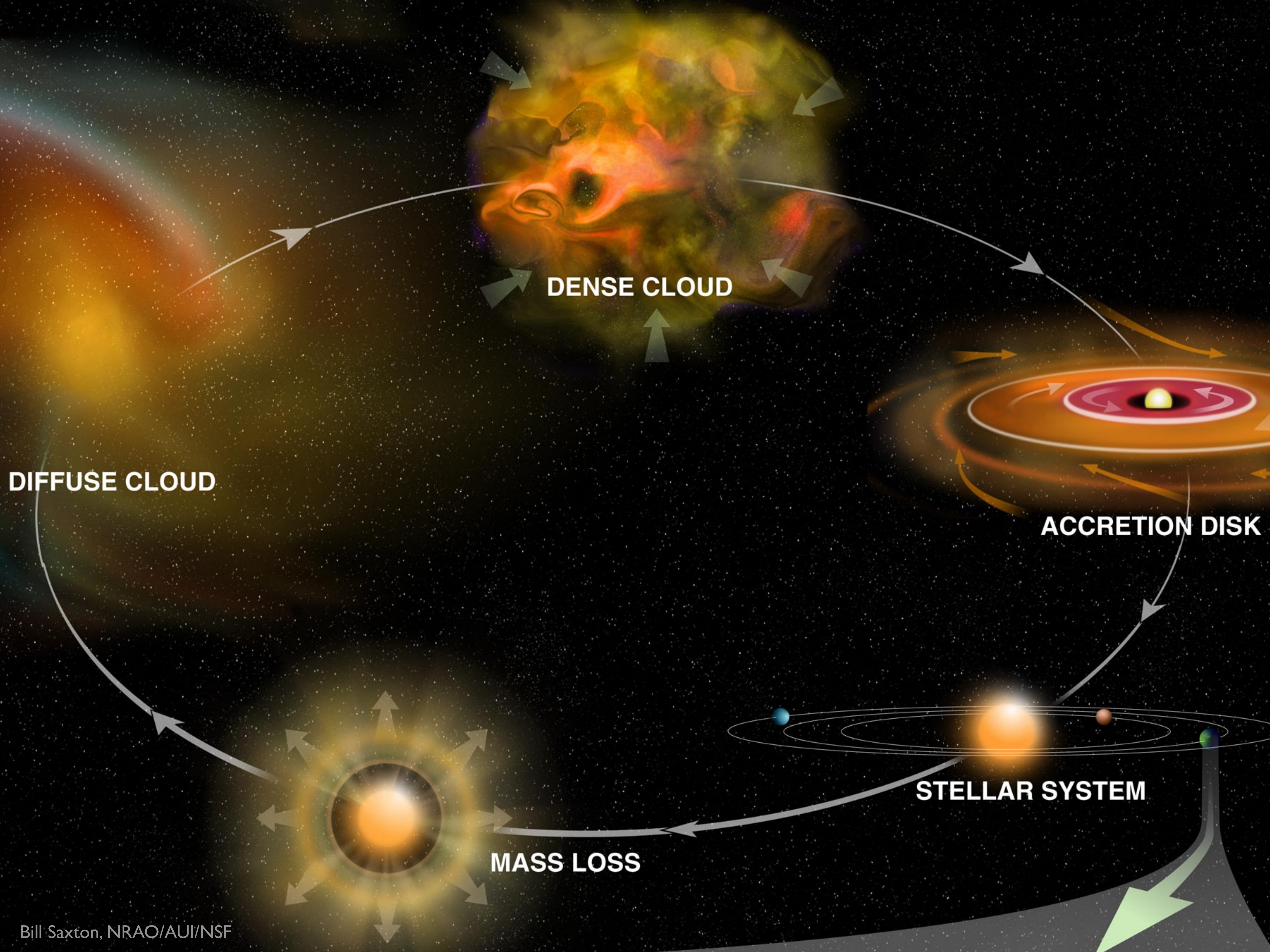
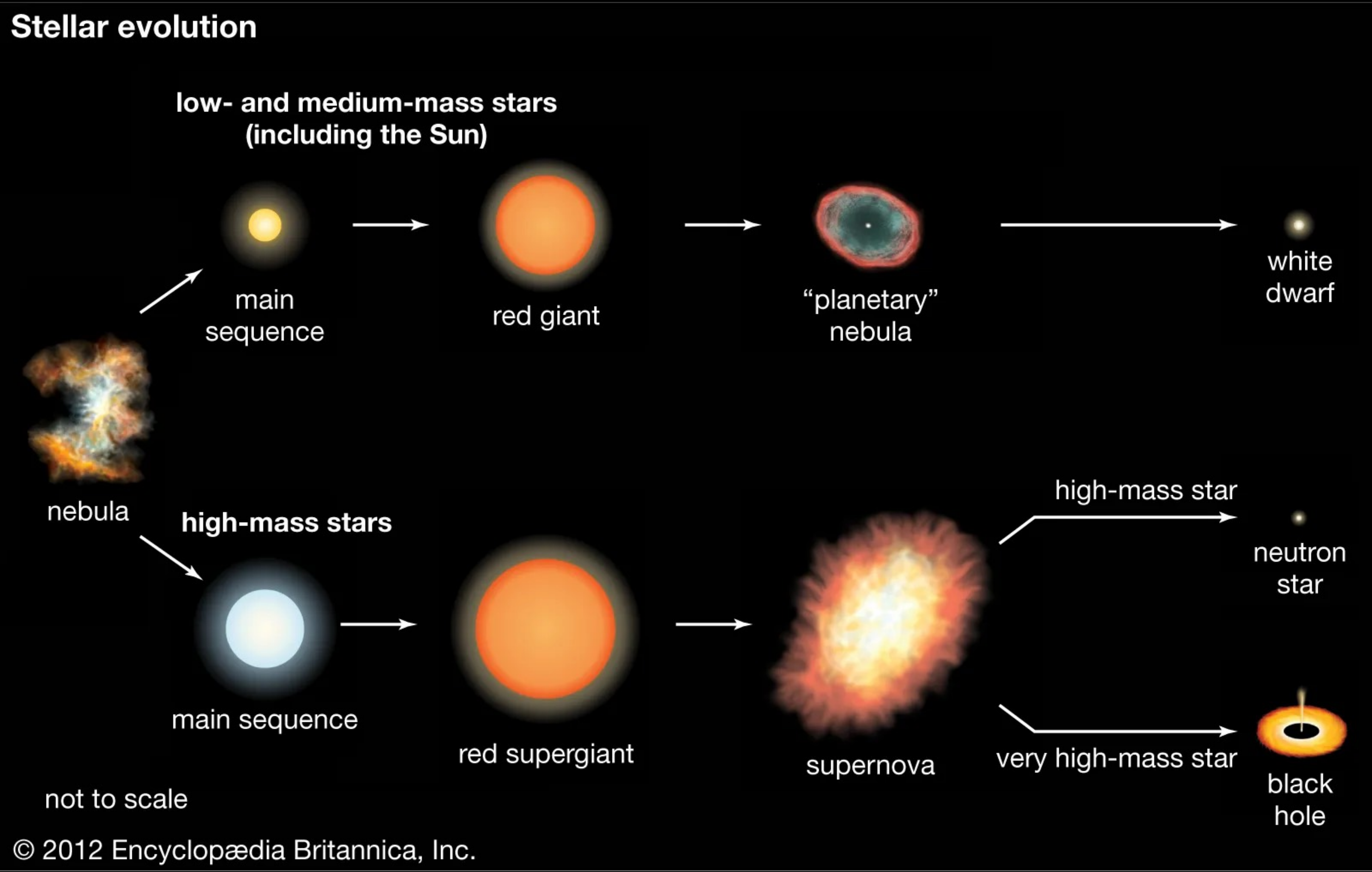
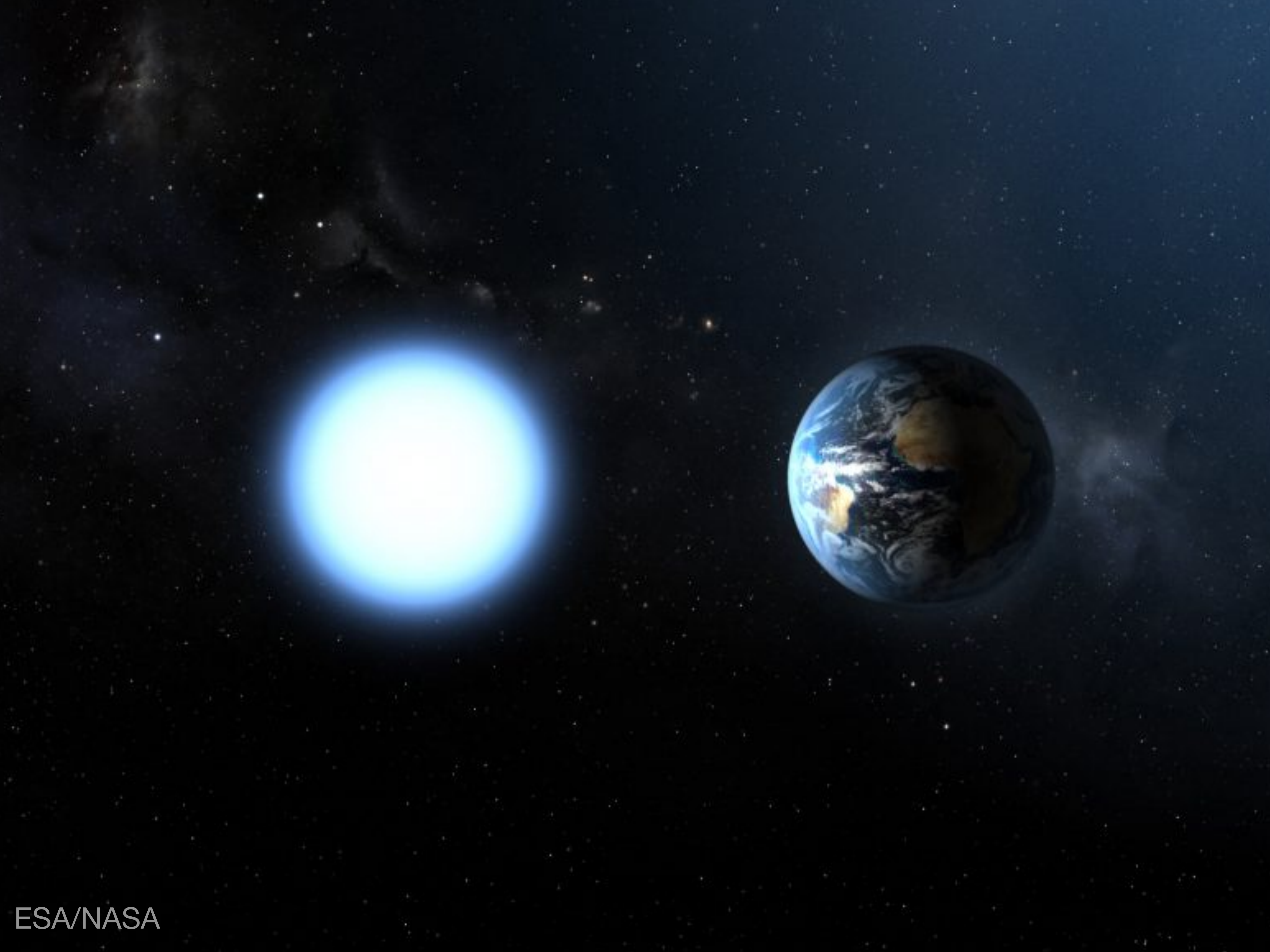
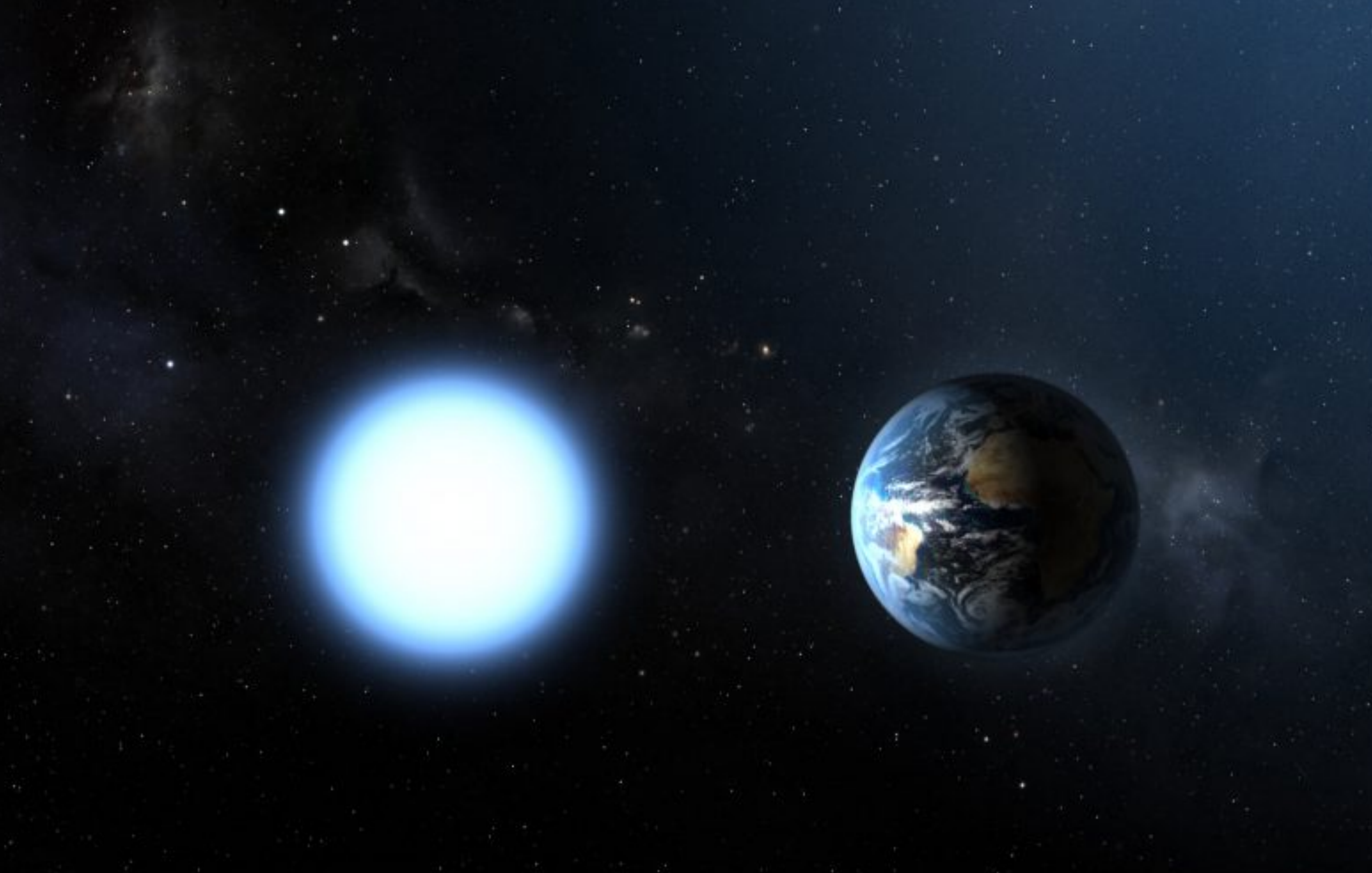
Mapping exoplanet compositions using polluted white dwarfs

Isabella Trierweiler
UCLA

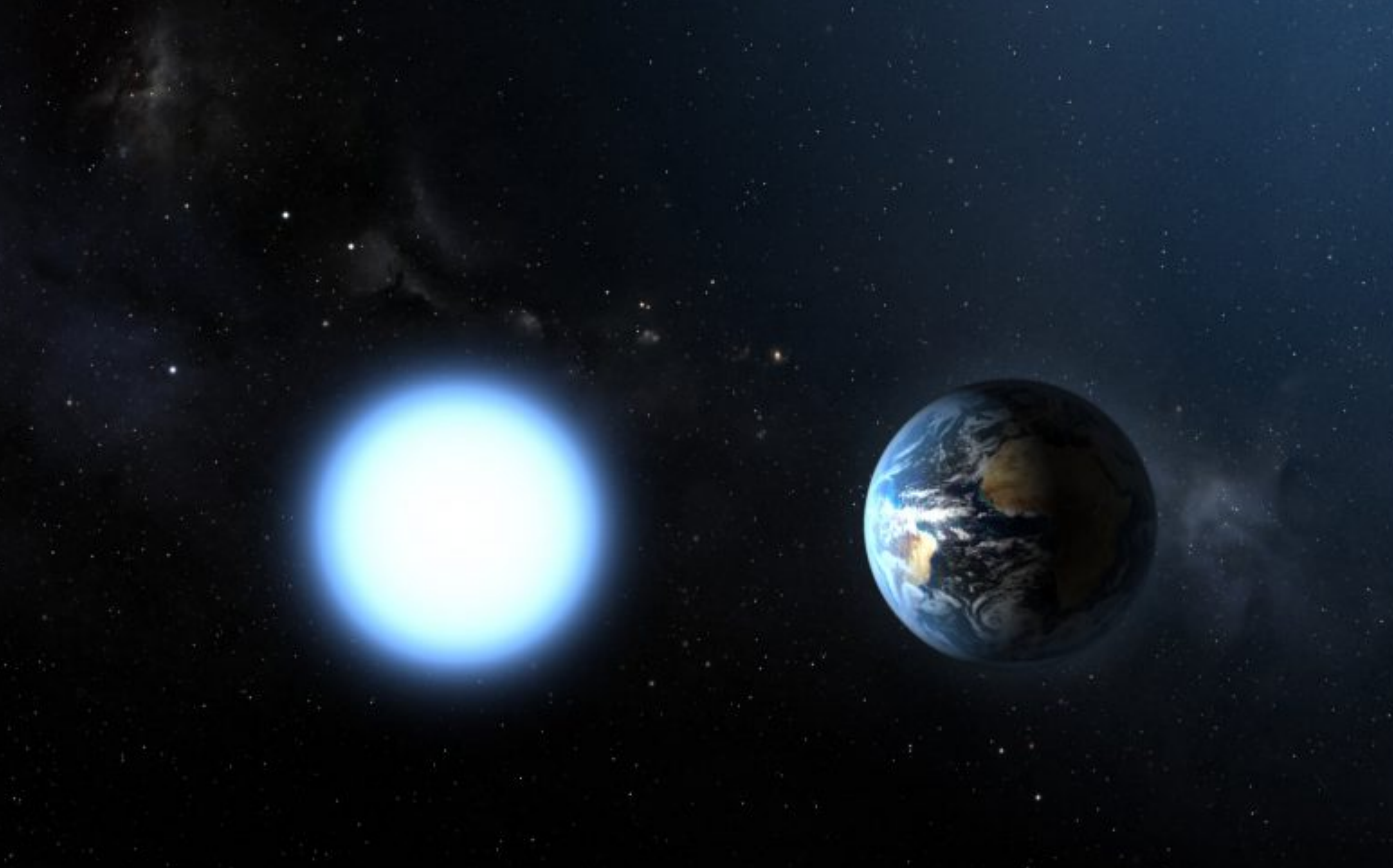

DENSE CLOUD
ACCRETION DISK
STELLAR SYSTEM
MASS LOSS
DIFFUSE CLOUD
Bill Saxton, NRAO/AUI/NSF


Stellar evolution
low- and medium-mass stars
(including the Sun)
main
sequence
red giant
“planetary”
nebula
white
dwarf
nebula
high-mass stars
high-mass star
neutron
star
main sequence
red supergiant
supernova
very high-mass star
black
hole
not to scale
© 2012 Encyclopædia Britannica, Inc.

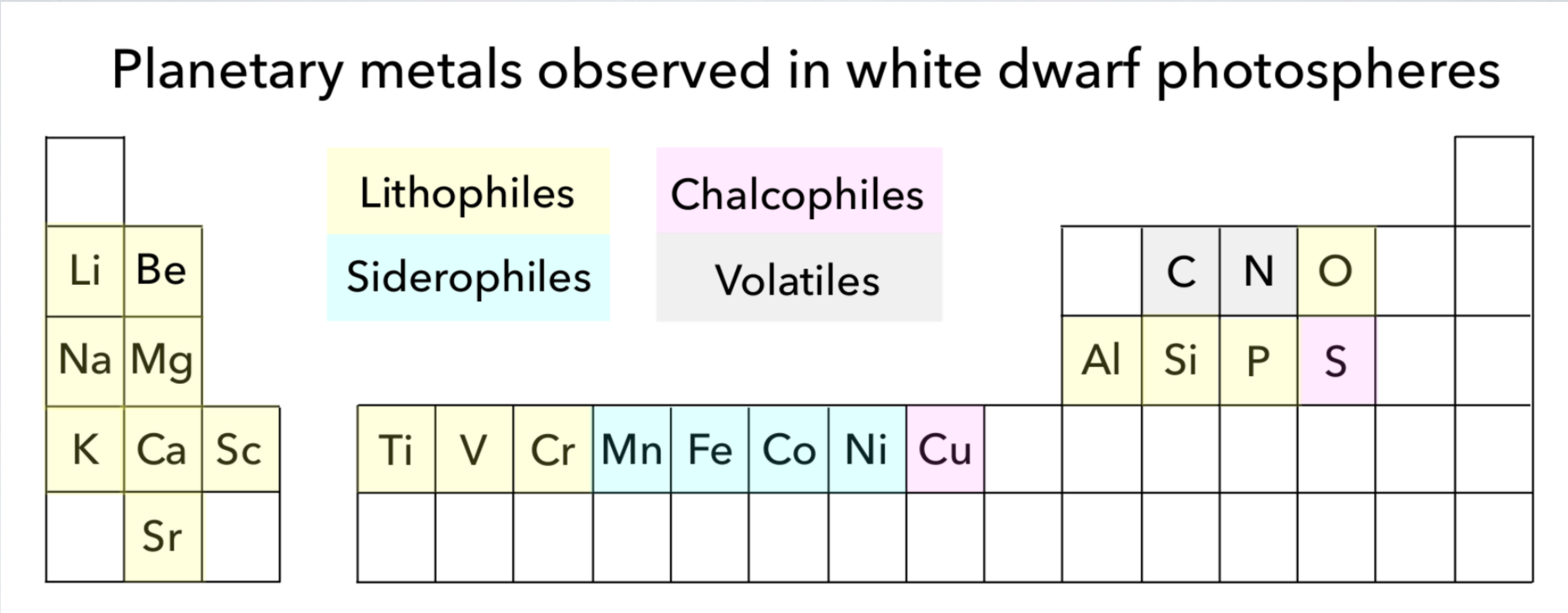

ESA/NASA



~1/3 of white dwarfs are polluted by heavy elements



Can recover bulk compositions for exoplanetary material that survived until the white dwarf phase

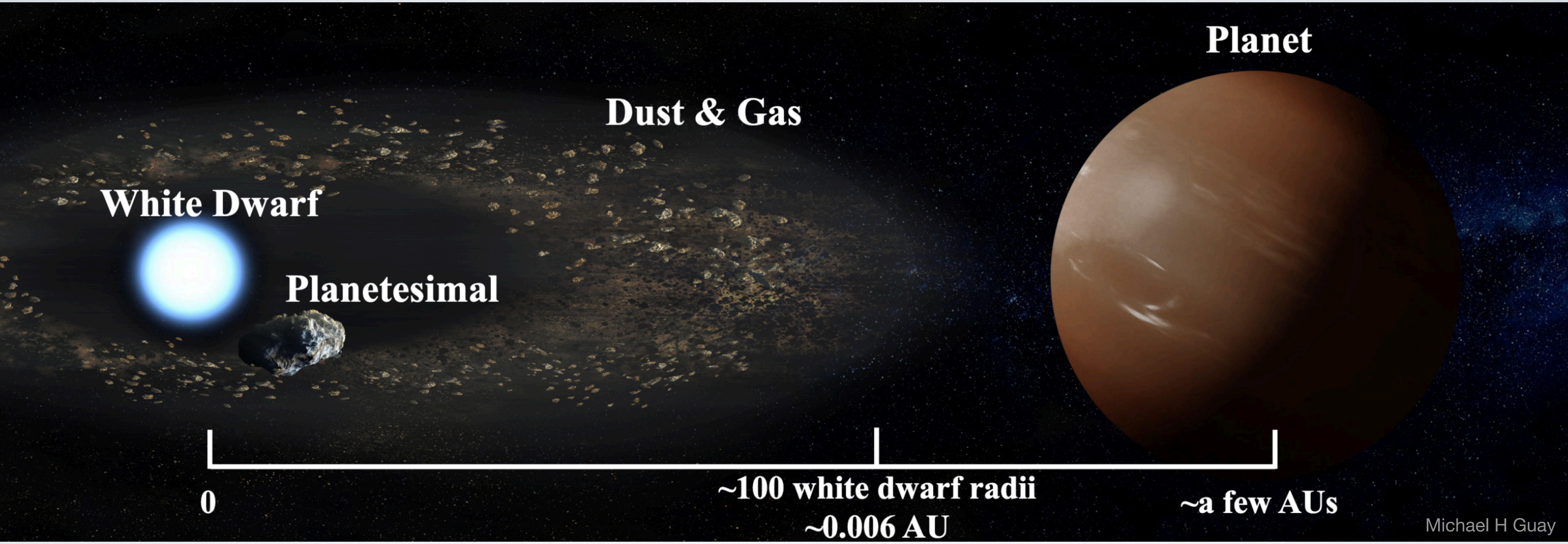


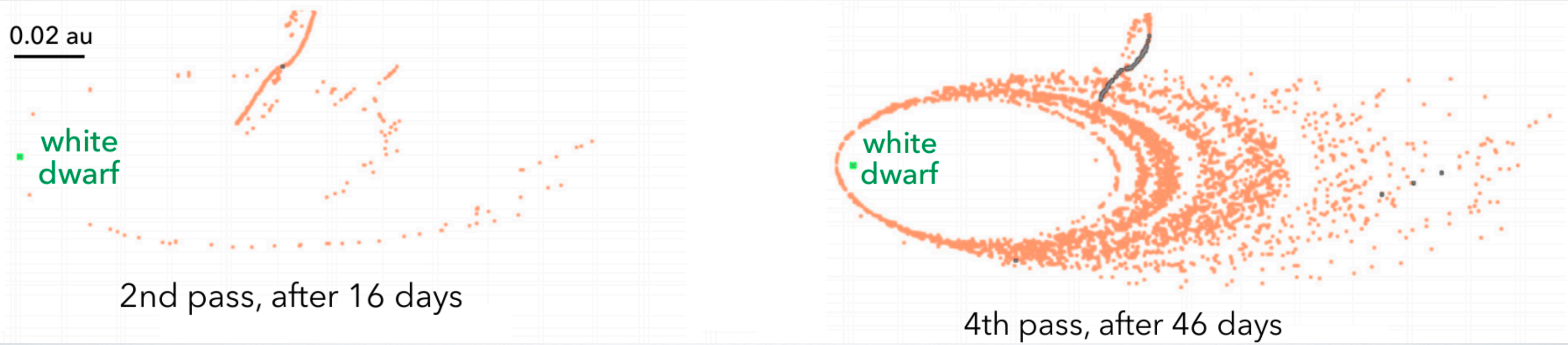
Veras 2021

Pollution is mostly rocky and sometimes icy

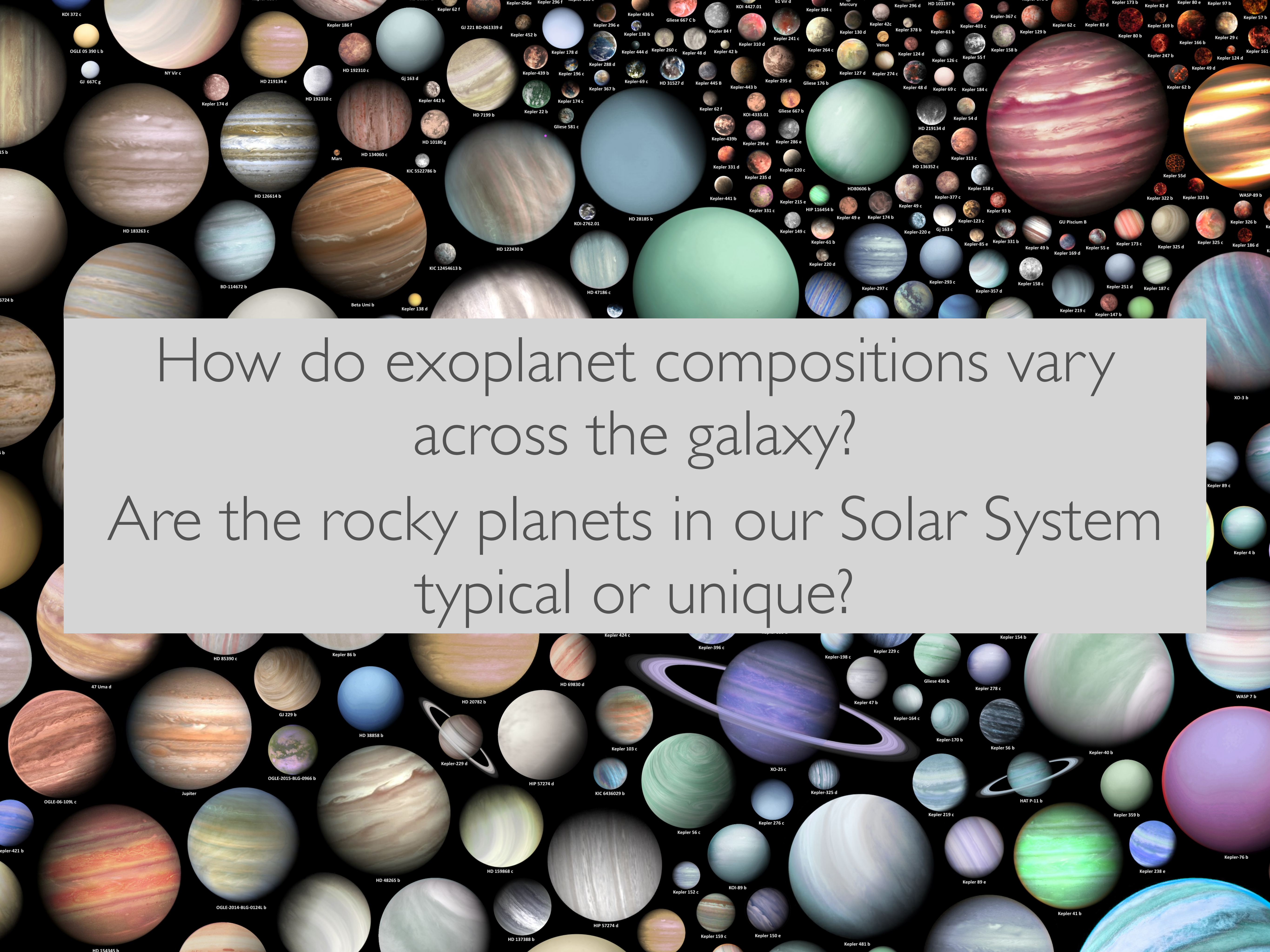
Pollution candidates include asteroids, comets, KBOs, exomoons

ACCRETION BY PLANET PERTURBATIONS





Malamud & Perets 2020

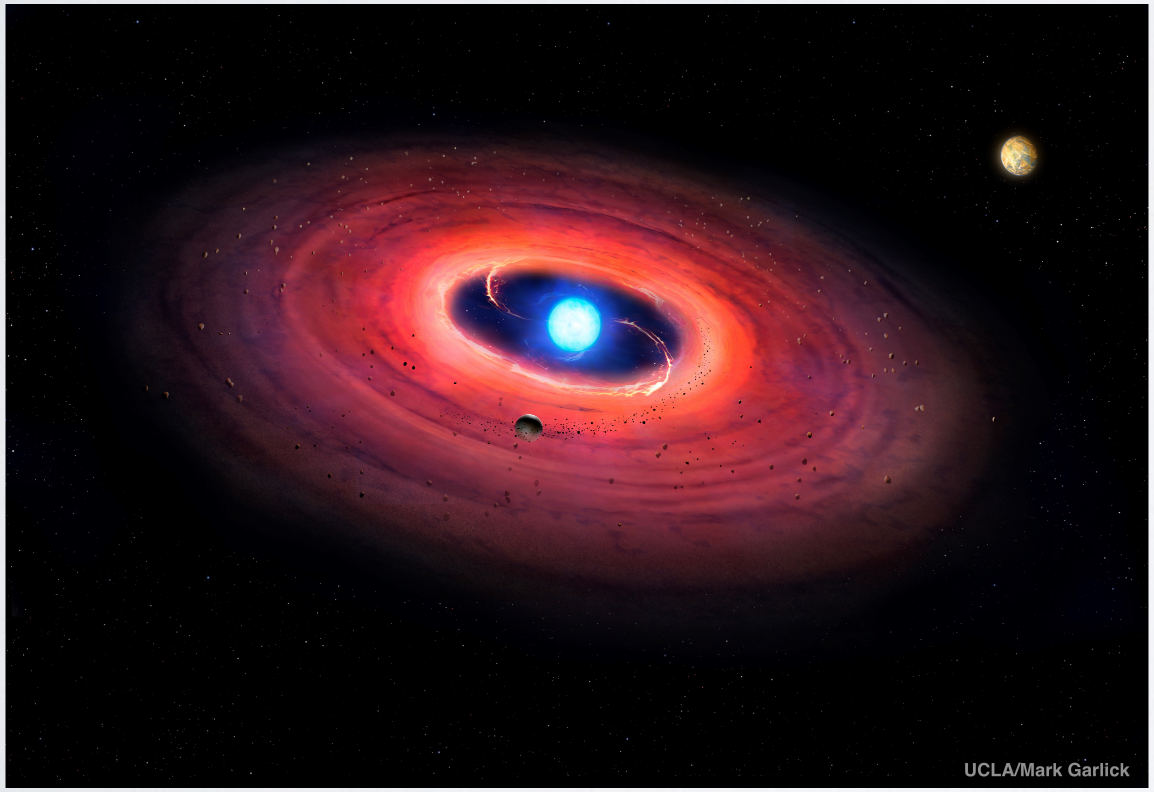


How do exoplanet compositions vary across the galaxy?

Are the rocky planets in our Solar System typical or unique?

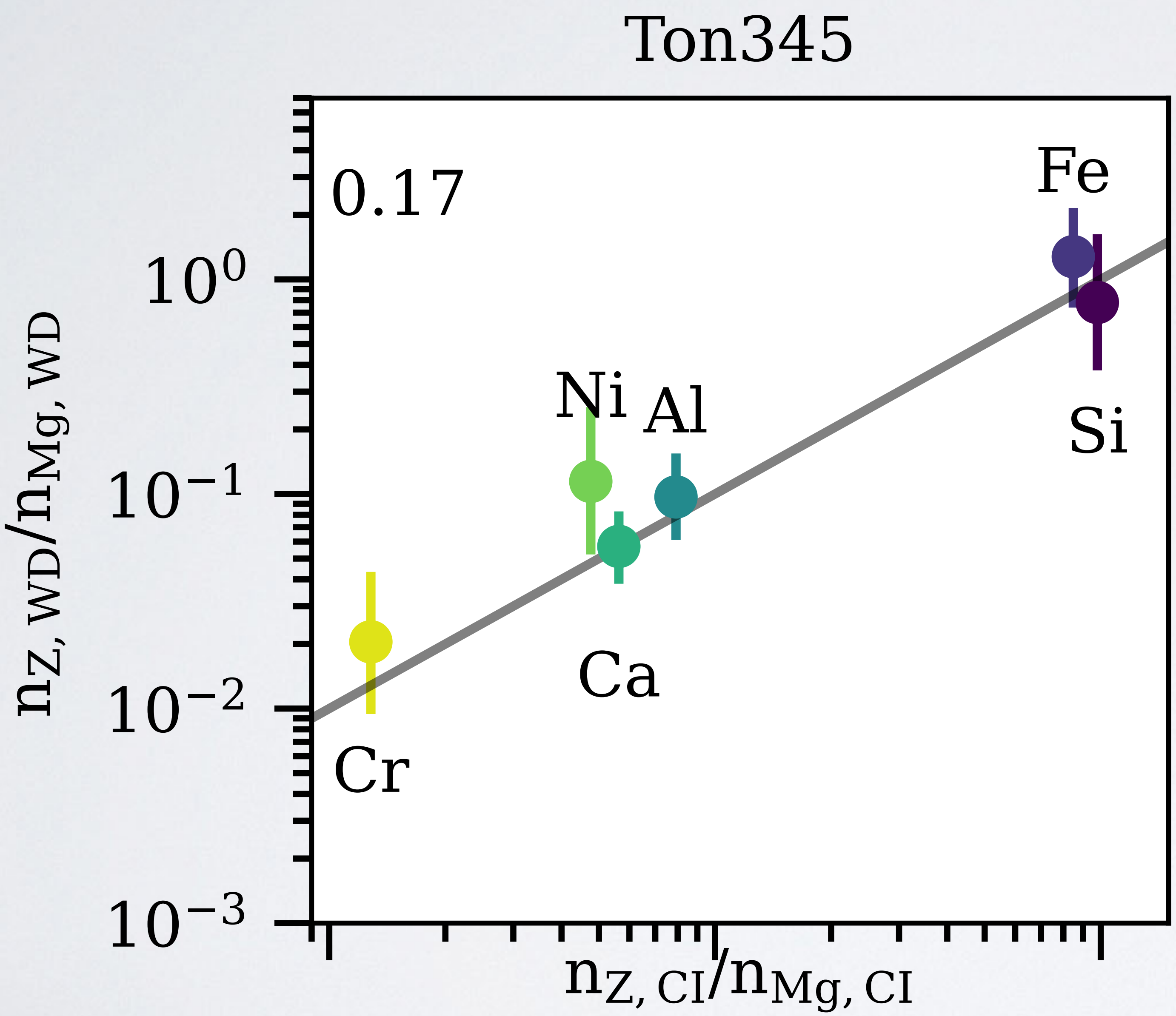
HOW DO EXOPLANET COMPOSITIONS VARY ACROSS THE GALAXY?

- White dwarf pollution provides samples of exoplanetary rocks in the solar neighborhood
- We test local exoplanet compositions by comparing polluted white dwarfs to solar system rocks and benchmark against local stellar abundances

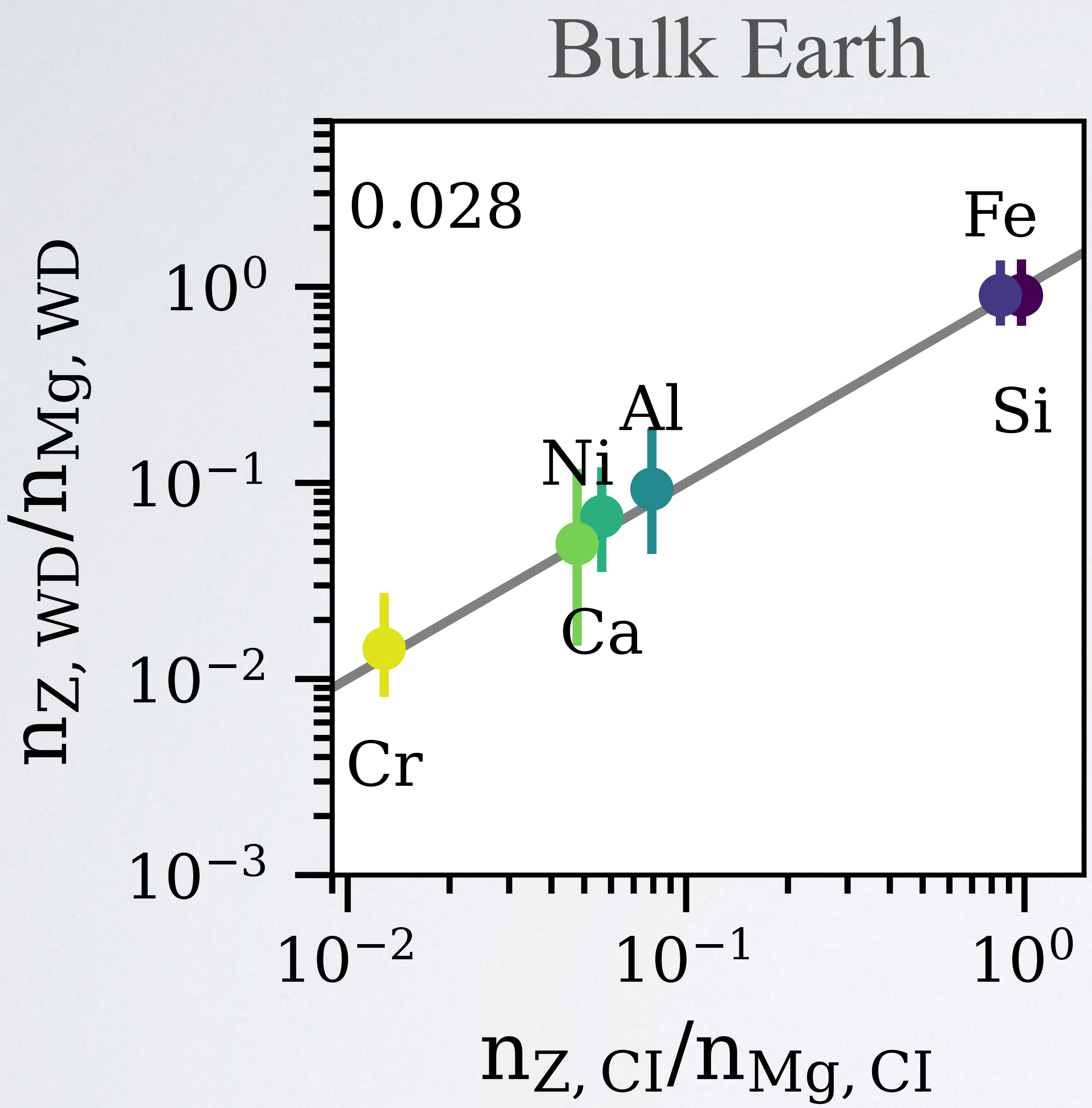


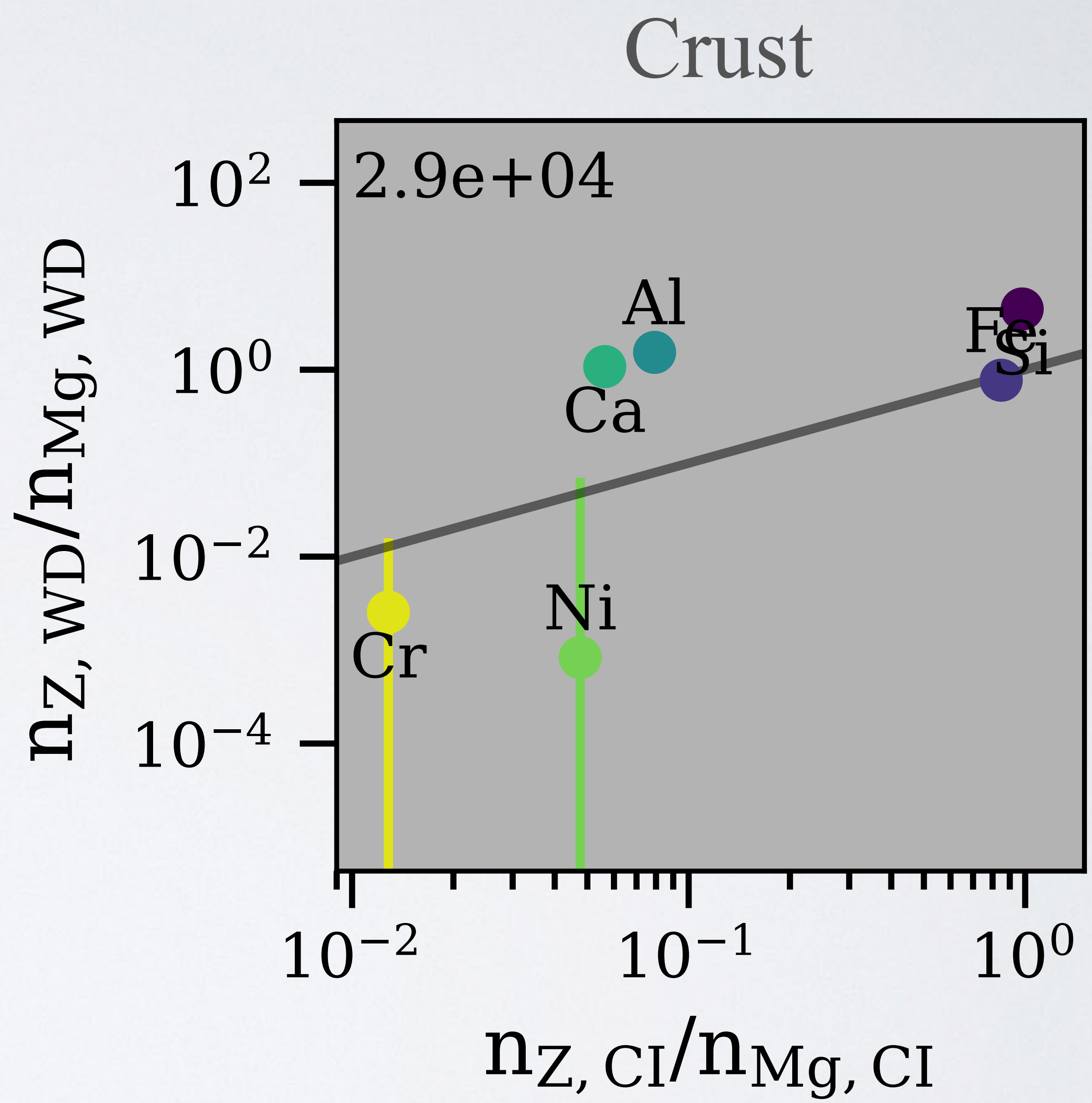
COMPARING EXO-ROCKS TO SOLAR SYSTEM CHONDRITES

Chondrites are best representation of Solar System compositions

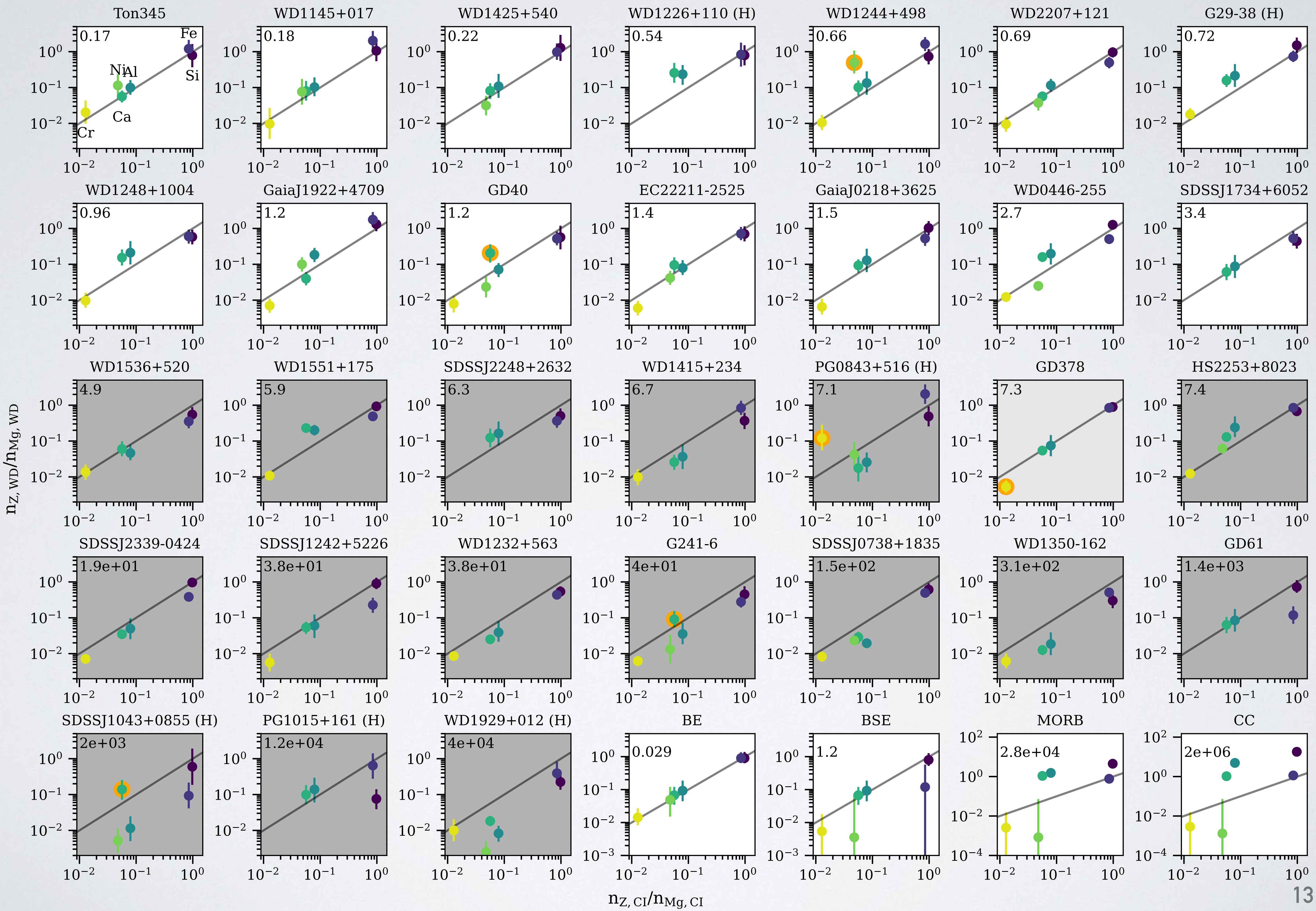


STATISTICALLY DISTINGUISH BETWEEN CHONDRITE AND CRUST

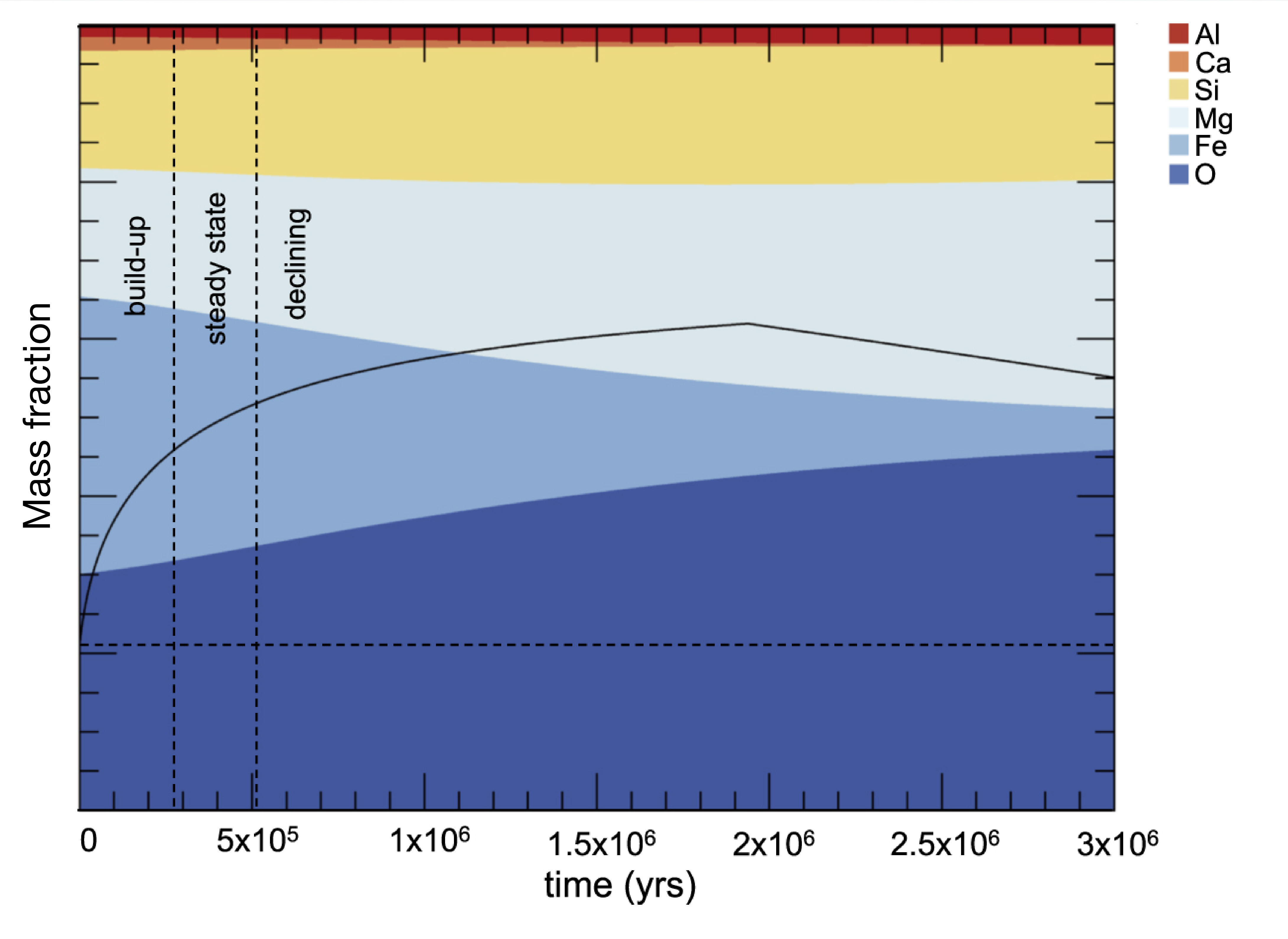




WHITE DWARFS – RAW DATA

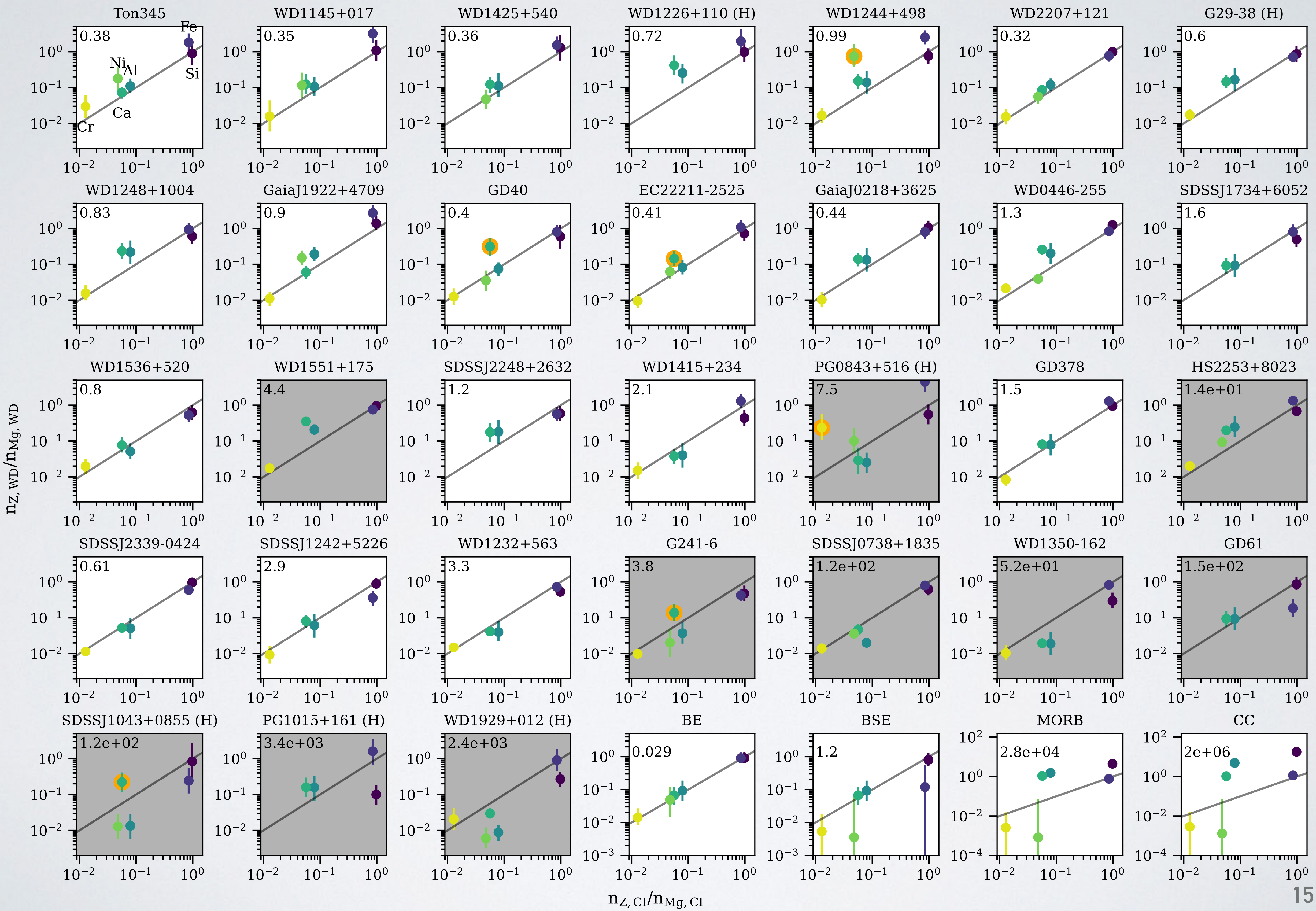


DIFFERENTIAL SETTLING INFLUENCES MEASURED COMPOSITION

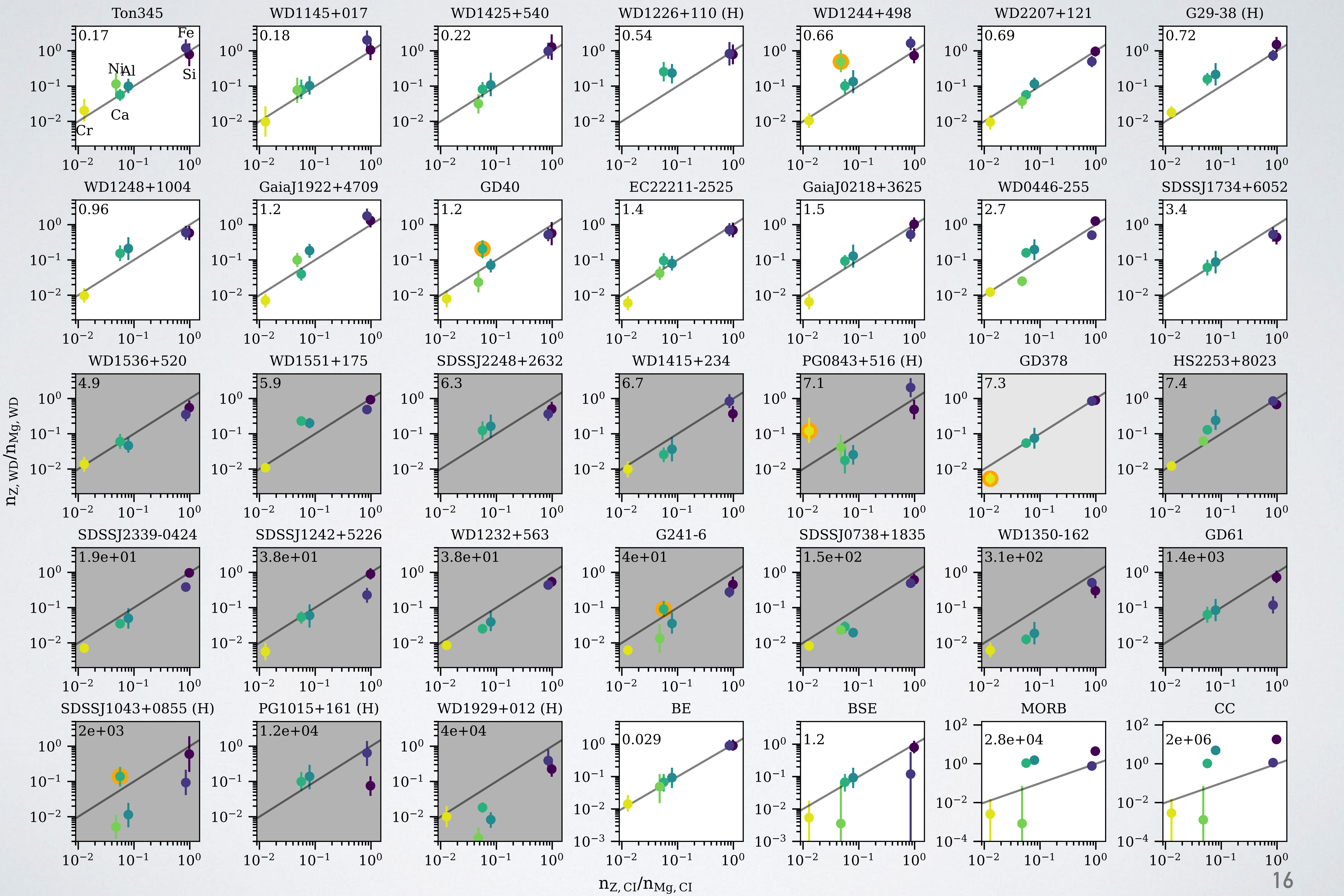


Doyle et al. 2020

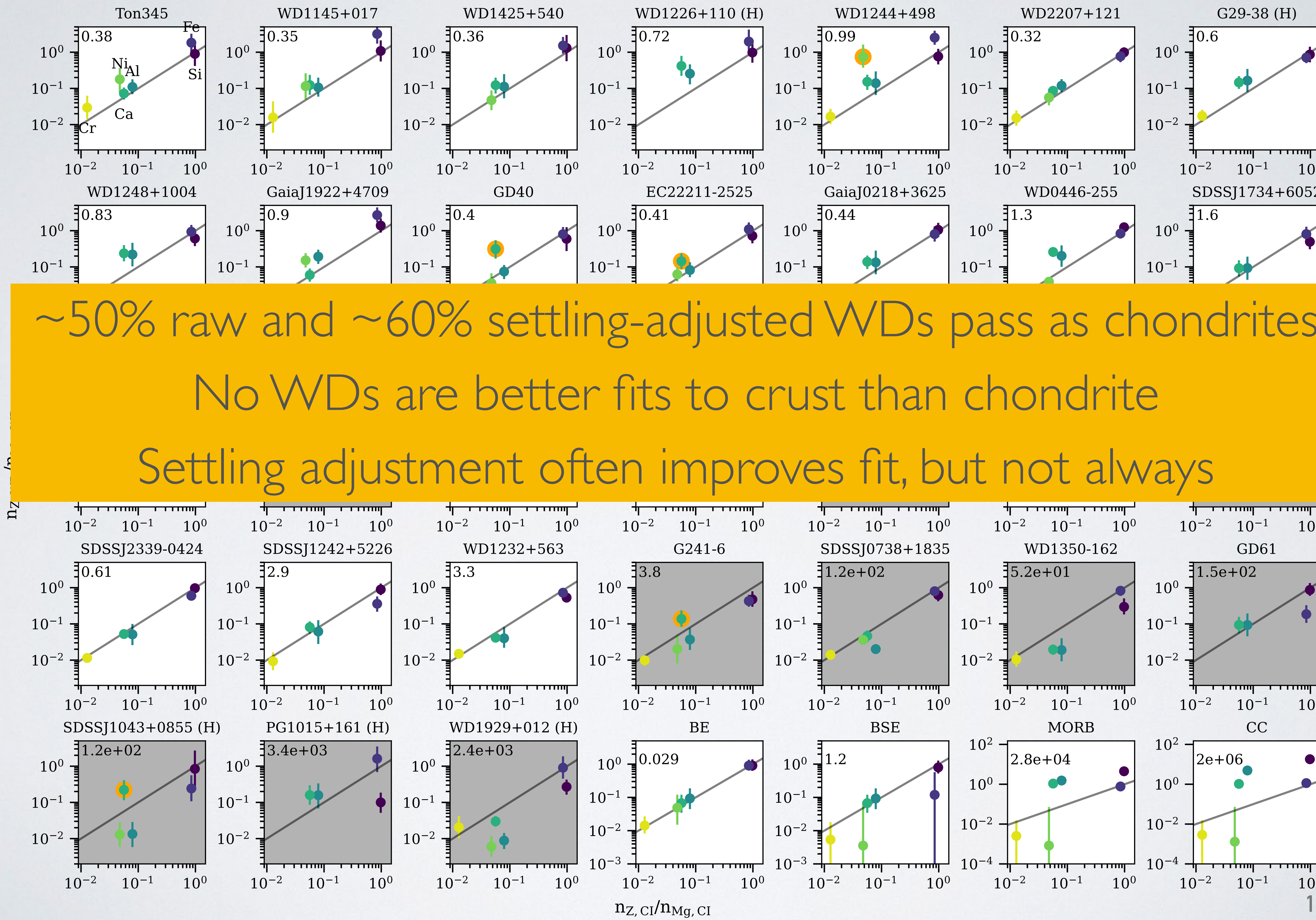
WHITE DWARFS - ADJUSTED FOR SETTLING IN THE ATMOSPHERE



WHITE DWARFS – RAW DATA



WHITE DWARFS - ADJUSTED FOR SETTLING IN THE ATMOSPHERE



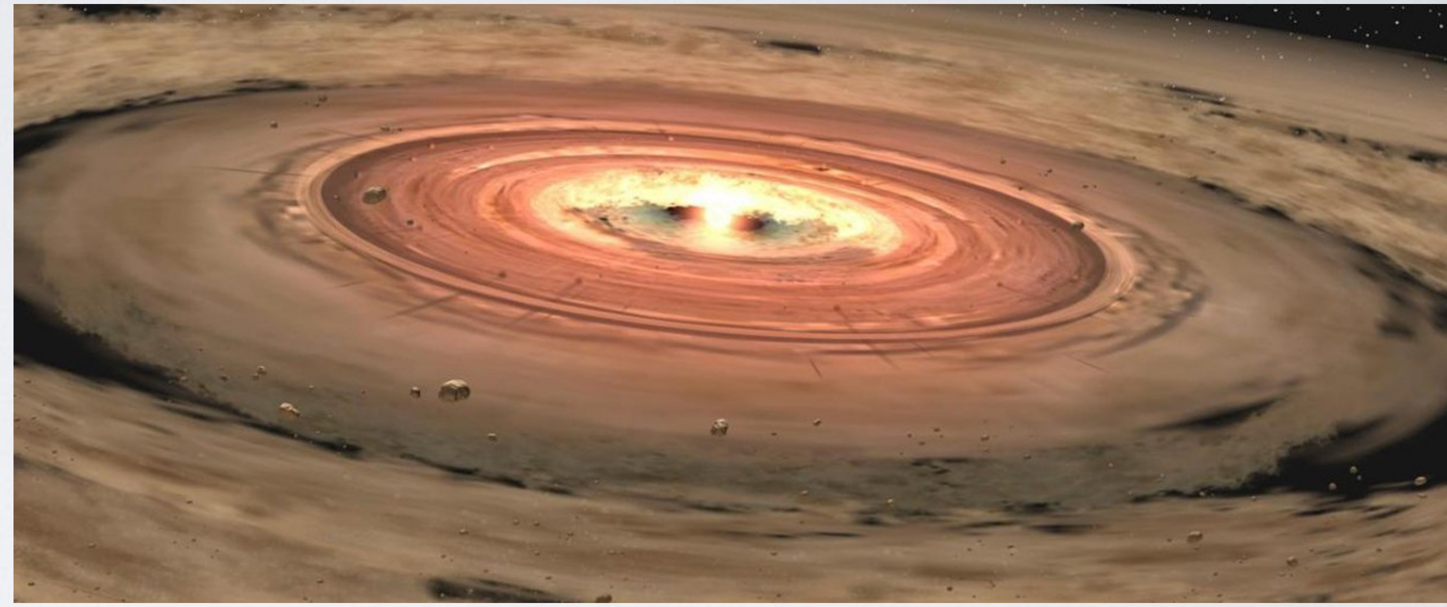
~50% raw and ~60% settling-adjusted WDs pass as chondrites

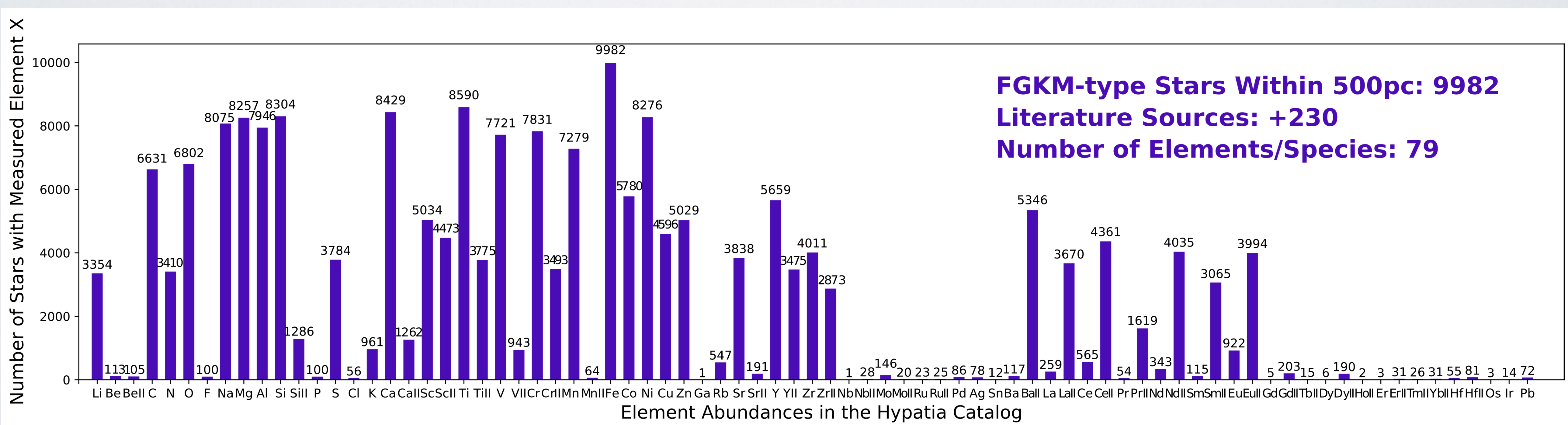
No WDs are better fits to crust than chondrite

Settling adjustment often improves fit, but not always

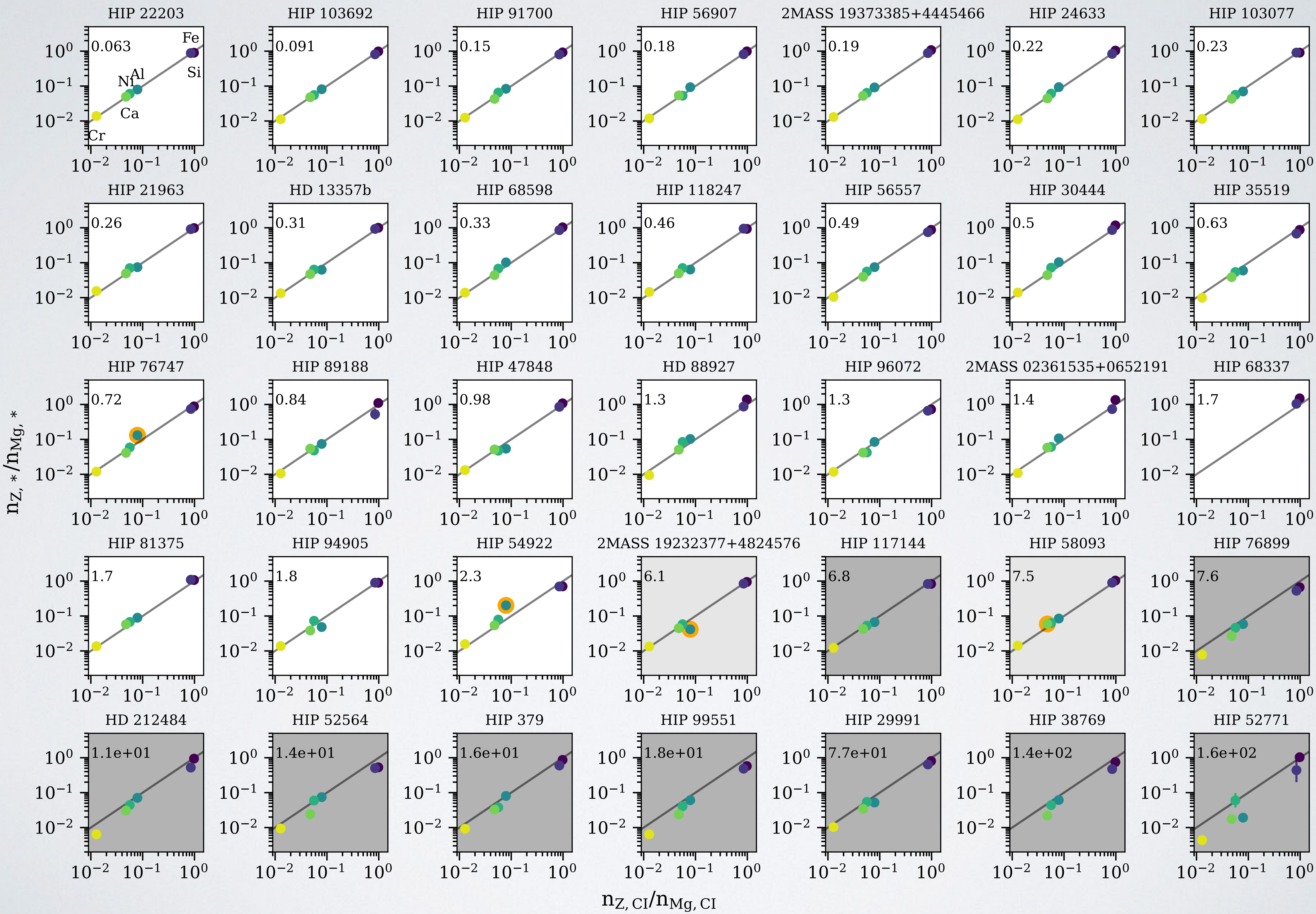
HYPATIA CATALOGUE STARS

Stellar abundances represent protoplanetary disk environments and correlate with planet compositions
(Thiabaud+ 2015, Bonsor+ 2021)



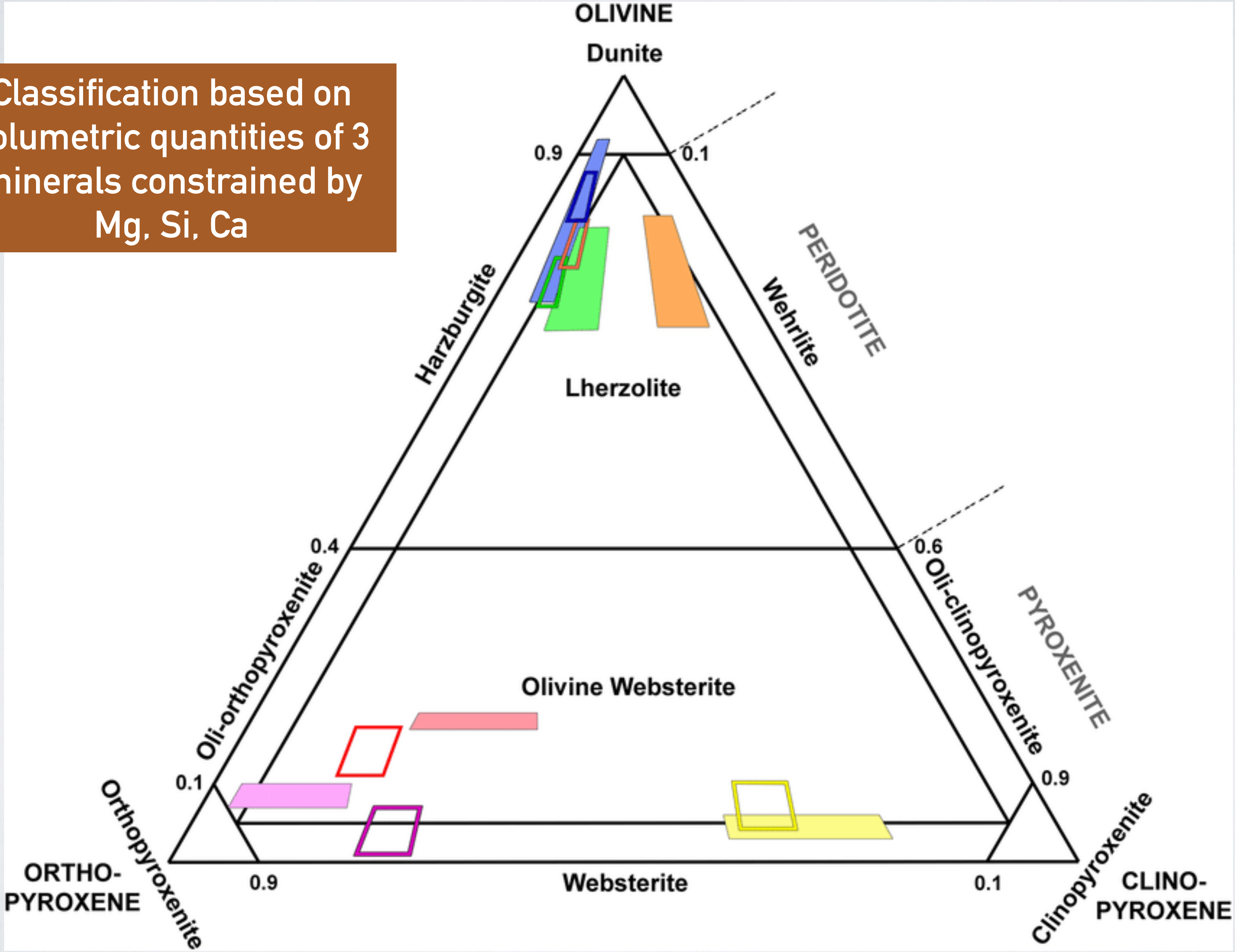


HYPATIA CATALOGUE STARS



CLASSIFYING WHITE DWARF POLLUTION BY MINERALOGY

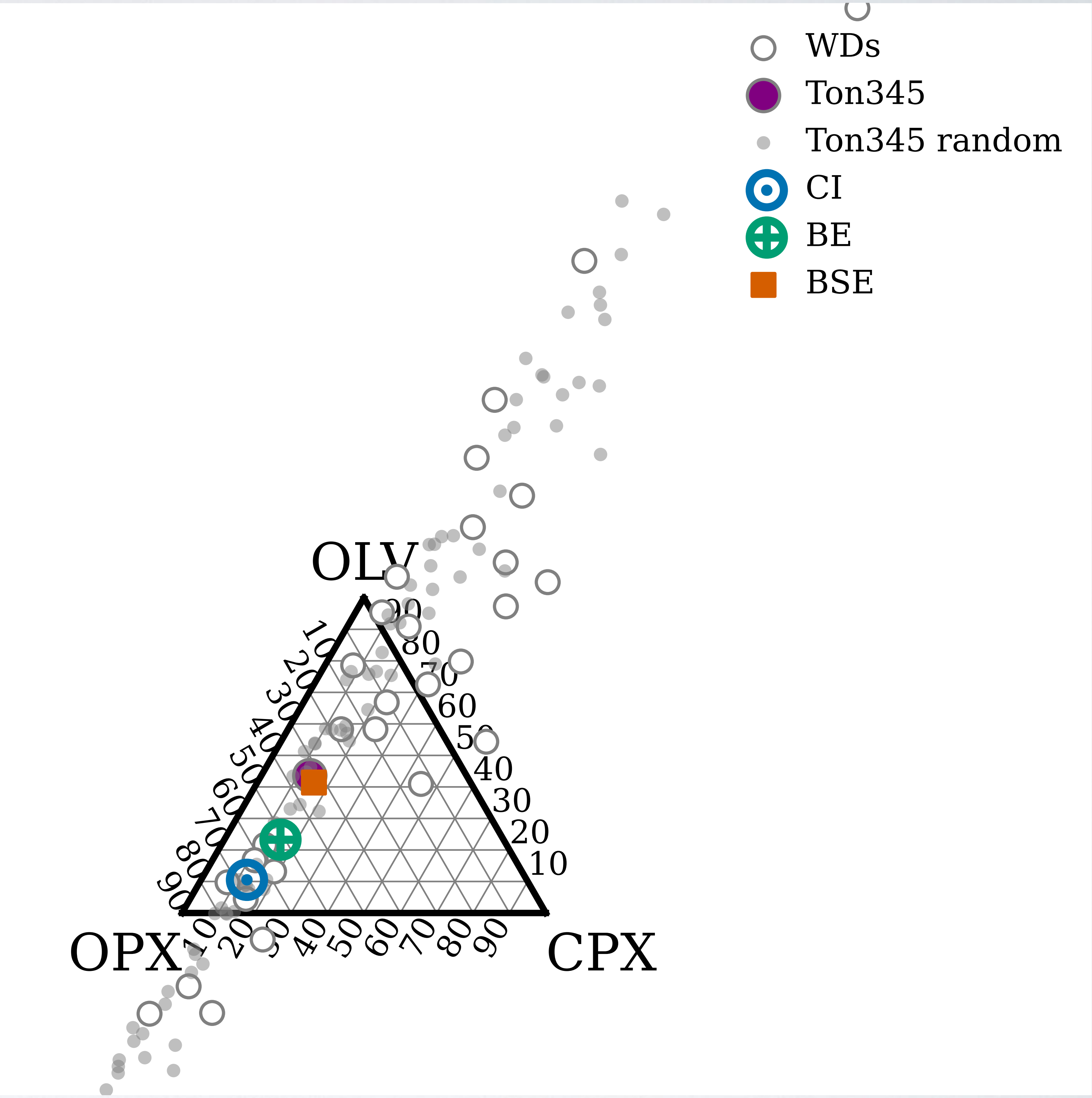
Classification based on volumetric quantities of 3 minerals constrained by Mg, Si, Ca



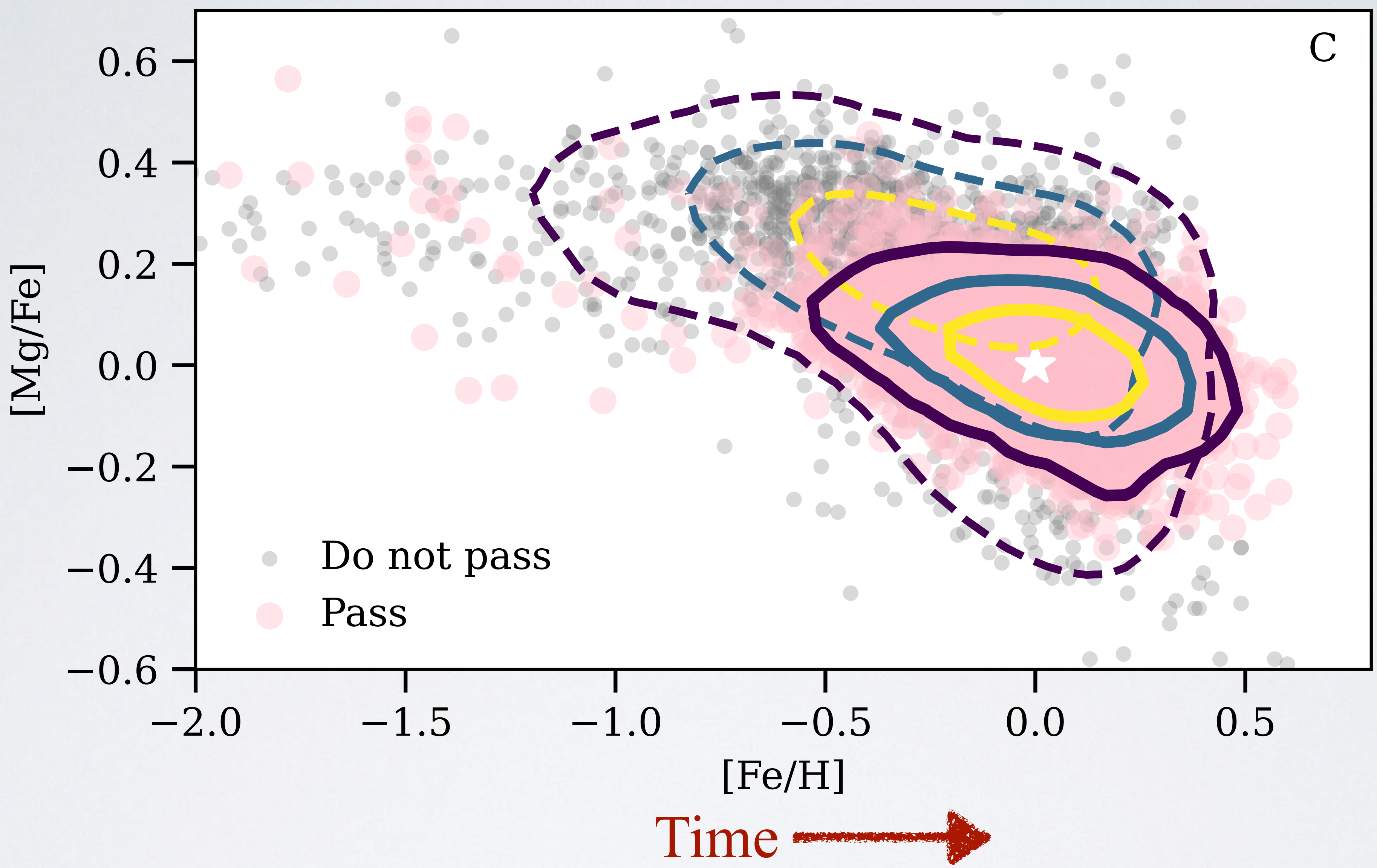
Veneranda, Lopez-Reyes, Manrique-Martinez et al. 2020

CLASSIFYING WHITE DWARF POLLUTION BY MINERALOGY

Uncertainties in Mg, Si, Ca abundances too large to constrain mineralogy

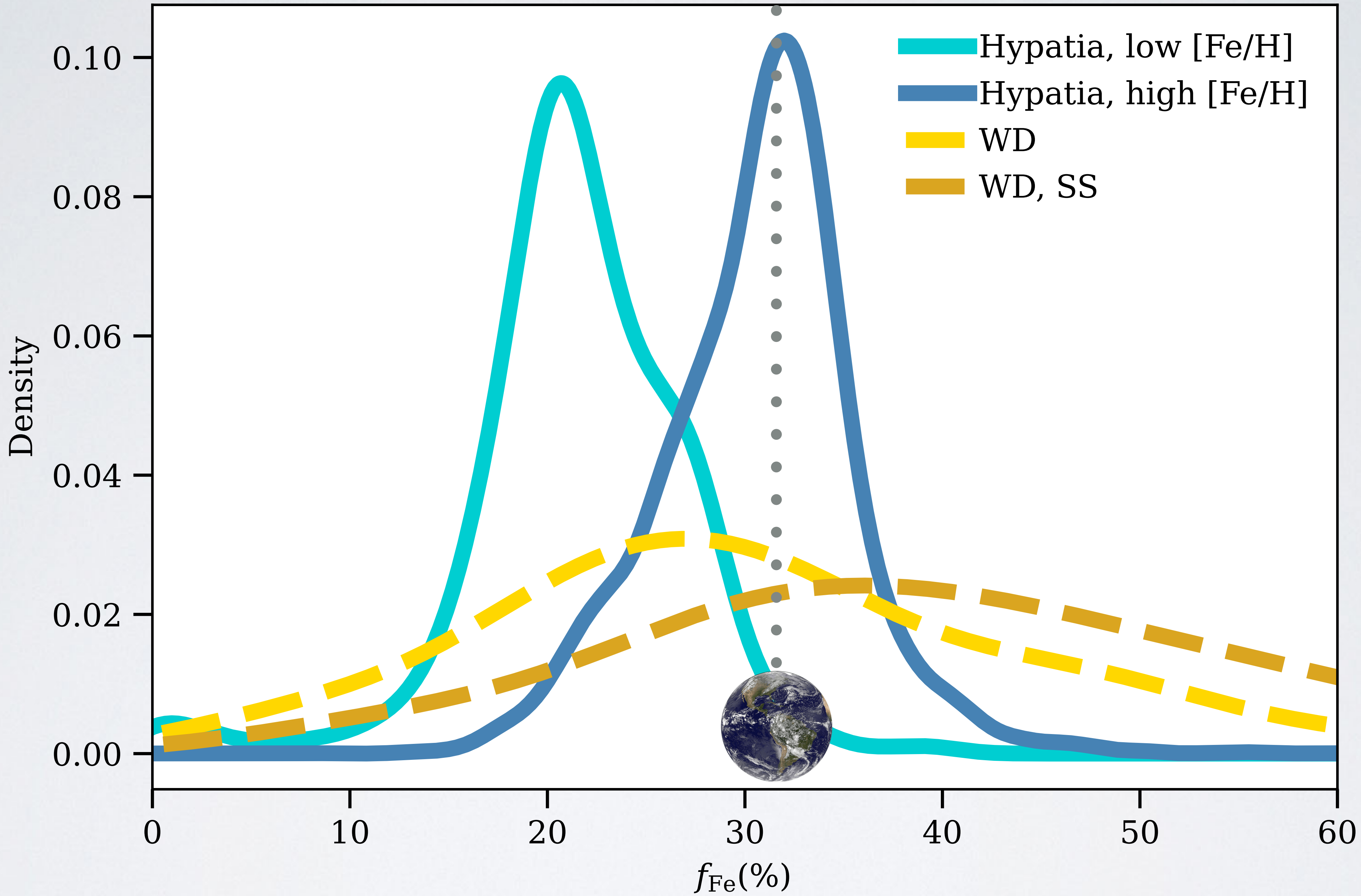


CONSIDERING EFFECTS OF GALACTIC CHEMICAL EVOLUTION



- Lithophile/siderophile ratio (Mg/Fe) changes with time
- Lower metallicity stars (forming at earlier times) tend to be less consistent with chondrites

EFFECTS OF GALACTIC CHEMICAL EVOLUTION - SMALLER CORES?

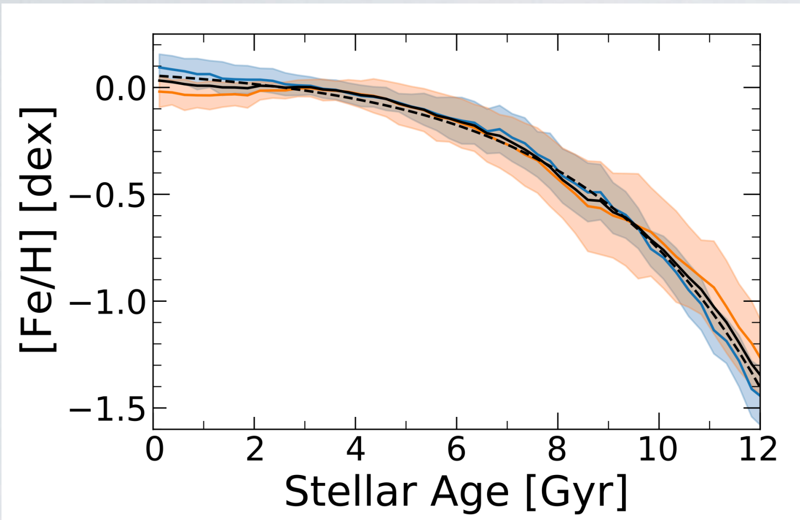


Expect smaller cores at early times or in very low metallicity regions of the galaxy

SUMMARY

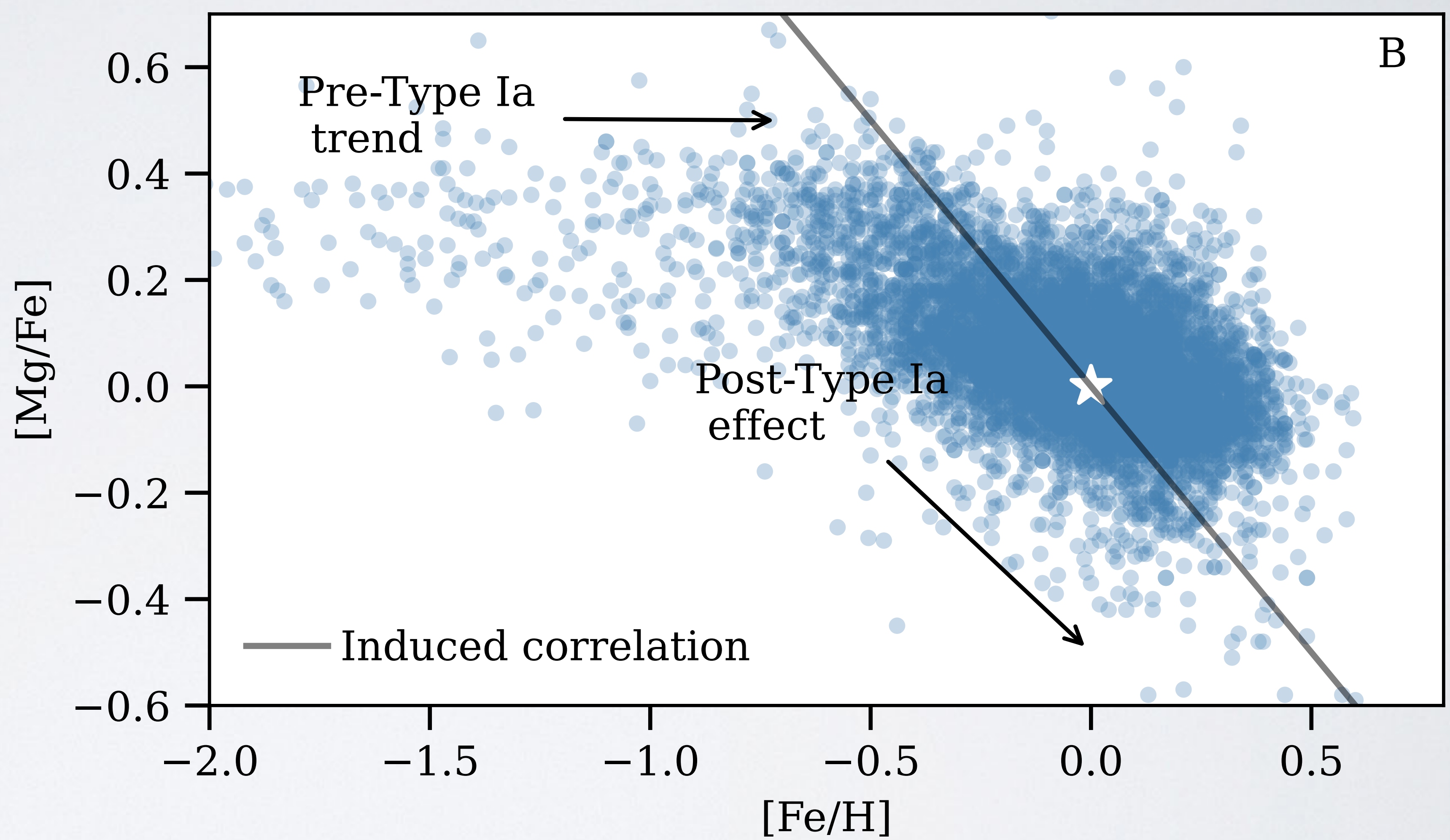
- >50% of exo-rocks sampled by polluted WDs are consistent with chondritic material
- No evidence for accretion of crust by WDs
- ~75% of local stars sample by Hypatia Catalog are consistent with chondrites
- On galactic scales, chemical evolution may lead to systematically smaller iron cores in planets at early times, but galactic effects are likely not impacting the current sample of polluted WD compositions

CONSIDERING EFFECTS OF GALACTIC CHEMICAL EVOLUTION

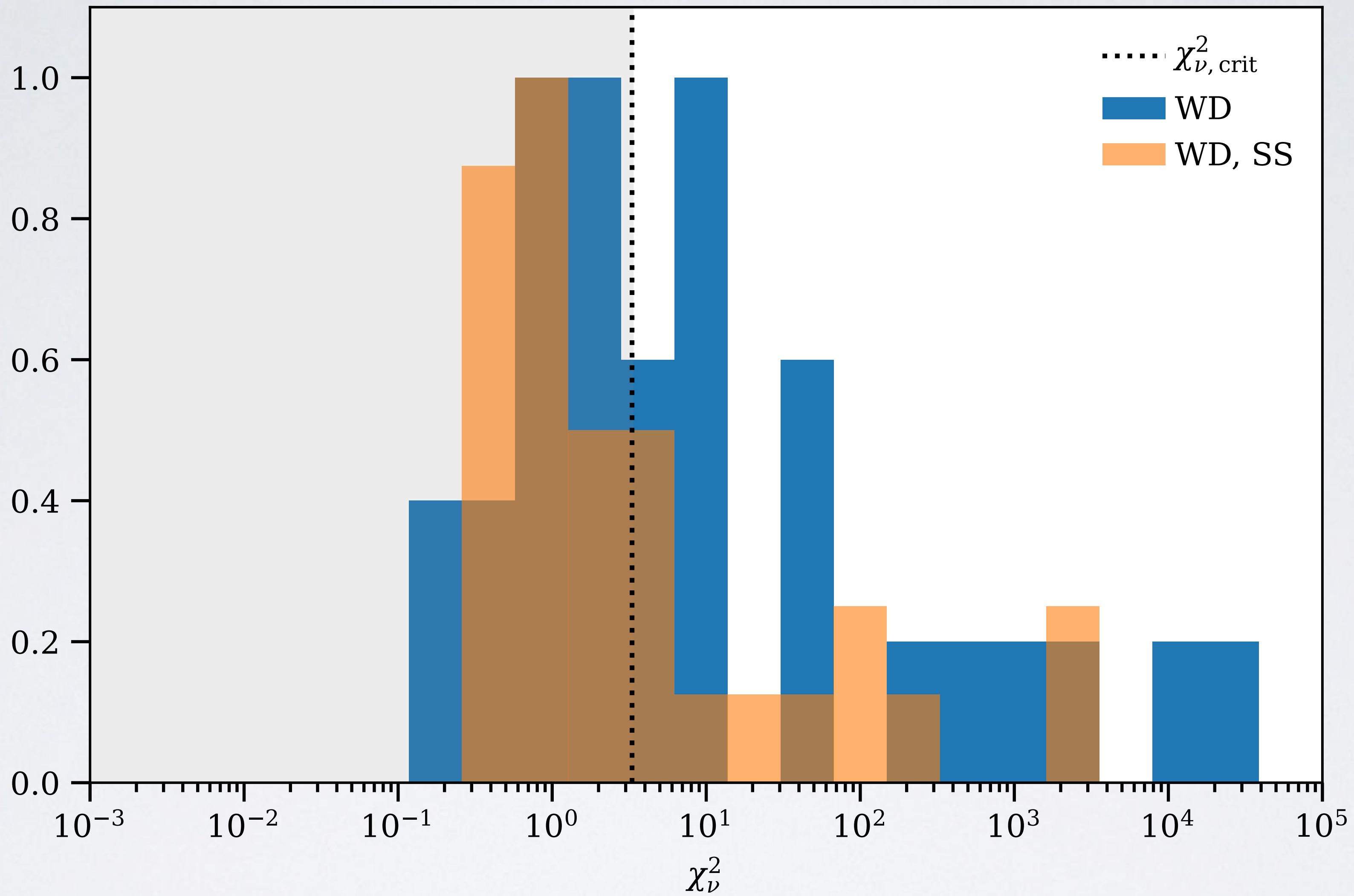


Bellardini+ 2022

Change in lithophile/siderophile ratios due to late effects from Type Ia supernovae

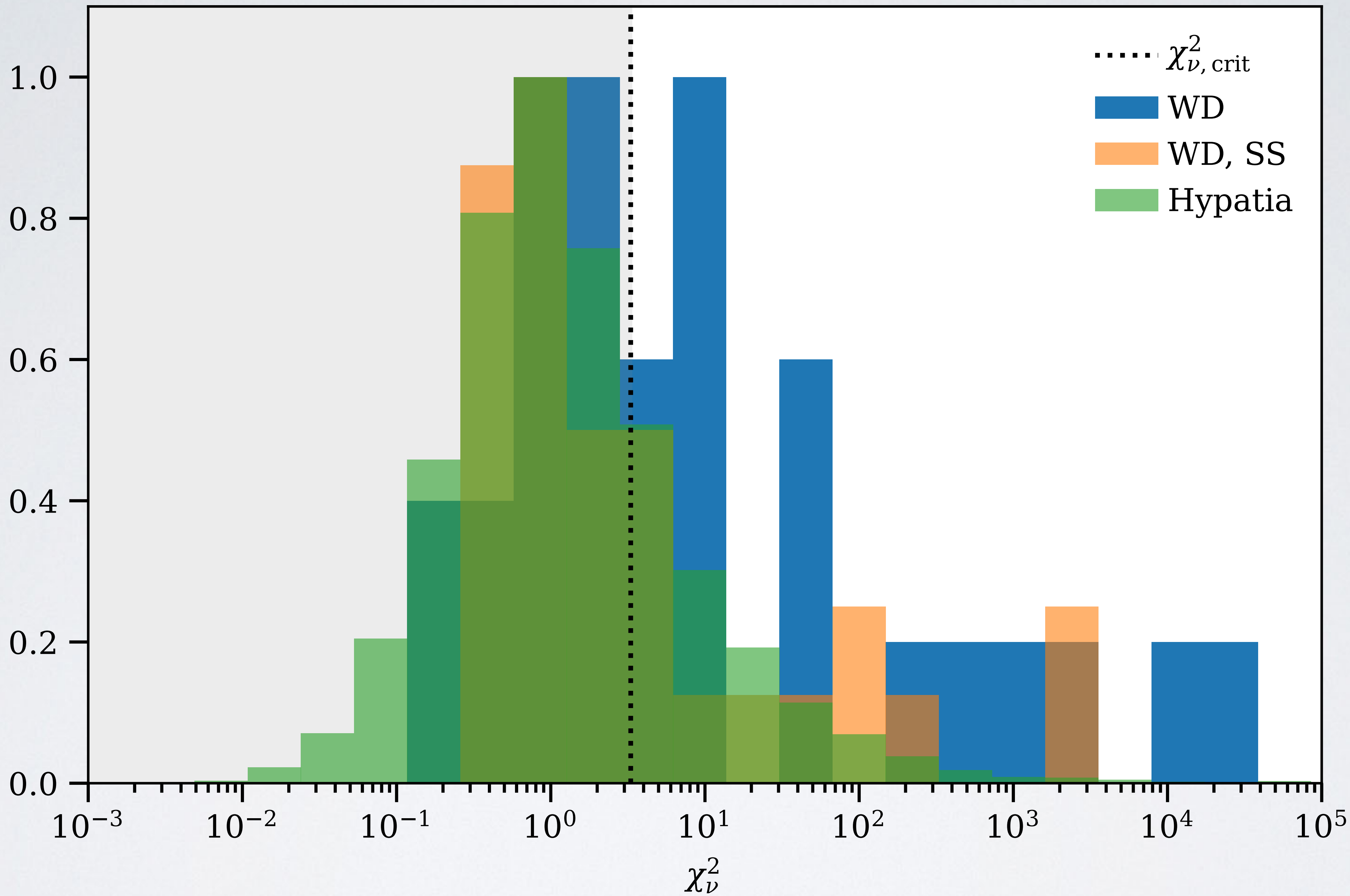


CHONDRITIC WHITE DWARFS



- No WDs are better fits to crust than chondrite
- ~50% raw and ~60% corrected WDs pass as chondrites
- Settling correction often improves fit, but not always

HYPATIA CATALOGUE STARS ARE CHONDRITIC



~75% of Hypatia Catalogue stars pass as chondritic