Polluted White Dwarfs: Constraints on the Origin & Geology of Exoplanets

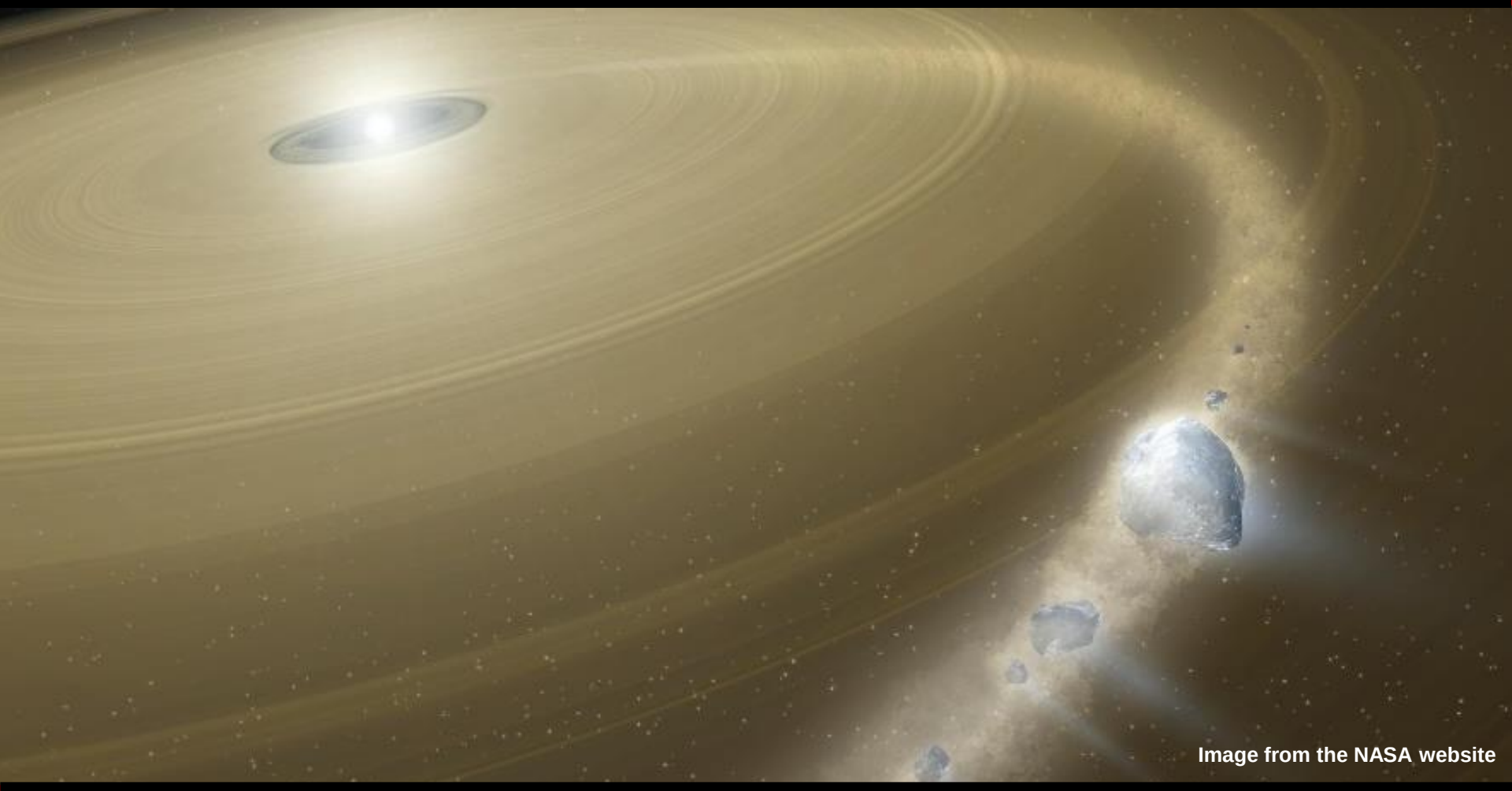

Image from the NASA website

John Harrison, Amy Bonsor, Oliver Shorttle, & Mihkel Kama
Institute of Astronomy, University of Cambridge
jhdh2@cam.ac.uk

What are white dwarfs?

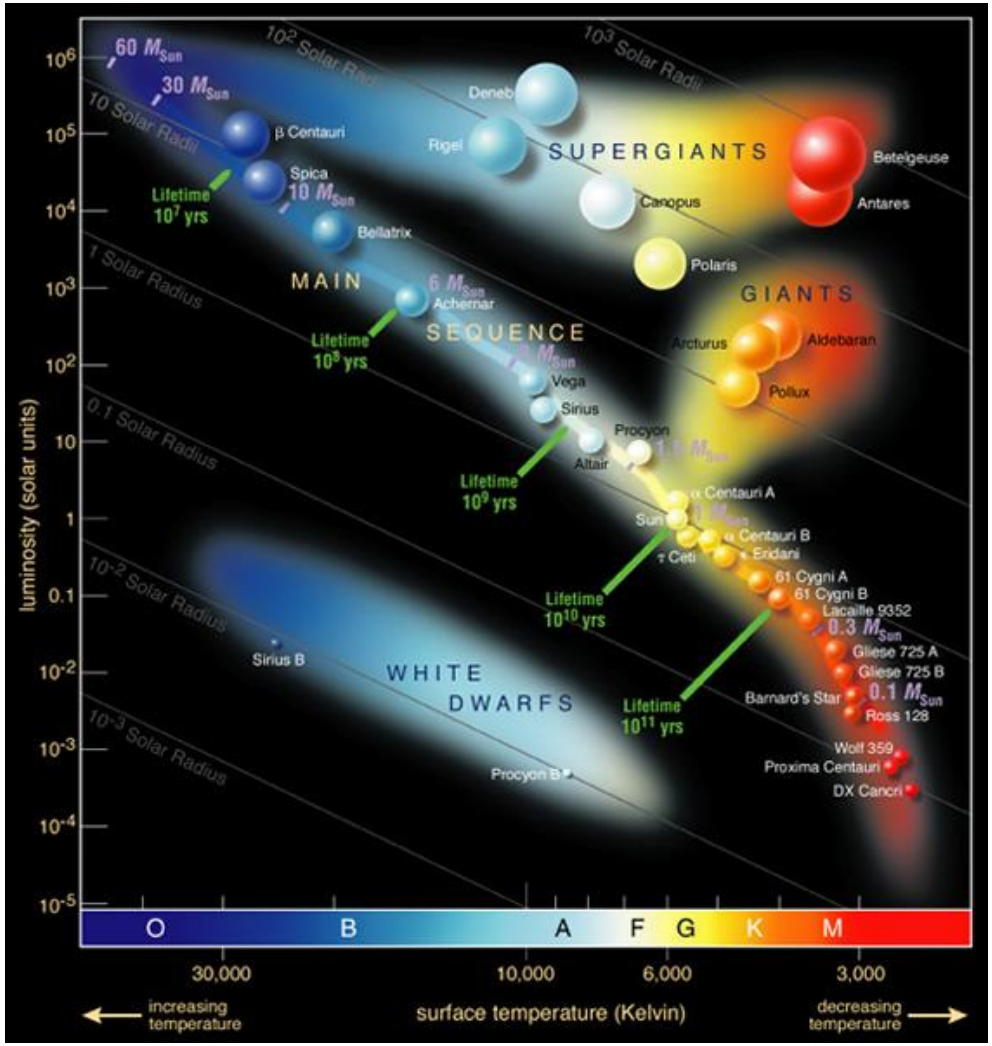

Image from the ESO website

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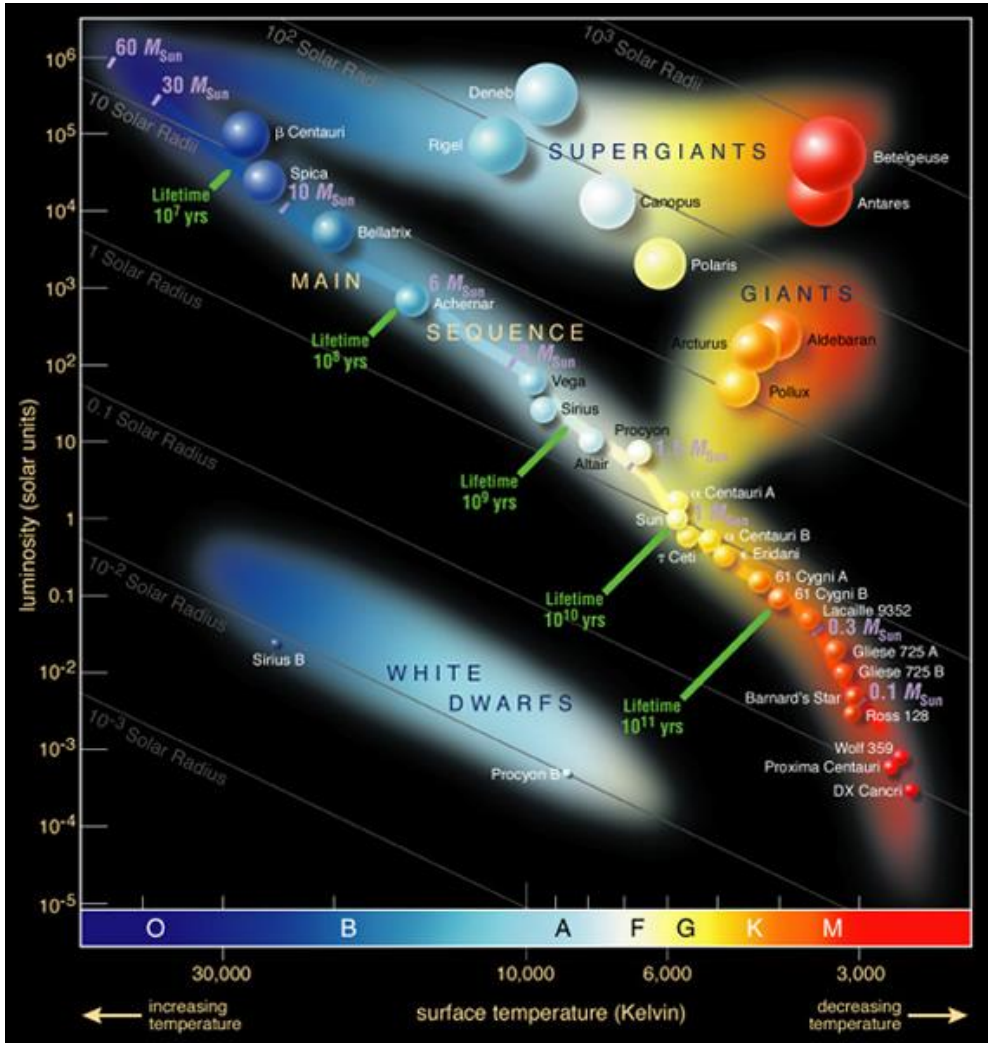
White dwarfs are the final stage of stellar evolution for stars with main sequence masses $< 7\ M_{\odot}$.



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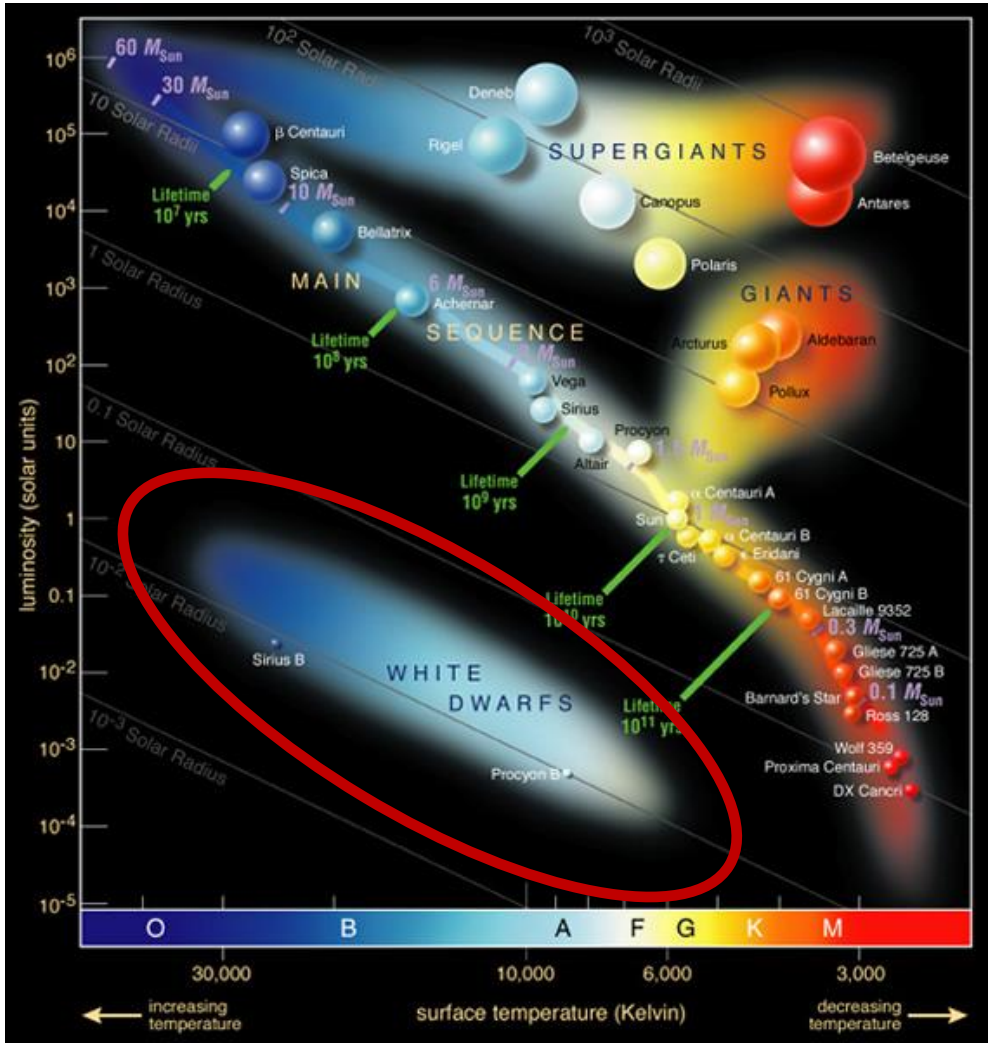

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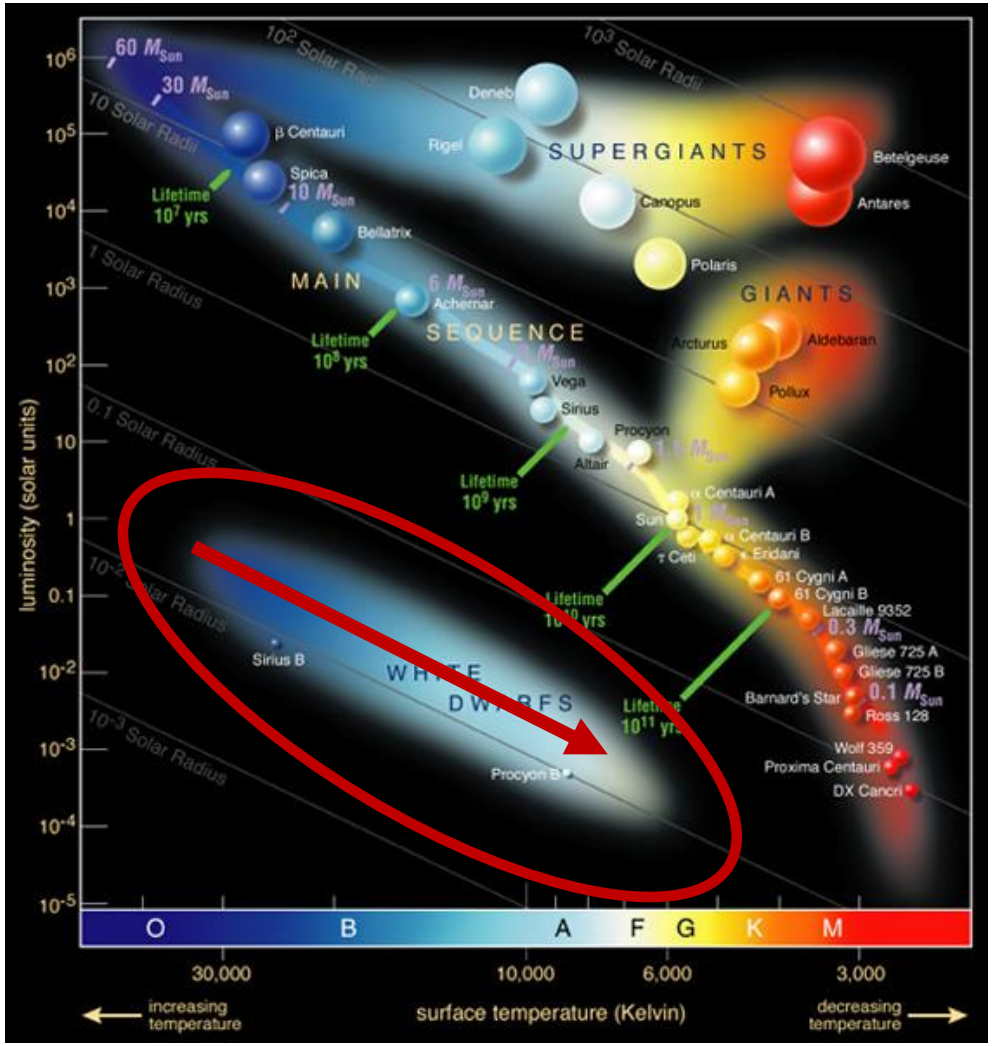

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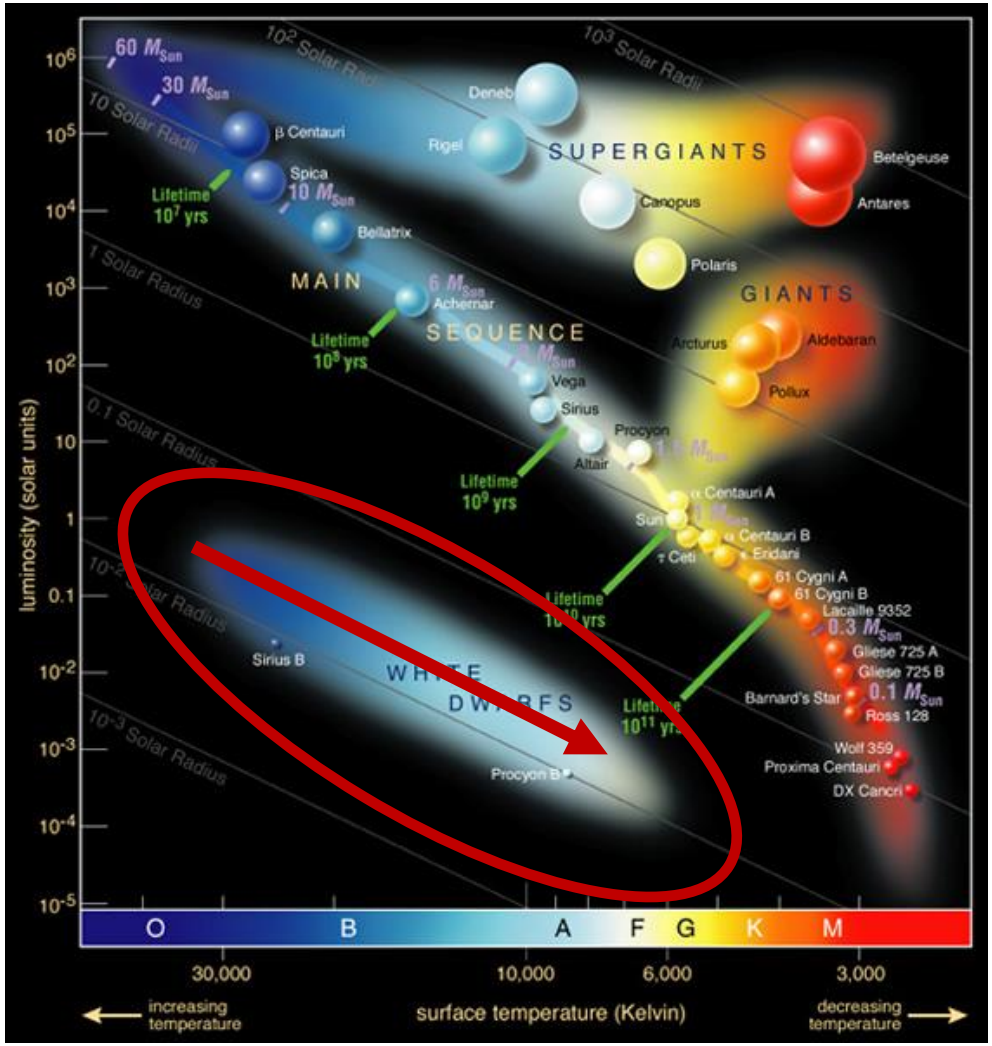

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Therefore, we can accurately **estimate** their **age**.

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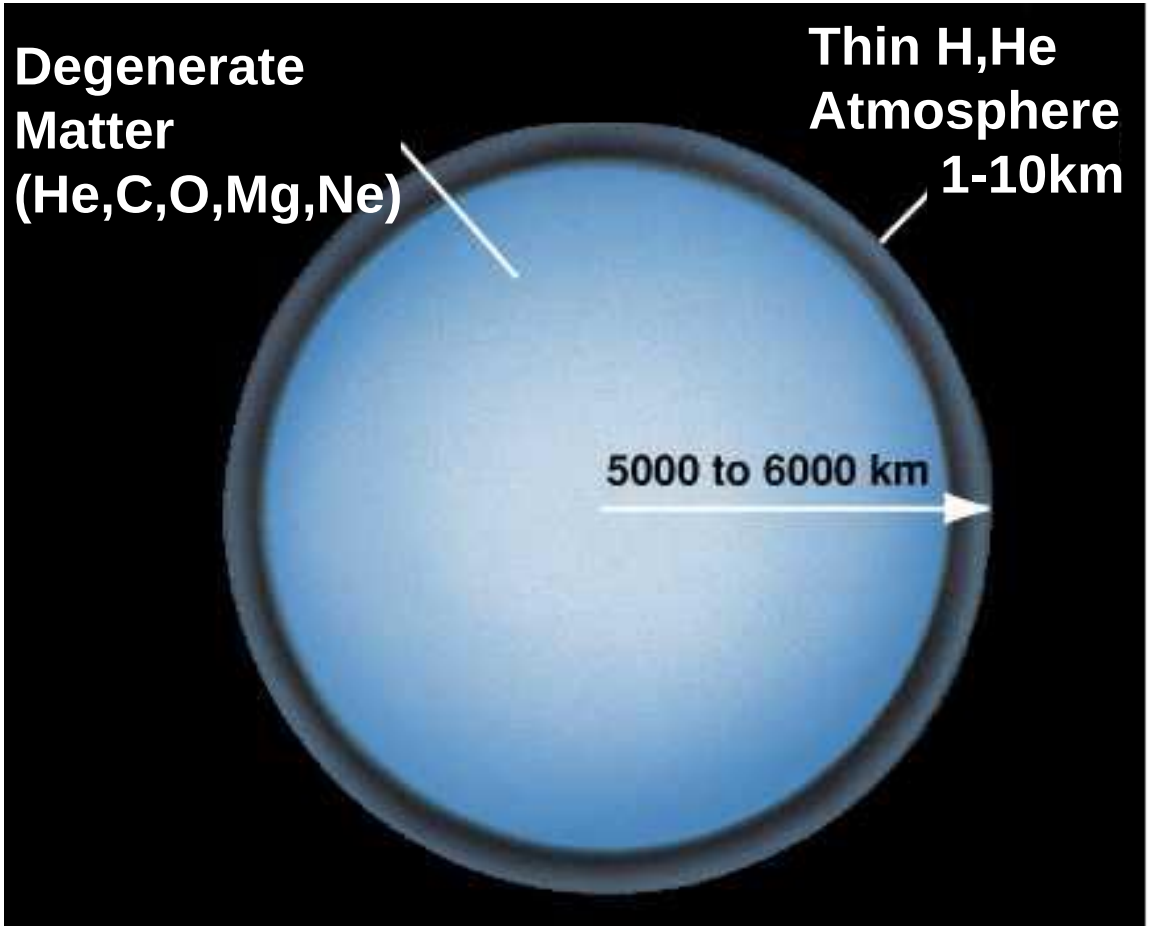

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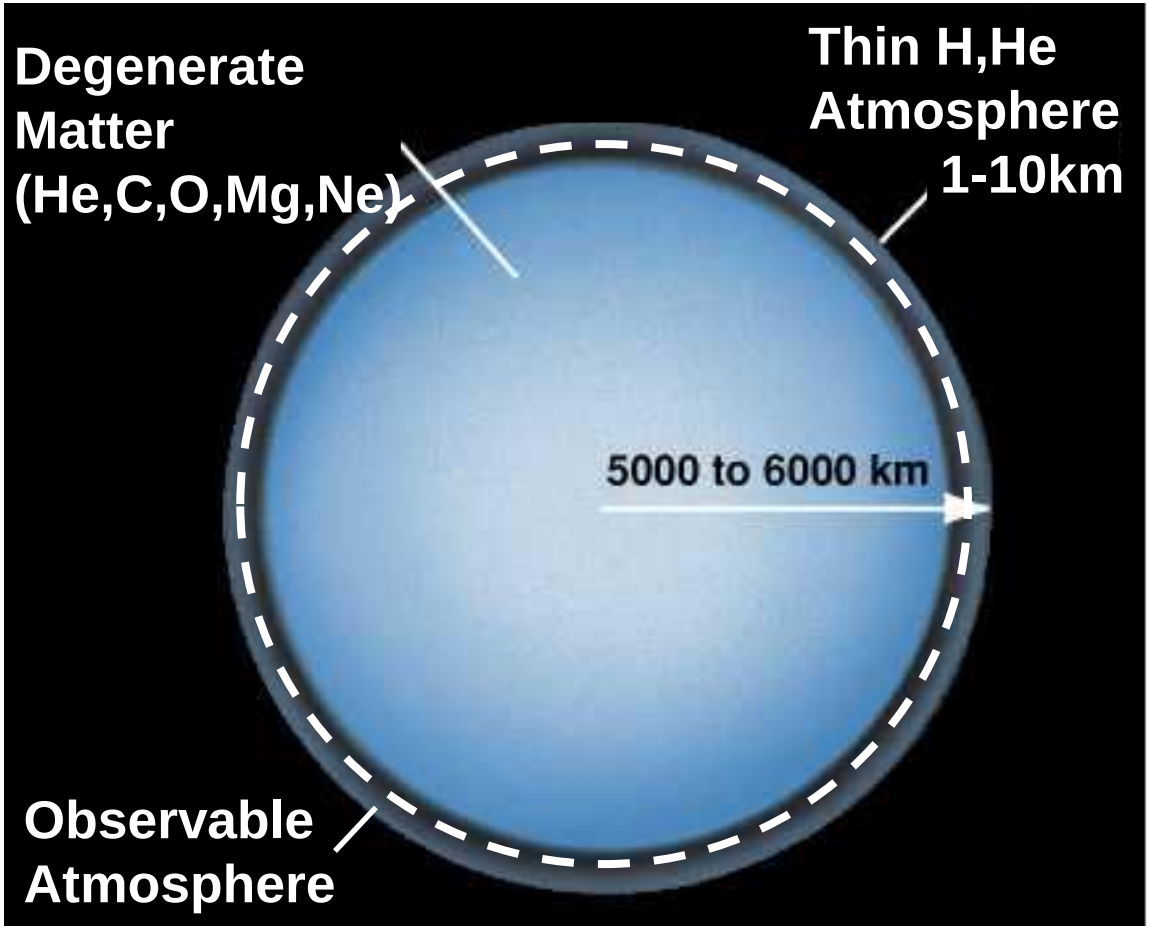

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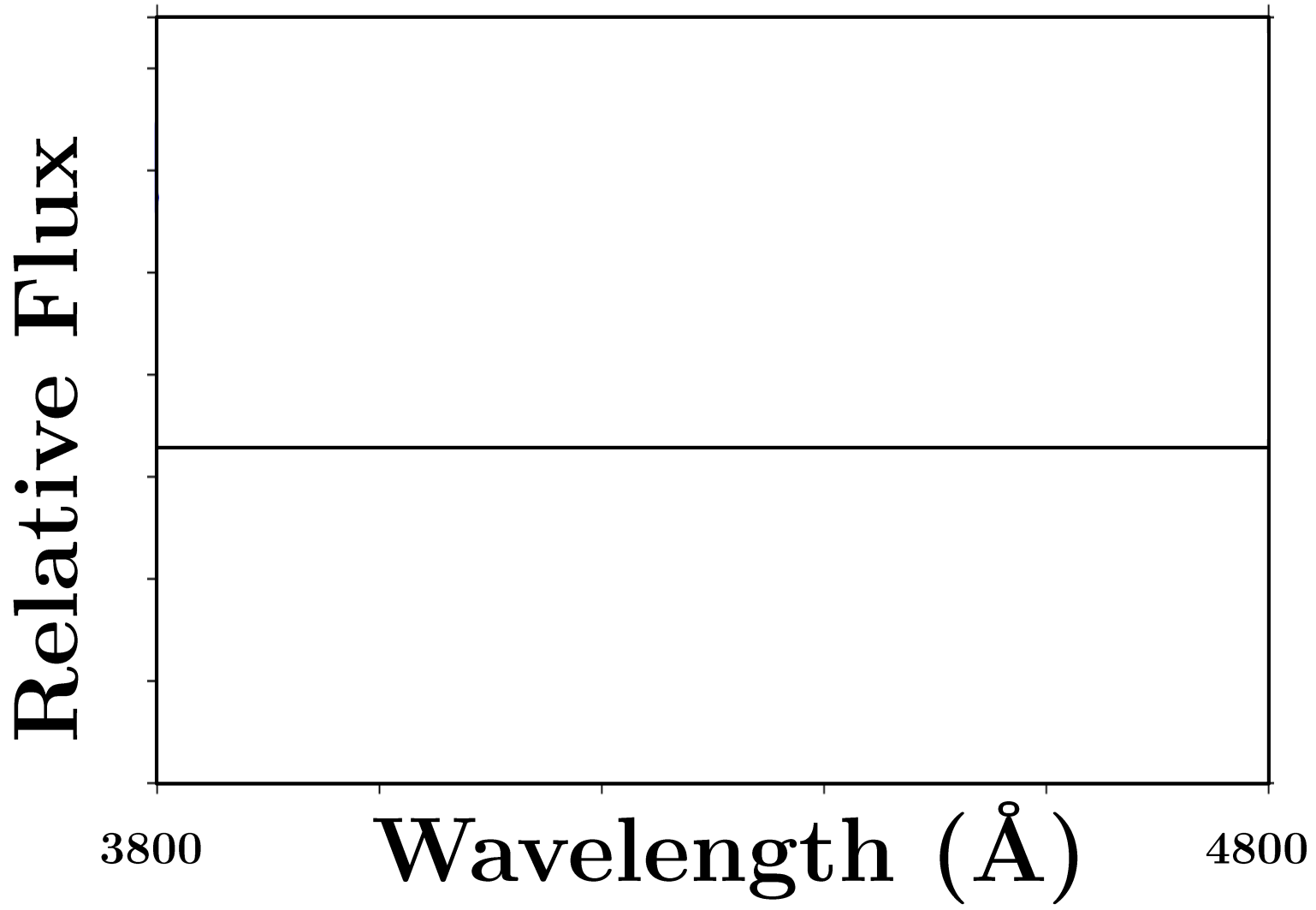

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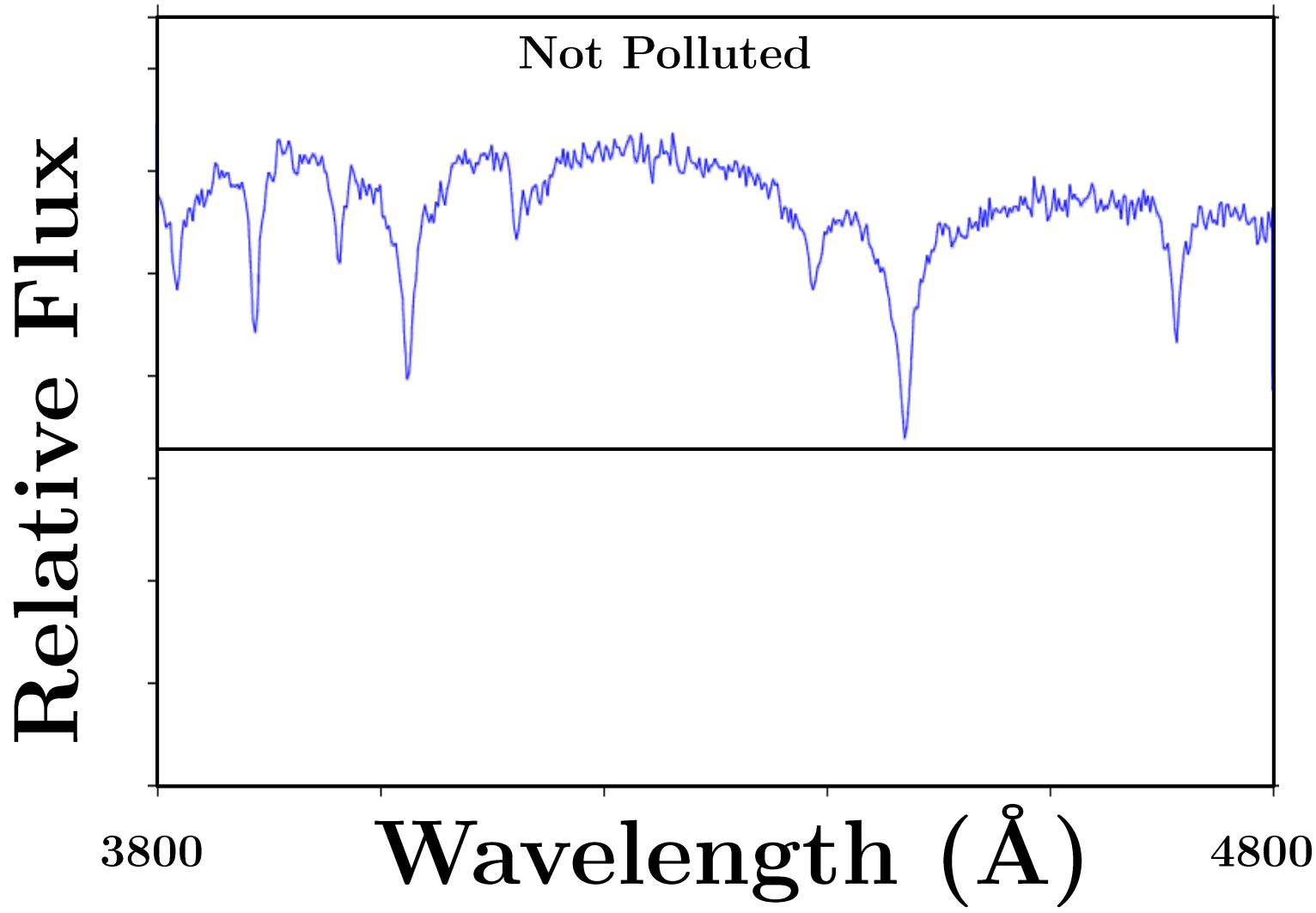

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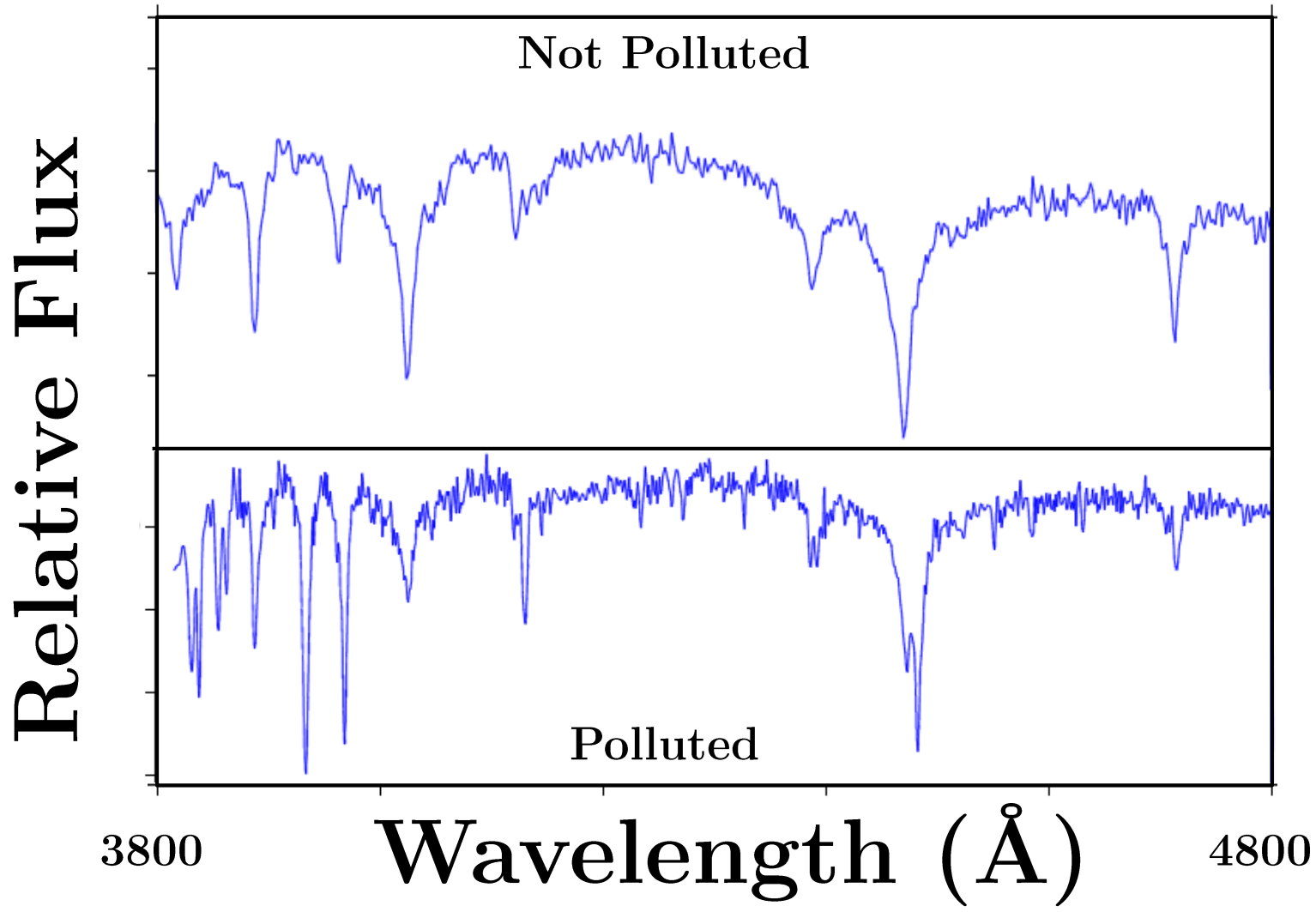

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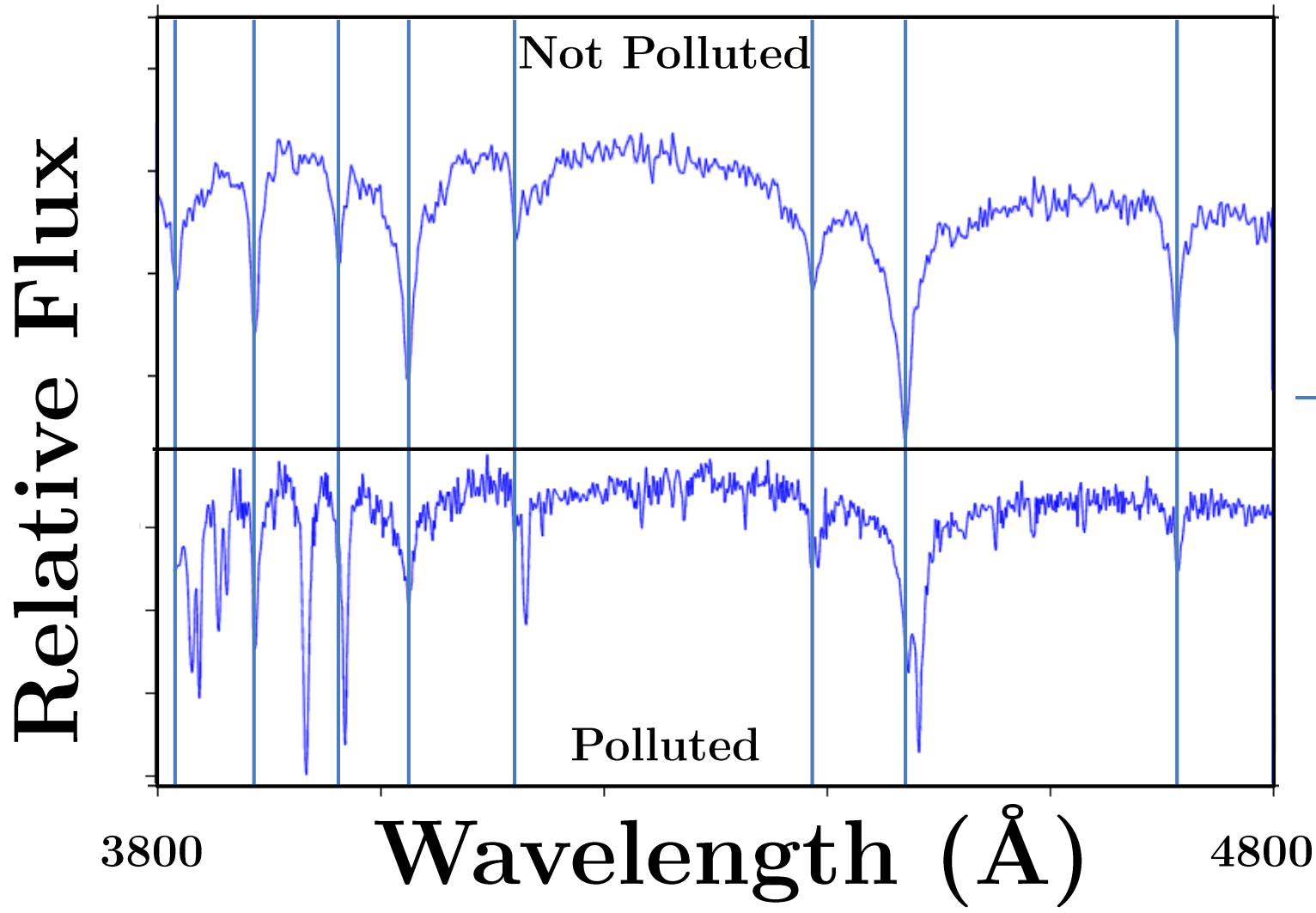

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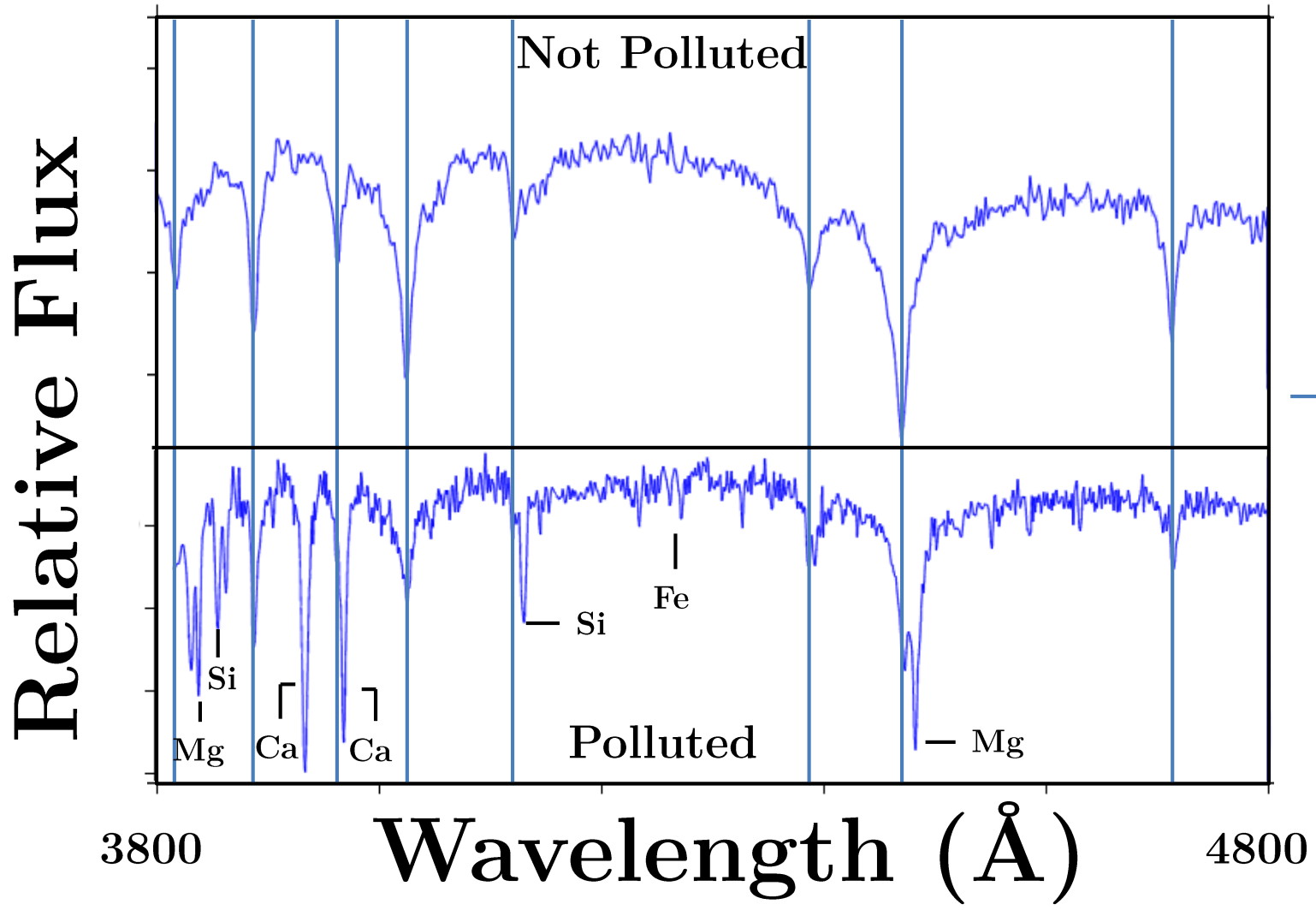

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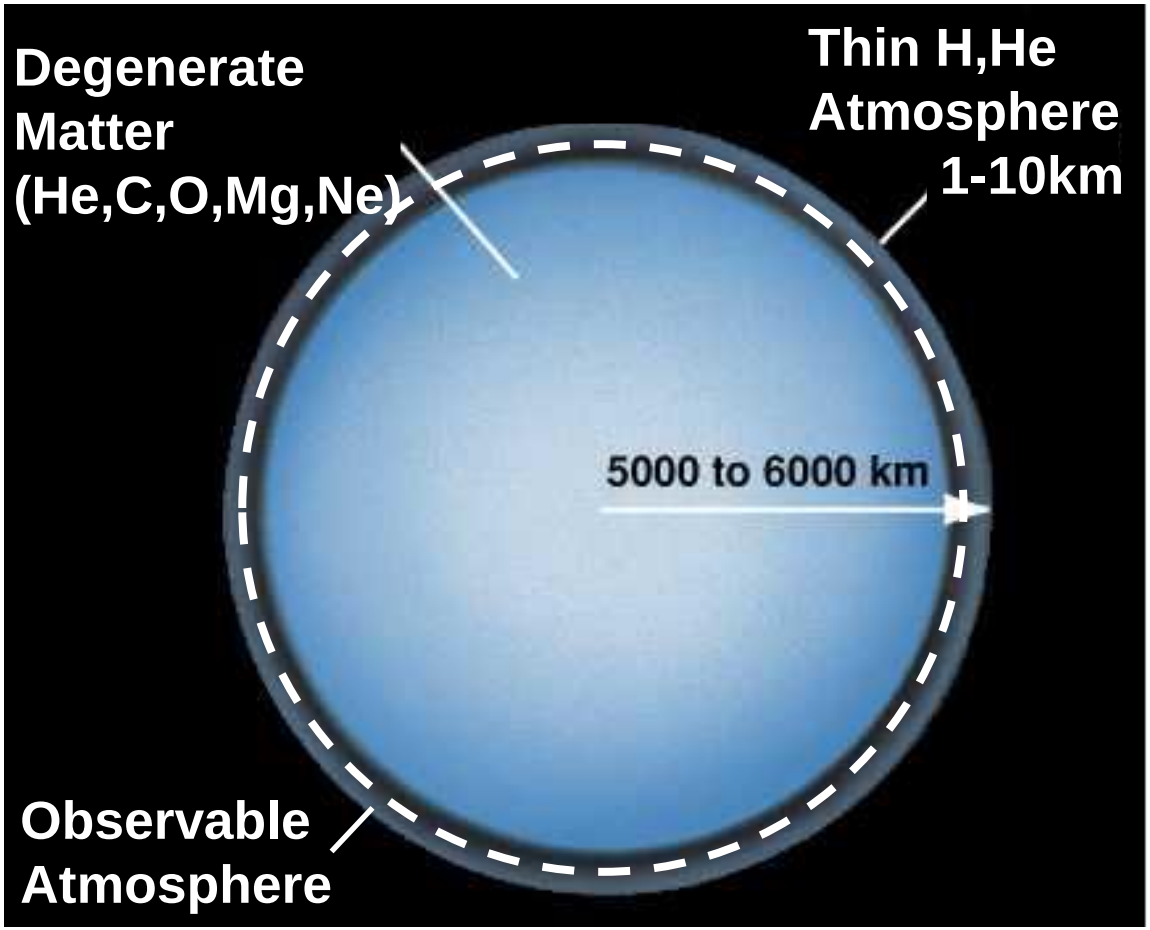

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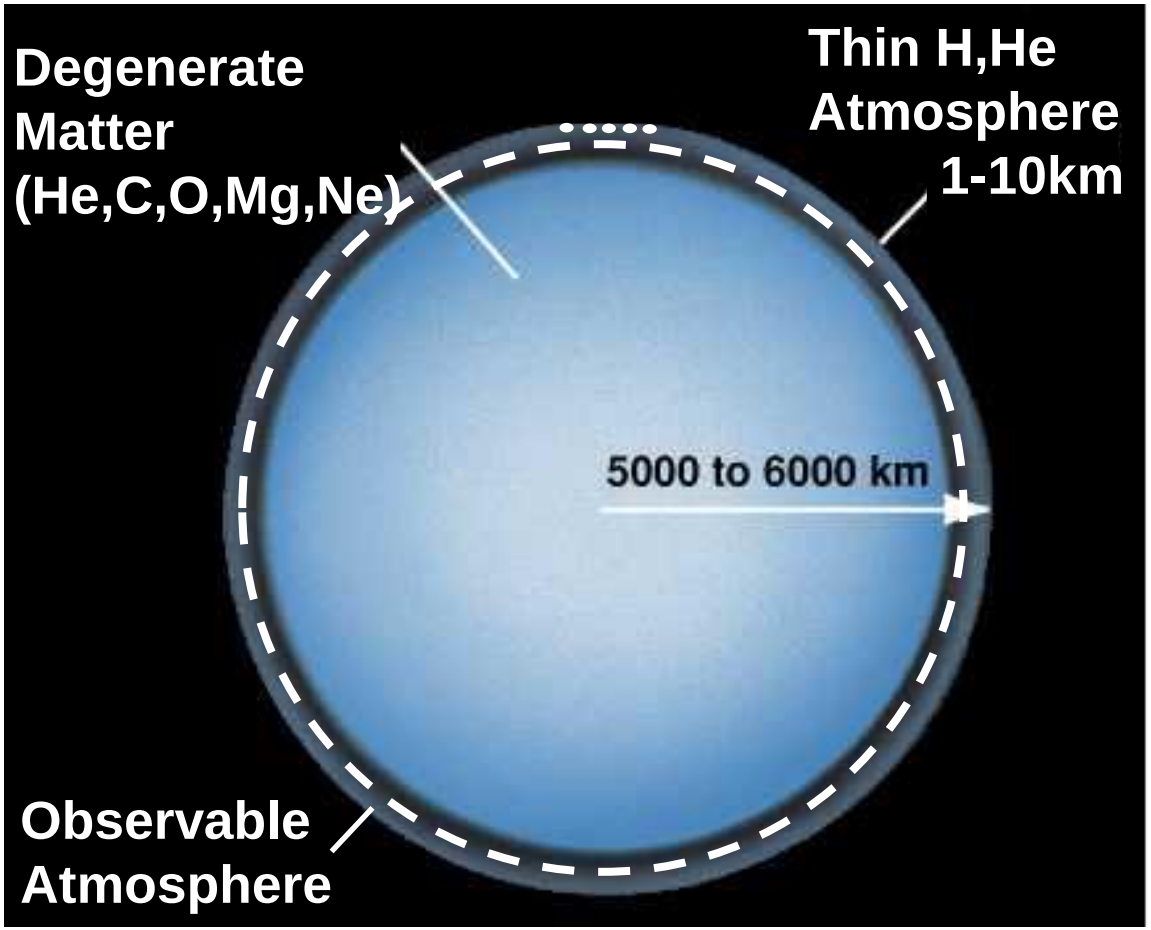

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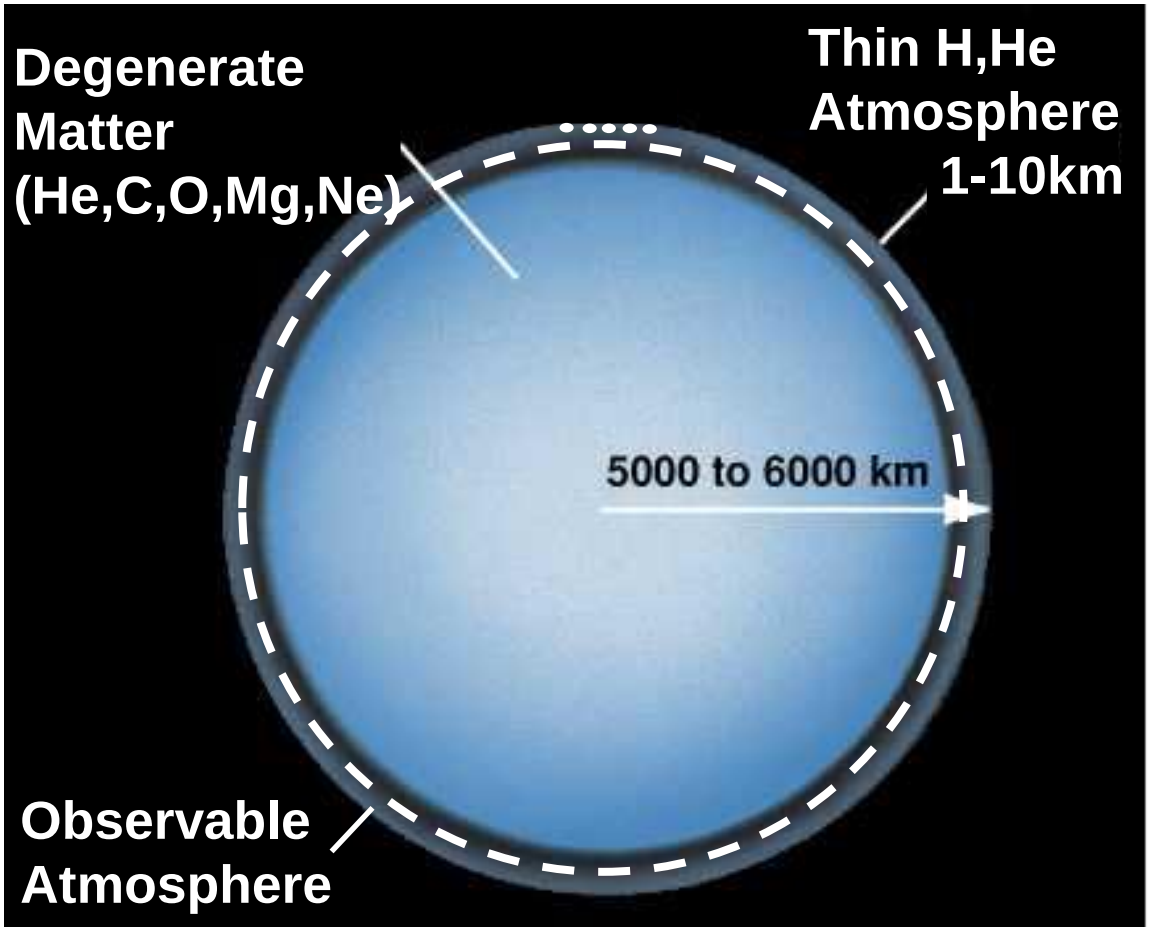
$\rho \sim 10^9\ kg/m^3$



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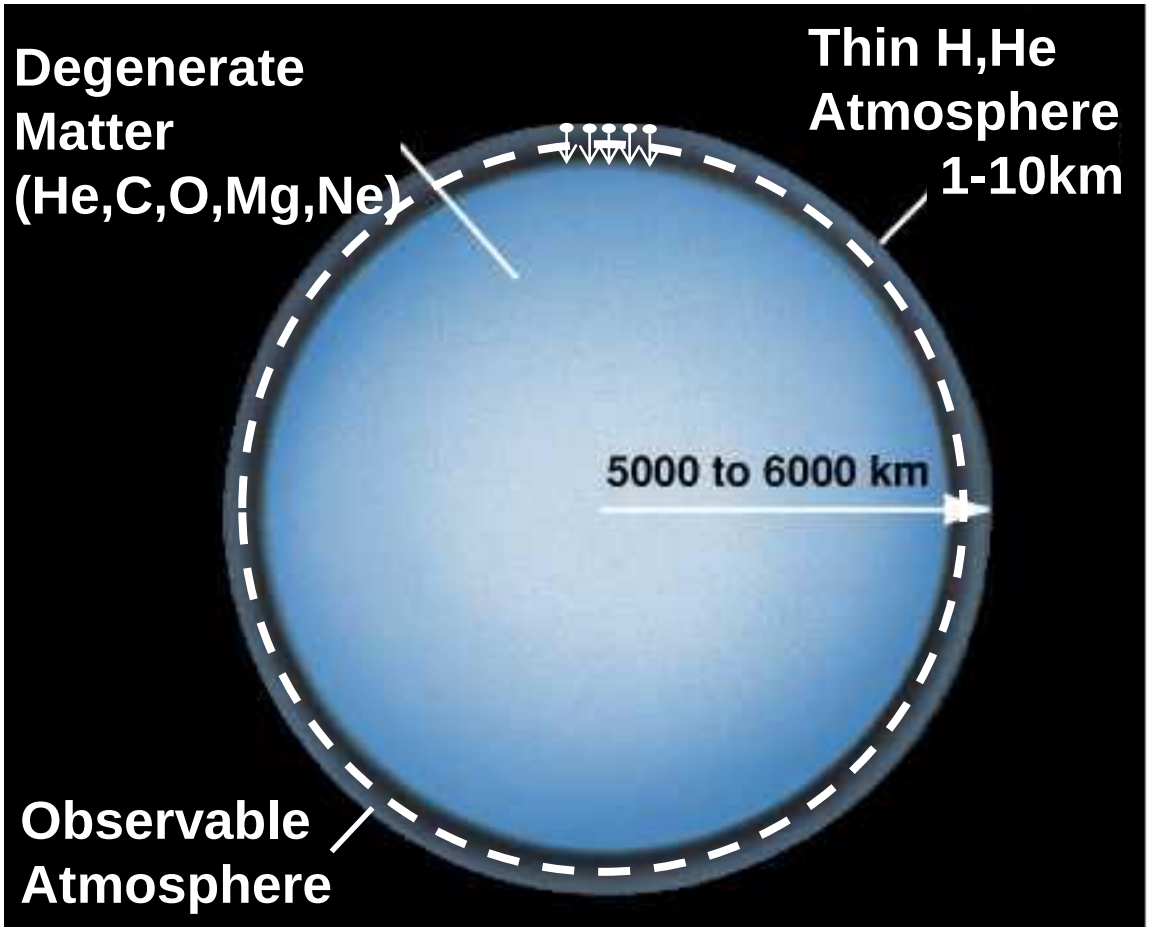

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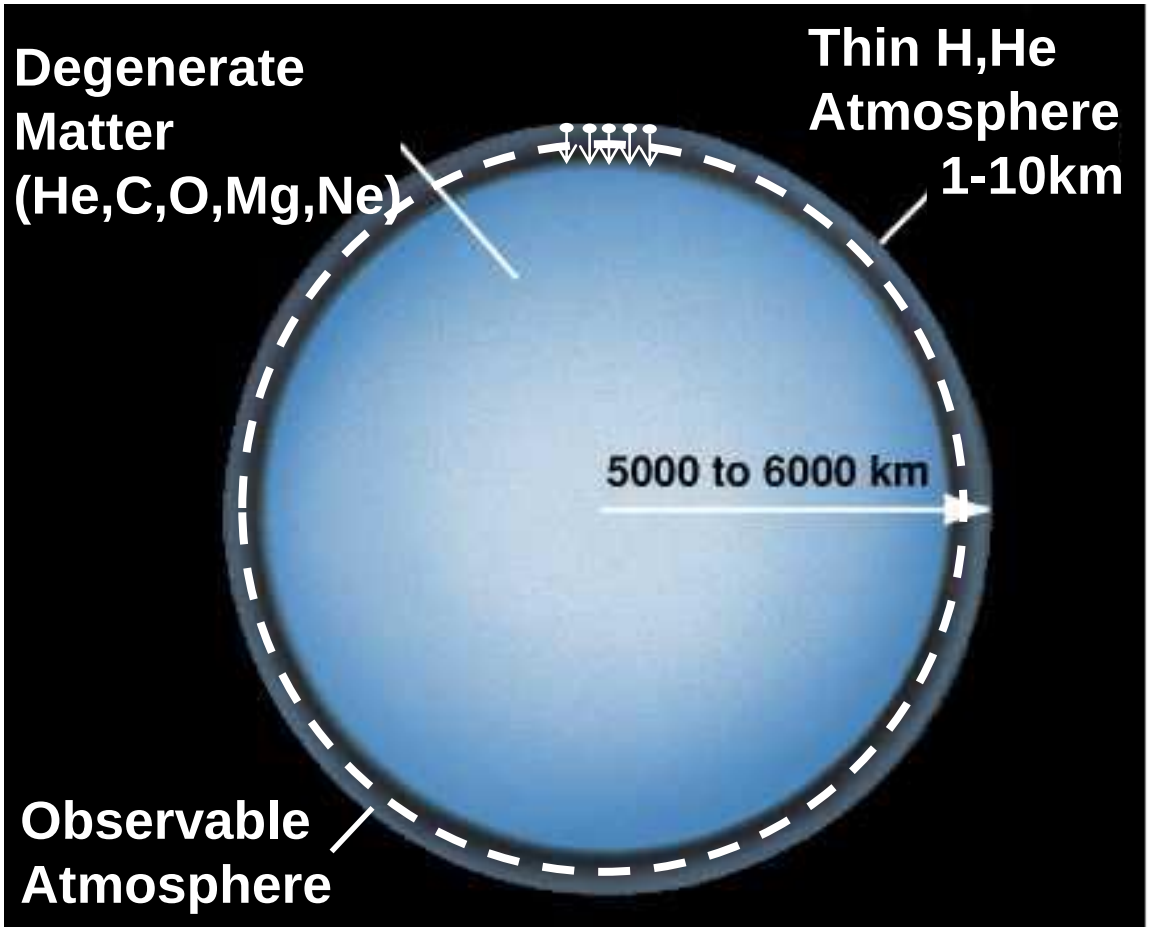

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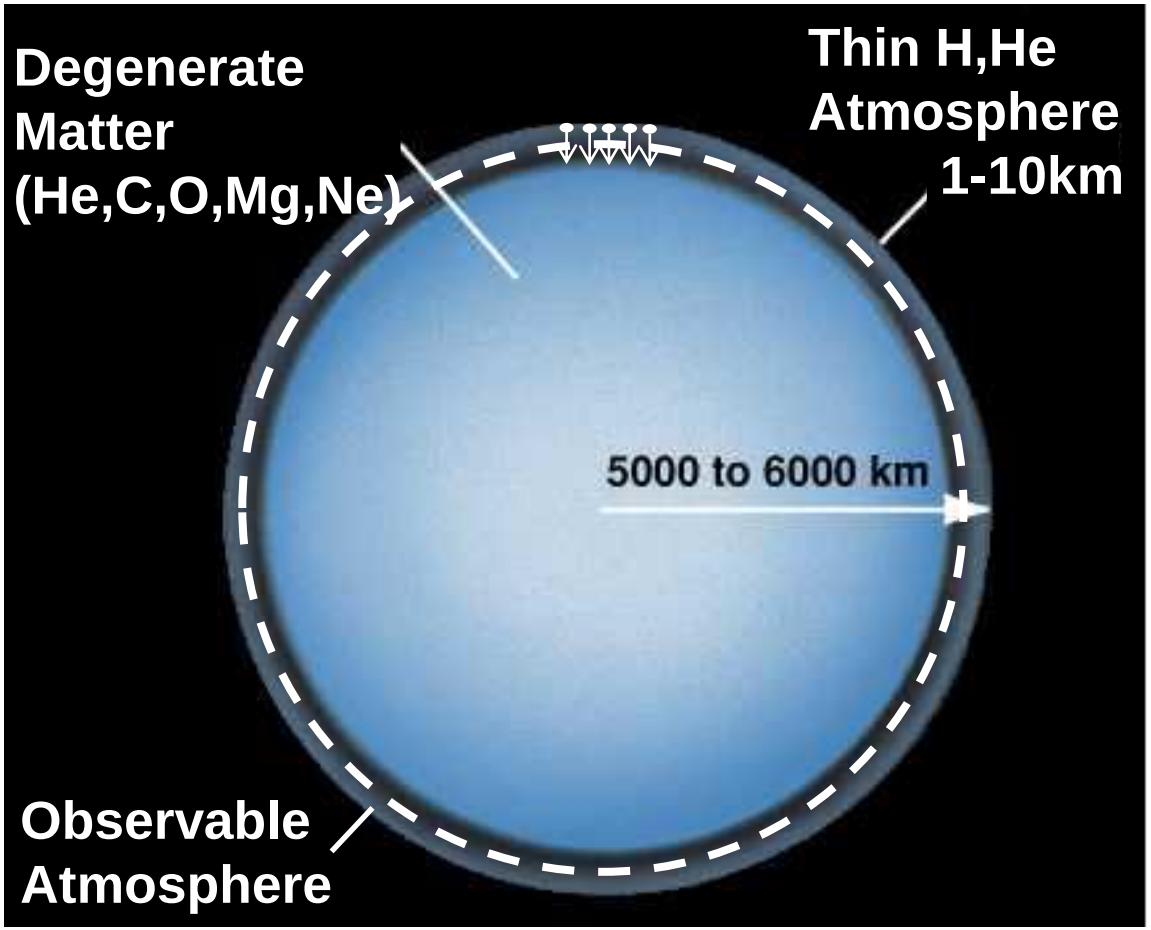
Polluted white dwarfs must have been **contaminated very recently** and most must be **currently accumulating metals** in their atmosphere



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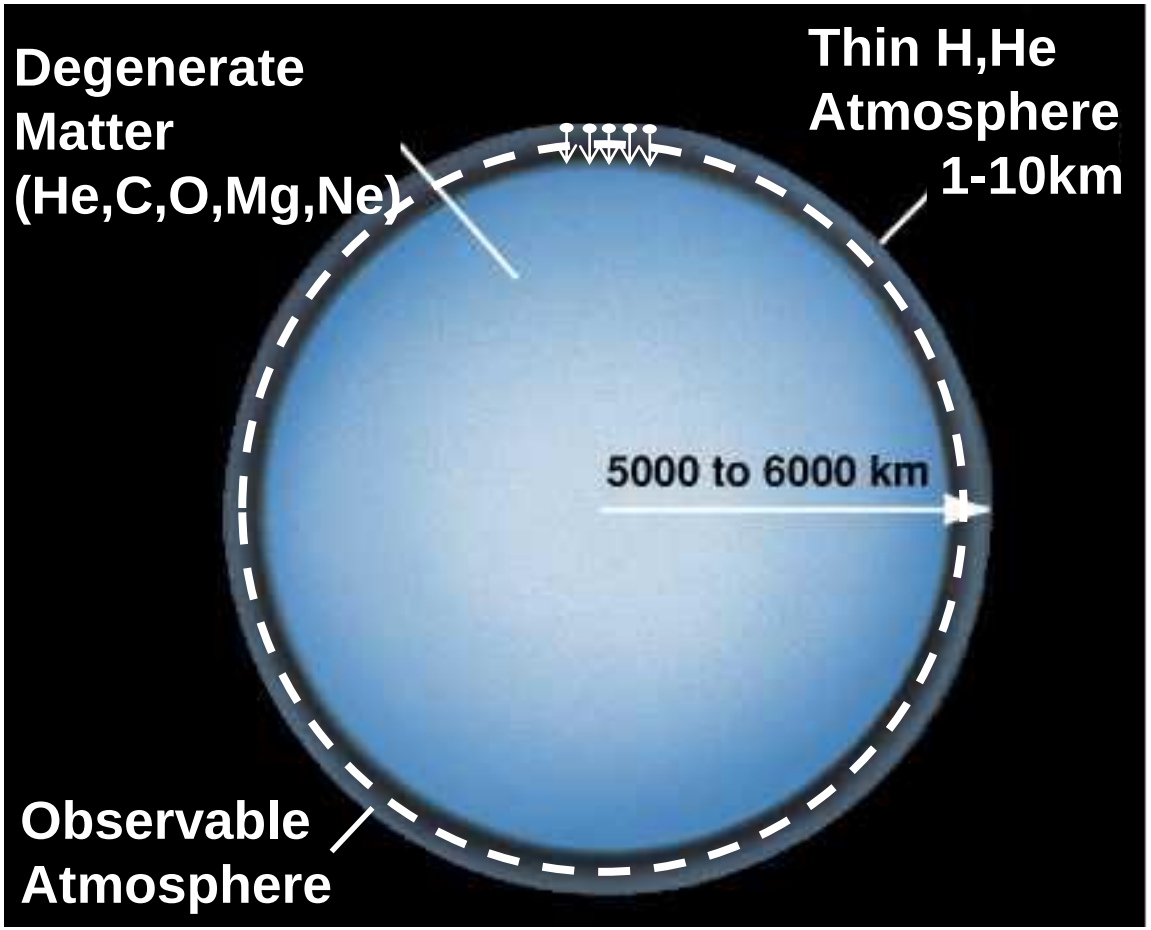

Cool white dwarfs **cannot** be polluted by **recycled primordial metals** nor can they be polluted by the **ISM** (Farihi et al. (2010), Jura & Young (2014))

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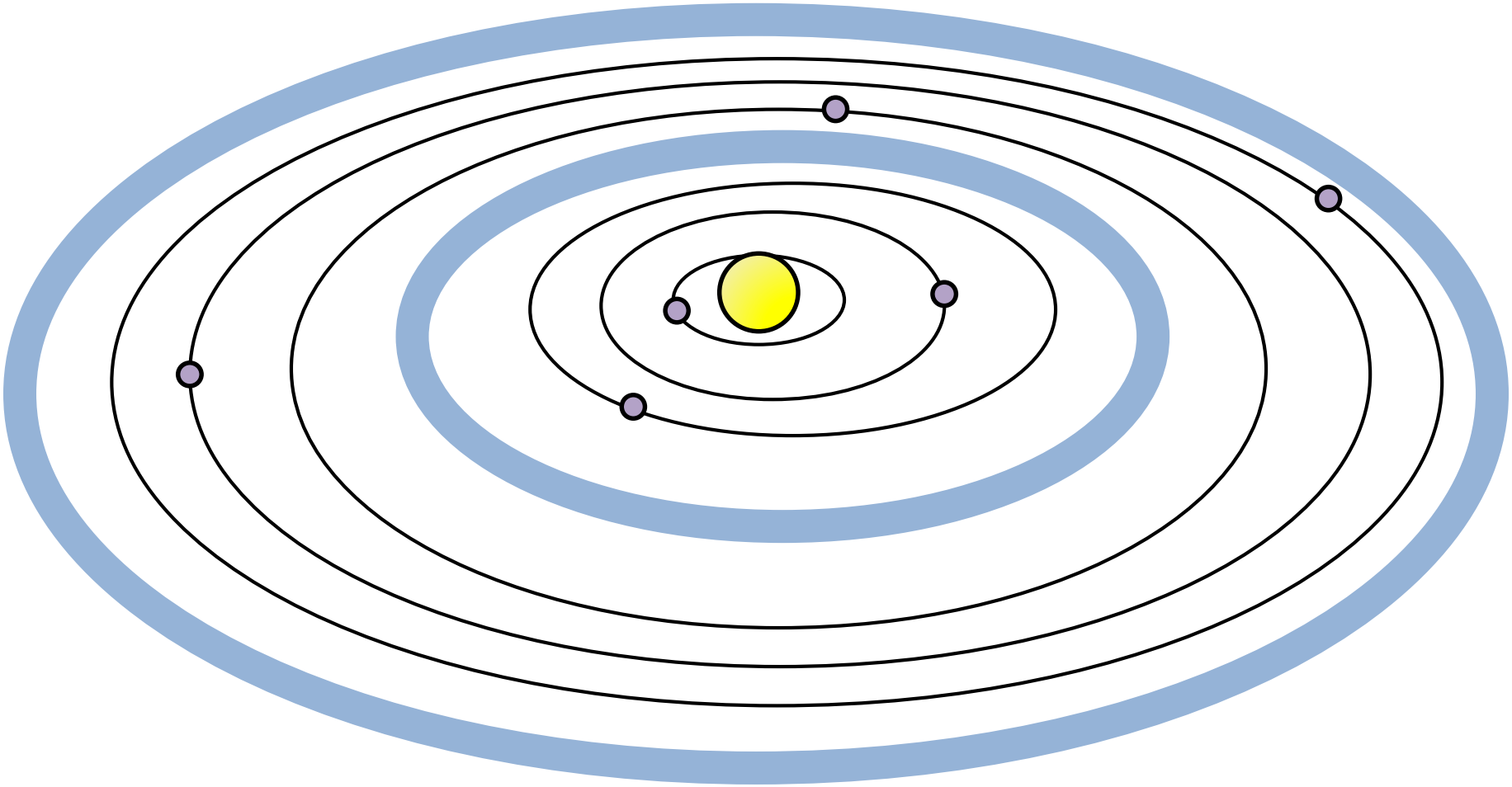
What causes white dwarf pollution?



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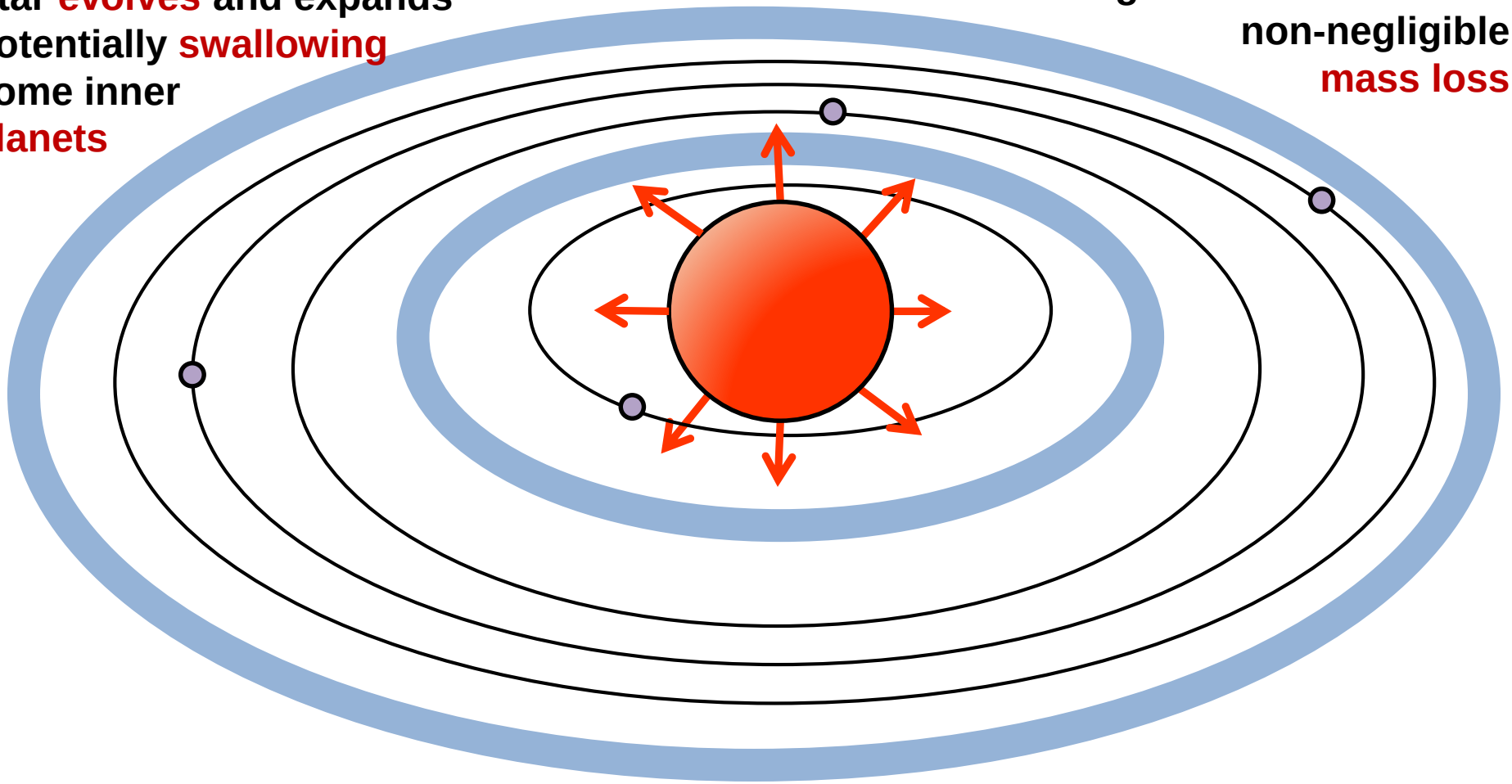
Star **evolves** and expands potentially **swallowing** some inner **planets**

Strong **stellar winds** cause non-negligible **mass loss**



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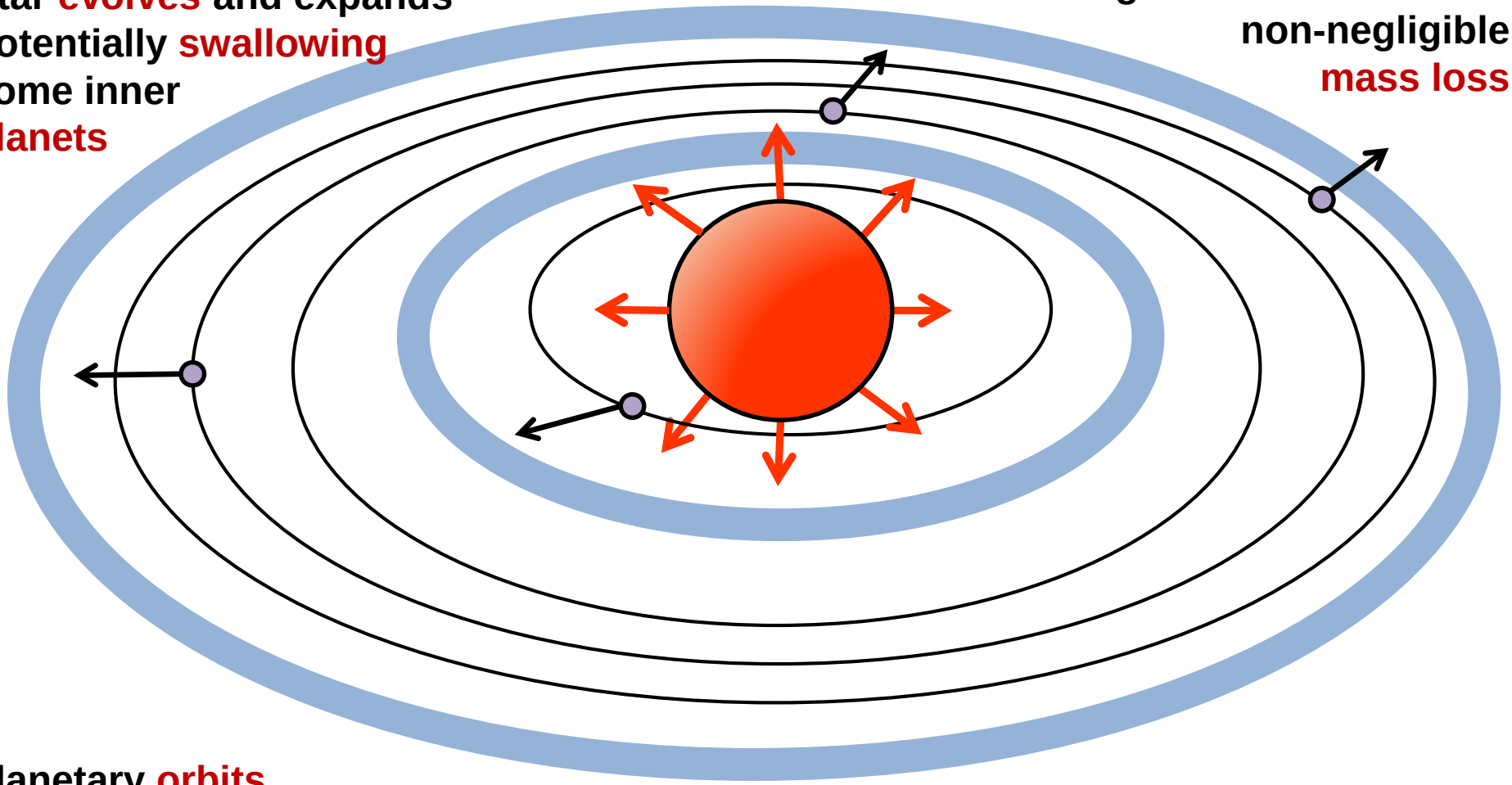

Planetary **orbits** **migrate** outwards

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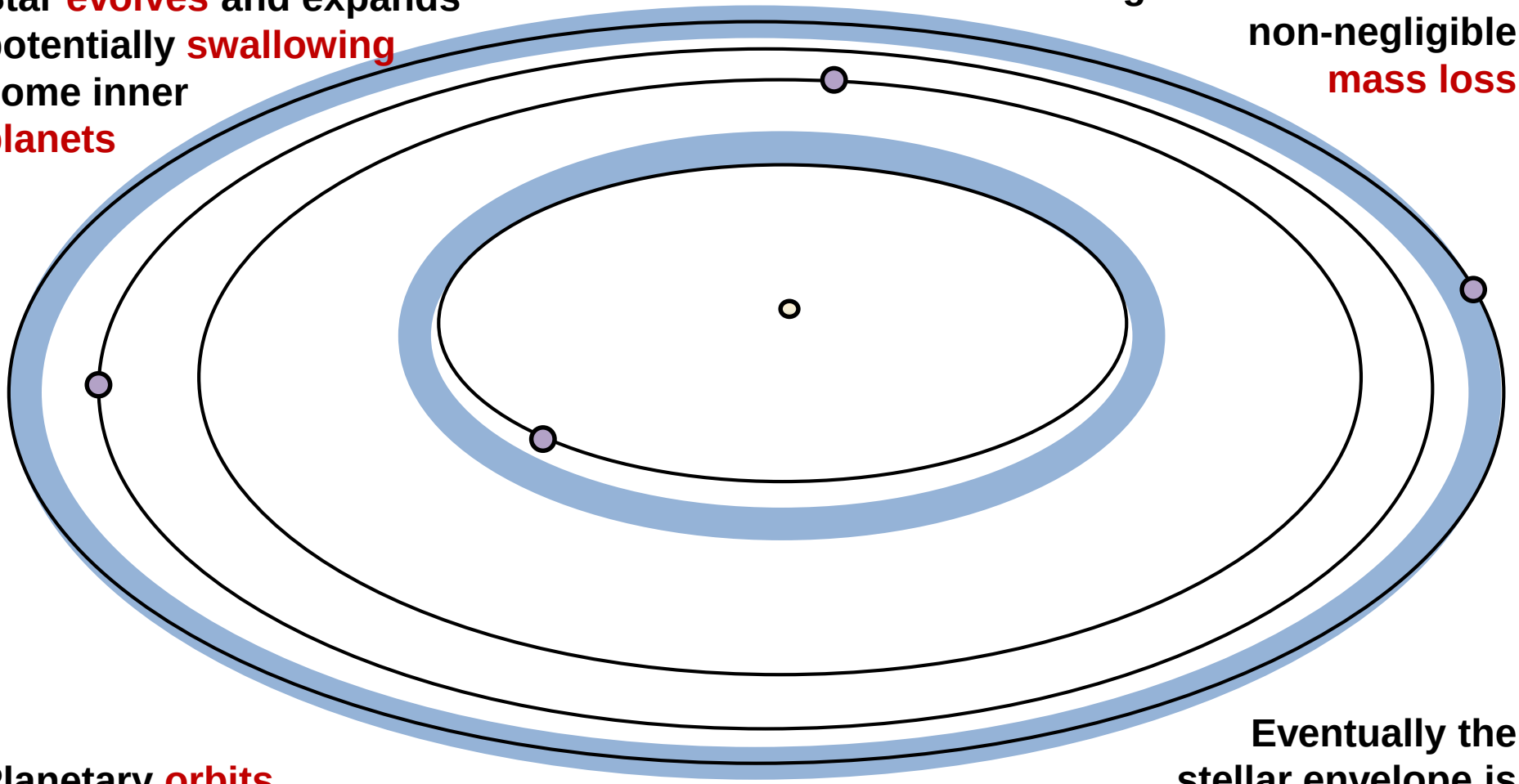

Planetary orbits migrate outwards

Eventually the stellar envelope is ejected and a white dwarf is produced

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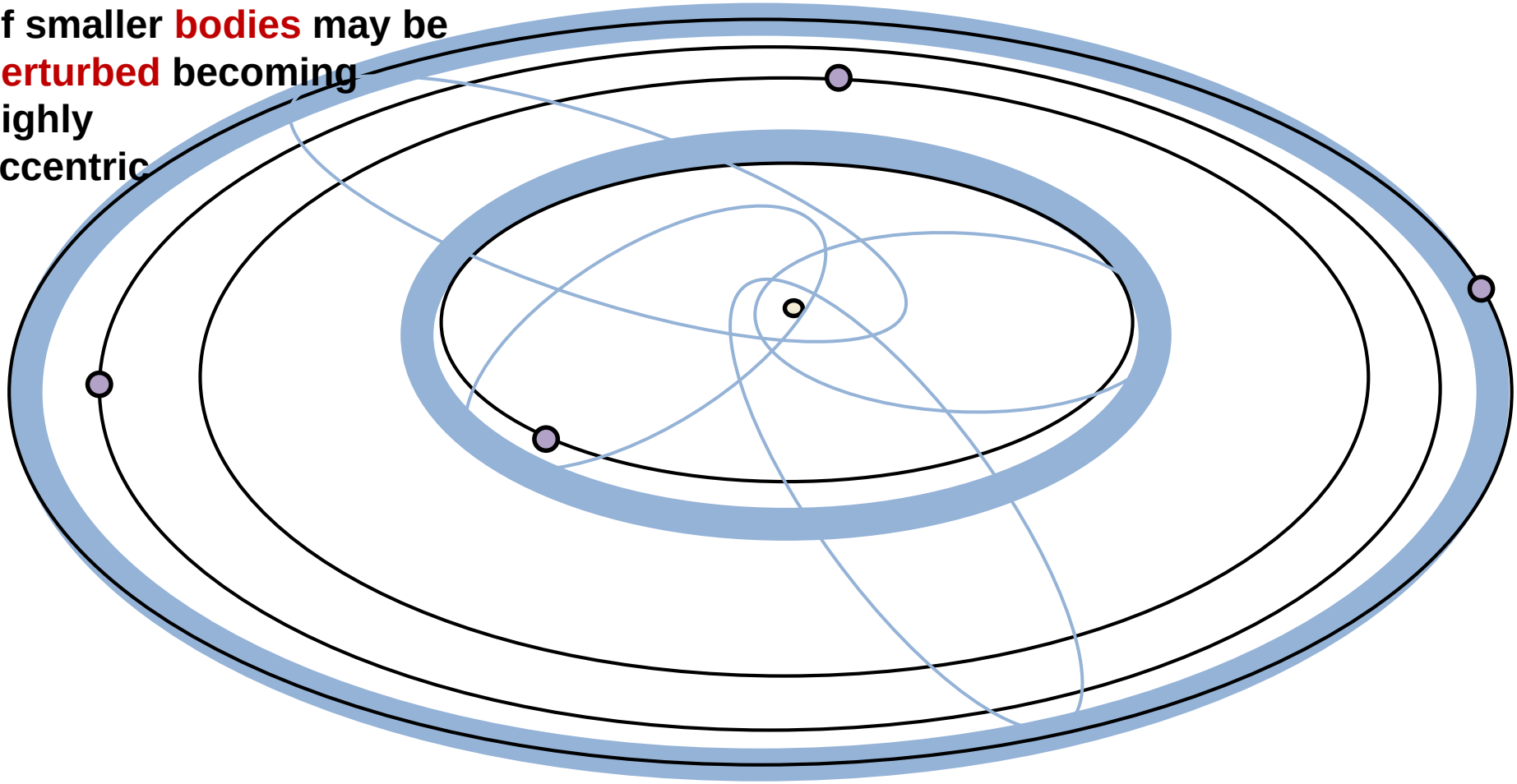
What causes white dwarf pollution?

During migration the orbits of smaller bodies may be perturbed becoming highly eccentric



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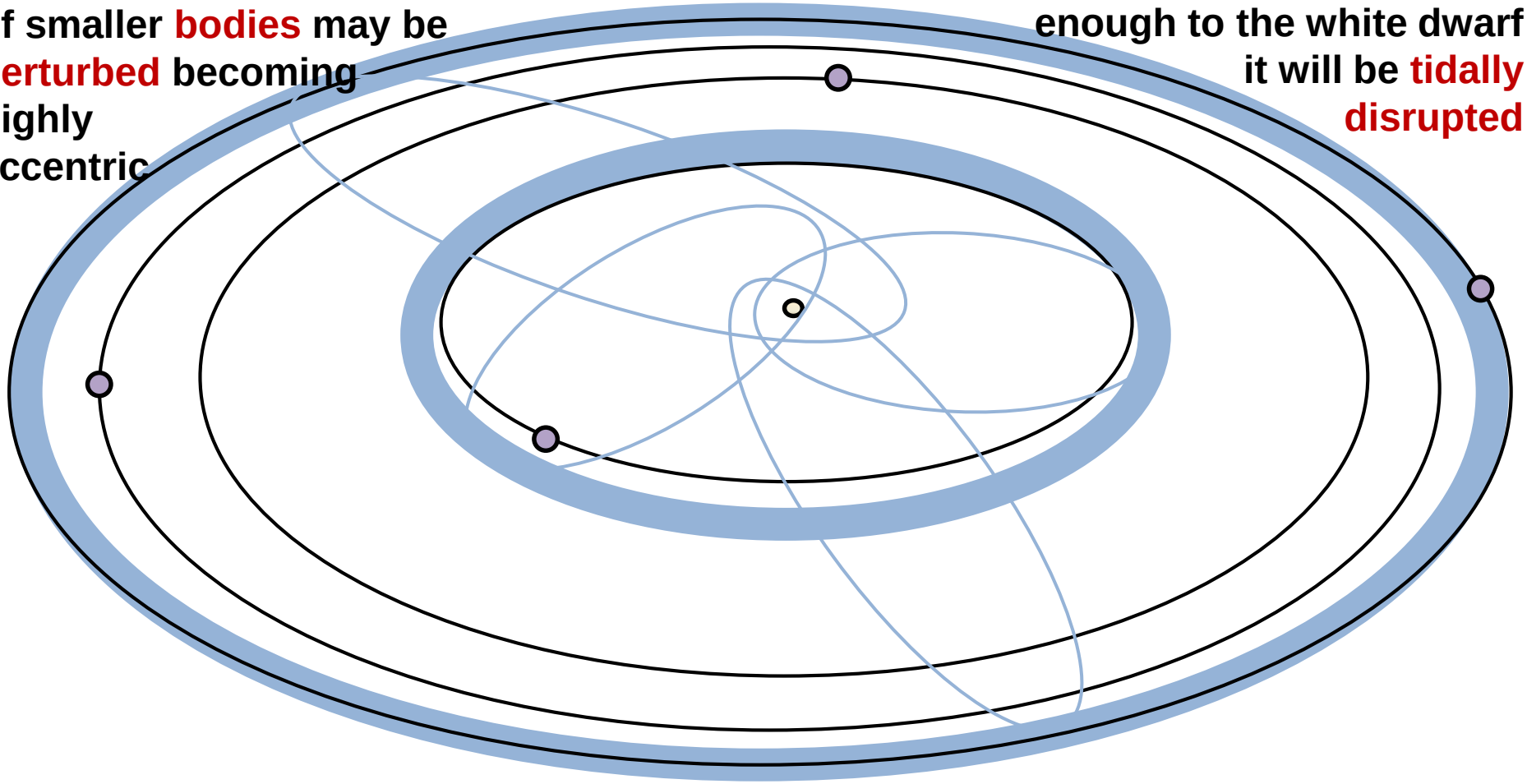
If a body is scattered close enough to the white dwarf it will be tidally disrupted



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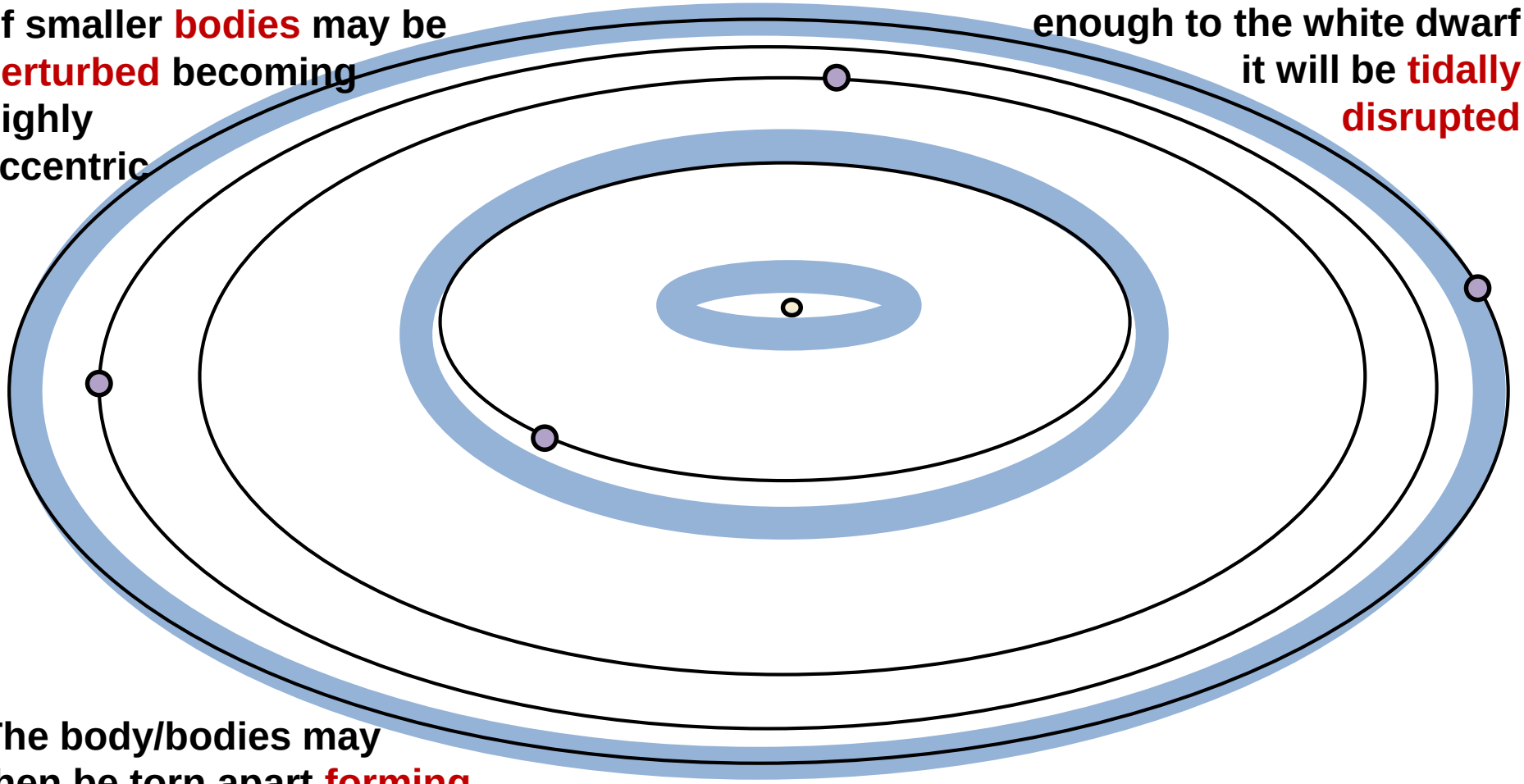

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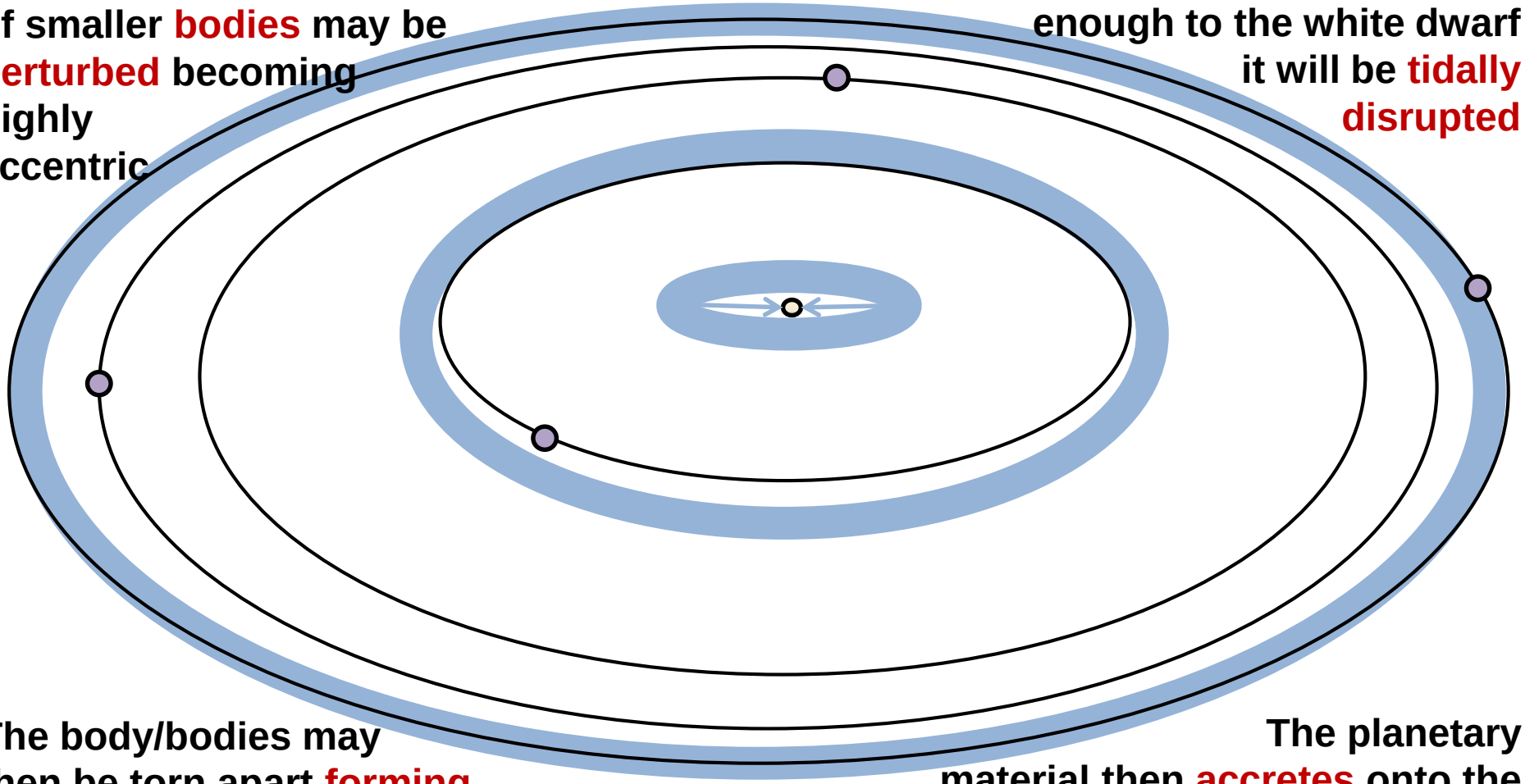

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The planetary material then accretes onto the white dwarf producing the polluted spectra

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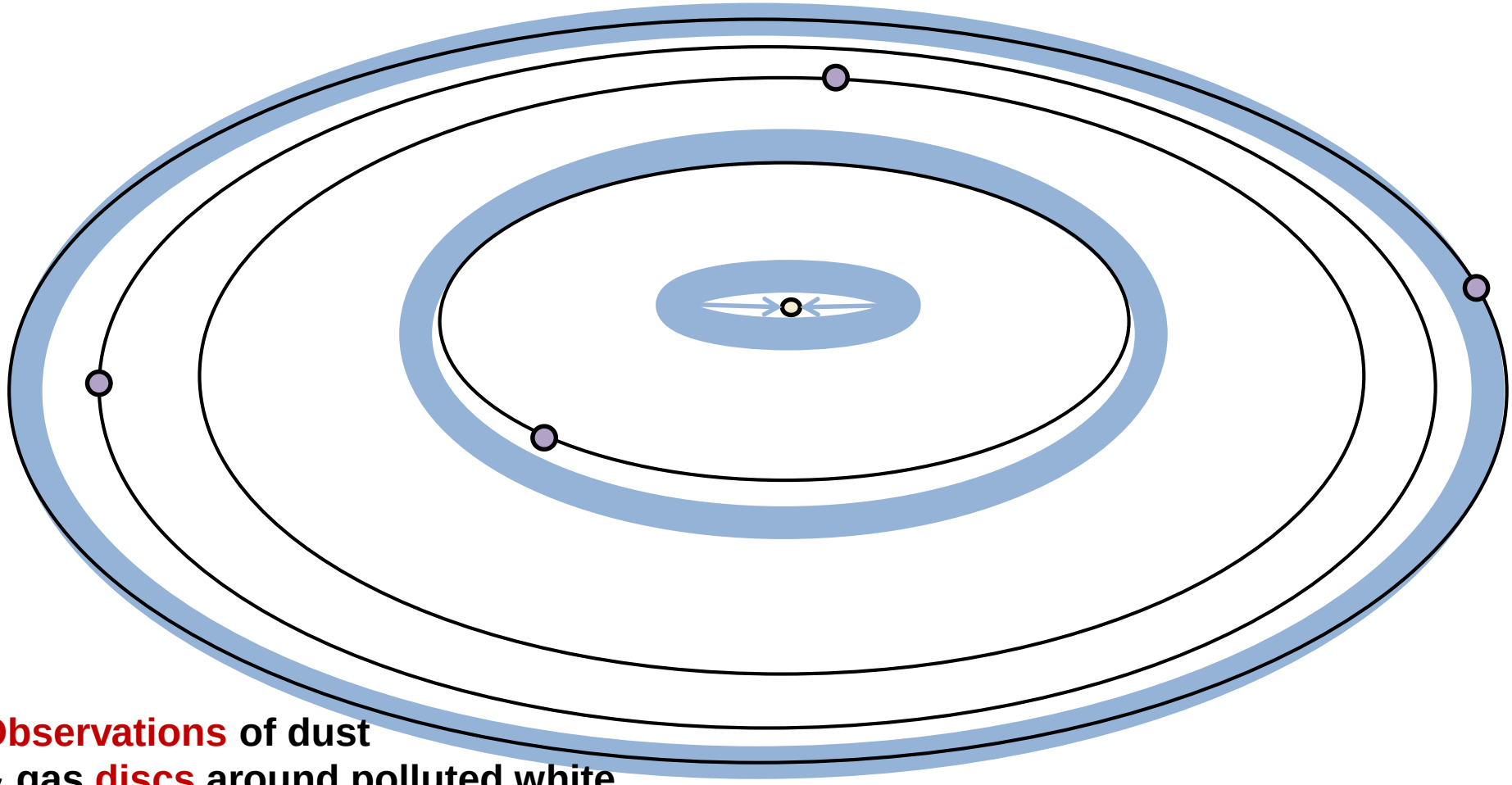

Observations of dust
& gas **discs** around polluted white
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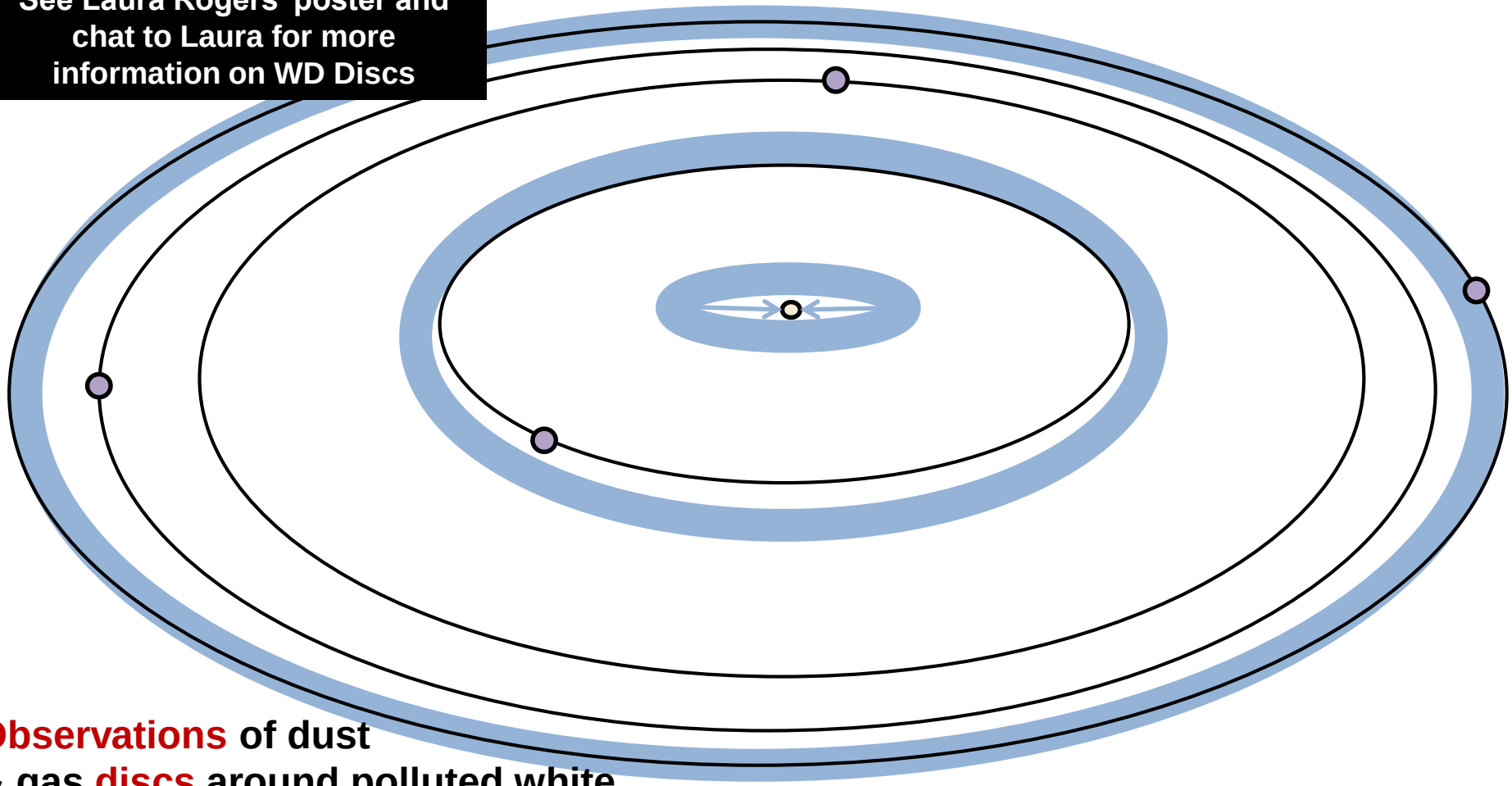
What causes white dwarf pollution?

See Laura Rogers' poster and chat to Laura for more information on WD Discs



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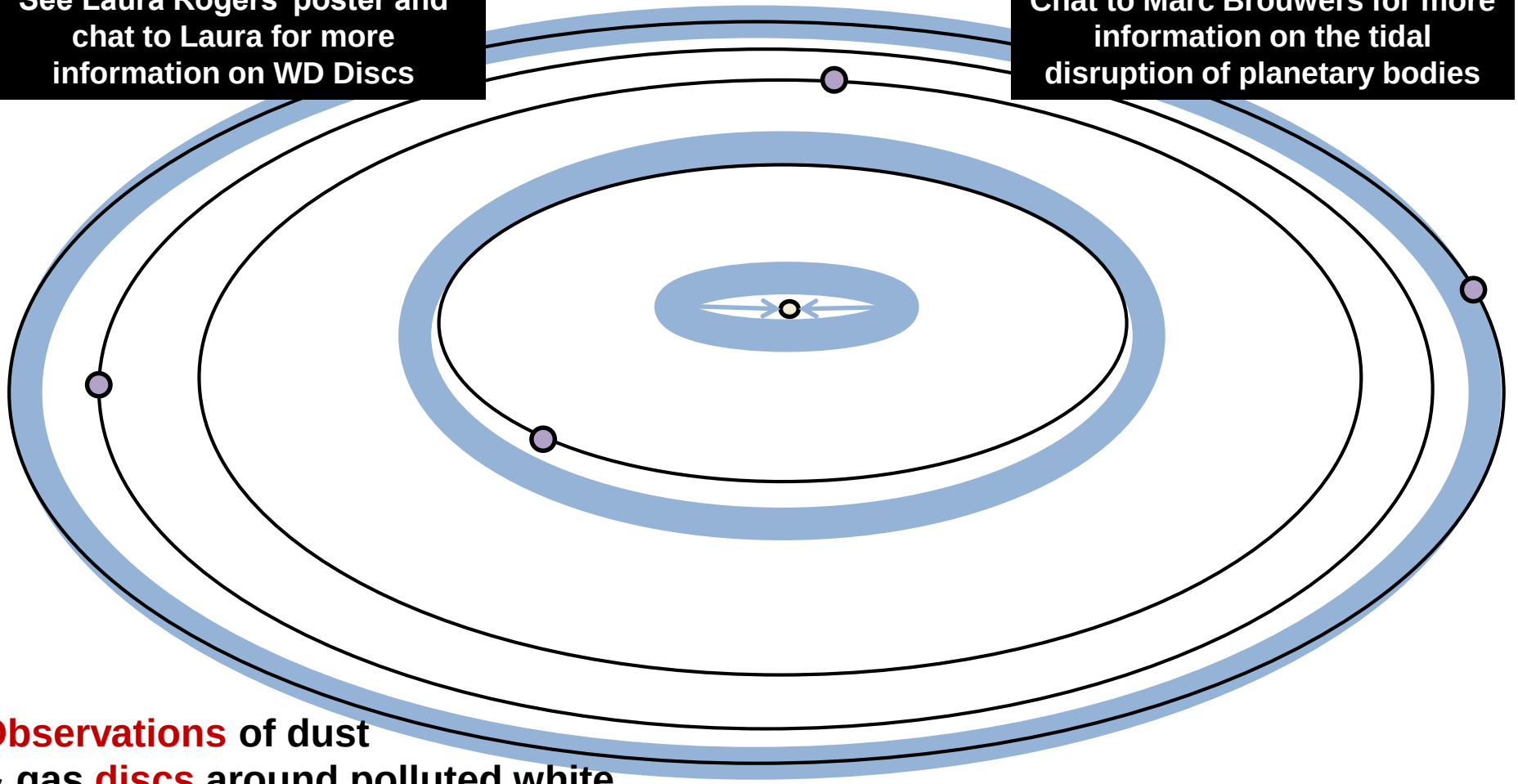
Chat to Marc Brouwers for more information on the tidal disruption of planetary bodies



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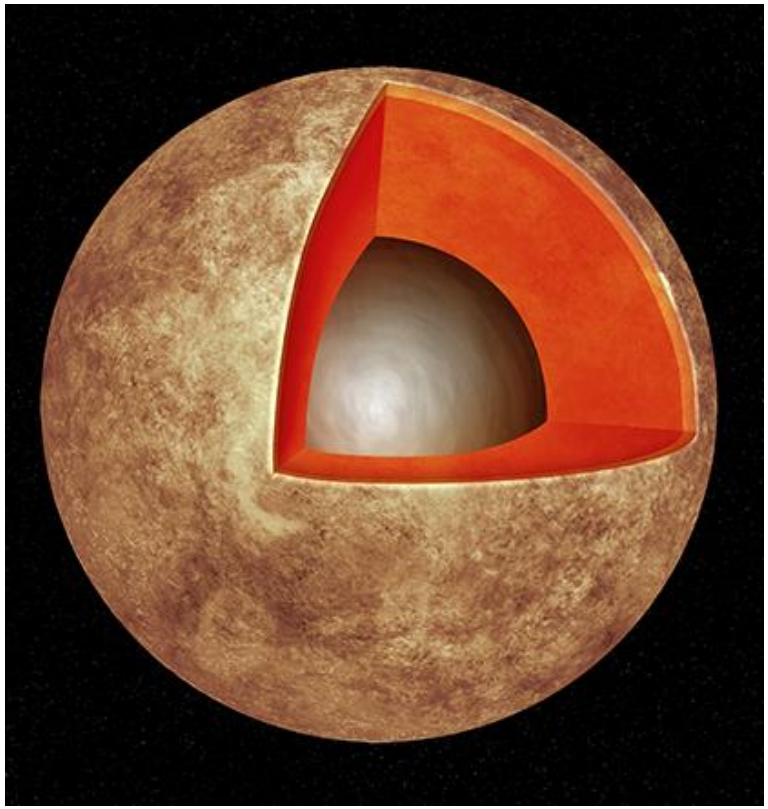

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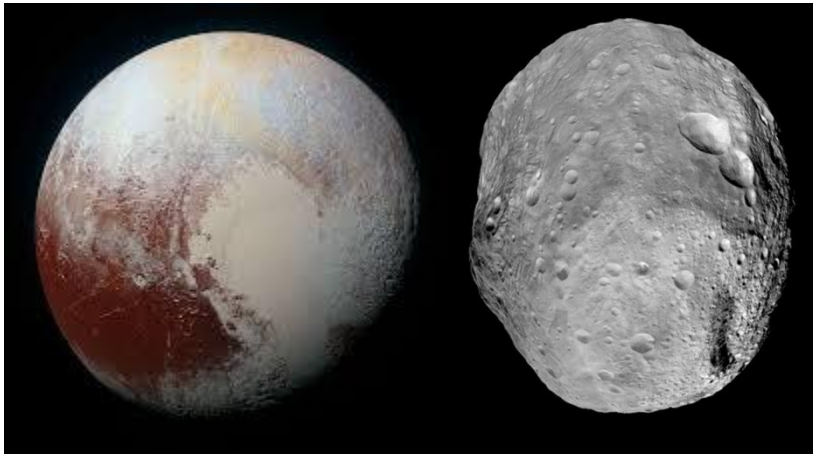

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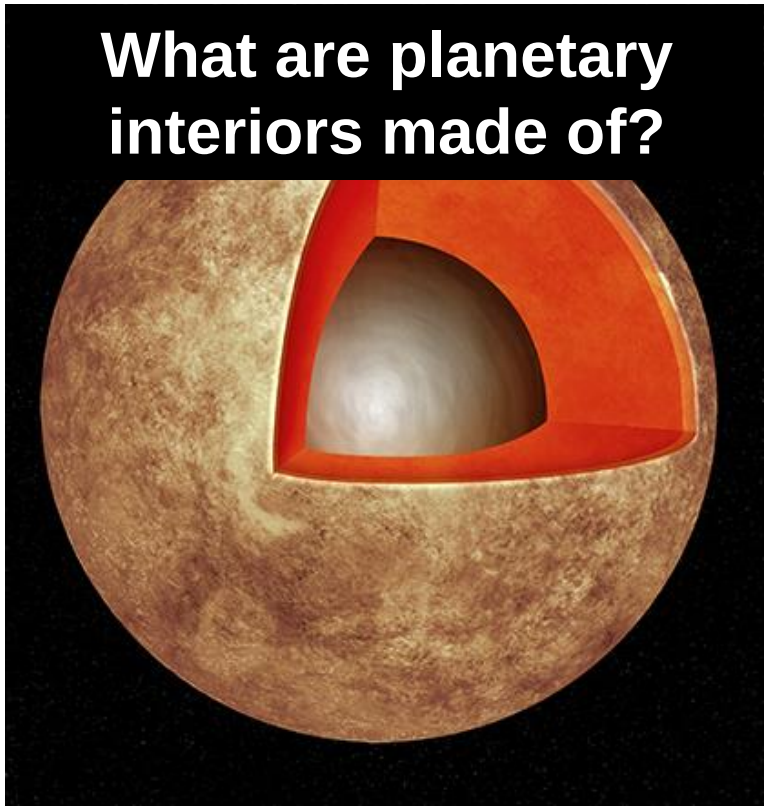

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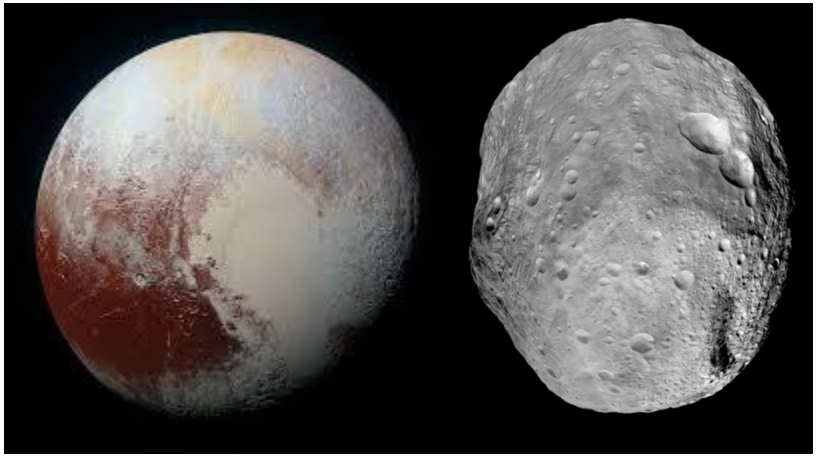

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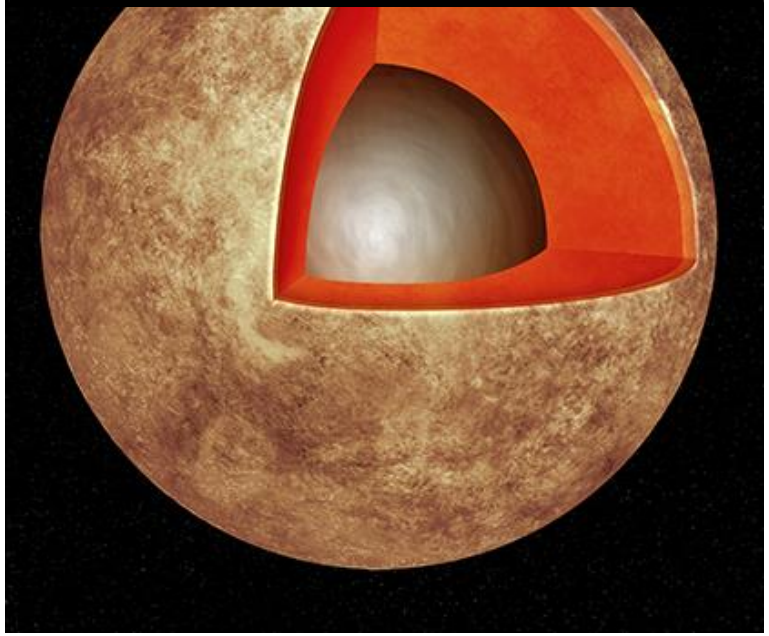

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To what extent does differentiation and collisional processing occur in exo-systems?

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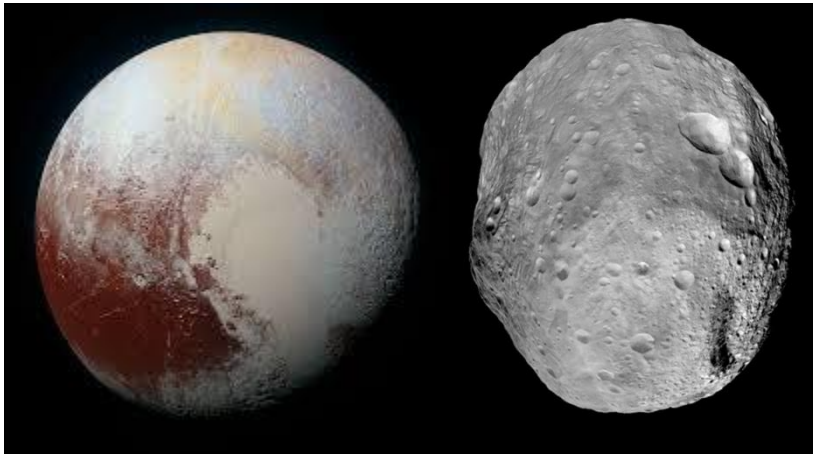

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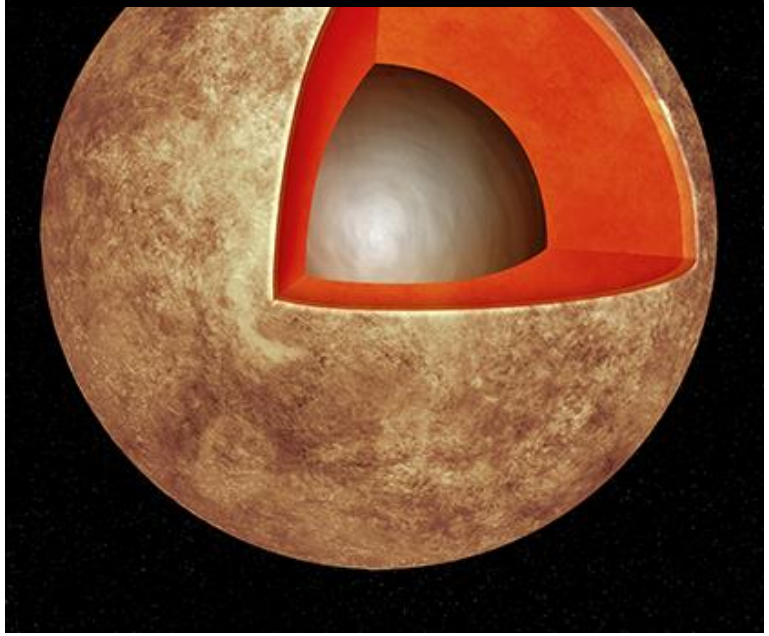

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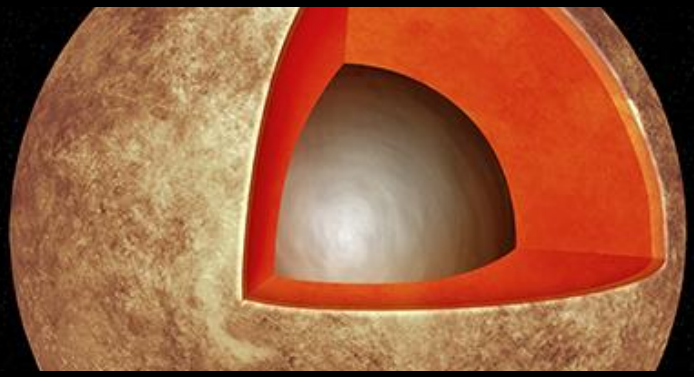

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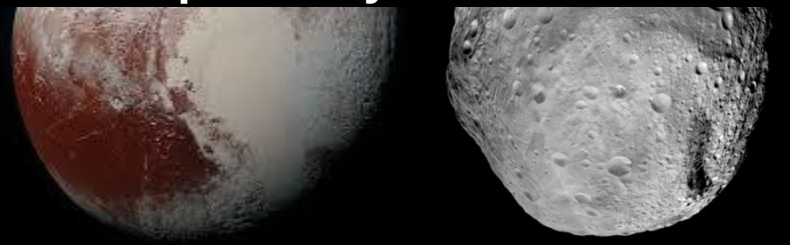

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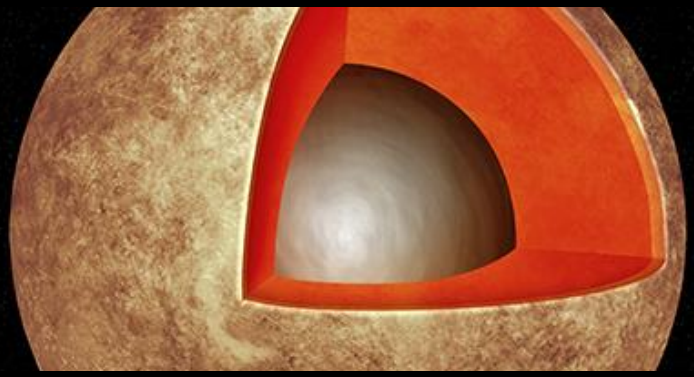

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Pollutant compositions provide signatures of these processes

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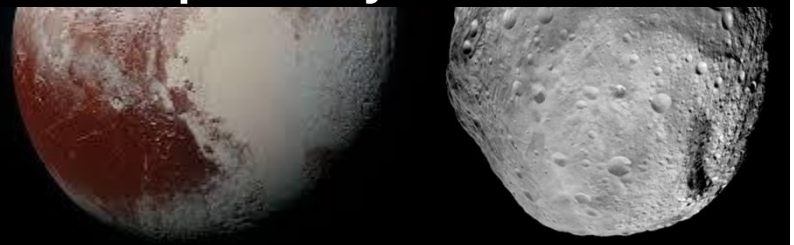

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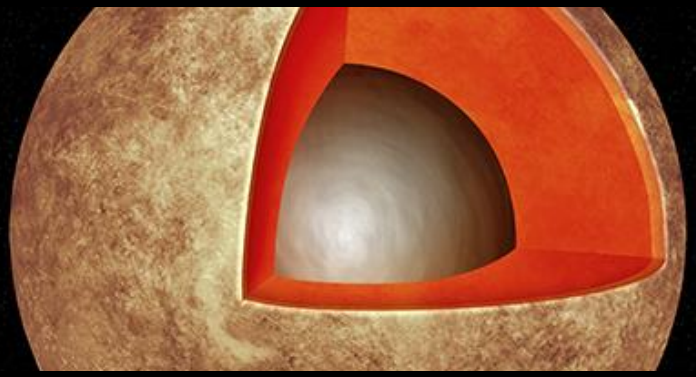

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Pollutant compositions can probe condensation vs volatilisation

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Our Research

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Fitted the atmospheric abundances of 238 polluted white dwarfs using a model where pollutants are planetesimals whose composition is determined by 3 factors:

- **Initial composition of the protoplanetary disc**
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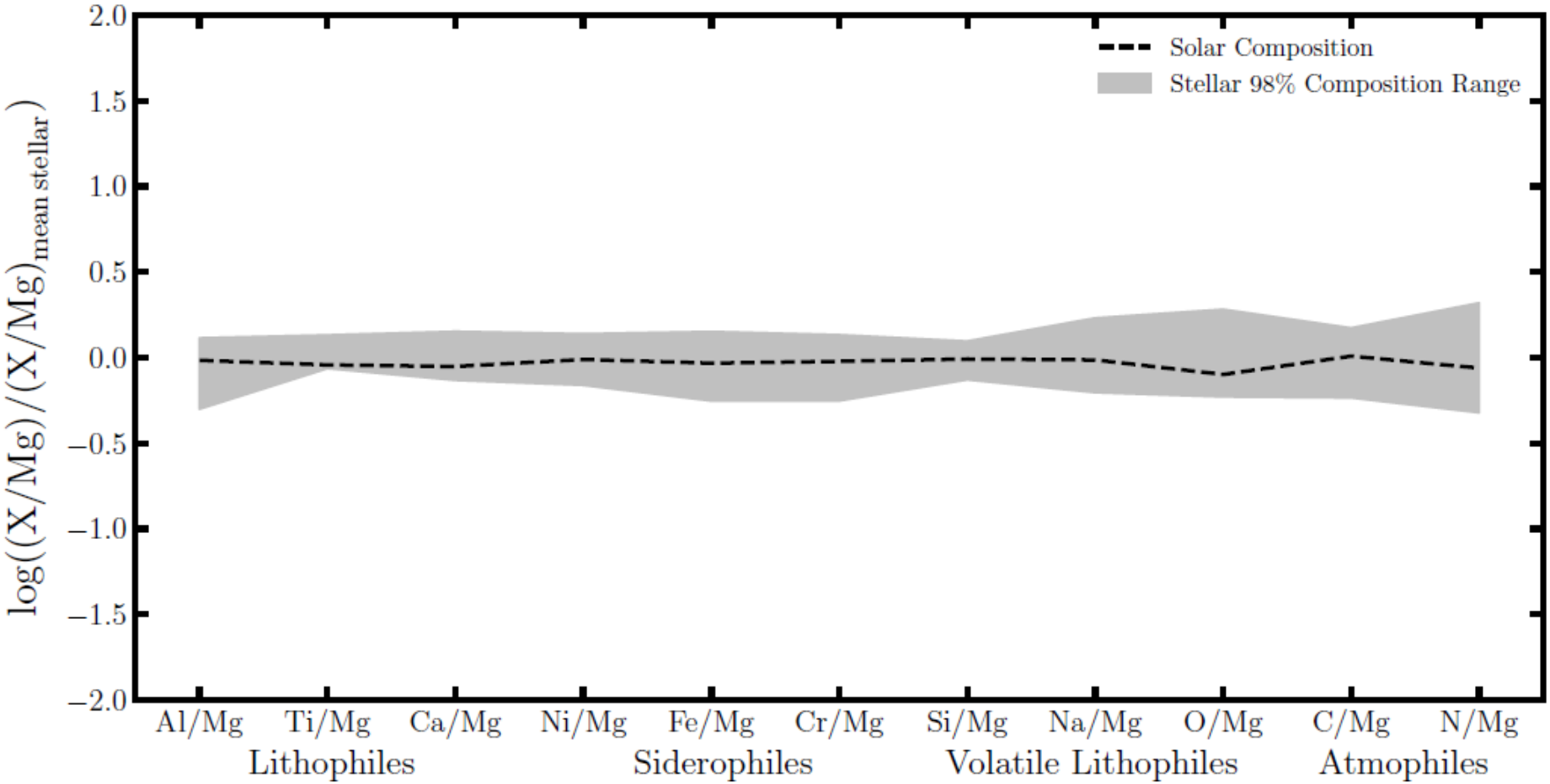
To constrain the model parameters & find the statistical significance for the inclusion of certain parameters we use the Bayesian inference algorithm PyMultiNest

Constraining the origin of the pollutant material



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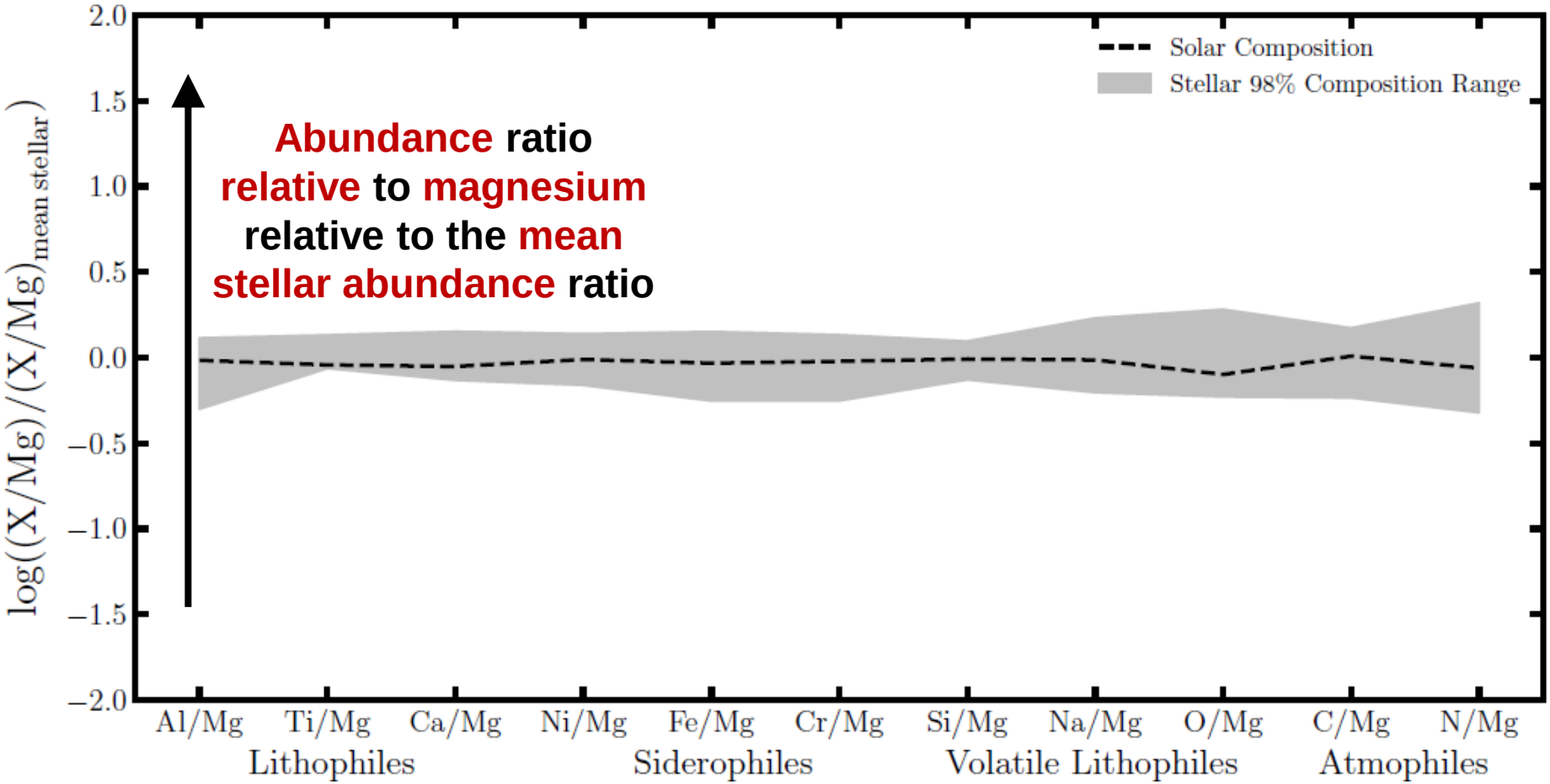

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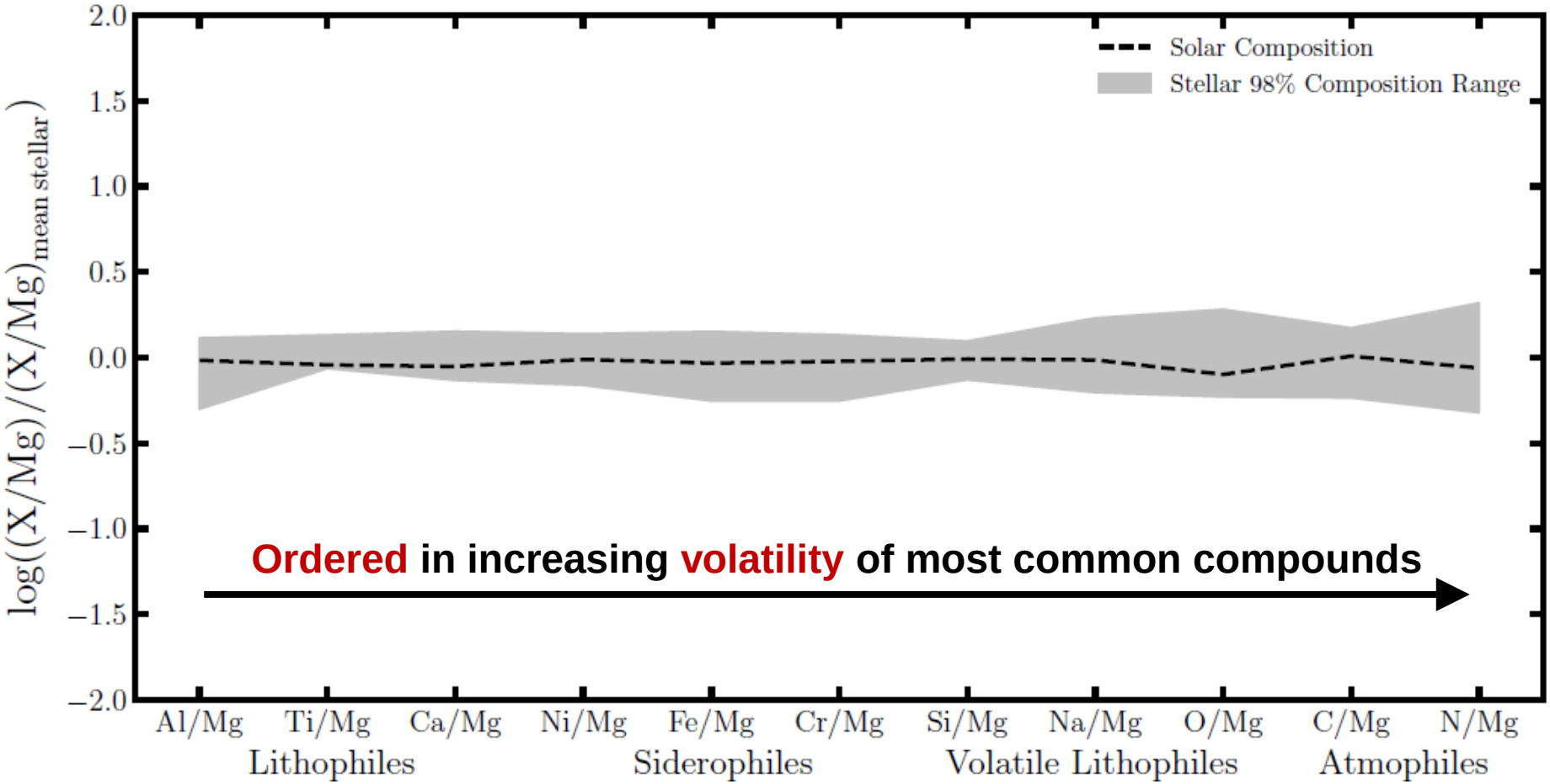

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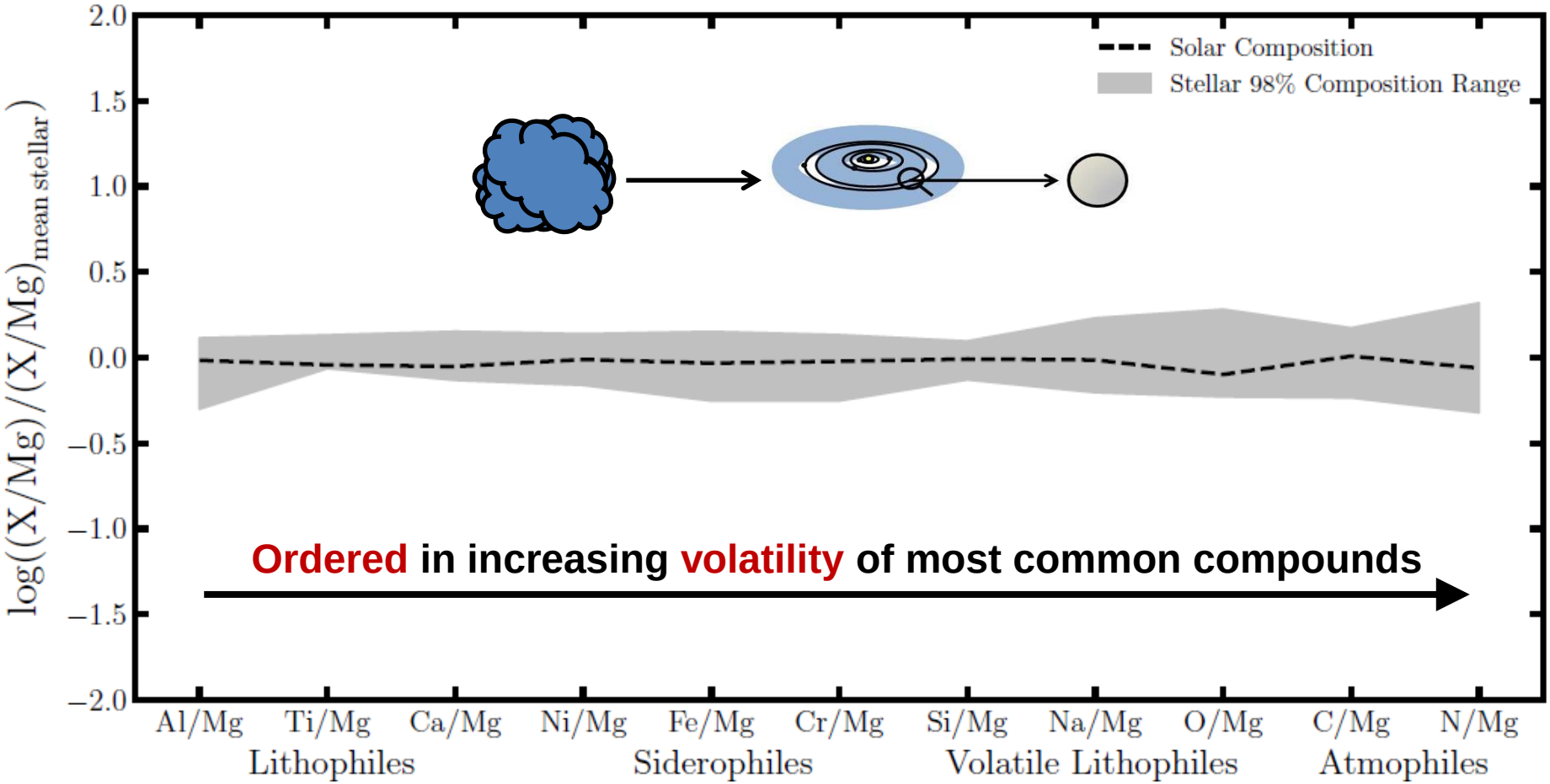

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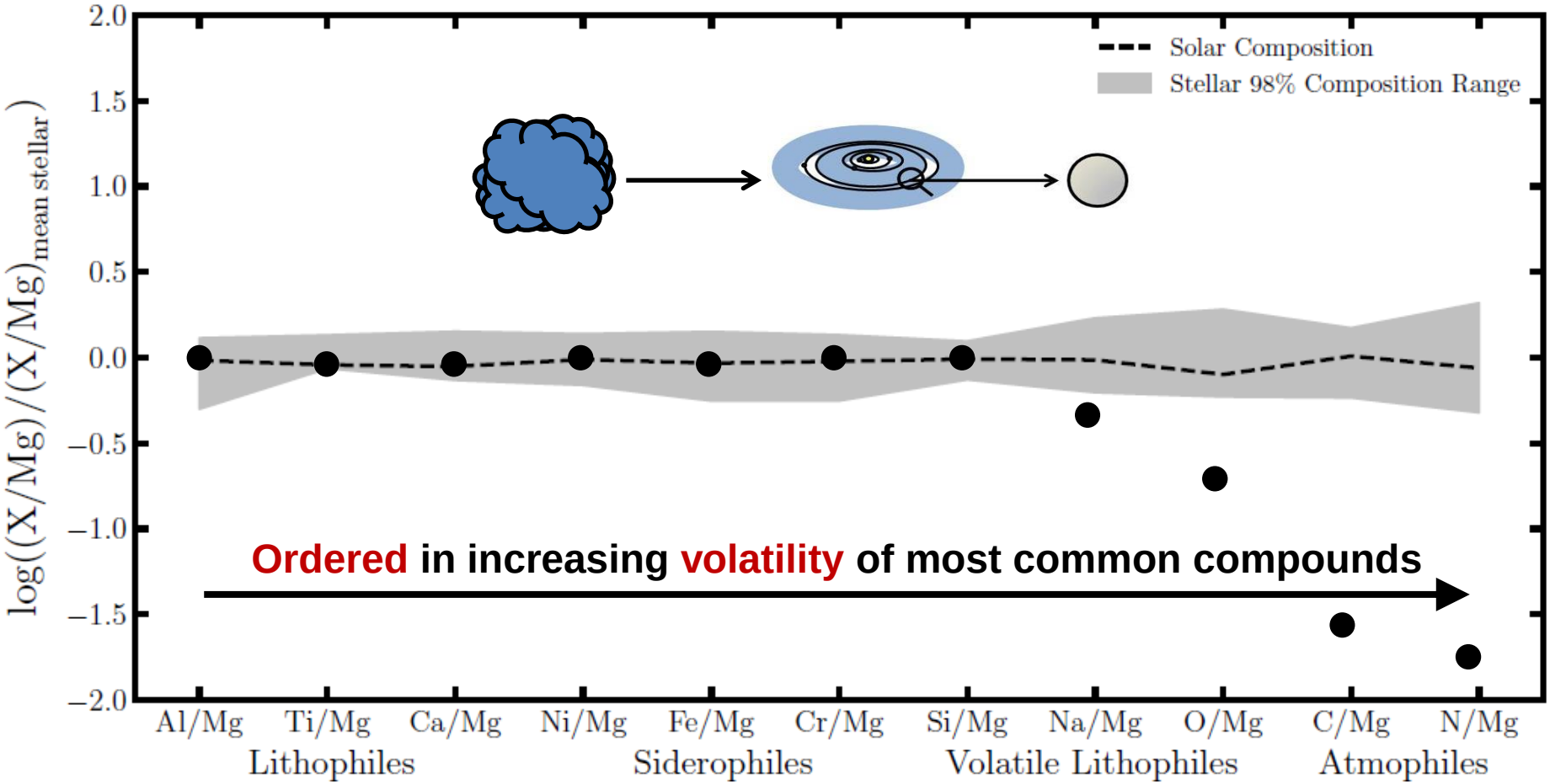

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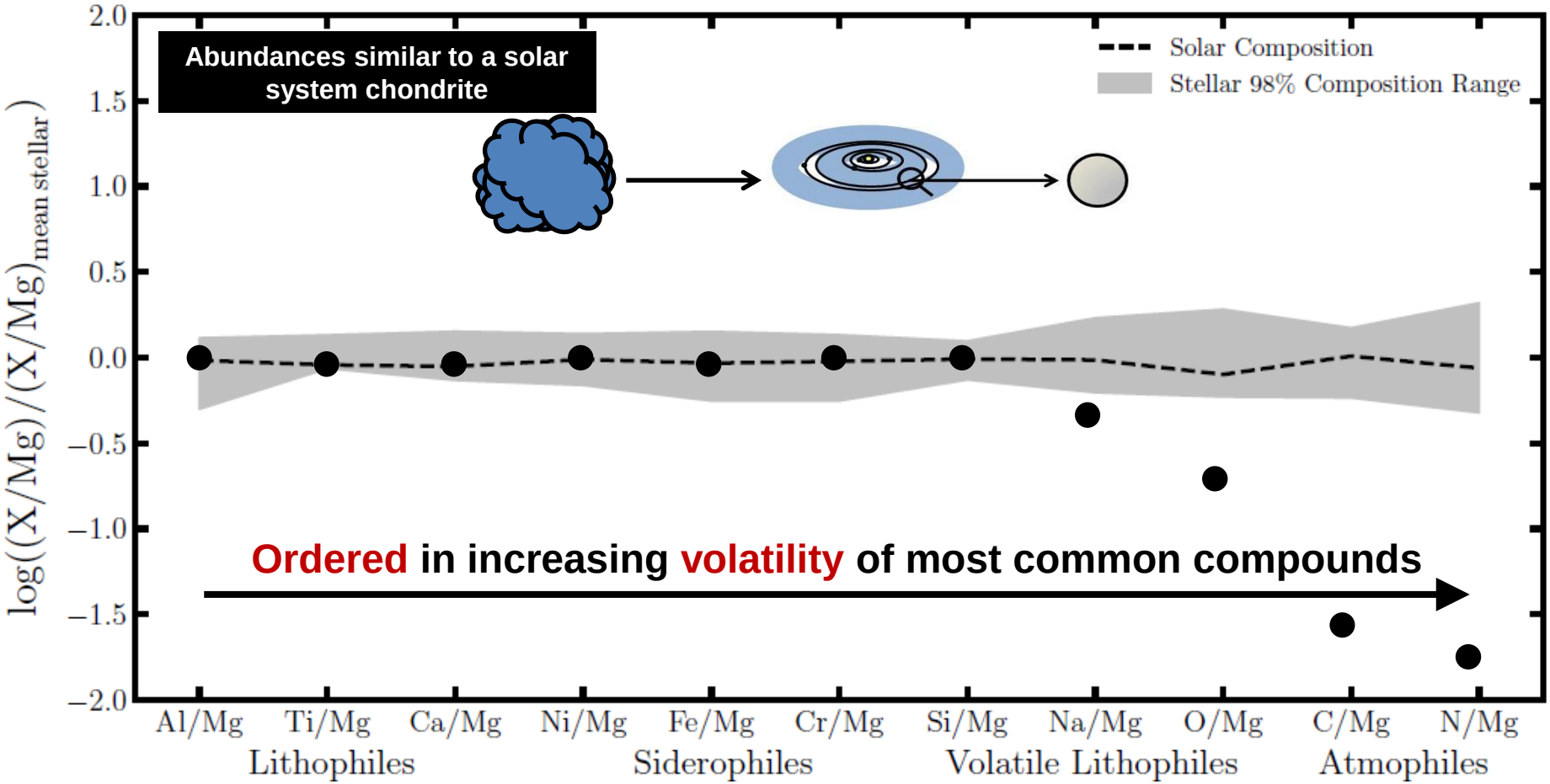

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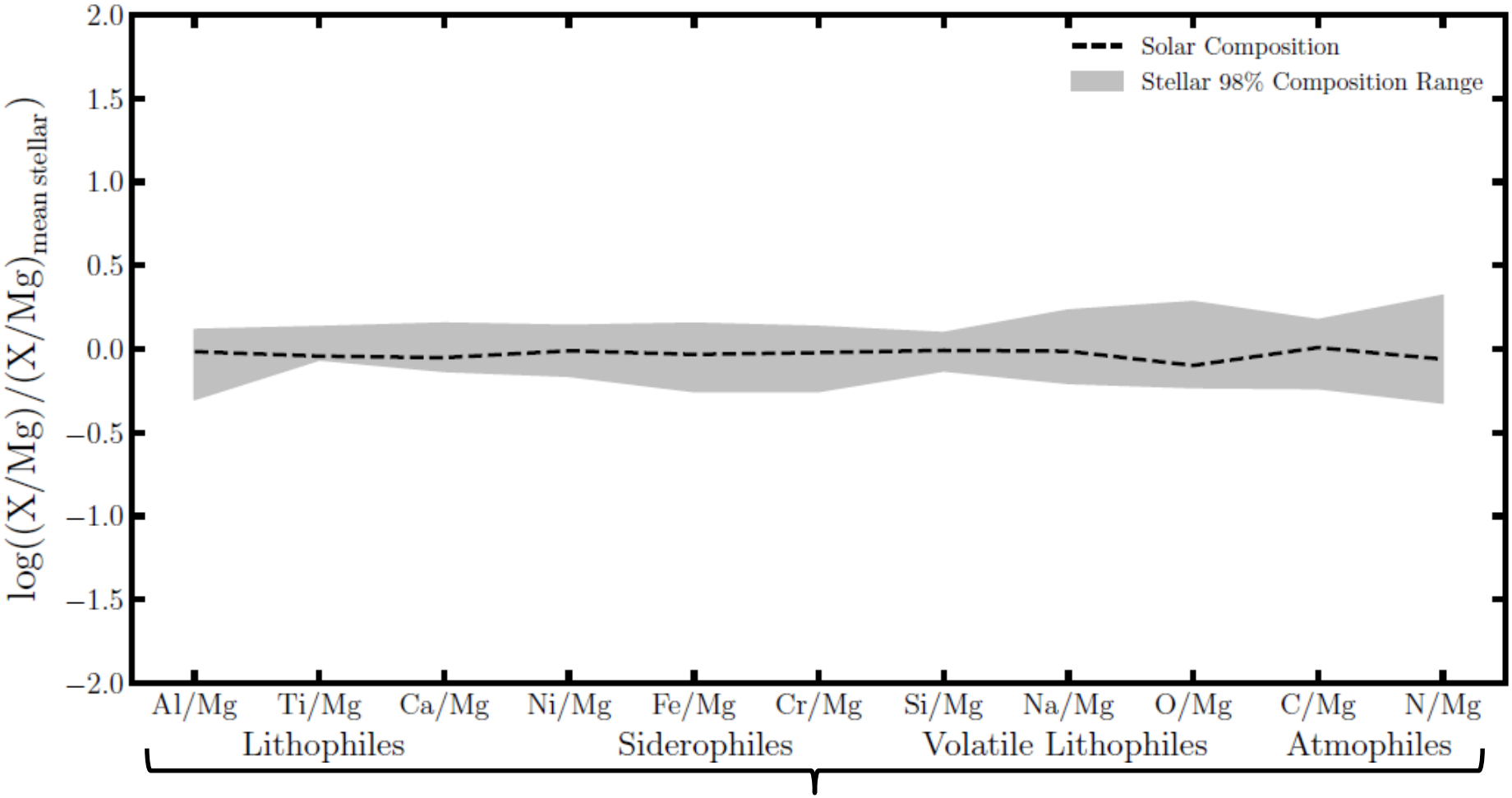

Simultaneously grouped via Goldschmidt classification

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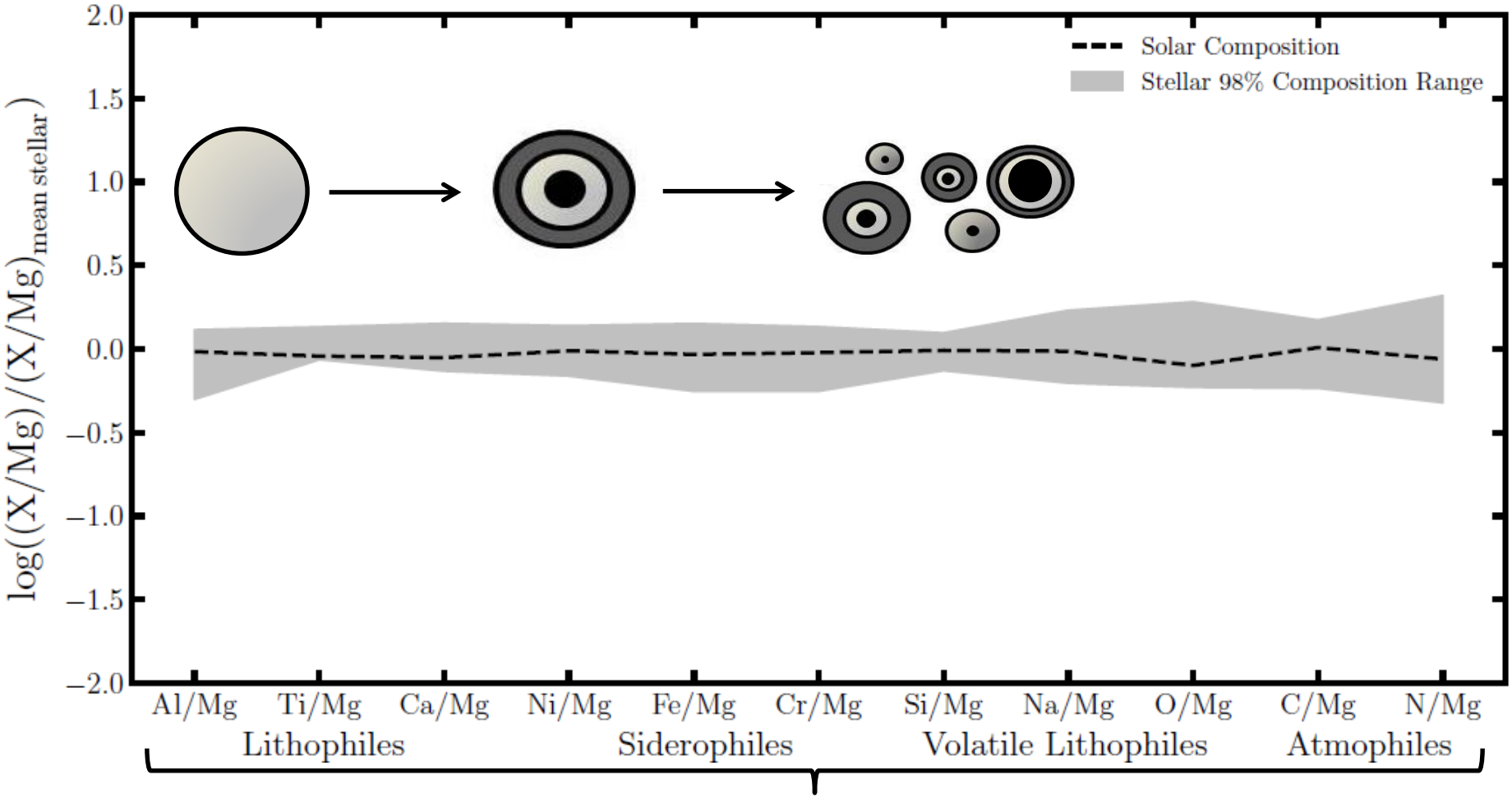

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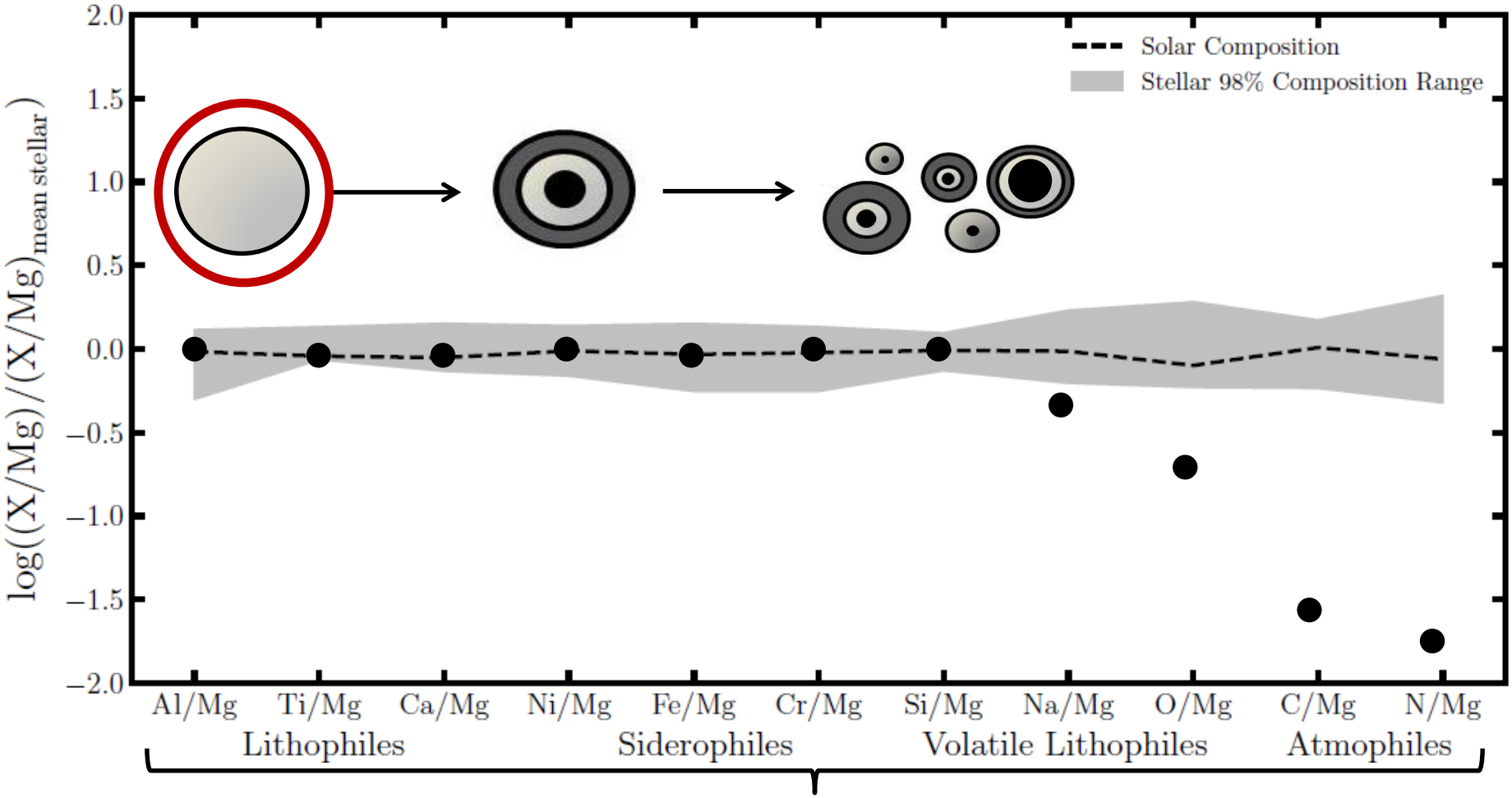

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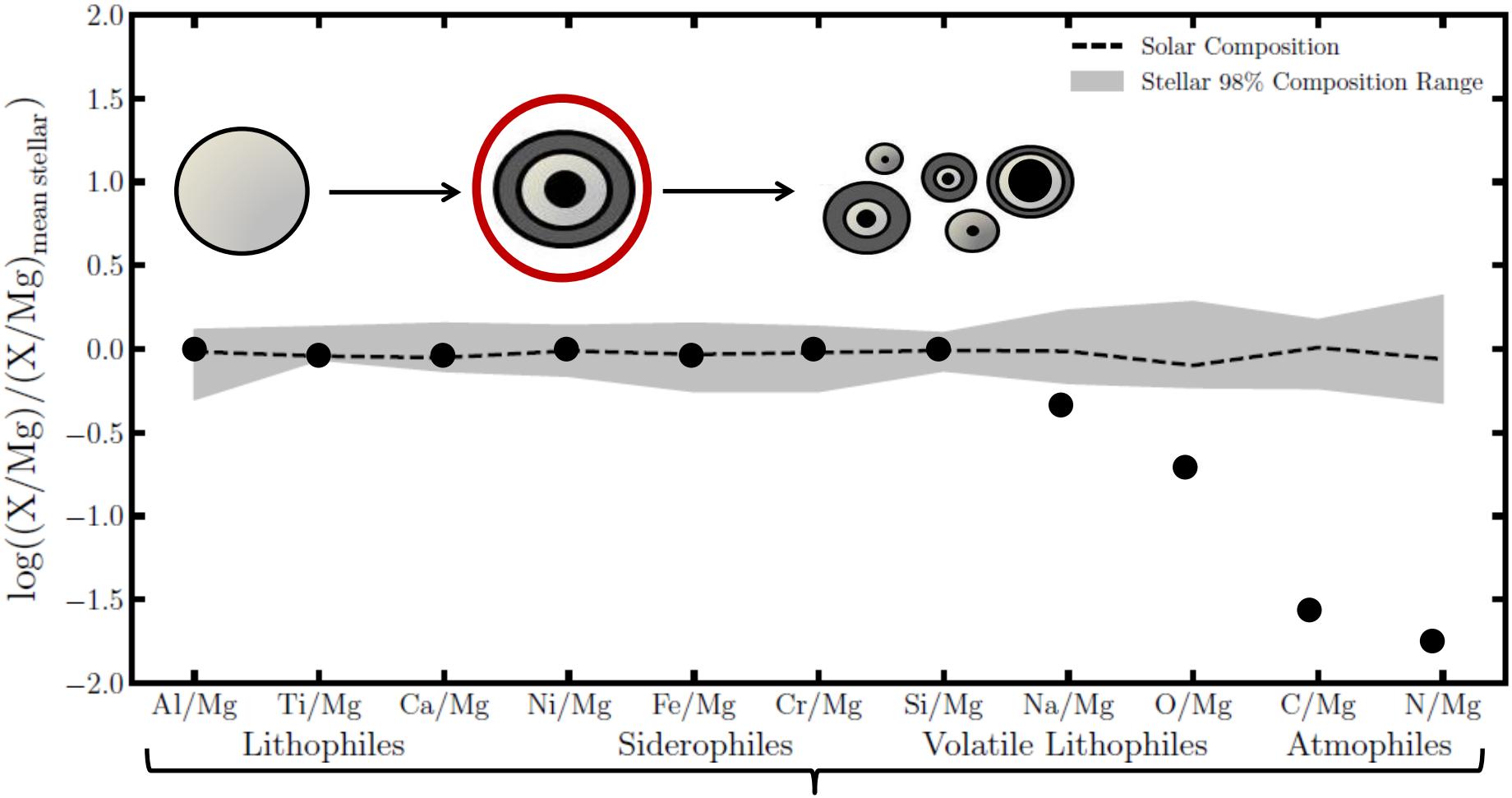

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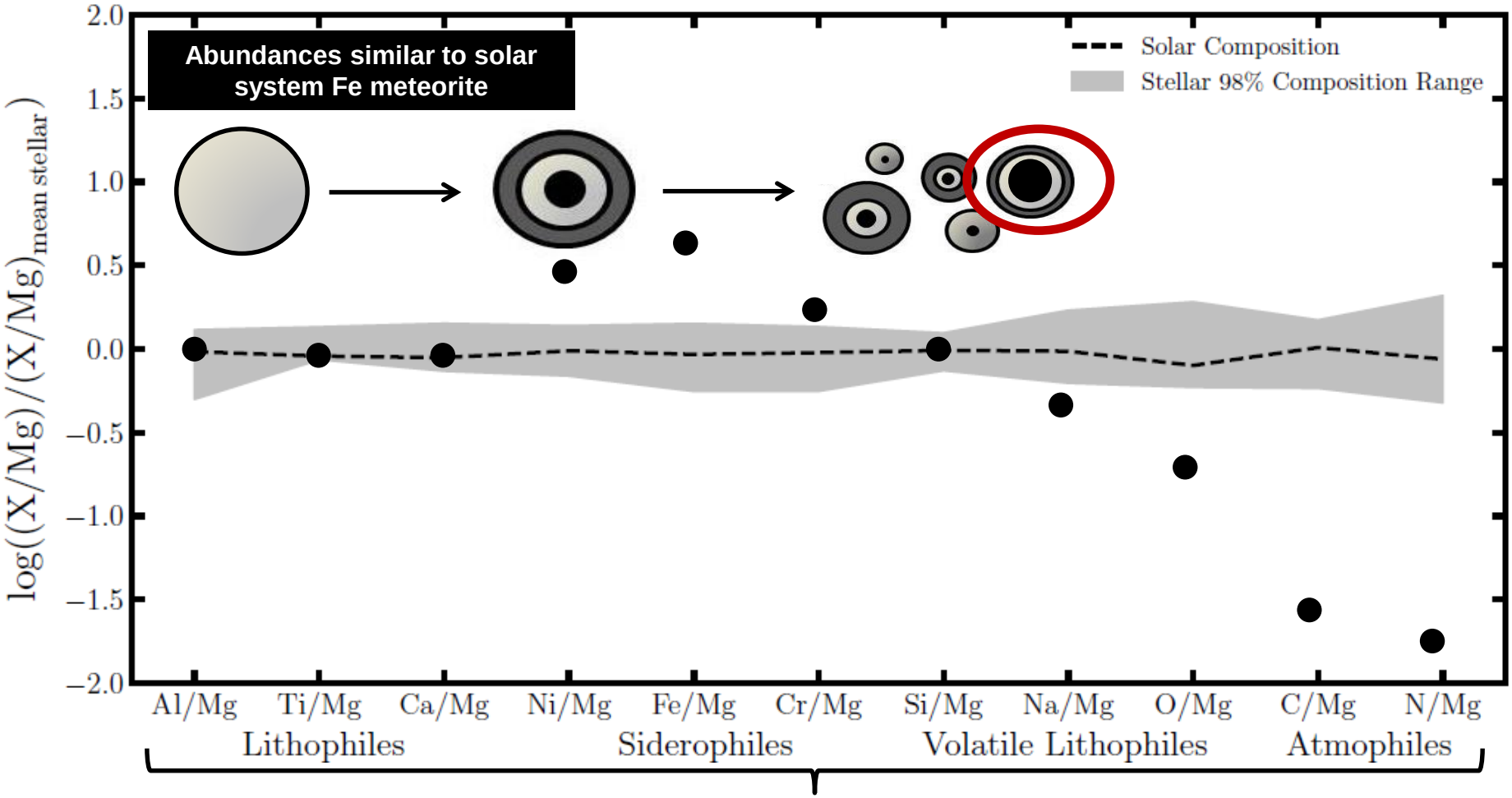

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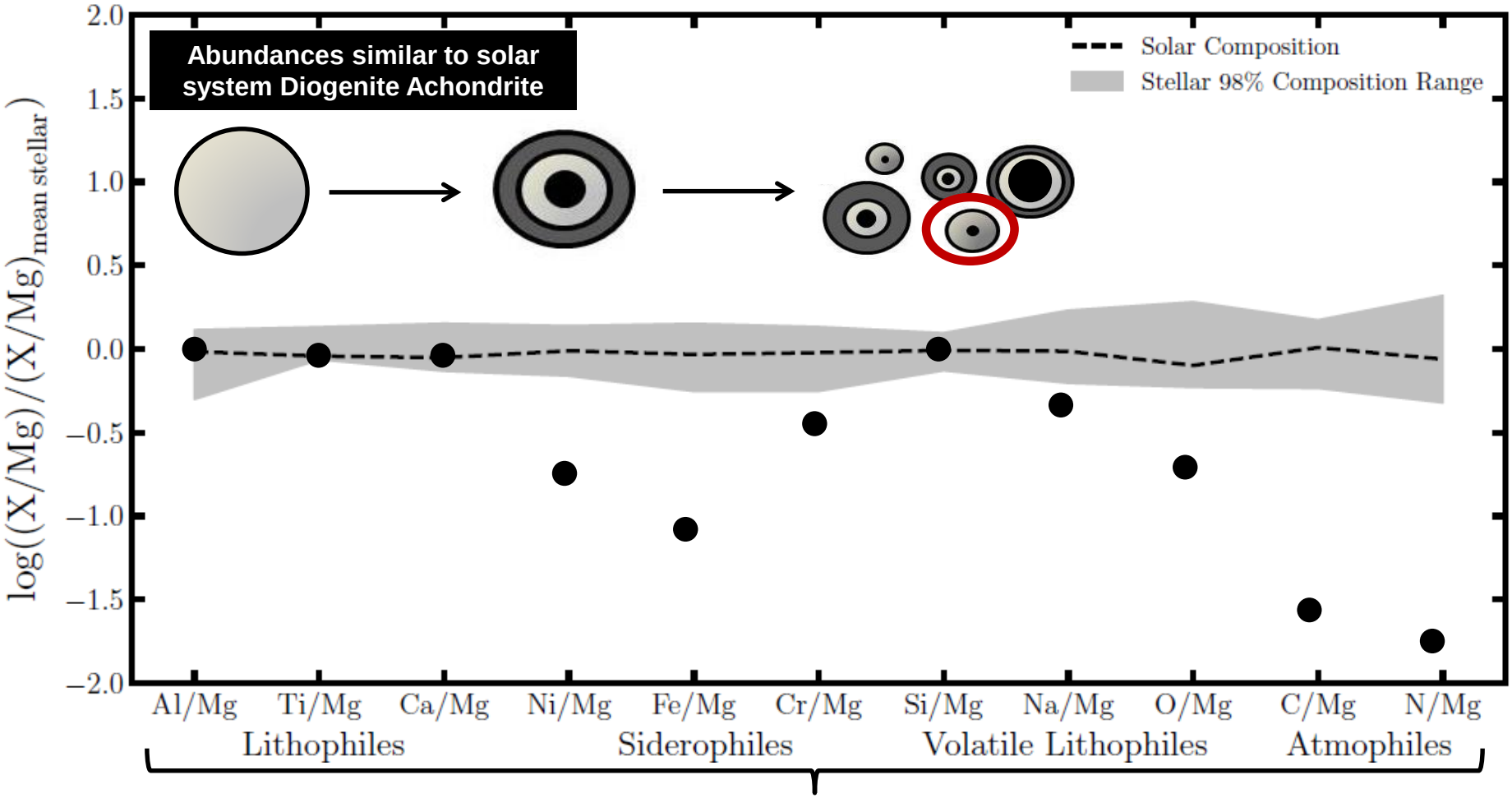

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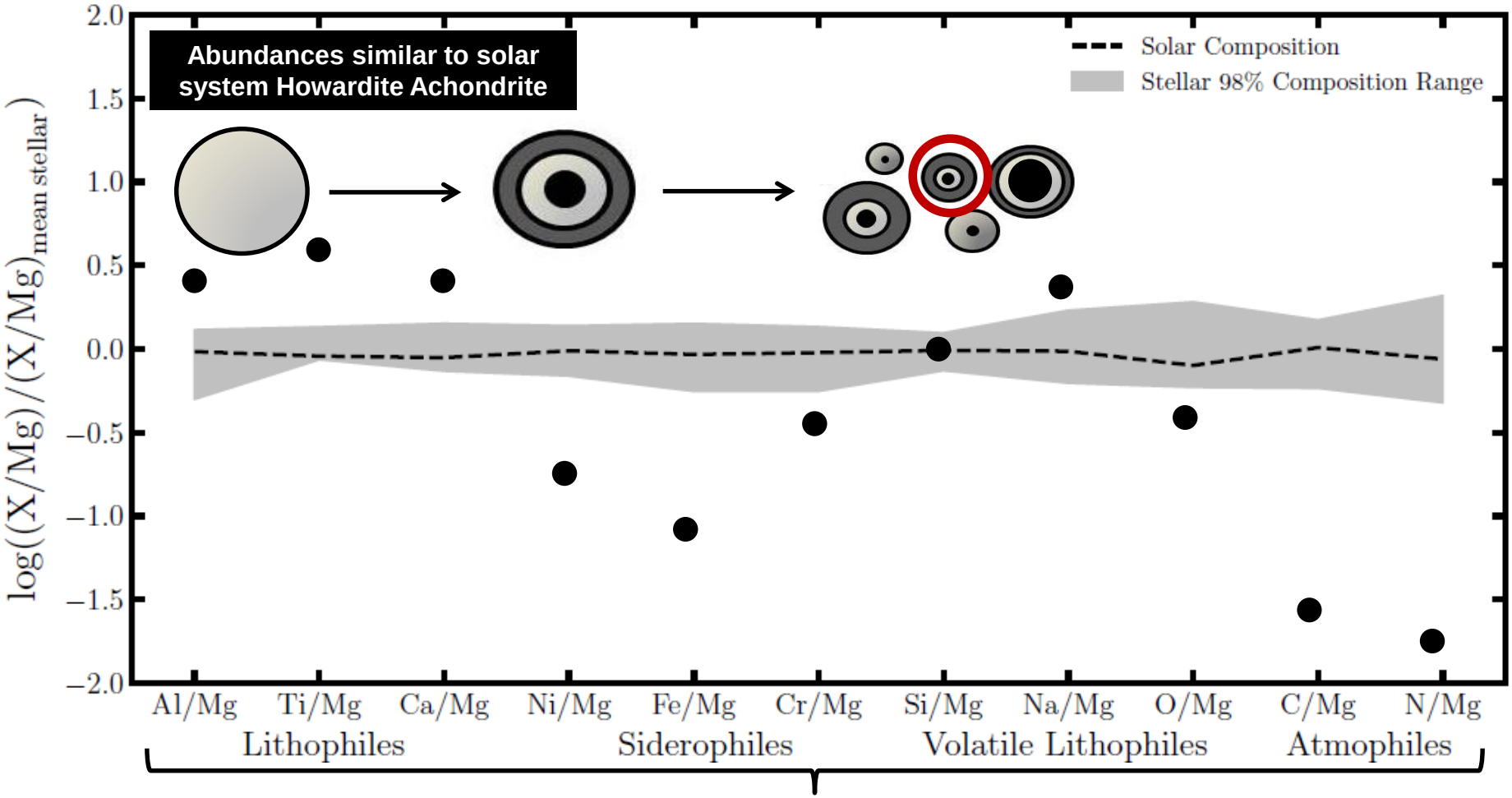

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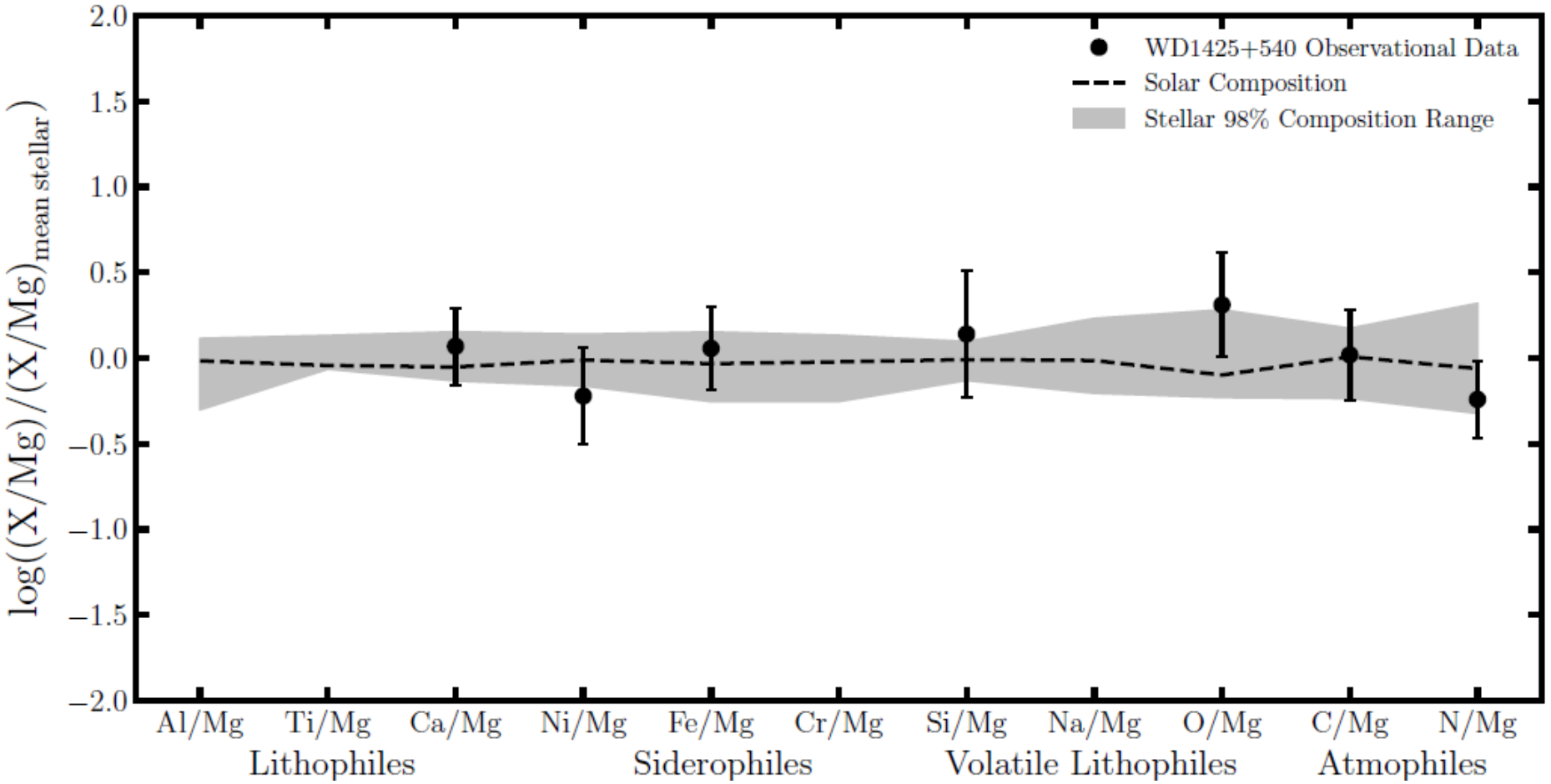

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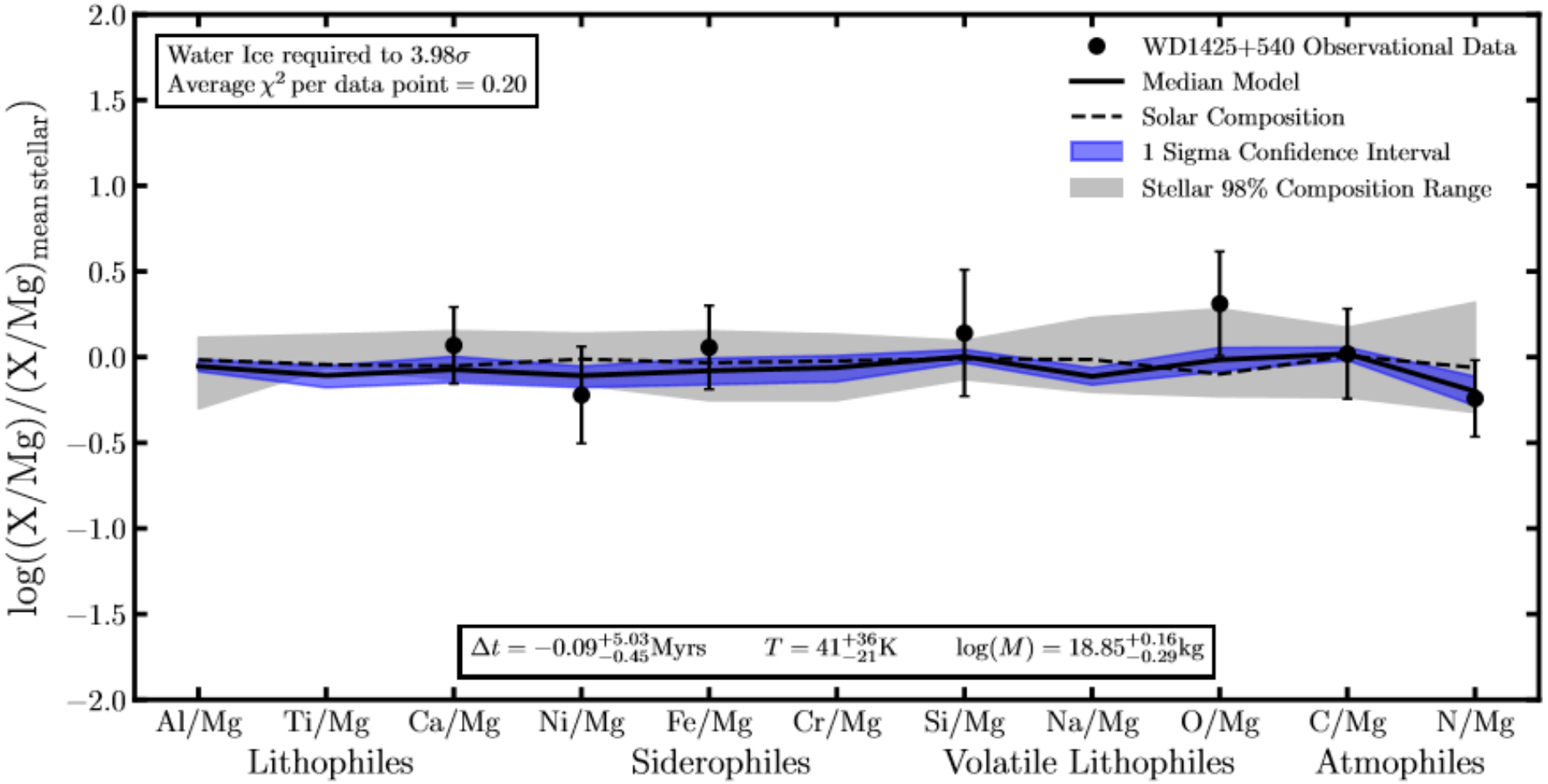

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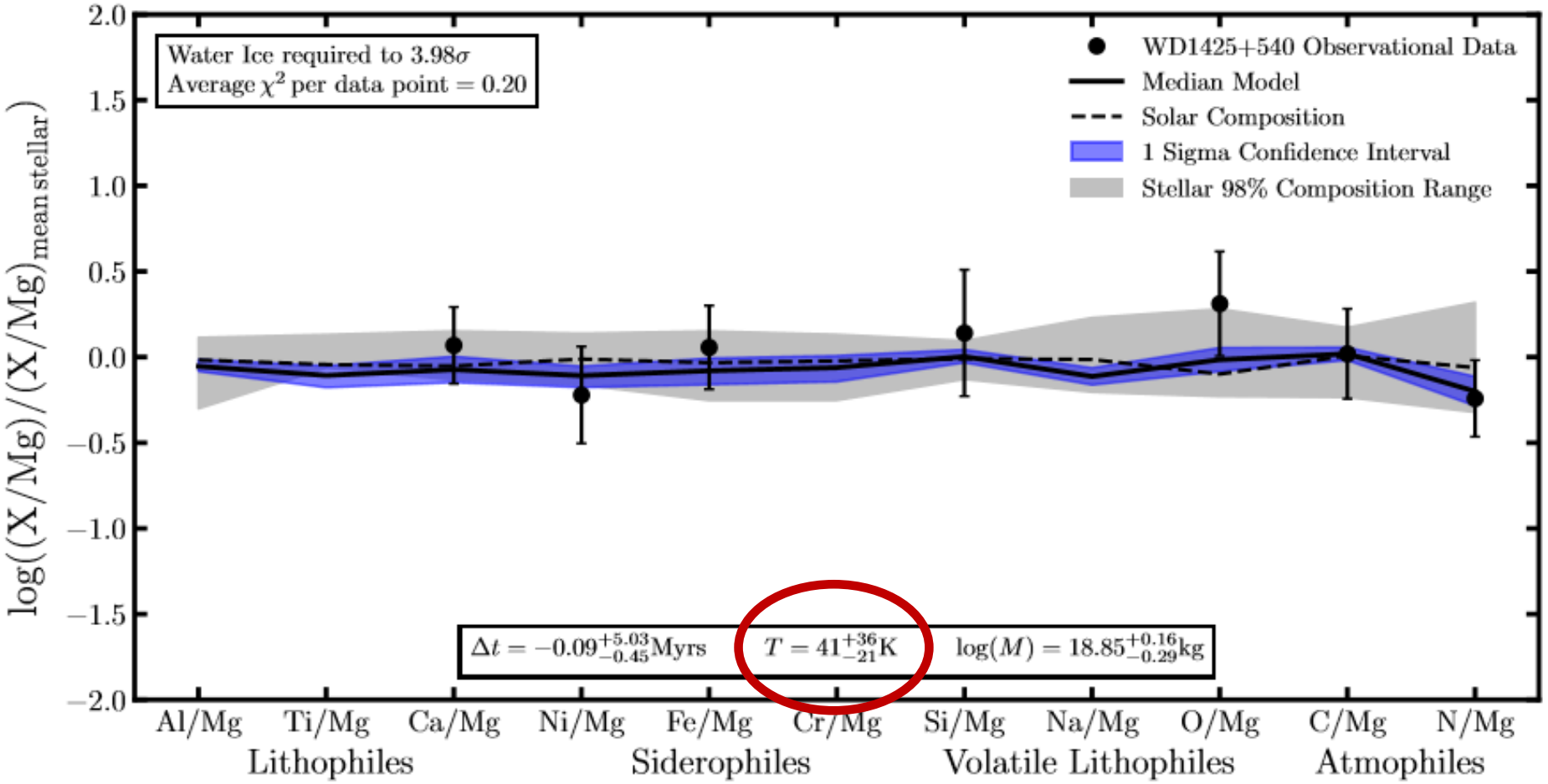

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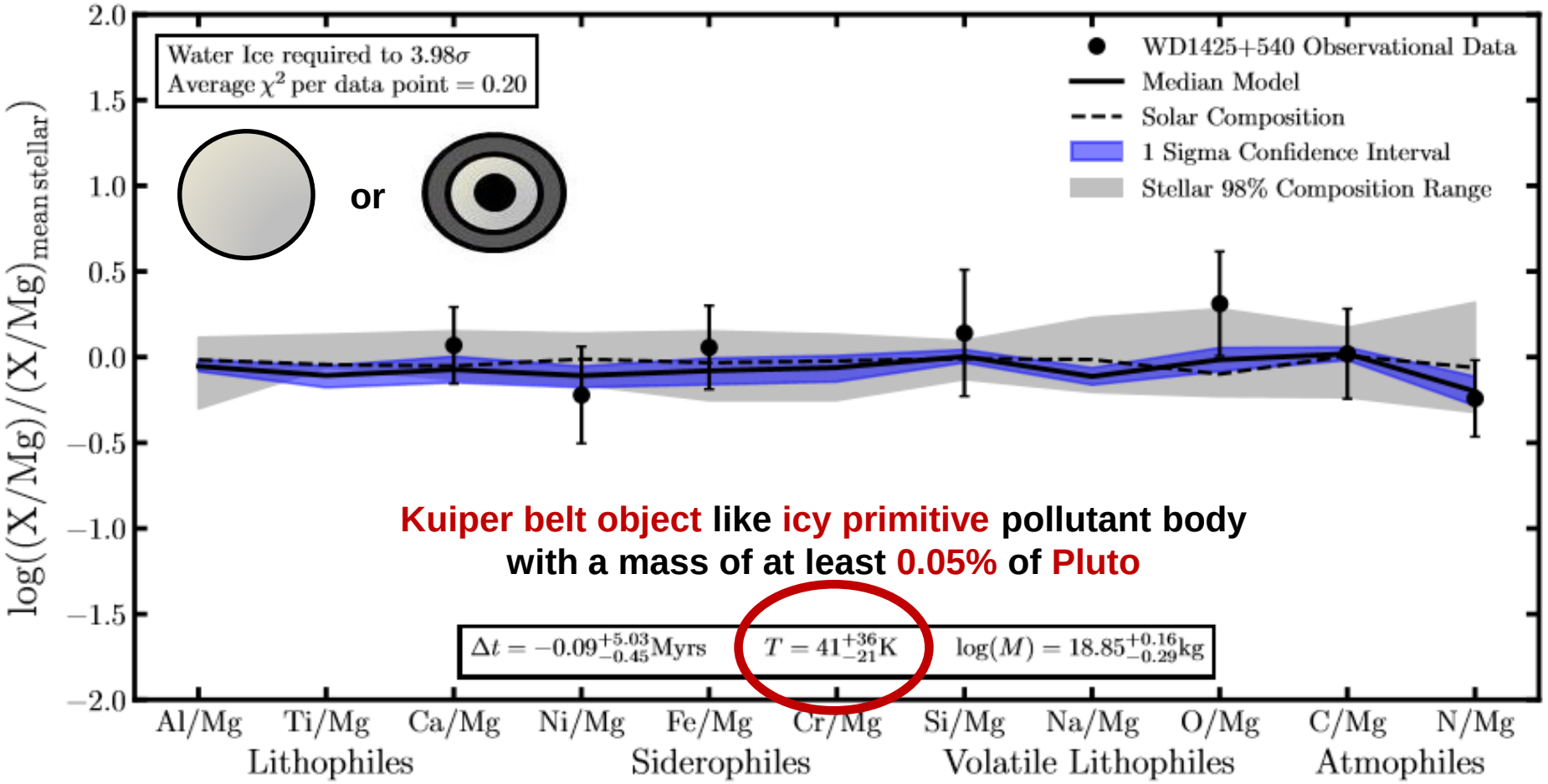

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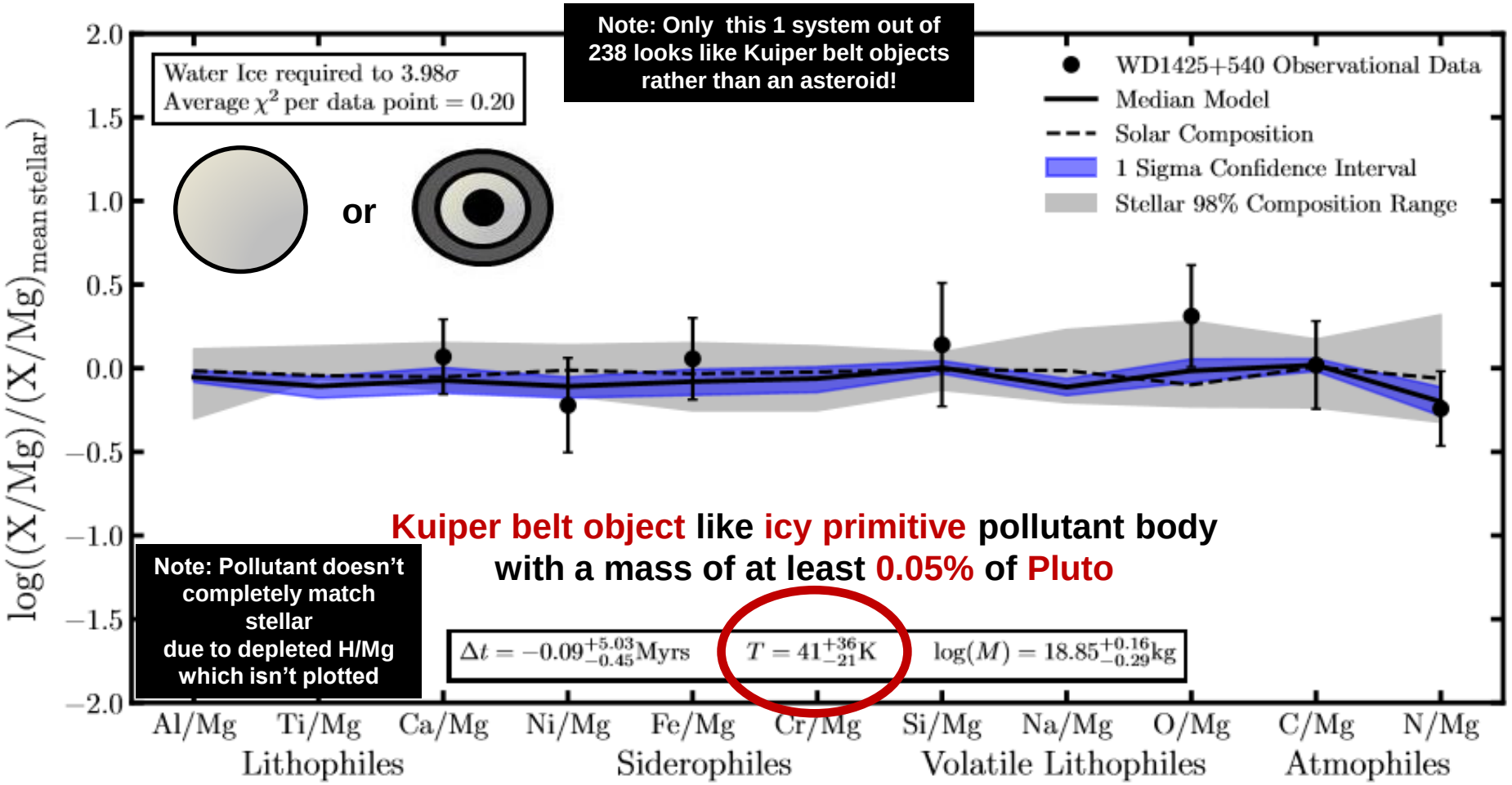

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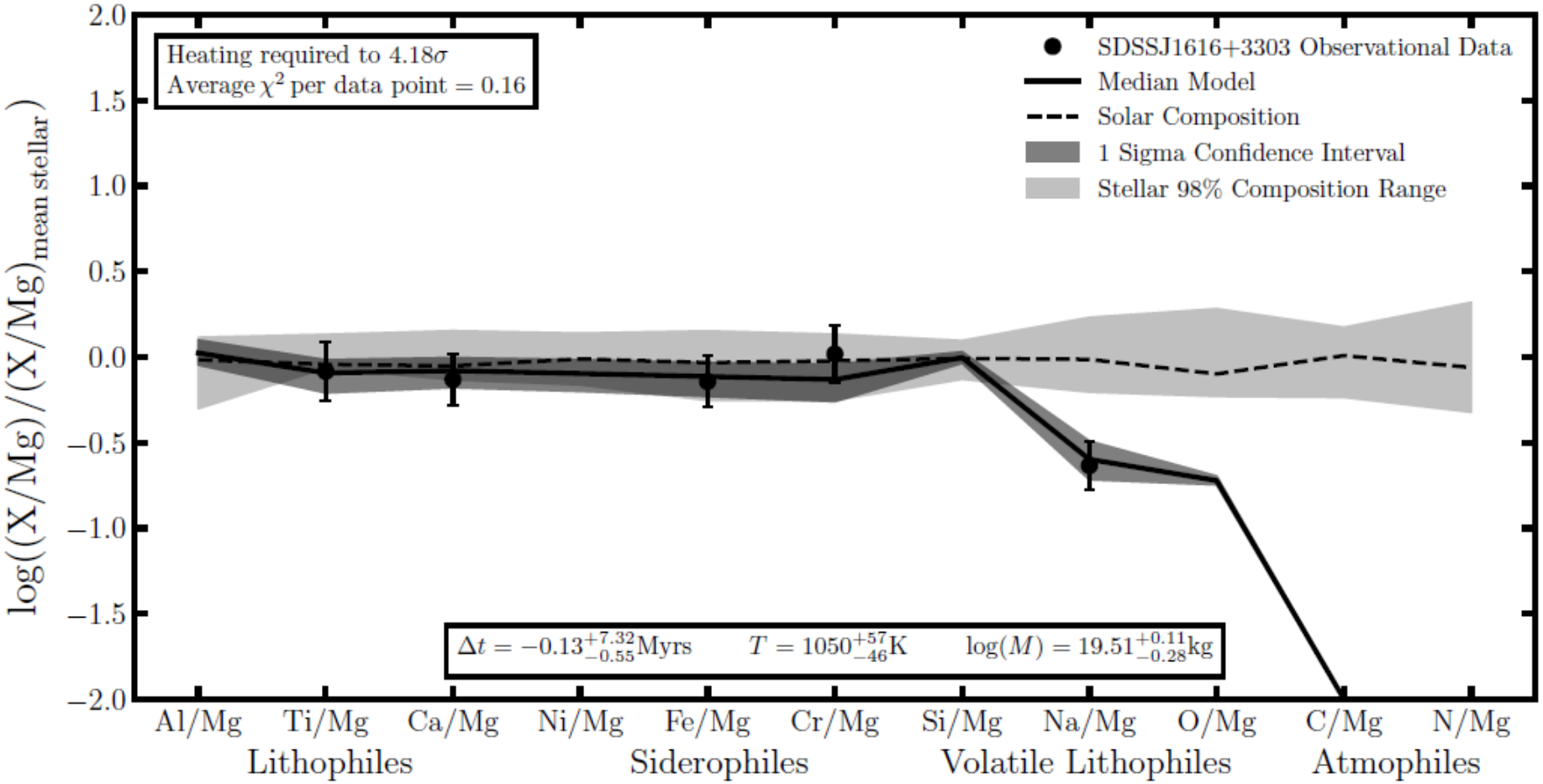

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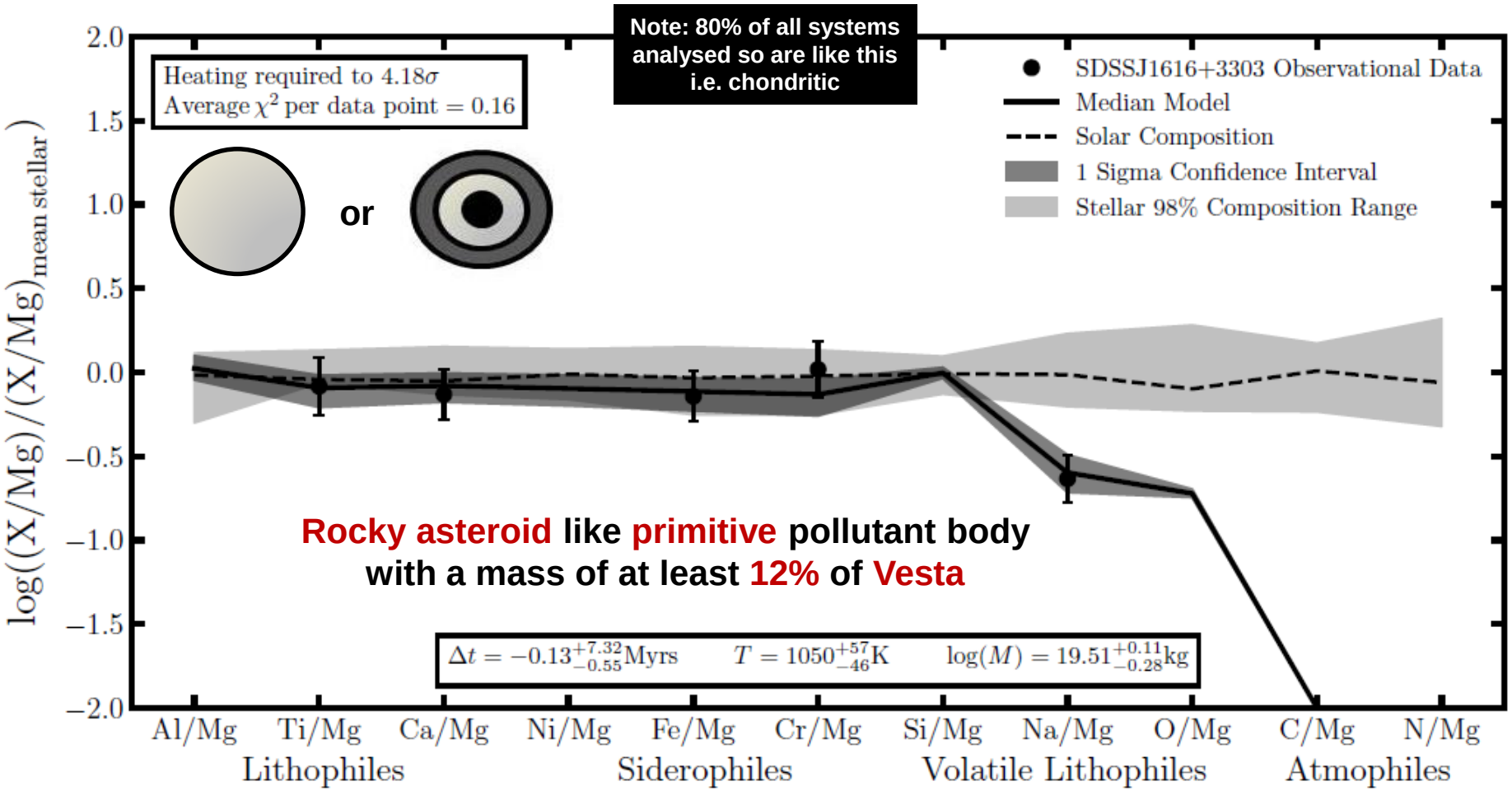

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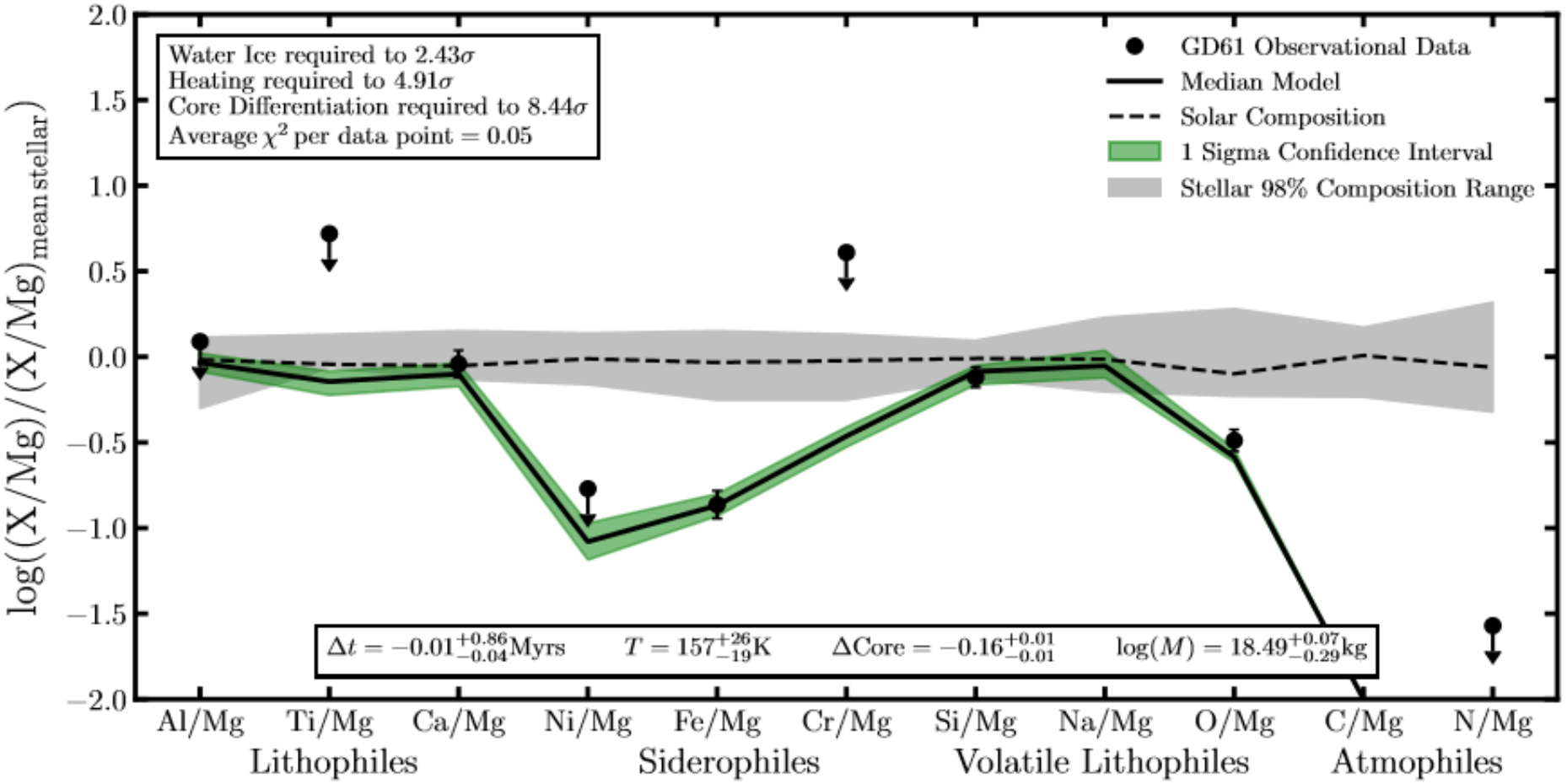

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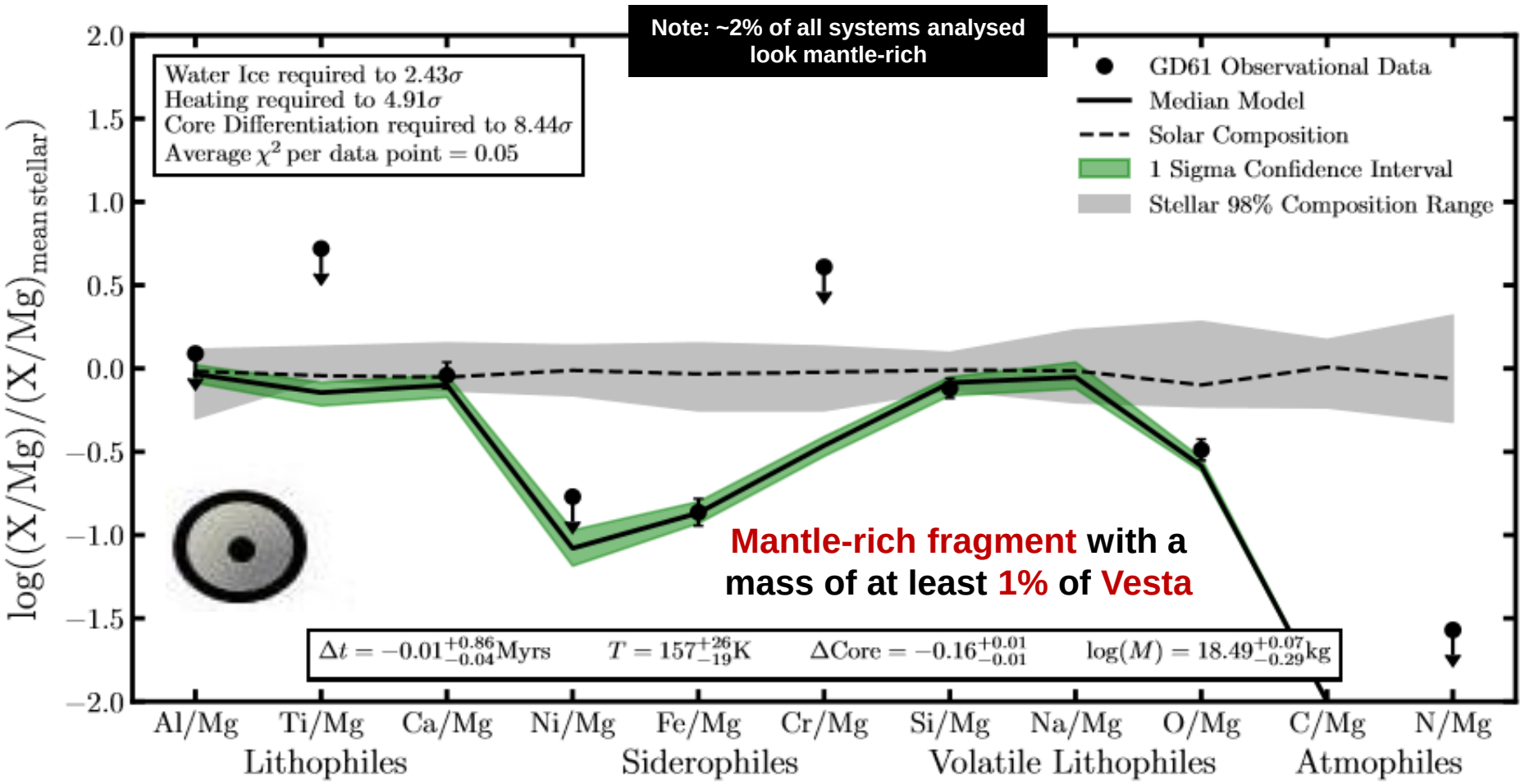

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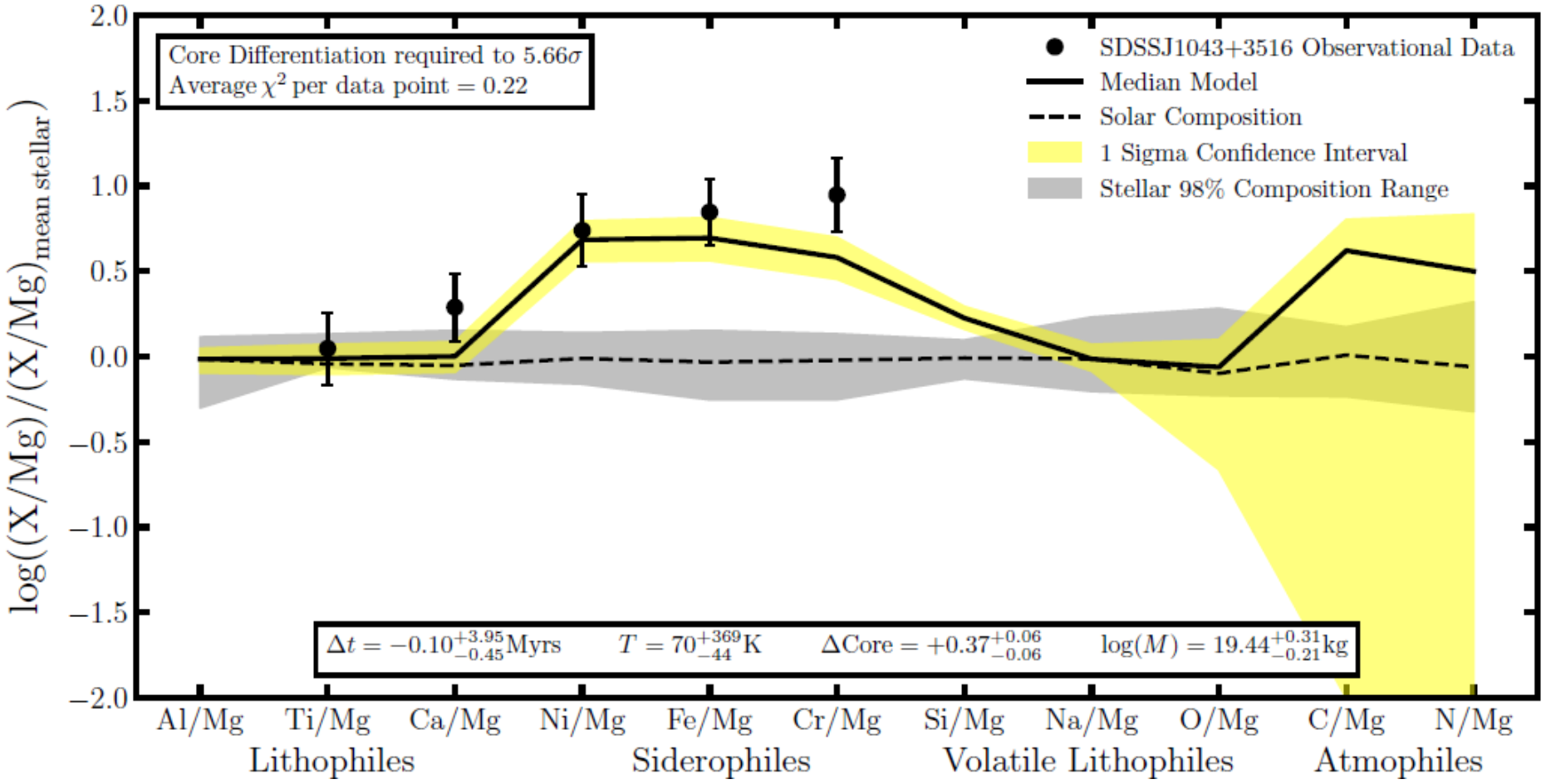

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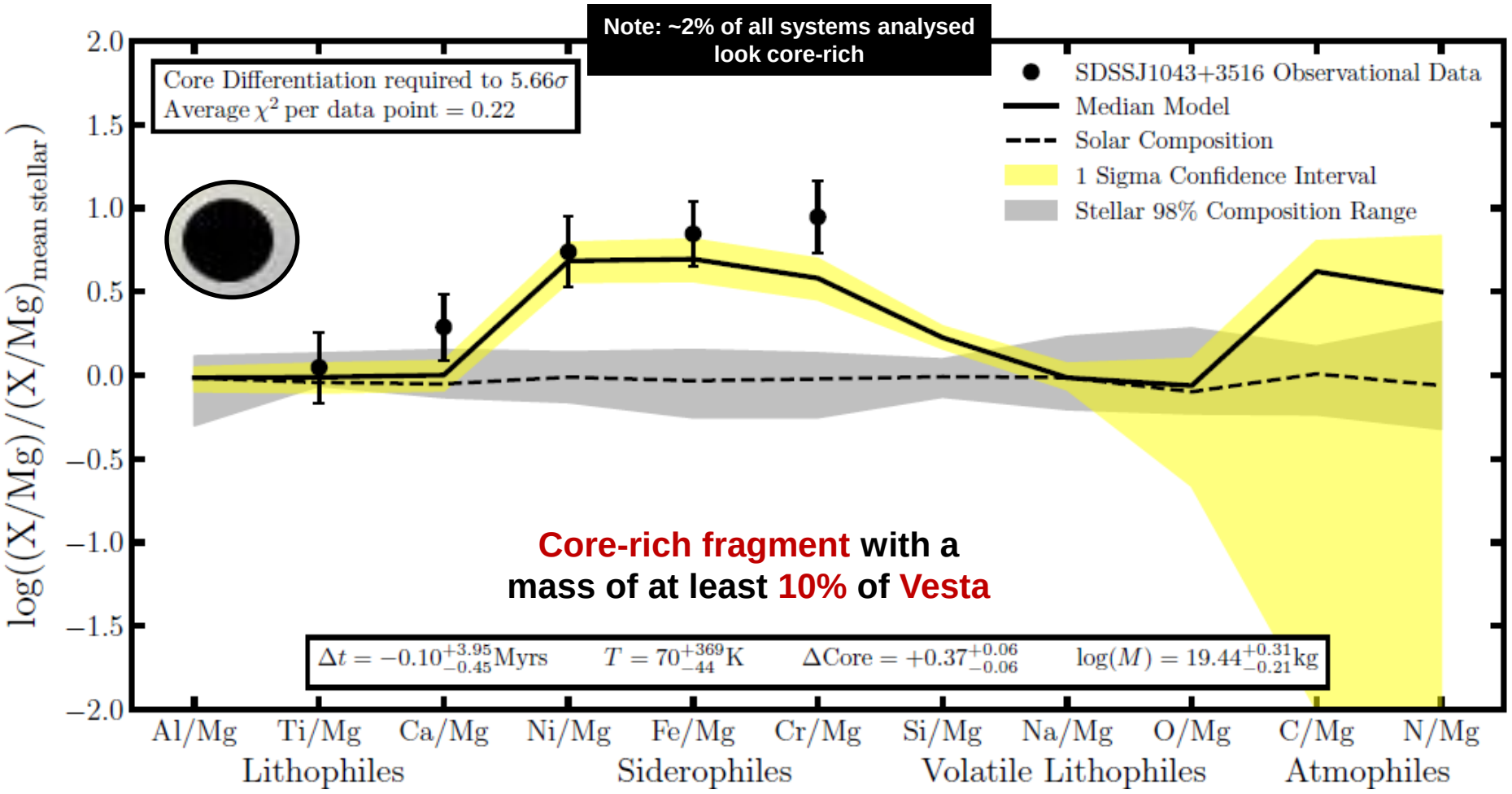

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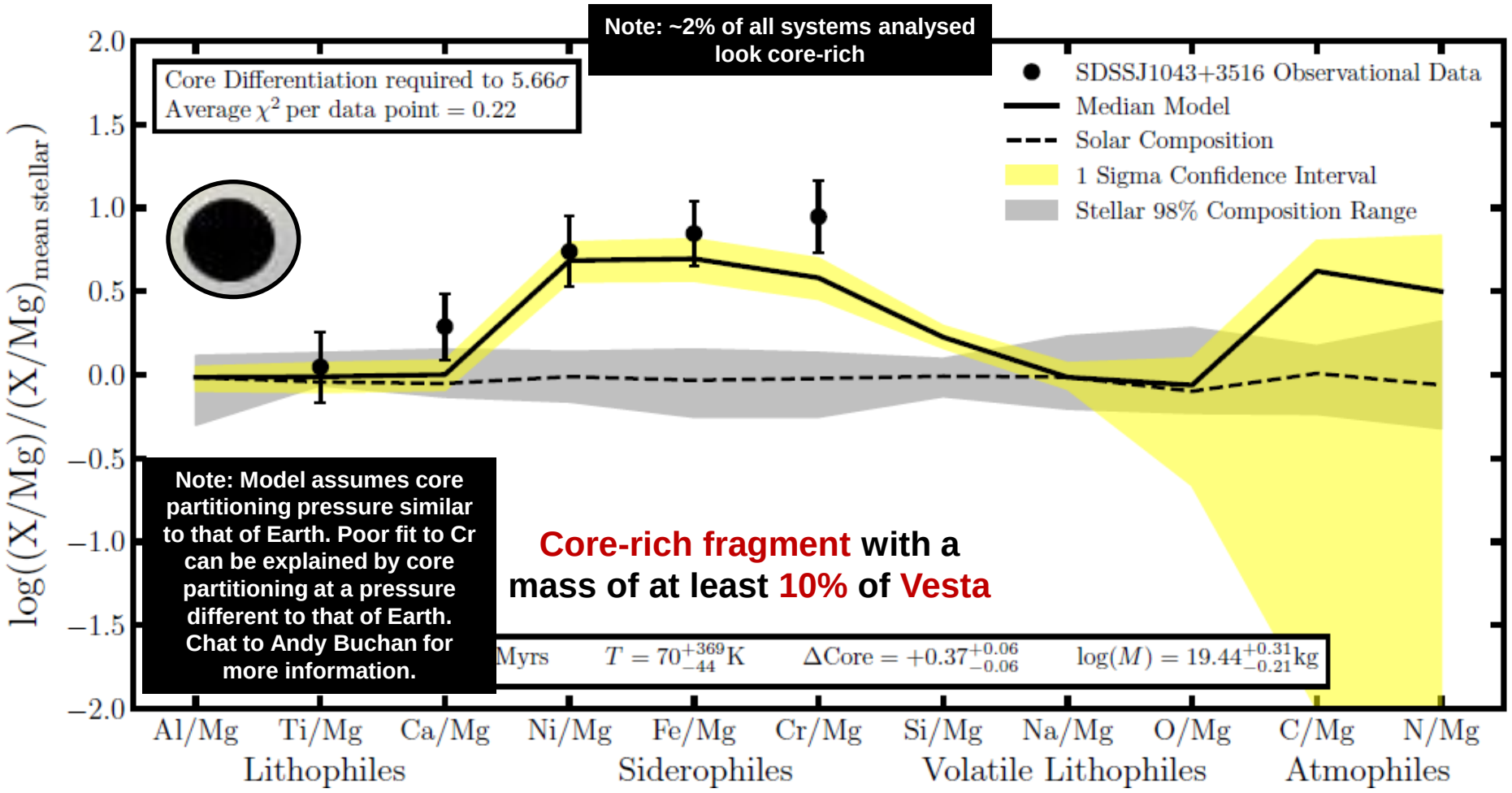

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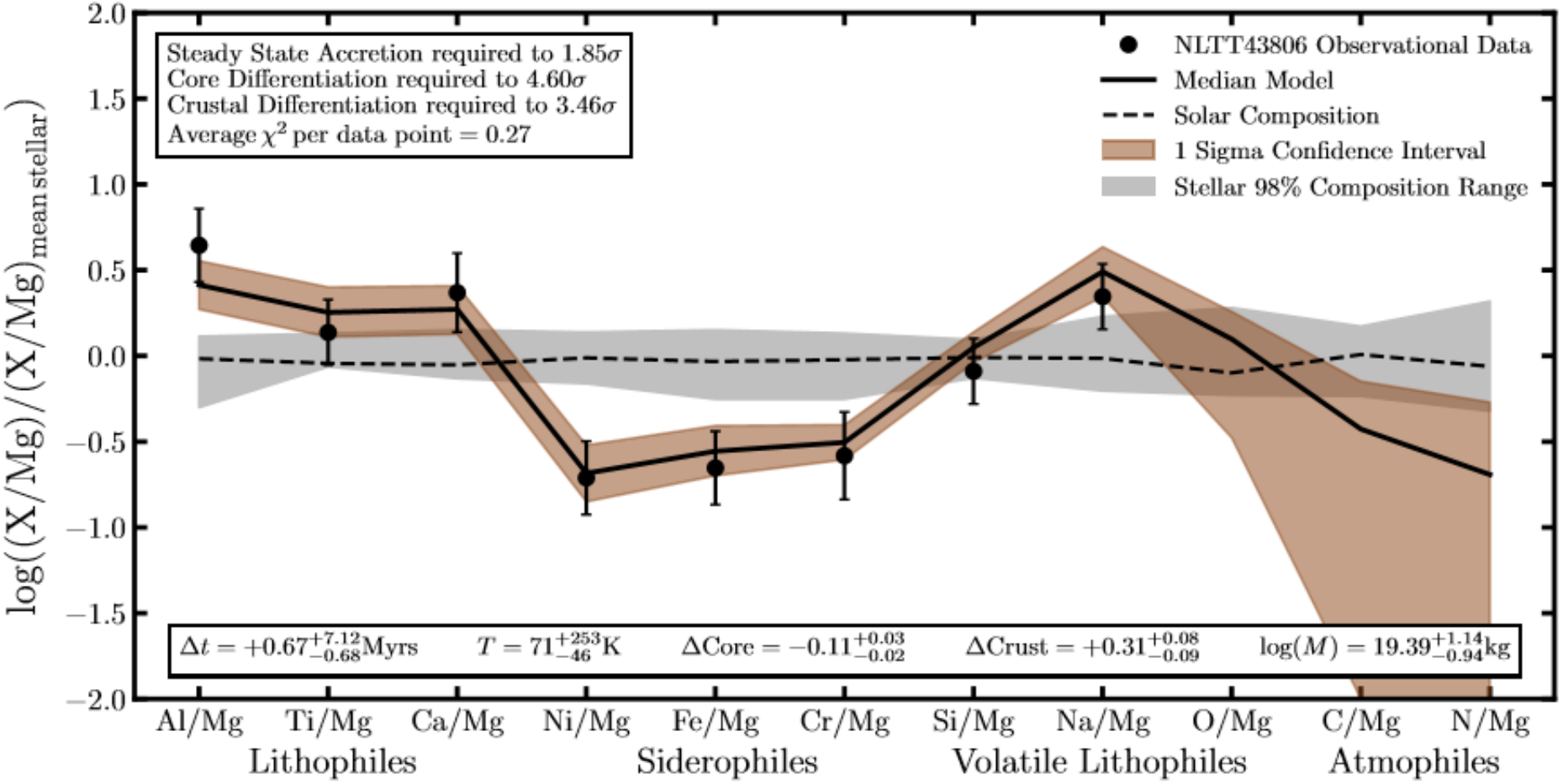

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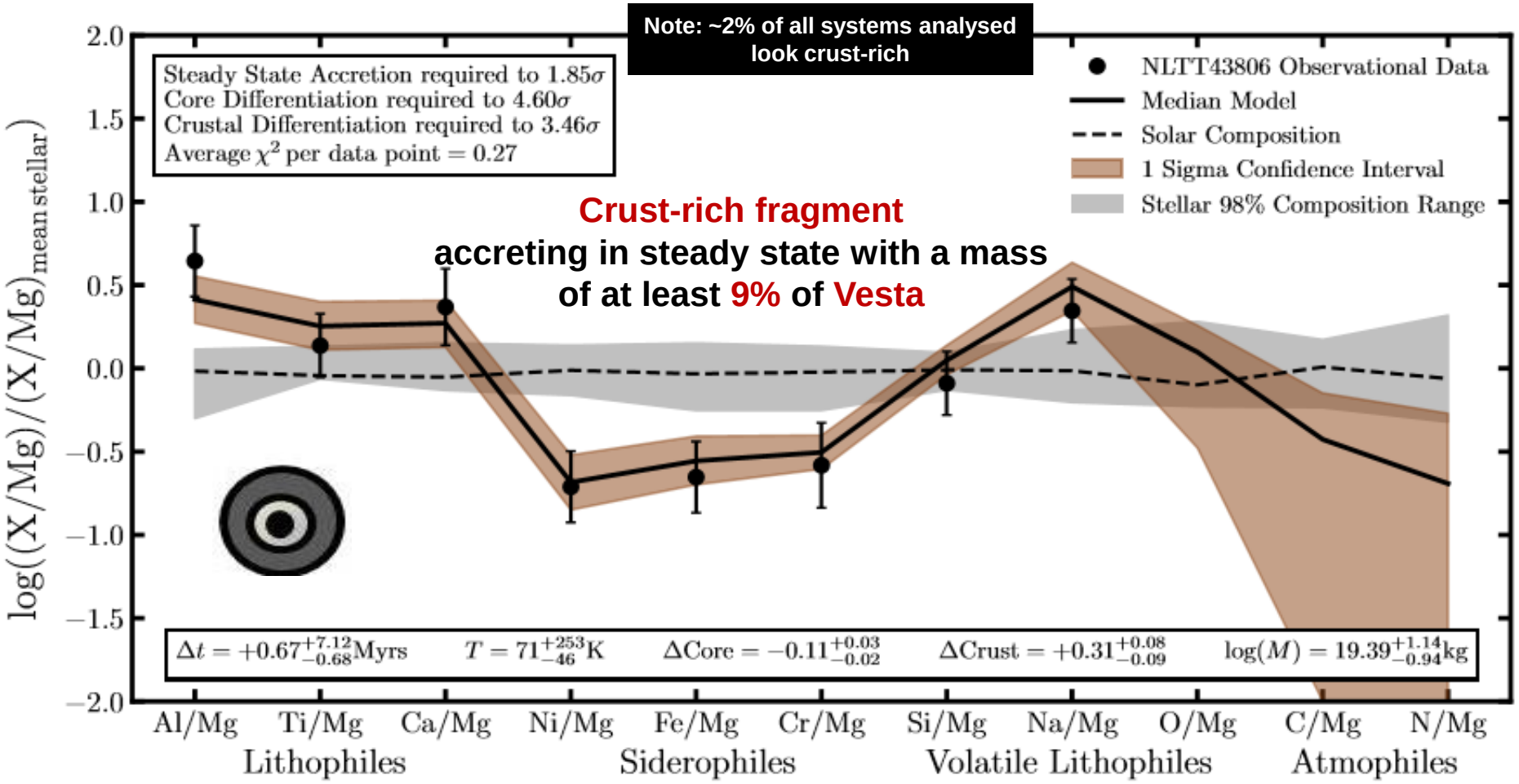

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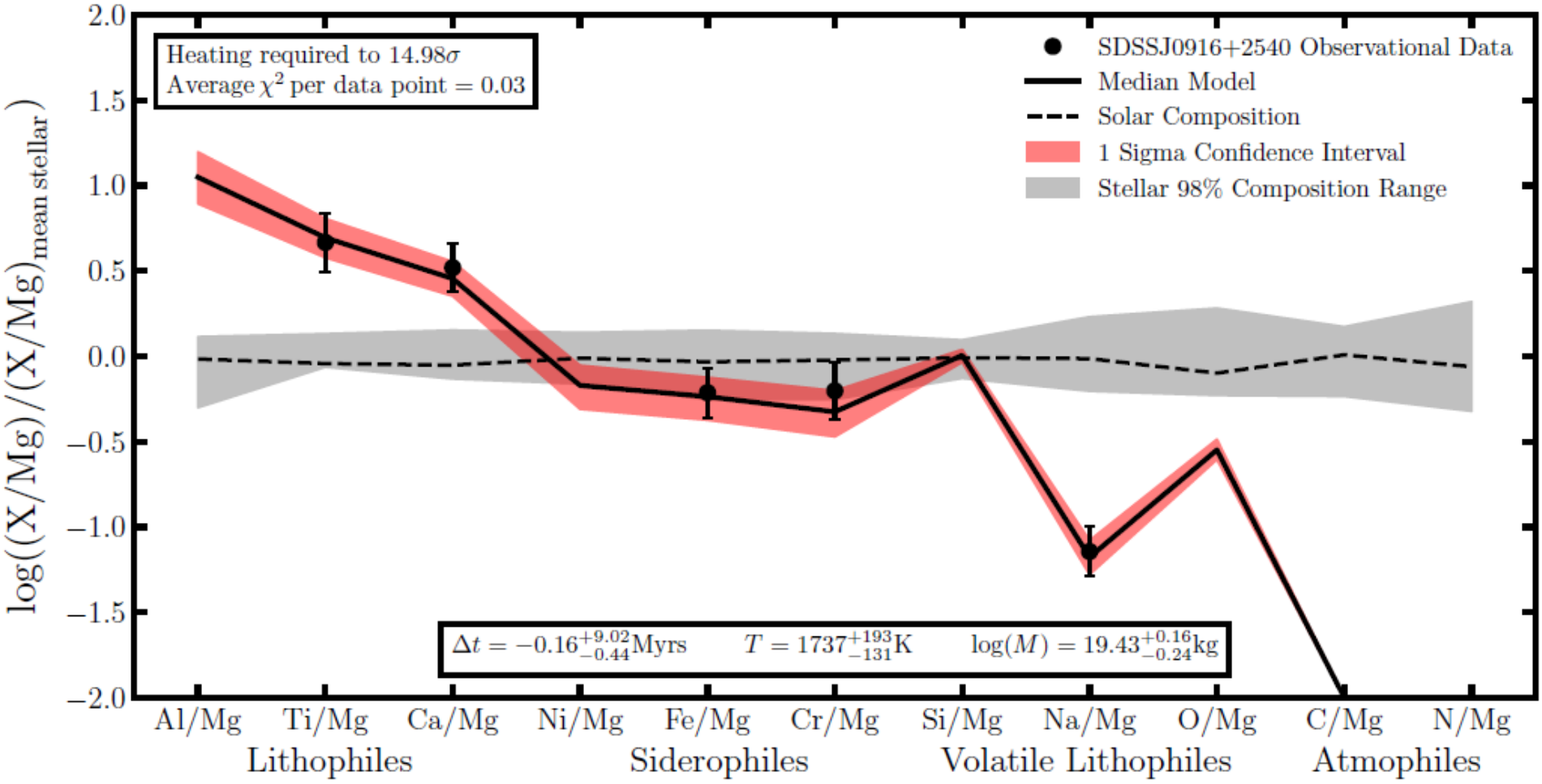

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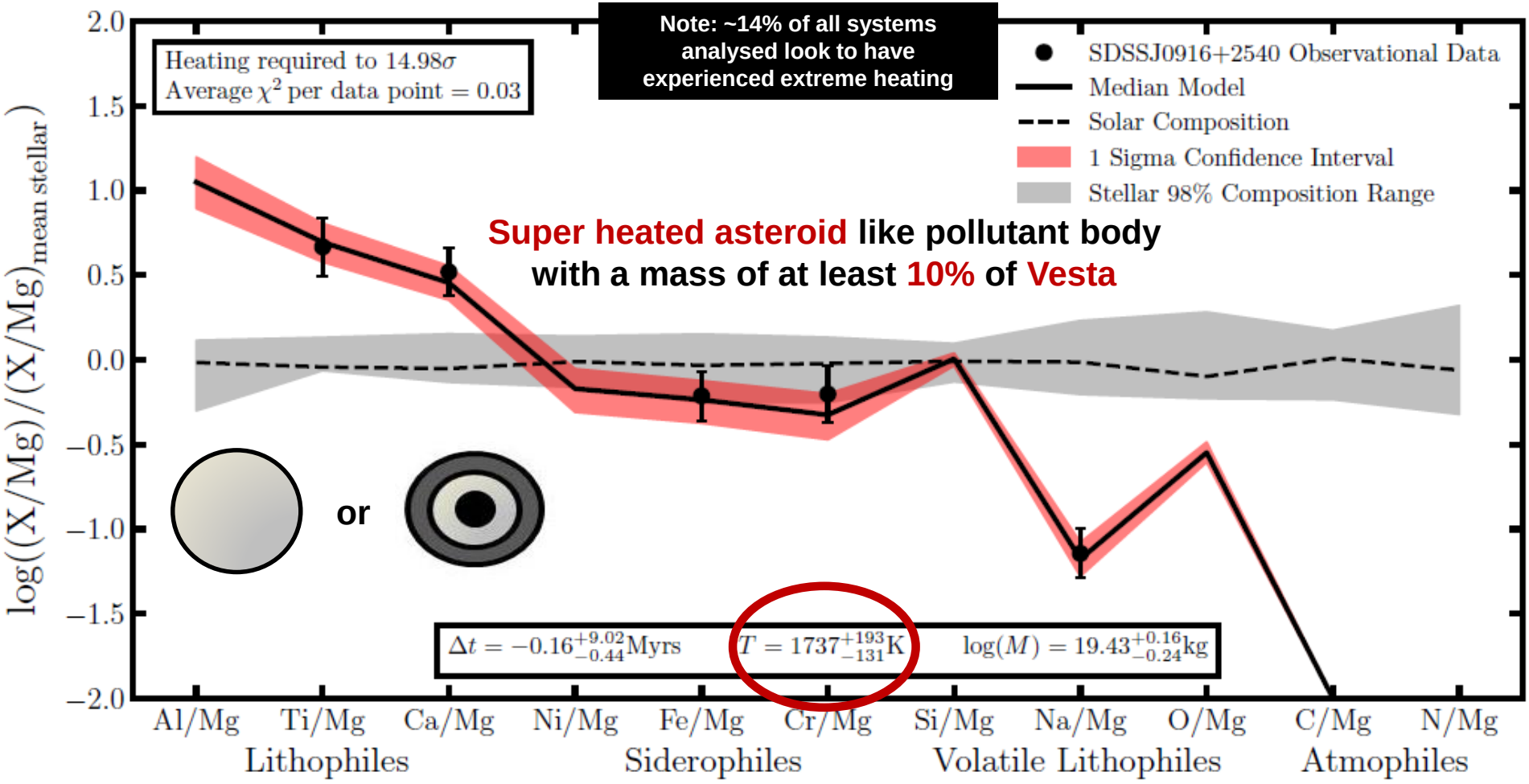

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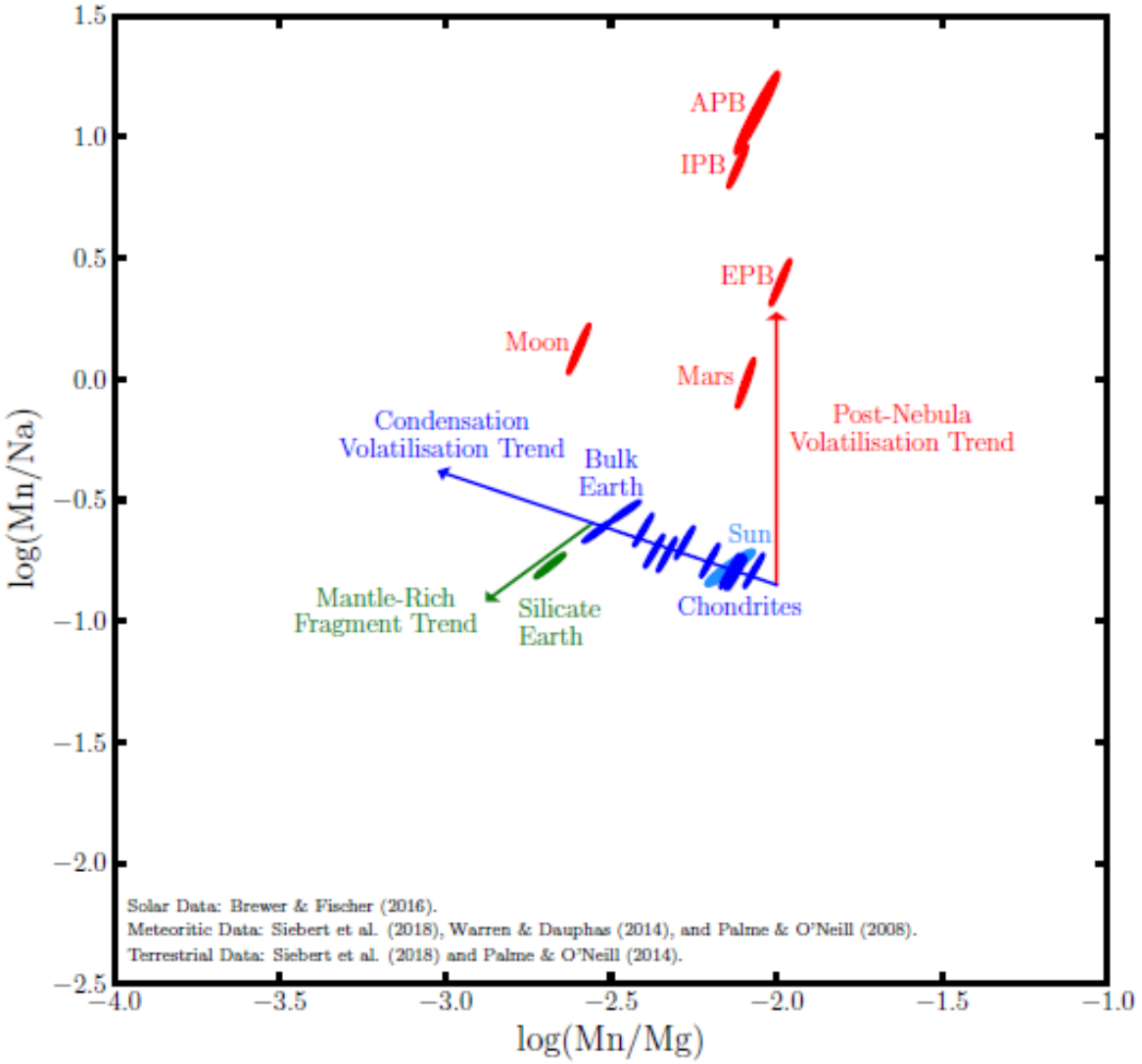
Probing the origin of volatile depletion in pollutant material



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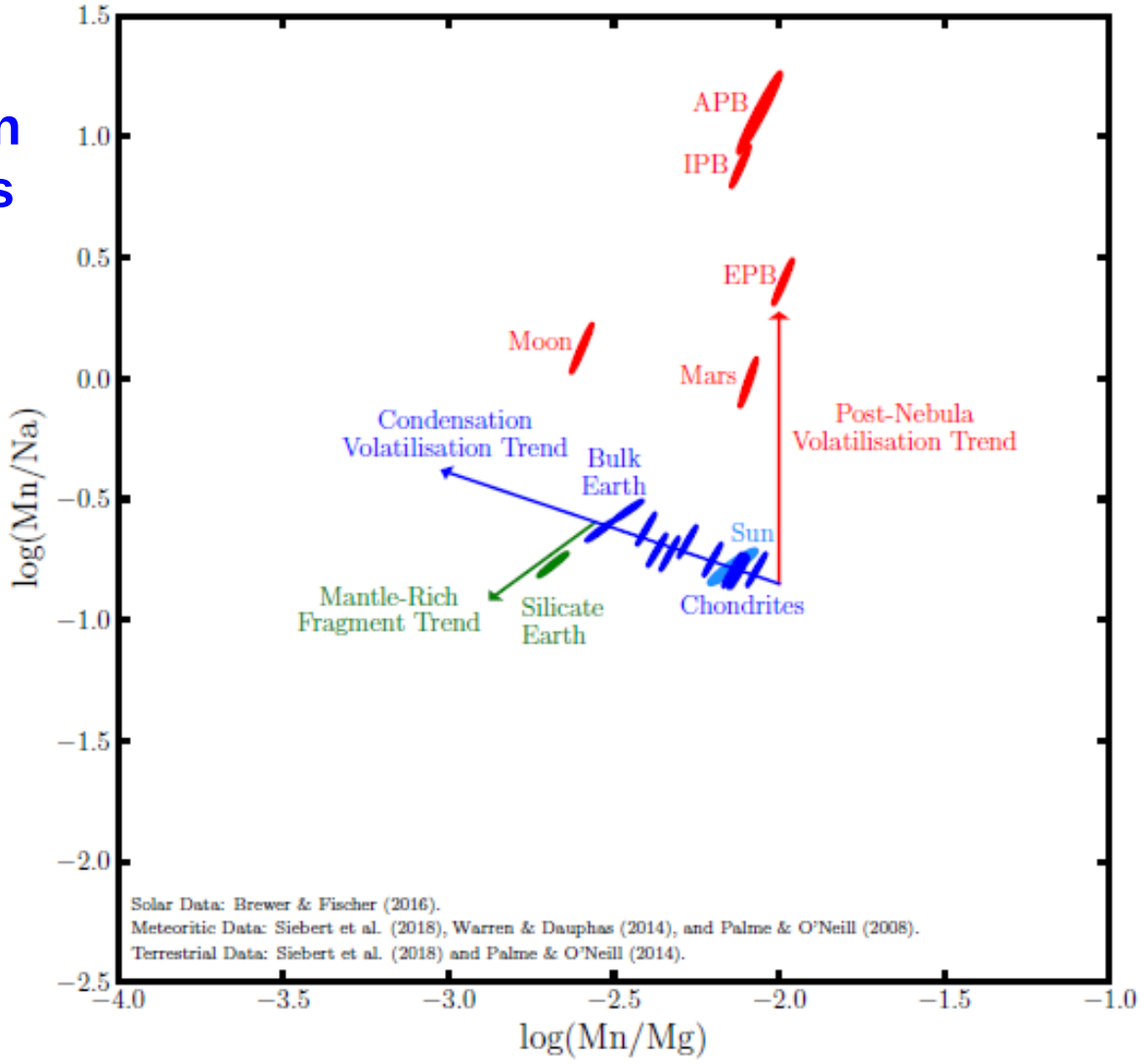
Probing the origin of volatile depletion in pollutant material

Nebula Condensation Temperatures

Na = 958K

Mn = 1158K

Mg = 1336K



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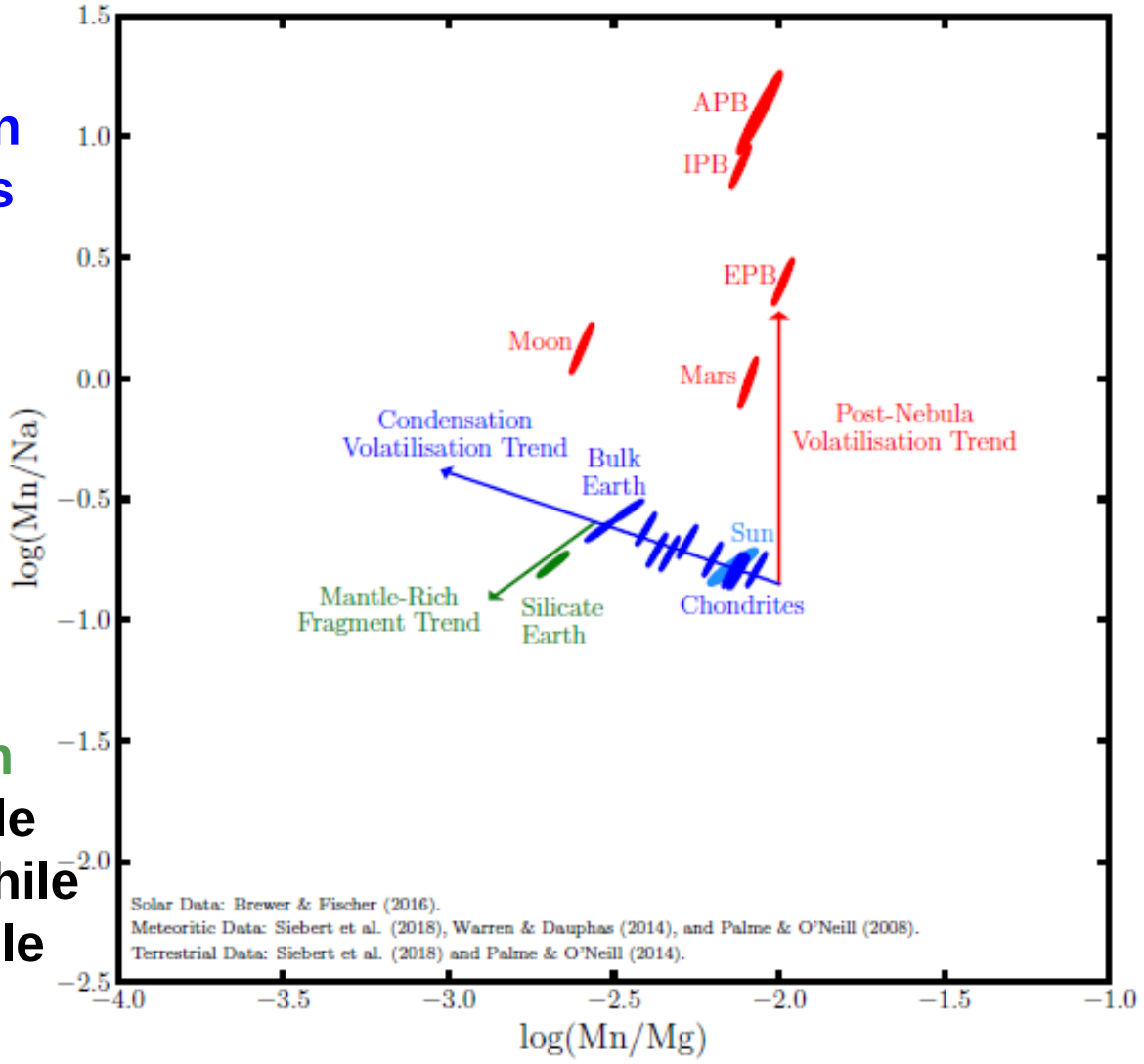

Goldschmidt Classification

Na - Lithophile

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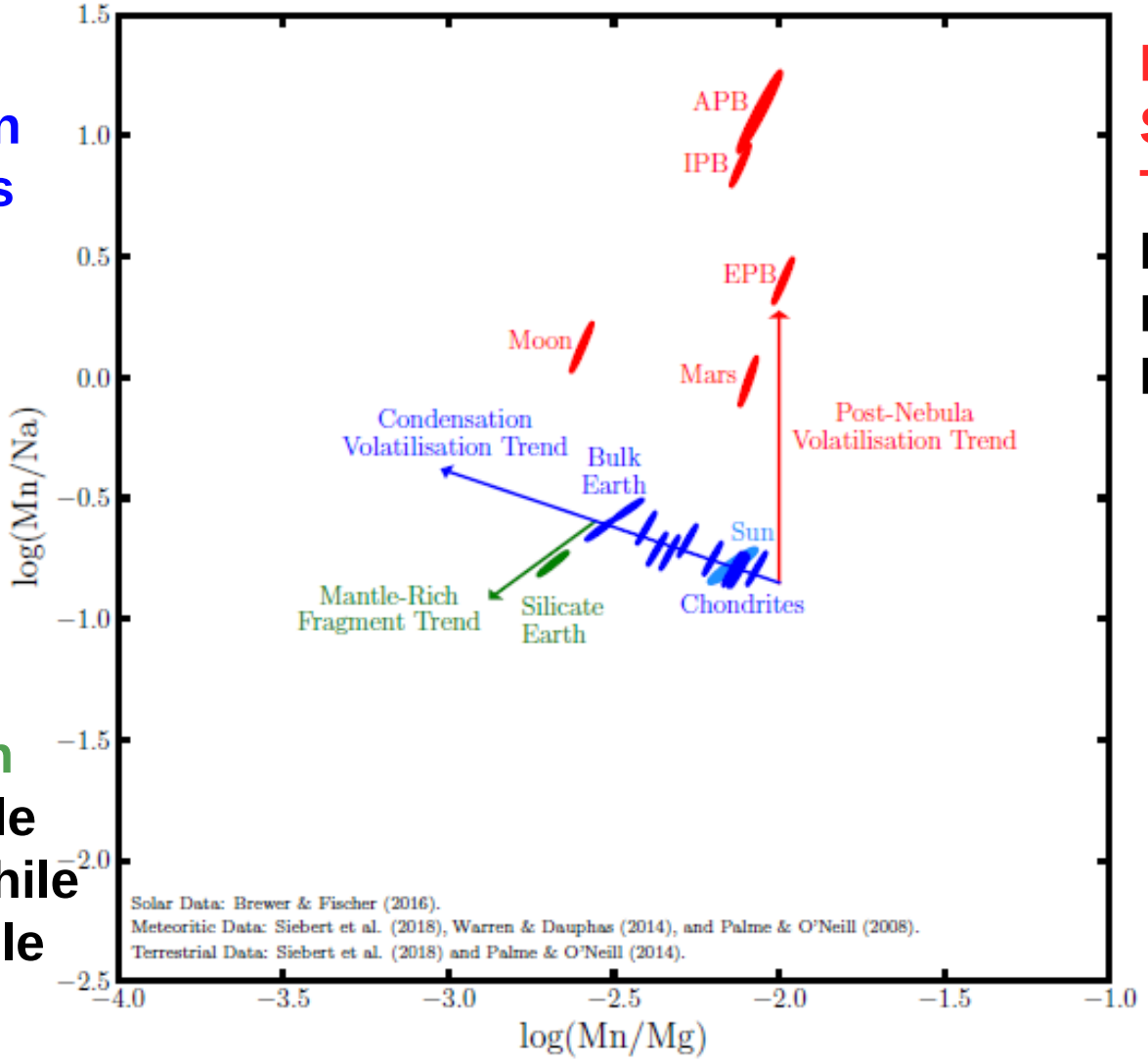

Post-Nebula Sublimation Temperatures

Na ~ 1100K

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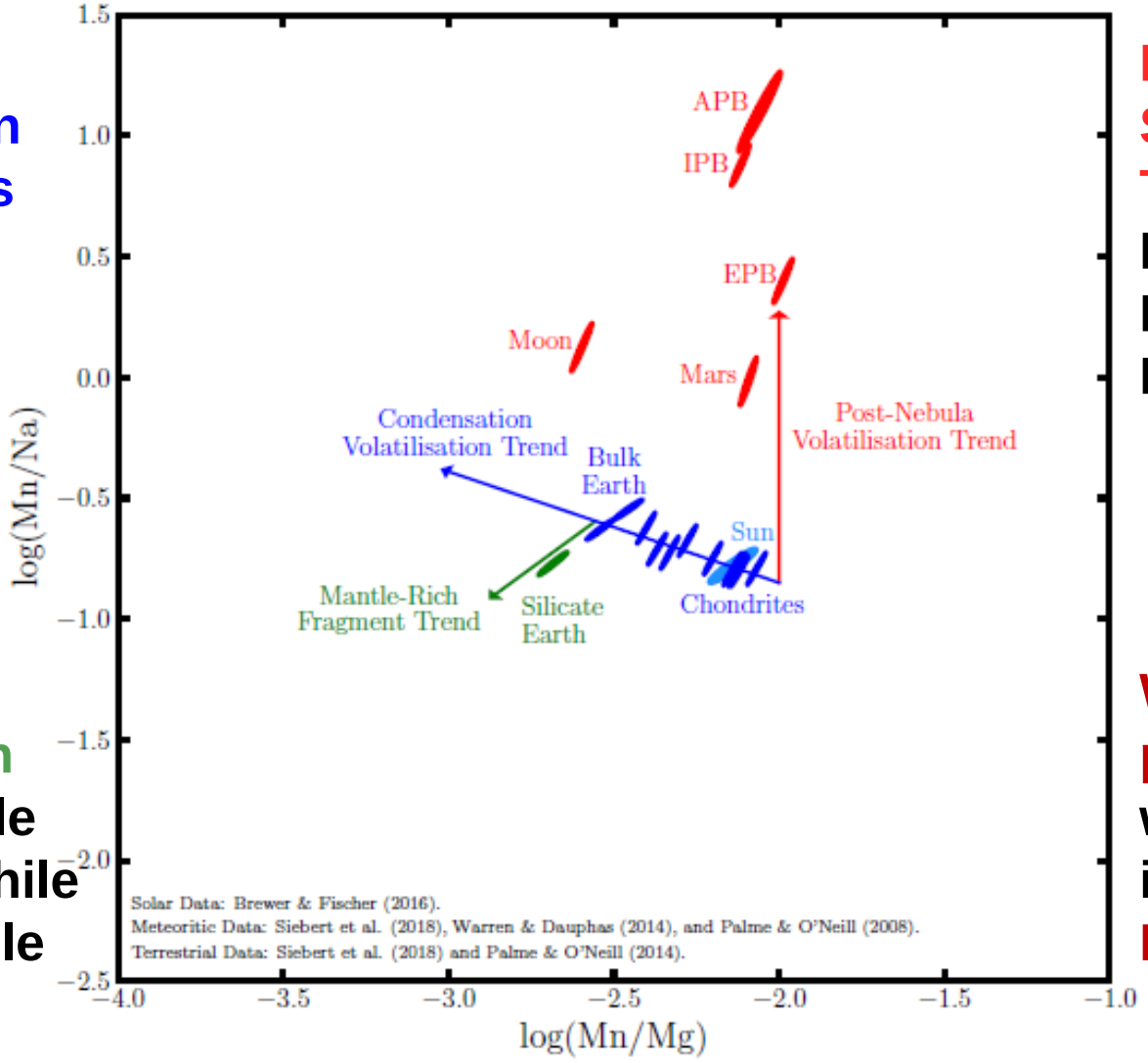

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Where do the pollutants of white dwarfs lie in Mn/Na vs Mn/Mg space?

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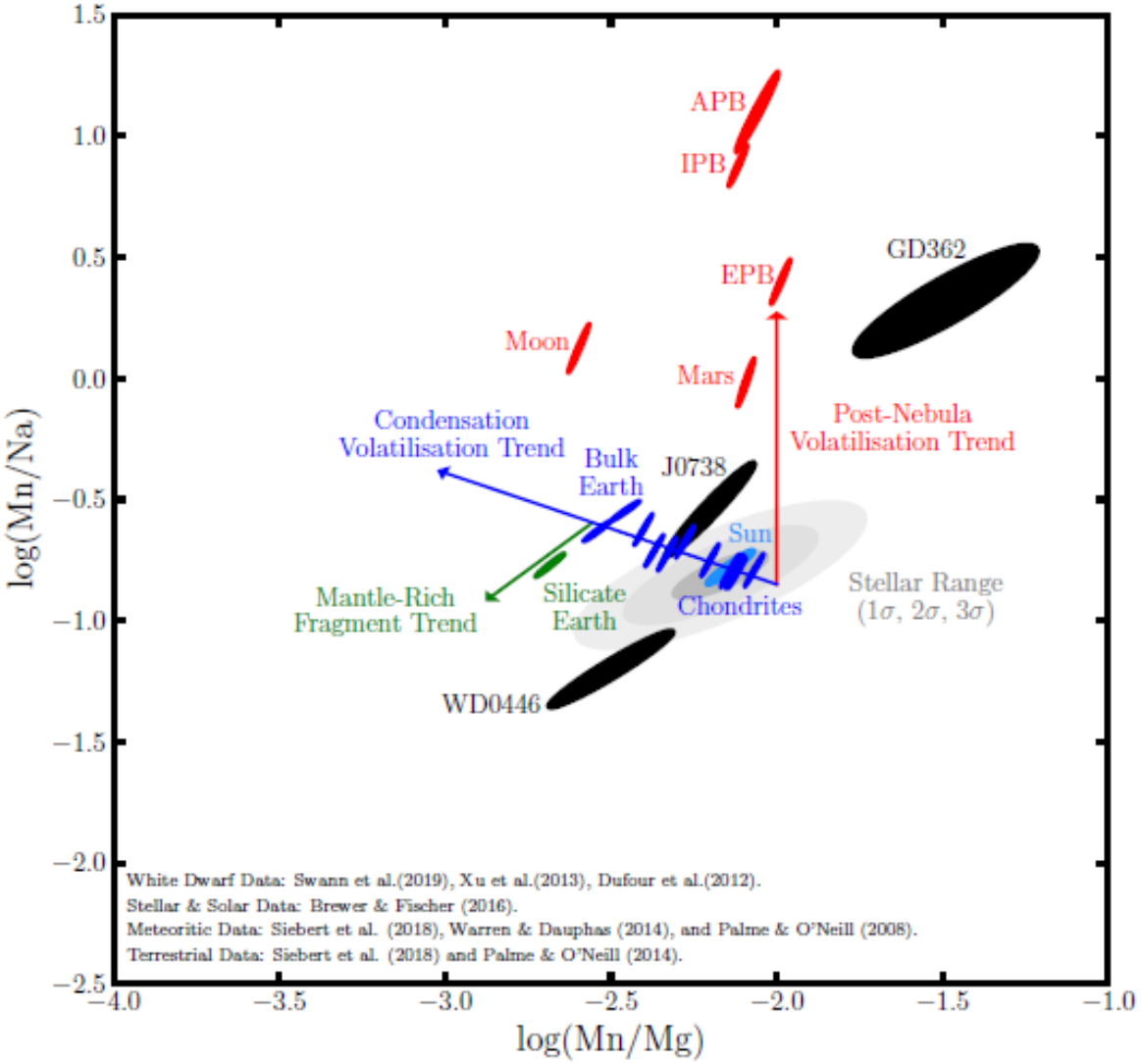

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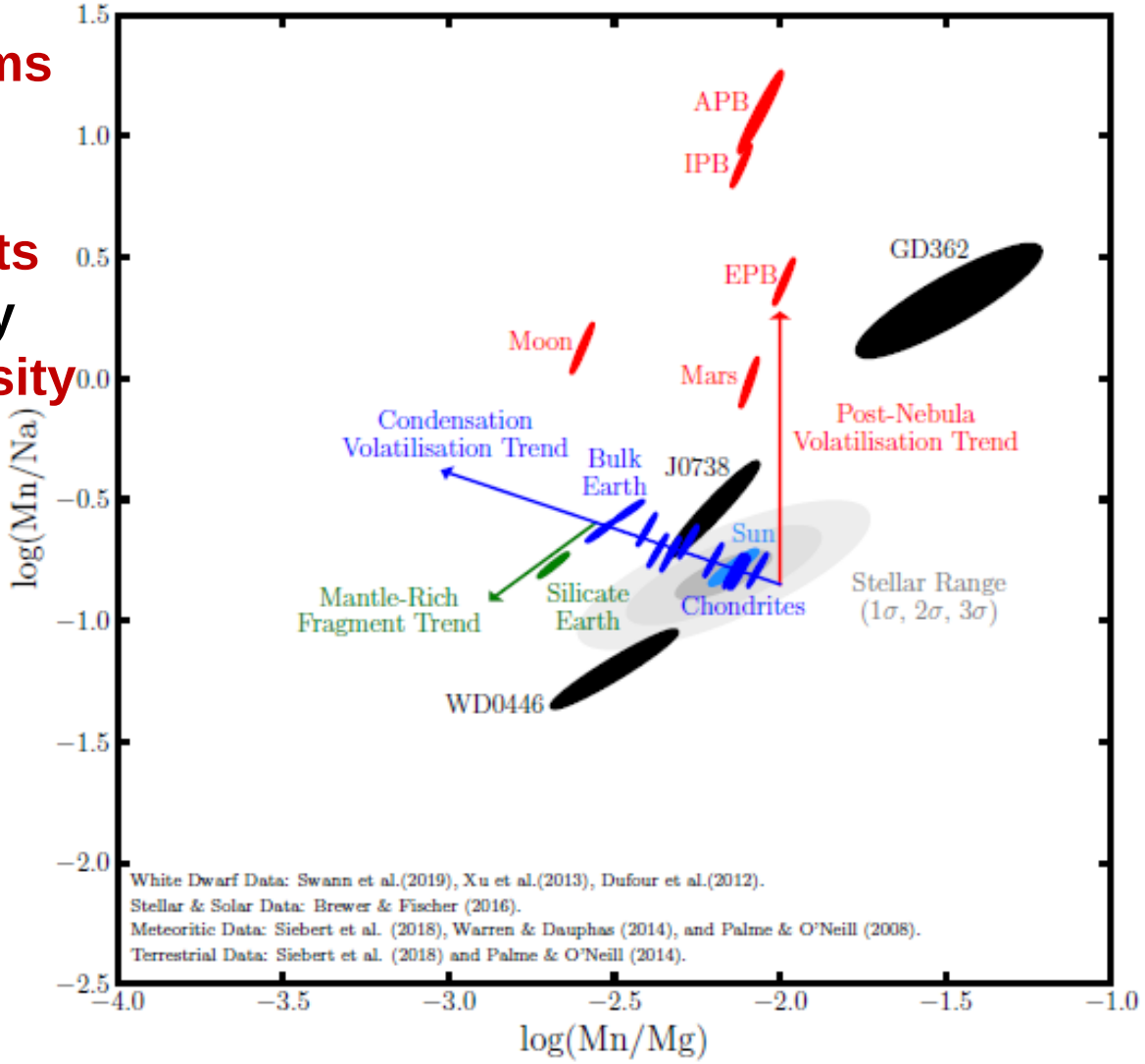
Probing the origin of volatile depletion in pollutant material

Only 3 systems have all 3 abundance measurements however, they show a diversity of locations.



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Probing the origin of volatile depletion in pollutant material

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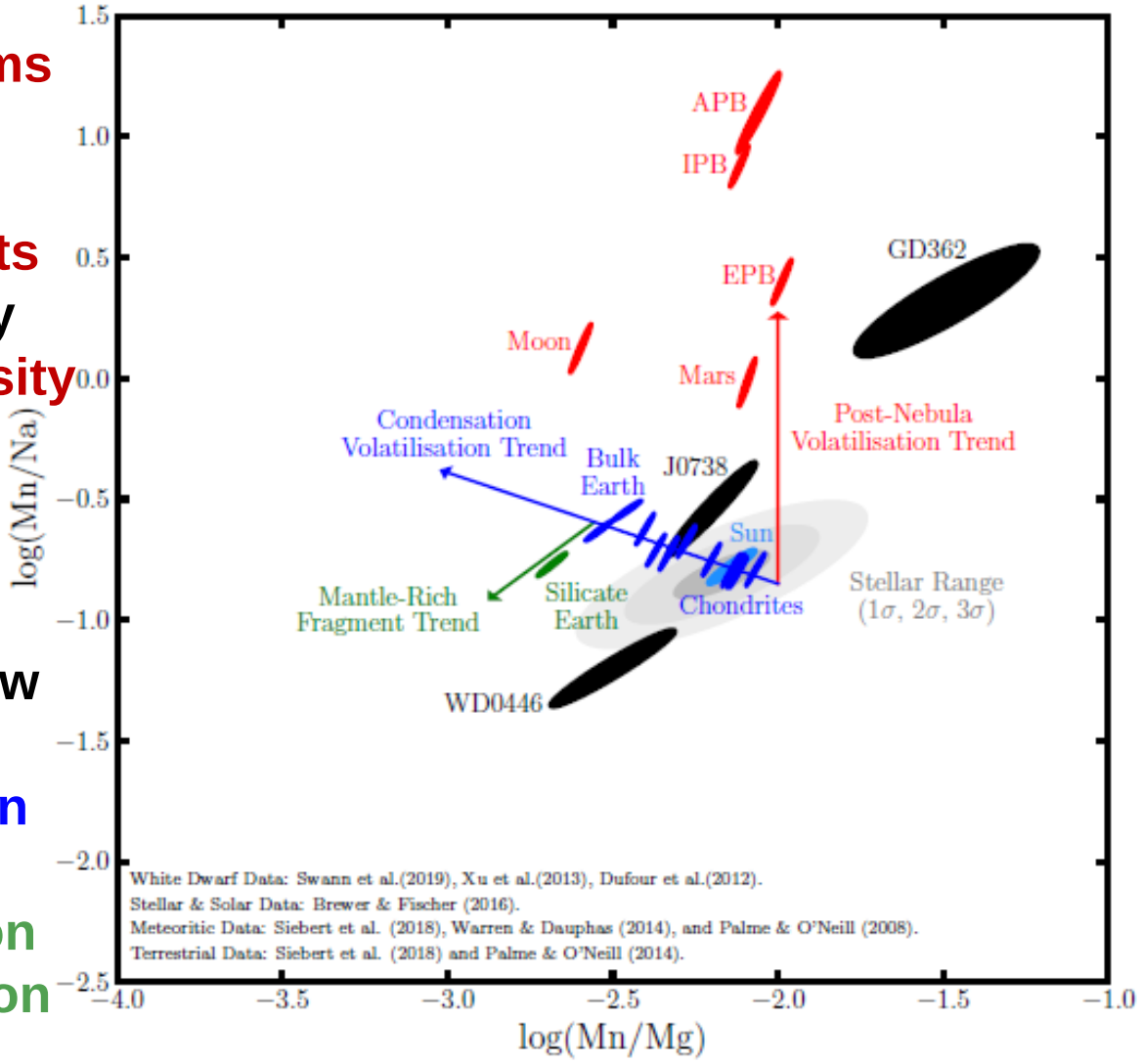
J0738 & **WD0446** show evidence for **condensation** followed by **differentiation /fragmentation**



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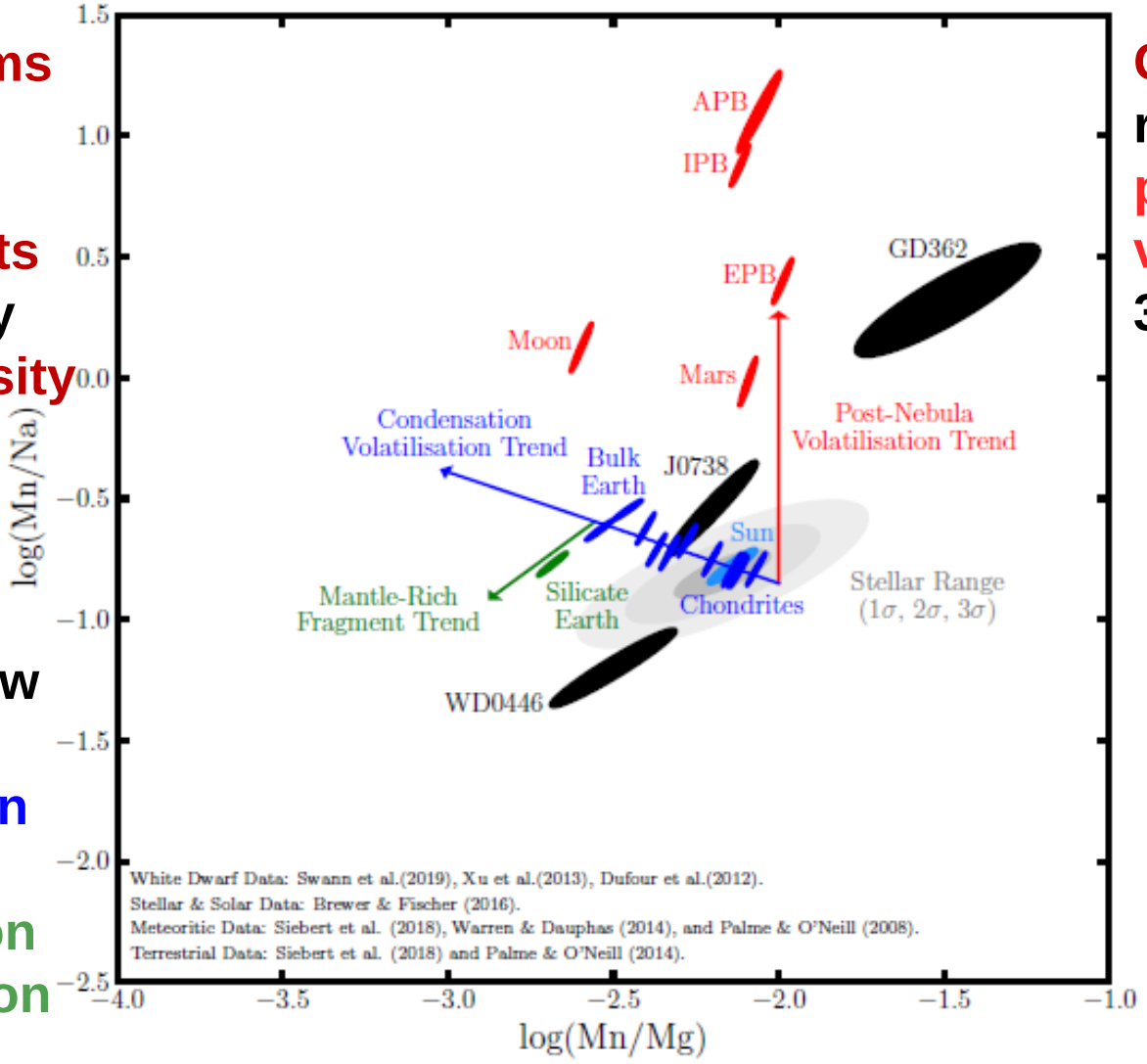

GD362 requires **post-nebula volatilisation** to 3 sigma

Harrison et al. (in prep)

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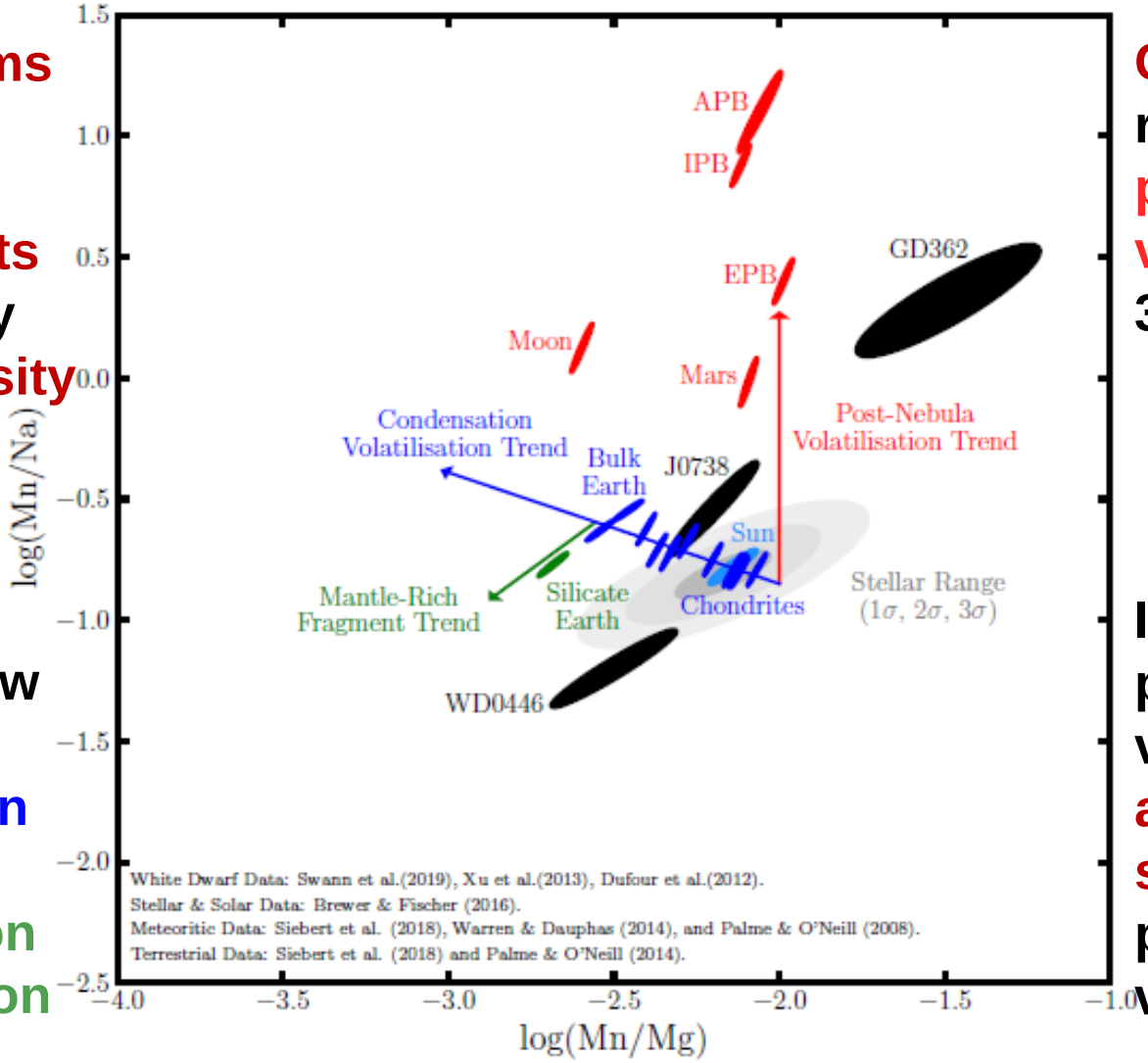

GD362 requires **post-nebula volatilisation** to 3 sigma

Is **GD362's** post-nebula volatilisation **analogous** to **solar system** post-nebula volatilisation?

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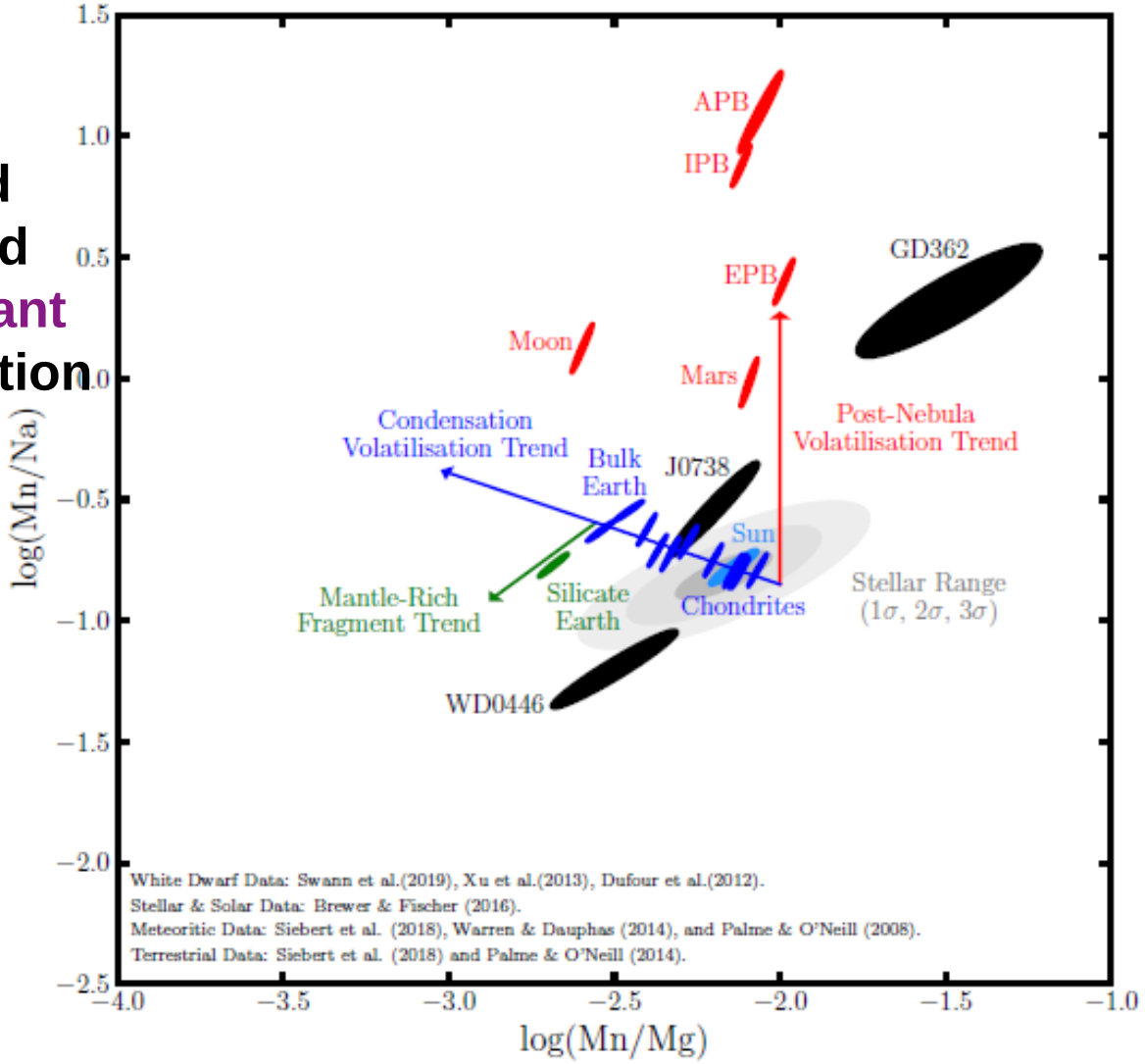
Probing the origin of volatile depletion in pollutant material

We **modelled** whether the **heating** could have occurred during the **giant branch** evolution of the star



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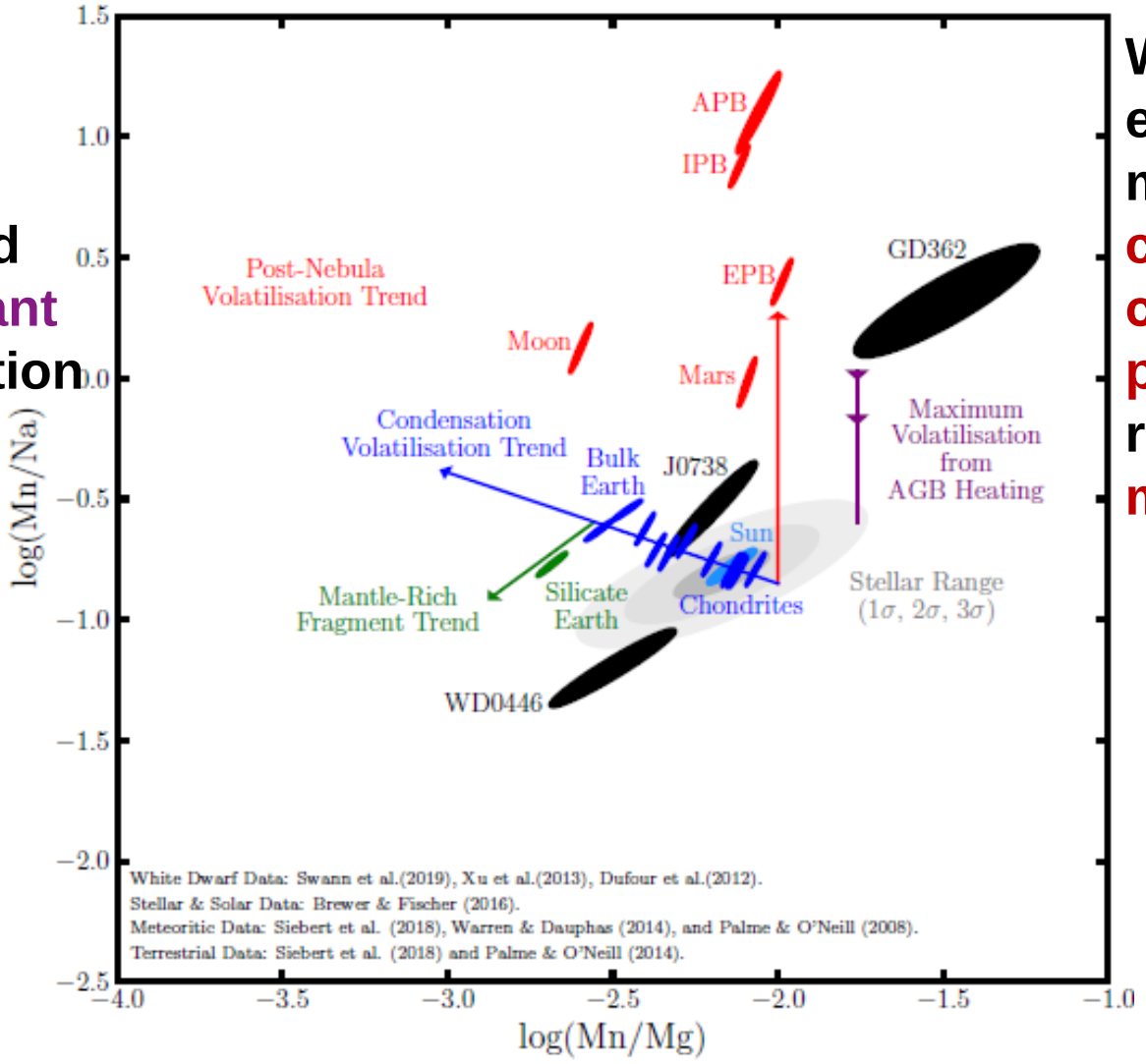

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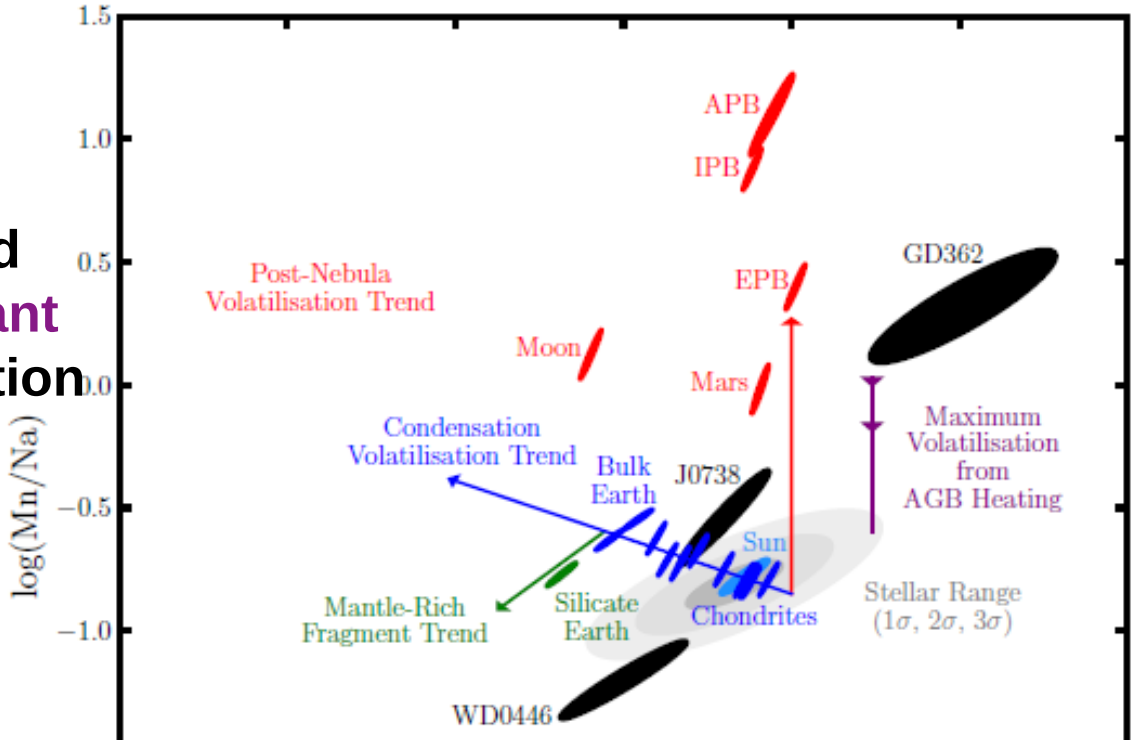
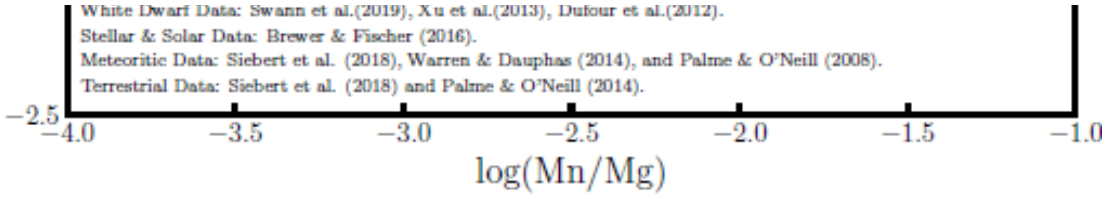


We found that even for the most **extreme case** we **couldn't produce** the required **melting**

Therefore, we conclude that the **pollutant** most **likely** went through a **magma ocean** stage due to collisional heating



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Conclusions

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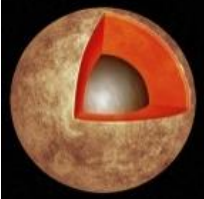

Pollutants provide evidence that planetary differentiation and collisional processing between differentiated bodies occurs often in exo-systems and so far pollutants only require solar system-like differentiation (Fe-Ni cores, Mg-Si-O mantles, Basaltic crusts)

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Thank you for your attention
I am happy to take any questions

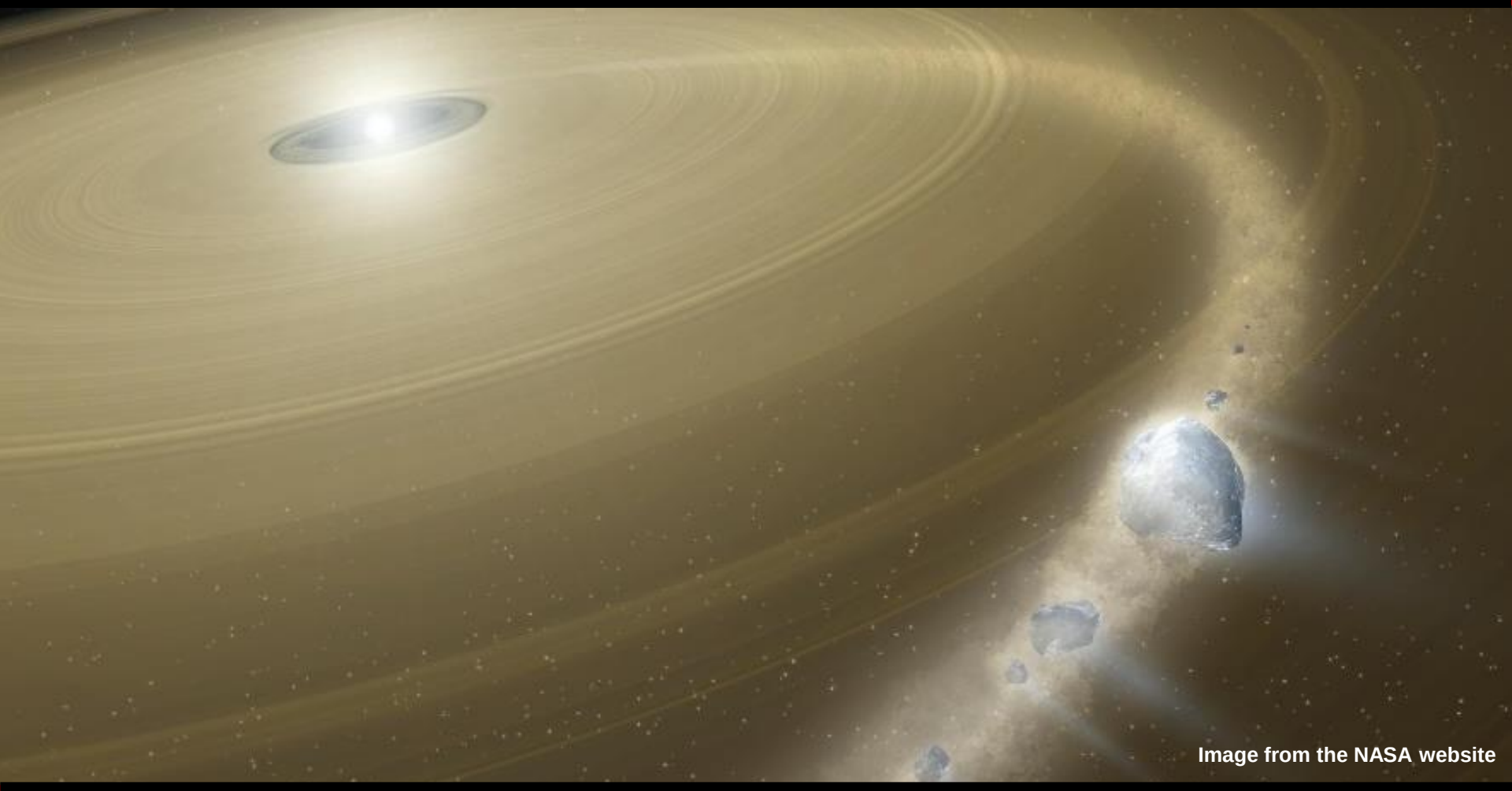

Image from the NASA website

John Harrison, Amy Bonsor, Oliver Shorttle, & Mihkel Kama
Institute of Astronomy, University of Cambridge
jhdh2@cam.ac.uk