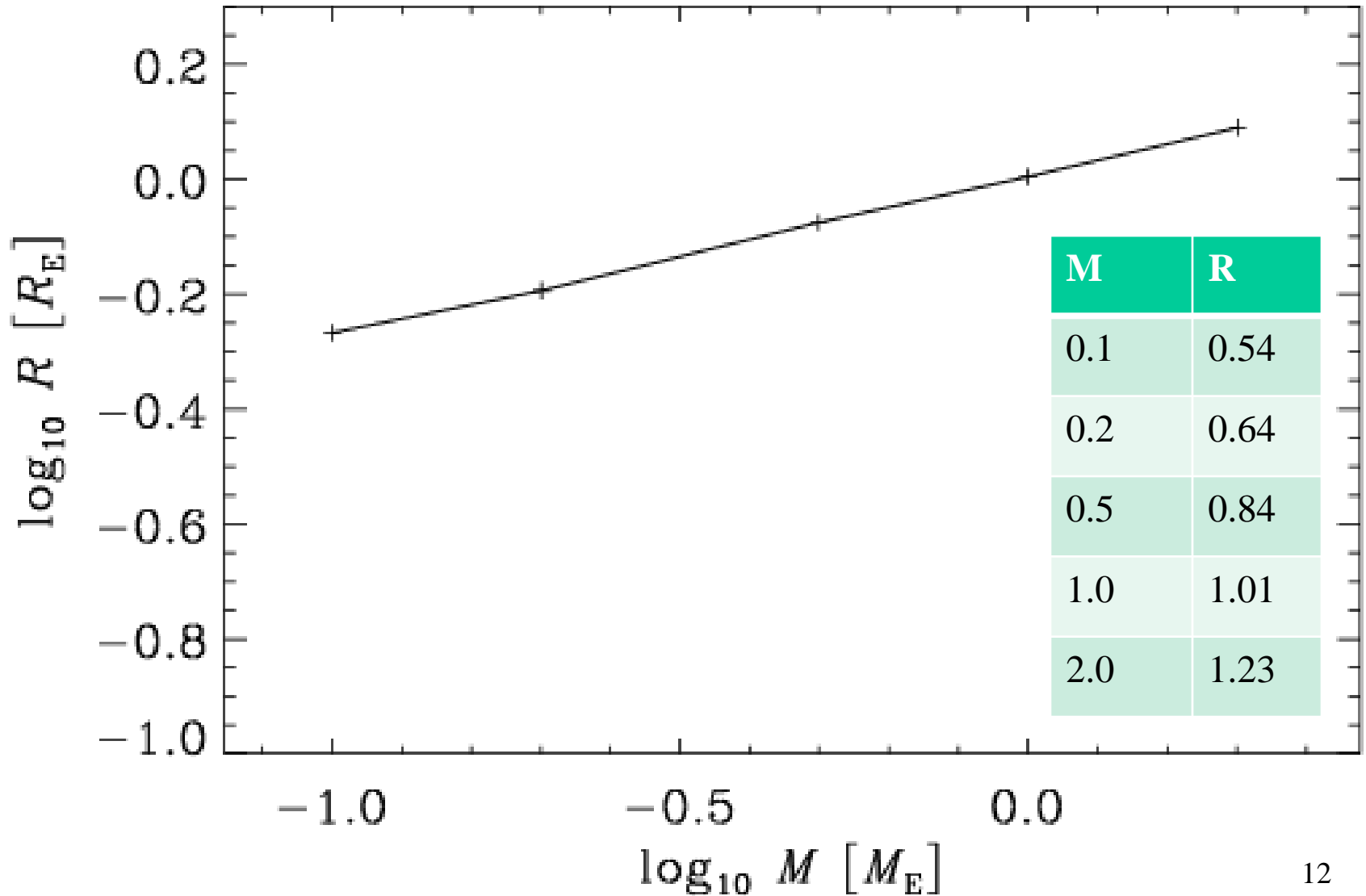
Fit a straight line through the data

we call this a
power law

$$y = 0.005 + 0.28\,x$$

$$\log_{10} R = 0.005 + 0.28\,\log_{10} M$$

$$R = 10^{0.005} \times M^{0.28}$$

$$R = 1.01 \times M^{0.28}$$

M	R
0.1	0.54
0.2	0.64
0.5	0.84
1.0	1.01
2.0	1.23

13
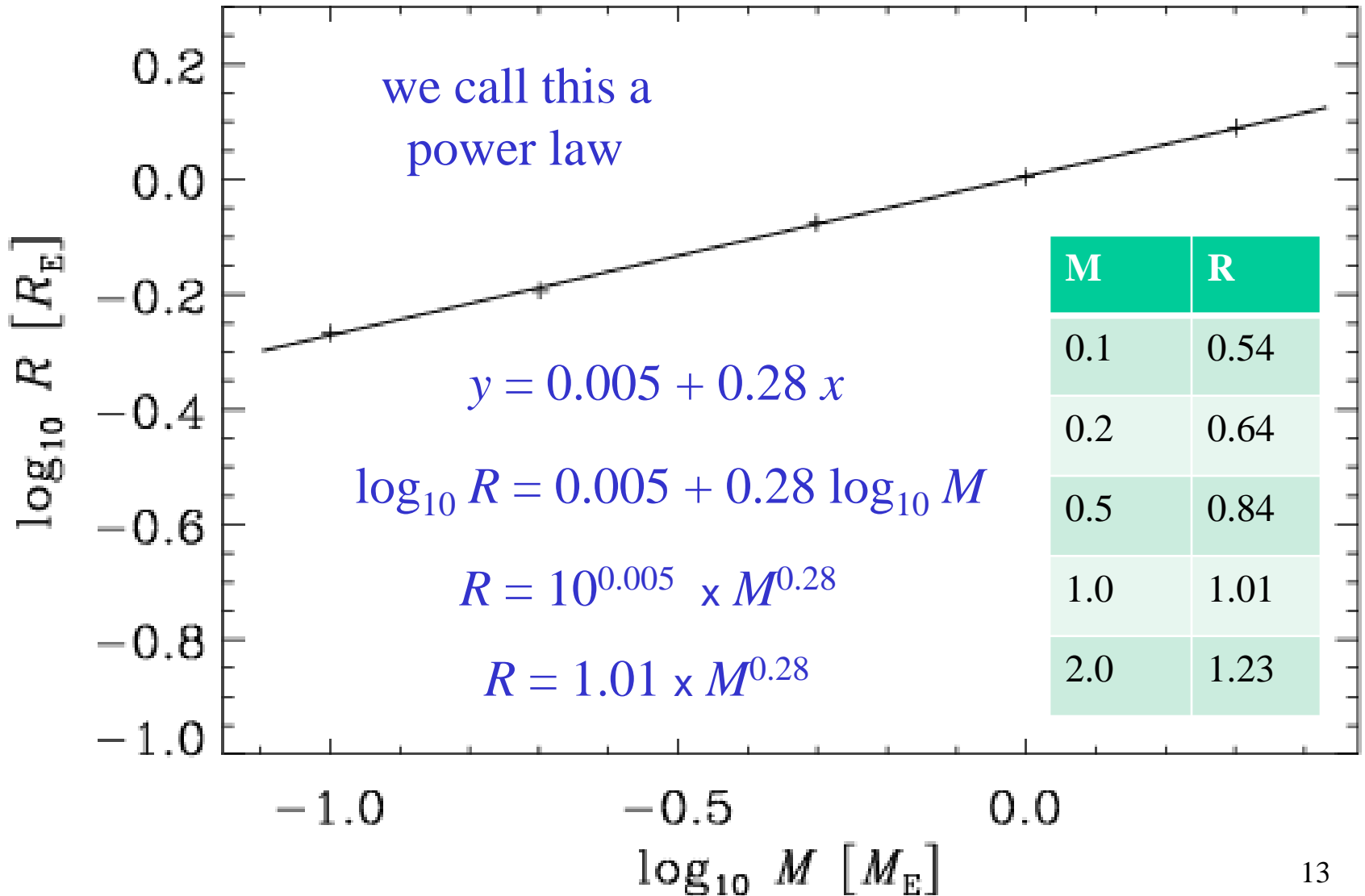
Conclusion

- It is a power law
- But the exponent (slope) is less than 0.33
- It is 0.28

expect: $M = \frac{4\pi}{3} R^3 \rho$

$$R = \left(\frac{M}{\frac{4\pi}{3}\rho} \right)^{1/3}$$

Crater dating

The vertical axis is labeled "Craters per 1 000 000 square kilometers" with values 0.1, 0.5, 1, 5, 10, 50, 100, 500, 1000. The horizontal axis is labeled "Crater Diameter (kilometers)" with values 2, 3, 4, 6, 8, 12, 16, 24, 32, 48, 64, 96, 128, 192, 256. The diagonal lines are labeled 4×10^9 years, 3×10^9 years, 10^9 years, and 10^8 years.
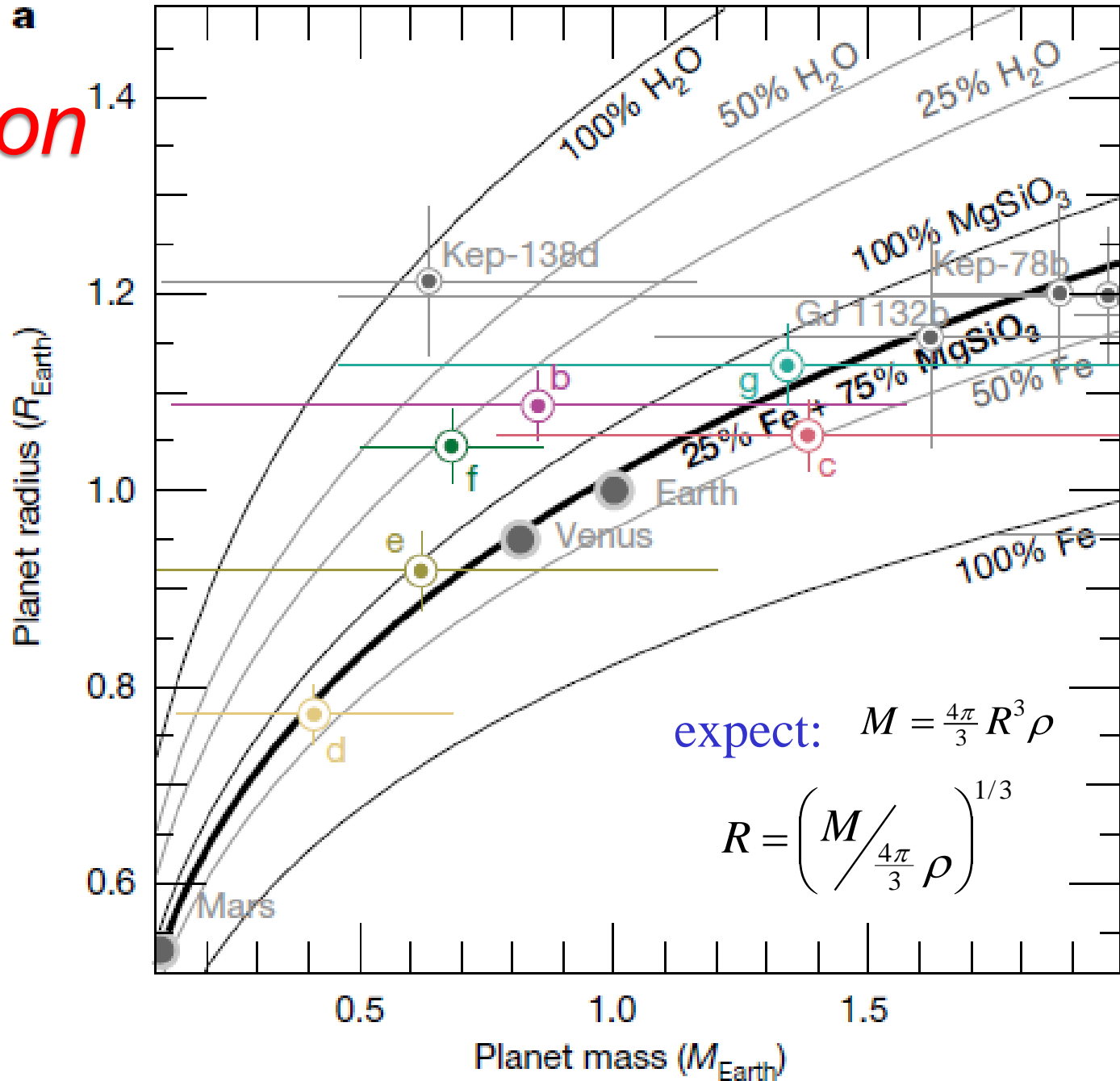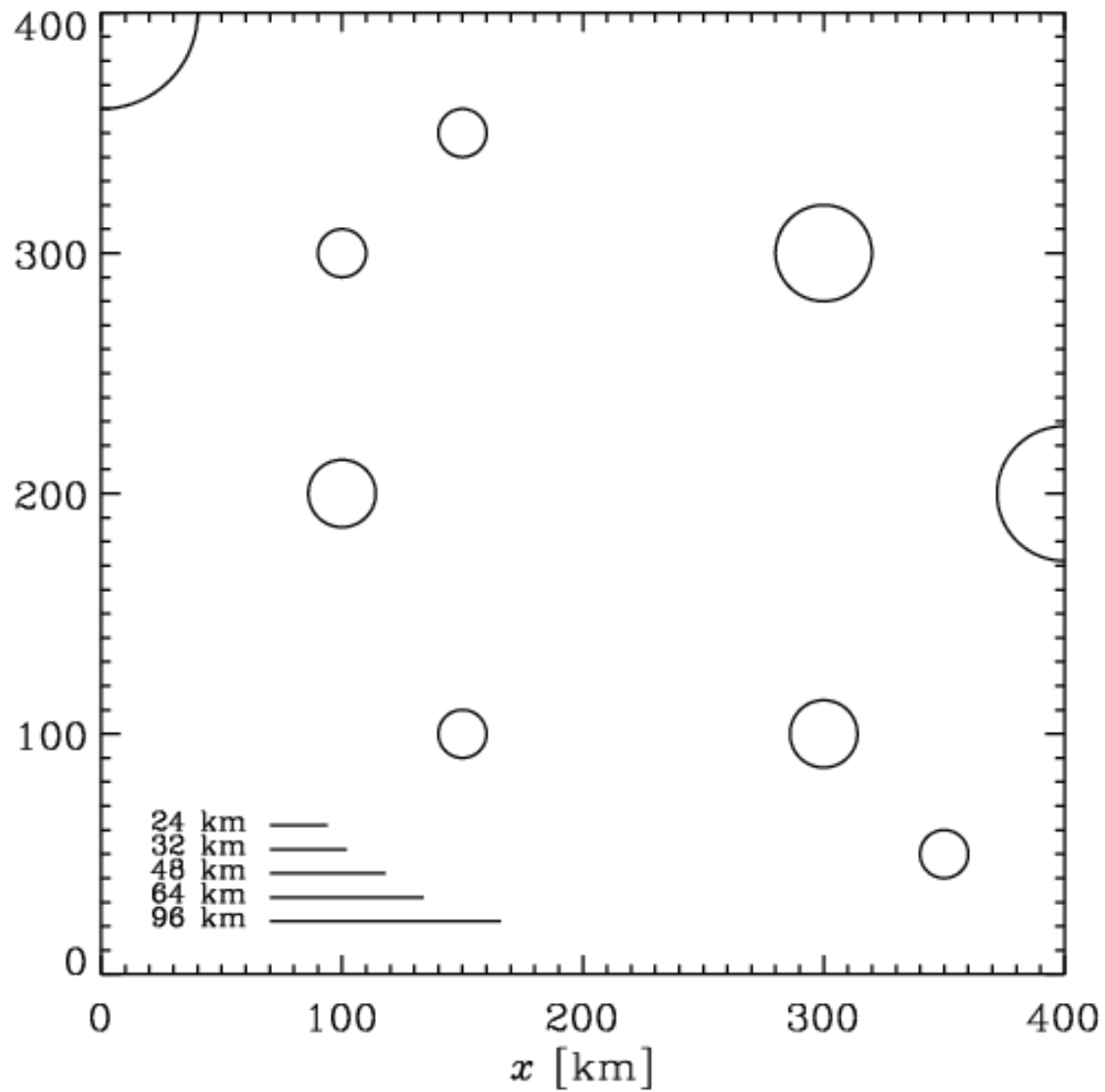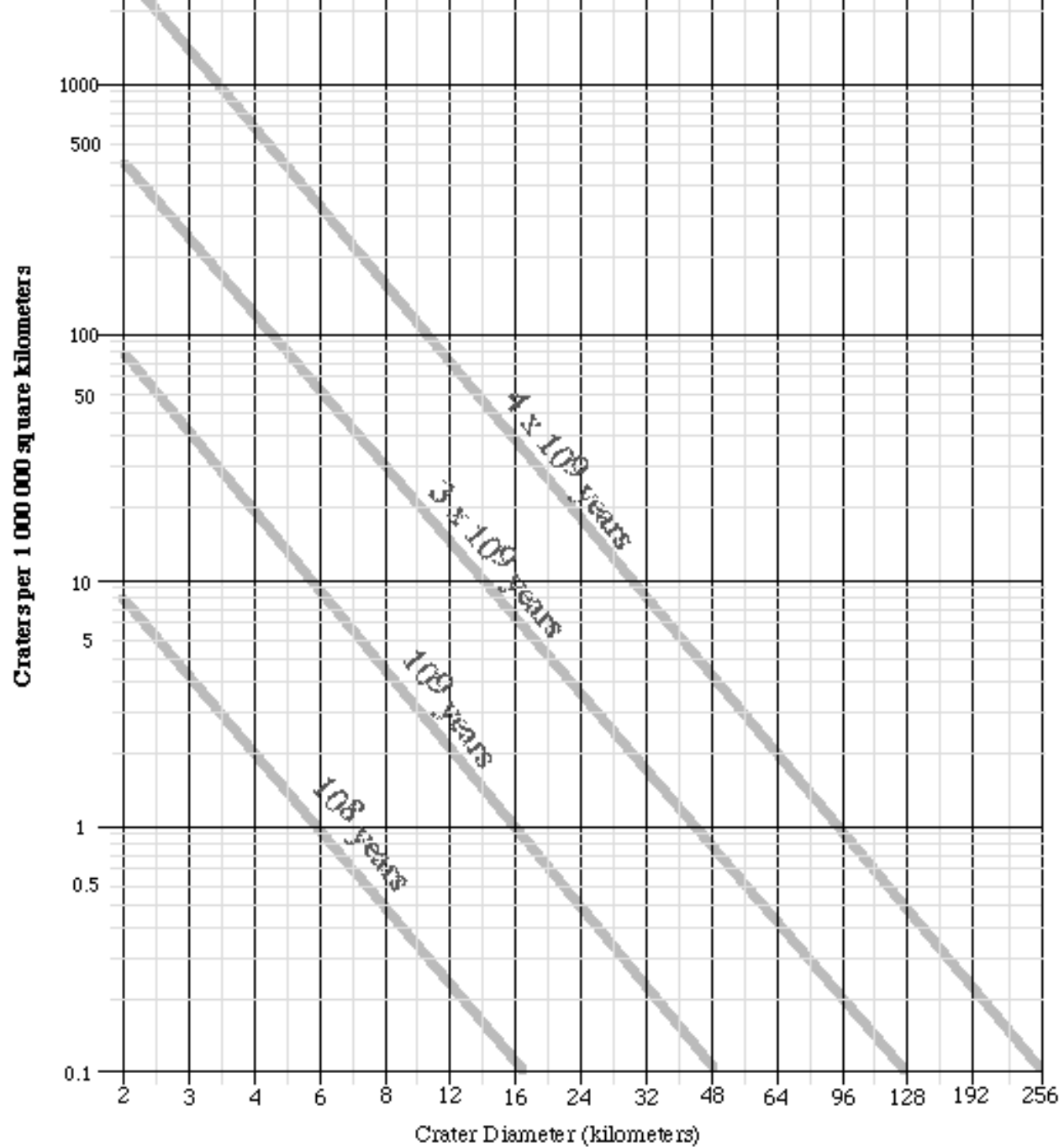
Proxima Centauri b

- Temperature (w/o greenhouse) 234 K
- Radius 0.8 – 1.5 RE
- Distance 4.22 ly
- Metallicity [Fe/H] = 0.24 (→ factor 1.74)
- Discovered 24 Aug 2016
- Southern hemisphere!

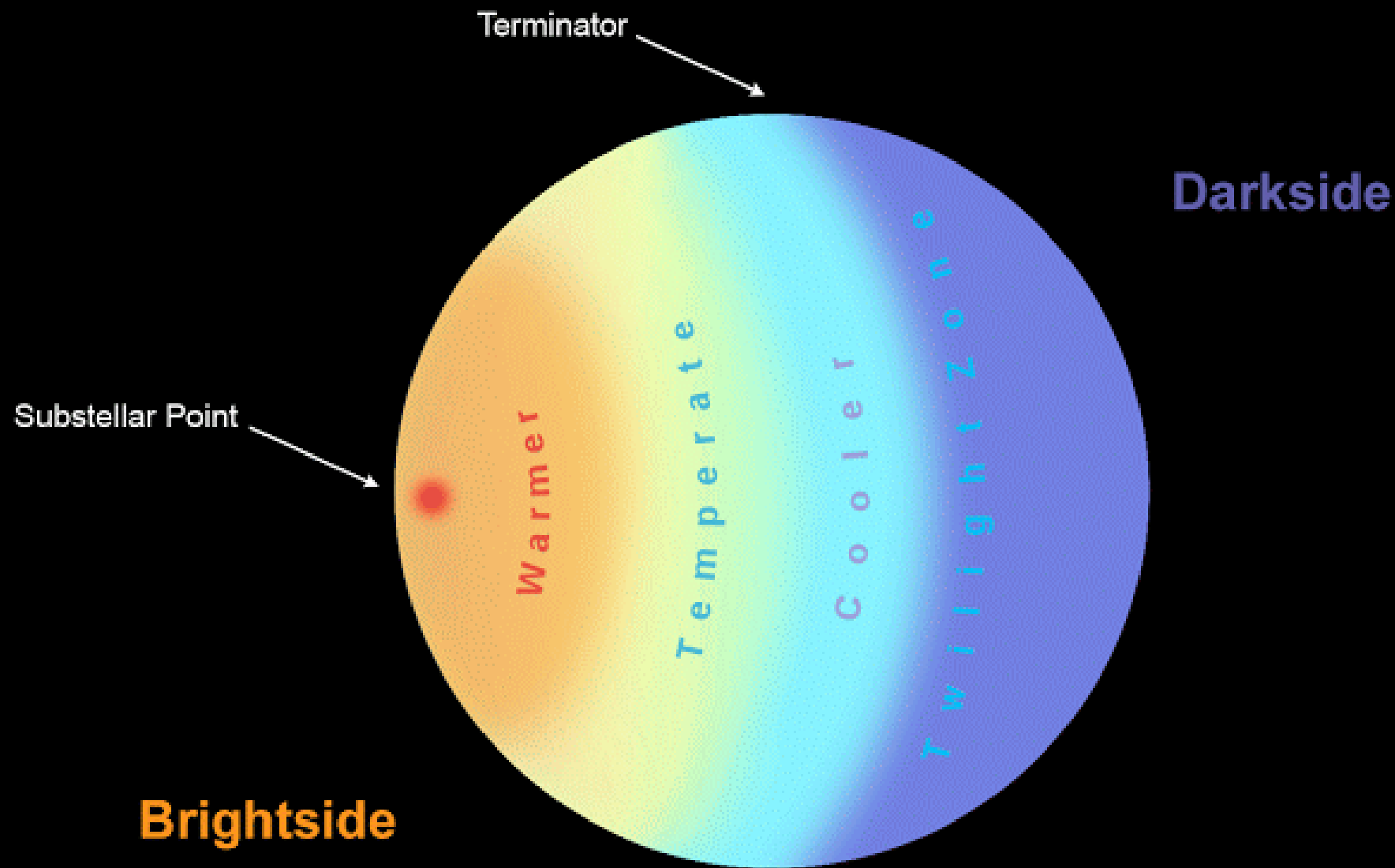# *Problems with M dwarfs*

(Dwarf = main sequence stars)

- M dwarfs have frequent flares
  - At least in their first 1 Gyr
- Closer planet: synchronous rotation
- What does this mean for life?

- (and what about effect of atmosphere)

Most stars are binaries

- Triple system (2 stars + planet) often not stable
- a: wide separation, each star with planet
- b: Stars close together: planet orbits 2 stars

Most stars are binaries

- Triple system (2 stars + planet) often not stable
- a: wide separation, each star with planet
- b: Stars close together: planet orbits 2 stars
- c: intermediate case: unstable? Short-lived?

Starshot

- StarChip: cm scale, g scale

- 2 Mpx camera

- 150 mg atomic battery

- 4m x 4m sail, non-absorbing! (evaporize?)

- Sub-gram photon thrusters

- Alpha Centauri (4.37 ly)

Propulsion

- 10^7 x 10 kW = 100 GW lasers from Earth
- Endure acceleration, vacuum, cold, protons
- 20 – 30 yr
- ~1000 StarChips ($\leftarrow$ dust coll *en route*)
- Accelerate one-by-one
- Within 10 min, 1 TJ to each sail
- Within 1 AU to Proxima Centauri b

Artist's conception

(of photon sail in general)

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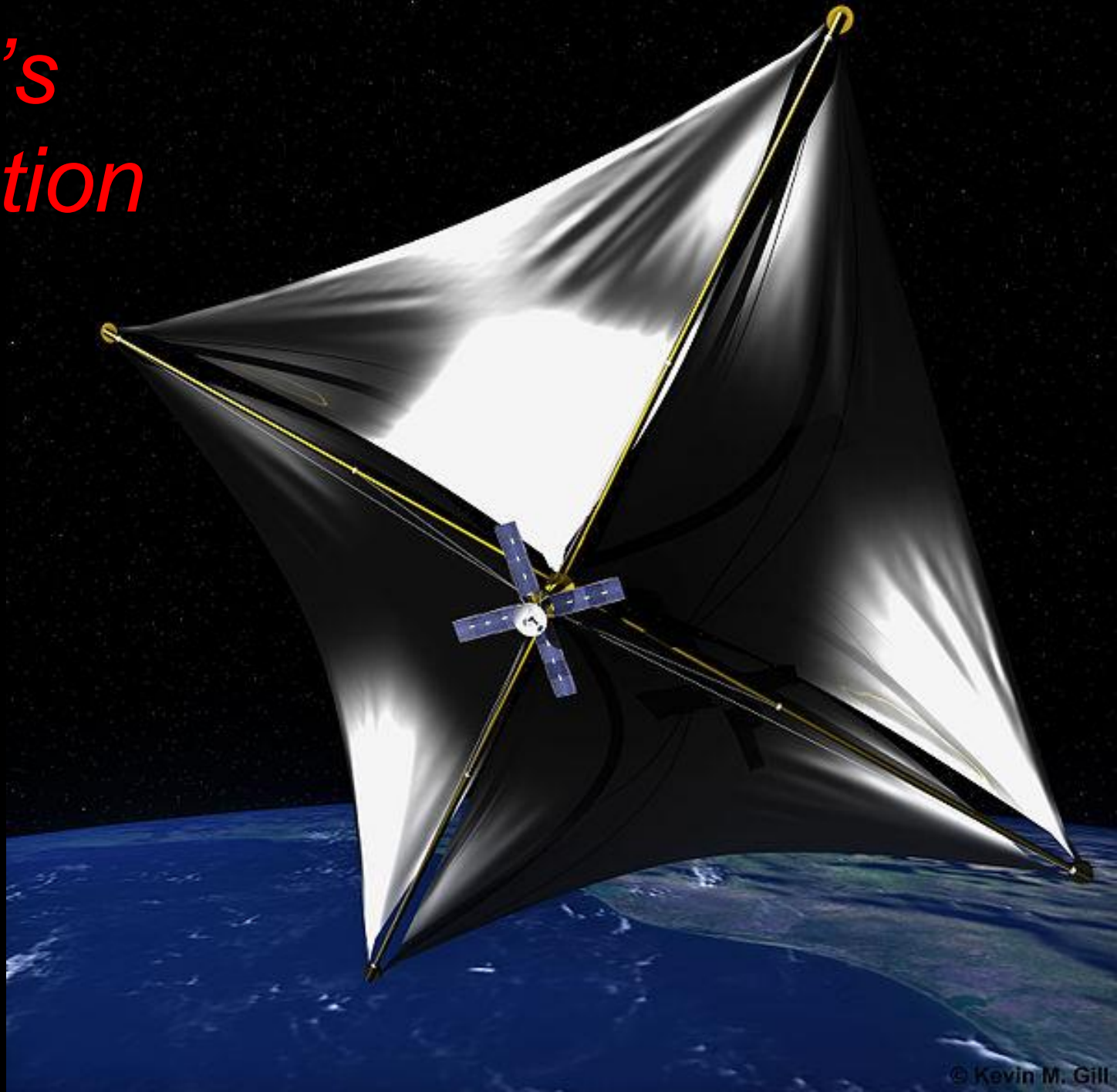
Next time

- The rest of Chapter 9
- Which radio frequency?
- Why just radio?
- Why not light?