Planetary Debris as the Origin of Metals in White Dwarfs

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Conspirators:

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Relevance to White Dwarfs

- *Who cares about disks and planets?*
  (for those who did not attend the Bamberg meeting)

- Stars do not evolve in isolation
  - environment impacts both formation and evolution
  - atmosphere is influenced by environment
  - emergent flux across EM spectrum is a convolution

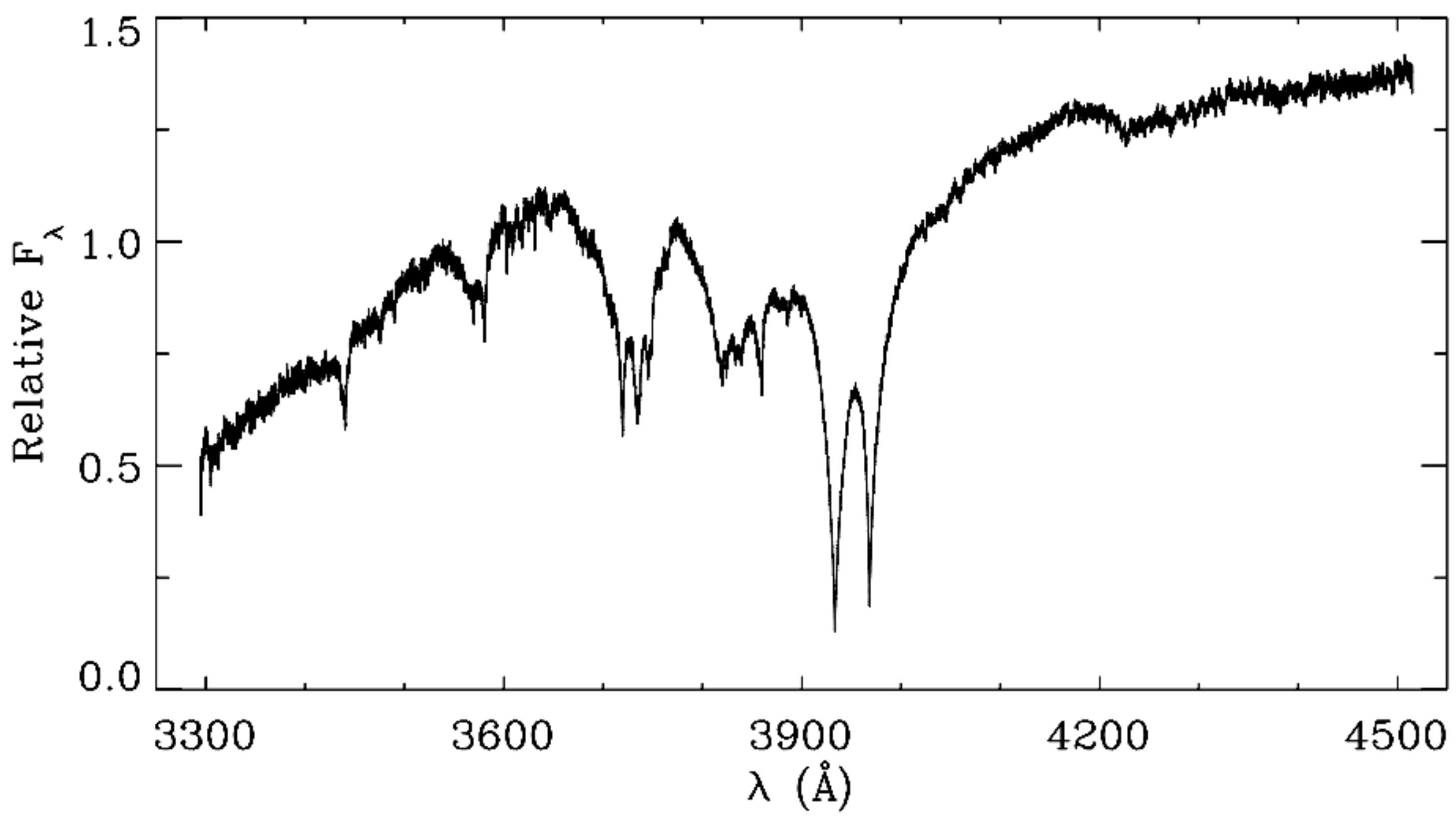
- Physical underpinning of stellar chemical content

Environmental Impact Factors

- Examples of important, external influences
  - forged and sustained hydrogen-deficiency
  - lack of DB stars in binaries and clusters
  - origin of He core white dwarfs
  - generation of magnetic fields
  - shaping of PNe
  - atmospheric evolution; dredge up vs. accretion
  - sources of free electrons
  - elemental abundance ratios

van Maanen's Star

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



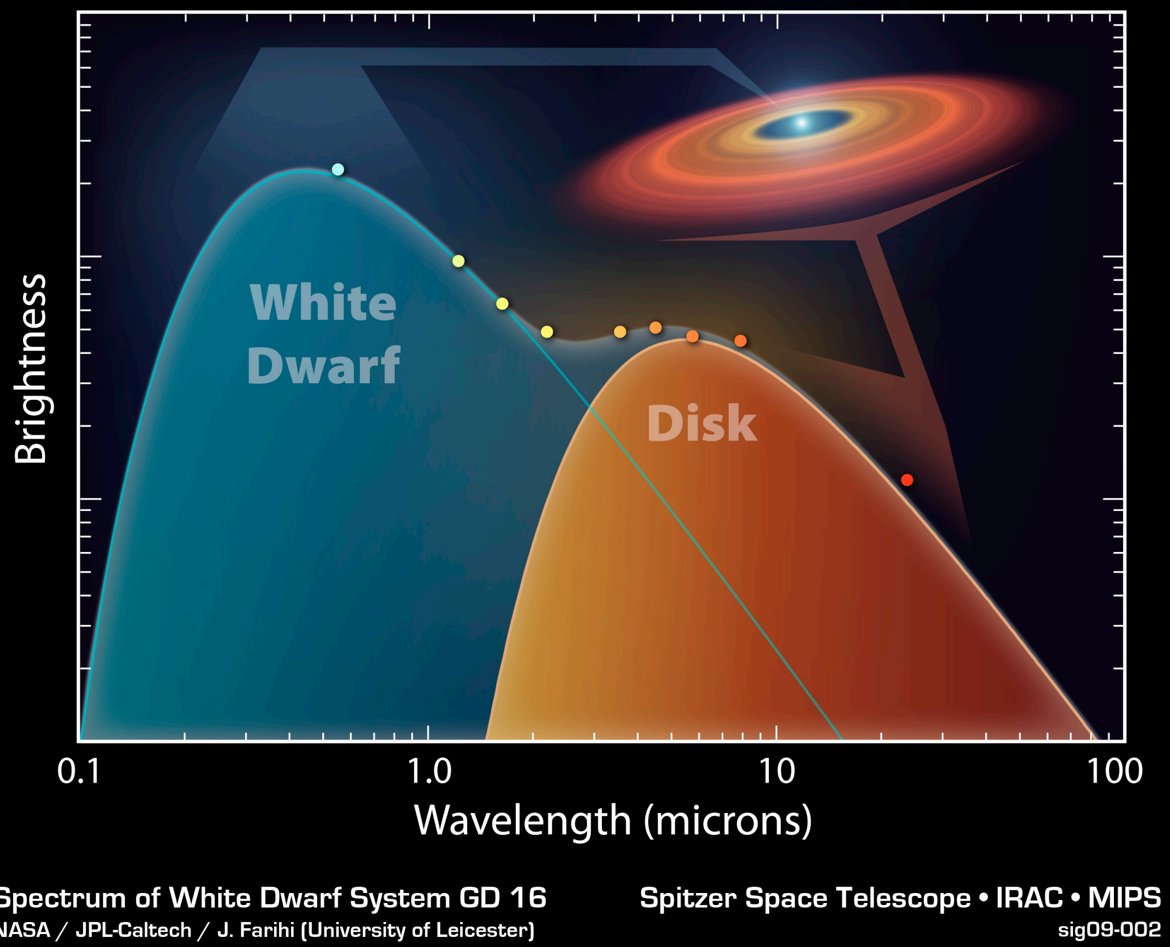
Spitzer Era Disk Studies

- 17+ white dwarfs with circumstellar dust
  - both DAZ and DBZ stars
  - *Spitzer* photometry (8 with spectroscopy)
  - infrared excesses between 2 and 24 microns
  - thermal emission peaks near 5 microns (T ≈ 1000 K)

- 3+ cases *also* have circumstellar metallic gas
  - double-peaked emission lines in the optical
  - material is extremely hydrogen and helium deficient
  - gas kinematics constrain orbit geometry

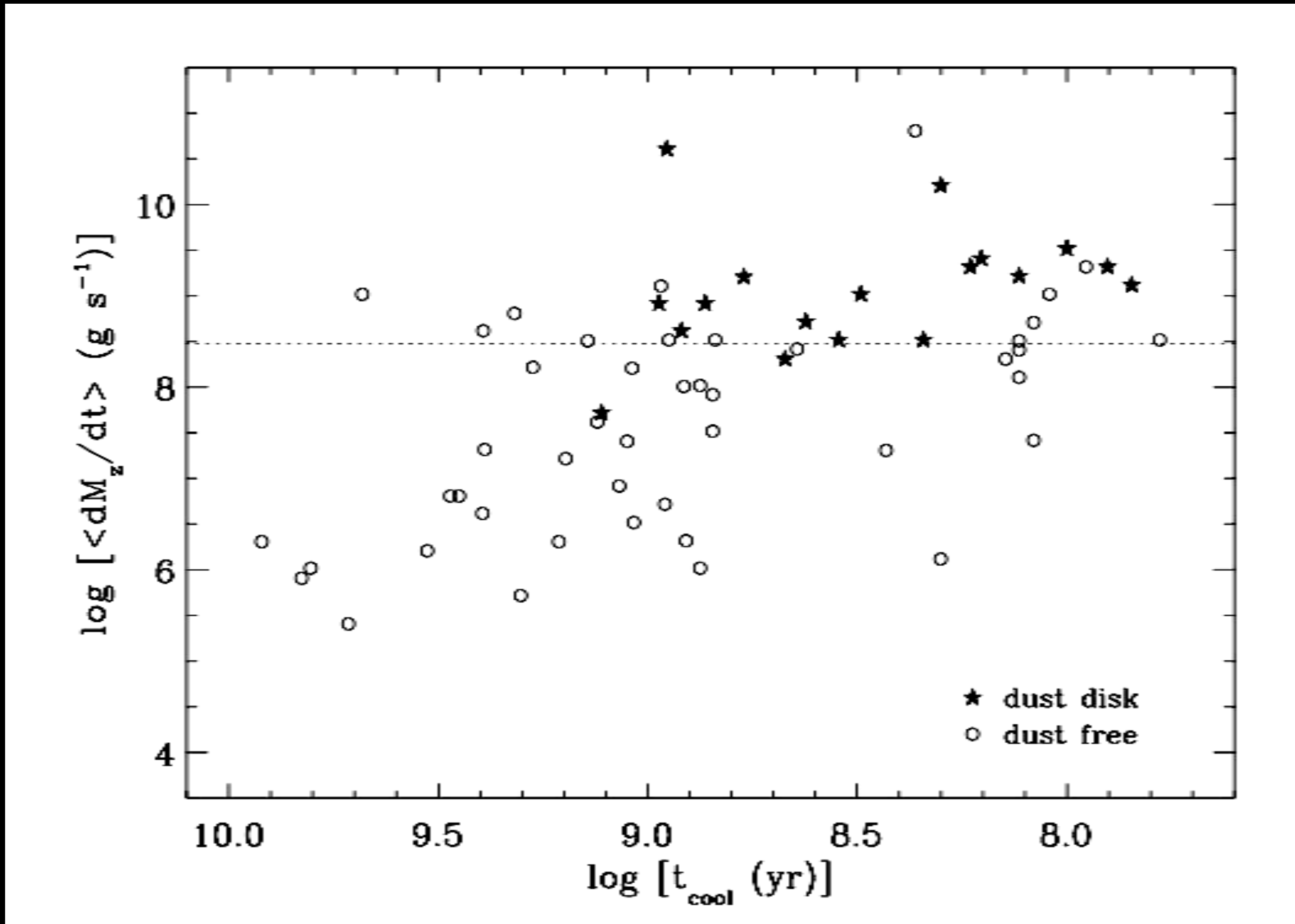
A Typical White Dwarf Disk

(Farihi, Jura, & Zuckerman 2009)



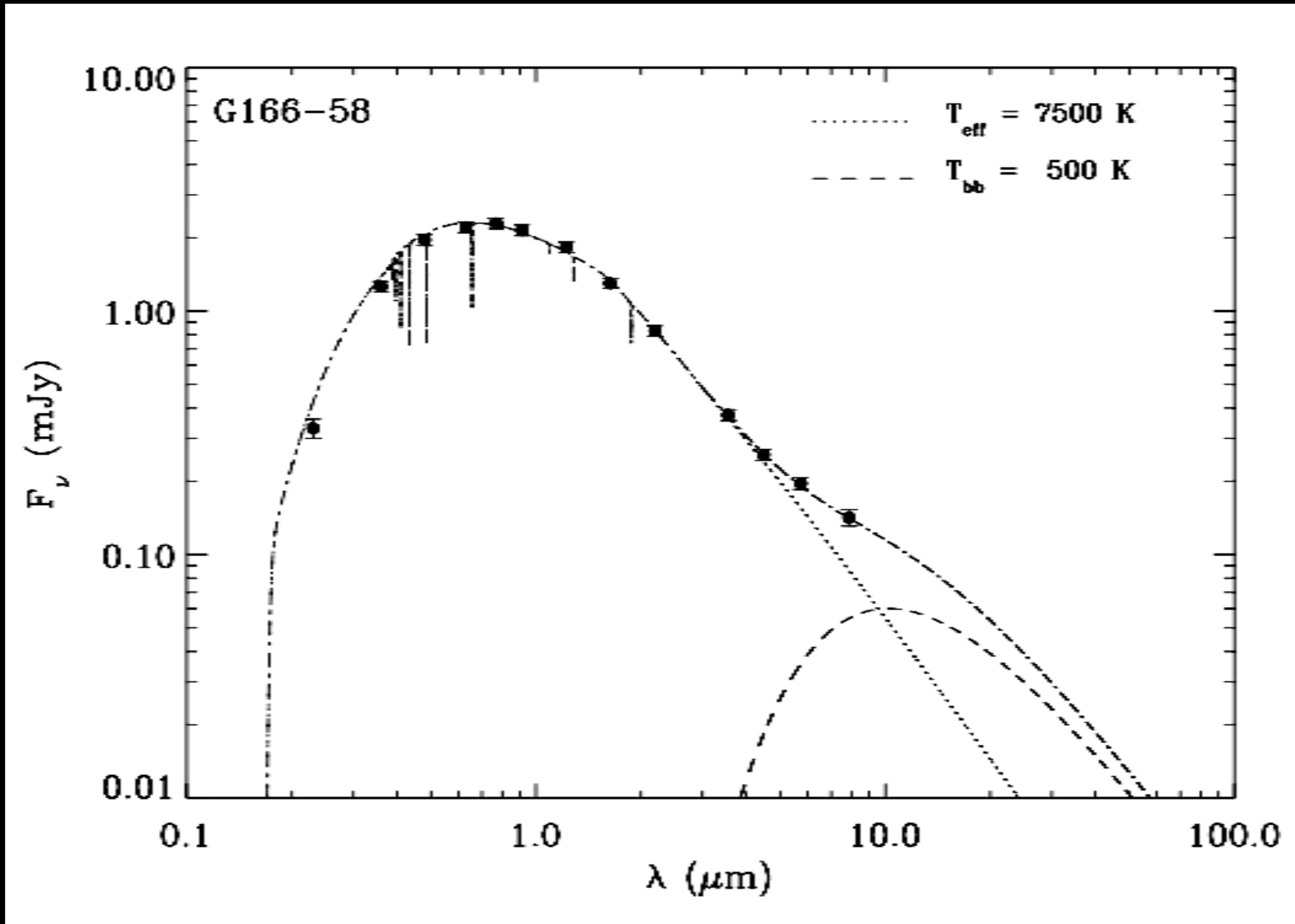
Disk Frequency

(Farihi, Jura, & Zuckerman 2009; 2010)



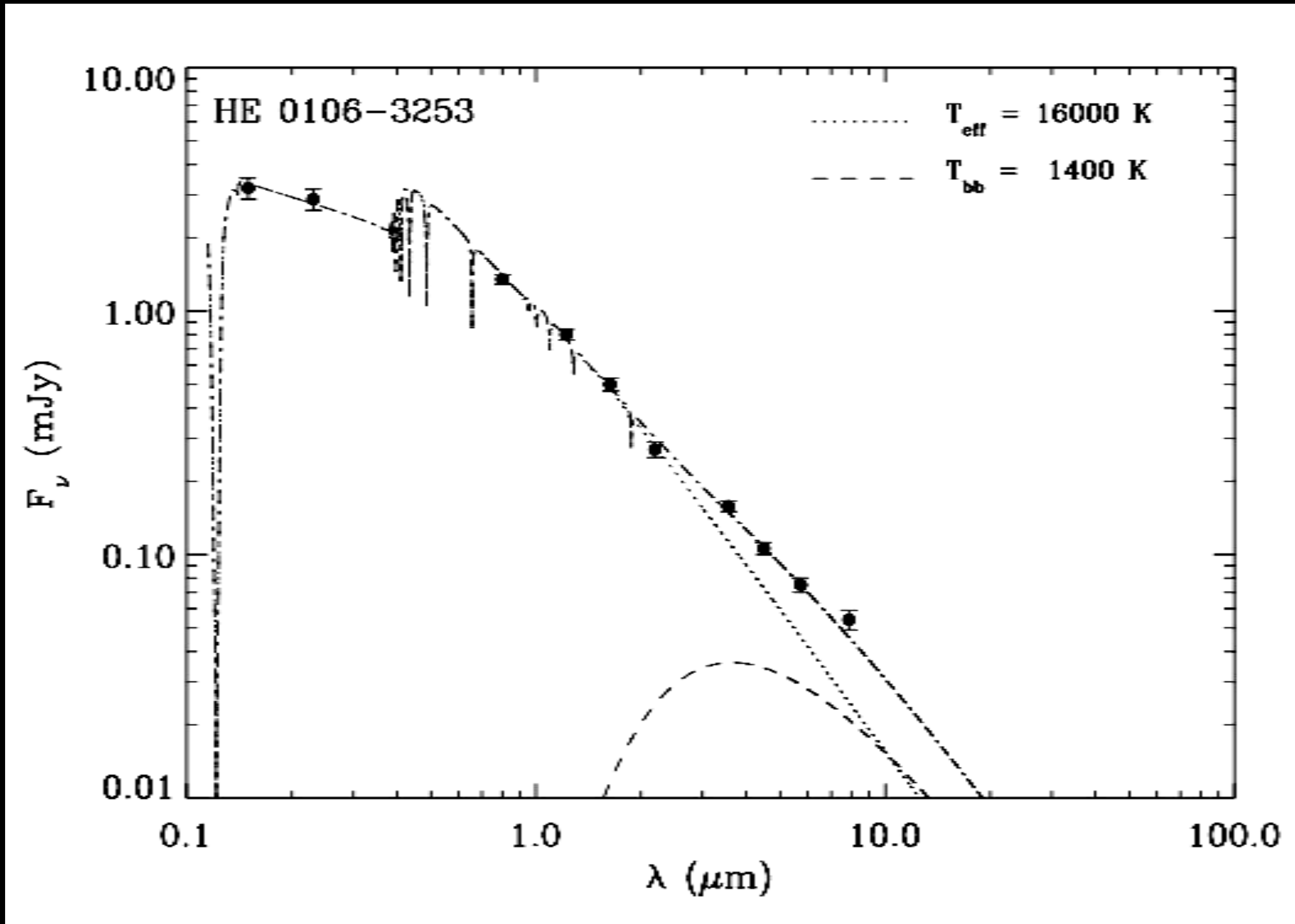
Dust Disks with Inner Holes

(Farihi, Zuckerman, & Becklin 2008)



Narrow Dust Rings

(Farihi, Jura, & Zuckerman 2010)



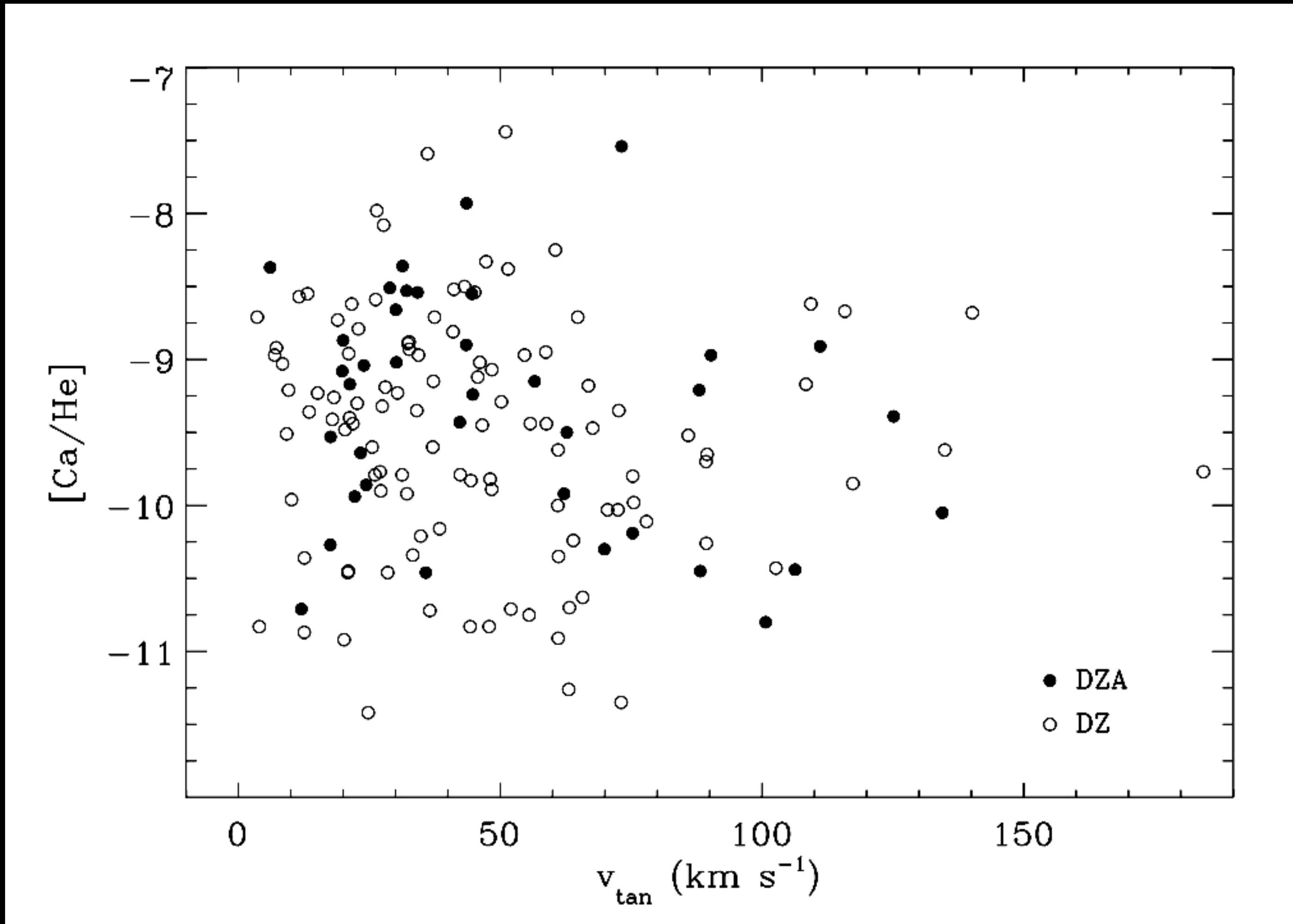
Planetary Debris in All Cases?

- Most polluted stars lack obvious infrared excess
  - *not pollution from companions*
  - collisions can effectively destroy dust grains
  - critical parent body mass / disk density to sustain dust
  - narrow rings of dust may be difficult to detect
- Interstellar medium (ISM) accretion impossible?
  - lack of cool dust from *Spitzer* observations
  - clouds virtually absent in Local Bubble

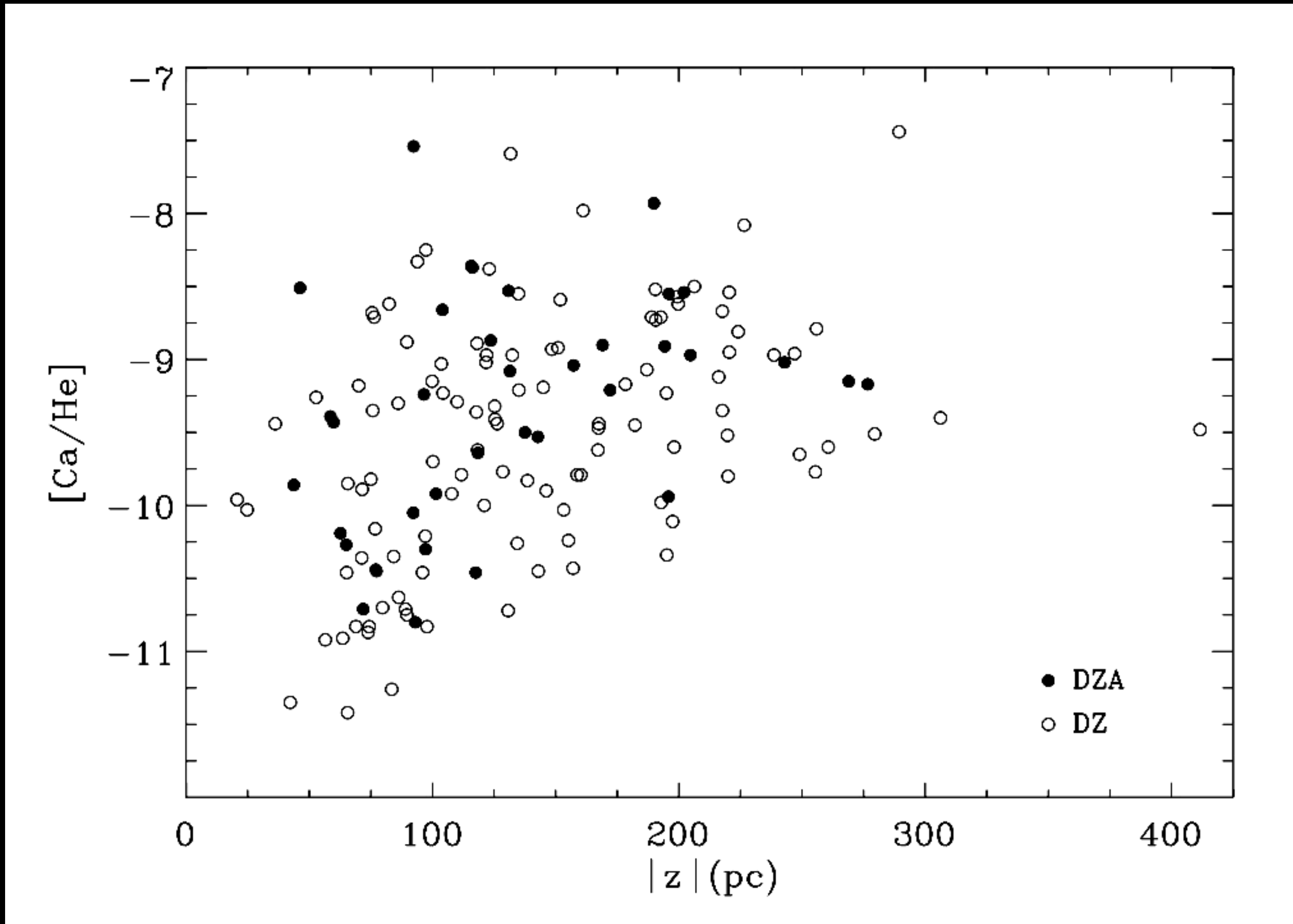
DZ Stars in the SDSS

- Previous ISM challenges
  - Sion et al. 1990 first to suggest asteroid debris in DZ stars
  - Aanested et al. 1993 analyzed 15 DZ stars; velocity-biased?
- Analyzed 146 DZ stars from SDSS DR4+
- Can the ISM plausibly account for the metals?
  - positions, heights, space velocities, orbits
  - metal and hydrogen abundances
  - ISM gas/dust accretion physics

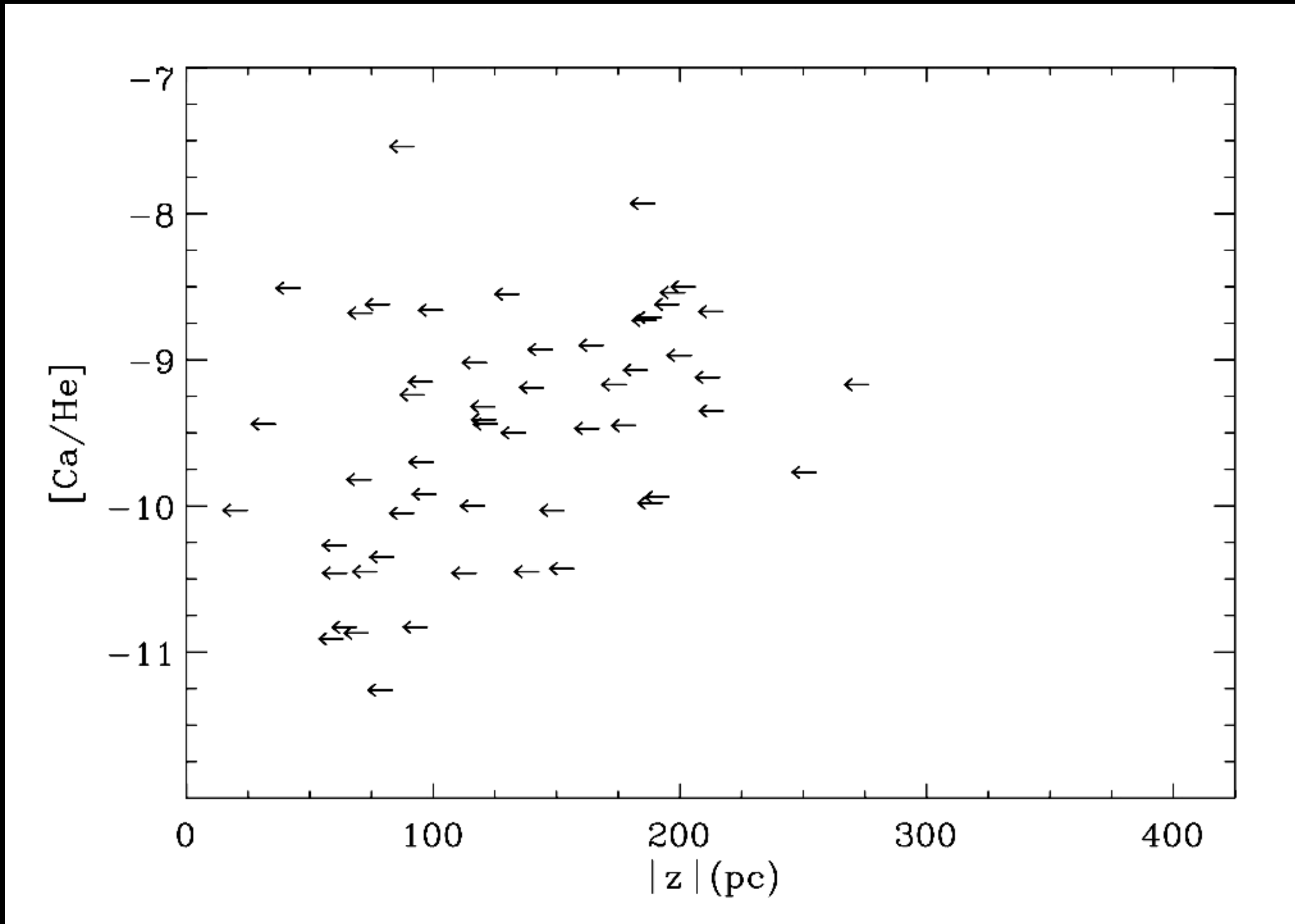
No Velocity Correlation



No Scale Height Correlation



Metal from Empty Space?



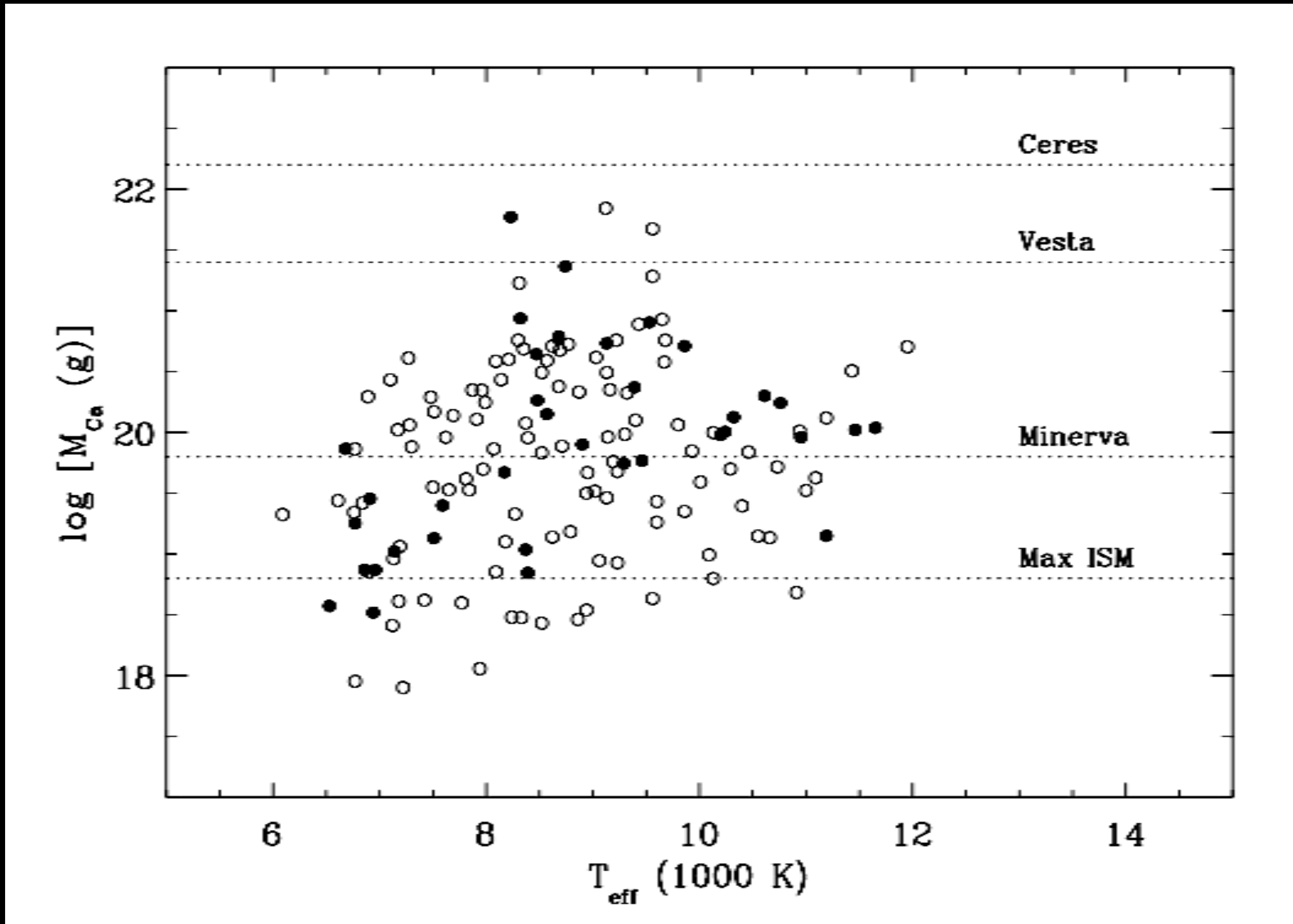
ISM Accretion Physics

- Problems with Bondi-Hoyle ISM capture
  - applies only to ideal fluids and plasmas
  - ignores angular momentum (Koester 1976)
  - ISM metals in dust grains; sublimation << R_{BH}
  - vastly over-predicts accreted hydrogen

- Problems with Eddington ISM capture
  - vastly under-predicts accreted metals

Calcium in Large Asteroids

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



Paradigm Shift

- *Assuming ISM accretion occurs:*
  - DAZ stars need small, hidden clouds
  - DZ stars need big, dense clouds
- DZ and DAZ stars created by same mechanism
  - only circumstellar pollution can explain both classes
- ISM accretion theory is no longer viable
  - for the *observed population* of metal-rich white dwarfs

Outlook

- between 3% and 30% of stars have rocky pollution
- detectable dust strong function of T_{eff} and dM_z/dt
  - subtle dust and gaseous debris likely at many more
- ISM accretion ruled out for current population
- average dM_z/dt correlates with T_{eff}
  - maximum enrichment occurs at hottest white dwarfs


das Ende…?