Planets around white dwarfs:

Discovery and interpretation of the observations

THE UNIVERSITY OF WARWICK

Boris Gänsicke

Outline

1. Preliminaries

2. White dwarfs photo-evaporating giant planets

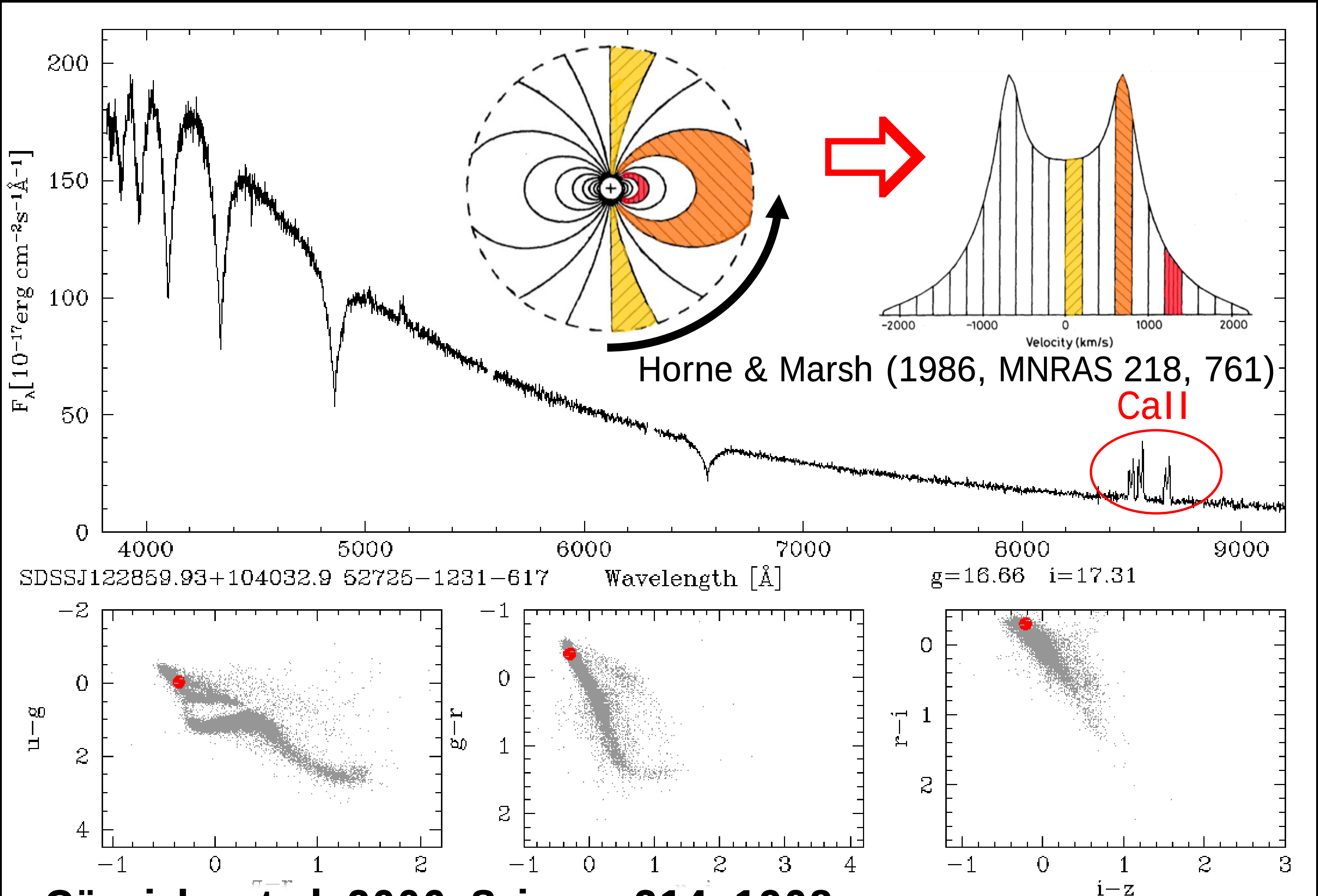
3. Magnetic planet-star interactions

Preliminaries – what we knew a year ago, and what you need to know for what follows

Many white dwarfs show signatures of accreting debris from rocky planetesimals. Signatures:

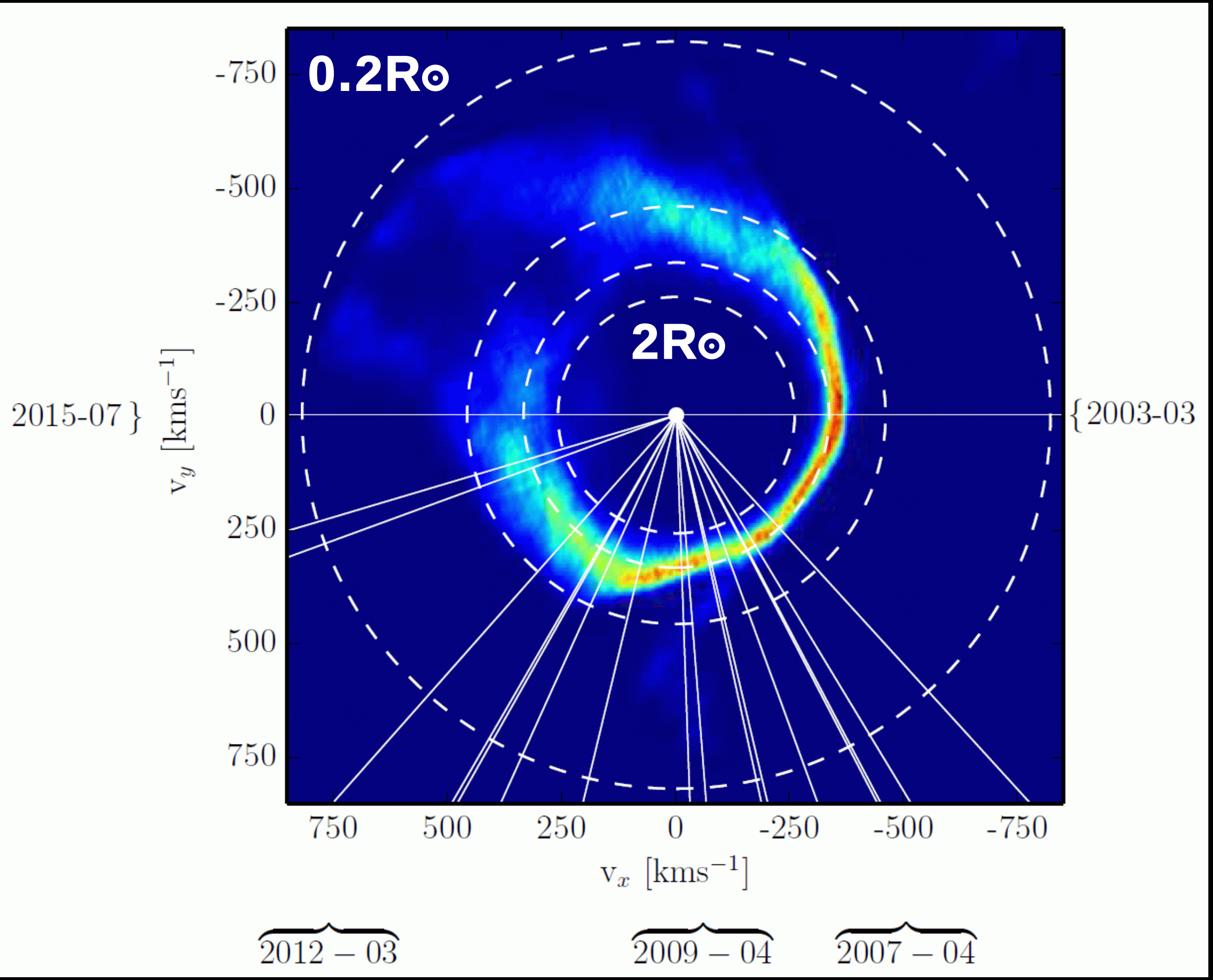
- dust discs
- gas discs
- metals

Gaseous debris discs = <u>double peaked emission lines</u>



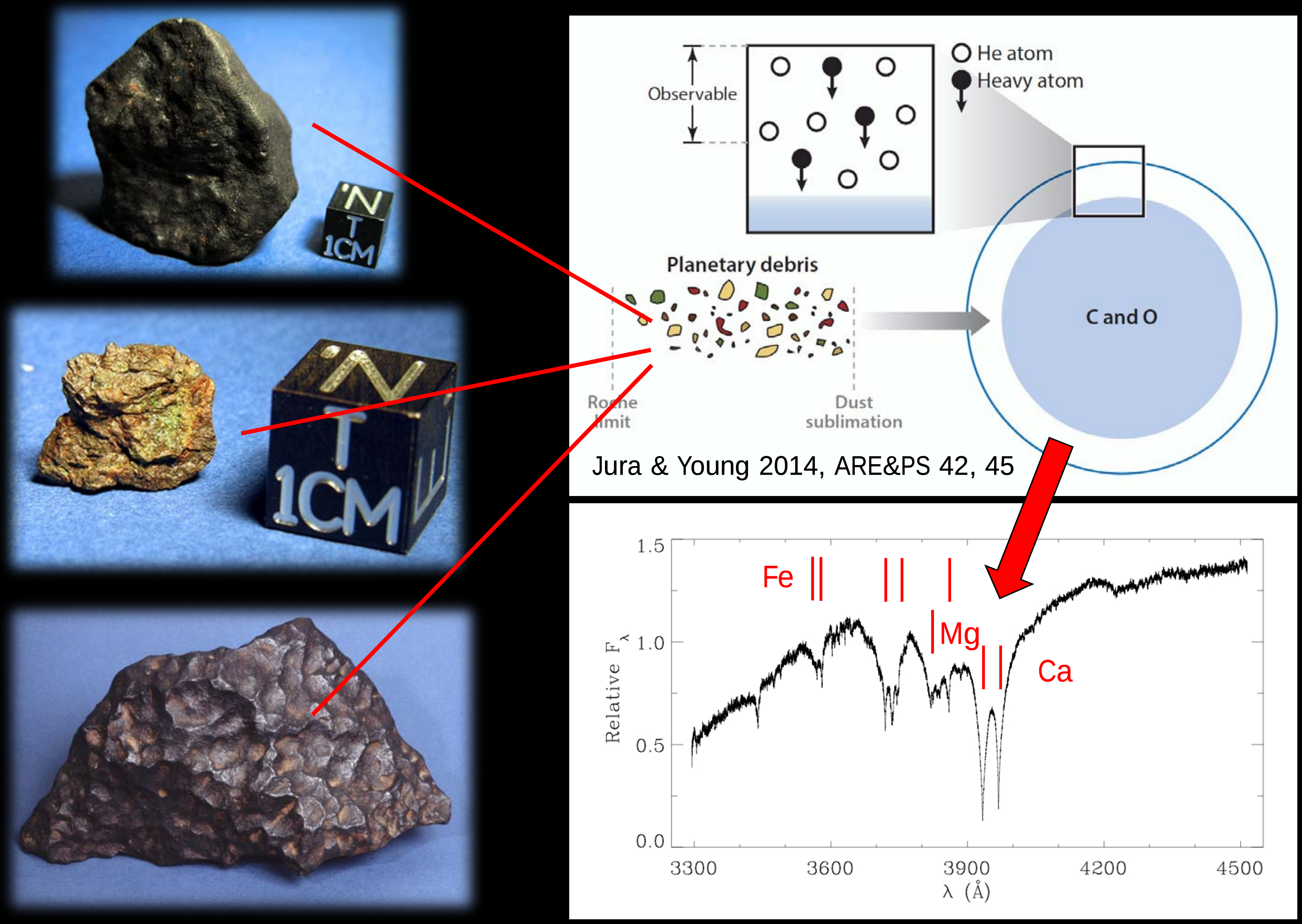
Gänsicke et al. 2006, Science 314, 1908

These discs are small, ≈1R⊙
= tidal disruption radius for "rocks"

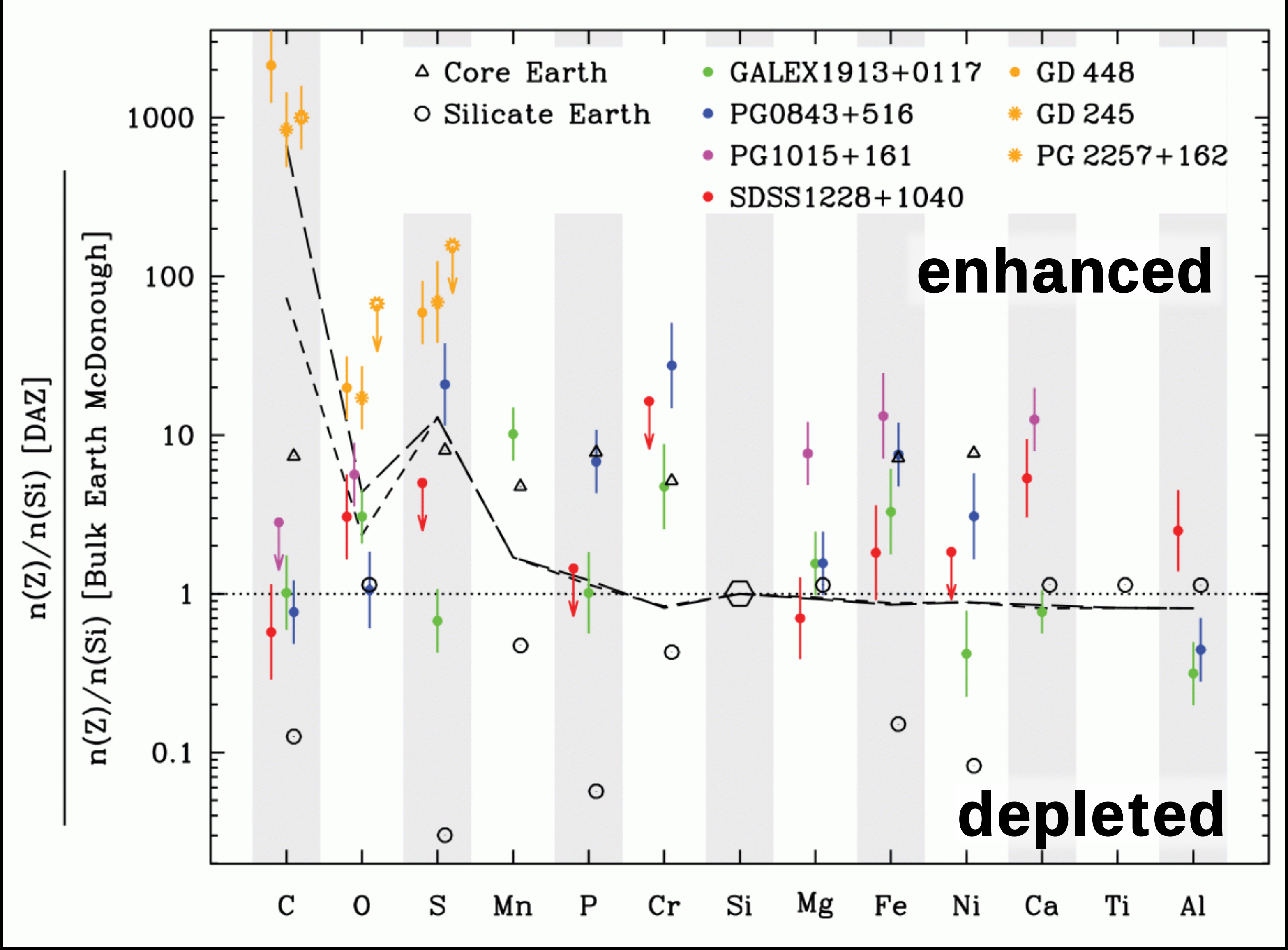


Manser et al. 2016, MNRAS 455, 4467

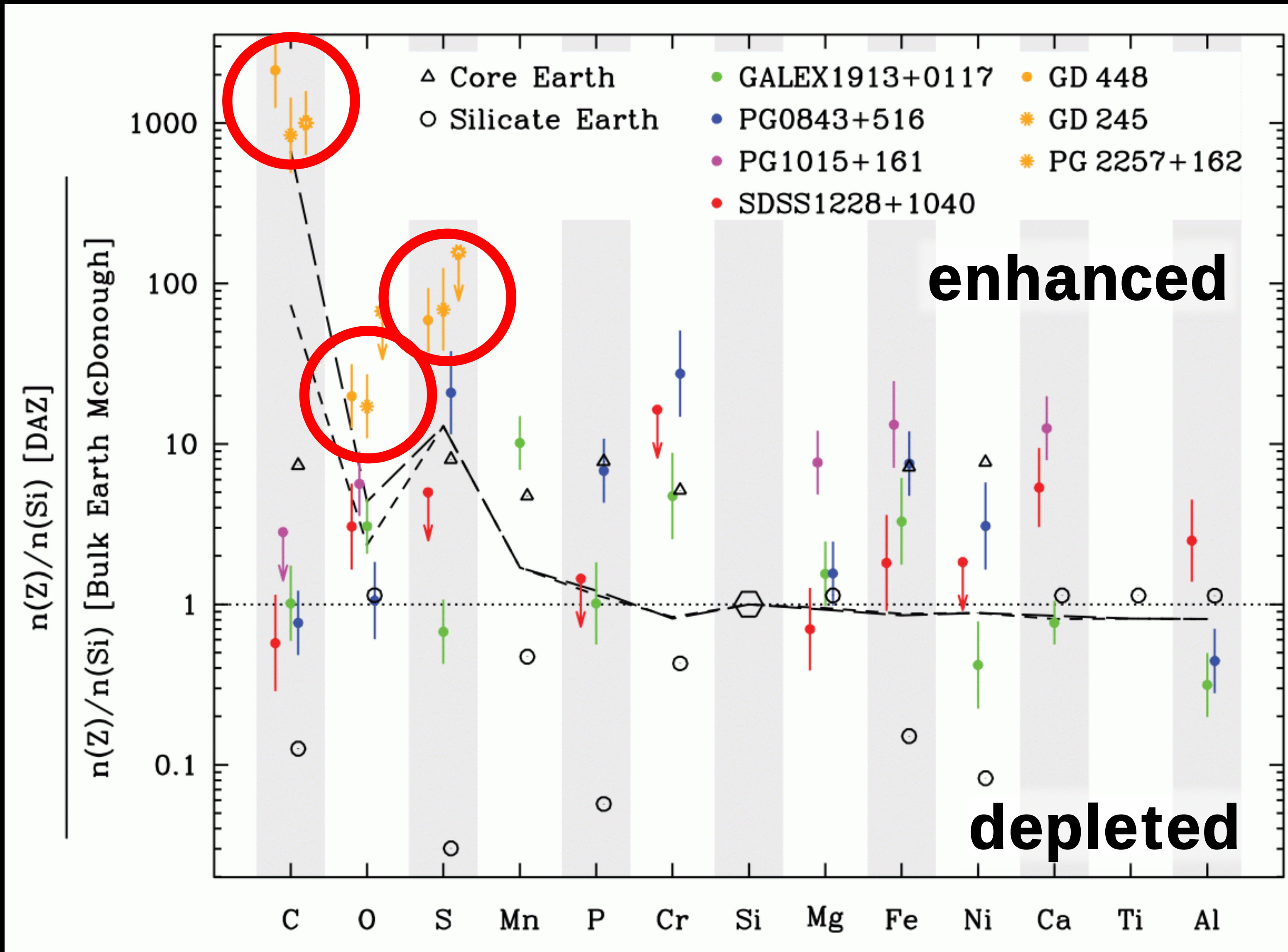
Photospheric metal pollution by planetary debris



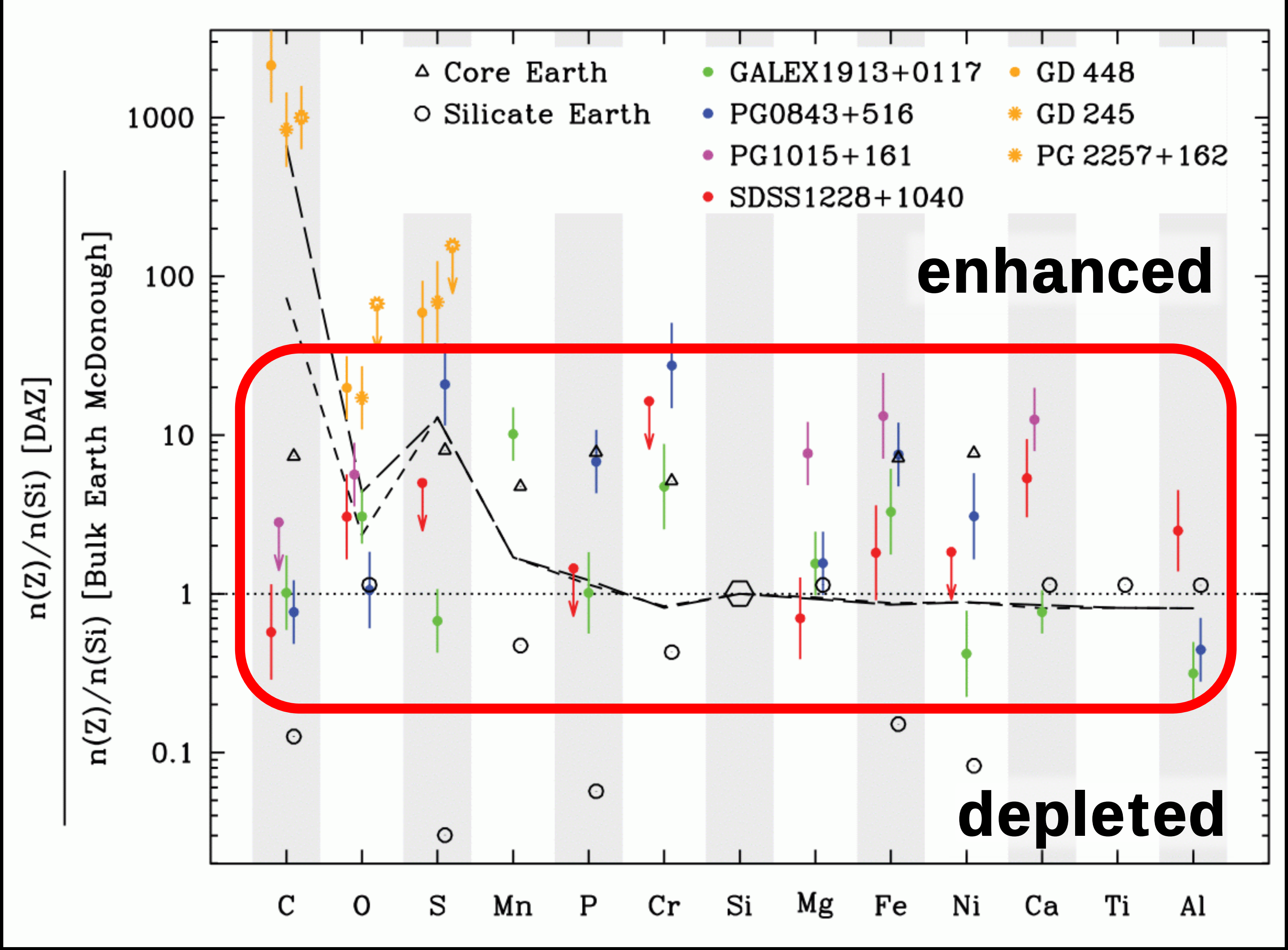
An introduction to geochemistry



Stellar companion = solar C, O, S



Dusty disc white dwarfs are all consistent with solid / rocky planetesimals



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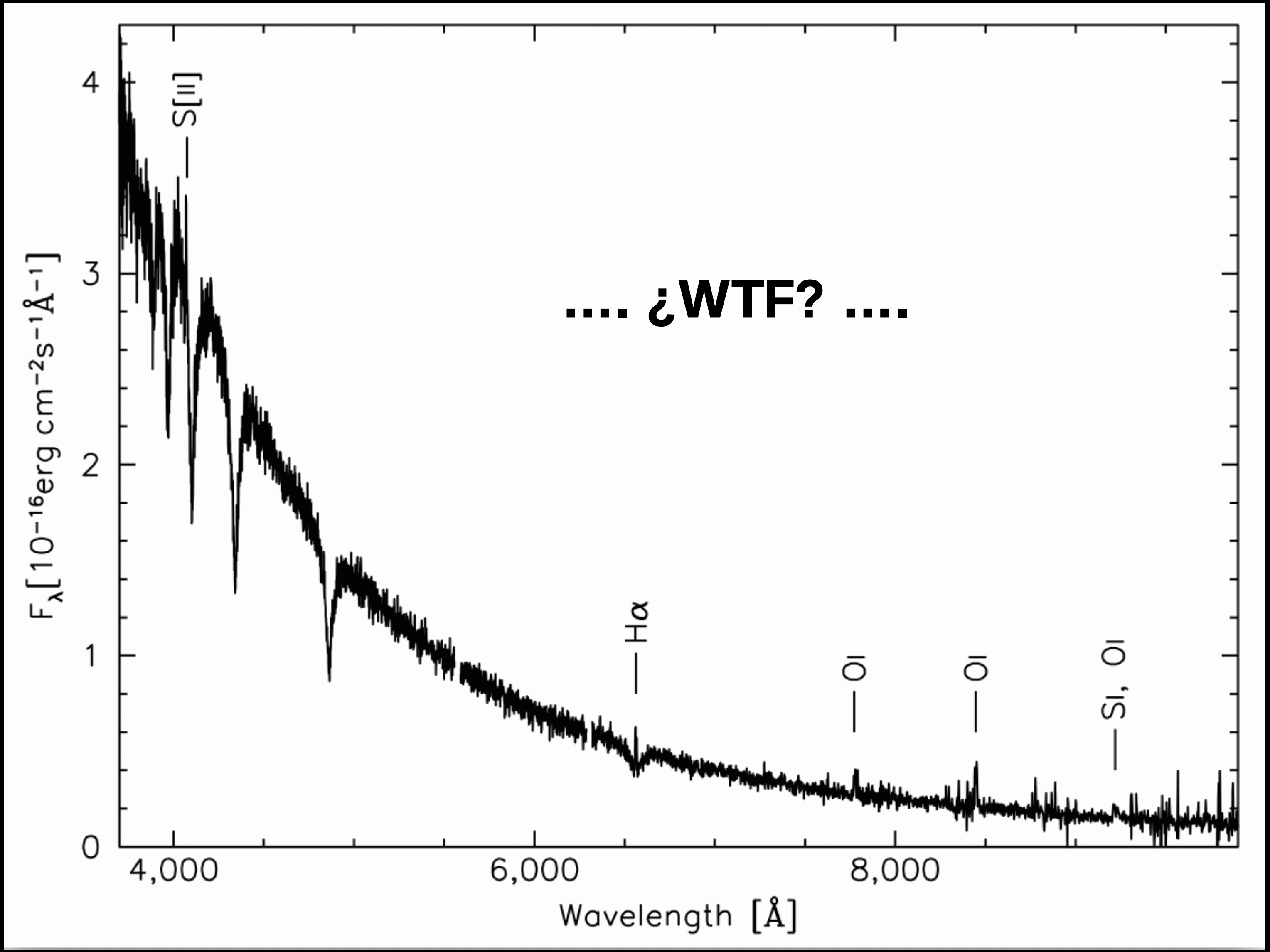
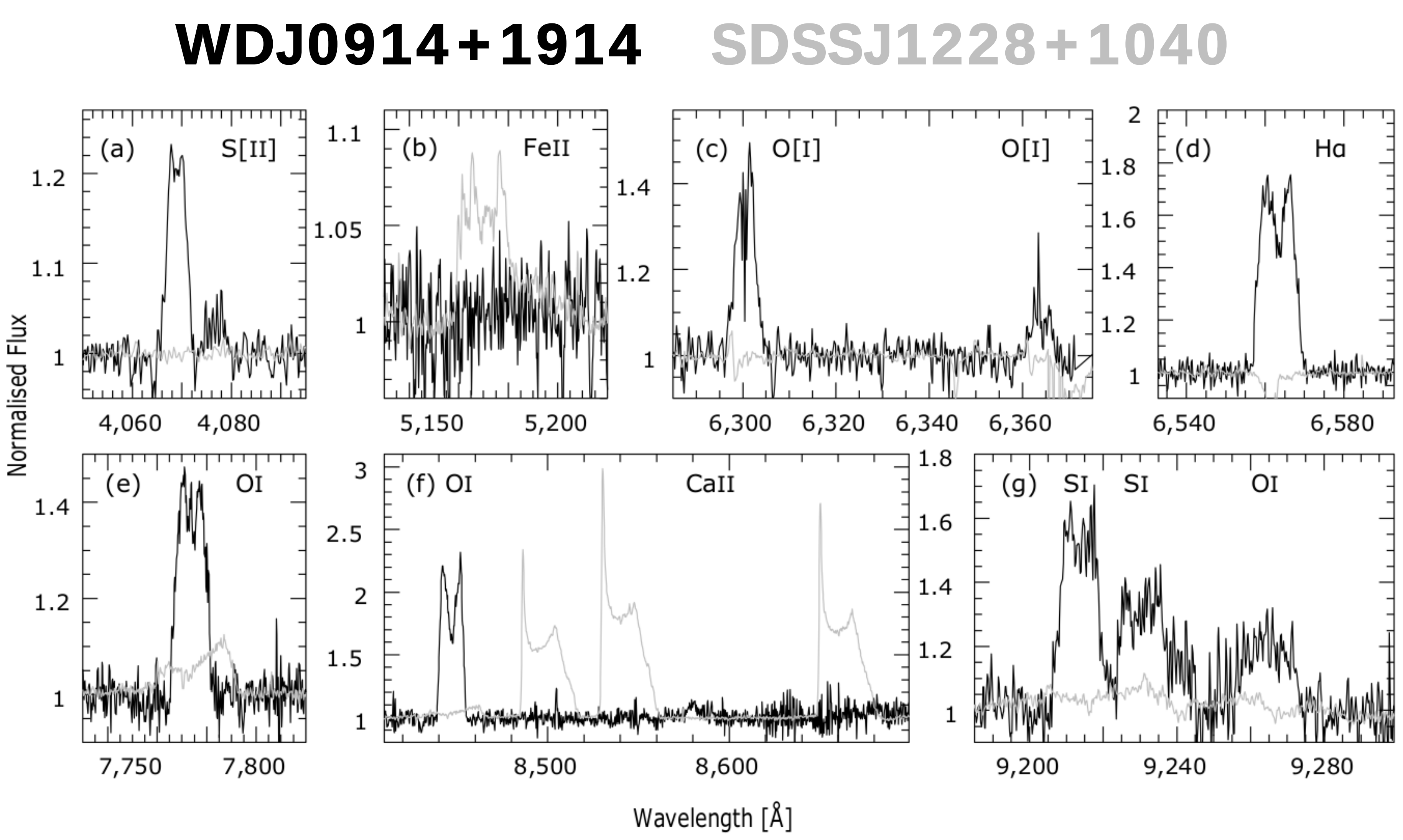
One of 1000s SDSS spectra of white dwarfs



Gentile Fusillo et al. 2019, MNRAS 482, 4570

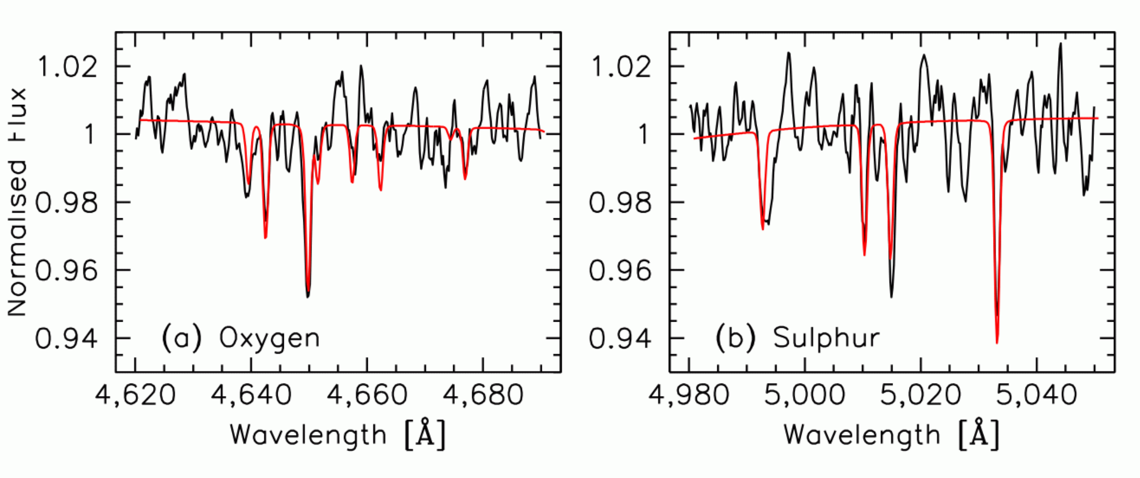
A disc composed of H, O, S

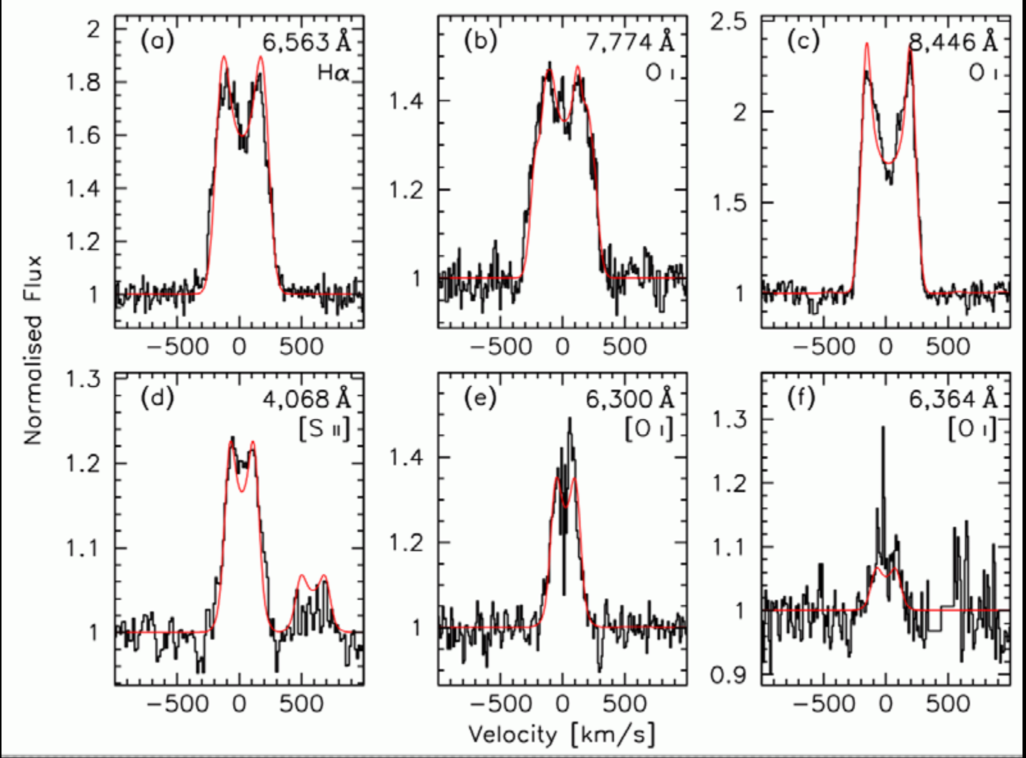


January 2019: 4h of X-Shooter spectroscopy

Another gaseous debris disc. Wait: H, O & S?

white dwarf photosphere: O, S





Circumstellar disc: H, O, S

Quick look into solar-system textbooks...

Lodders & Fegley, Chemistry of the Solar System

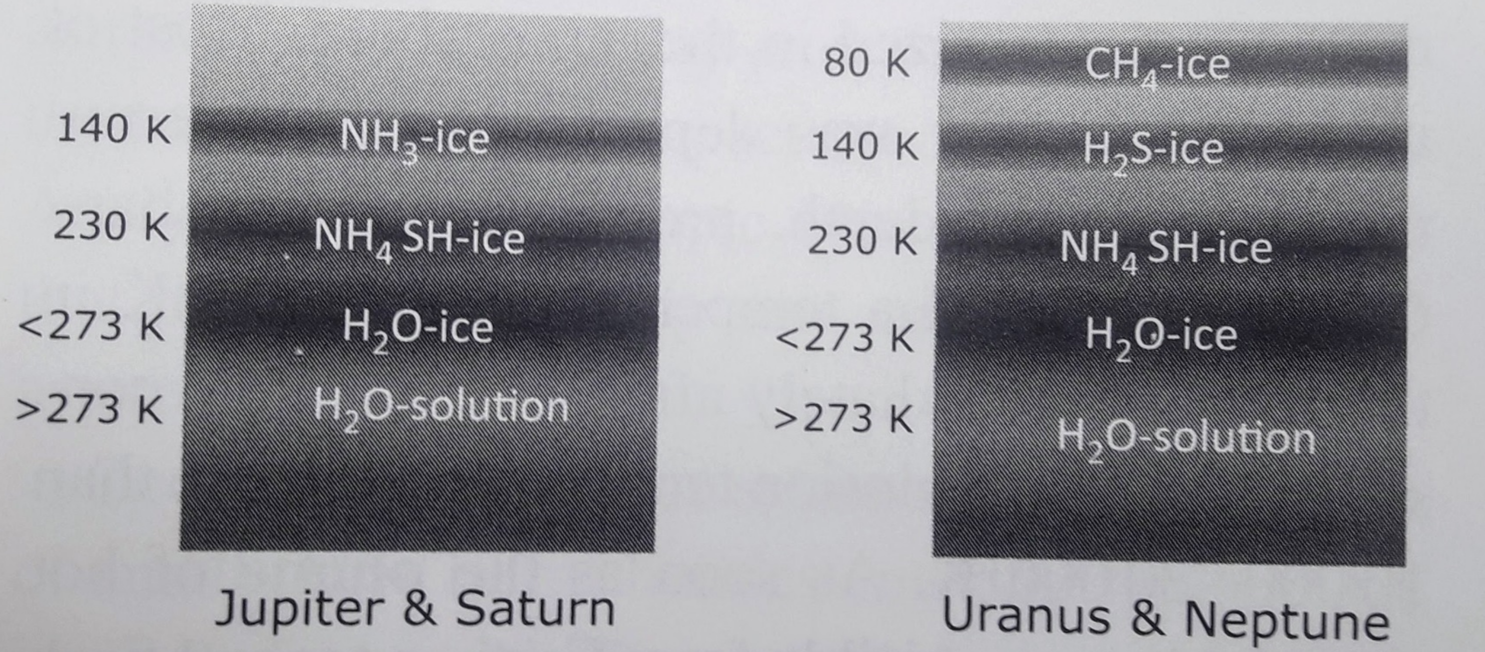


Figure 8.8 Illustration of the theoretically derived cloud layers on the giant planets.

H_2S in Uranus & Neptune

Possible Microwave Absorption by H_2S Gas in Uranus' and Neptune's Atmospheres

IMKE DE PATER

Astronomy Department, 601 Campbell Hall, University of California, Berkeley, California 94720

1991, Icarus 91, 220

ARTICLES

2018, Nat.Ast 2, 420

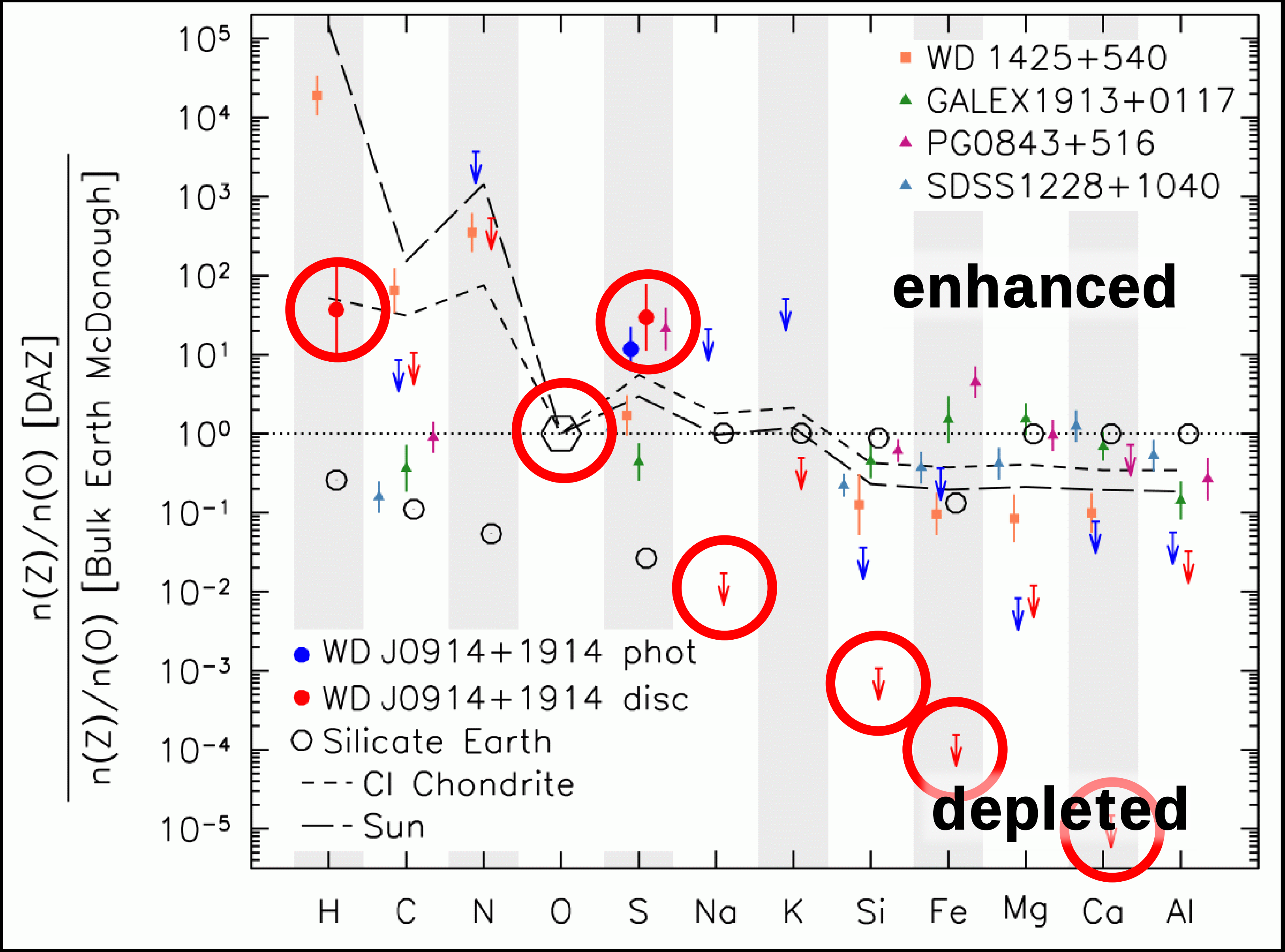
https://doi.org/10.1038/s41550-018-0432-1

nature astronomy

Detection of hydrogen sulfide above the clouds in Uranus's atmosphere

Patrick G. J. Irwin[1*], Daniel Toledo[1], Ryan Garland[1], Nicholas A. Teanby[2], Leigh N. Fletcher[3], Glenn A. Orton[4] and Bruno Bézard[5]

Purely volatile material around the white dwarf



A giant planet … but why is it losing mass?

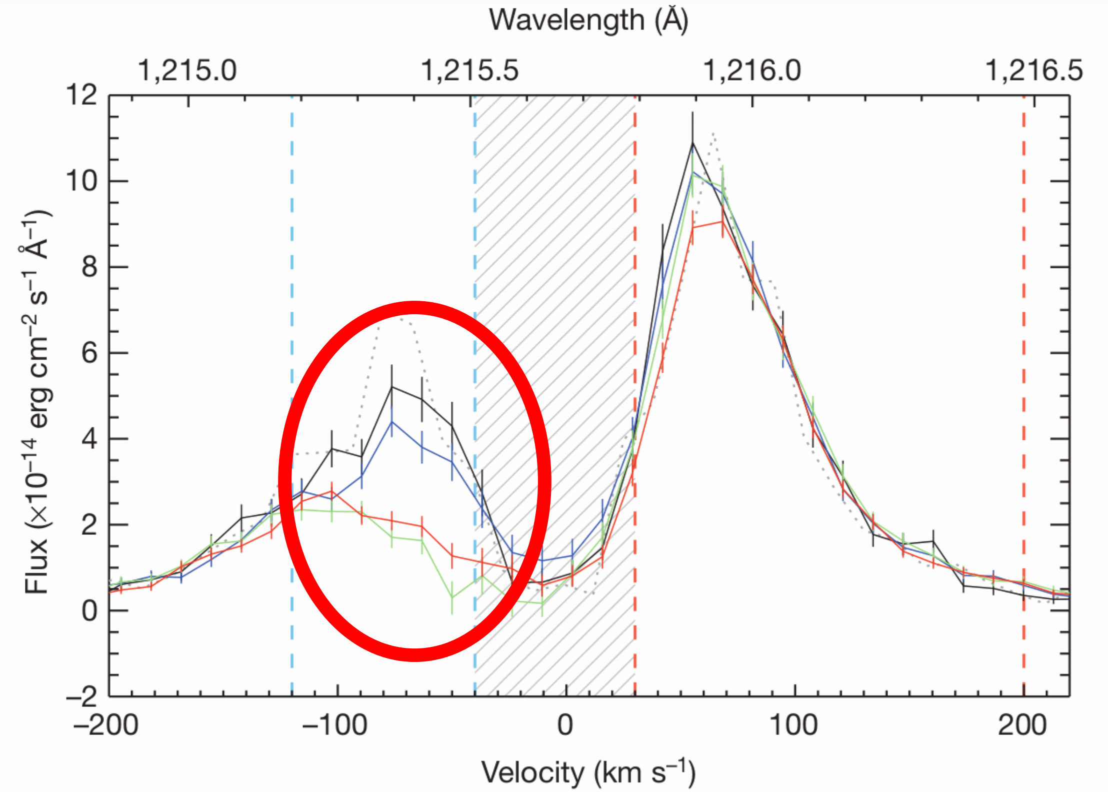
A giant planet … but why is it losing mass?

LETTER **2015, Nature 522, 459**

doi:10.1038/nature14501

A giant comet-like cloud of hydrogen escaping the warm Neptune-mass exoplanet GJ 436b

David Ehrenreich[1], Vincent Bourrier[1], Peter J. Wheatley[2], Alain Lecavelier des Etangs[3,4], Guillaume Hébrard[3,4,5], Stéphane Udry[1], Xavier Bonfils[6,7], Xavier Delfosse[6,7], Jean-Michel Désert[8], David K. Sing[9] & Alfred Vidal-Madjar[3,4]



Extreme-ultraviolet irradiation drives mass loss

The Astrophysical Journal, 816:34 (11pp), 2016 January 1
doi:10.3847/0004-637X/816/1/34

CrossMark

UV DRIVEN EVAPORATION OF CLOSE-IN PLANETS: ENERGY-LIMITED, RECOMBINATION-LIMITED, AND PHOTON-LIMITED FLOWS

James E. Owen[1,3] and Marcelo A. Alvarez[2]
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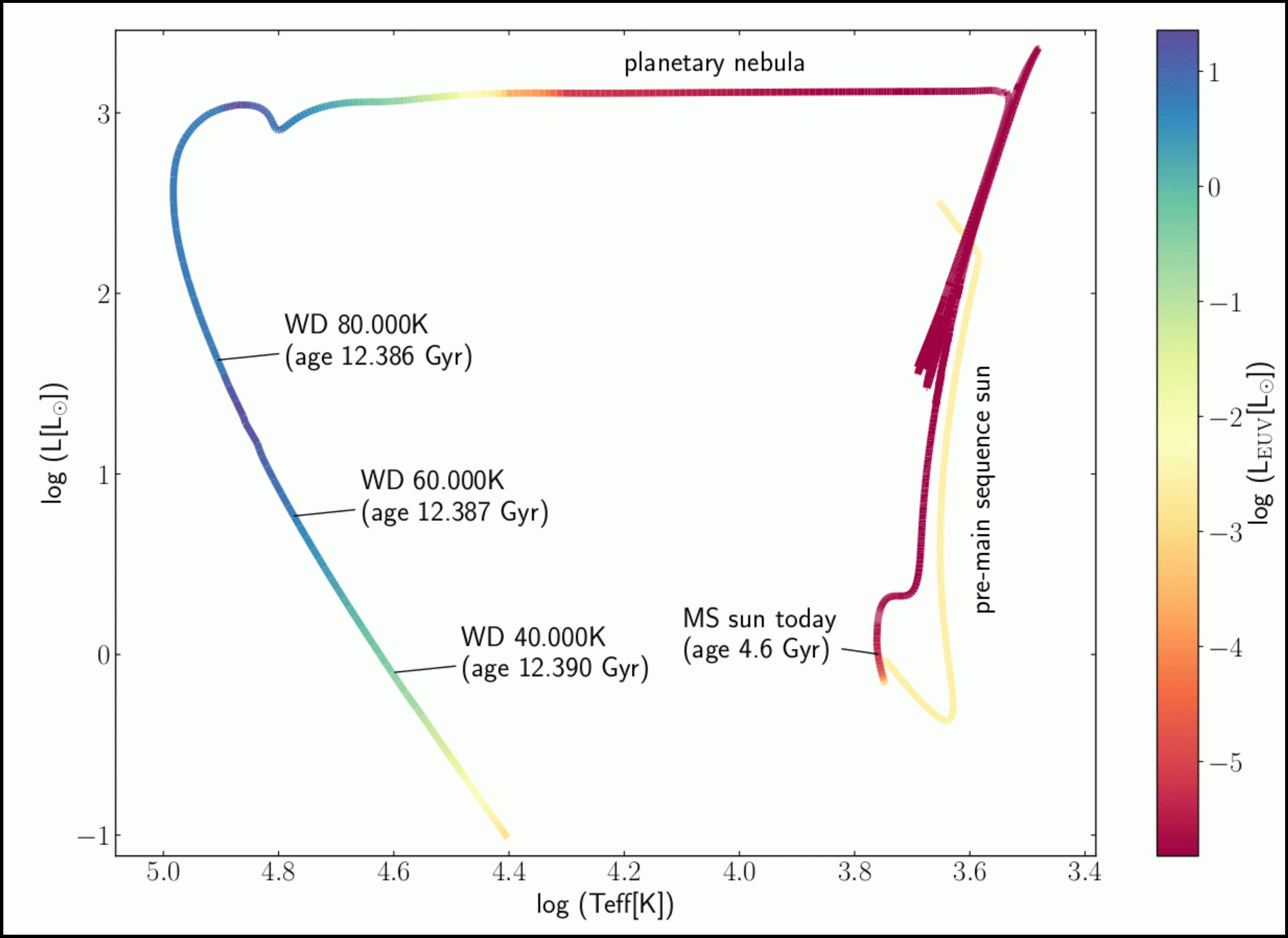
[2] Canadian Institute for Theoretical Astrophysics, 60 St George Street, Toronto, M5S 3H8, ON, Canada
Received 2015 April 23; accepted 2015 November 6; published 2015 December 29

$$\dot{M} = \frac{\epsilon \tau F_{\rm EUV} R_{\rm P}^3}{G M_{\rm P} K(\xi)}$$

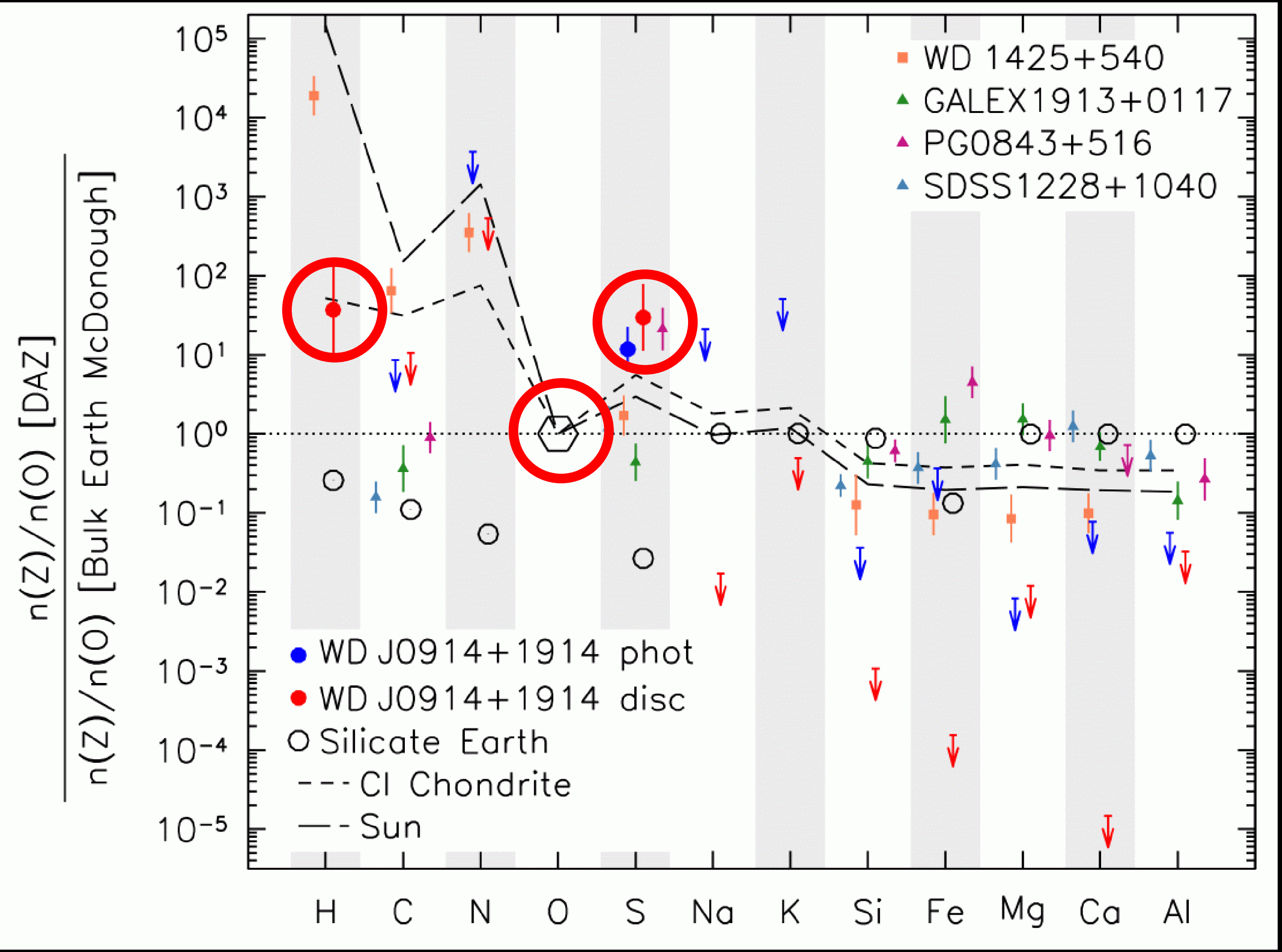
See also Murray-Clay et al. 2009, ApJ 693, 23

White dwarfs are <u>GREAT</u> at photo-evaporating giant planets

Schreiber et al. 2019, ApJL 887, 4

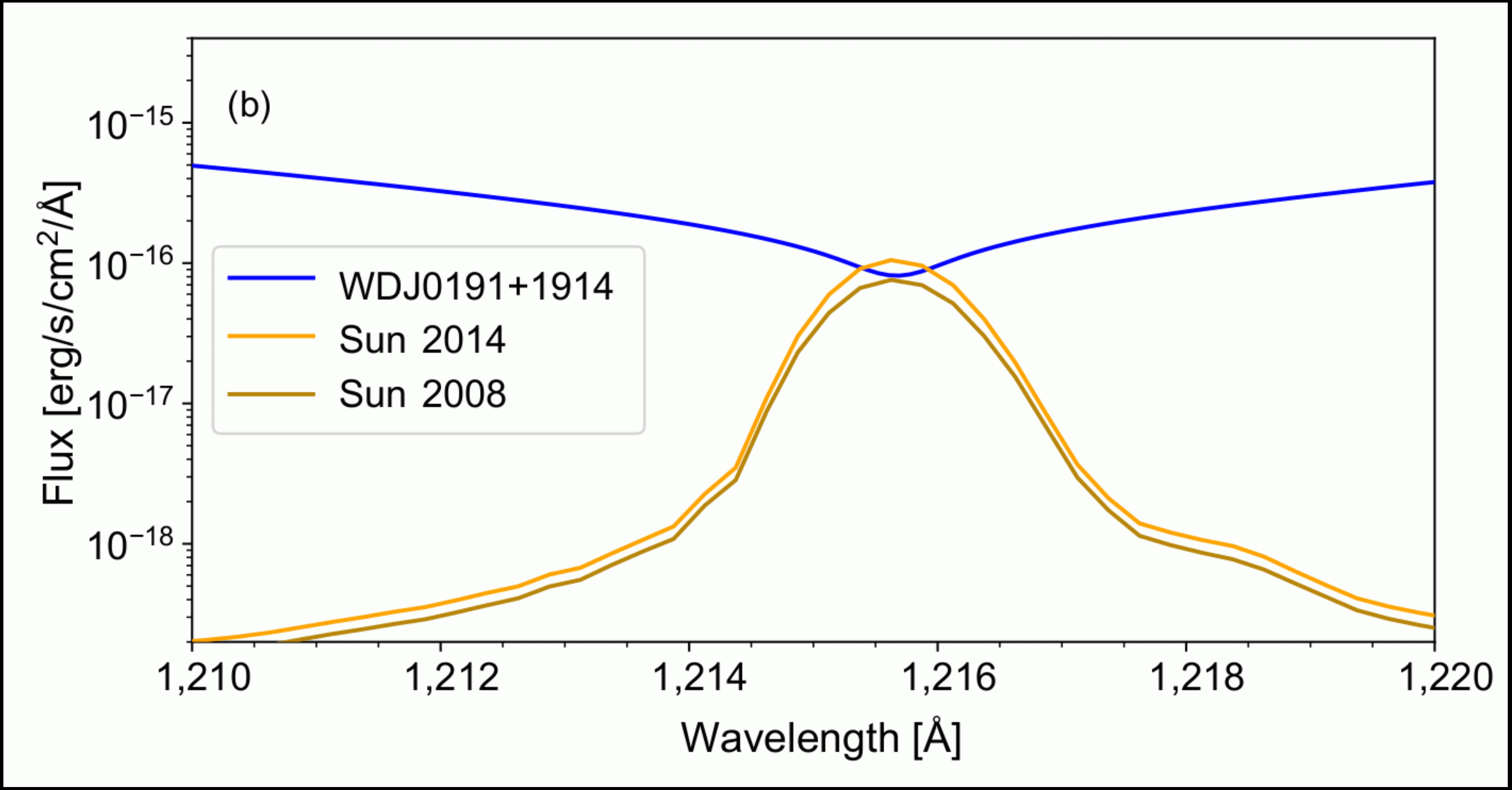


The disc is hydrogen-depleted



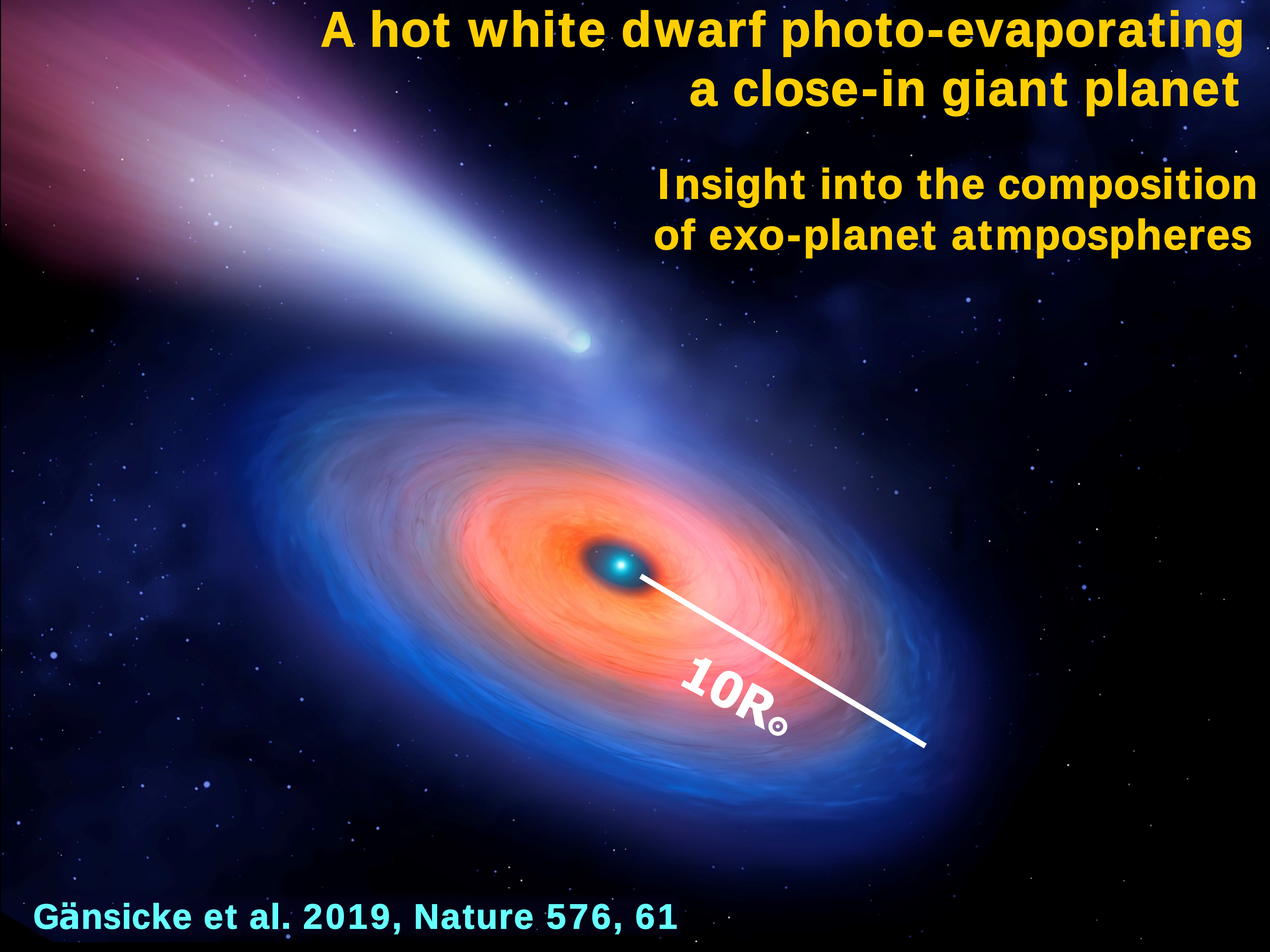
WDJ0914+1914 has a large Lα flux

… and even the Sun stops the inflow of hydrogen …
⇒ most hydrogen is blown out of the system



A hot white dwarf photo-evaporating a close-in giant planet

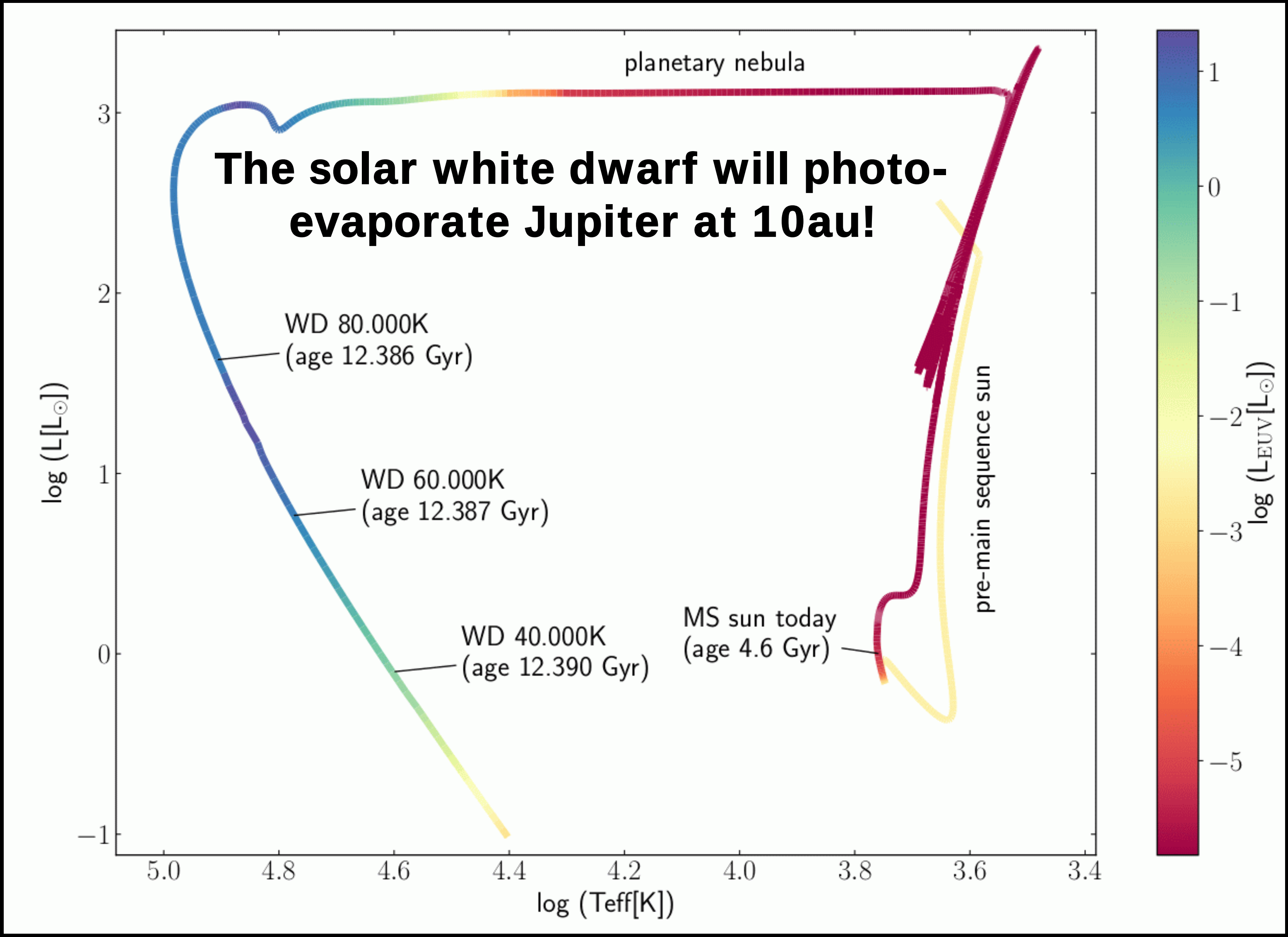
Insight into the composition of exo-planet atmpospheres



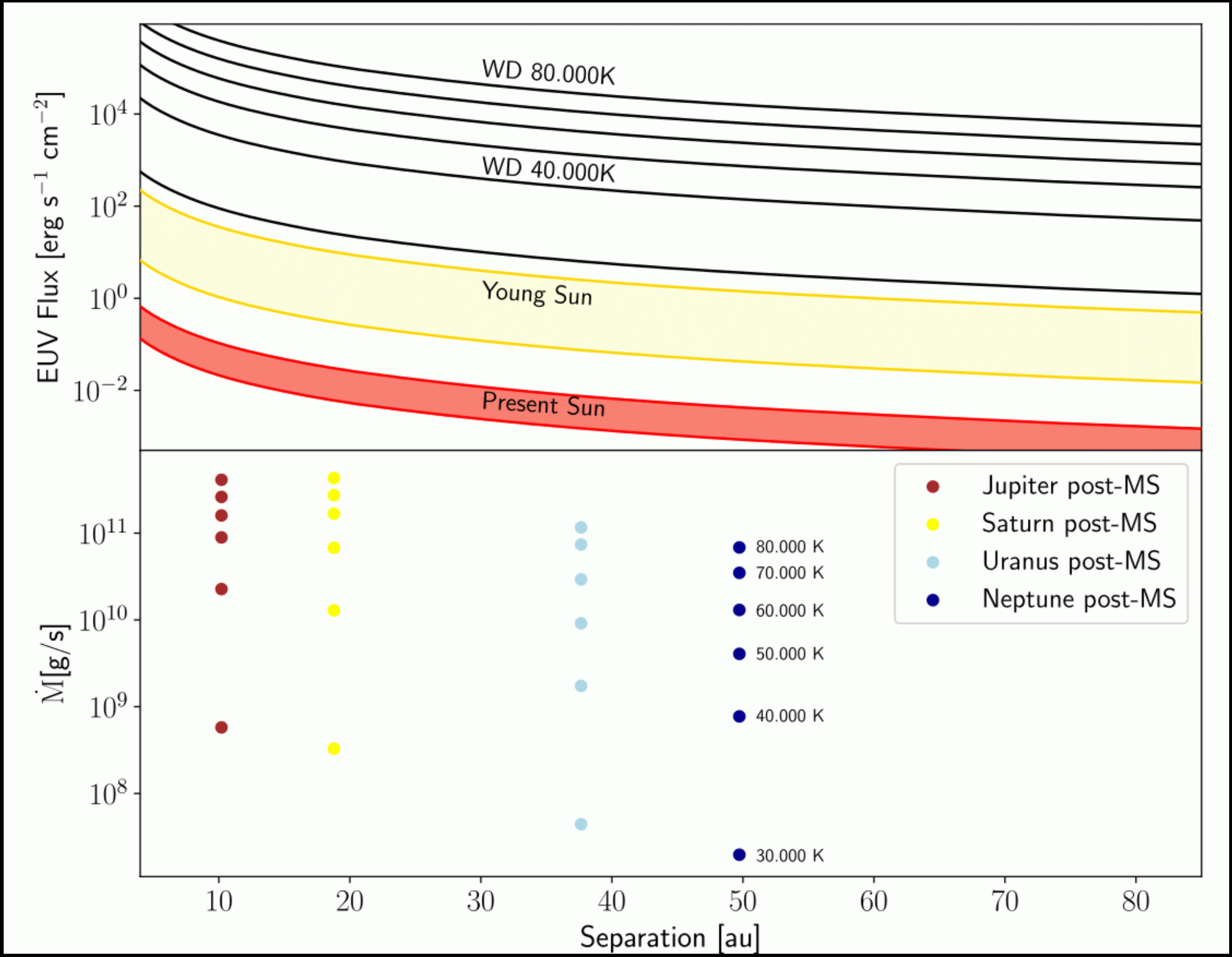
Gänsicke et al. 2019, Nature 576, 61

So, one day, the Sun we become a white dwarf

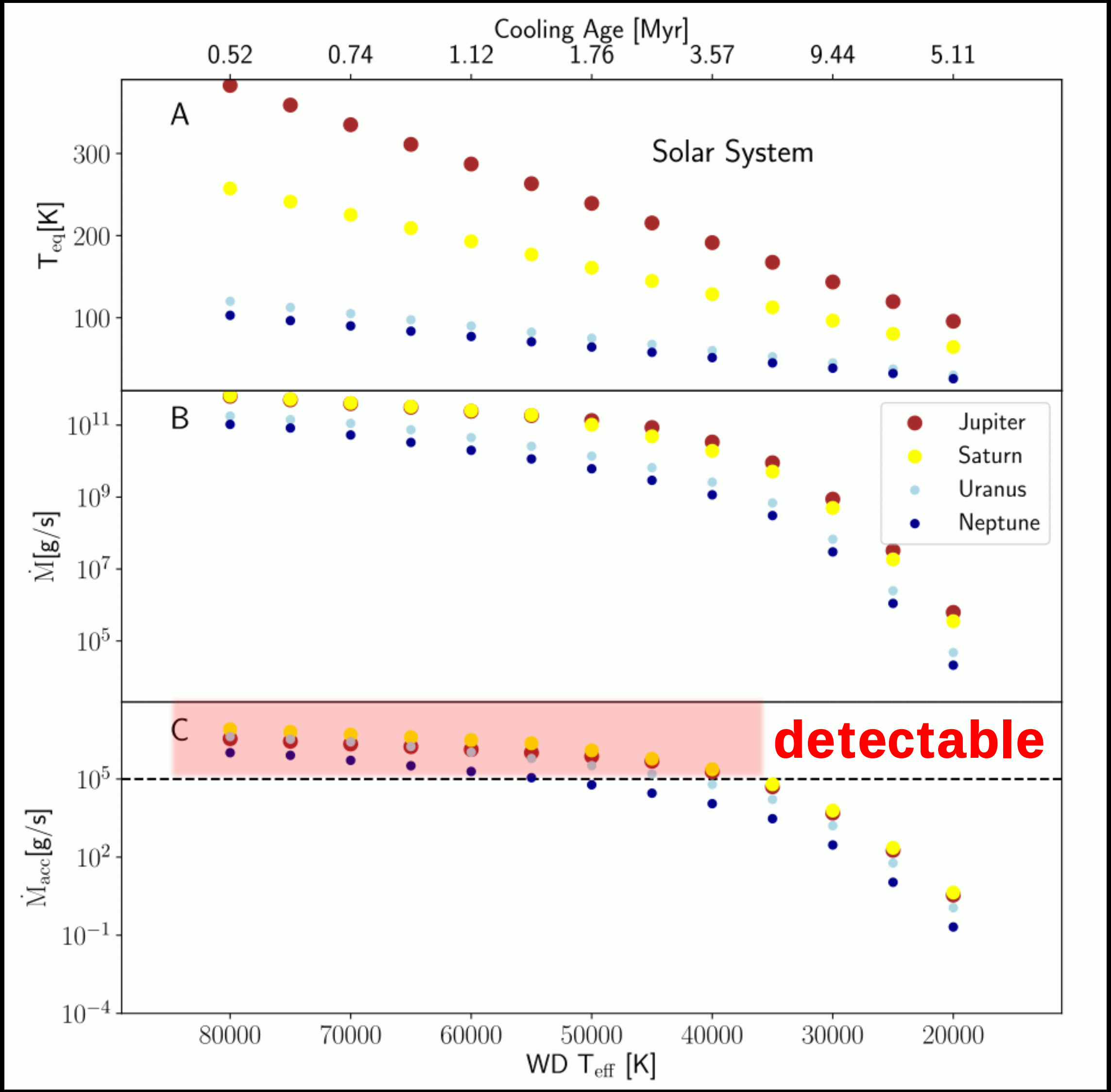
Schreiber et al. 2019, ApJL 887, 4



Mass loss rates from the giant planets



Atmosphere material from Jupiter, Saturn, Uranus & Neptune will be detectable in the Solar white dwarf!



If the Solar white dwarf will have detectable signatures of material evaporated off the giant planets …

… what about other hot & young white dwarfs?

~50 % of hot white dwarfs have volatile-contaminated (C, S, P) photospheres ....

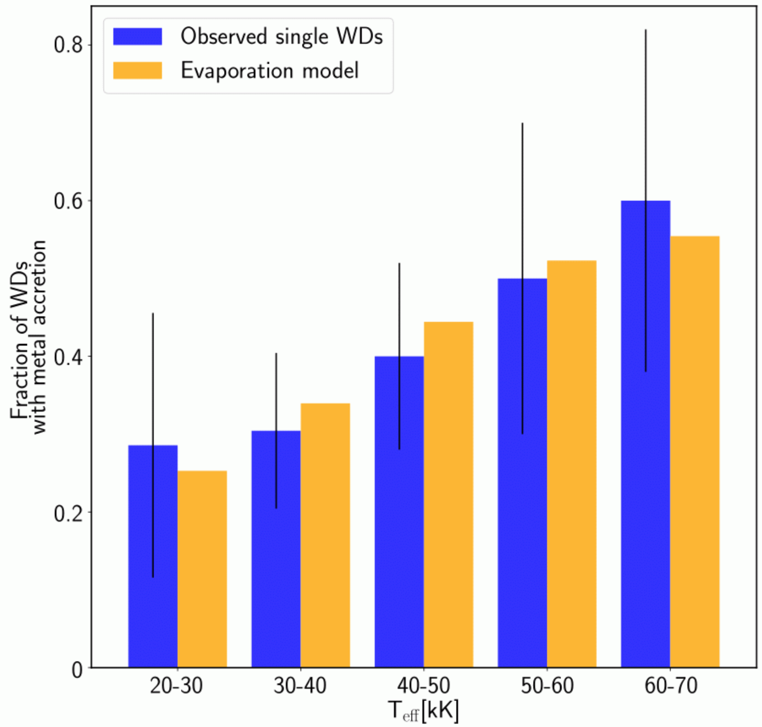


Figure 4. Comparison between the observed fraction of photospheric trace metals detected in hot white dwarfs (blue, Barstow et al. 2014) with the predictions of our model population of evaporating giant planets (orange, assuming a planet occurrence rate of 65%). In general the agreement is very good for planet occurrence rates exceeding ≃50%.

... accreting the atmospheres of evaporating giant planets?

Schreiber et al. 2019, ApJL 887, 4
Barstow et al. 2014, MNRAS 440, 1680

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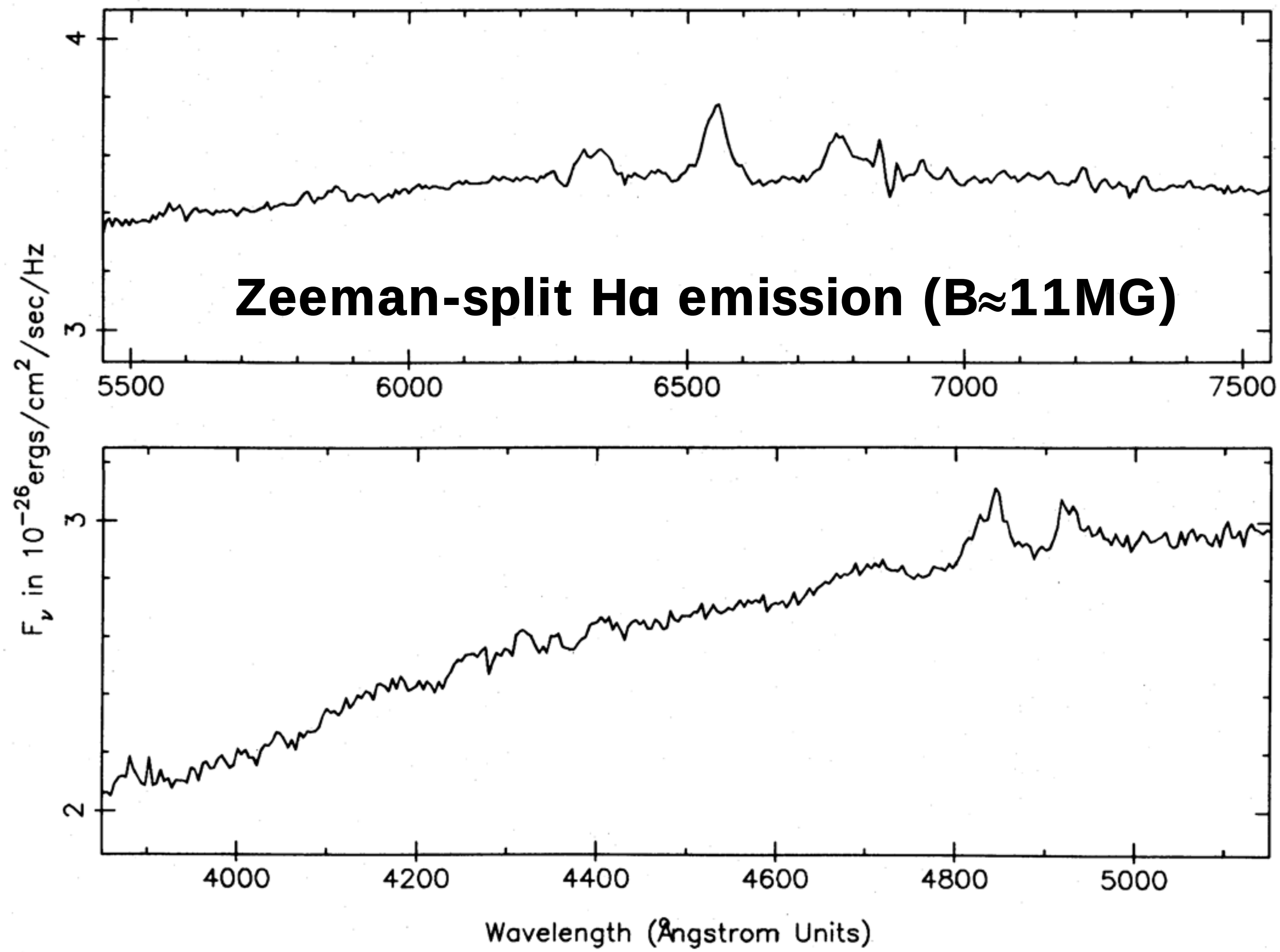
GD356, a freak

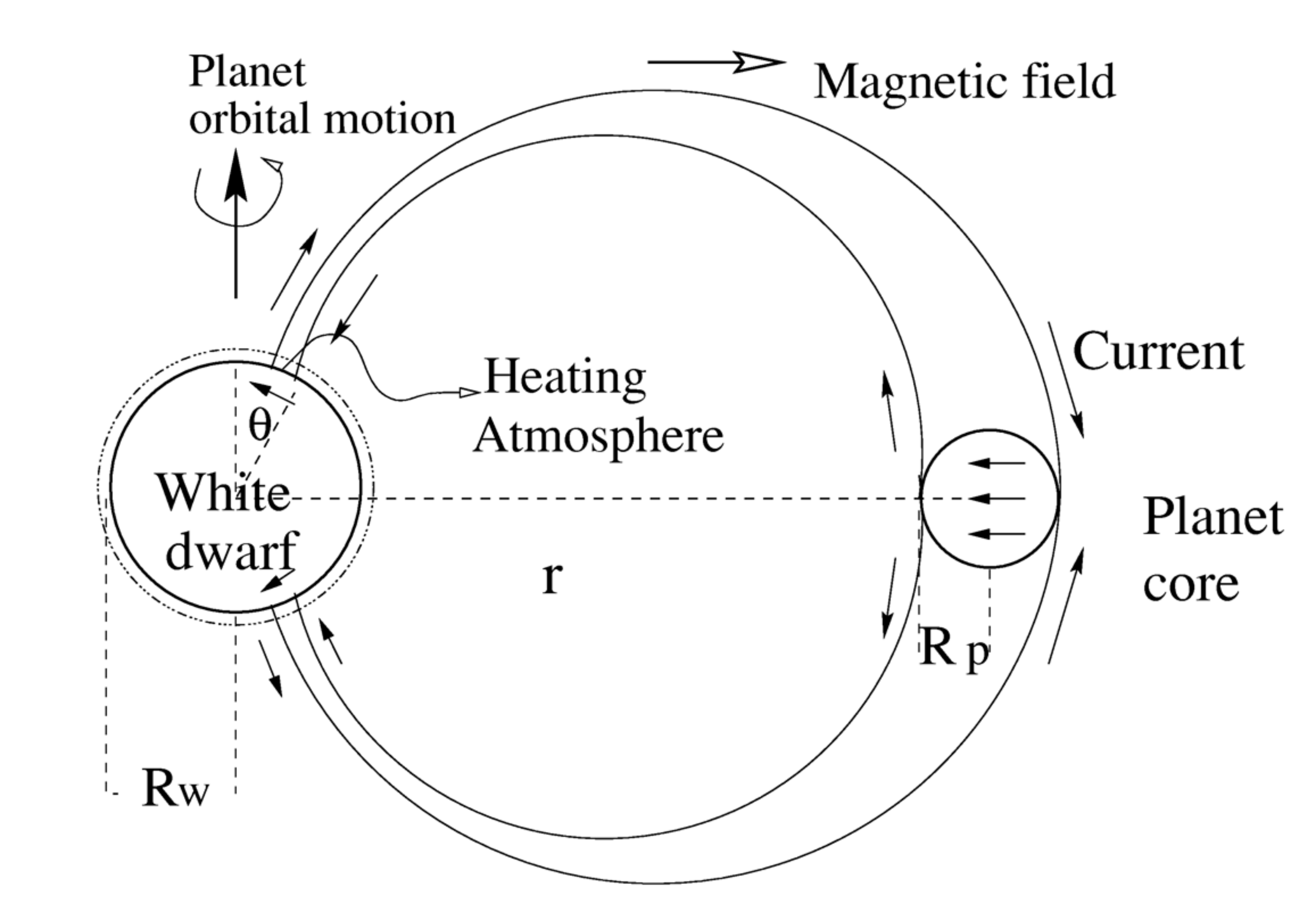
EMISSION LINES IN THE MAGNETIC WHITE DWARF GD 356

JESSE L. GREENSTEIN AND JAMES K. MCCARTHY
Palomar Observatory, California Institute of Technology
Received 1984 July 16; accepted 1984 August 30



Greenstein & McCarthy 1985, ApJ 289, 732

The unipolar inductor model



Li et al. 1998, ApJ 503, L151
Veras & Wolszczan, 2019, MNRAS 488, 153

Reding et al. 2020, ApJ 894, 19

CrossMark

An Isolated White Dwarf with 317 s Rotation and Magnetic Emission

Joshua S. Reding[1], J. J. Hermes[2], Z. Vanderbosch[3,4], E. Dennihy[5], B. C. Kaiser[1], C. B. Mace[1], B. H. Dunlap[3], and J. C. Clemens[1]

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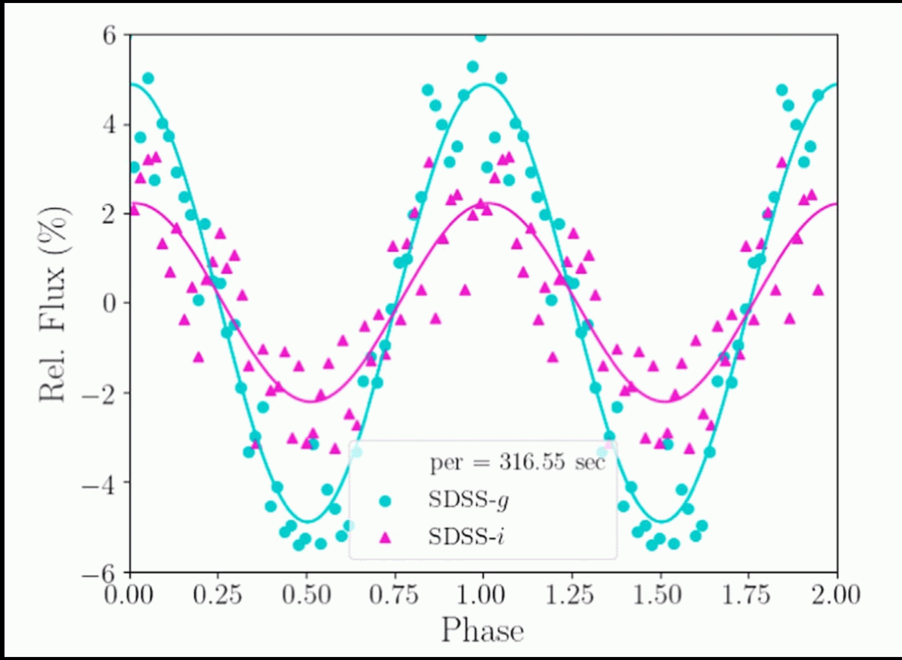
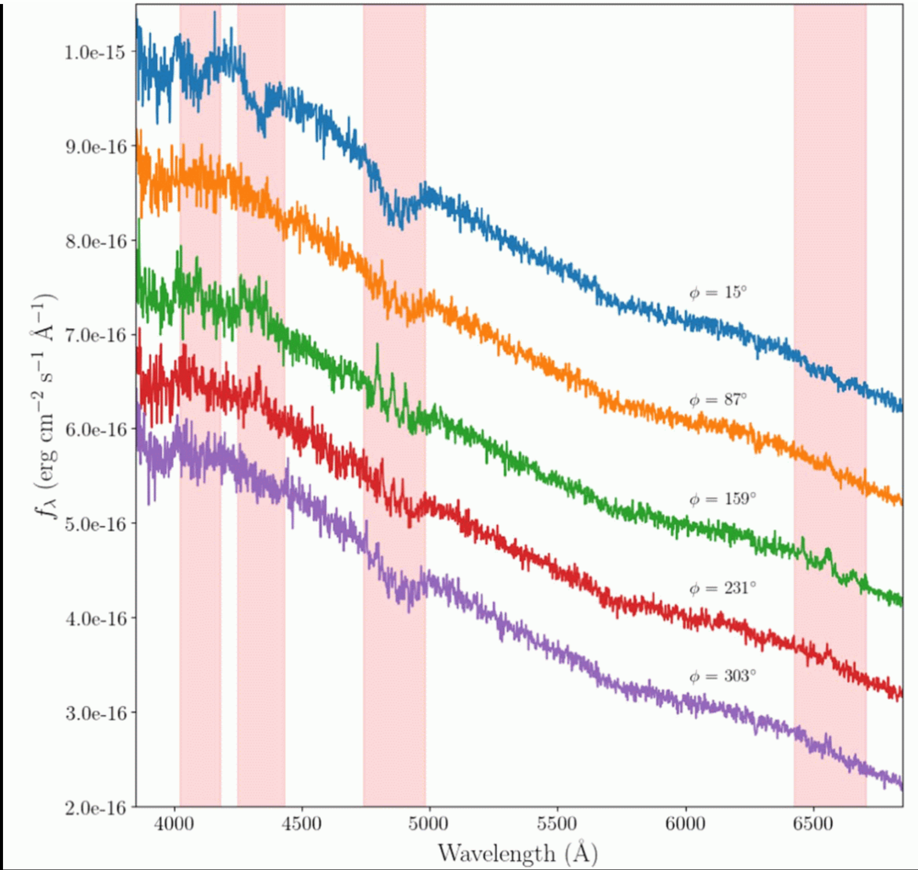
[2] Boston University, Department of Astronomy, Boston, MA 02215, USA
[3] University of Texas at Austin, Department of Astronomy, Austin, TX 78712, USA
[4] McDonald Observatory, Fort Davis, TX 79734, USA
[5] NSF's National Optical-Infrared Astronomy Research Laboratory, Gemini Observatory, Colina el Pino S/N, La Serena, Chile

Received 2020 February 29; revised 2020 March 19; accepted 2020 March 21; published 2020 April 30





Reding et al. 2020, ApJ 894, 19

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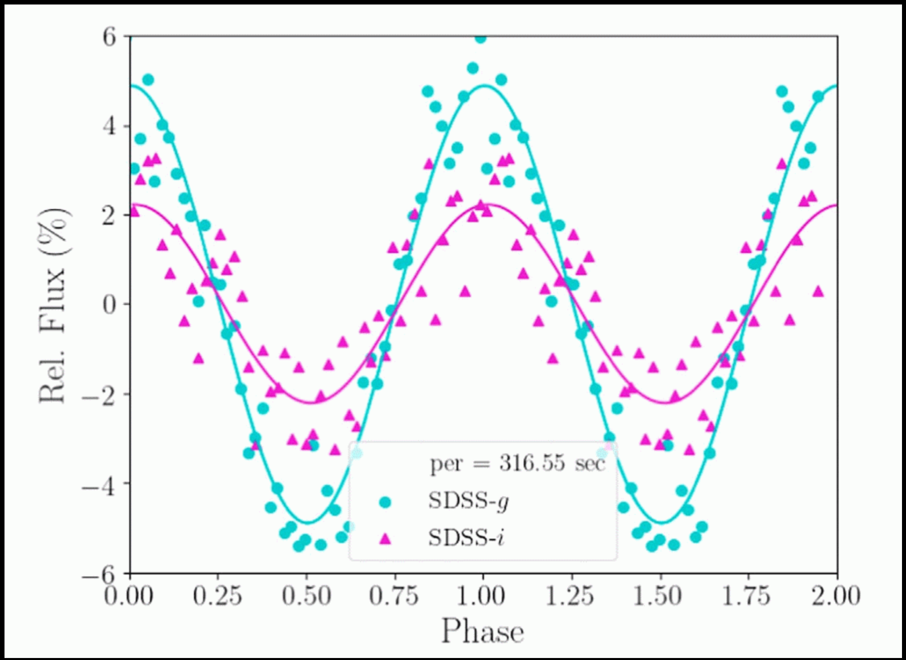
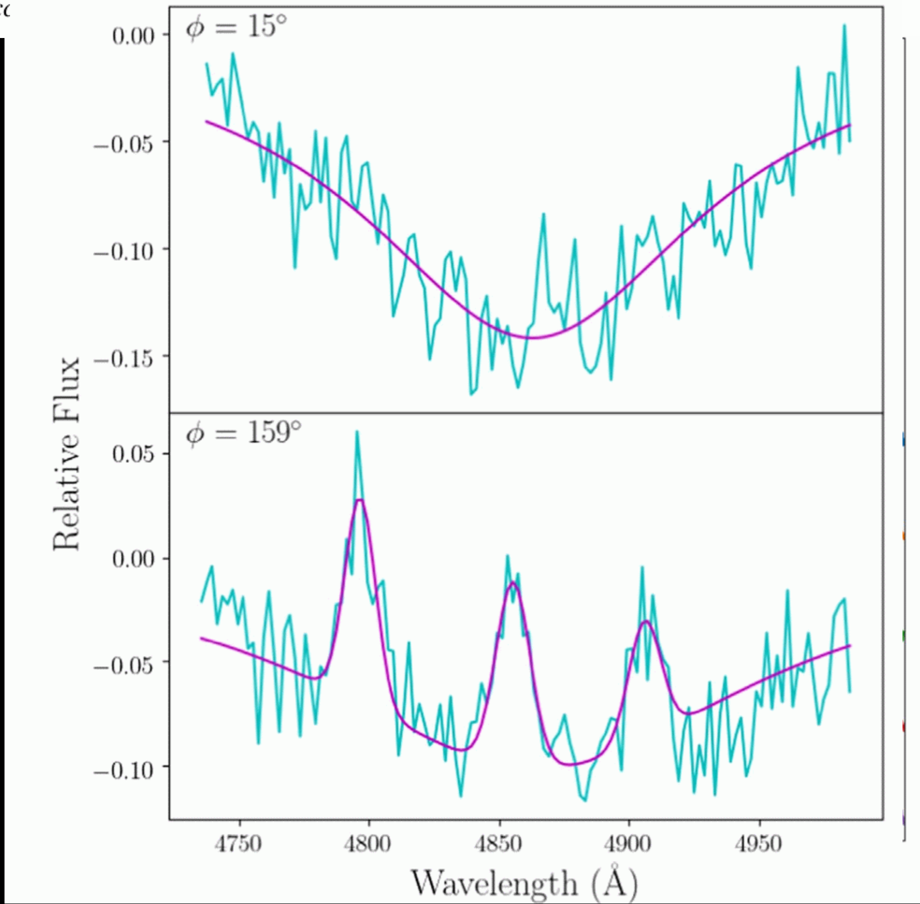
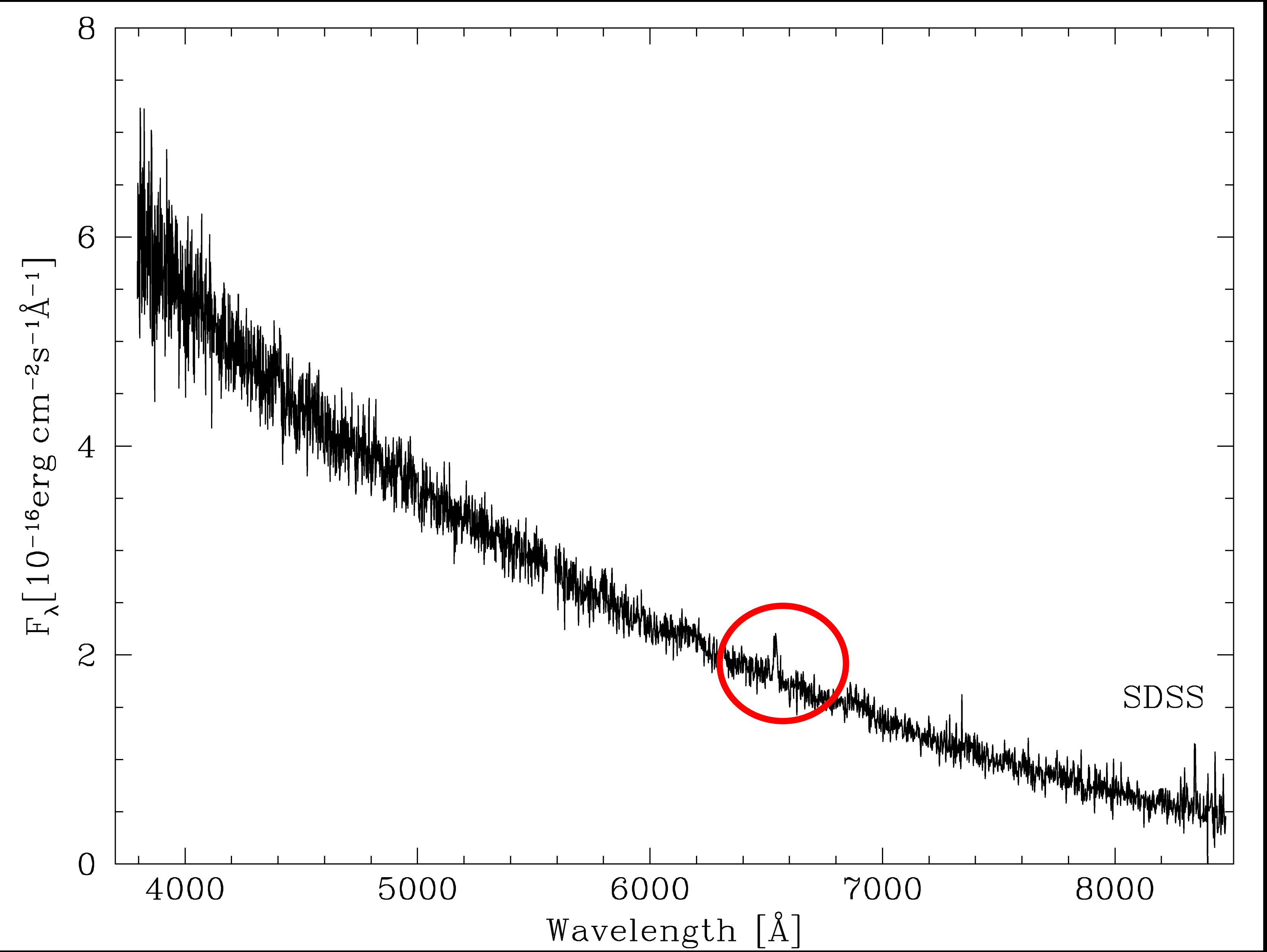
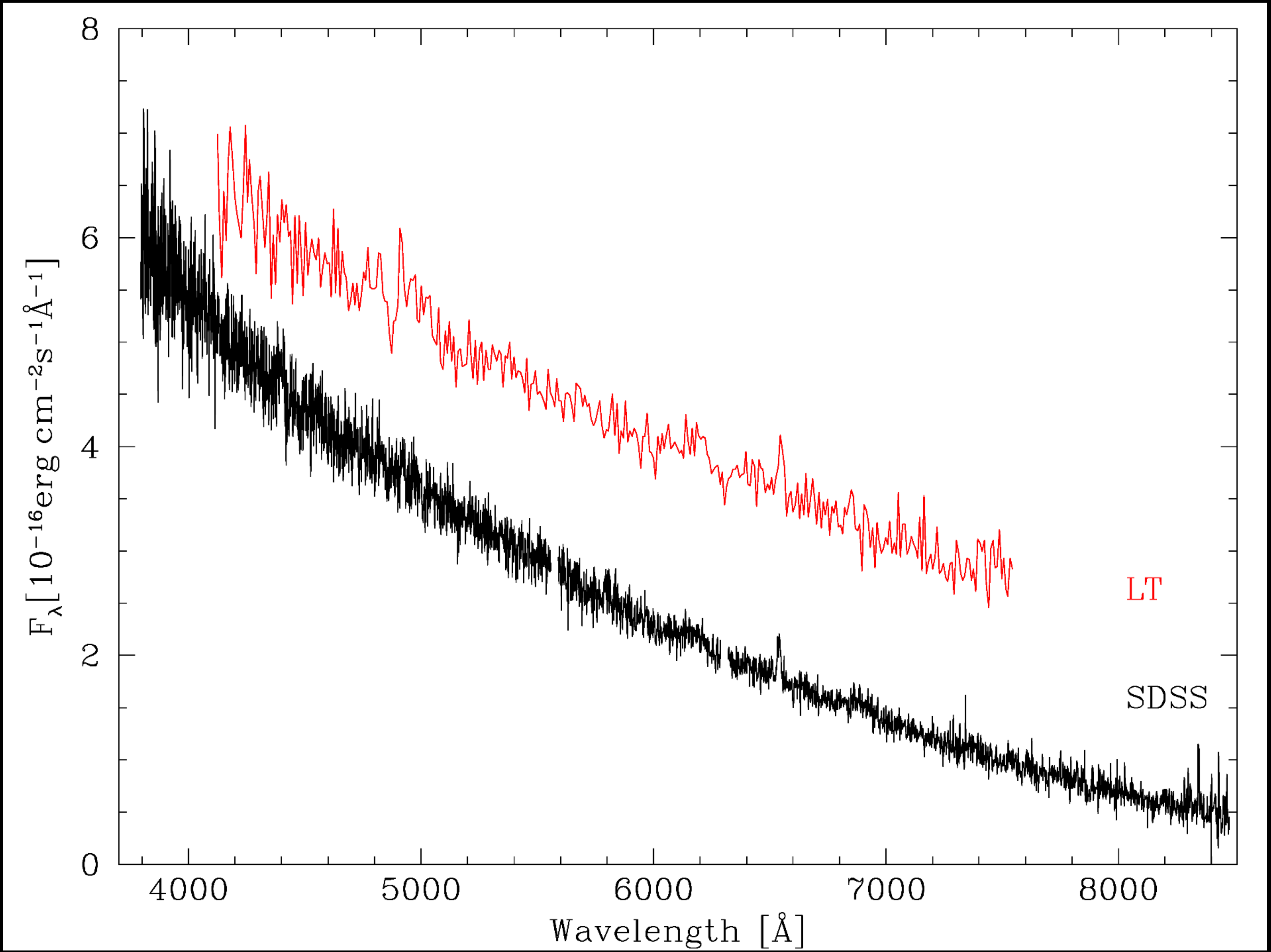




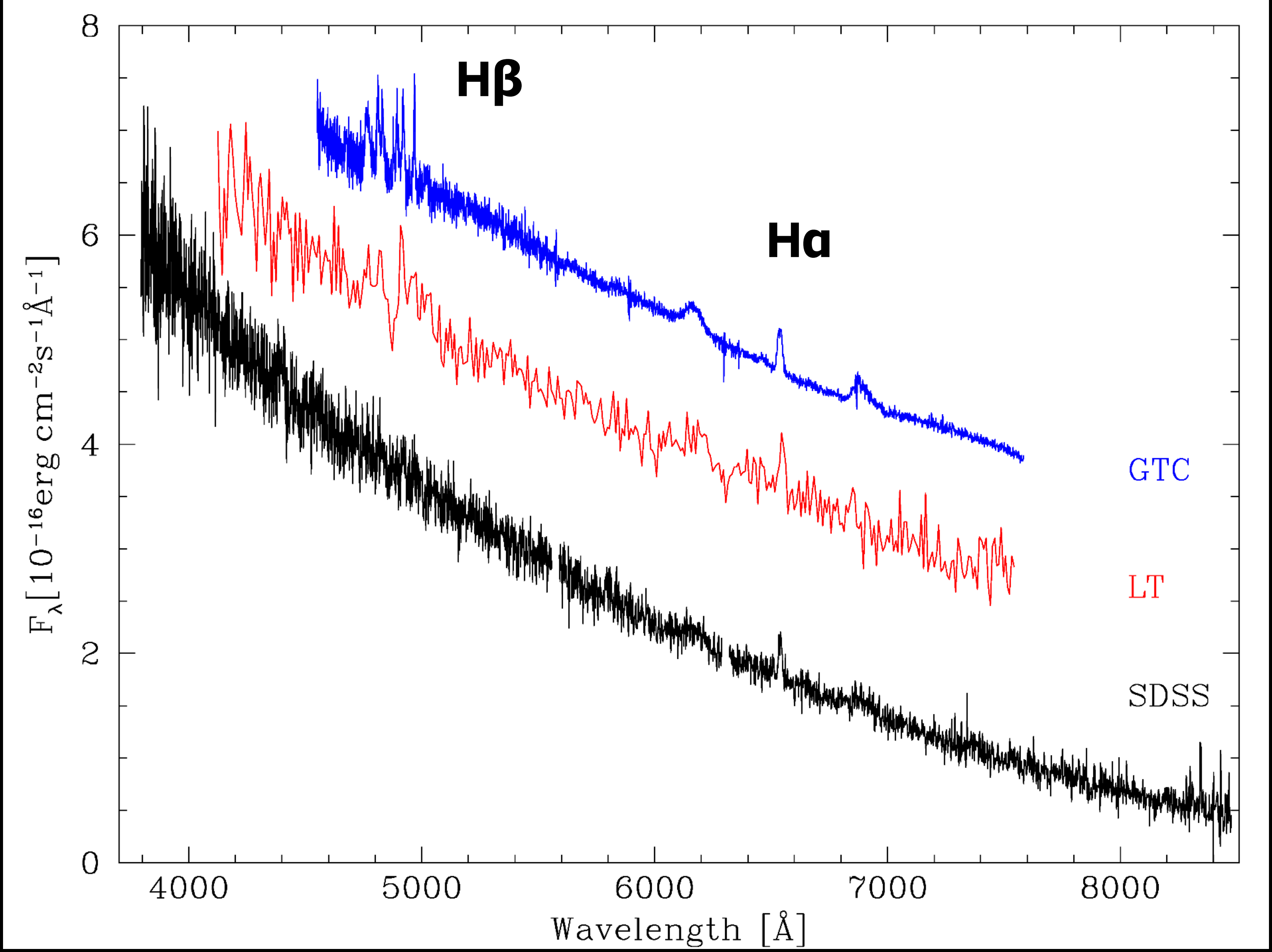
2004: a cataclysmic variable (Szkody et al. 2006) ?



2020: 2m Liverpool Telescope



Call in the artillery (=GTC)

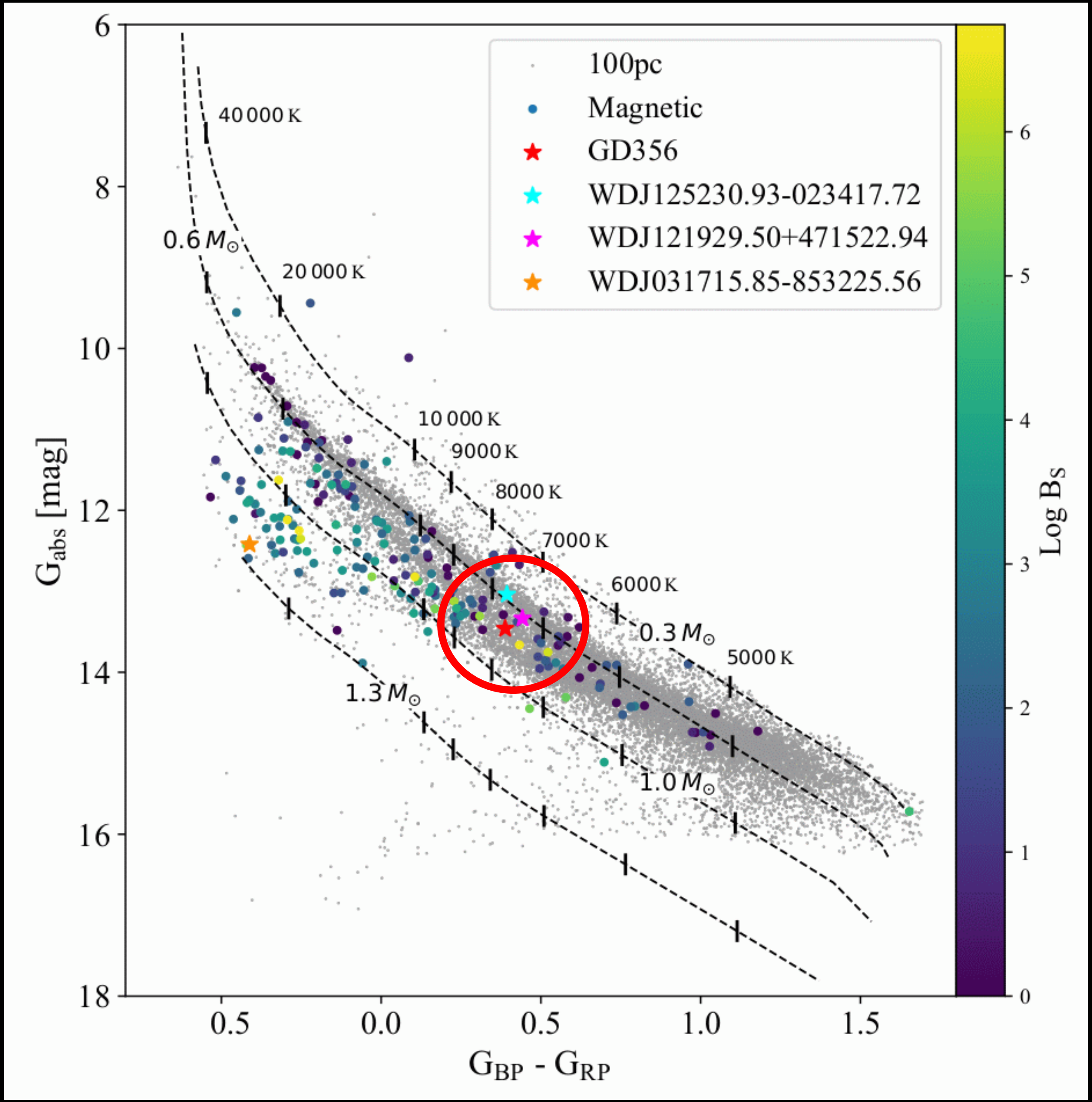


Except P_{spin} *very* similar properties!

Parameter		GD356	SDSS J1252–0234	SDSS J1219+4715
Parallax	ϖ [mas]	49.65 ± 0.03	12.94 ± 0.11	14.28 ± 0.12
Distance	d [pc]	20.1 ± 0.1	77.1 ± 0.7	69.6 ± 0.6
Gaia photometry	G [mag]	14.9808 ± 0.0007	17.4775 ± 0.0019	17.5612 ± 0.0018
Proper motion	μ_α [mas/yr]	-119.40 ± 0.06	49.64 ± 0.25	-113.28 ± 0.11
	μ_δ [mas/yr]	-190.61 ± 0.08	-39.95 ± 0.16	-3.492 ± 0.15
Effective temperature	$T_{\rm eff}$ [K]	7698 ± 74	7856 ± 101	7500 ± 148
Surface gravity	$\log g$ (cgs)	8.22 ± 0.04	7.98 ± 0.06	8.09 ± 0.04
Mass	$M_{\rm wd}$ [$M_\odot$]	0.733 ± 0.023	0.583 ± 0.031	0.649 ± 0.022
Cooling age	$\tau_{\rm cool}$ [Myr]	1805 ± 120	1117 ± 86	1506 ± 114
Magnetic field*	B [MG]	11 ± 1.1	5 ± 0.1	18.5 ± 1.0
Spin period	P [h]	1.9280 ± 0.0011	0.0881328 ± 0.0000036	15.26415 ± 0.00019

… not particularly massive, double-degenerate mergers are possible, but require fairly low-mass progenitors (that don't seem to be very frequent)

Where do these three sit in the HRD?



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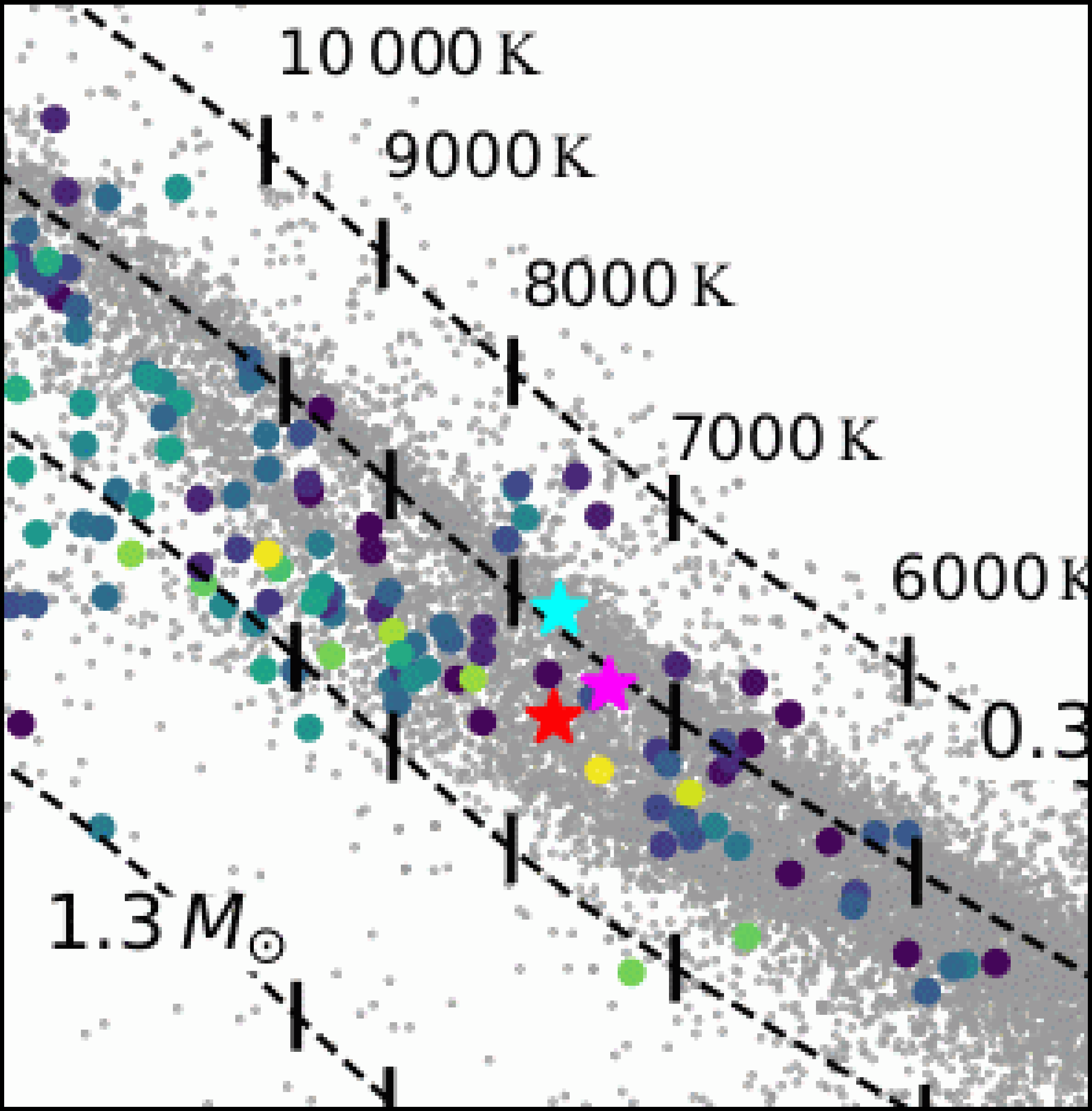

Single magnetic white dwarfs with Balmer emission lines:

A small class with consistent physical characteristics as possible signposts for close-in planetary companions

The clustering seems to require:

(1) a mechanism that turns the emission lines on at ≈1.5Gyr cooling age (toy model is in the works) ...

(2) ... and that quite quickly switches off again (Veras & Wolzczan)

(3) plus close-in (conductive) planets around a fair fraction of white dwarfs

Gänsicke et al. 2020, MNRAS submitted