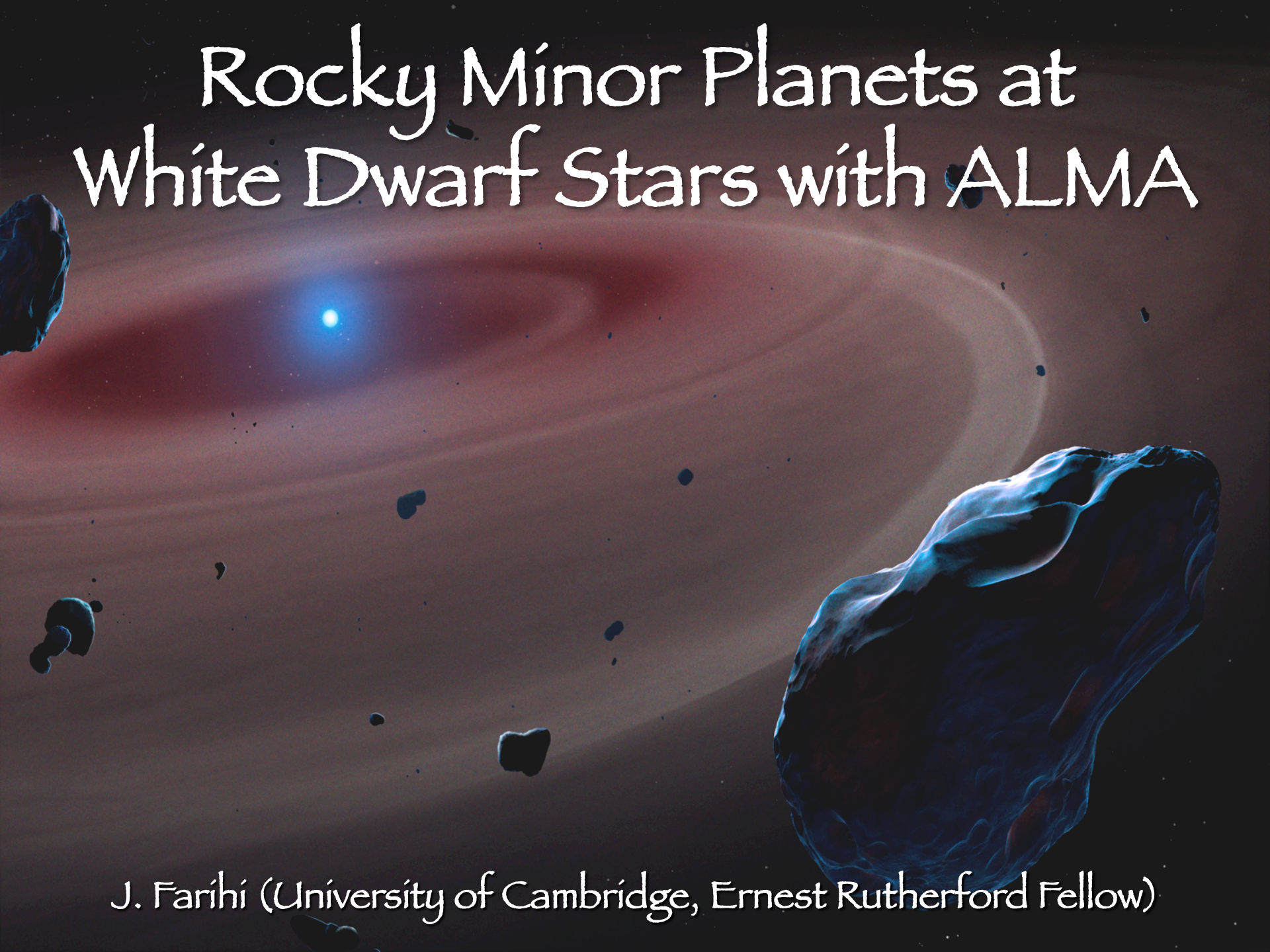
Rocky Minor Planets at White Dwarf Stars with ALMA

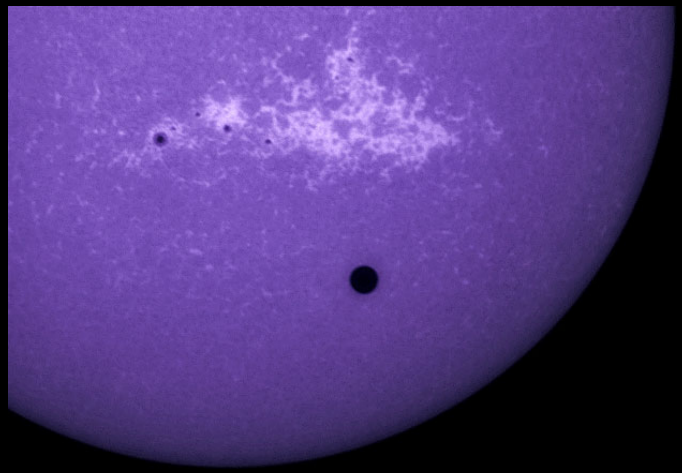


J. Farihi (University of Cambridge, Ernest Rutherford Fellow)

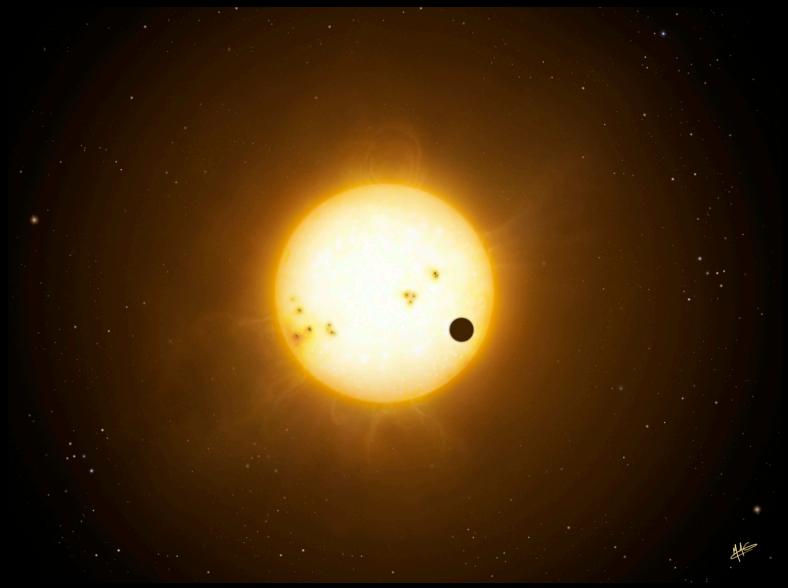
Contributors

A. Bonsor	(Grenoble)
B. T. Gänsicke	(Warwick)
J. S. Greaves	(St Andrews)
D. Koester	(Kiel)
O. Panic	(Cambridge)
M. C. Wyatt	(Cambridge)

Solid Exoplanets on the Rise

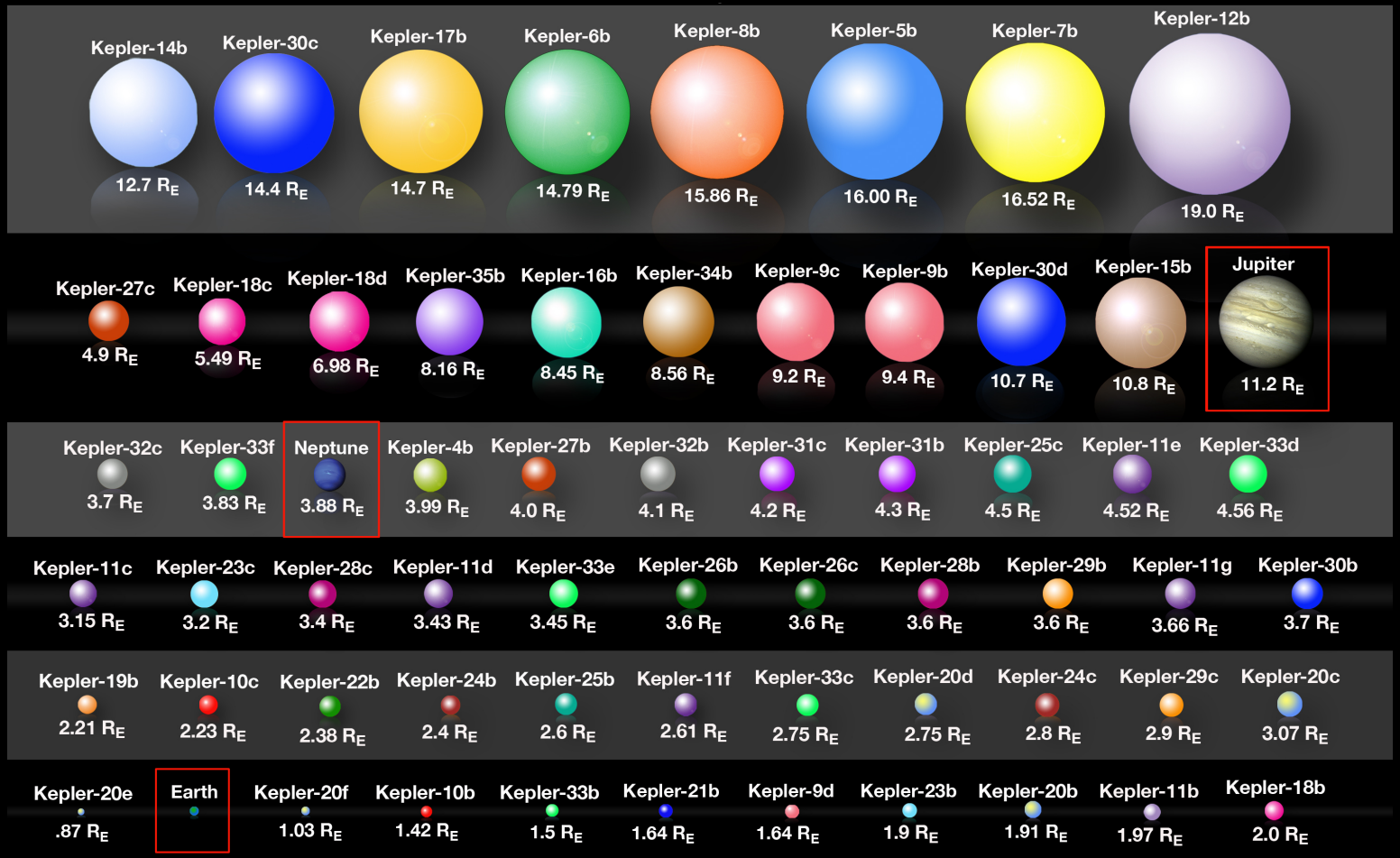


Venus transit 2012

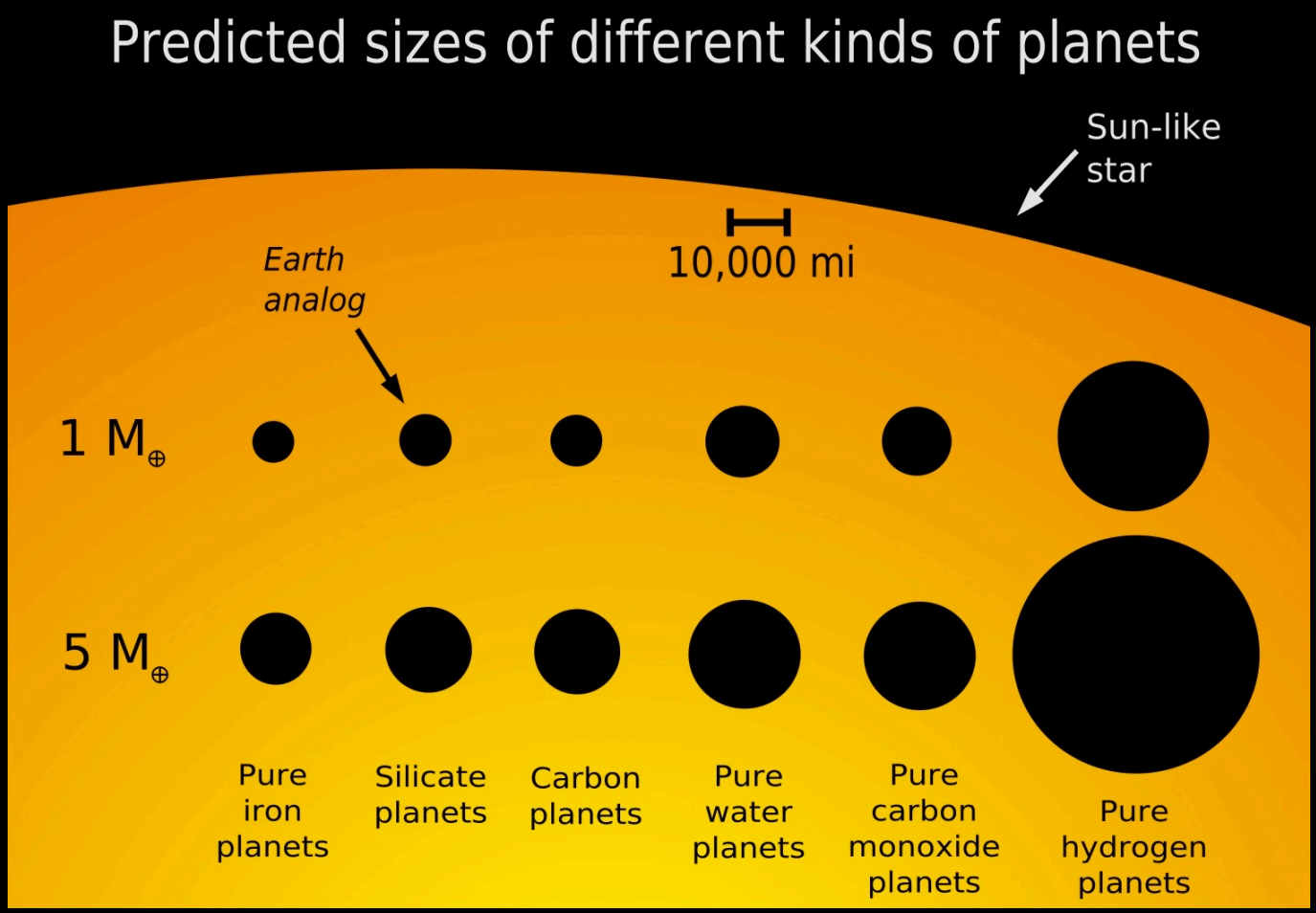


Exoplanet transit

Kepler Zoo 2012.2

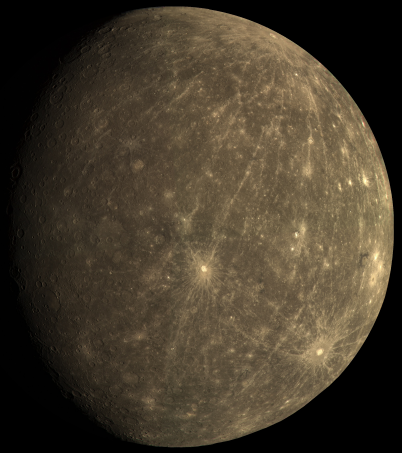


Planet *R-M* is Degenerate



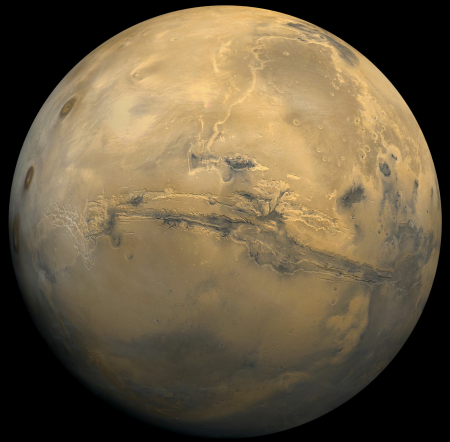
Some Possible Compositions

Iron-rich (Mercury)



Iron-poor (Moon)

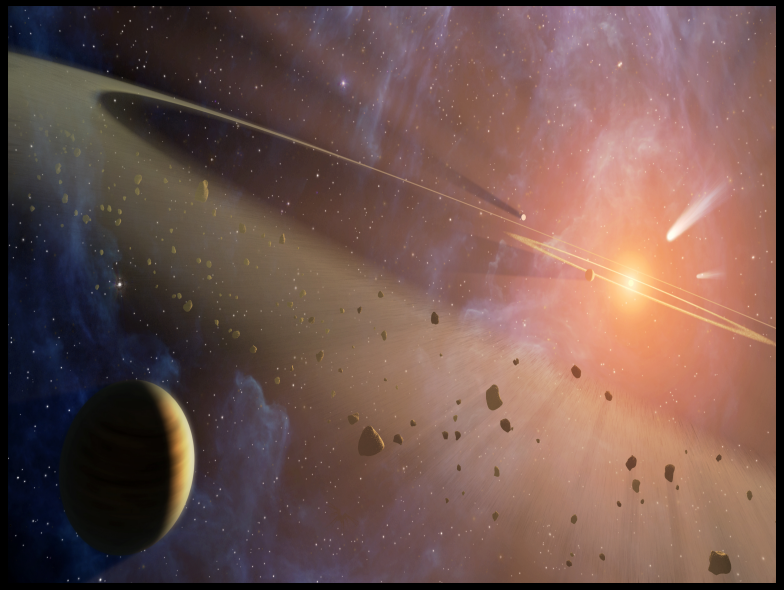
Silicate-rich (Mars)



Earth-like

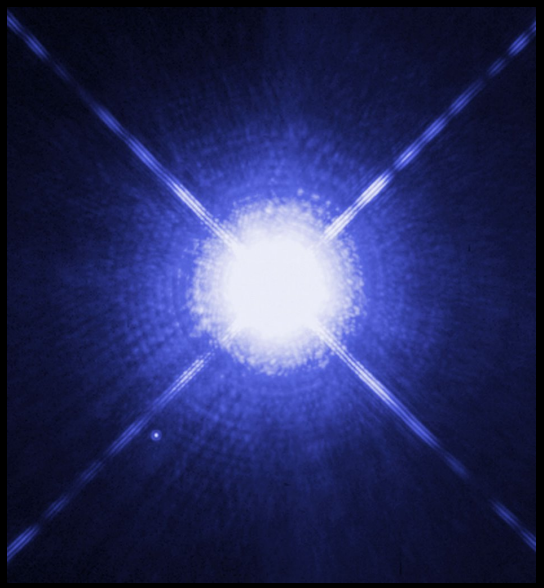
Asteroids are Terrestrial

- Primordial building blocks of the terrestrial planets



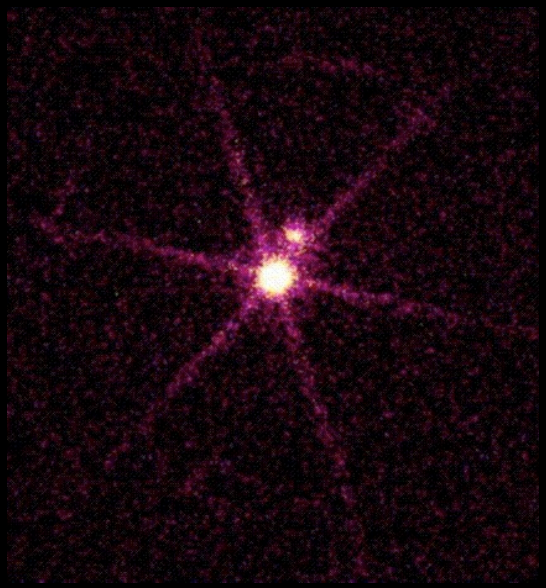
- Meteorites are fragments
- Possibly delivered Earth's water & volatiles

Sírius B: Future Sun



Optical

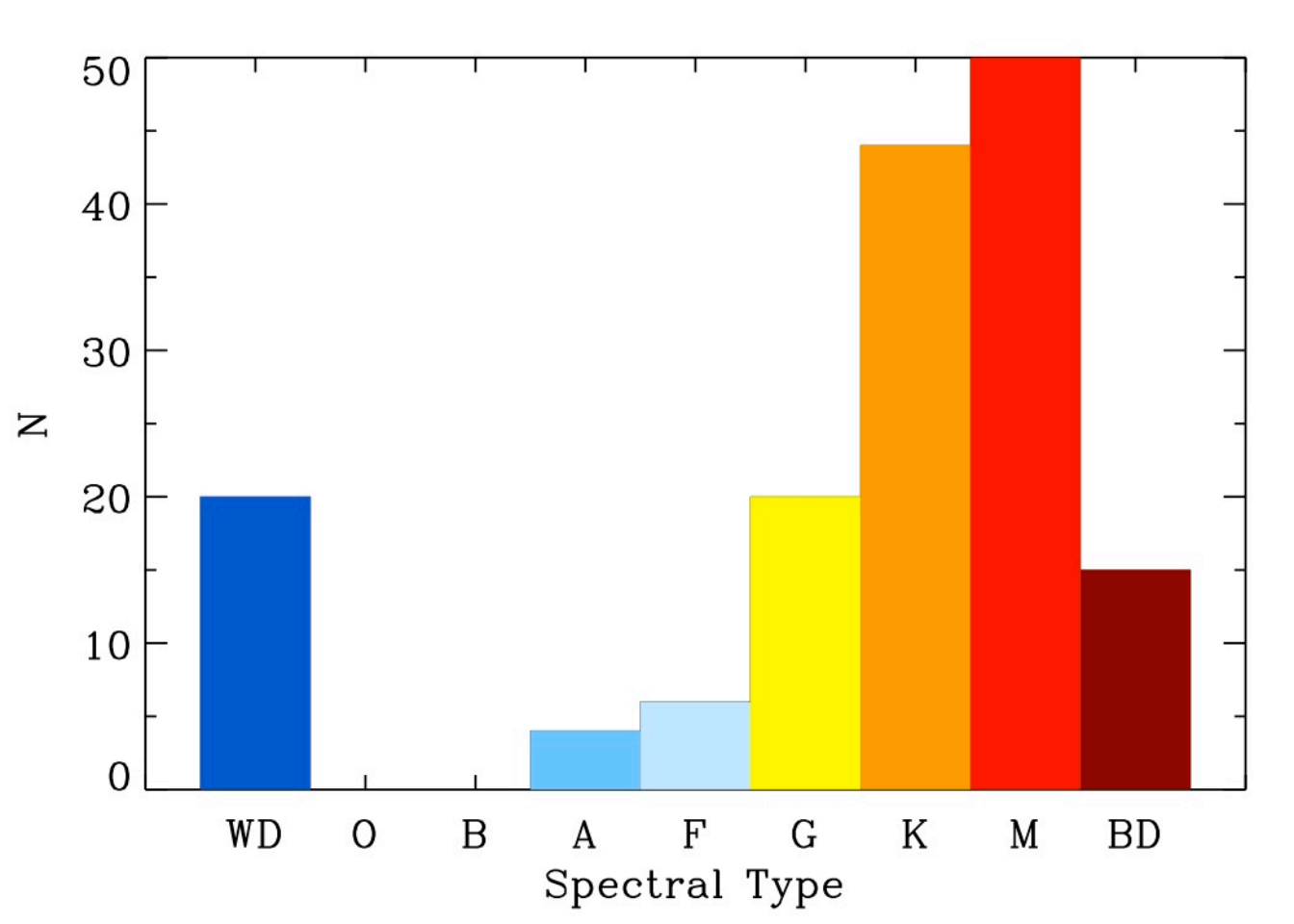
Artist



X-ray

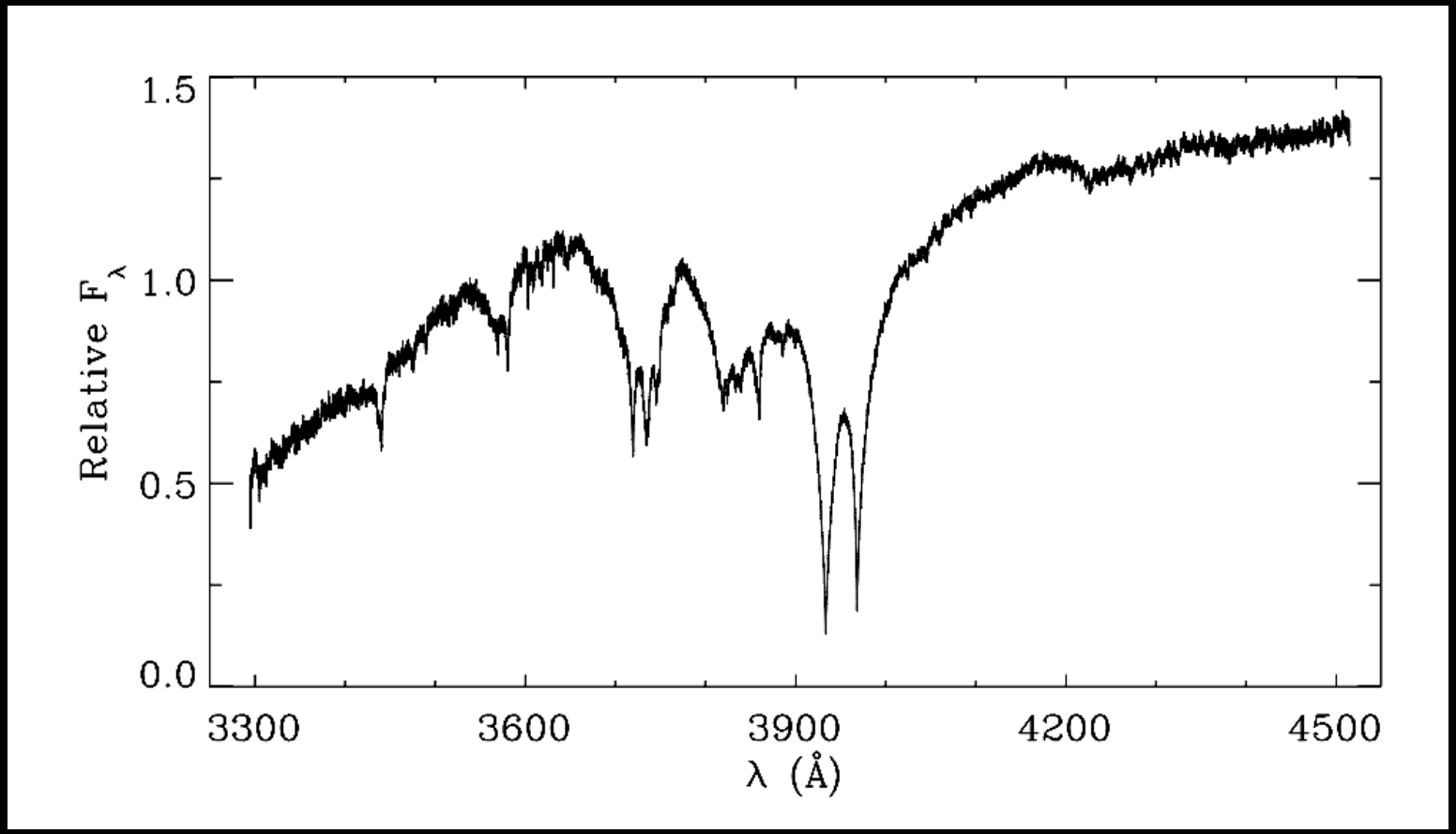
Known Stars $d < 10$ pc

(RECONS Project: T.J. Henry)



van Maanen's Star

(van Maanen 1917; SPY project: R. Napiwotzki)

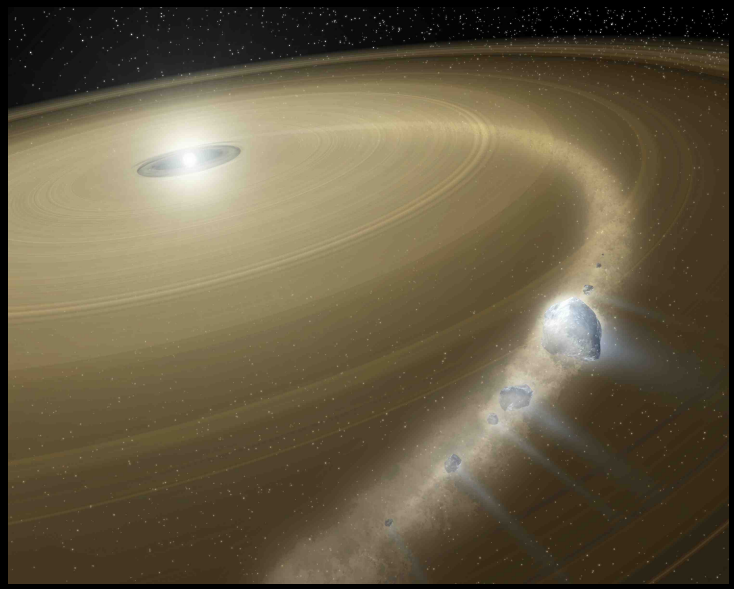


Metal-Contaminated Stars

- Gravity strong and radiation weak as they cool
  - pure hydrogen or helium atmospheres
- Metal-rich white dwarfs externally polluted
  - phenomenon is not ISM or companions
- Excellent astrophysical detectors
  - *the photospheric abundances of polluted white dwarfs indirectly measure the composition of the accreted matter*

Asteroid Destruction

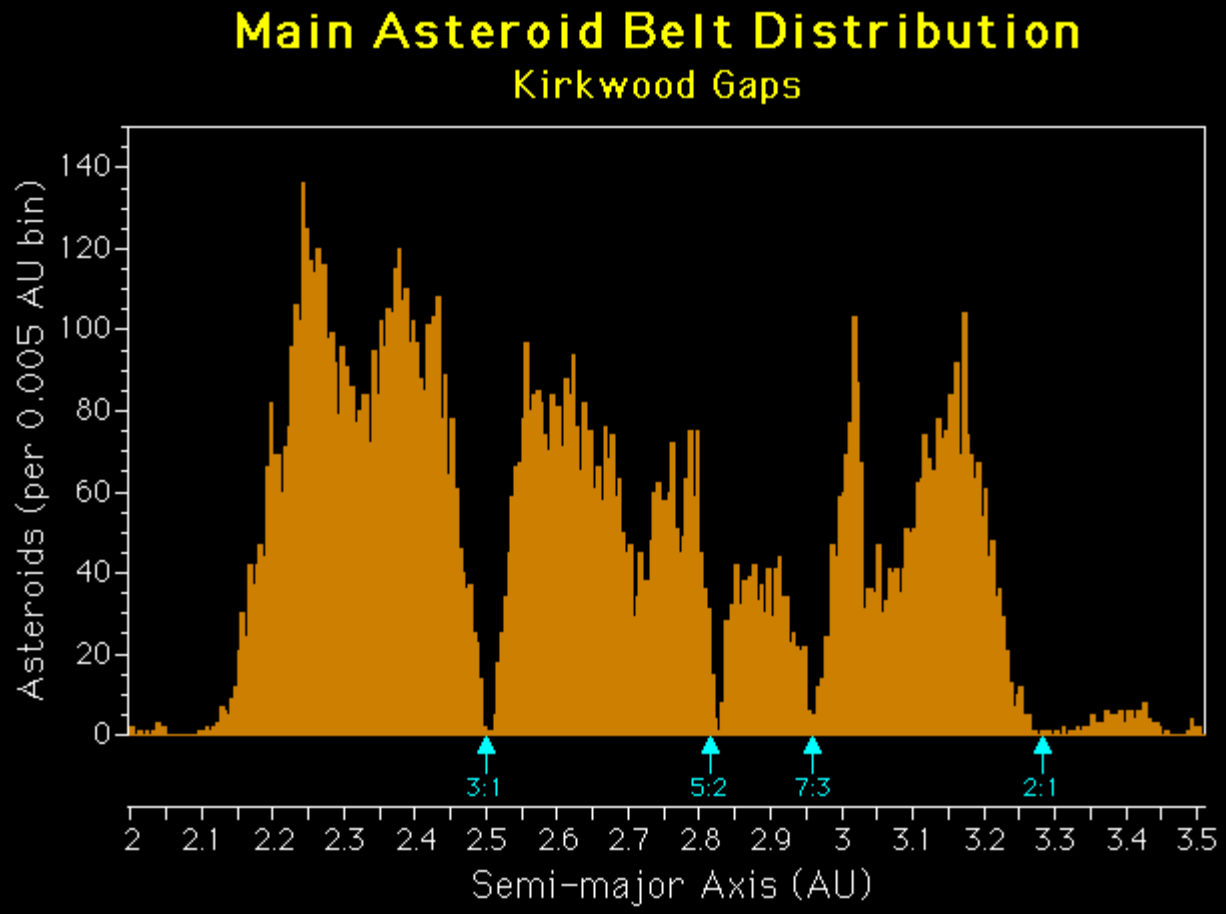
- White dwarfs are *compact*
  - asteroids tidally shredded



- White dwarfs are *pristine*
  - star is polluted by debris

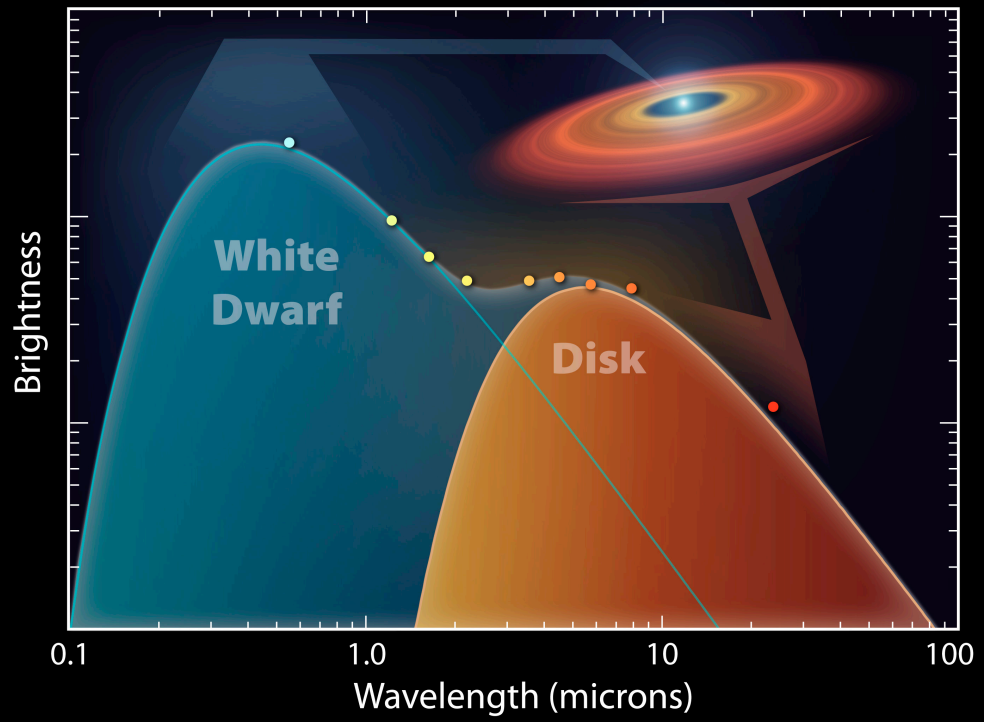
- How do we know this?
  - disk mass, location, composition; heavy elements in star

Destabilized Asteroids



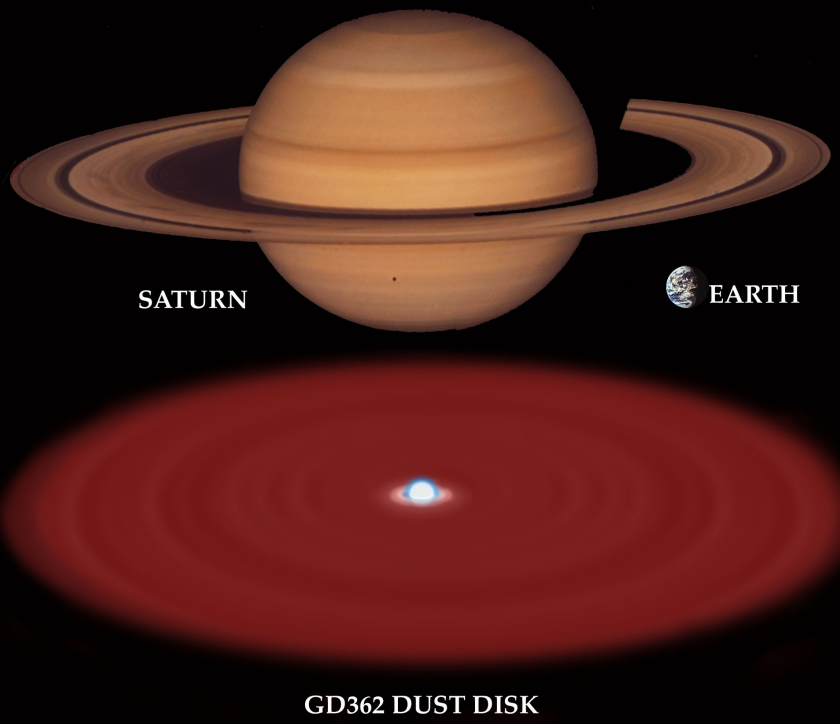
Typical Dust Disks

(Farihi, Jura, Zuckerman 2009; Becklin et al. 2005)



Spectrum of White Dwarf System GD 16
NASA / JPL-Caltech / J. Farihi (University of Leicester)

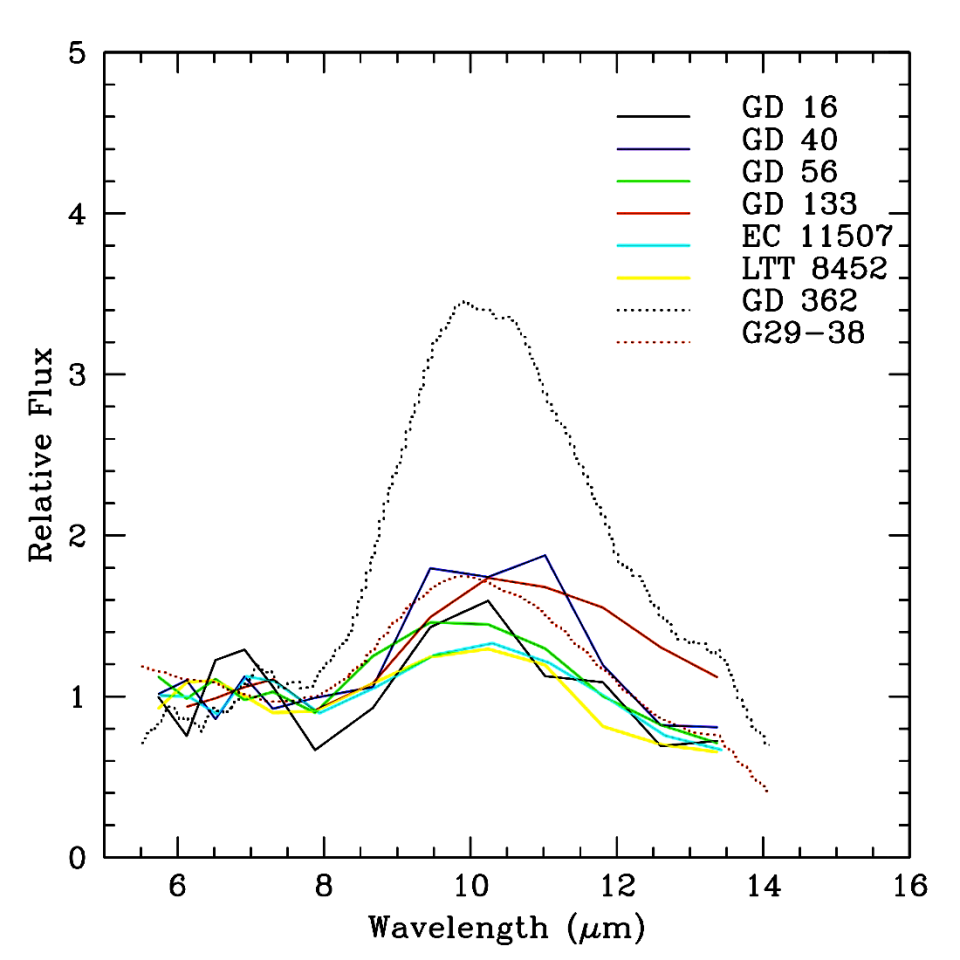
Spitzer Space Telescope • IRAC • MIPS
sig09-002



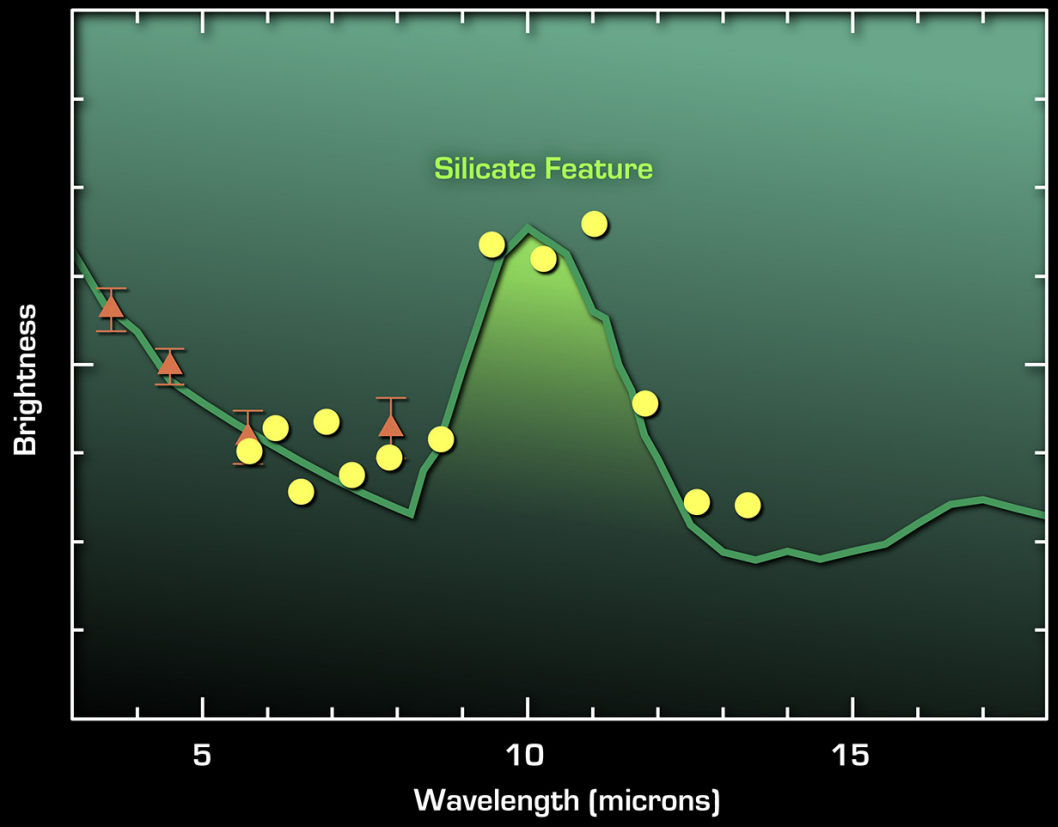
GD362 DUST DISK

Silicate Emission

(Jura, Farihi, Zuckerman 2009)

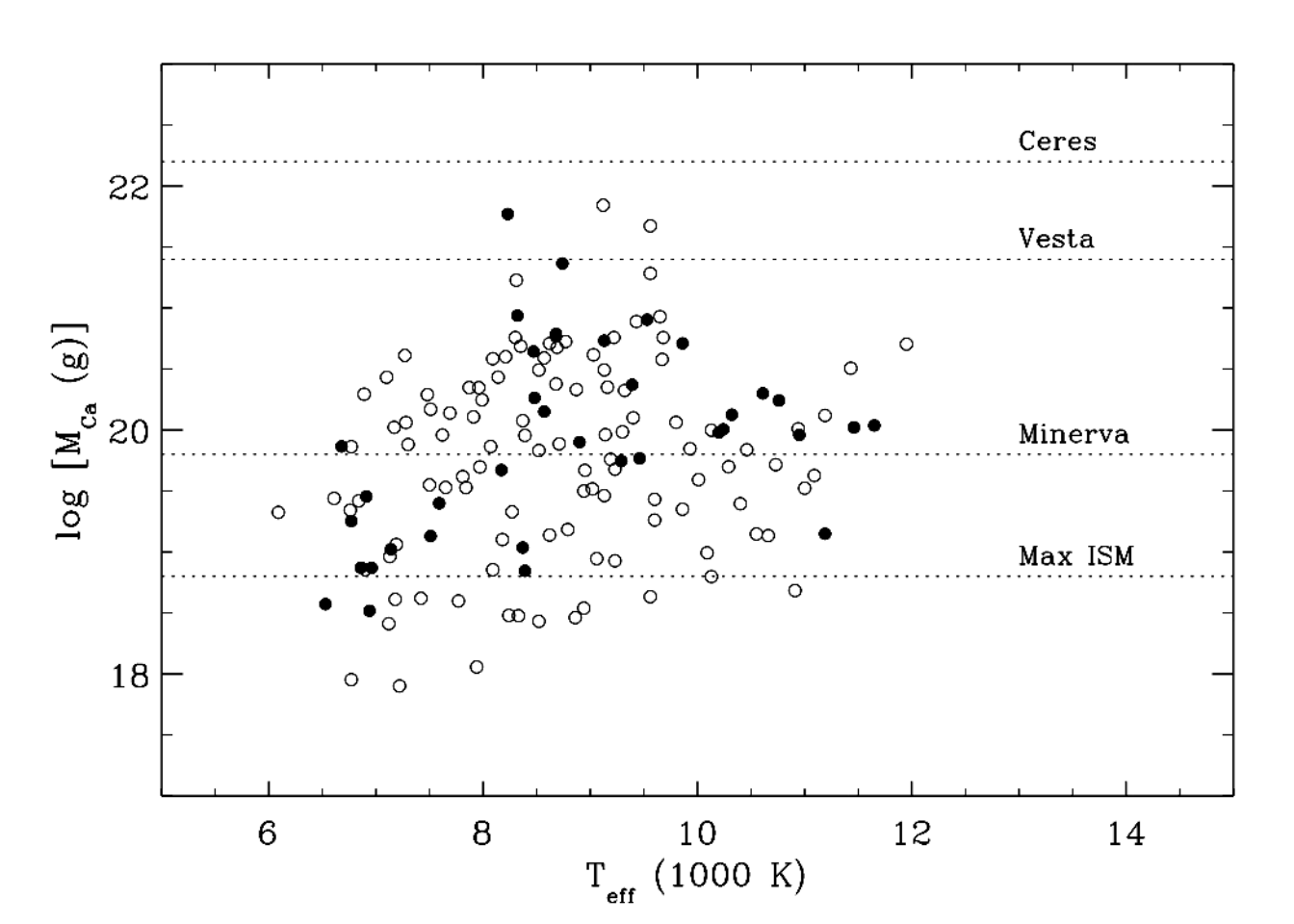


Olivine is Terrestrial



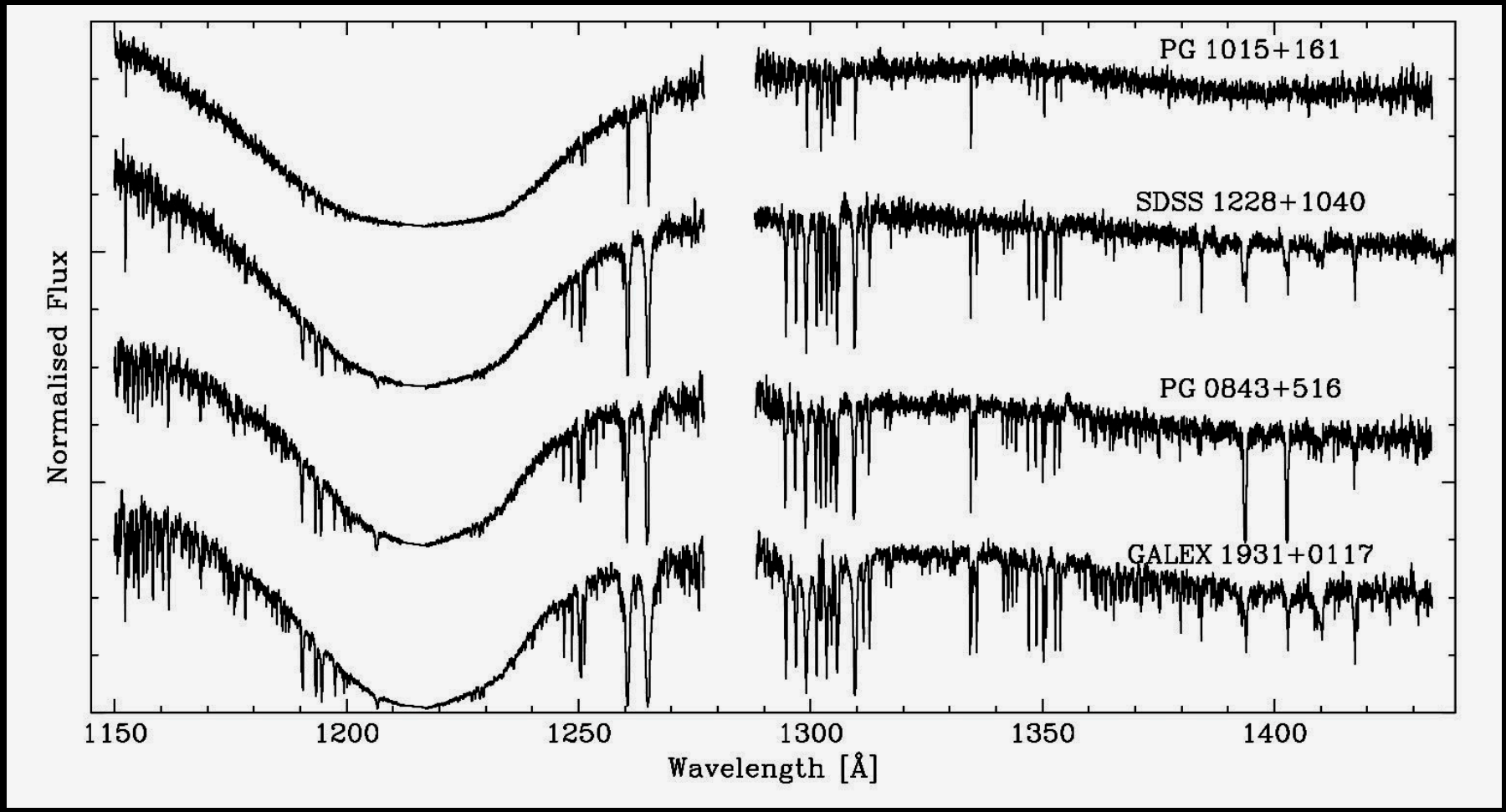
Sizable to Large Asteroids

(Farihi, Barstow, Redfield, Dufour, Hambly 2010)



Rocky Debris Confirmed by *HST*

(Gänsicke, Farihi, et al. 2012)



Debris Properties

- Stellar pollution is refractory-rich, volatile-poor
  - dominated by Mg and Fe silicates
- Overall abundances broadly mimic the bulk Earth
  - more carbon-depleted than chondrites
- Some evidence for differentiated bodies
  - stripping, melting, collisions (e.g. Moon)
- $M_{accreted} > 10^{22}$ g; up to 10^{25} g (Pluto)

Recent Exo-Rock Highlights

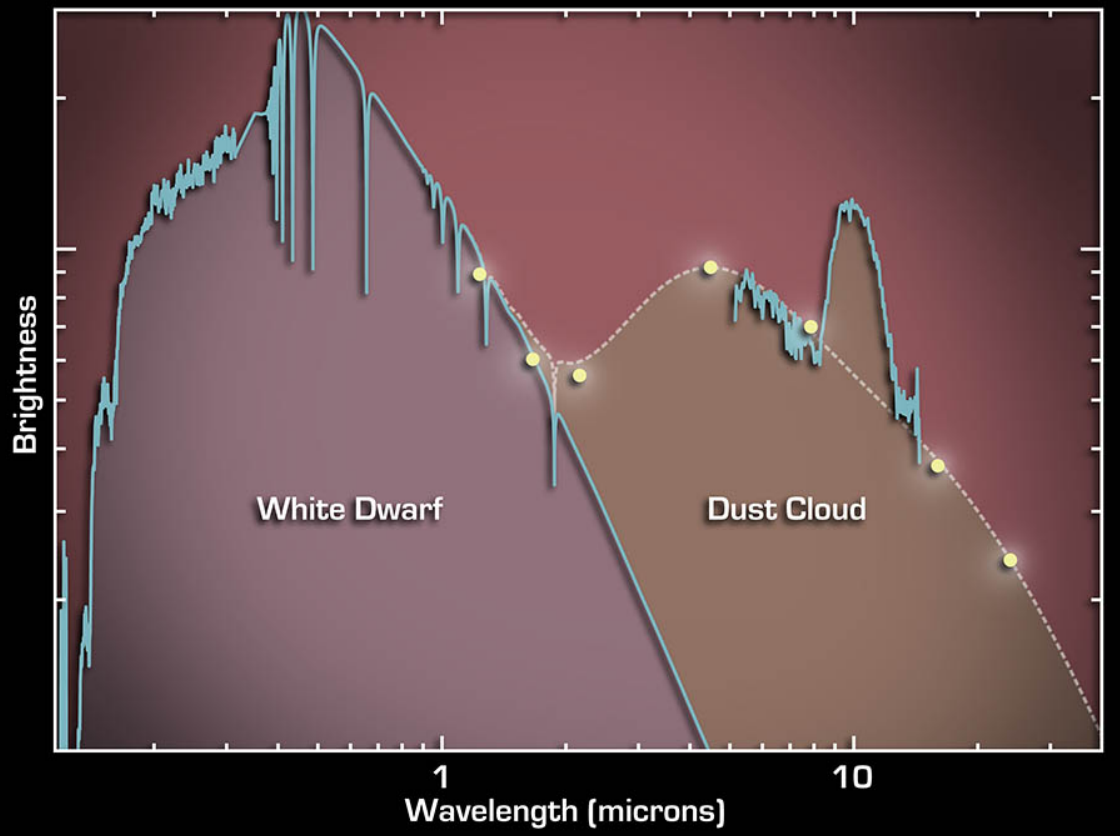
- Evidence for water in a few cases (2011)
- Carbon and volatile deficient parent bodies (2012)
- Evidence for differentiation (2012)
- Rocky planetesimals in the Hyades (2013)
- Procyon B is polluted (2013)

The Need for ALMA

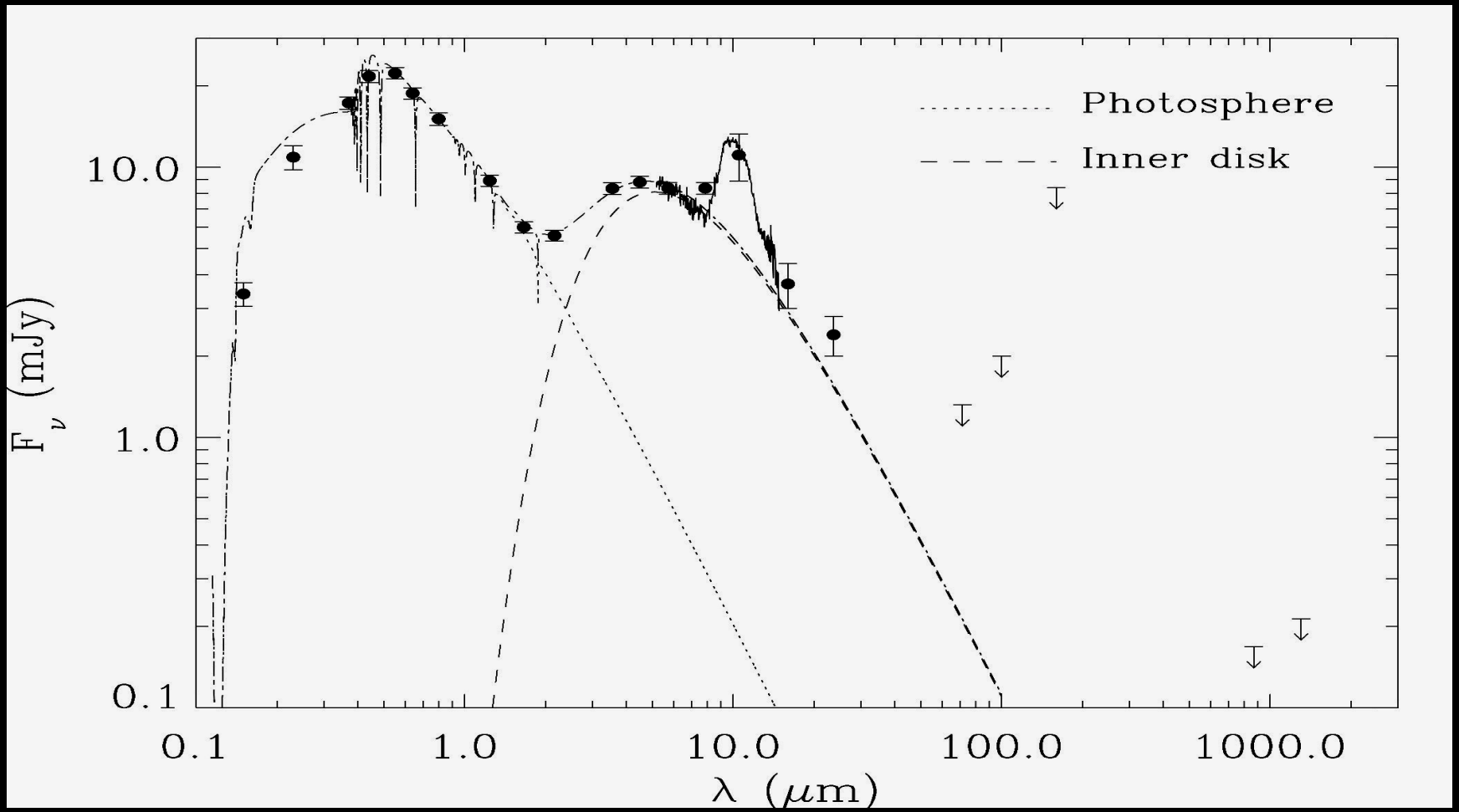
- Reservoir of planetesimals is necessary
- ALMA can detect and image these directly
- Connect formation region with chemistry

G29-38: The Prototype

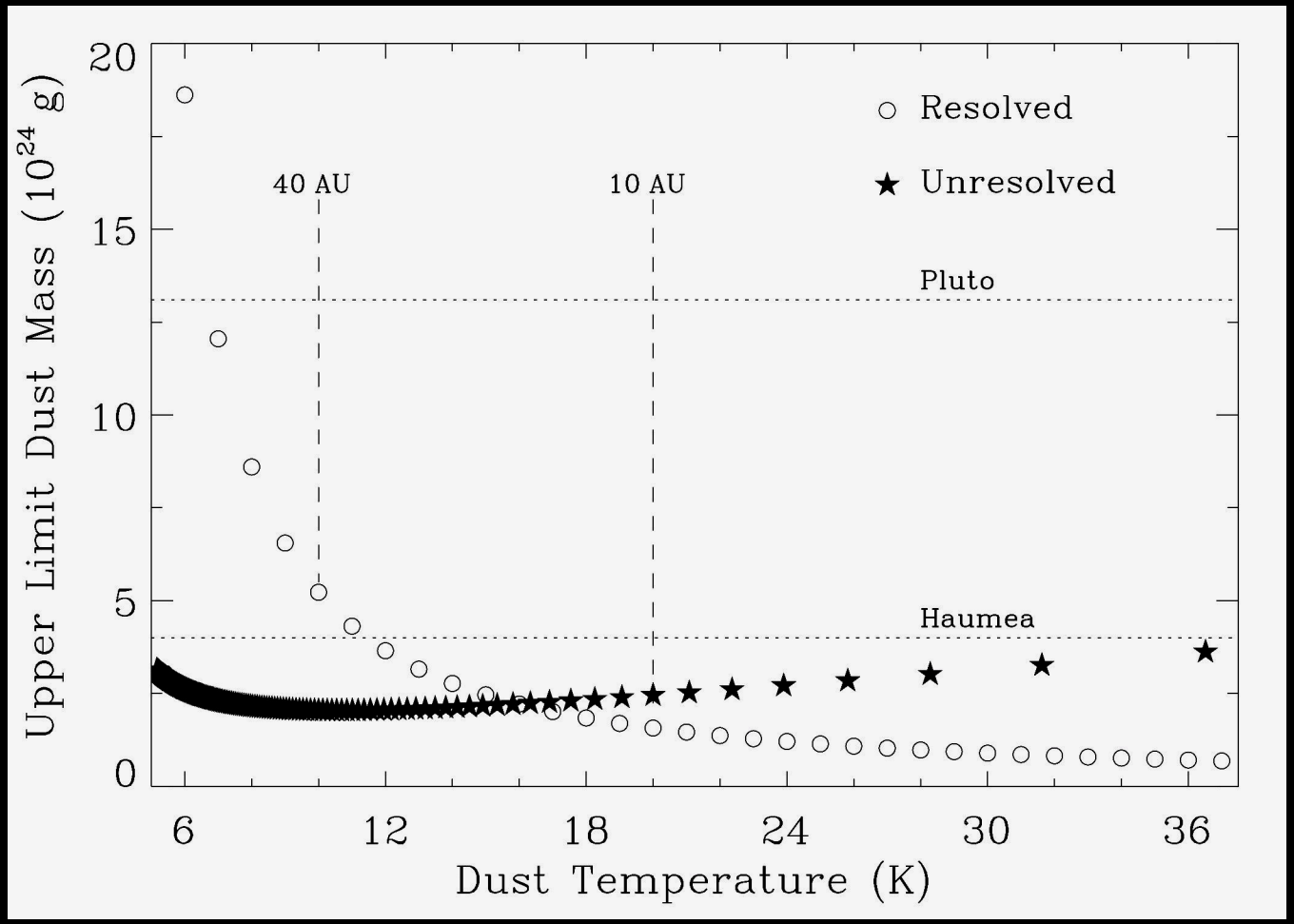
(Zuckerman & Becklin 1987)



G29-38 with MIPS, PACS, ALMA



ALMA Dust Mass Limits



ALMA Exo-Rocks!

- Bulk chemistry of rocky minor planets
- Mass constraints for large planetesimals
- Frequency of water-rich, extrasolar asteroids
- Rock chemistry as a function of orbital distance
- ALMA is the only way to make the connection


Mahalo!