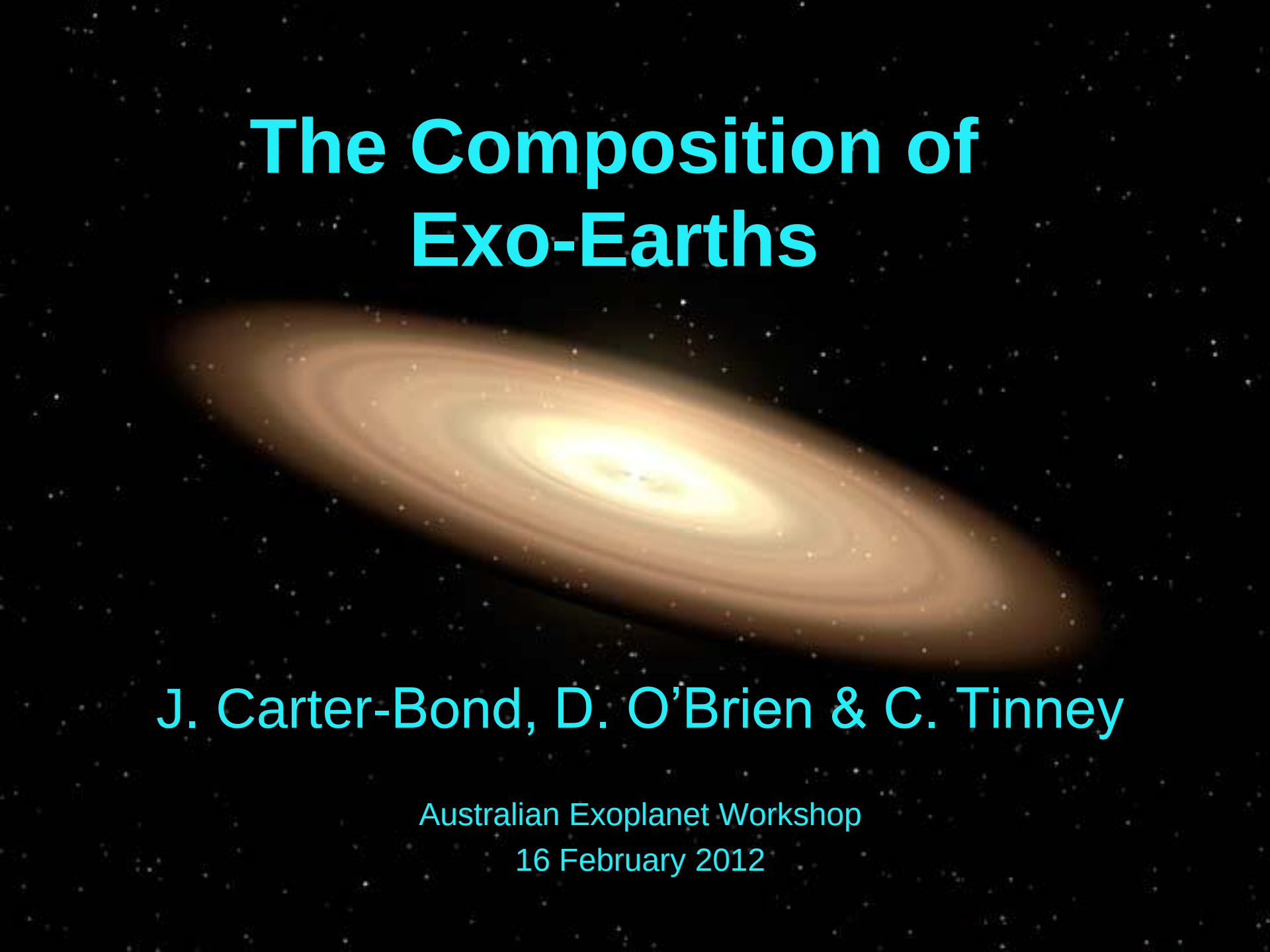
The Composition of Exo-Earths



J. Carter-Bond, D. O'Brien & C. Tinney

Australian Exoplanet Workshop

16 February 2012

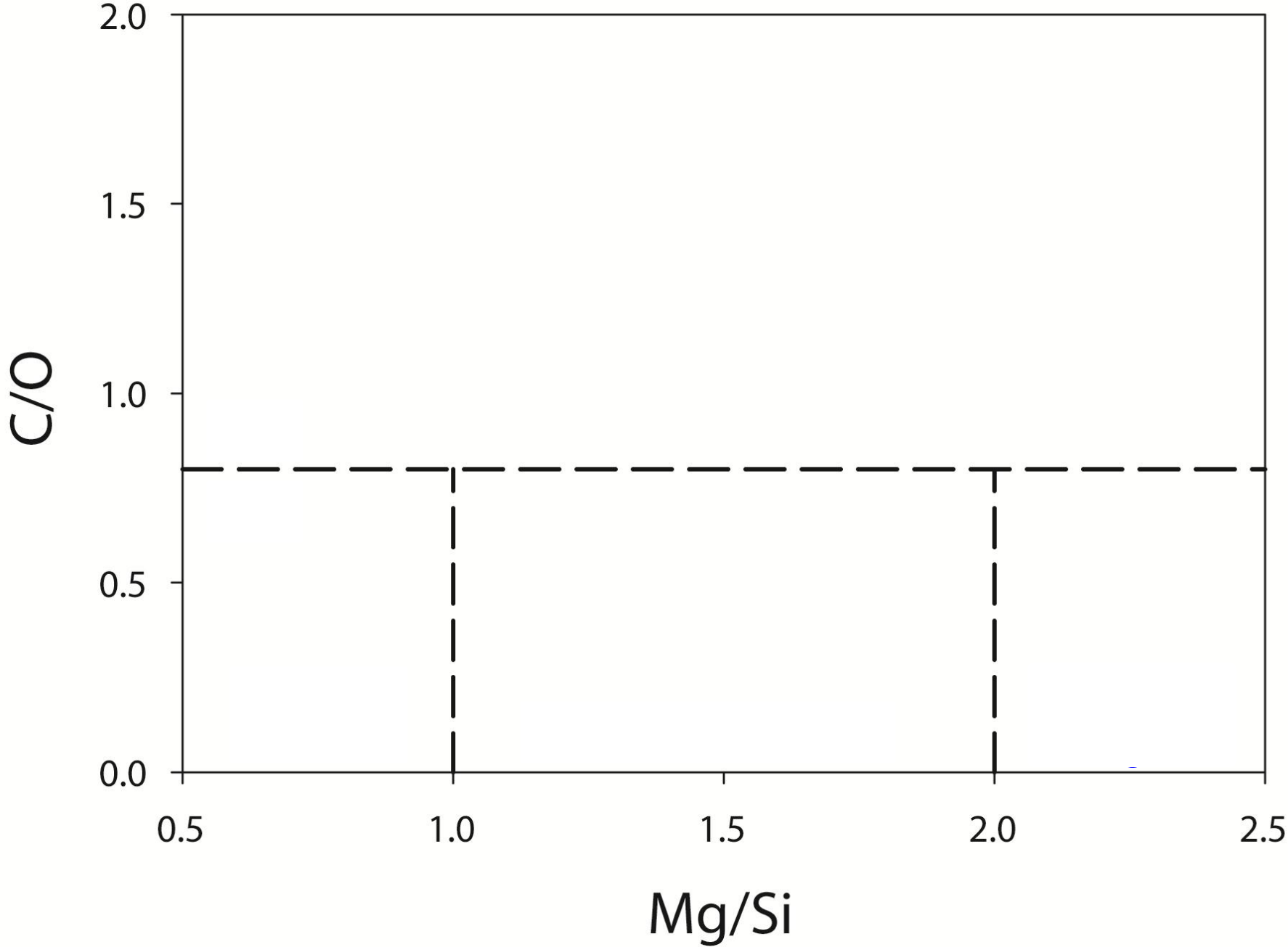
Stars → building blocks → terrestrial planets

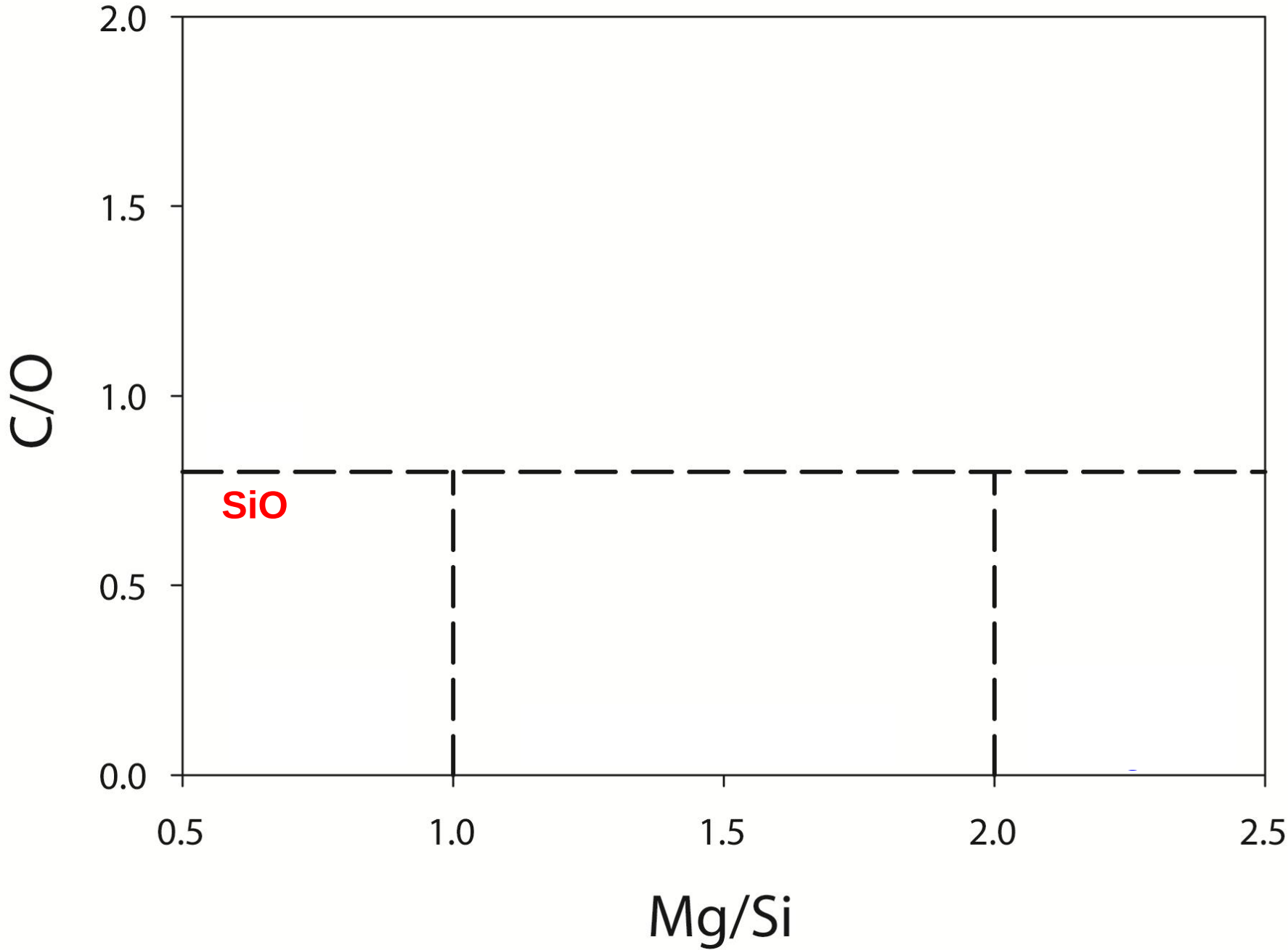
- In terms of extrasolar terrestrial planets, we generally consider other “Earth-like” planets
  - Metallic core, silicate mantle and crust
  - Active on the planetary scale
  - Atmosphere

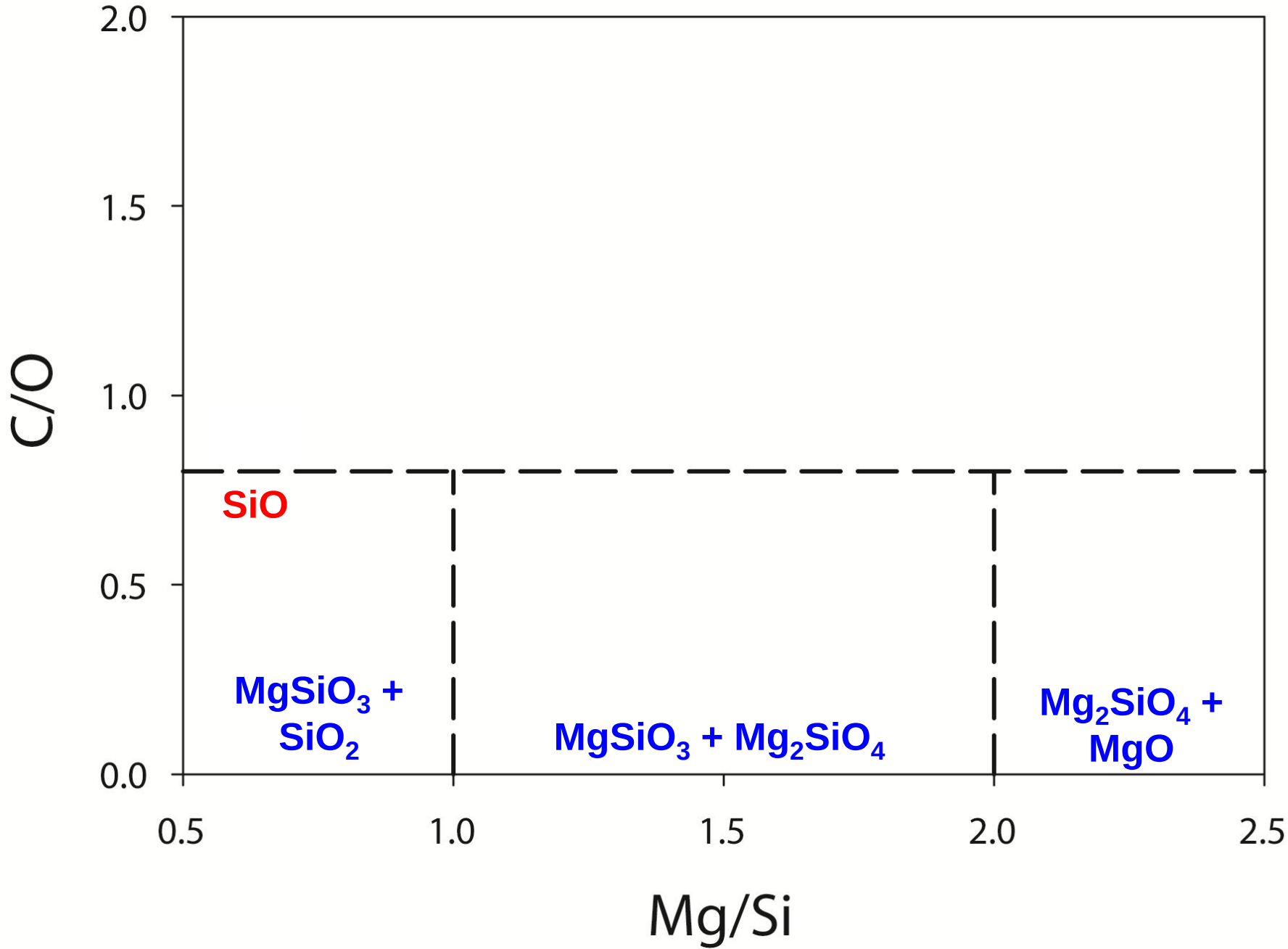
- ***BUT*** extrasolar planetary systems are chemically unusual!

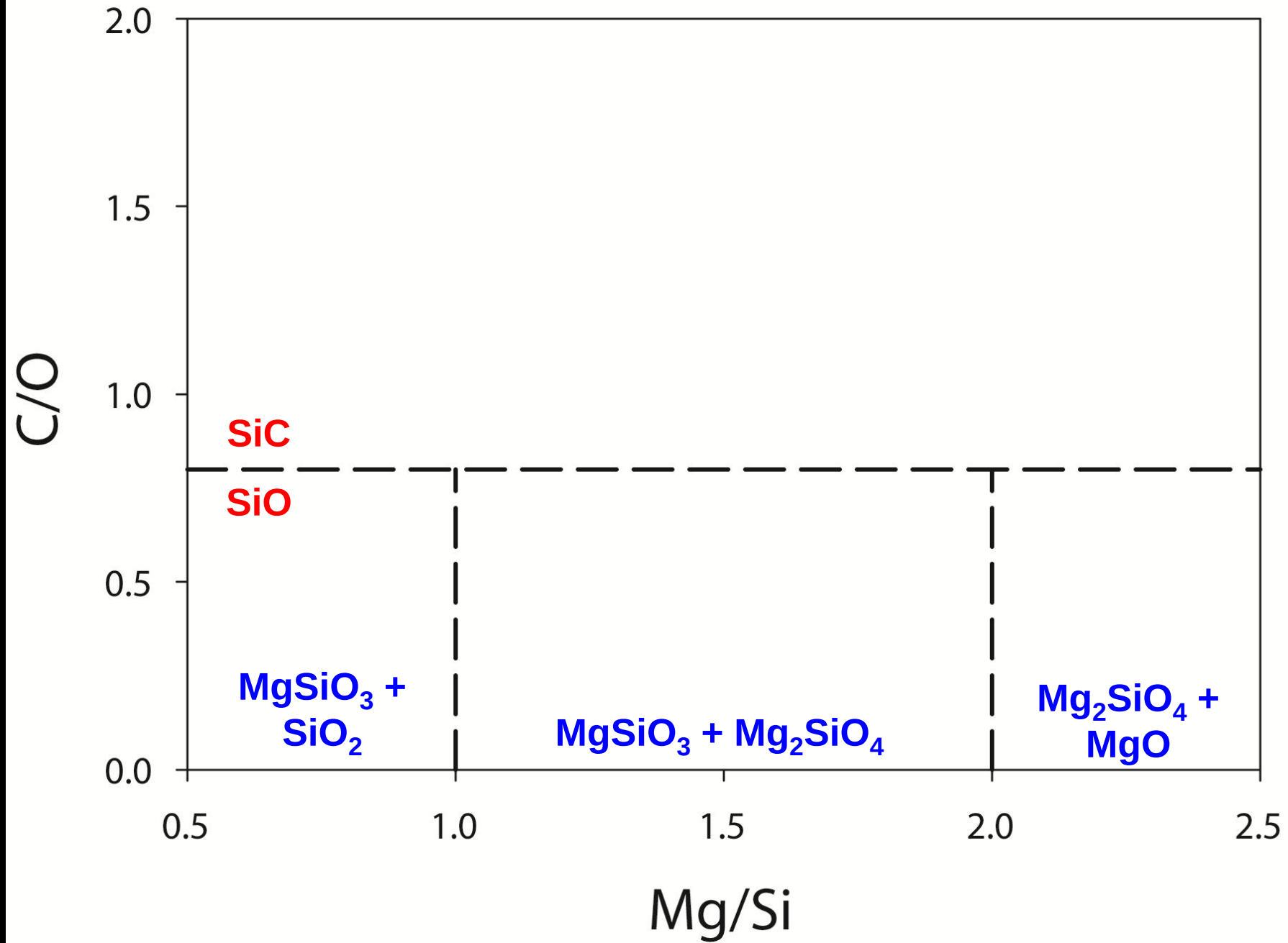
- Since these different compositions may produce different planetary building blocks, what types of terrestrial planets may exist?

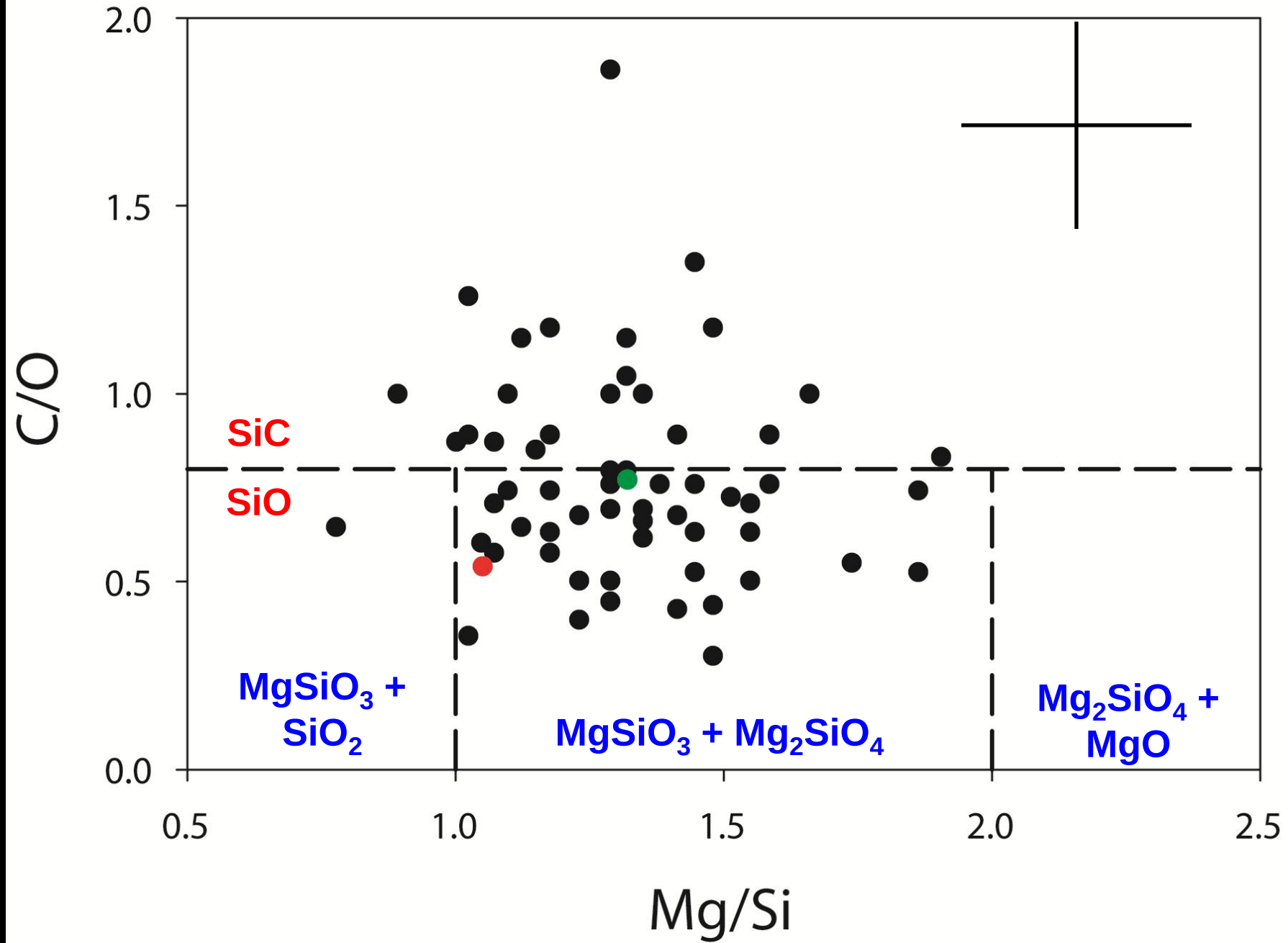
How common is Earth?


2.0
1.5
1.0
0.5
0.0
C/O
0.5
1.0
1.5
2.0
2.5
Mg/Si


2.0
1.5
1.0
0.5
0.0
C/O
SiO
0.5
1.0
1.5
2.0
2.5
Mg/Si


2.0
1.5
1.0
0.5
0.0
C/O
SiO
MgSiO3 + SiO2
MgSiO3 + Mg2SiO4
Mg2SiO4 + MgO
0.5
1.0
1.5
2.0
2.5
Mg/Si

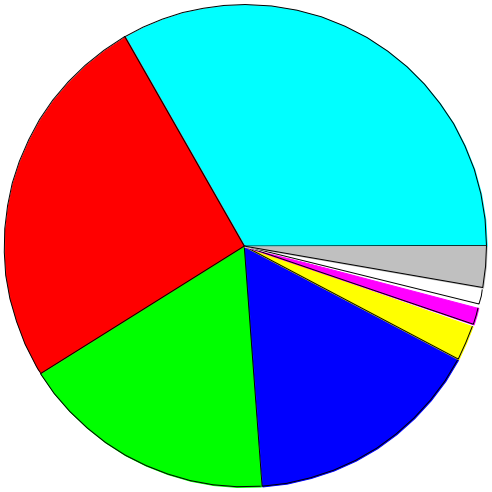

2.0
1.5
1.0
0.5
0.0
C/O
SiC
SiO
MgSiO3 + SiO2
MgSiO3 + Mg2SiO4
Mg2SiO4 + MgO
0.5
1.0
1.5
2.0
2.5
Mg/Si


2.0
1.5
1.0
0.5
0.0
C/O
SiC
SiO
MgSiO3 + SiO2
MgSiO3 + Mg2SiO4
Mg2SiO4 + MgO
0.5
1.0
1.5
2.0
2.5
Mg/Si

Chemistry meets Dynamics

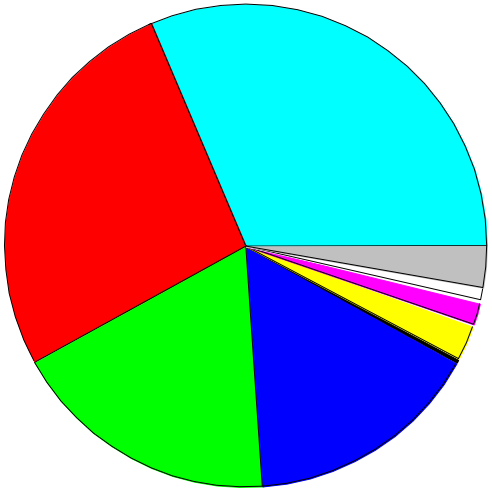
- Use very high resolution n-body accretion simulations of terrestrial planet accretion (e.g. O'Brien et al. 2006) for extrasolar planetary systems
- Use equilibrium thermodynamics to predict compositions
- Use spectroscopic photospheric abundances of 16 elements: H, He, C, N, O, Na, Mg, Al, Si, P, S, Ca, Ti, Cr, Fe, Ni
- Assign each embryo a composition based on formation region

HD72659



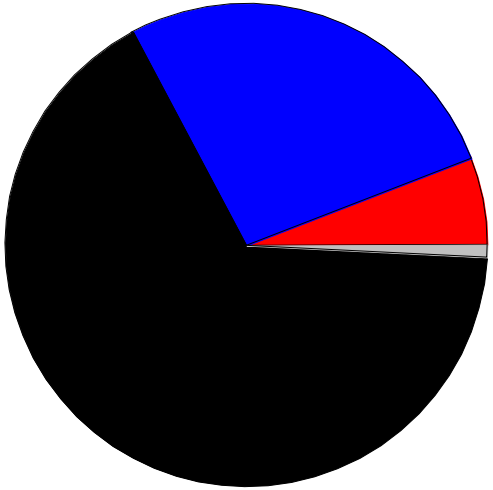
1.03 M $_{Earth}$
0.95AU
C/O = 0.40

Gl777

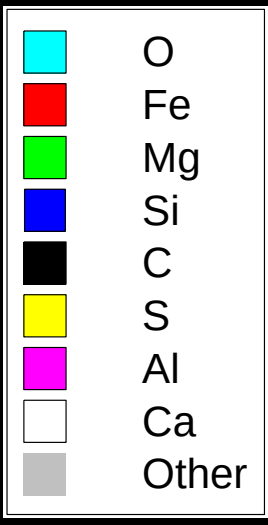


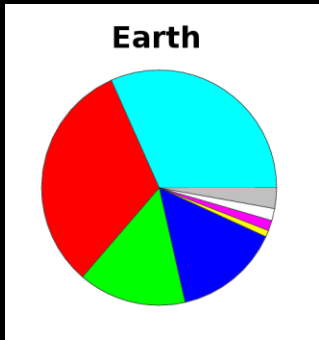
1.10 M $_{Earth}$
0.89AU
C/O = 0.78

HD108874



0.46 M $_{Earth}$
0.38AU
C/O = 1.35





See Bond et al. (2010) A*pJ*

What About Migration?

Giant planet migration is believed to have occurred in many extrasolar planetary systems.

Migration can move a large amount material both inwards and outwards → possibly change final planet composition.

Consider Three Scenarios

1. In-Situ formation (Gas giant doesn't migrate from 1AU)

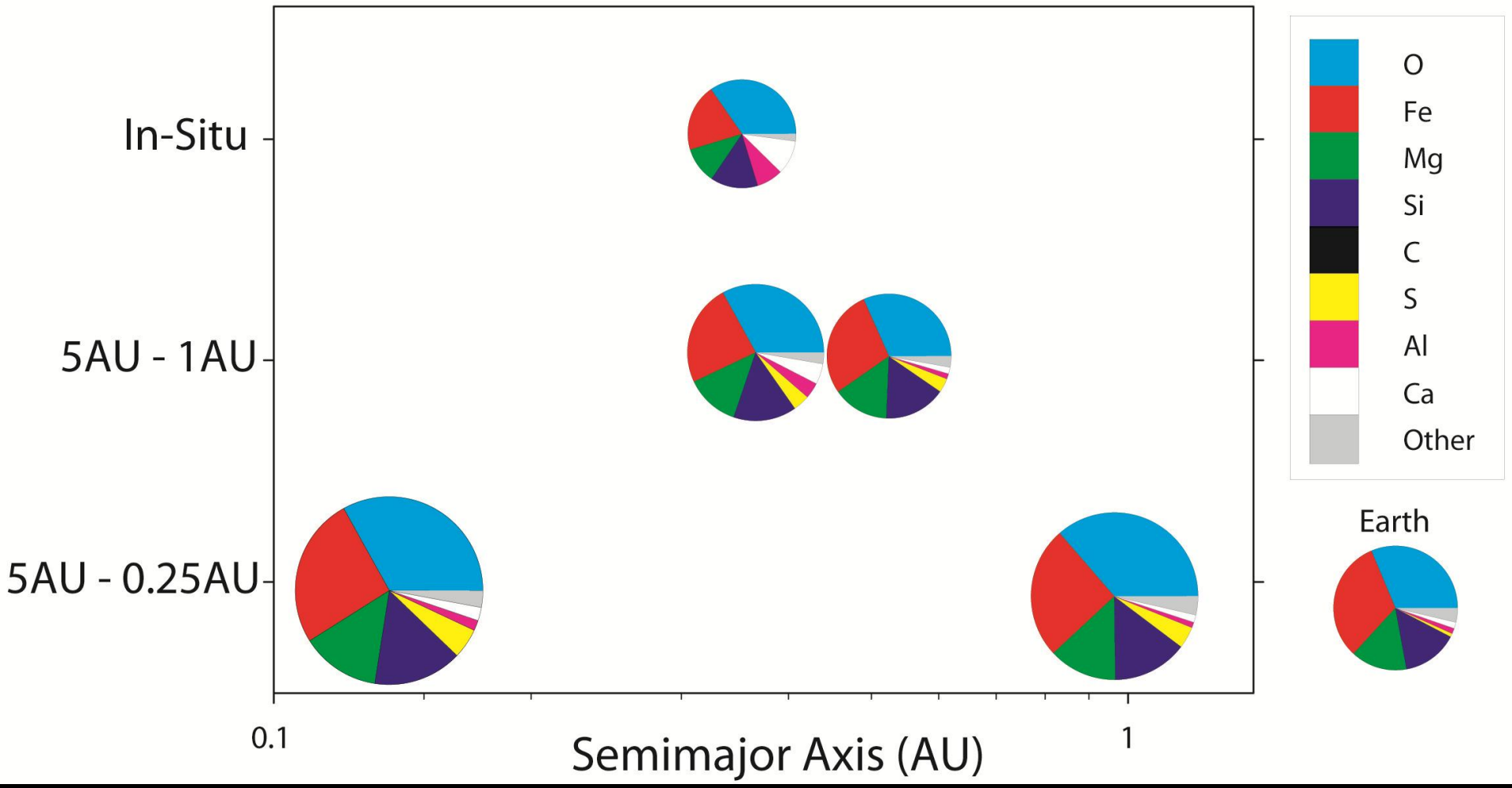
2. Jupiter-mass body migrates from 5AU to 1AU

3. Jupiter-mass body migrates from 5AU to 0.25AU

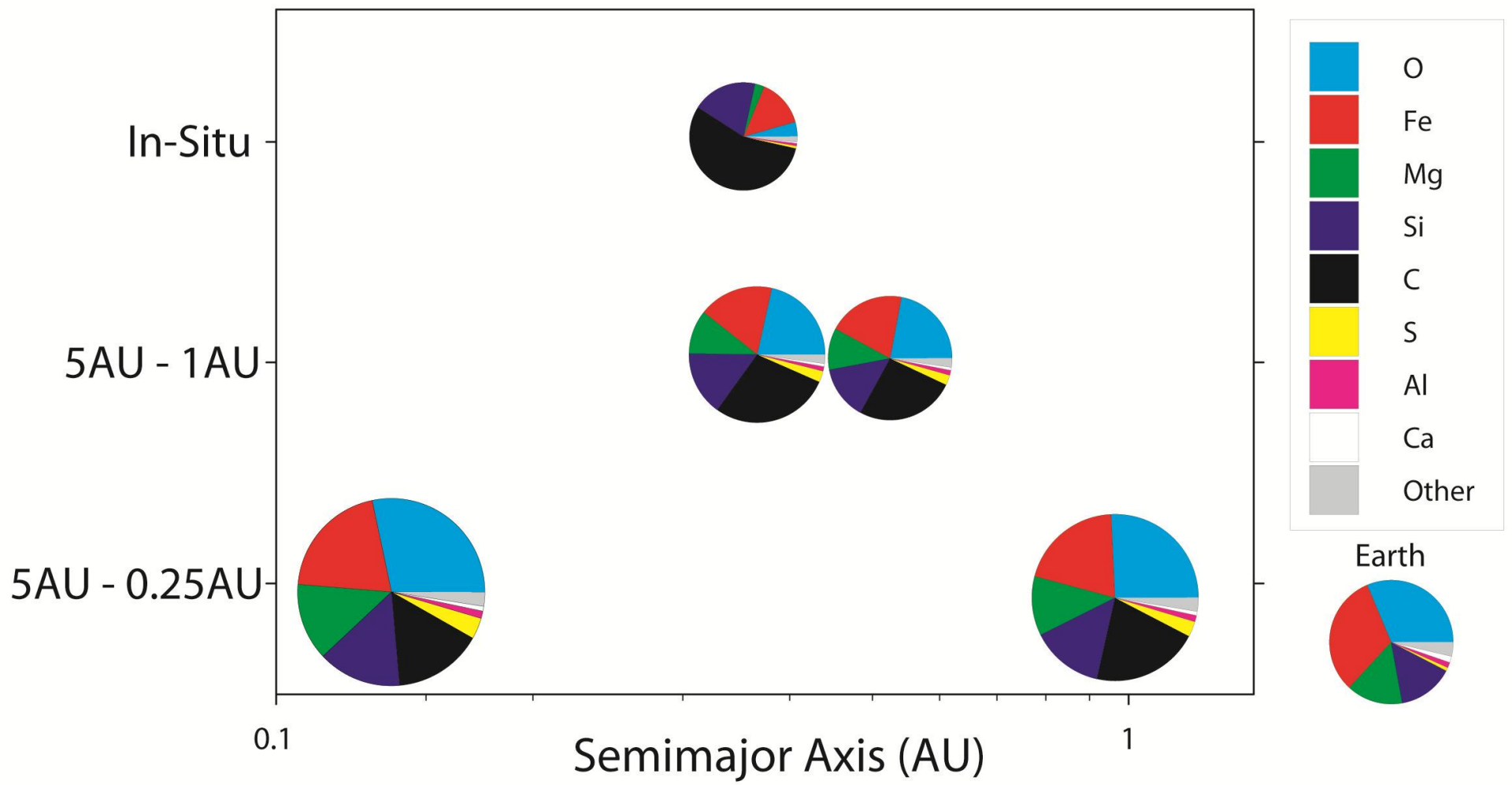
Consider Two Compositions

1. Solar
2. HD4203 (C/O = 1.85)

Solar Composition:



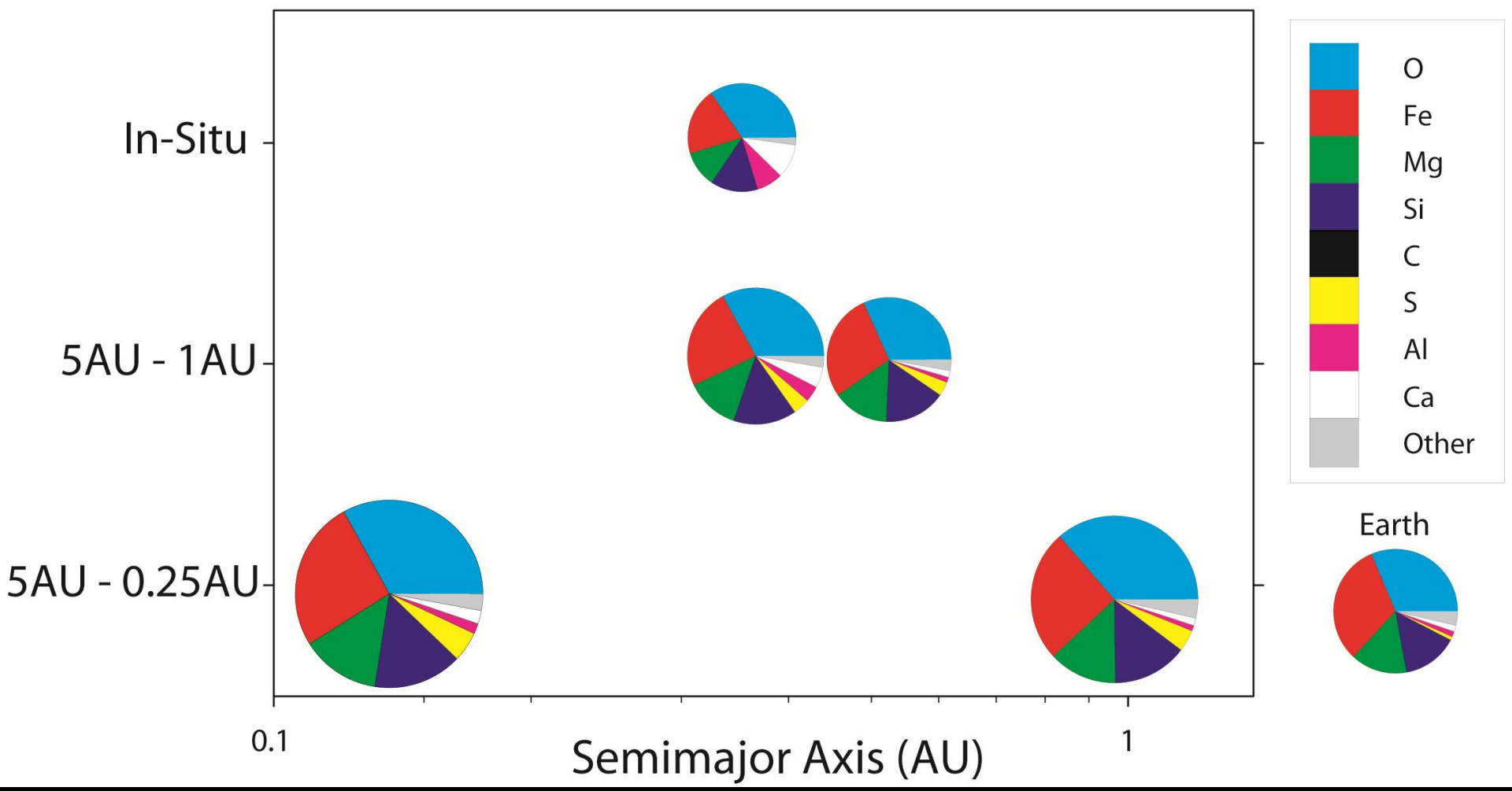
HD4203 Composition:



Water?

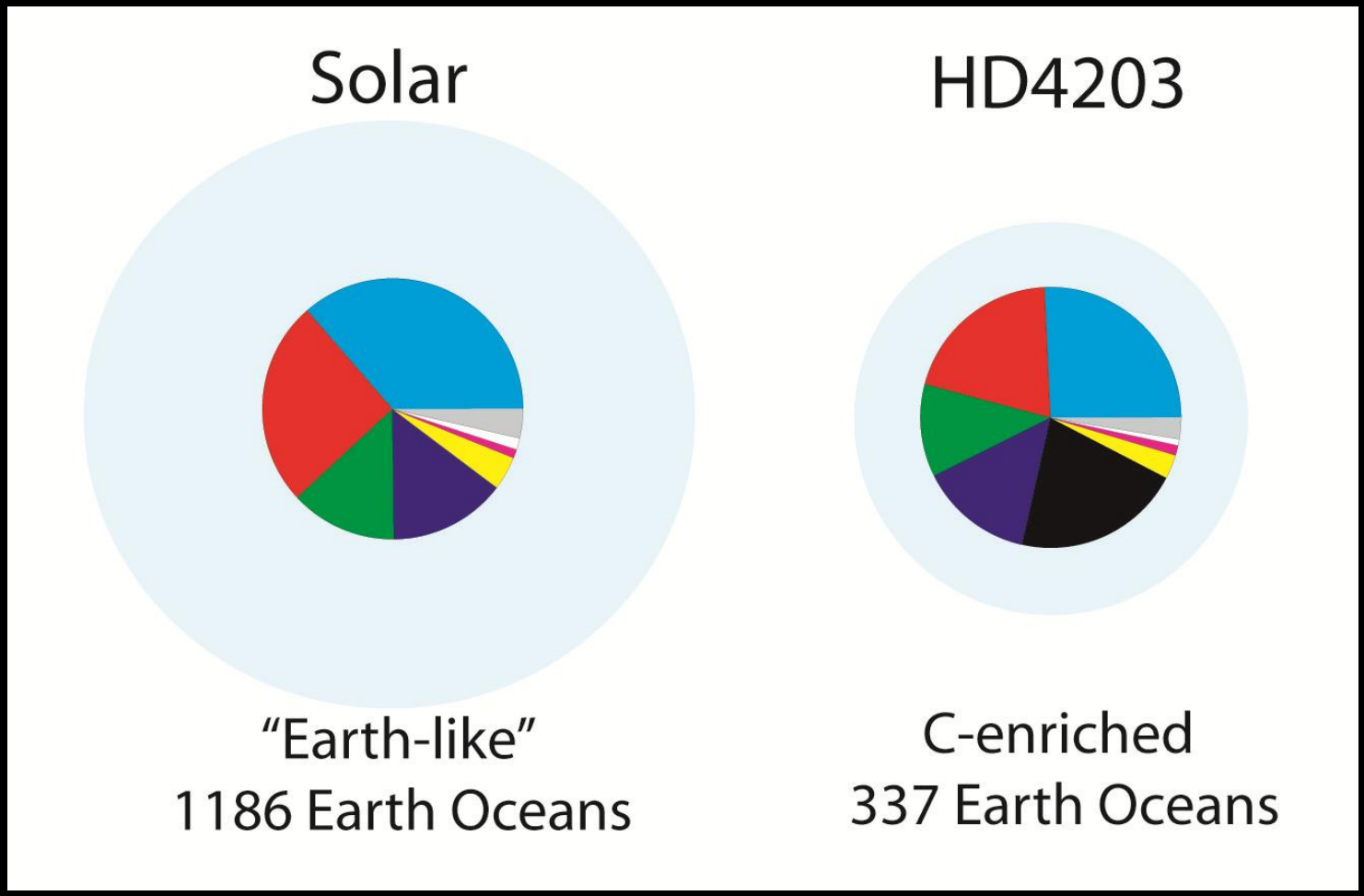
- Migration can deliver massive amounts of water to the “dry” inner regions of the planetary systems.
- In-situ – no water delivered
- All migration – water and hydrous phases delivered

Water?


In-Situ
5AU - 1AU
5AU - 0.25AU
0.1
1
Semimajor Axis (AU)
O
Fe
Mg
Si
C
S
Al
Ca
Other
Earth

Water?

Example: 3.05 M_{Earth} at 0.91AU



Take-Home Message

- Large range of stellar compositions suggests a wide range of terrestrial planets
- Final planet compositions depend somewhat on giant planet migration history
- Wide variety of biological, chemical and planetary implications