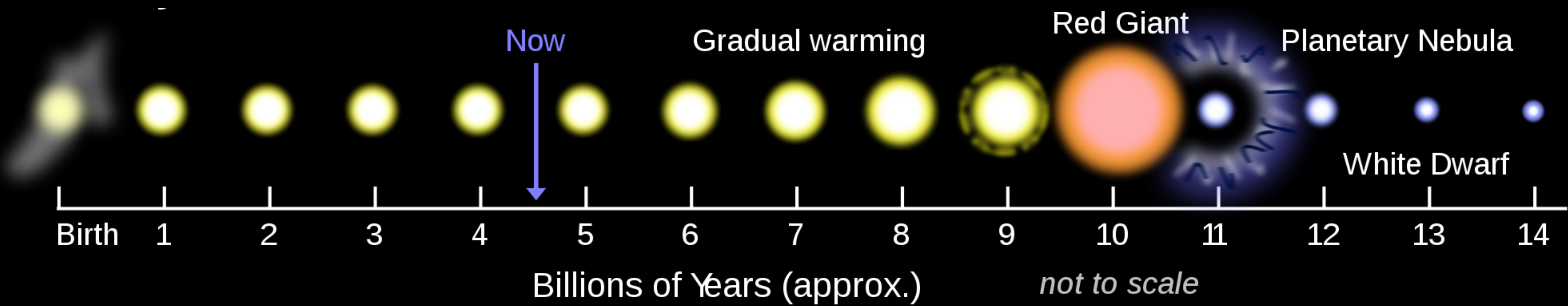
What **White Dwarfs** Reveal About **Rocky Exoplanets** and **Exo-asteroids**

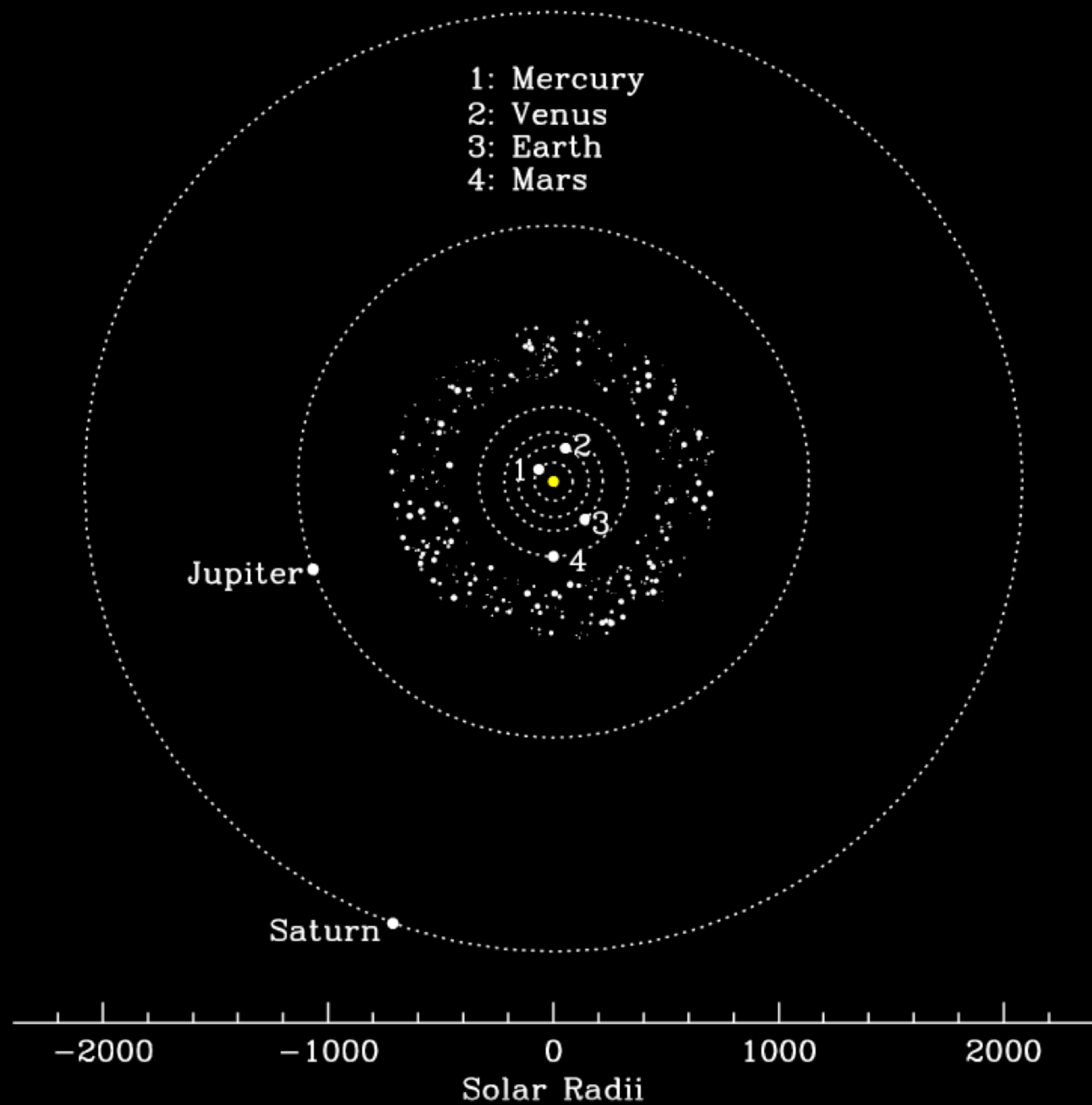
J.J. Hermes

http://sites.bu.edu/buwd

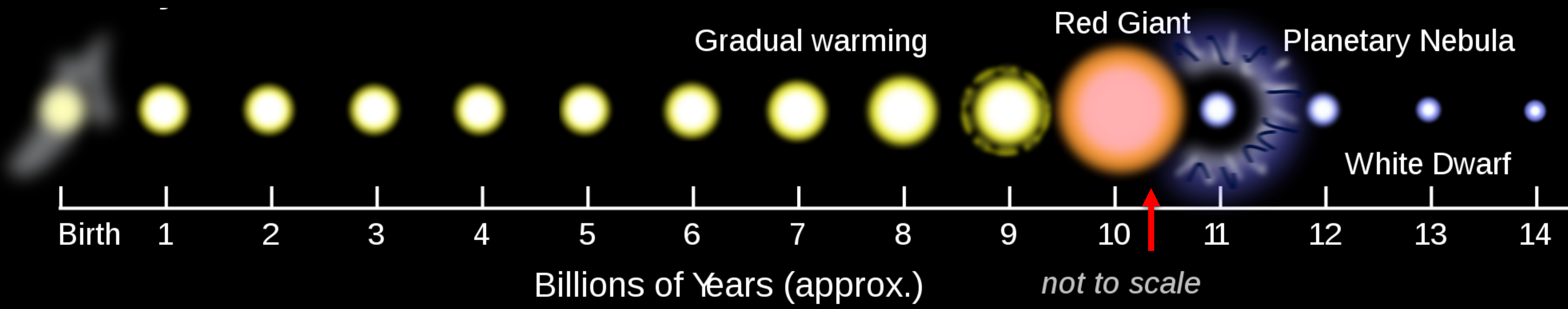
BOSTON UNIVERSITY



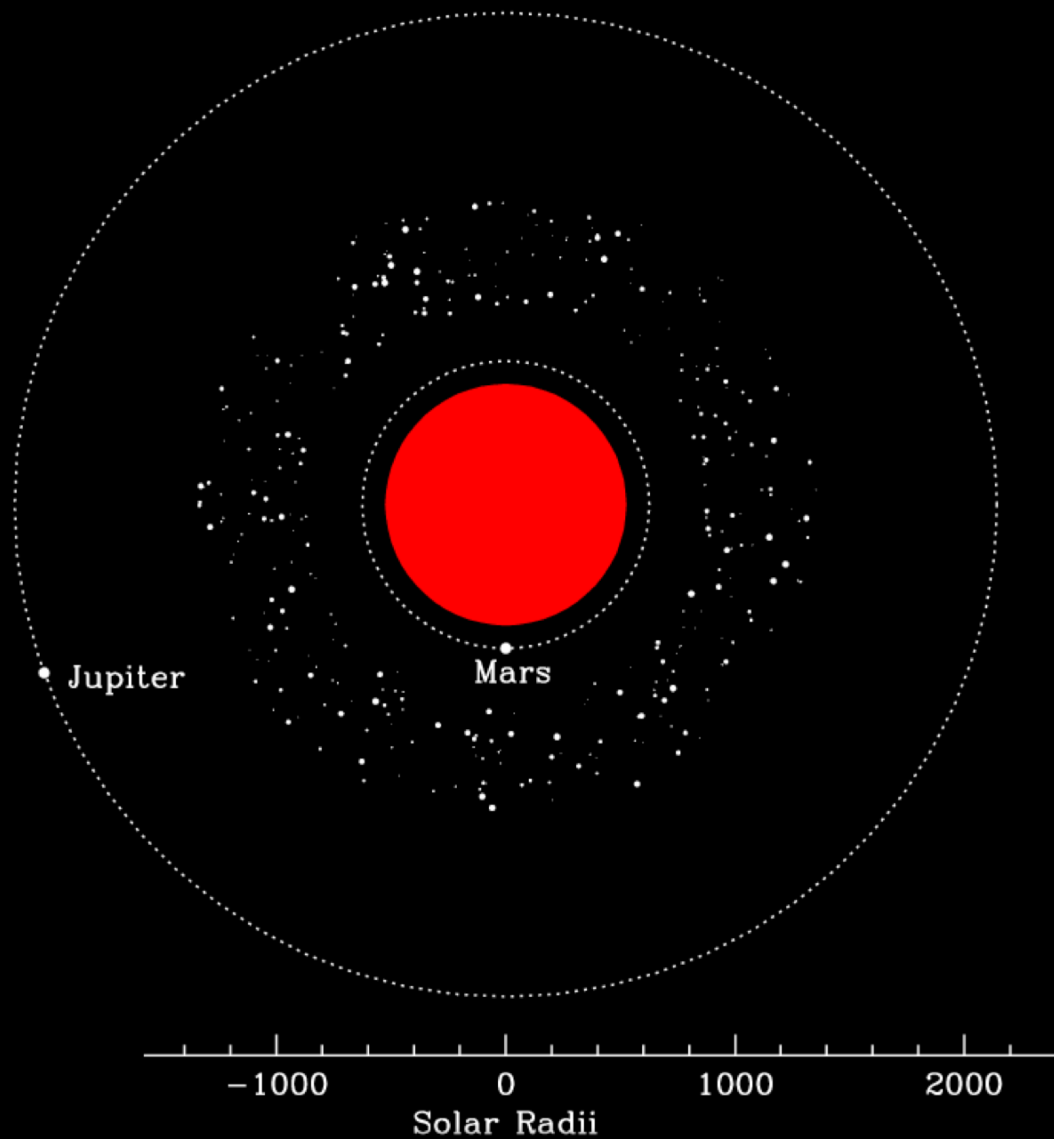
Today



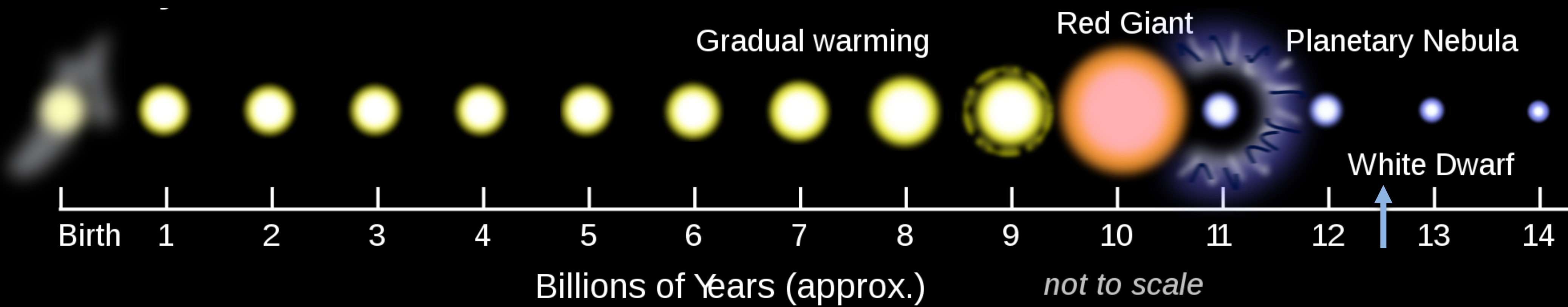
Boris Gänsicke



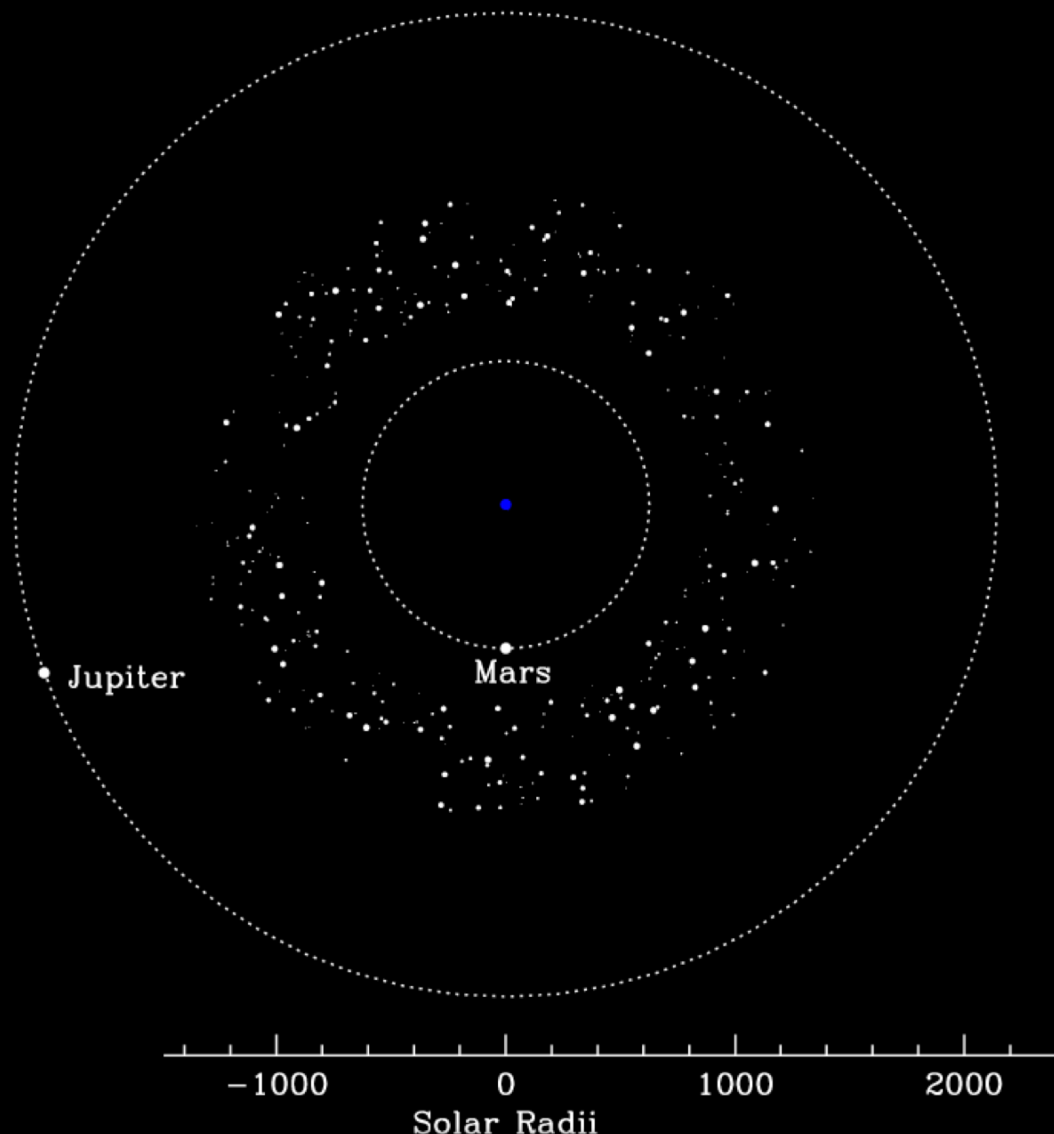
5 billion years from now



Boris Gänsicke



8 billion years from now



Boris Gänsicke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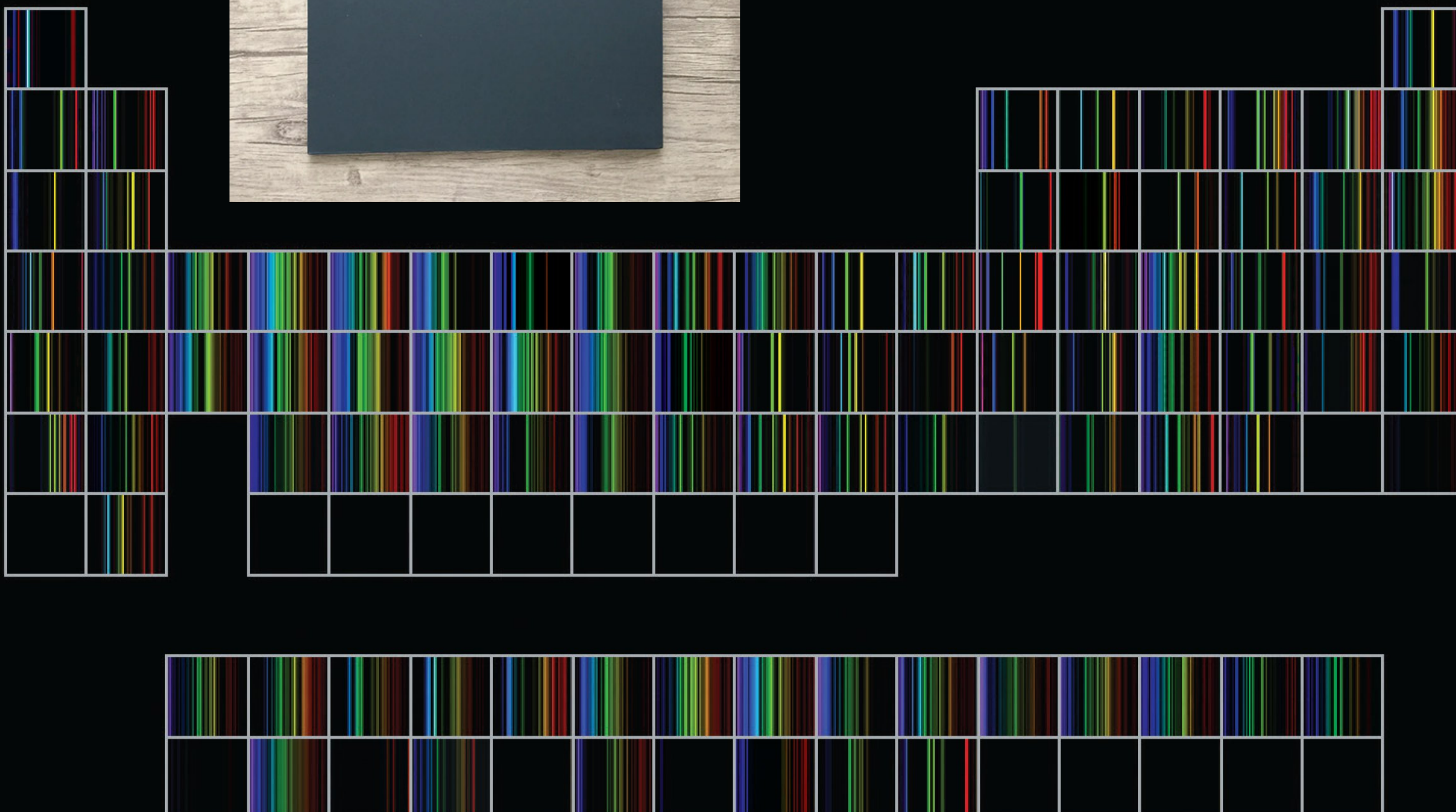
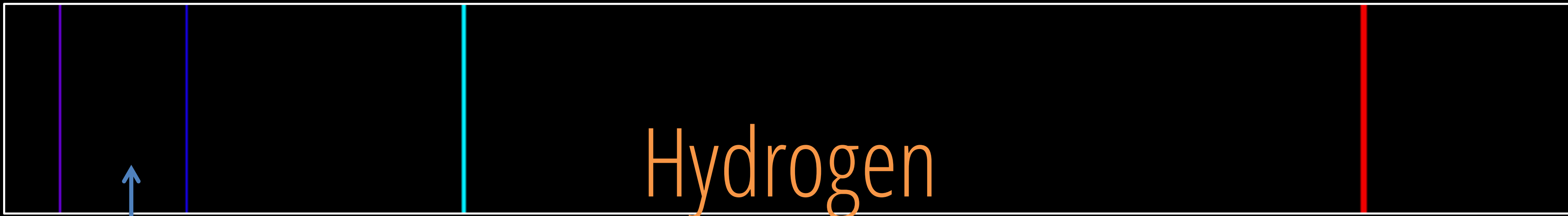


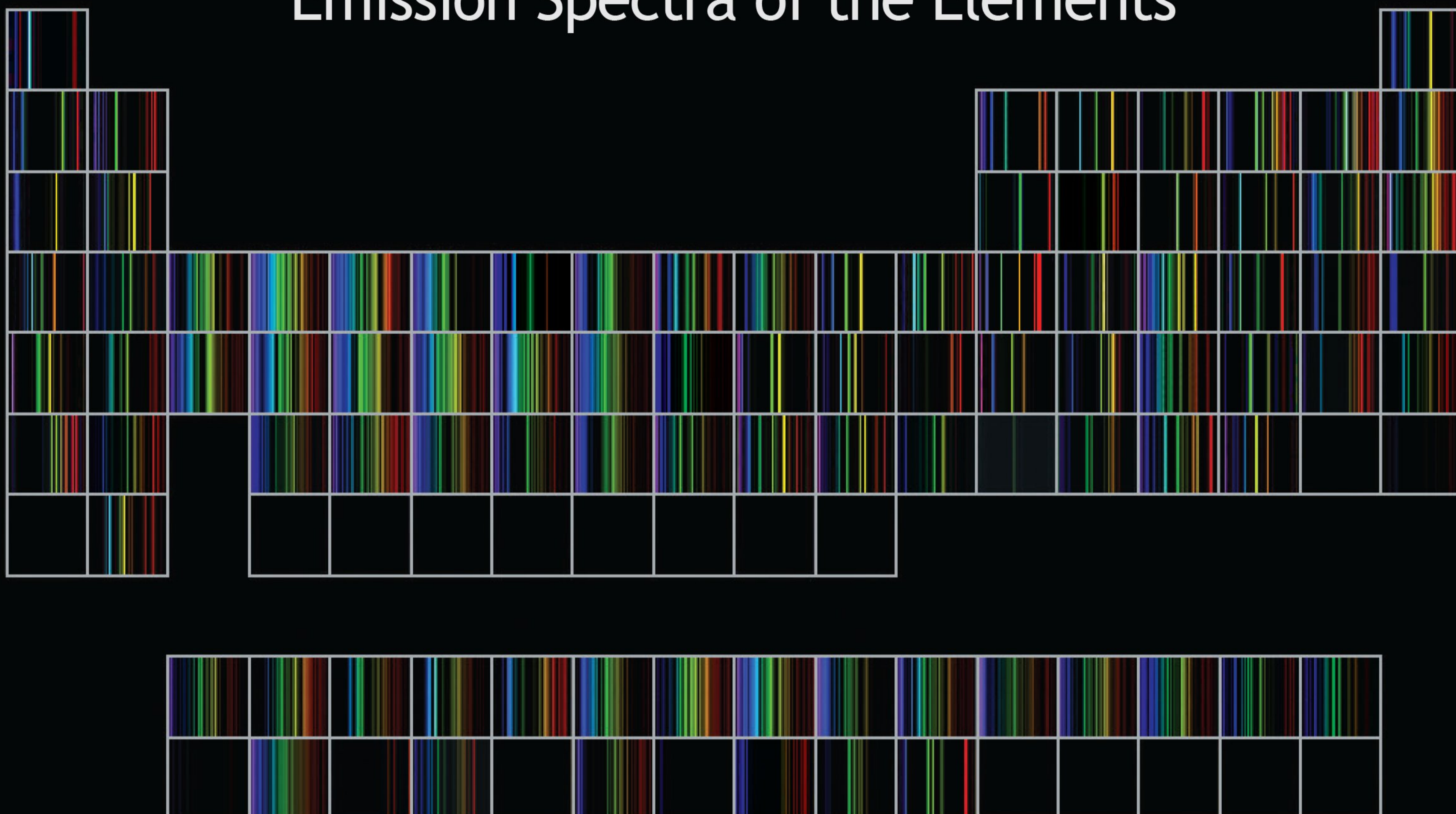
field tested systems

REAL-TIME CLASSROOM SPECTROSCOPY

www.fieldtestedsystems.com/ptable/



Emission Spectra of the Elements



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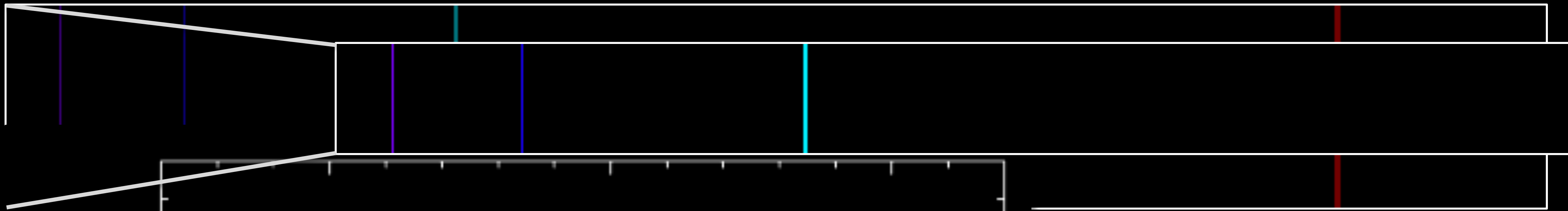
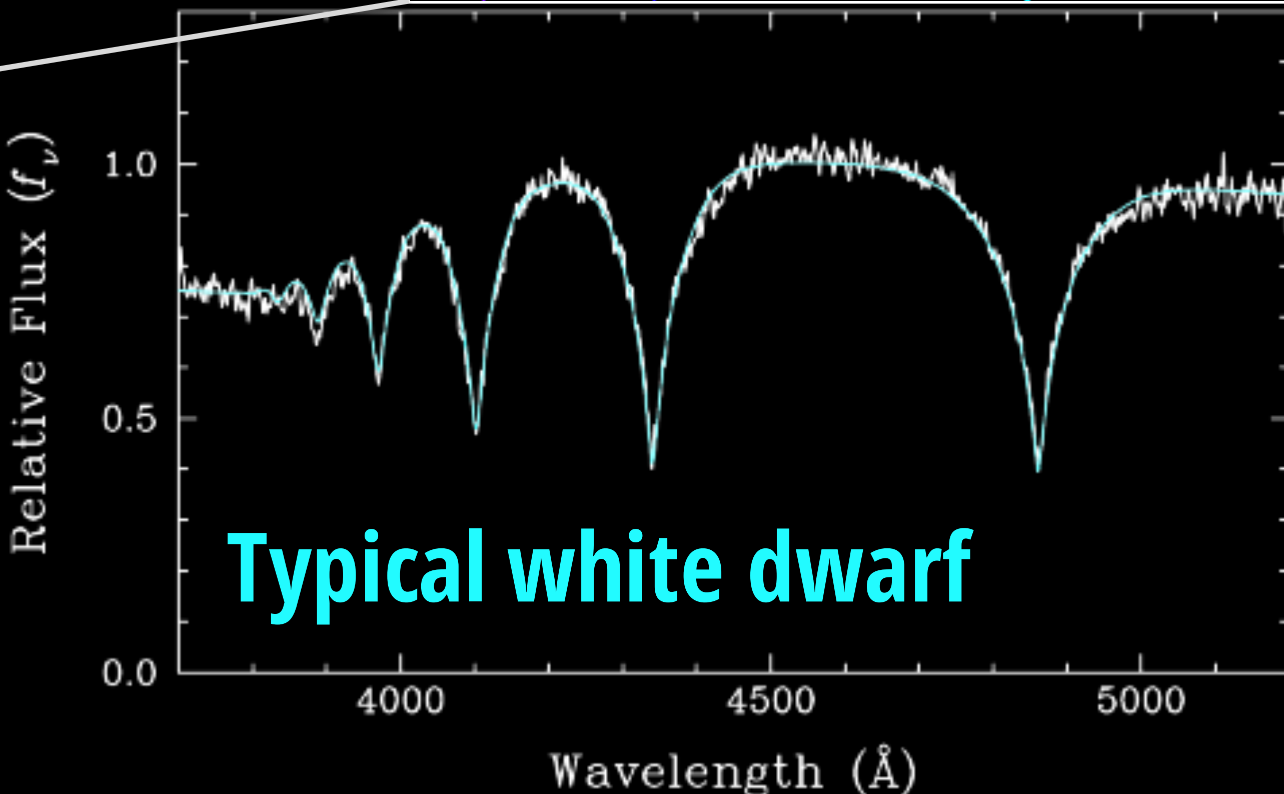
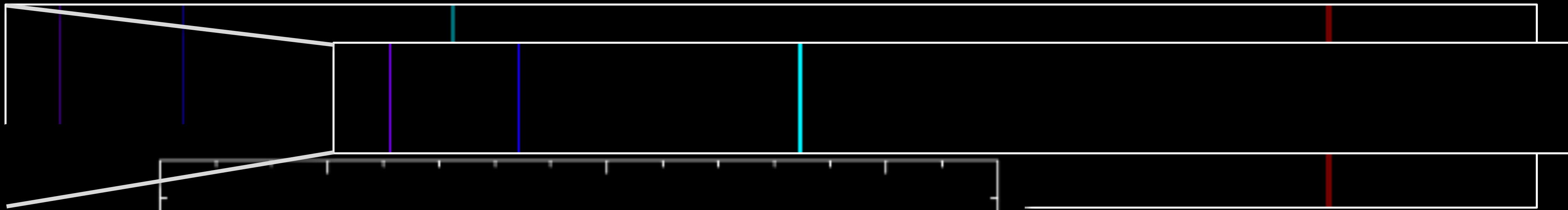
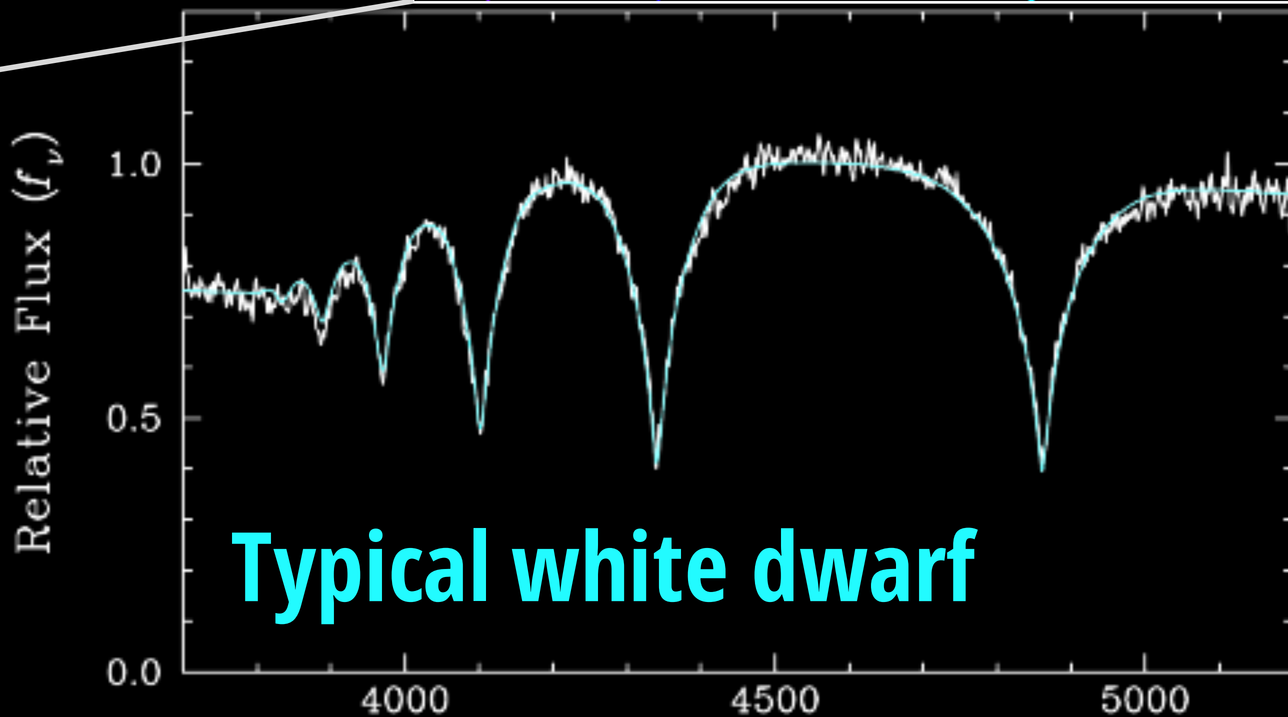


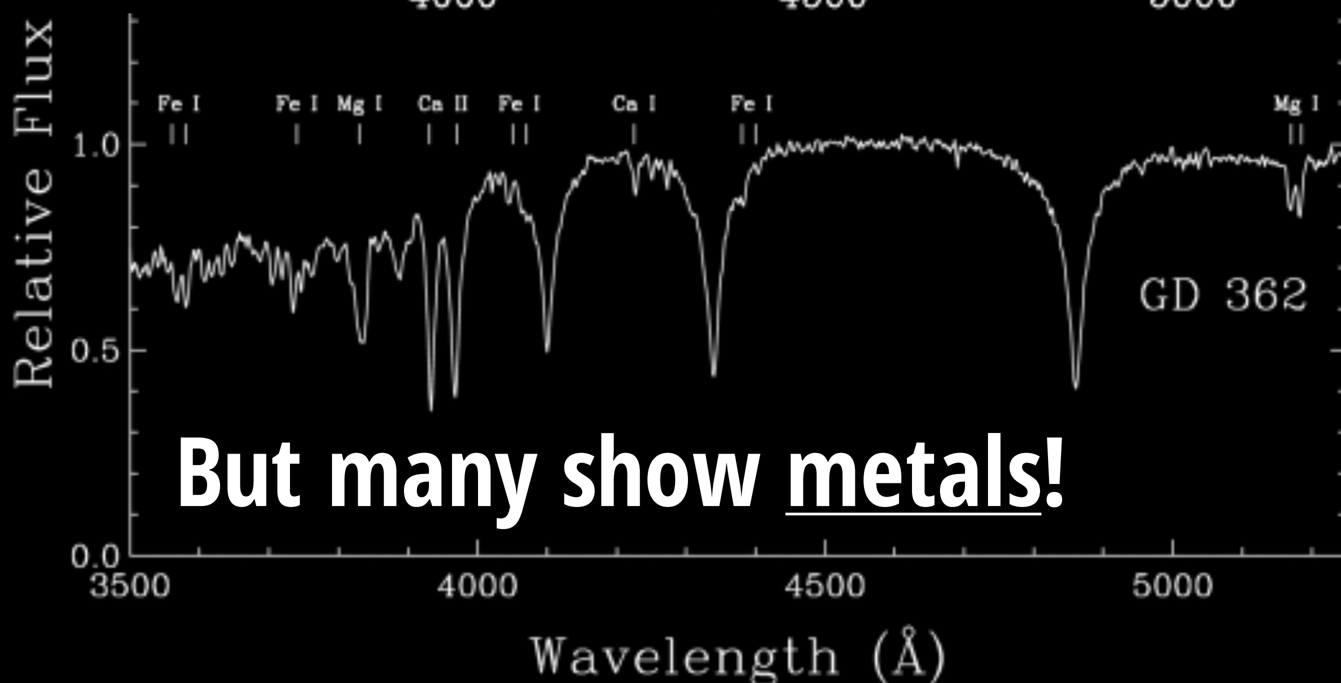


Settling times << years

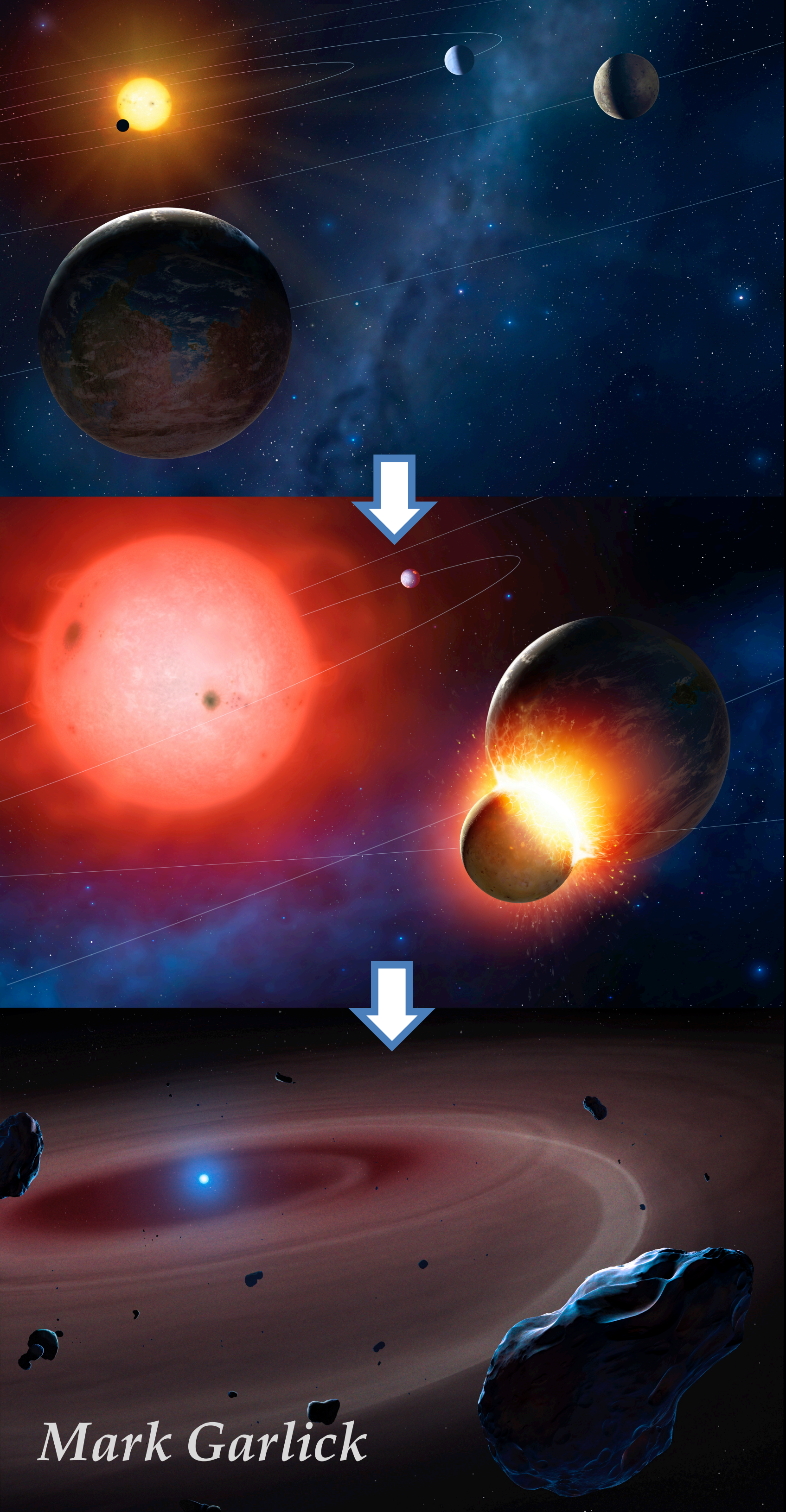
Expect pure hydrogen photospheres




Relative Flux (f_ν)
1.0
0.5
0.0
4000
4500
5000
Typical white dwarf


Relative Flux
Fe I
Fe I
Mg I
Ca II
Fe I
Ca I
Fe I
Mg I
1.0
0.5
0.0
3500
4000
4500
5000
GD 362
Wavelength (Å)
But many show metals!


Sharyn Morrow



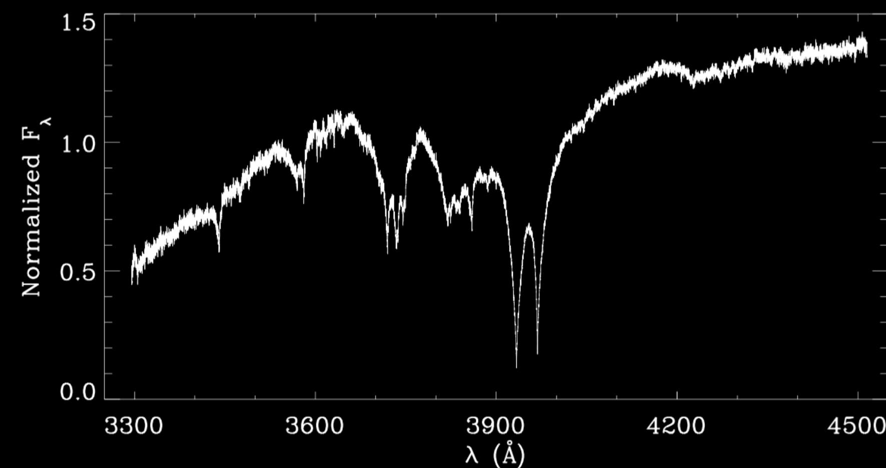
1. Pollution in white dwarfs reveals the future of planetary systems around stars like our Sun.

2. As the star evolves, the **orbits** of surviving planets **expand**. Objects destabilize, some **scatter** in.

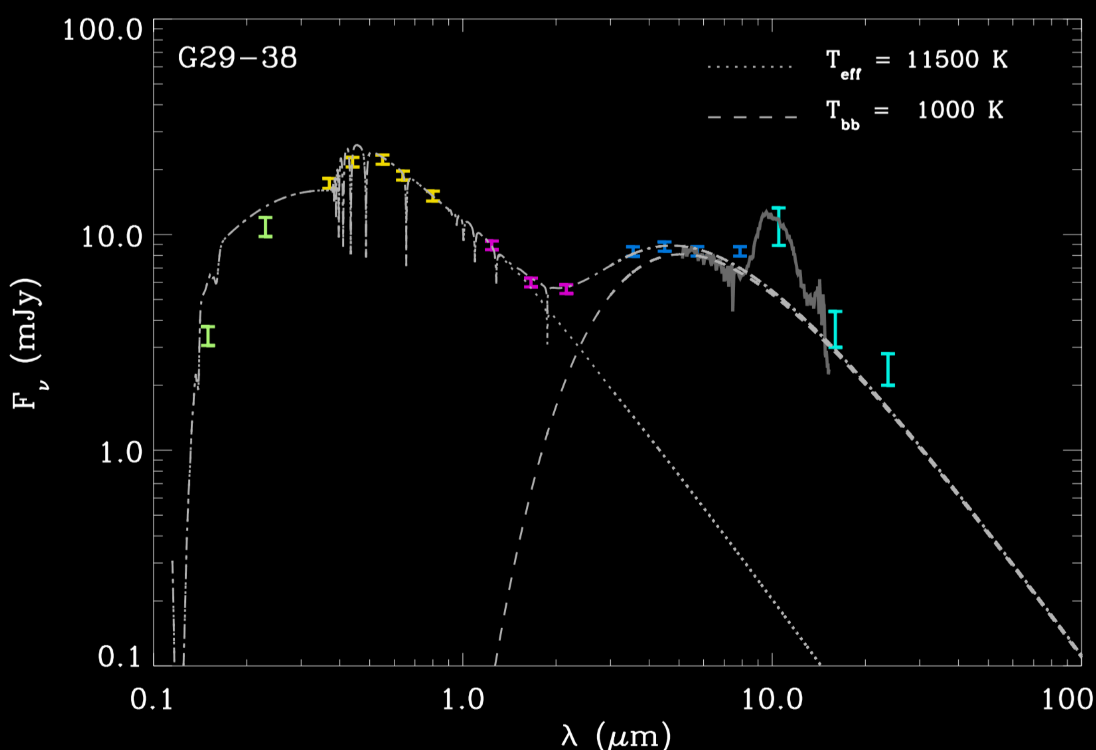
3. Ancient solar systems have leftover debris. We can see it if it pollutes a pristine **white dwarf**.

Observational evidence for this hypothesis:

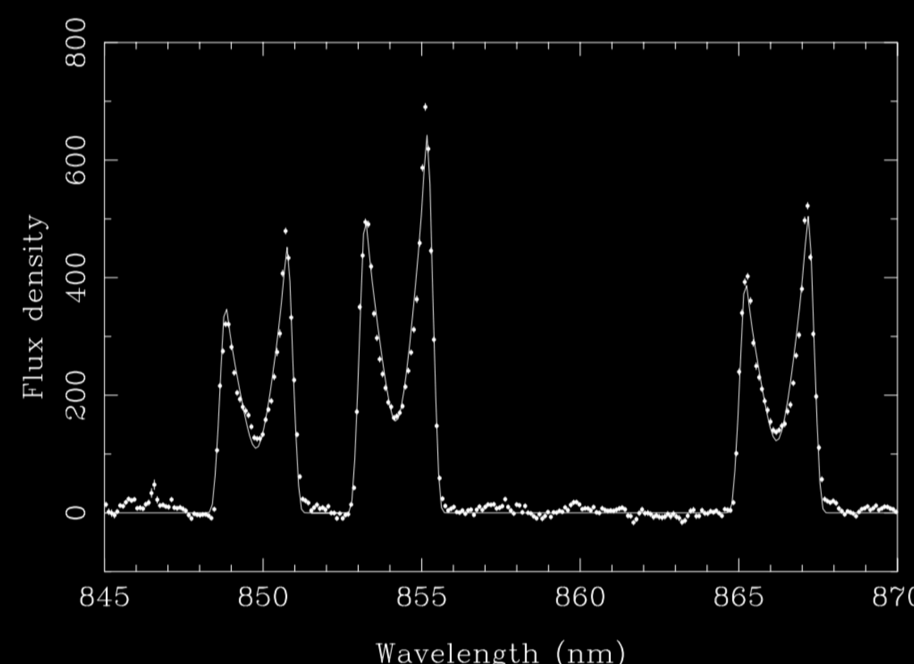
(a) Photospheric pollution



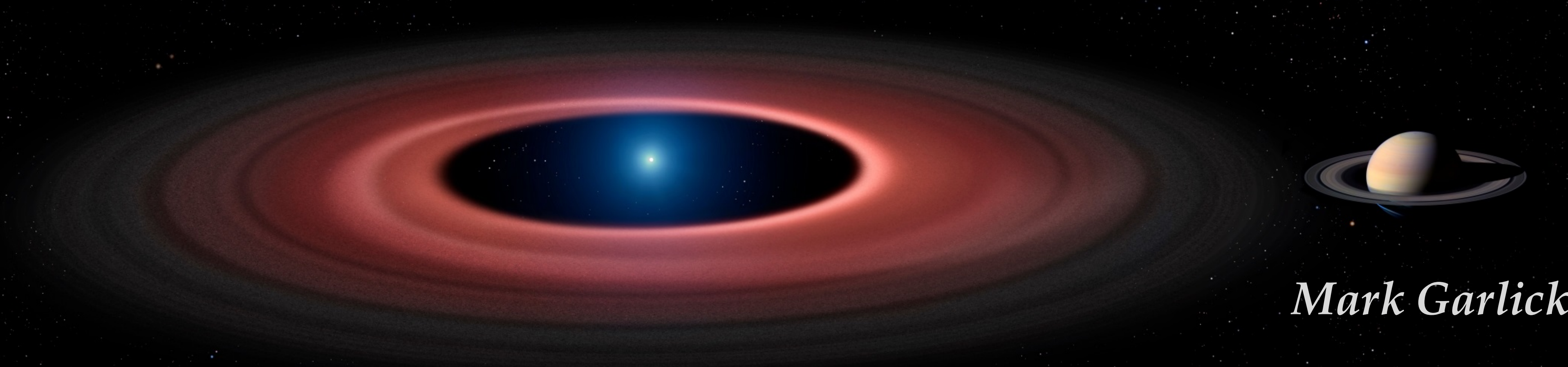
(b) IR excess (**dust** disks)



(c) Ca emission (**gas** disks)



Farihi 2016, Veras 2016



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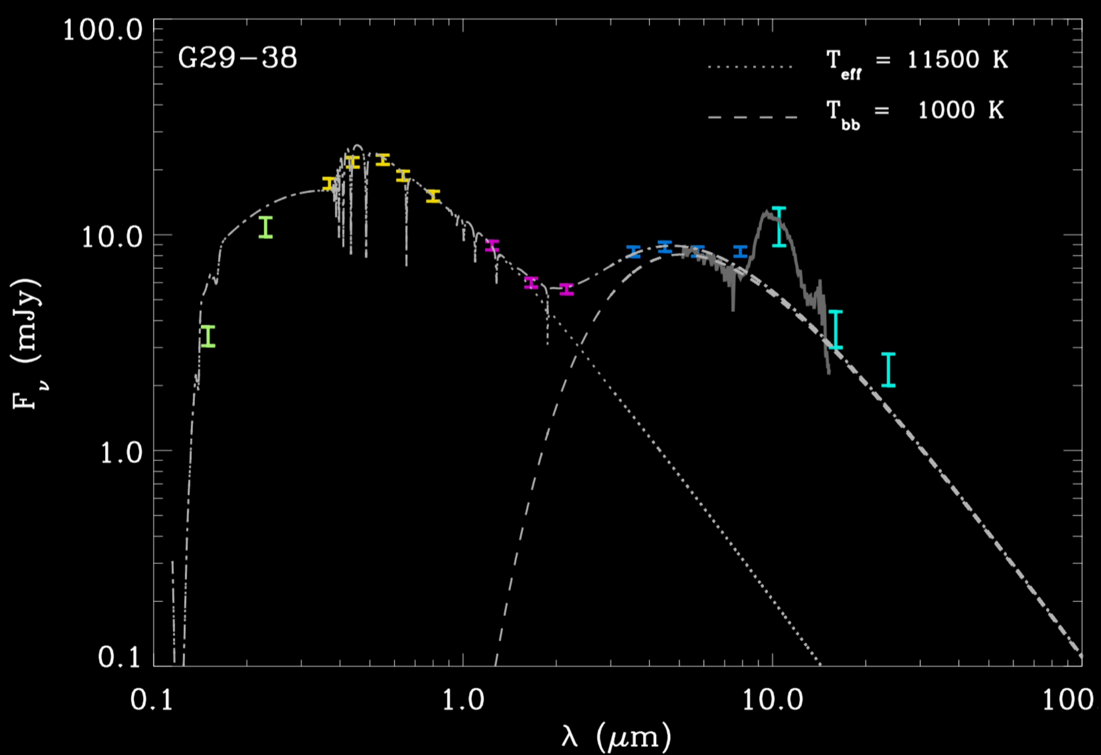

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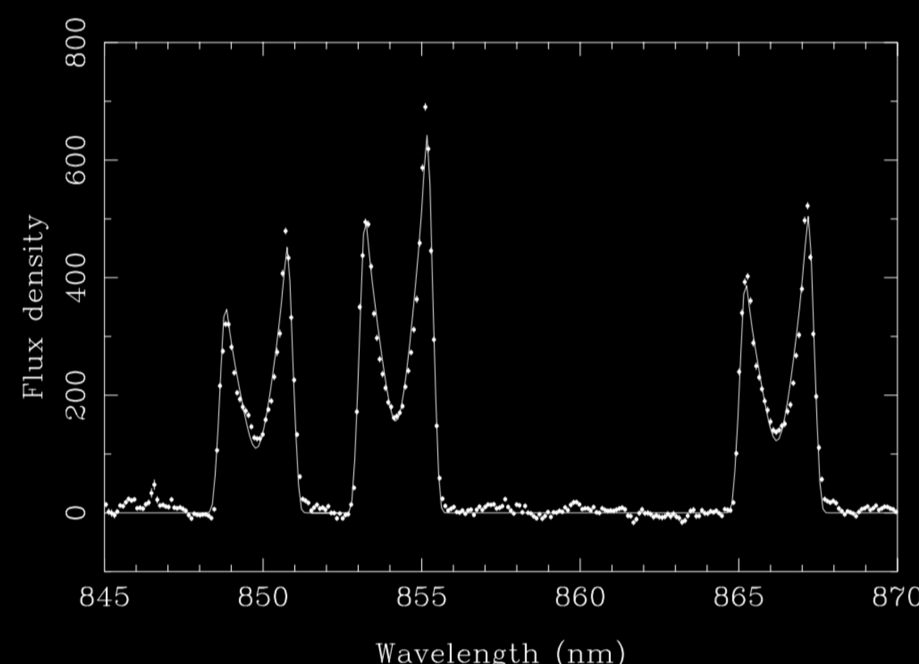
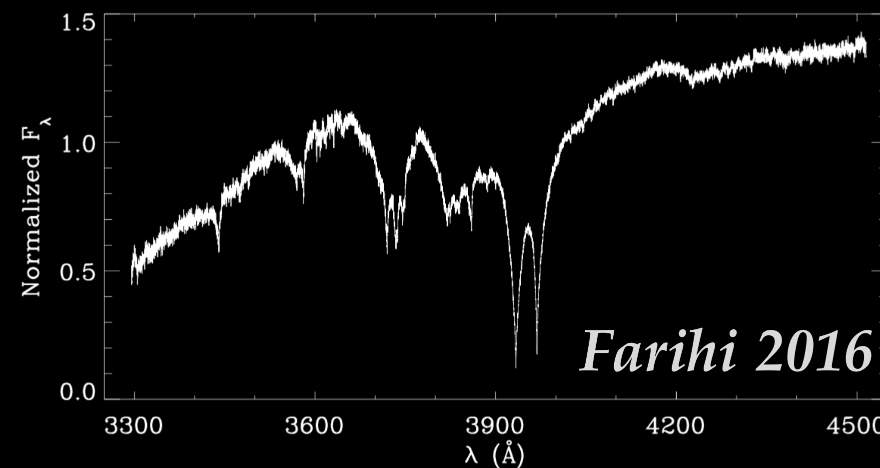


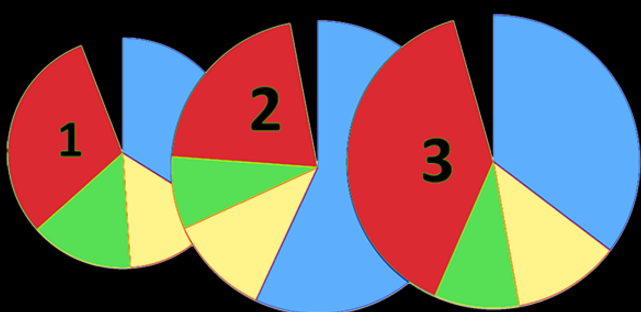
Farihi 2016, Veras 2016

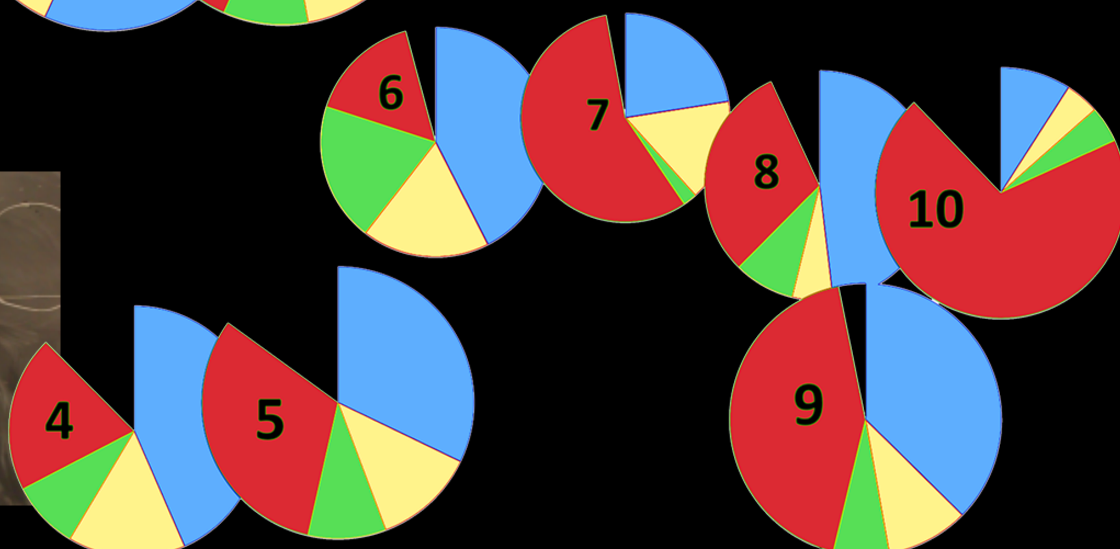
(a) Photospheric pollution

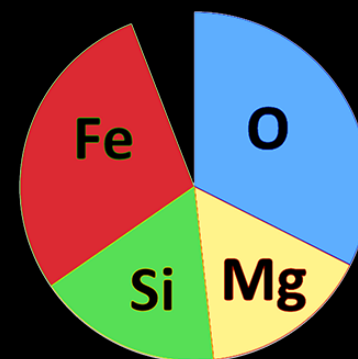
We can **directly** measure **abundance ratios** with spectroscopy



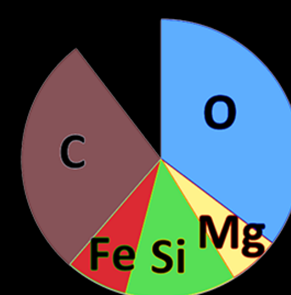
Abundances of rocks falling on 10 different white dwarfs:







Bulk Earth



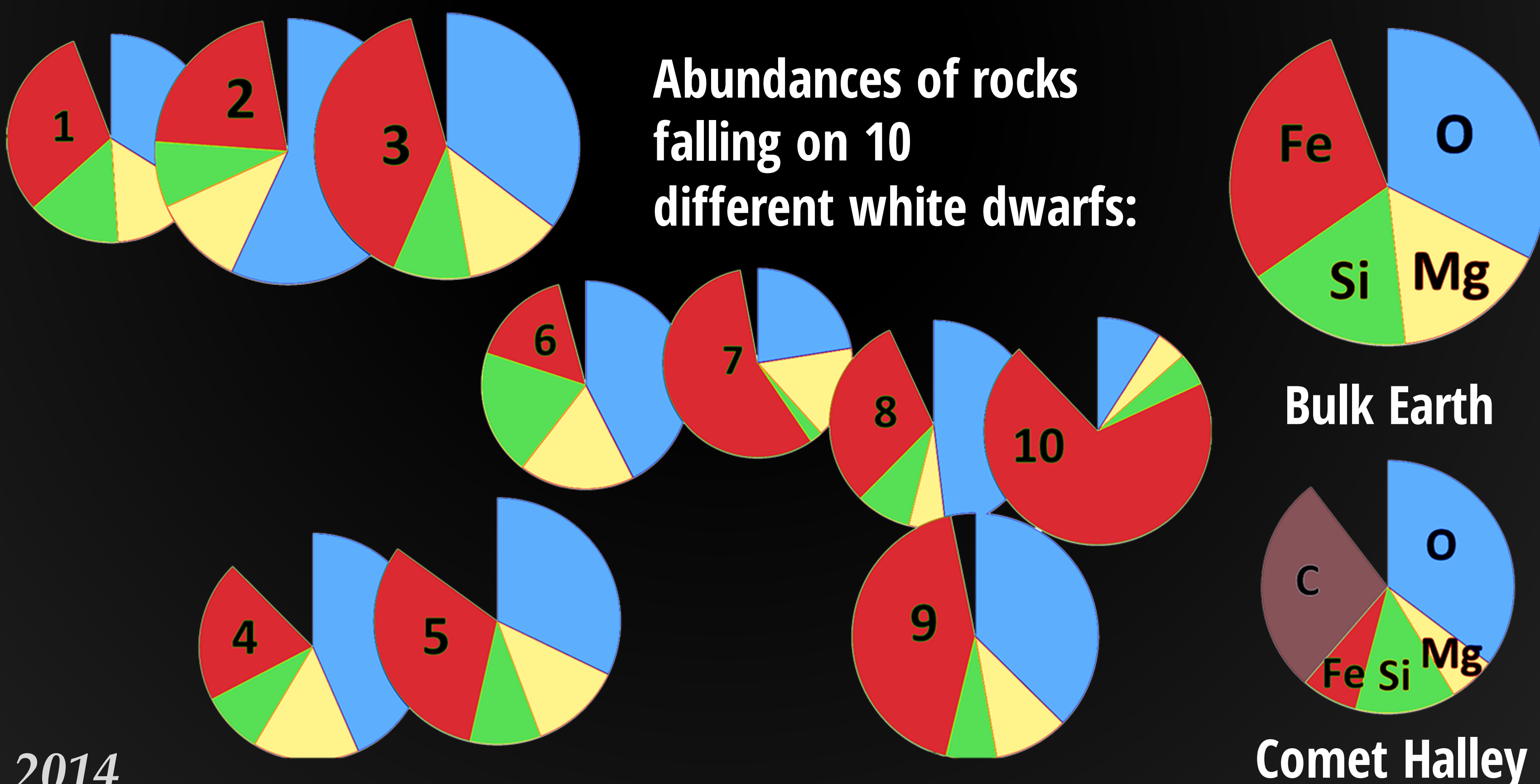
Comet Halley

Xu et al. 2014

Comets crash into our Sun all the time.
Each one contributes less than 0.0000000000001% of the Sun’s metals

NASA/SOHO

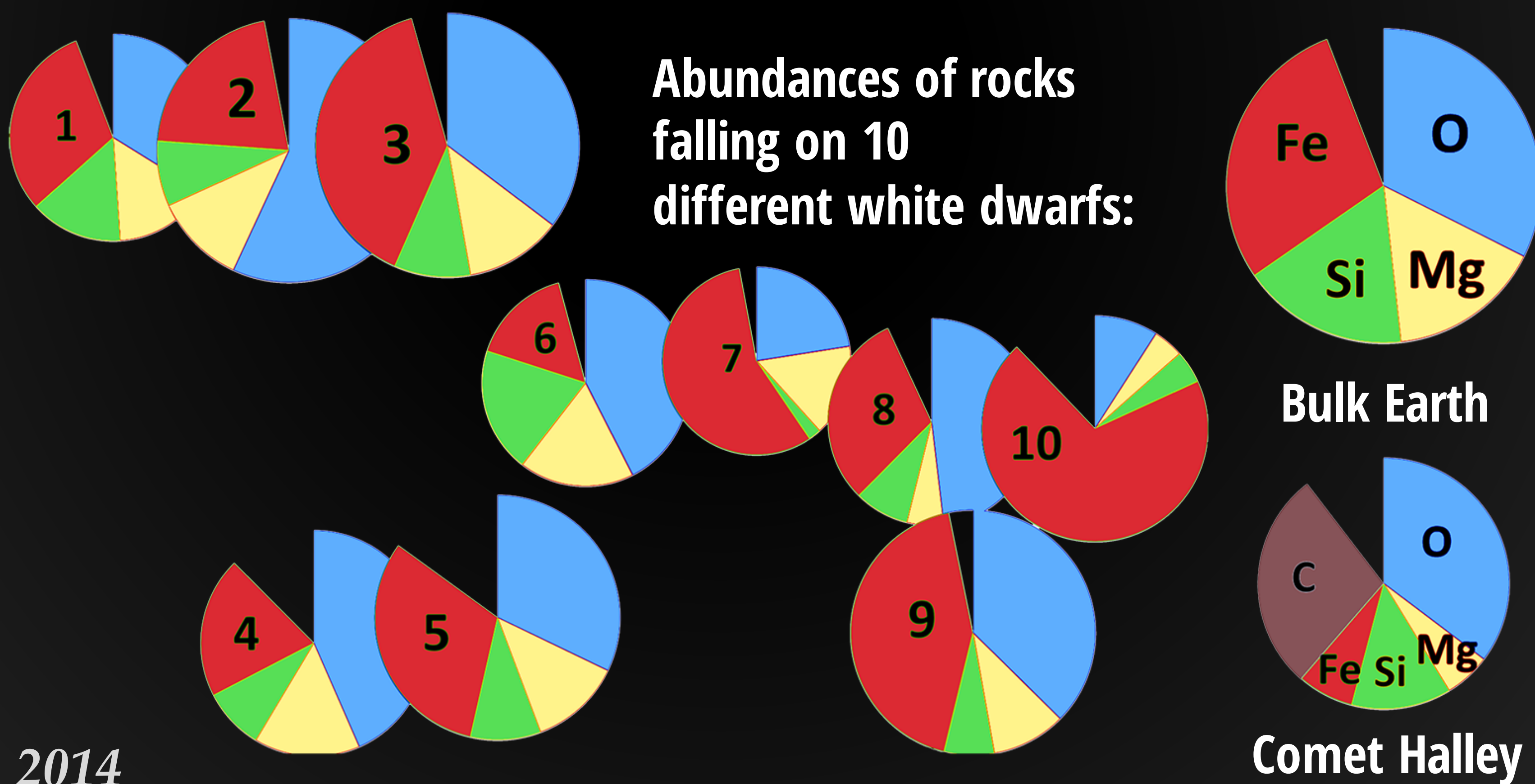
We can **directly** measure **abundance ratios** with spectroscopy



Xu et al. 2014

Rocks = MgO, Al_2O_3, SiO_2, CaO, TiO_2, Cr_2O_3, MnO, FeO, Fe_2O_3, …

Volatiles = CO_2, H_2O



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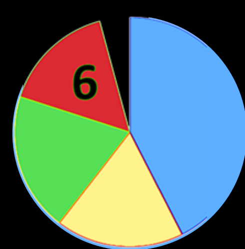
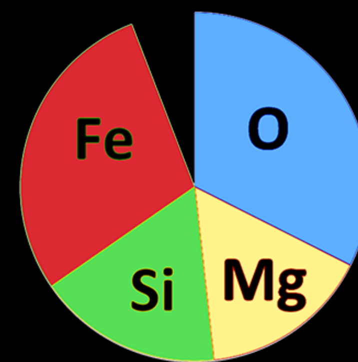
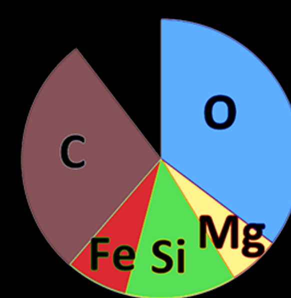




Bulk Earth



Comet Halley

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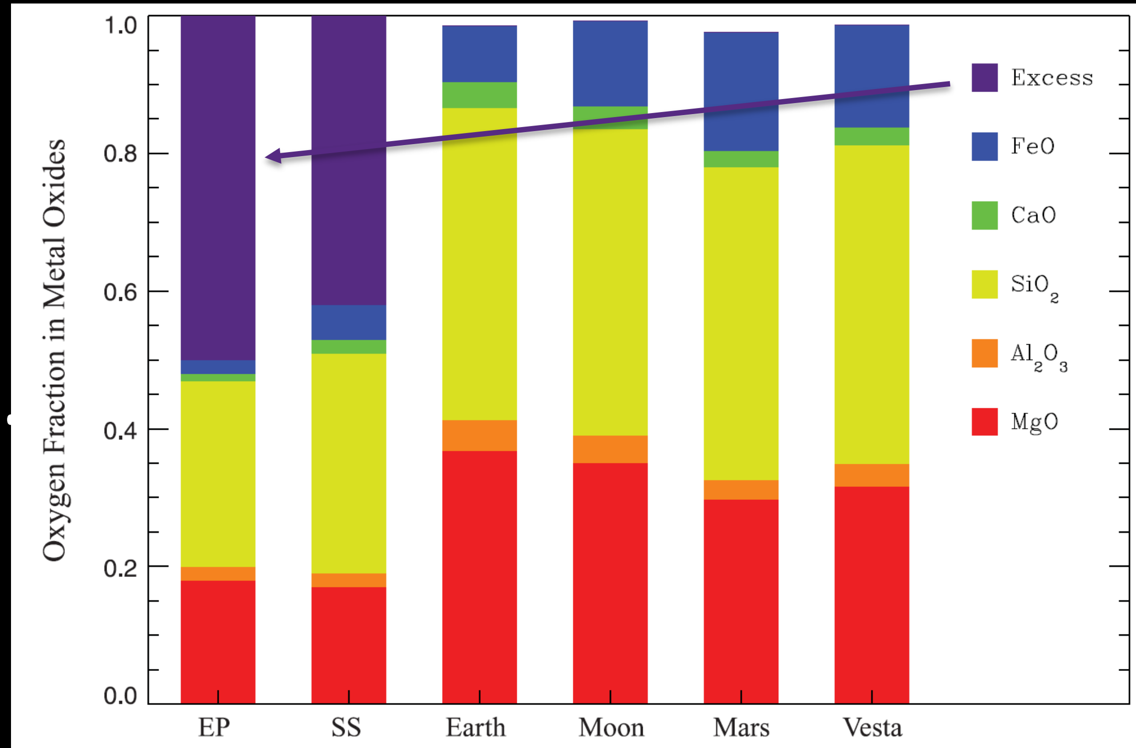
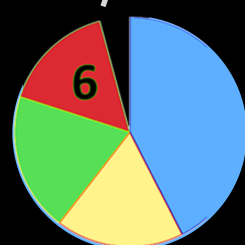
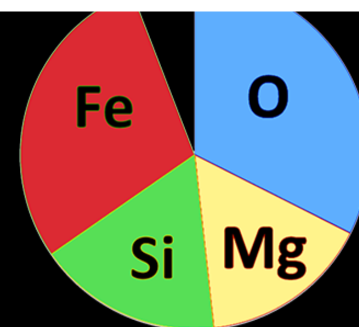


Farihi et al. 2013

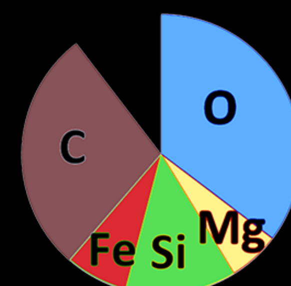
Volatiles = CO_2, **H_2O**

This white dwarf has very little Carbon, so **excess Oxygen likely from H_2O**



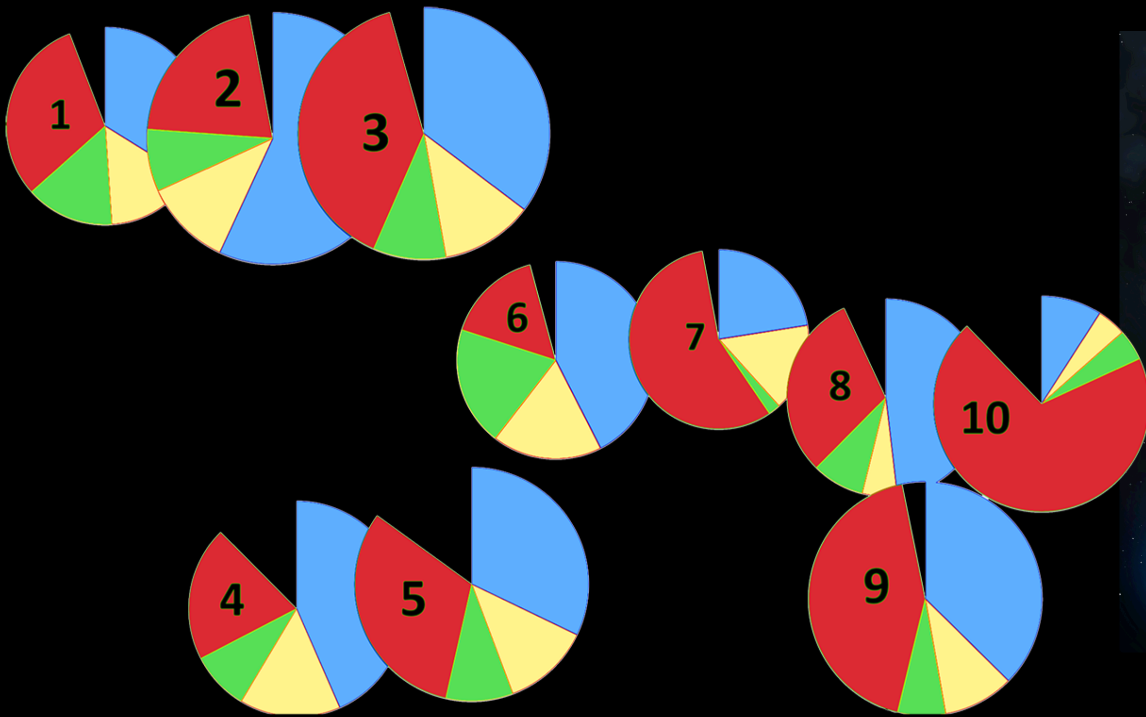


Bulk Earth

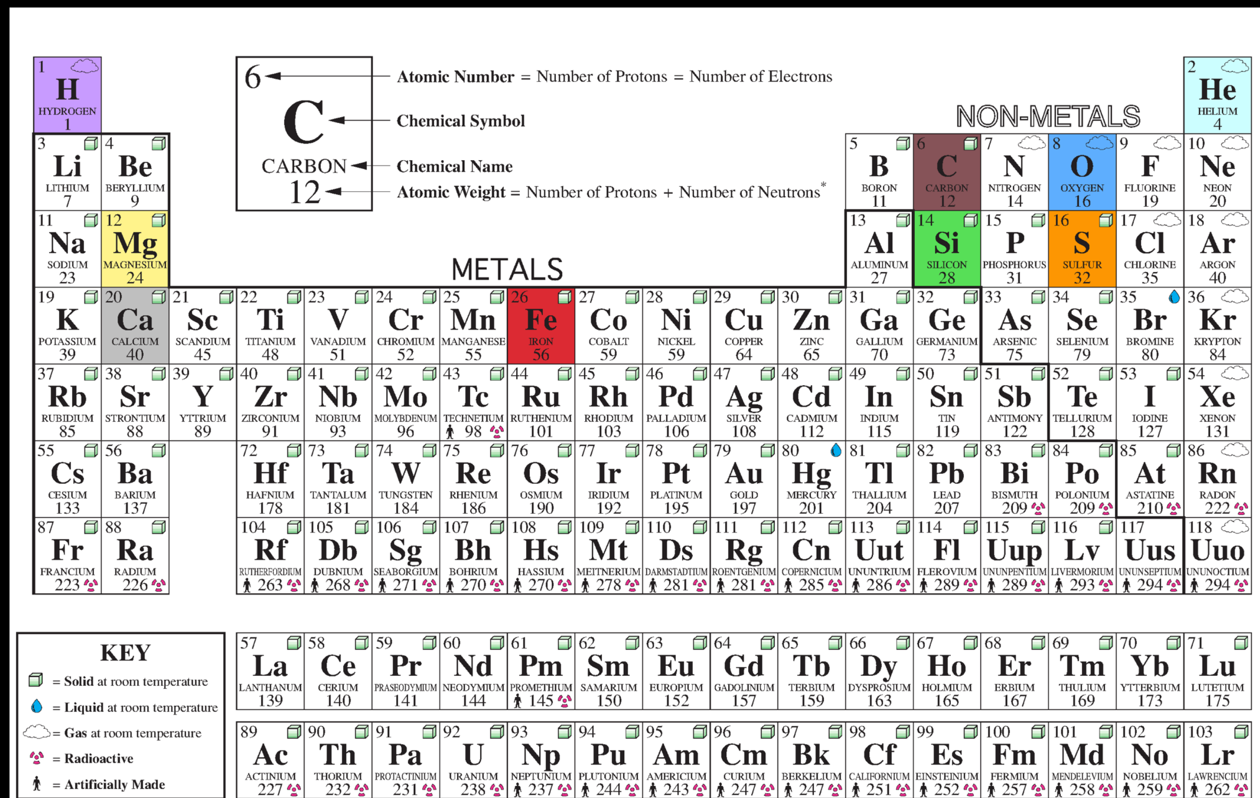


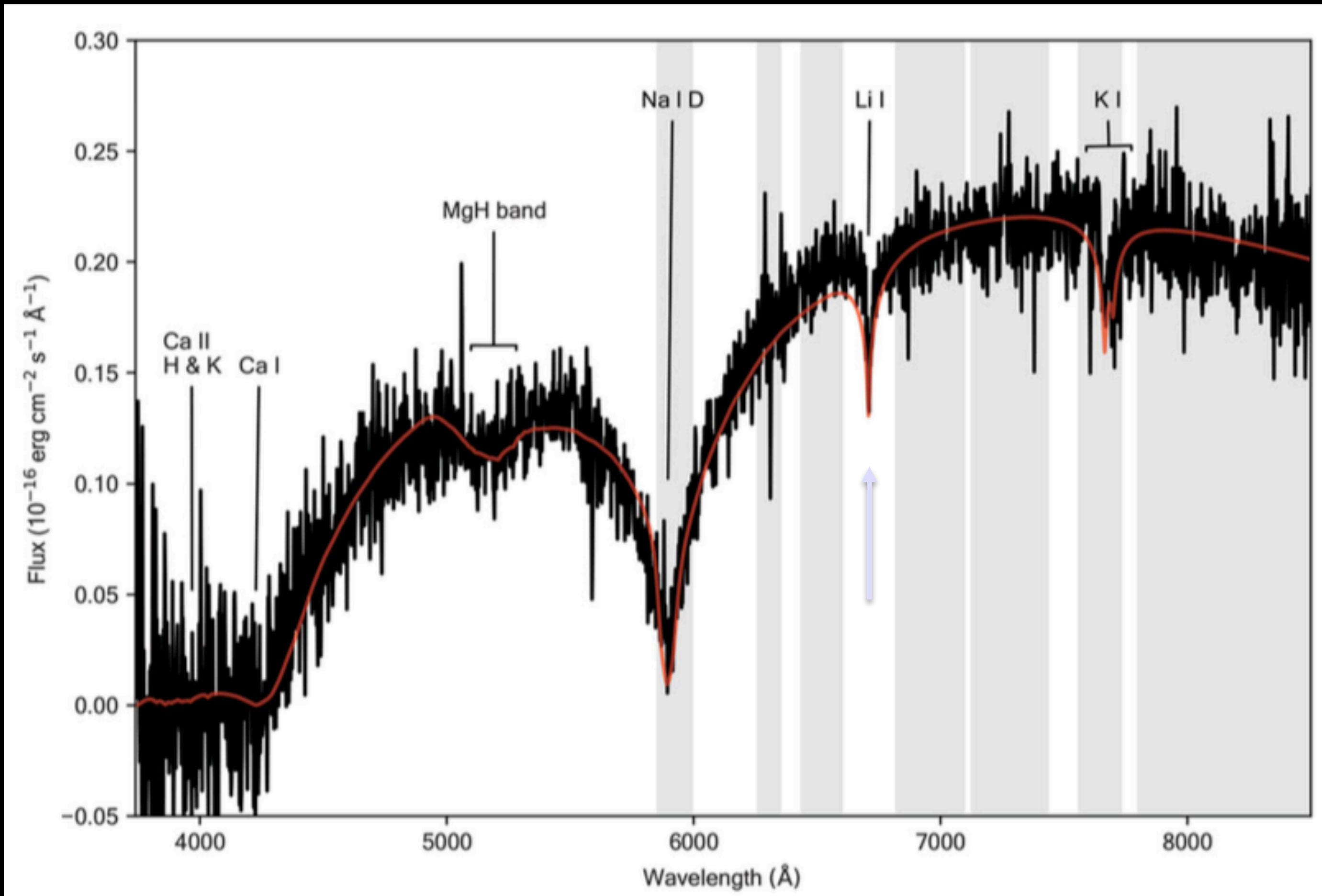
Comet Halley

The parent body was originally composed of 26% water by mass



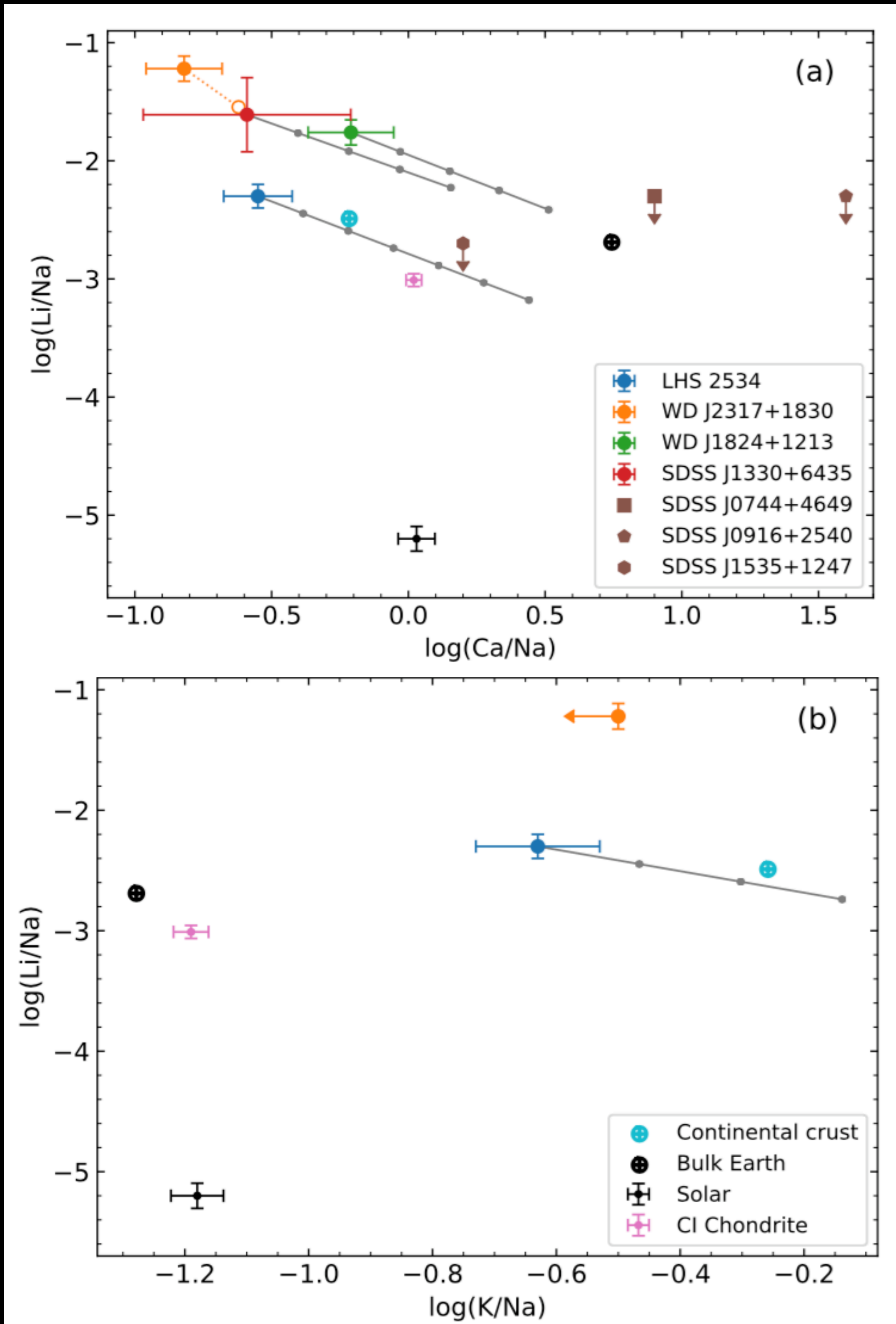
As with bulk Earth the dominant elements in exo-asteroids are **Iron**, **Oxygen**, **Silicon**, **Magnesium**

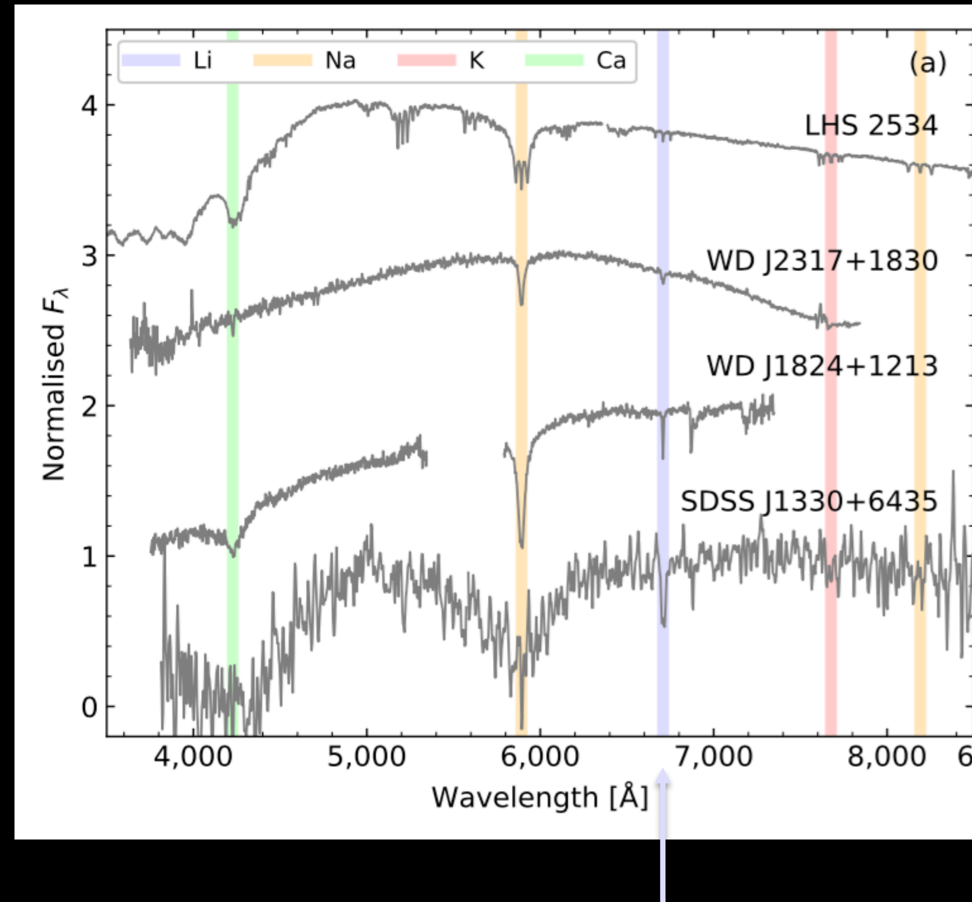




Kaiser et al. 2021

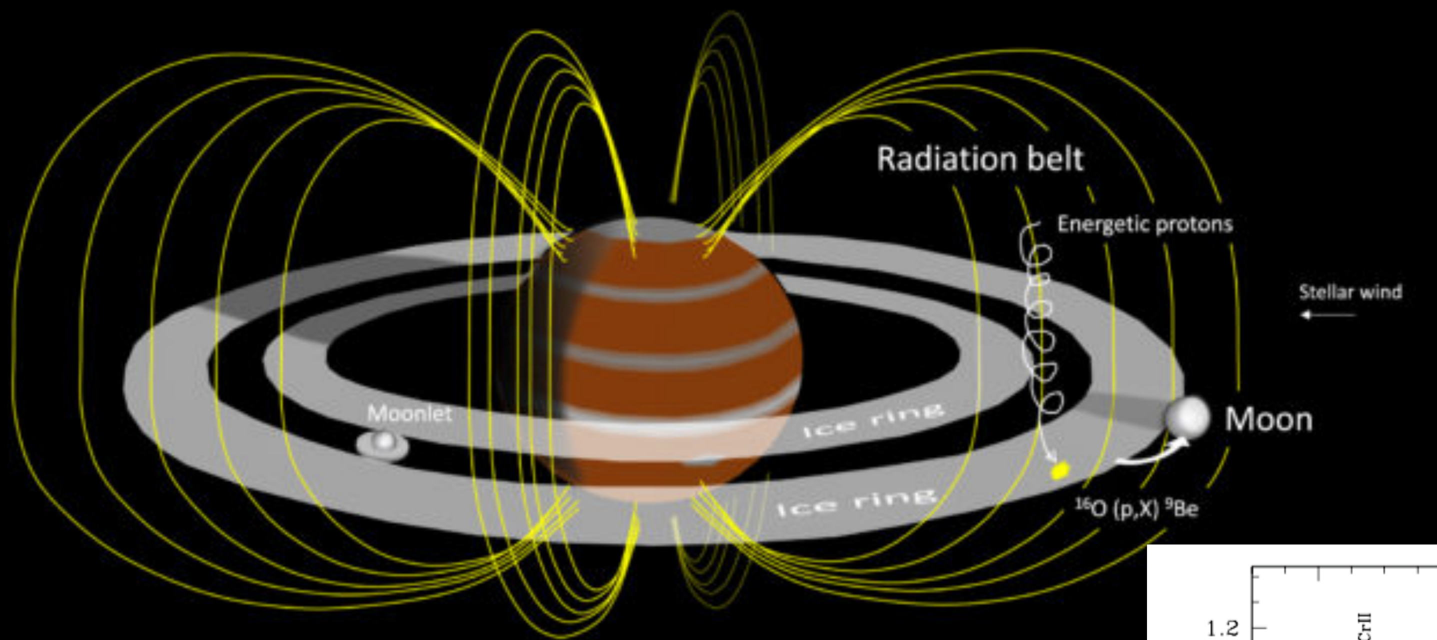
Lithium has recently been found in cool white dwarfs



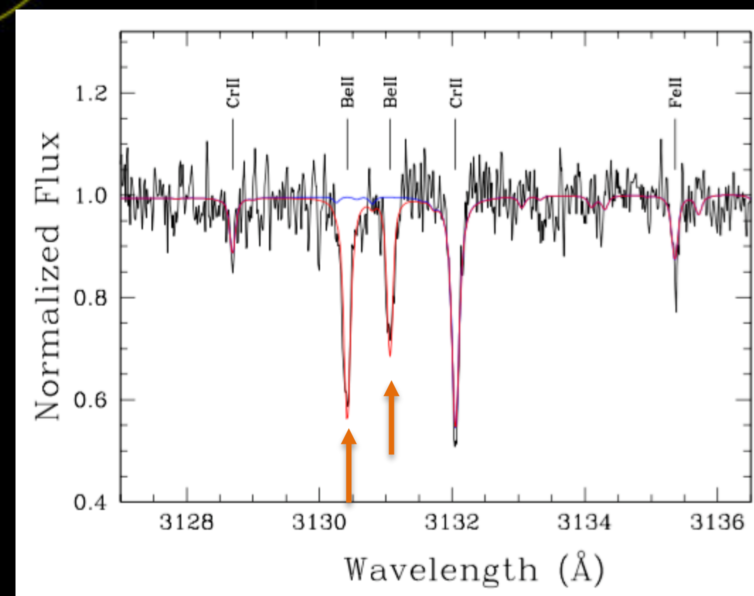


Lithium may reveal that at least some rocks polluting white dwarfs come from the **crusts** of larger planets

Hollands et al. 2021



Beryllium has also recently been detected in two white dwarfs



Klein et al. 2021

Doyle et al. 2021

One theory: **Be** found in high abundances produced by **spallation** on an icy moon around a giant planet

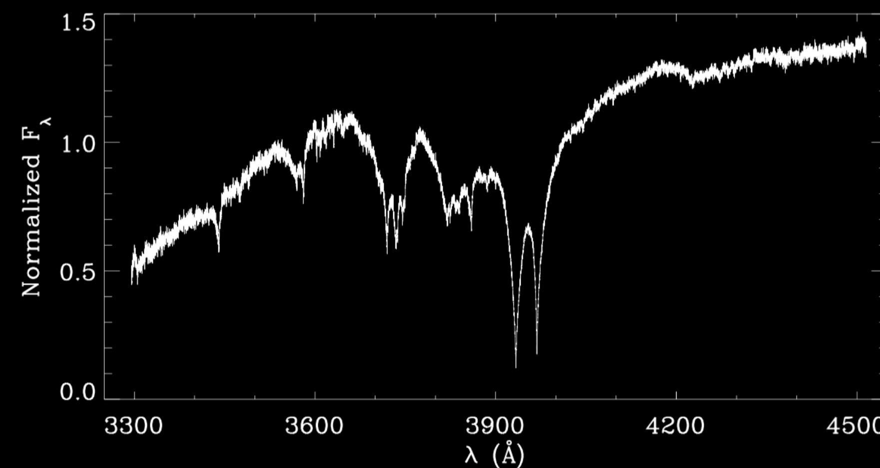
Simply by observing **metals** in white dwarfs we can directly constrain the **composition of exo-asteroids**

Bottom Line: Alien Rocks are **Just Like Rocks in our Solar System**

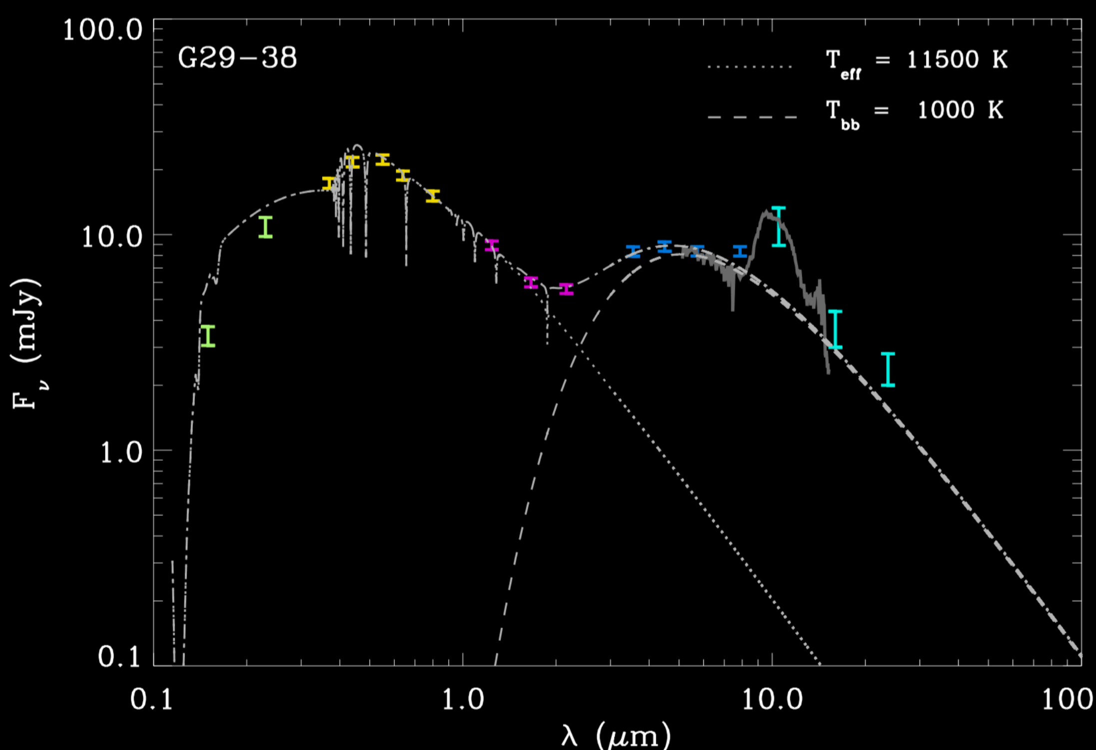
They are mostly composed of:
Iron, **Oxygen**, **Silicon**, **Magnesium** **... and Water!**

Observational evidence for this hypothesis:

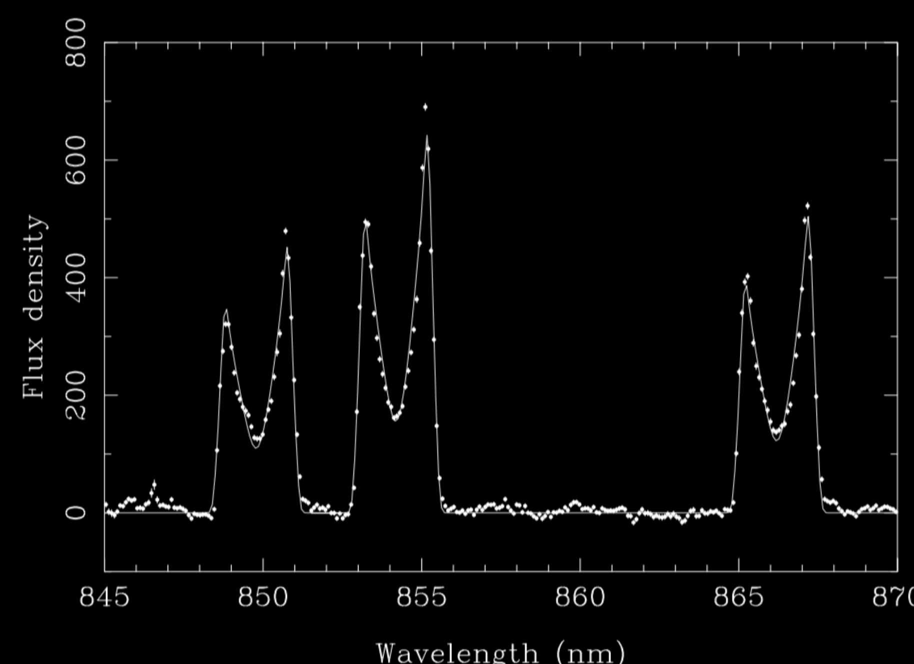
(a) Photospheric pollution



(b) IR excess (**dust** disks)

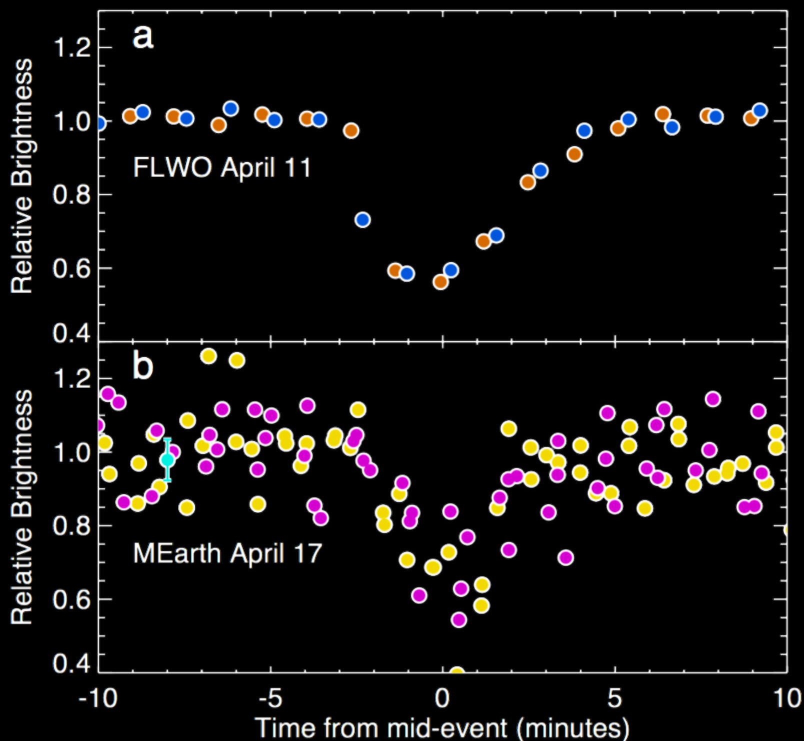


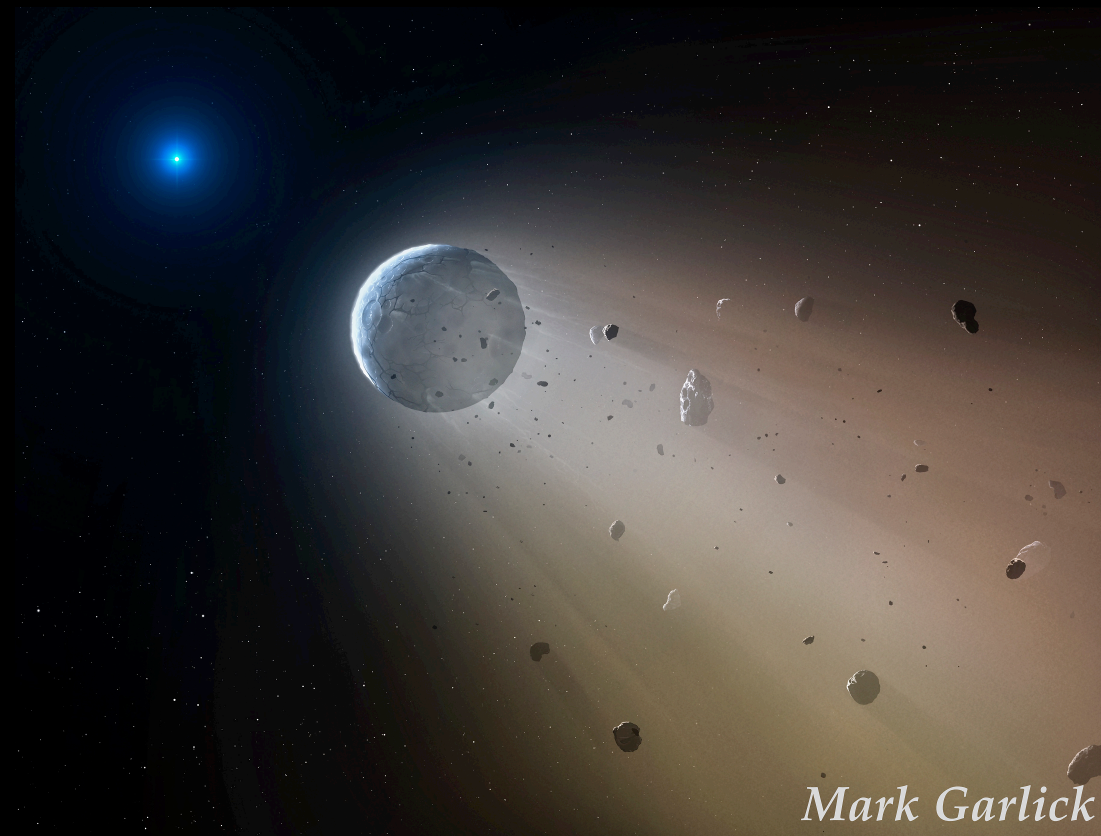
(c) Ca emission (**gas** disks)

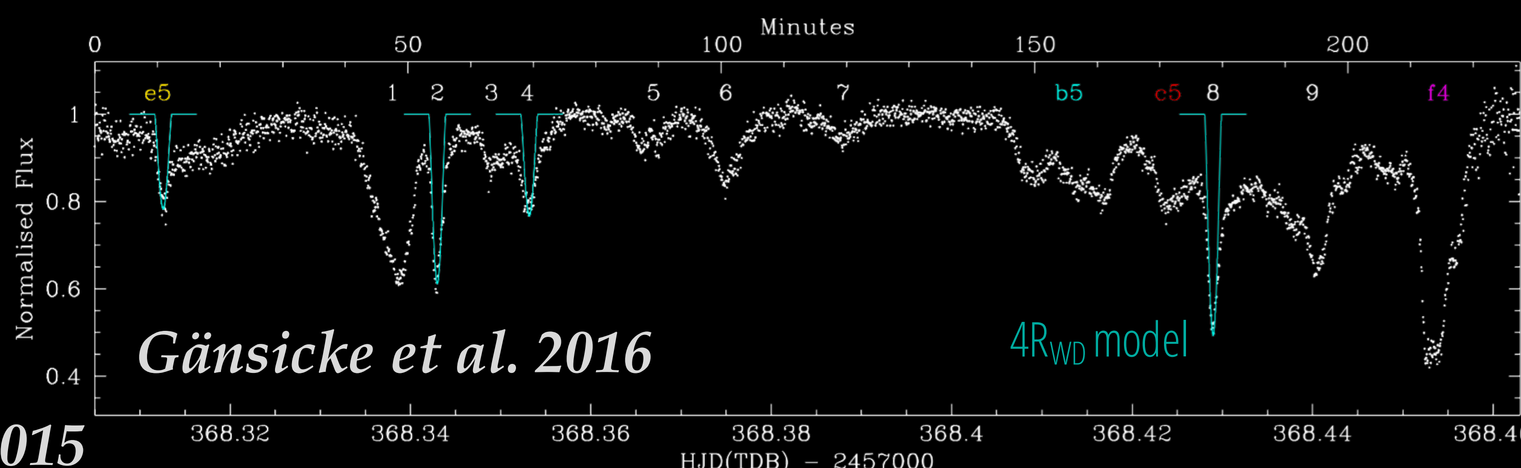


Farihi 2016

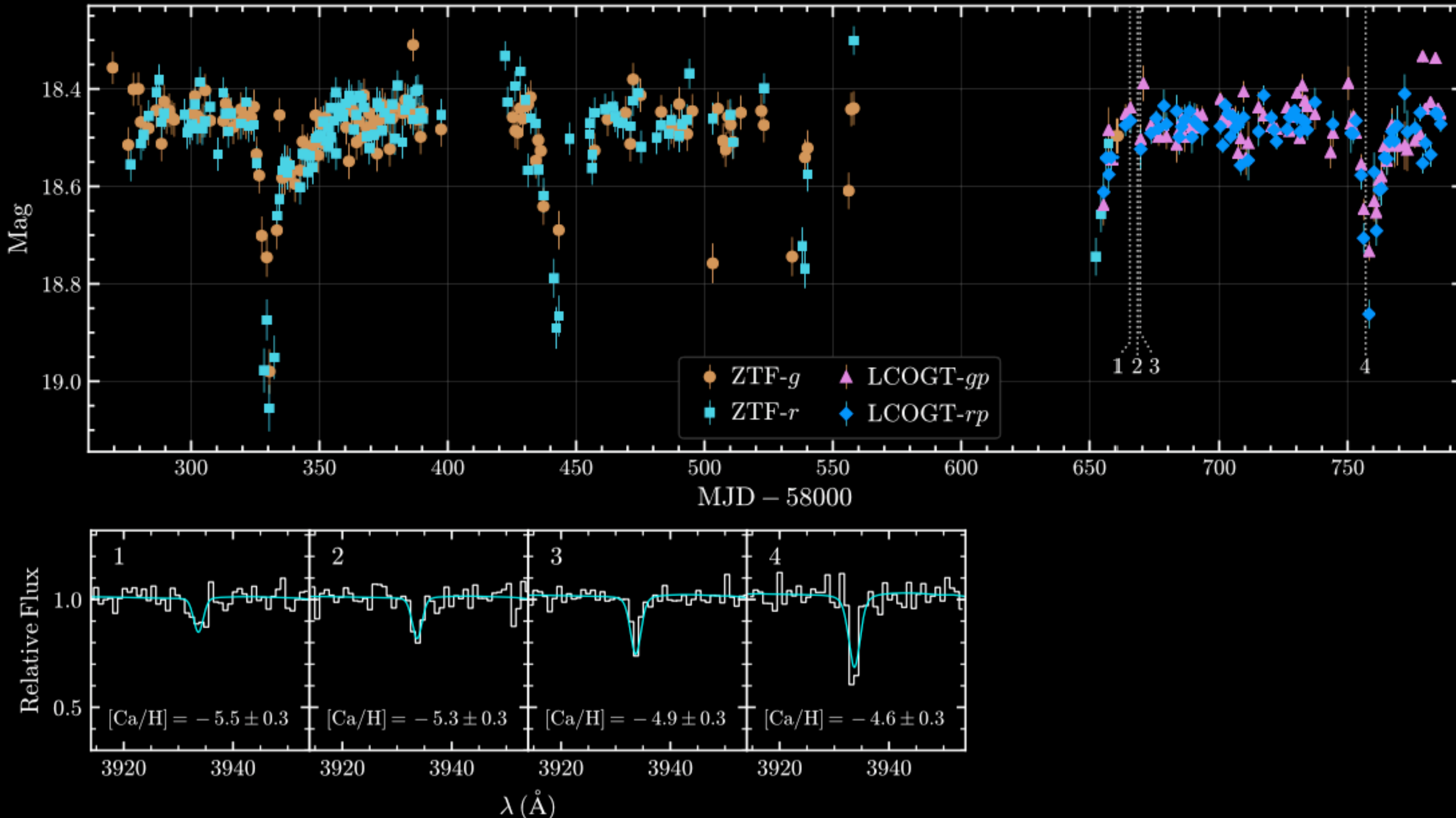
(d) Transits of the white dwarf (WD1145+017)





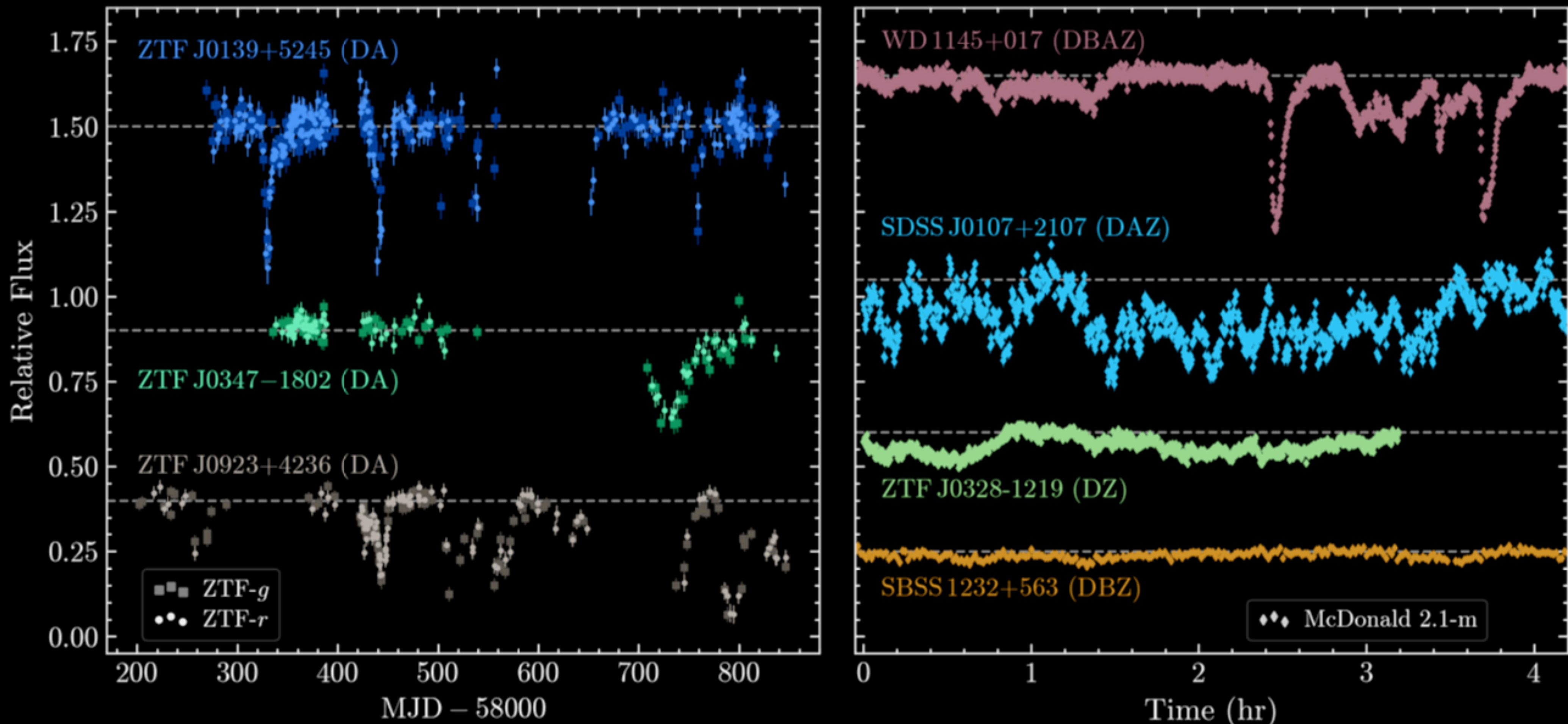


Vanderburg et al. 2015



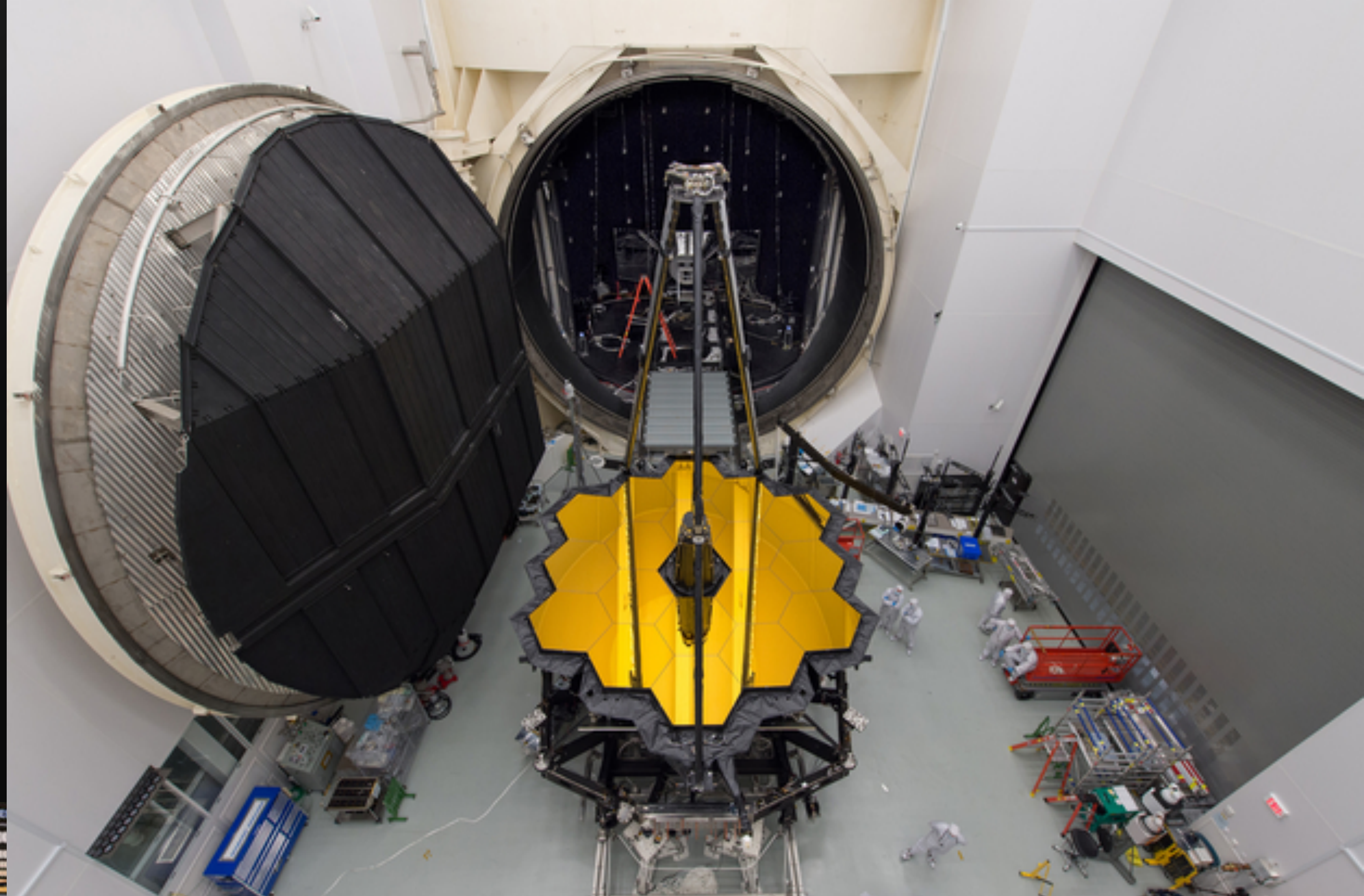
We are finding more white dwarfs with **periodic transits from debris**

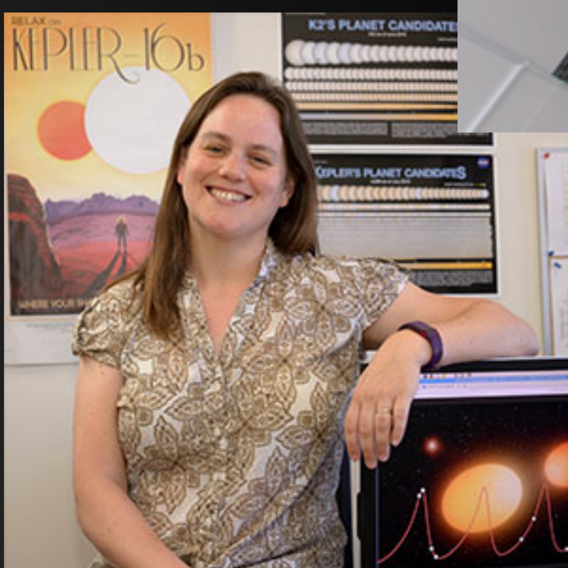
Vanderbosch, Hermes, et al. 2020



We are finding more white dwarfs with
periodic transits from debris

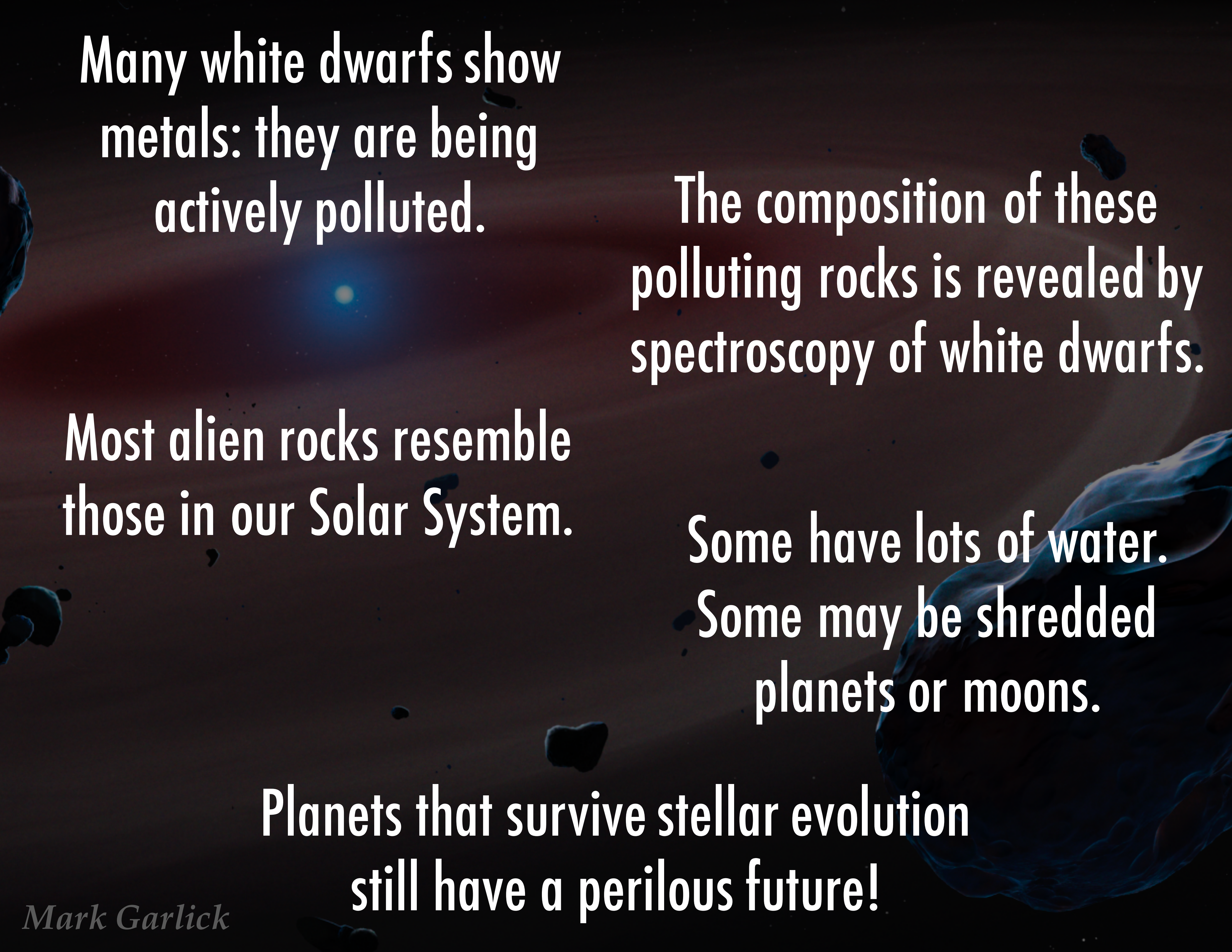
Guidry, Vanderbosch, Hermes, et al. 2021





PI: Susan Mullally

24.6 hr of JWST time awarded to look for surviving **giant planets** around **4 white dwarfs** in Cycle 1


Many white dwarfs show metals: they are being actively polluted.
The composition of these polluting rocks is revealed by spectroscopy of white dwarfs.
Most alien rocks resemble those in our Solar System.
Some have lots of water. Some may be shredded planets or moons.
Planets that survive stellar evolution still have a perilous future!
Mark Garlick