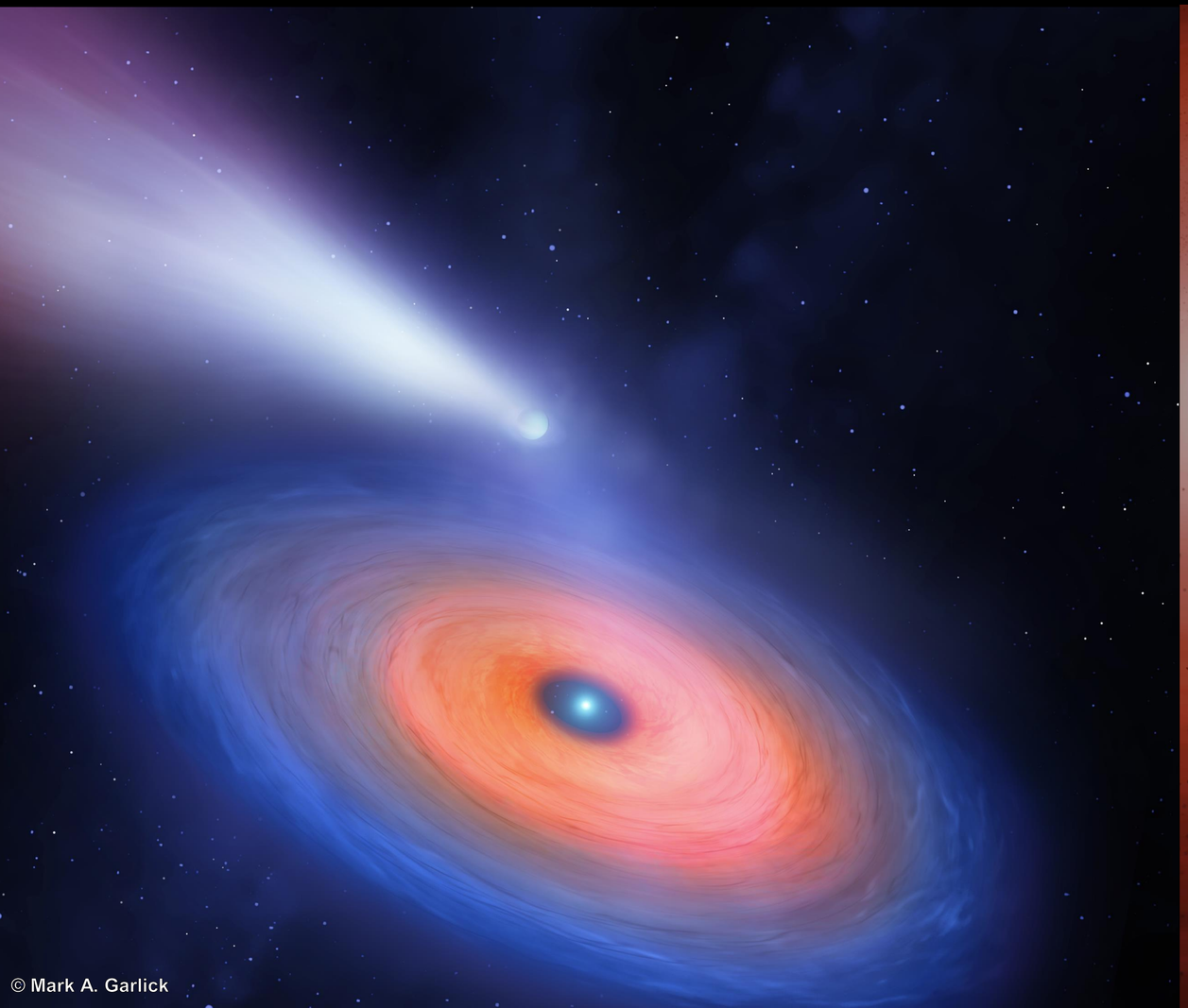
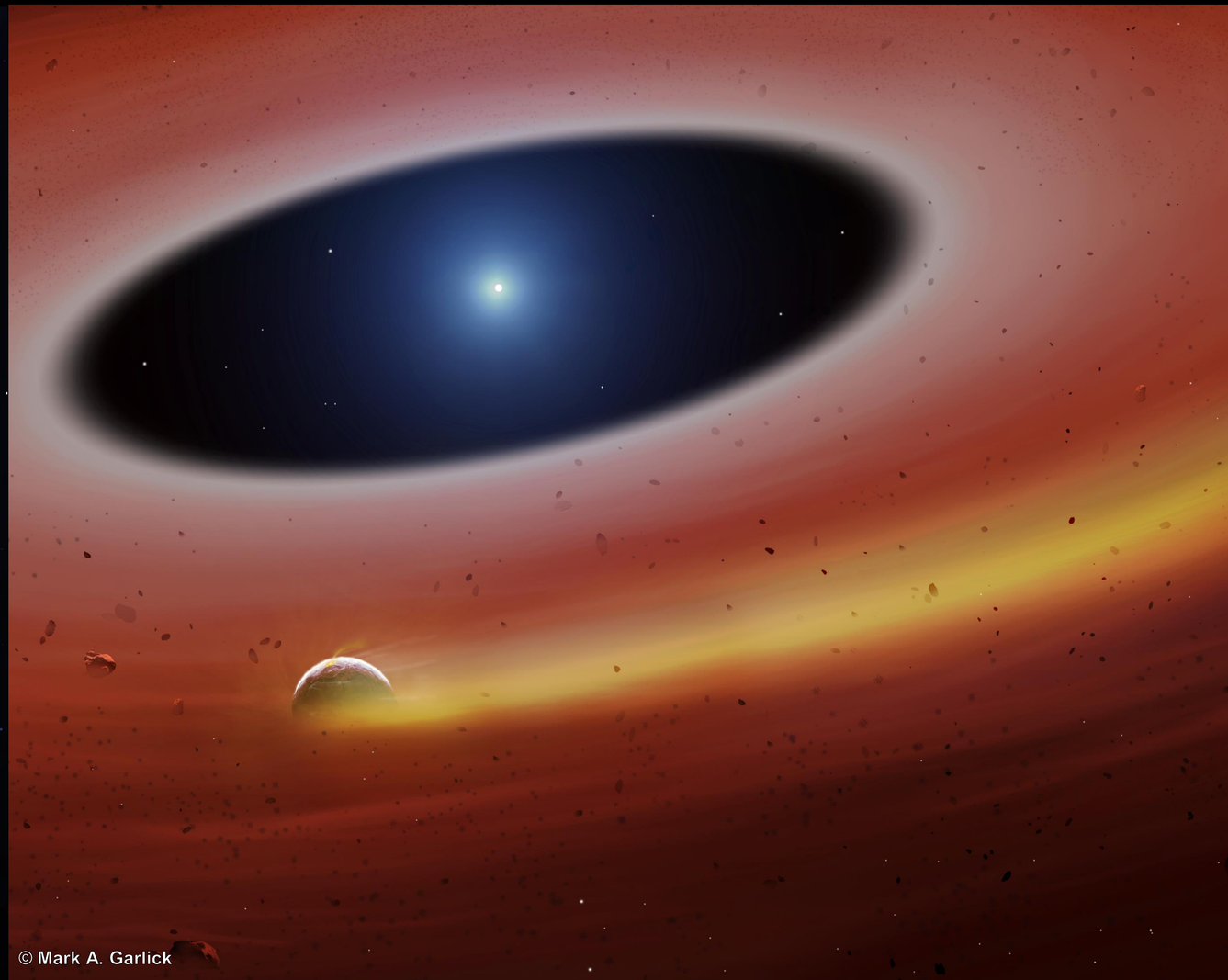
Gaseous planetary discs around white dwarfs

Christopher Manser - Imperial College London, UK

c.j.manser92@googlemail.com





Delivering material to white dwarf atmospheres

Image credit: ESA/NASA

% White dwarfs are white dwarfs

100%

Delivering material to white dwarf atmospheres

Accretion from debris discs

Zuckerman & Bucklin 1987; Jura 2003

Image credit: hammacher.com

Direct impact

Alcock et al. 1986; Brown et al 2017;
McDonald & Veras, Submitted

Evaporating giant planets

Gänsicke et al. 2019; Schreiber et al. 2019

Image credit: ESA/NASA

% White dwarfs are metal polluted

25-50%

Zuckerman et al. 2003; 2010; Koester et. al. 2014

Delivering material to white dwarf atmospheres

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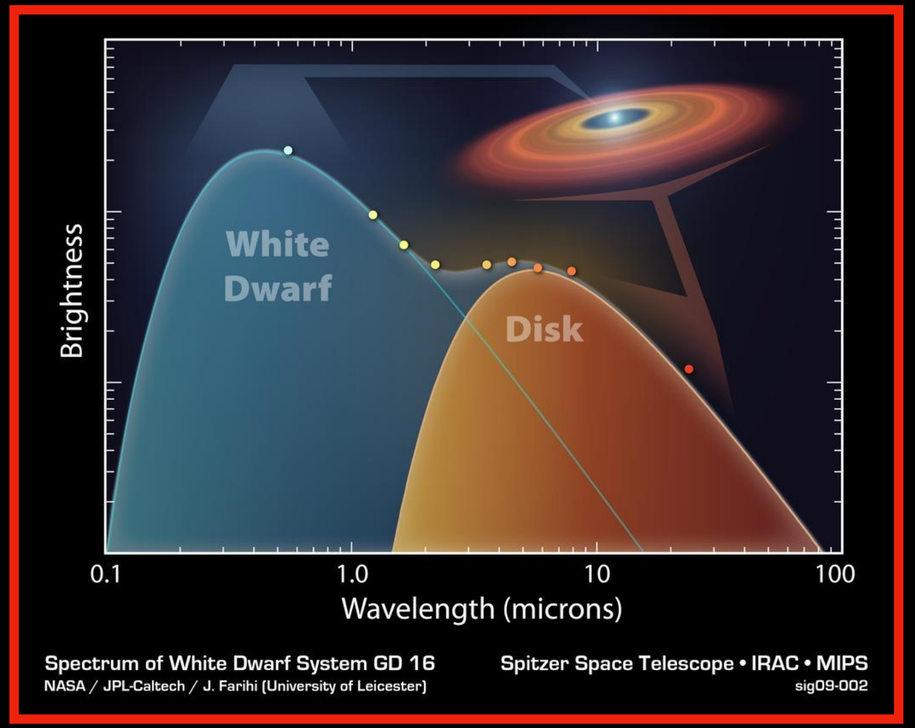
Zuckerman & Bucklin 1987; Jura 2003

Image credit: hammacher.com



Evaporating giant planets

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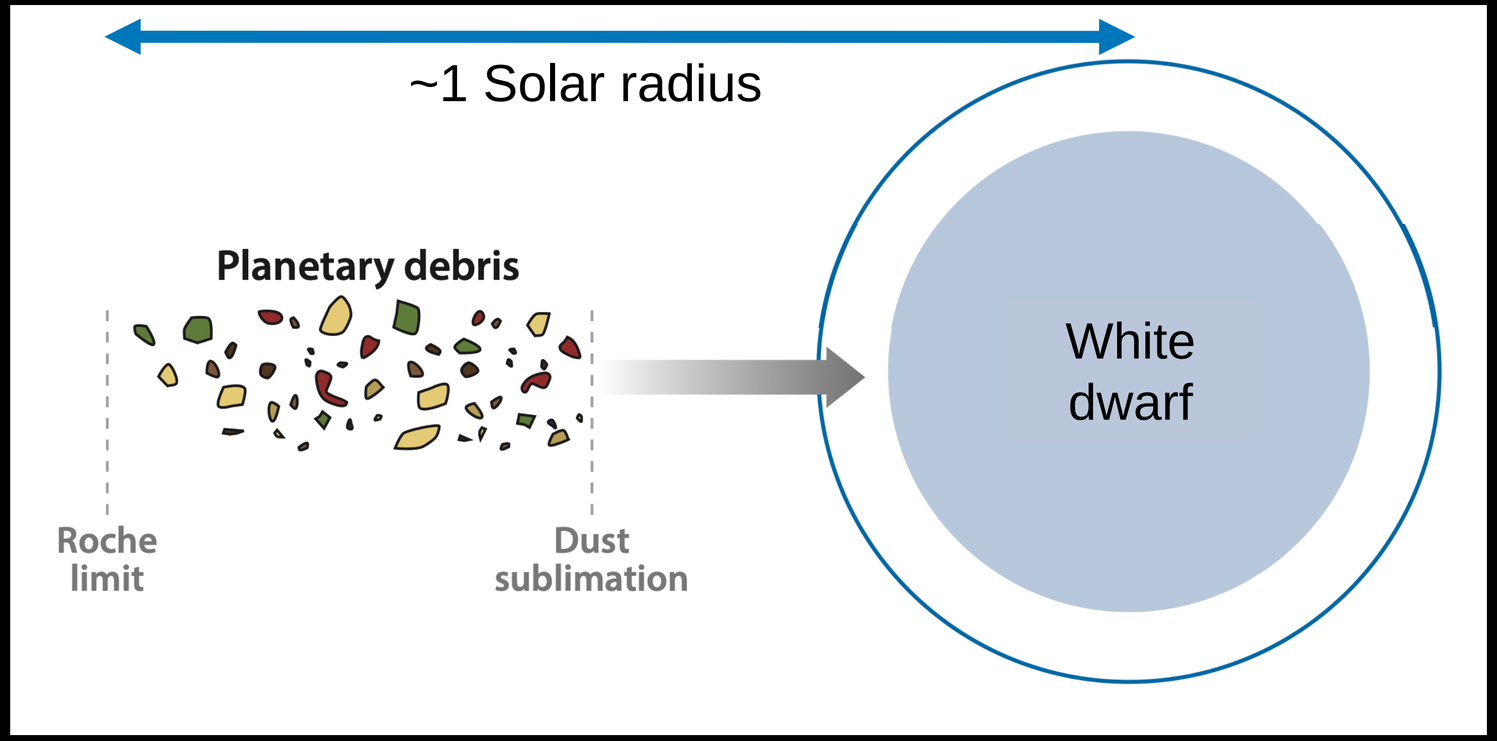
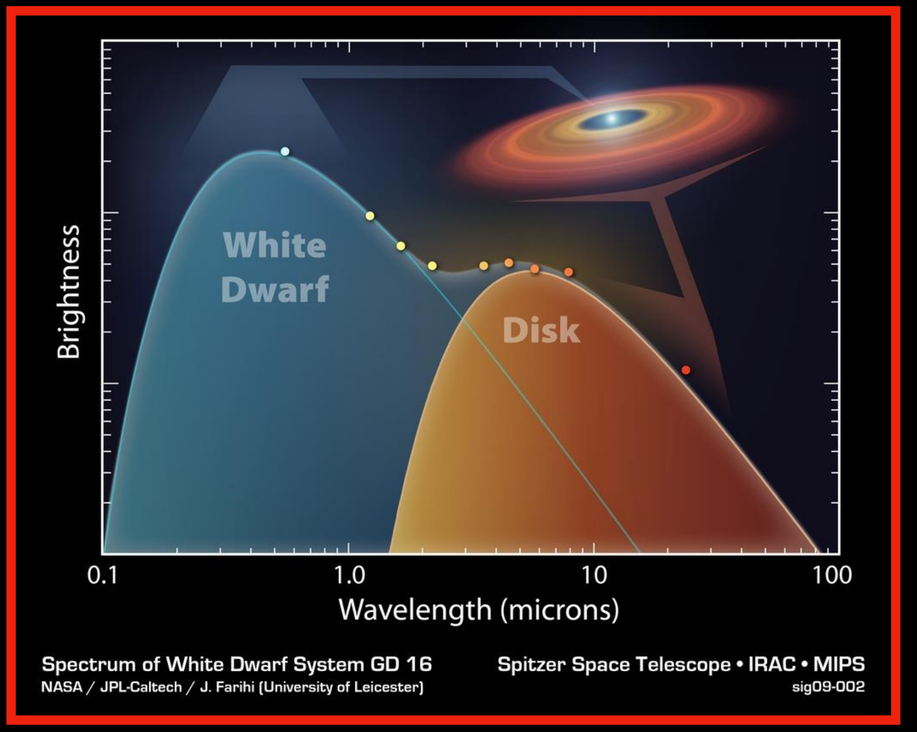
% White dwarfs with observed dusty disc

1-3%

Farihi et al. 2009; Rocchetto et al. 2015, Wilson et al. 2019

Debris discs around white dwarfs





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Jura & Young 2014 AREPS, 42, 45

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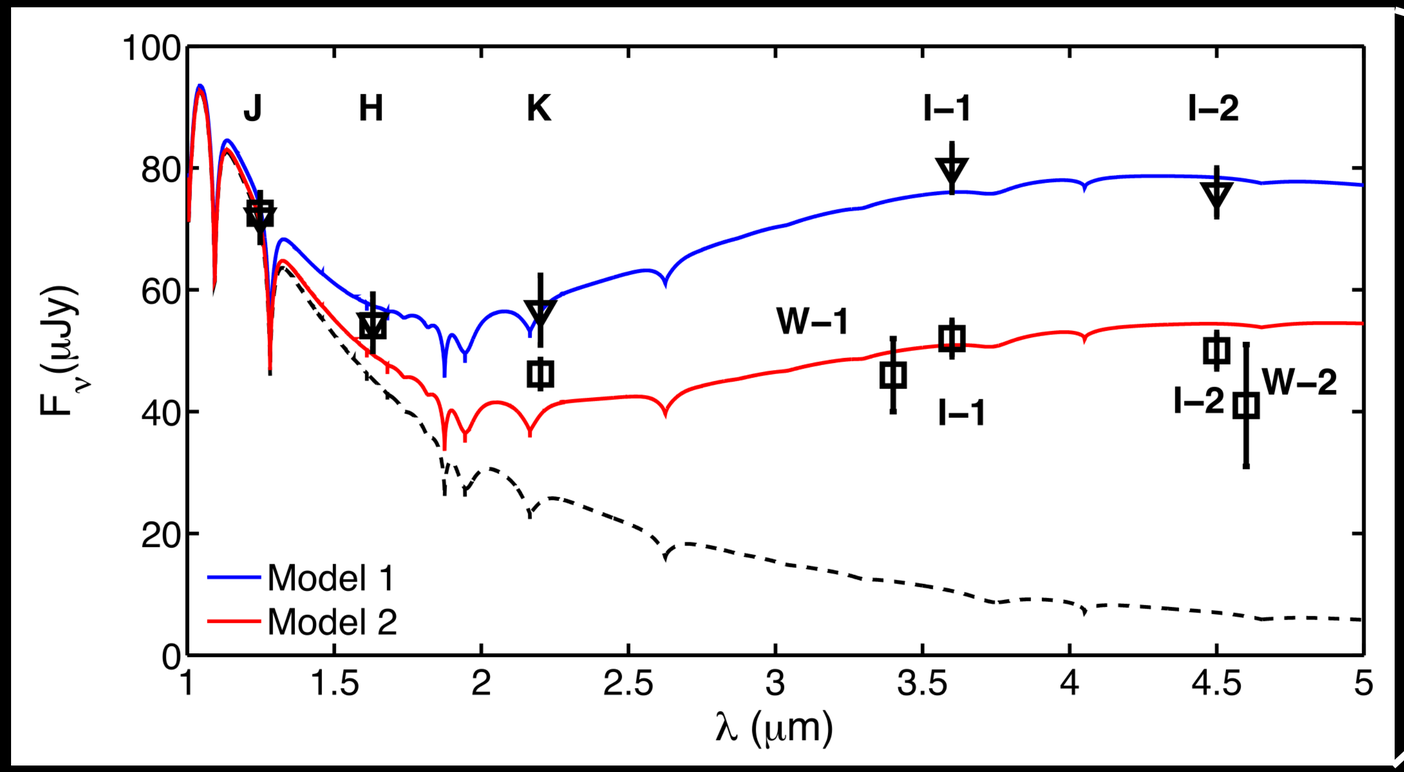
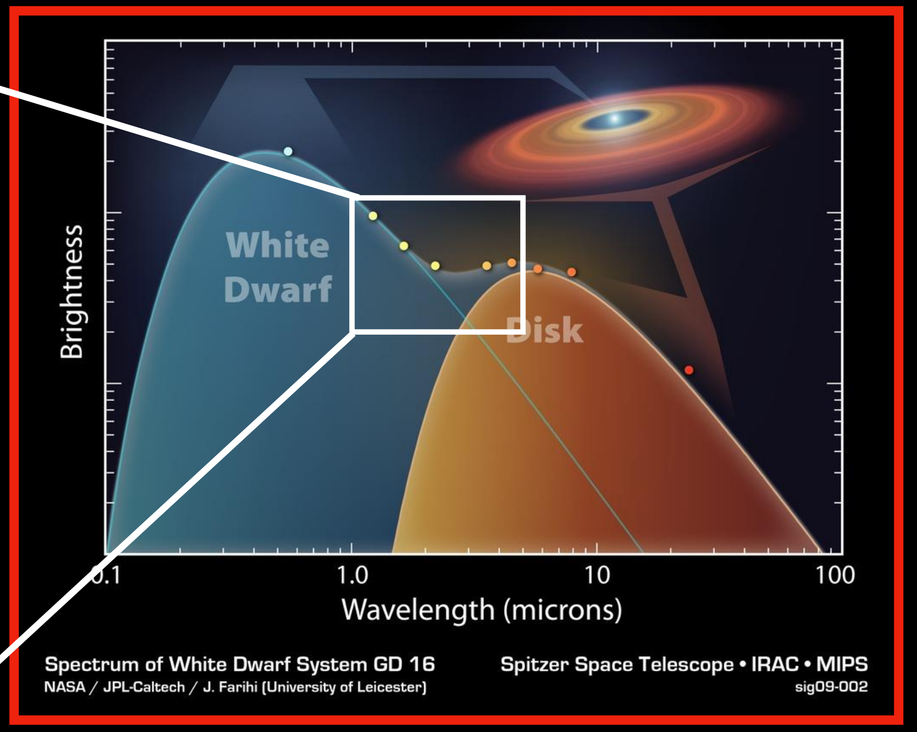
Debris discs and their variability





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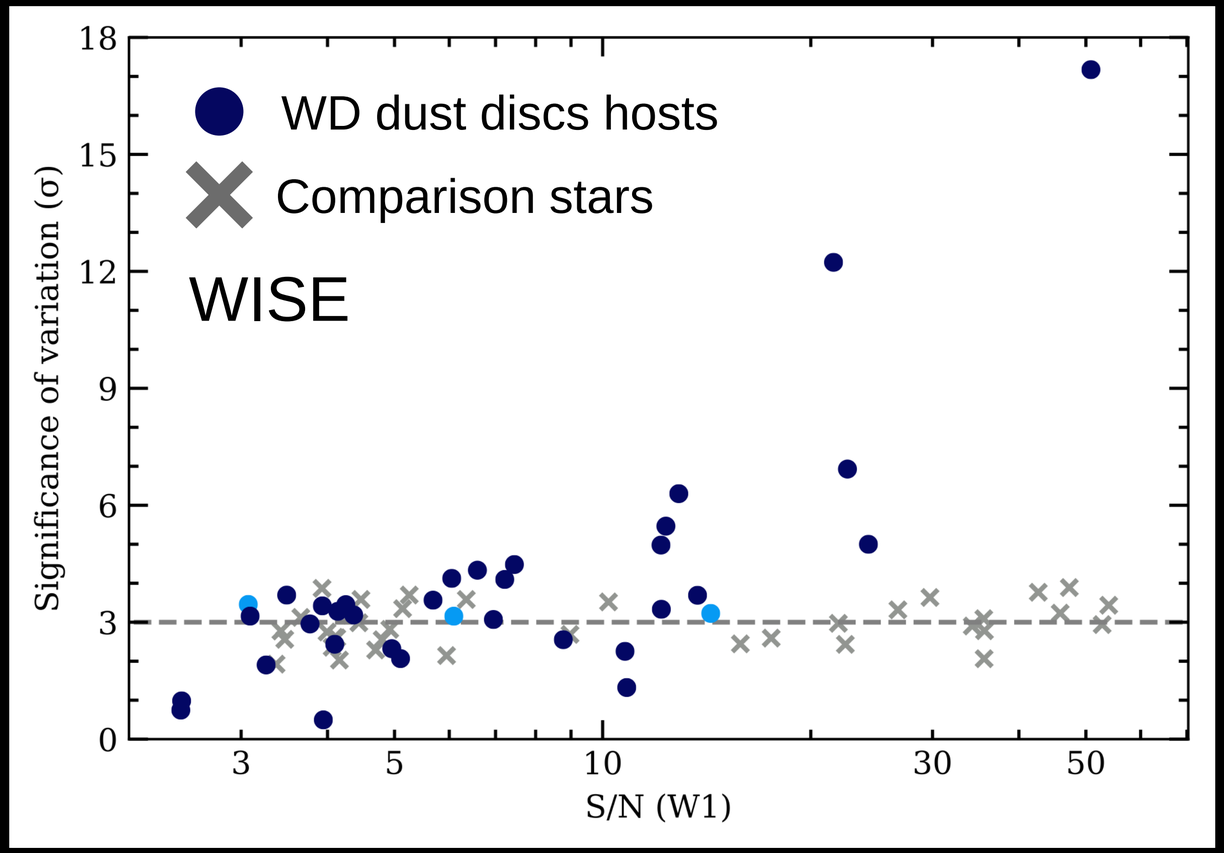

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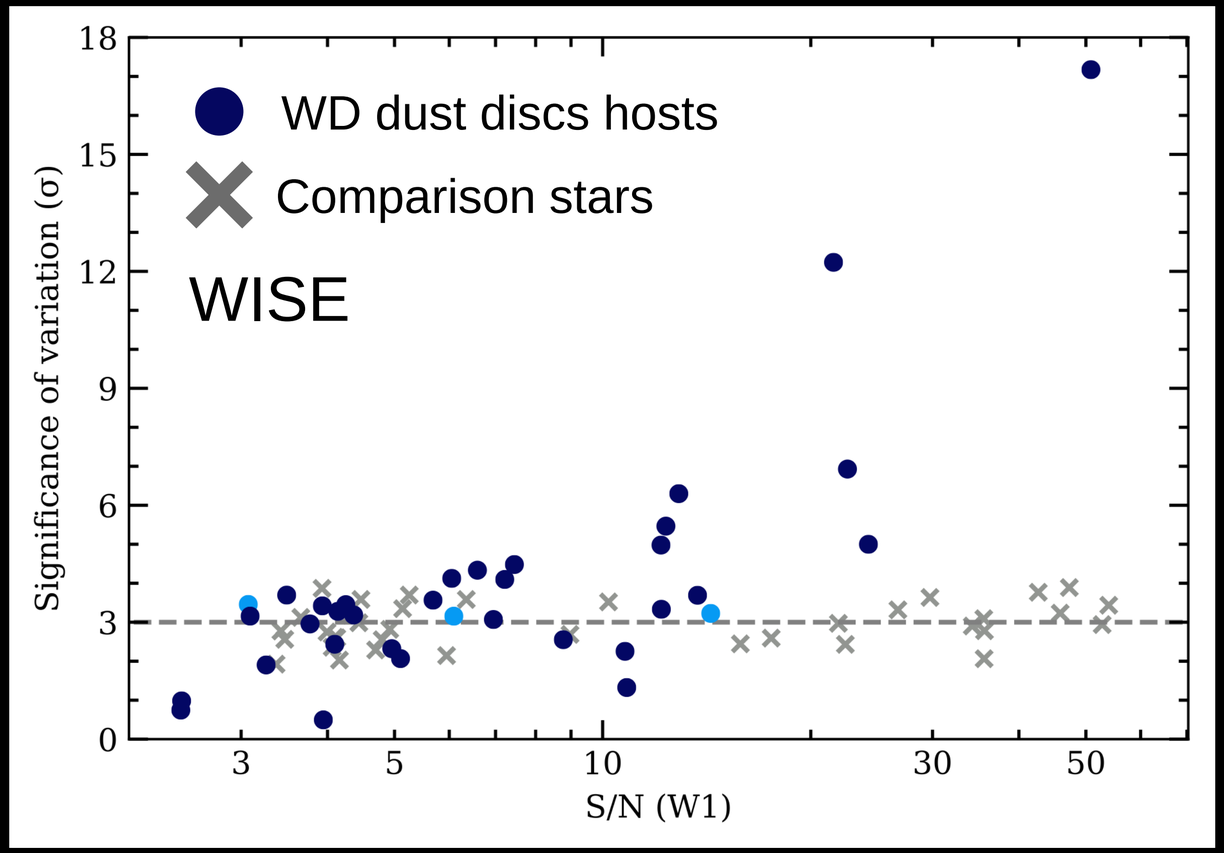

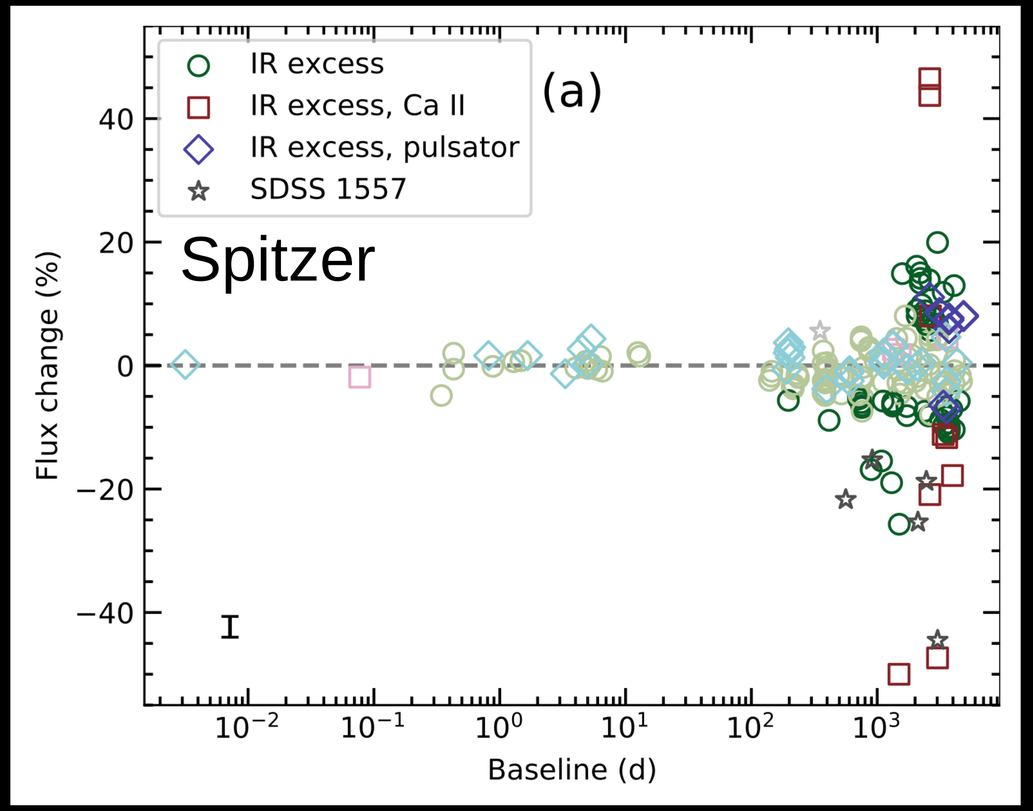

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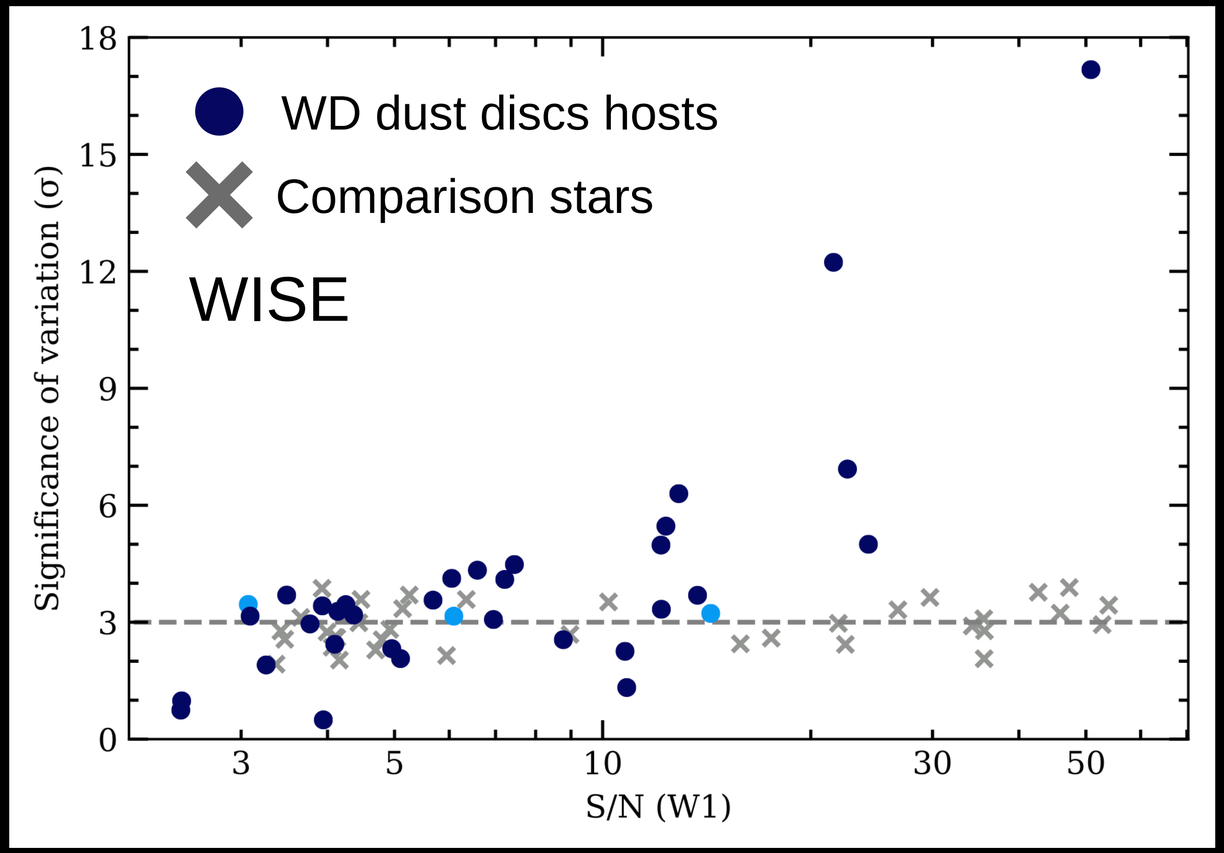

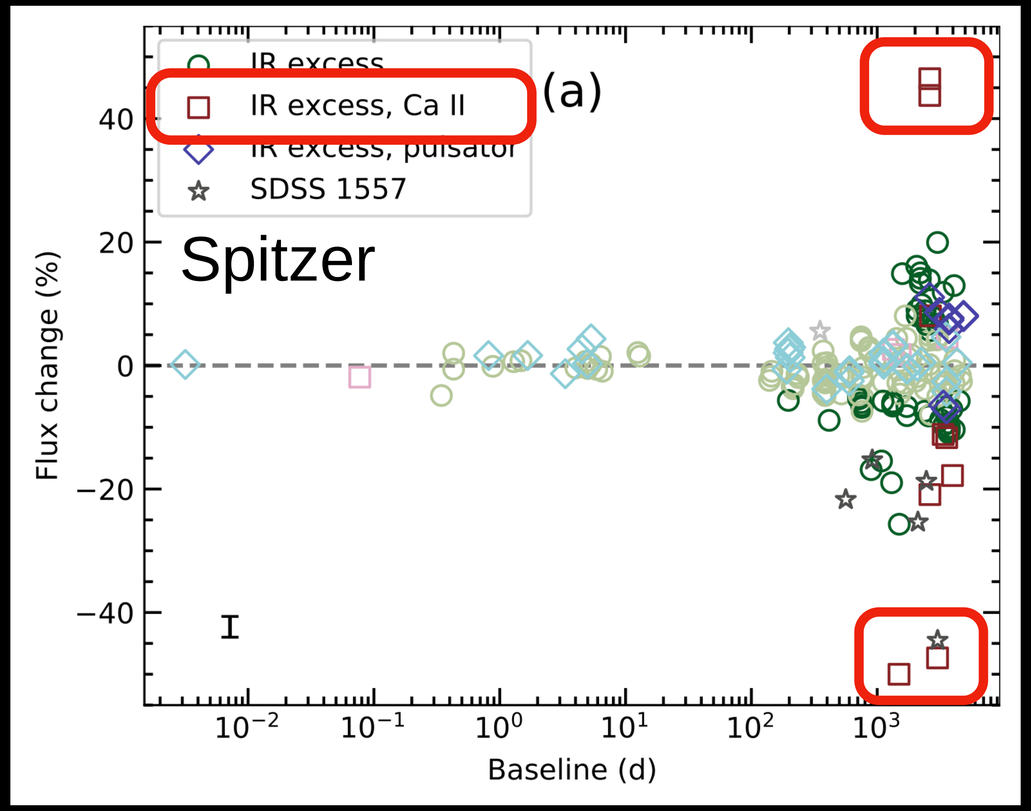

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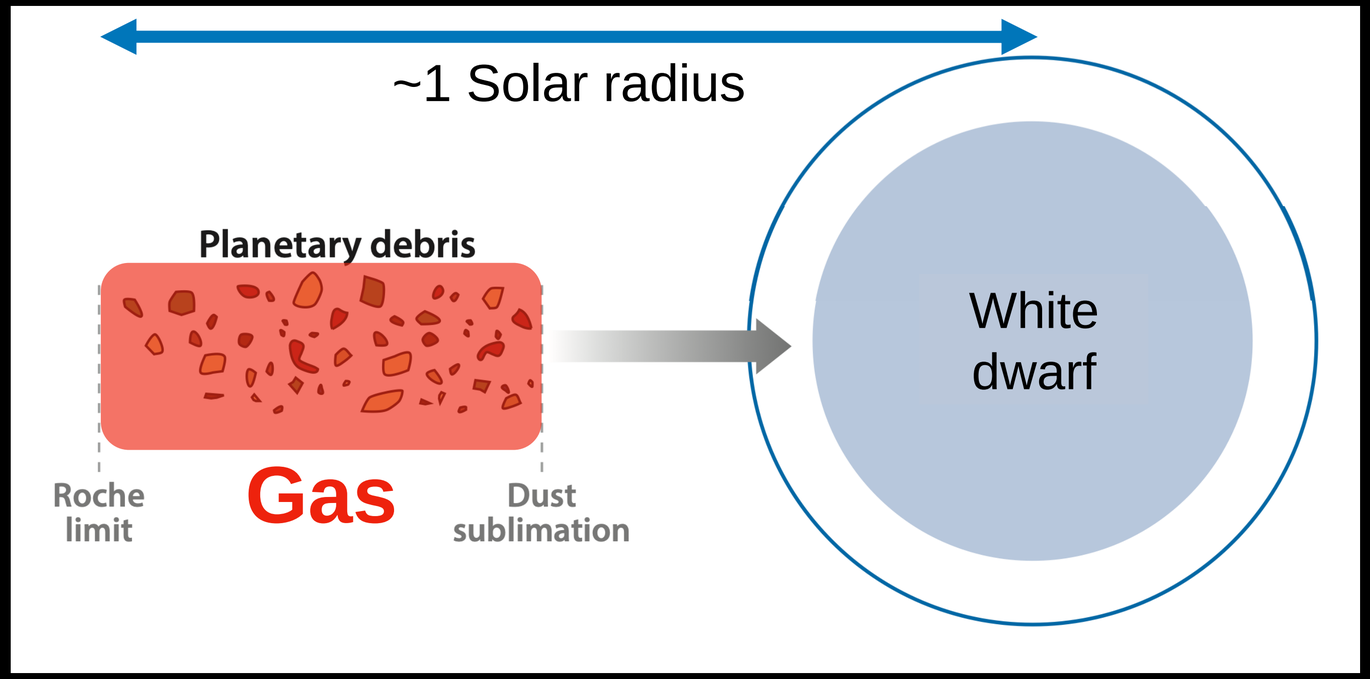
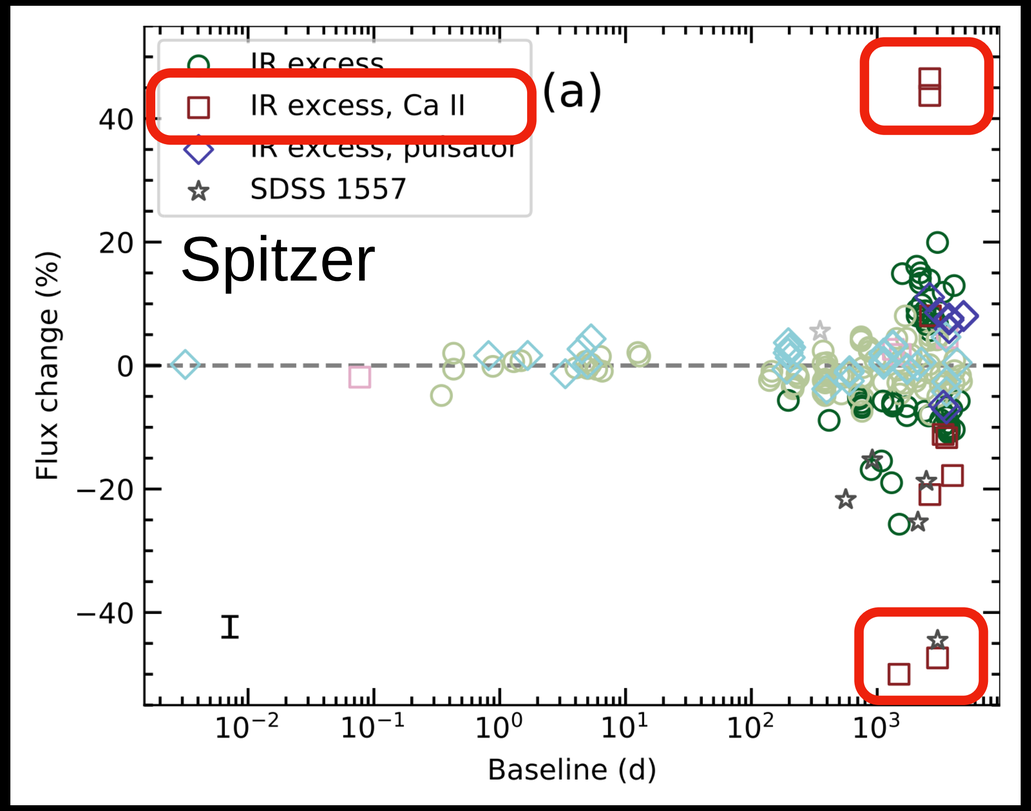




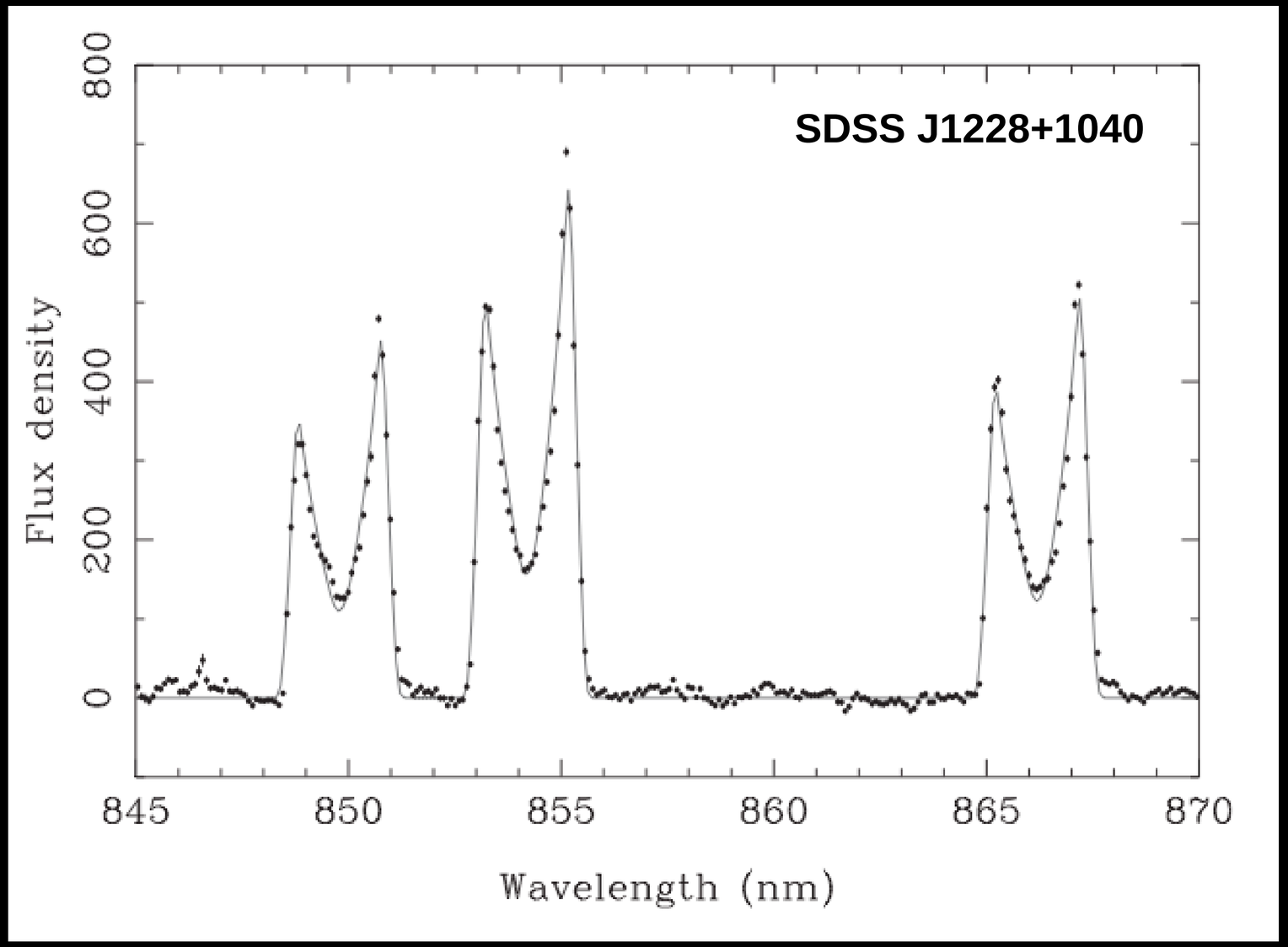
% White dwarfs with circumstellar planetary gas

~0.1%

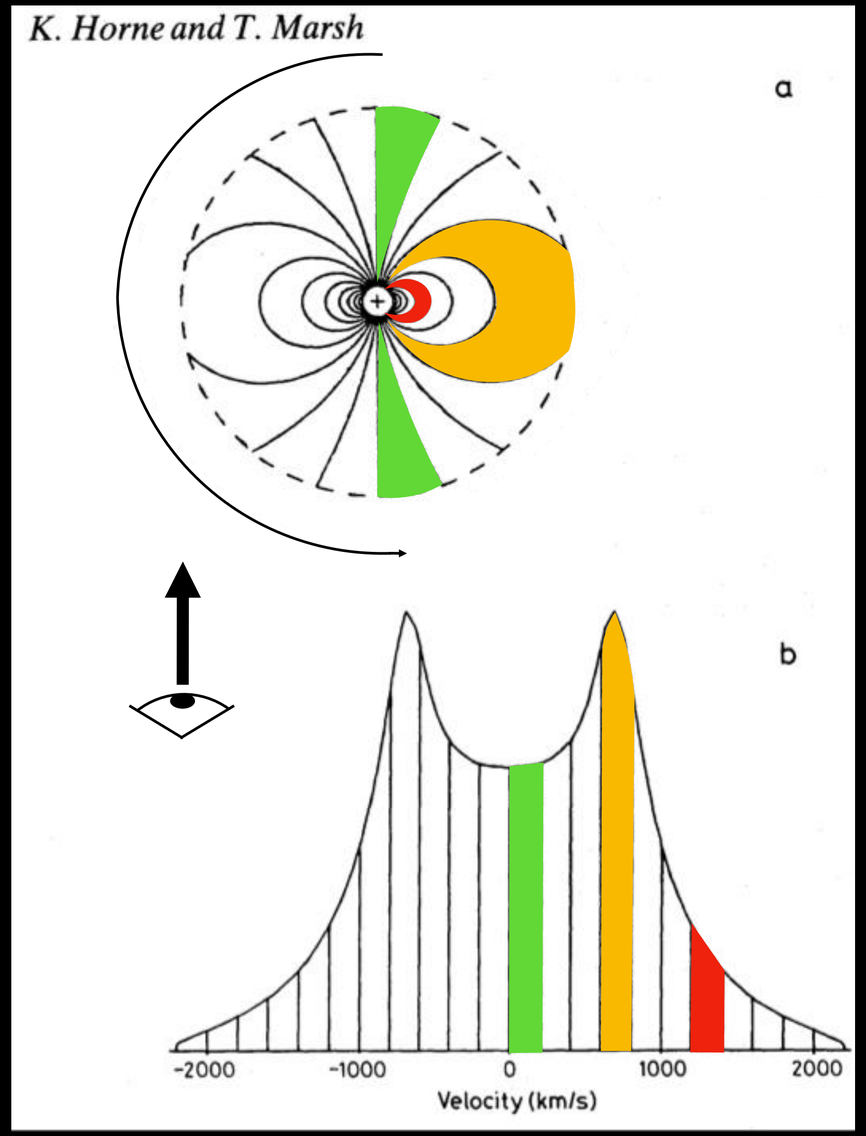
Manser et al. 2020

Jura & Young 2014 AREPS, 42, 45
Swan et al. 2020, MNRAS, 496, 5233

Gaseous emission - morphology



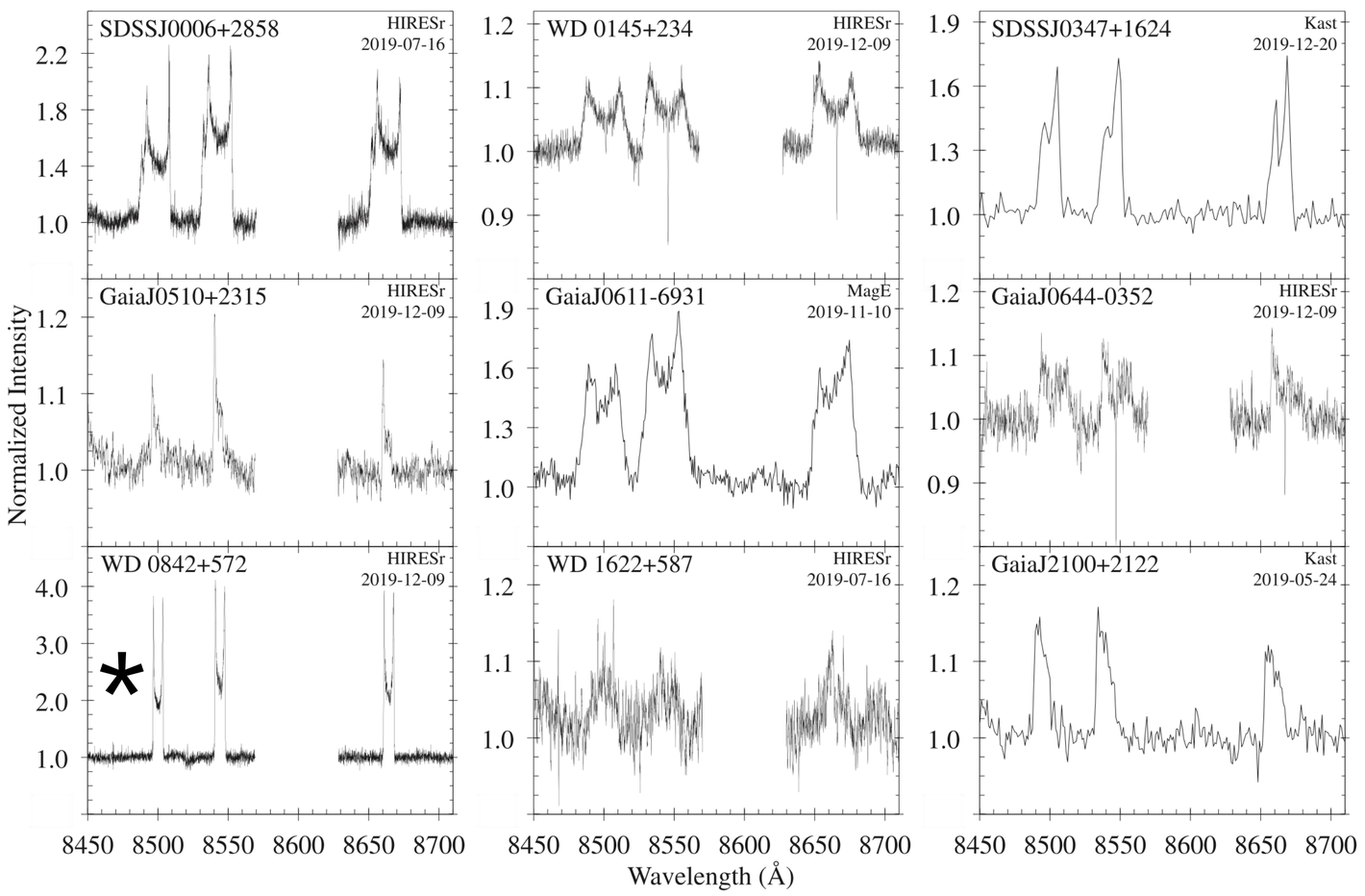
Gänsicke et al. 2006, Science, 314, 1908

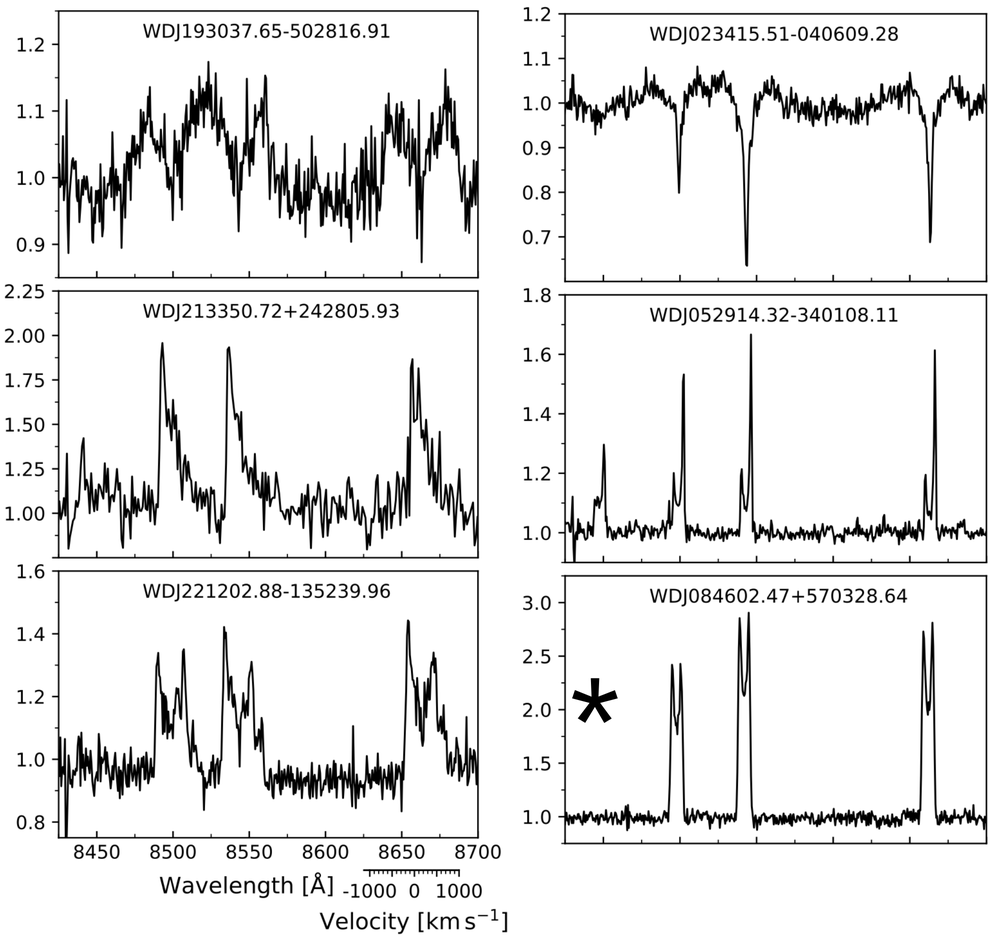


Horne & Marsh 1986, MNRAS, 218, 761

21 Systems known so far!

Number tripled in 2020 by Melis et al., Dennihy et al. & Gentile Fusillo et al. with 14 new systems





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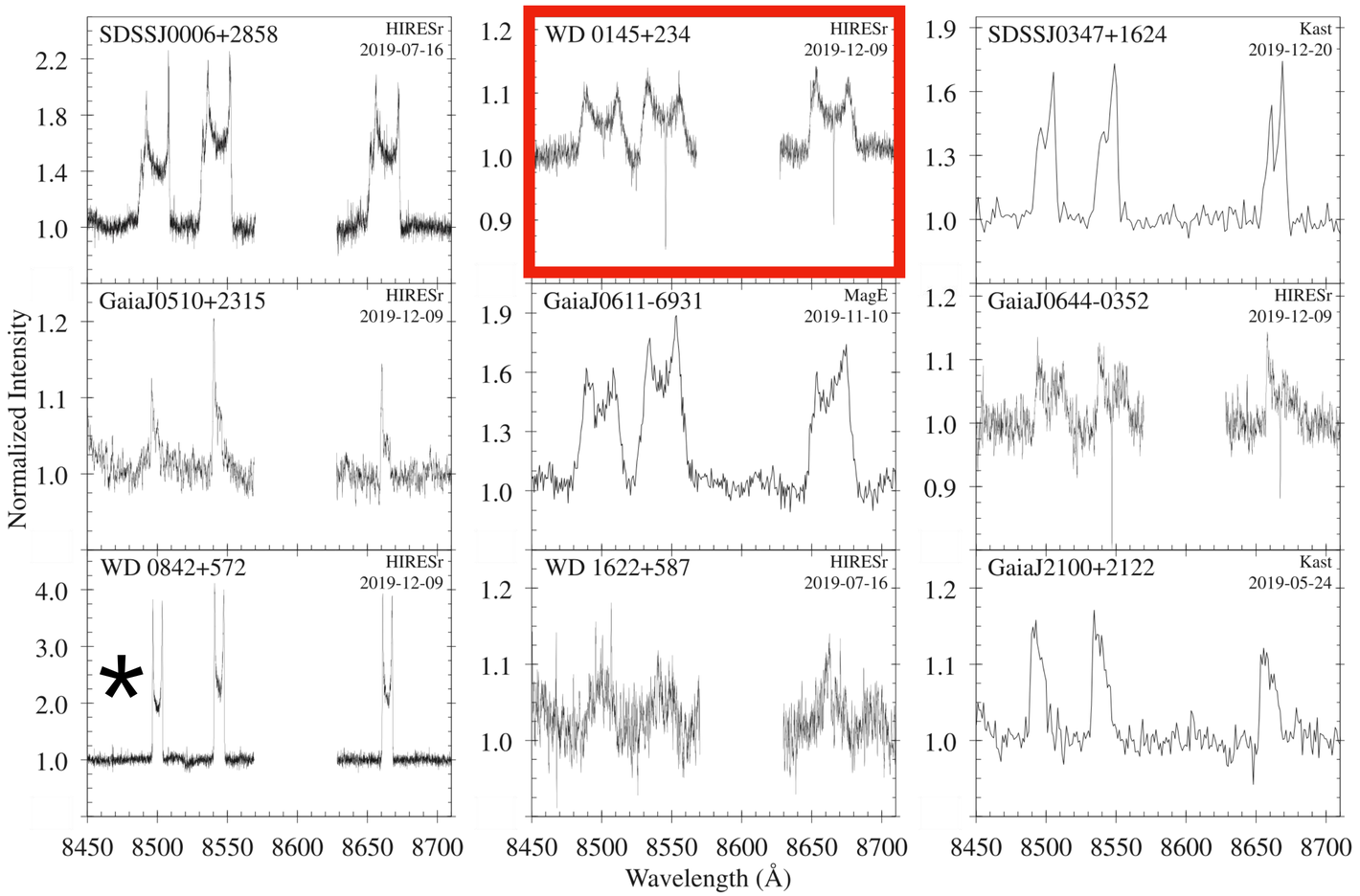
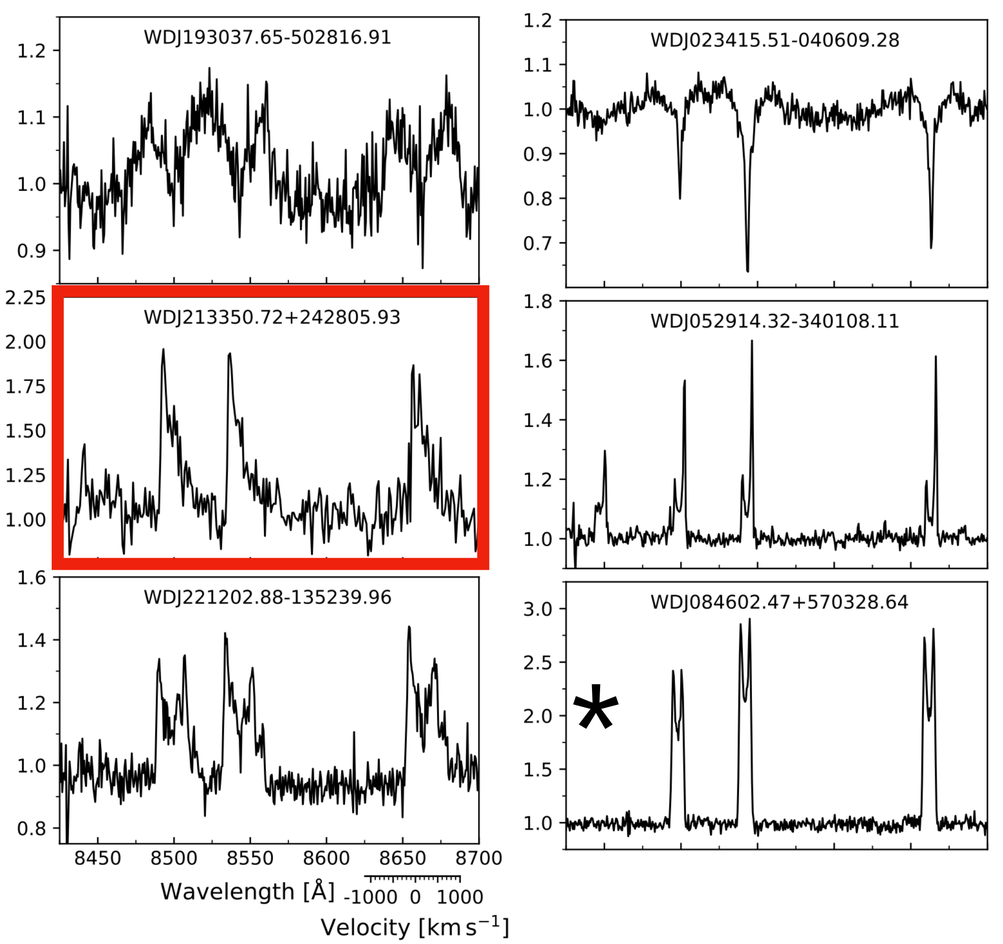
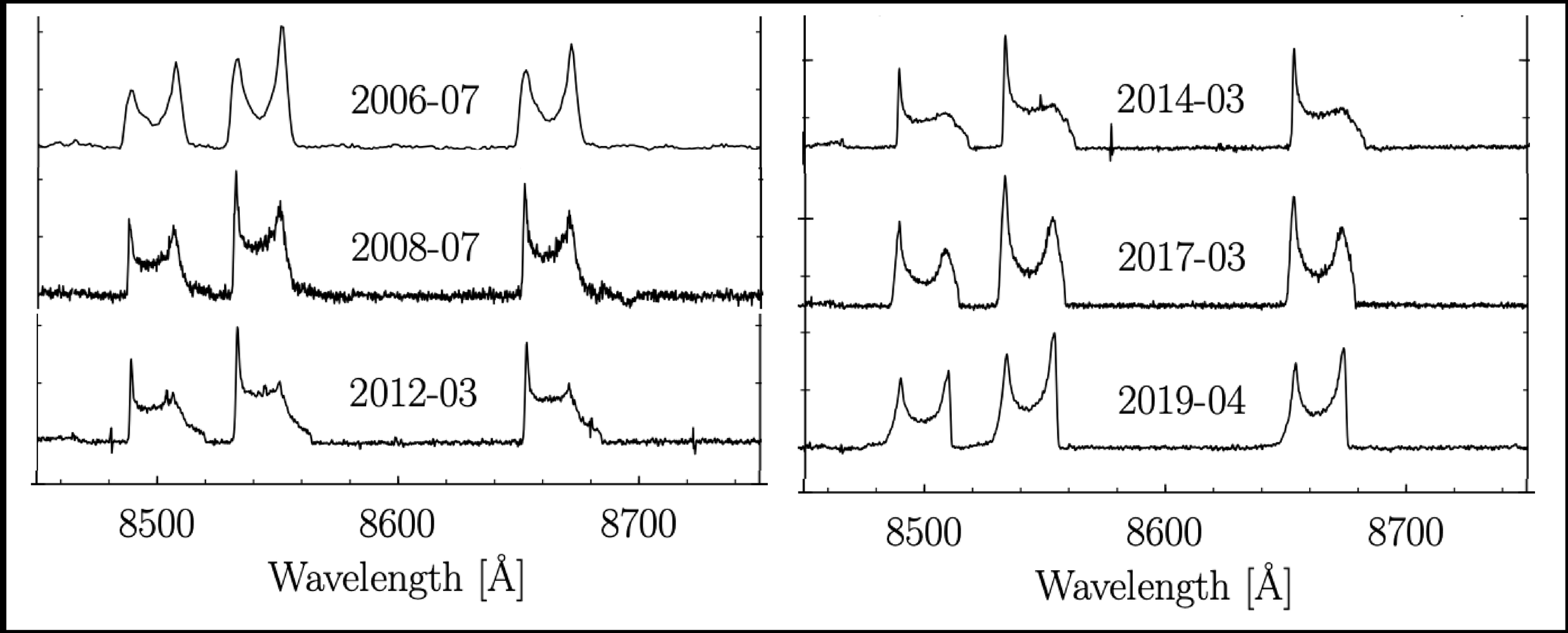




* Same system

Morphological variations

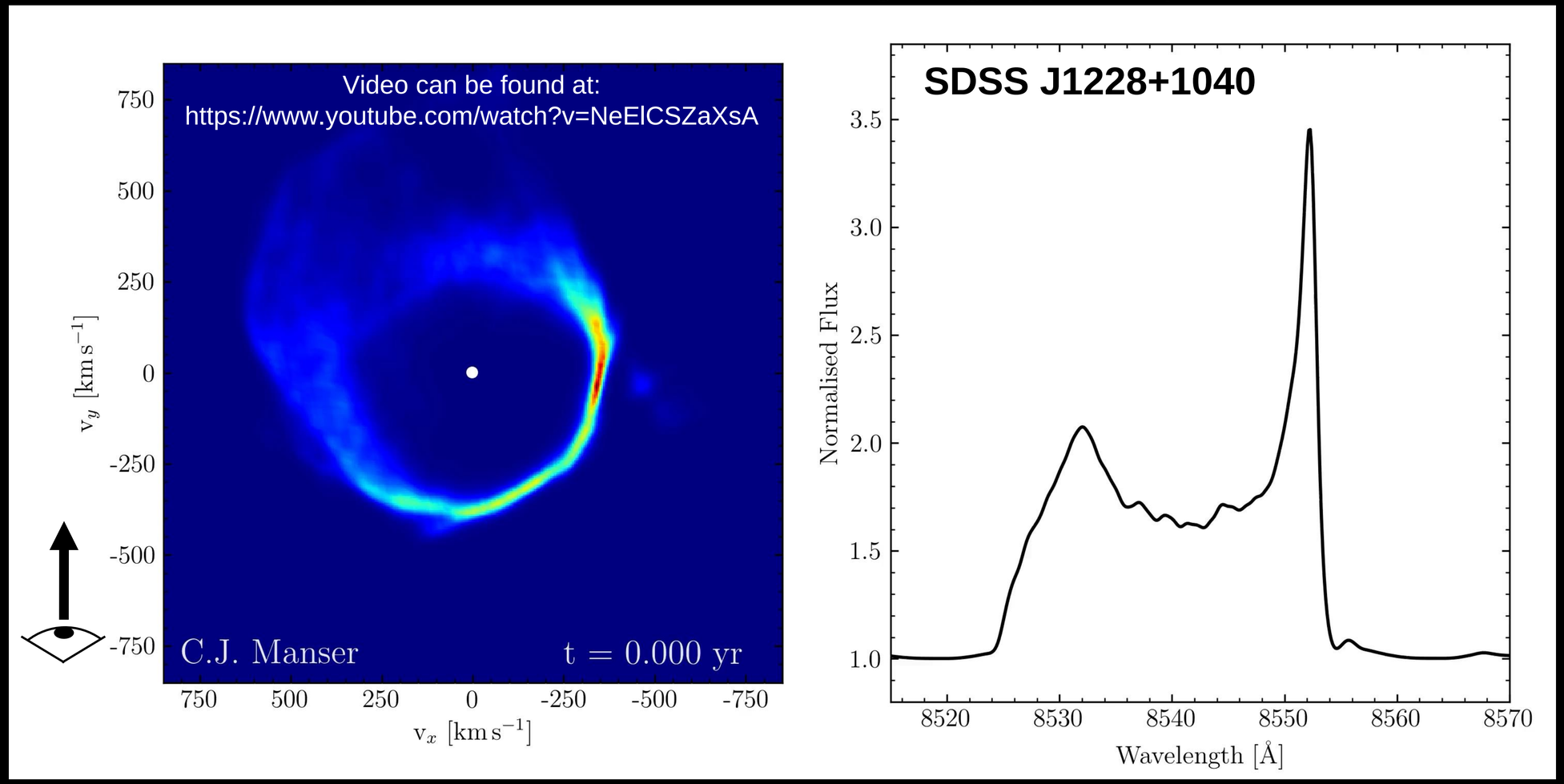
SDSSJ1228+1040 over 13 years



Manser et al. 2016, MNRAS, 455, 4467

Doppler Tomography to produce velocity images

Intensity pattern in the disc undergoing apsidal precession



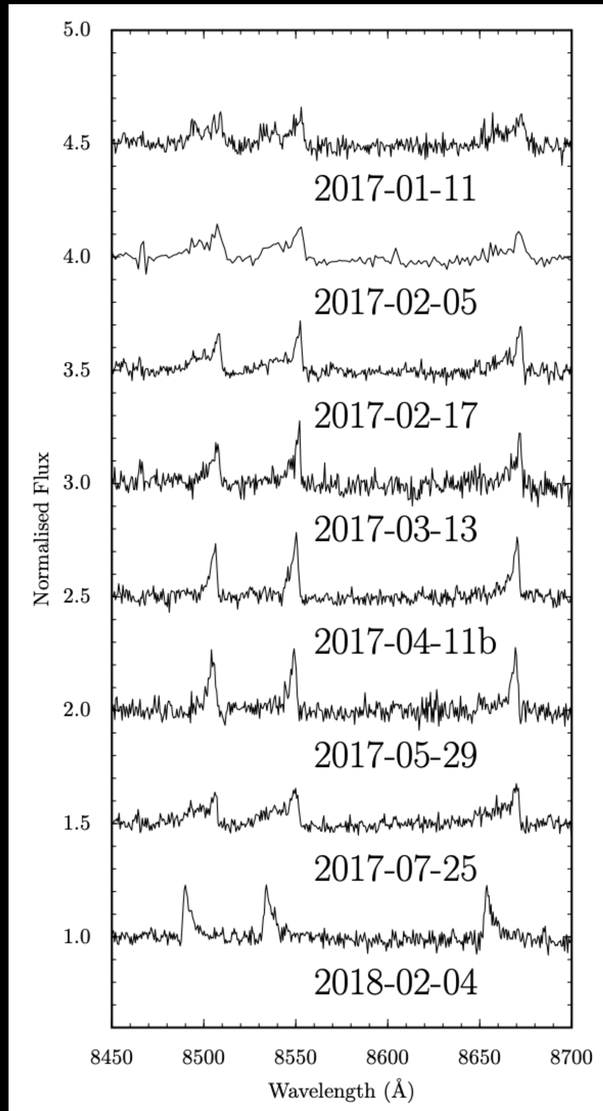
Precession period = 25 yrs

Manser et. al. 2016, MNRAS, 455, 4467

Orbital period ~ order of hours.

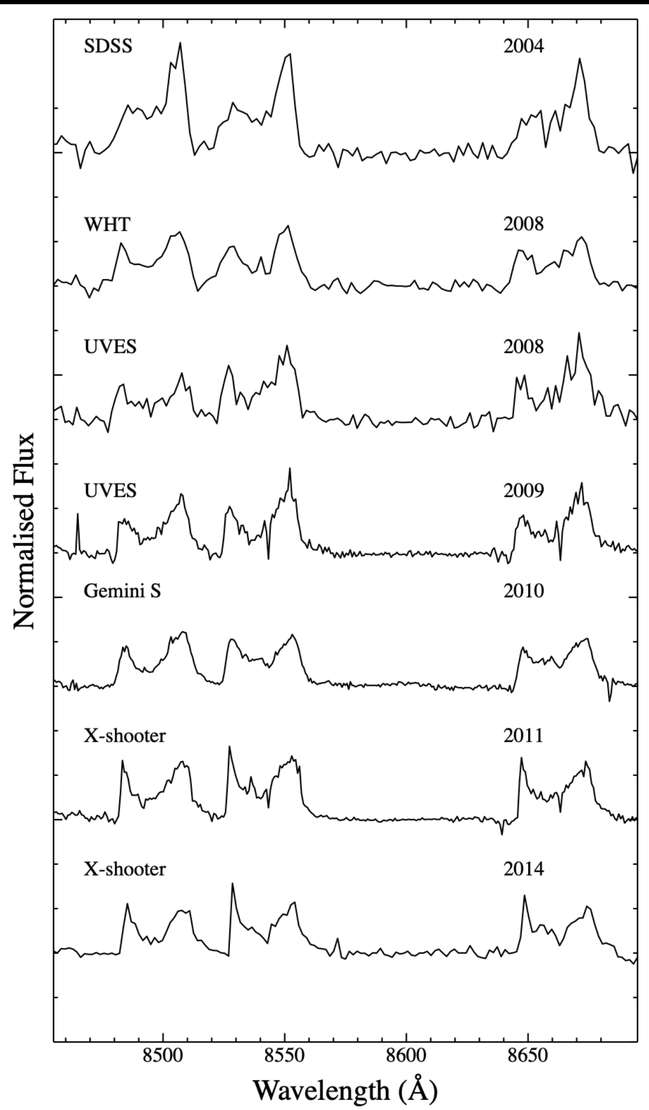
Morphological variations are common!

HE 1349-2305



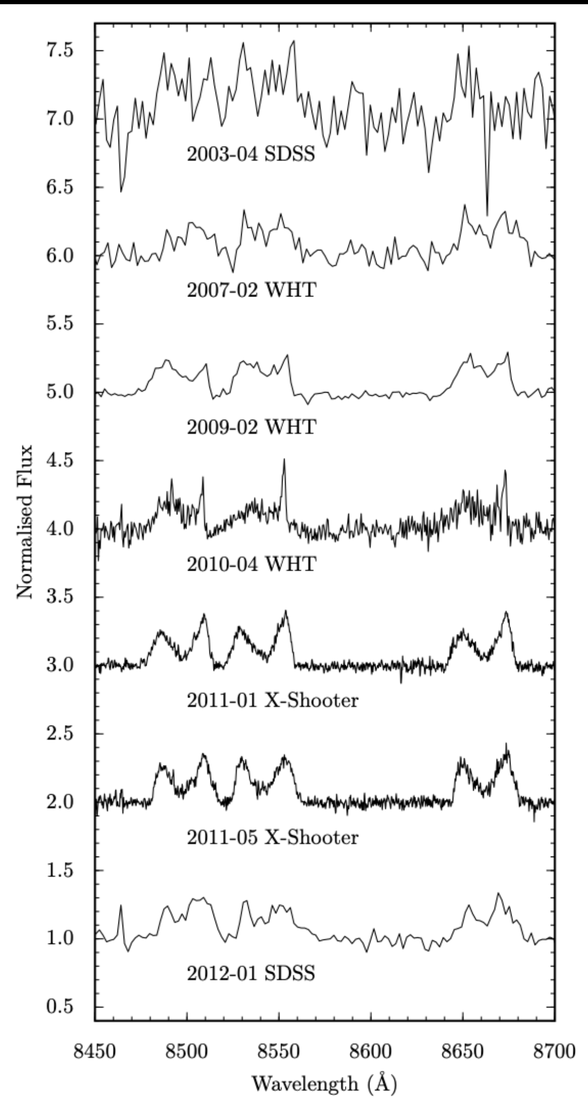
Dennihy et al. 2018, ApJ, 854, 40

SDSS J0845+2257



Wilson et. al. 2015, MNRAS, 451, 3237

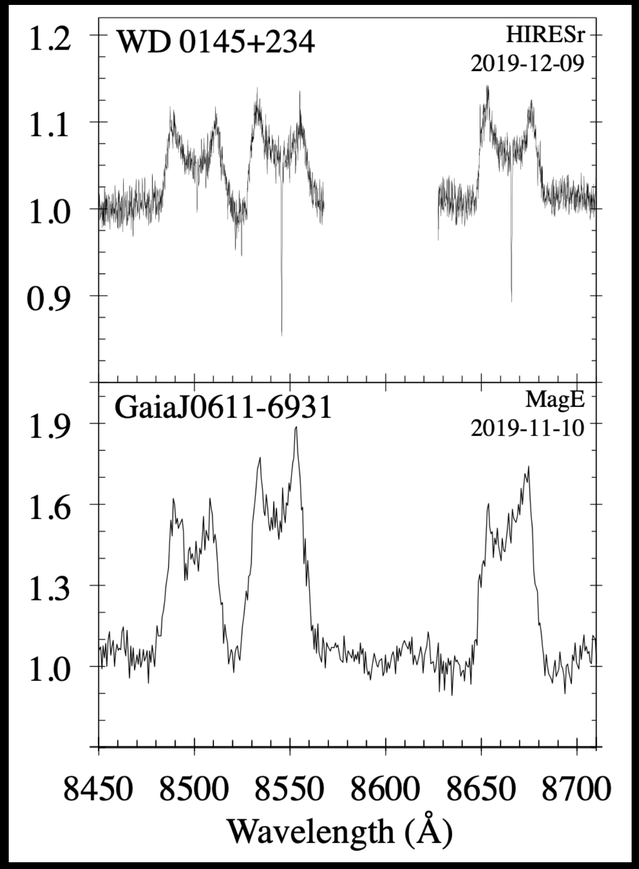
SDSS J1043+0855



Manser et. al. 2016, MNRAS, 462 1461

Observed gaseous planetary discs…

… in emission
Co-orbital with dust



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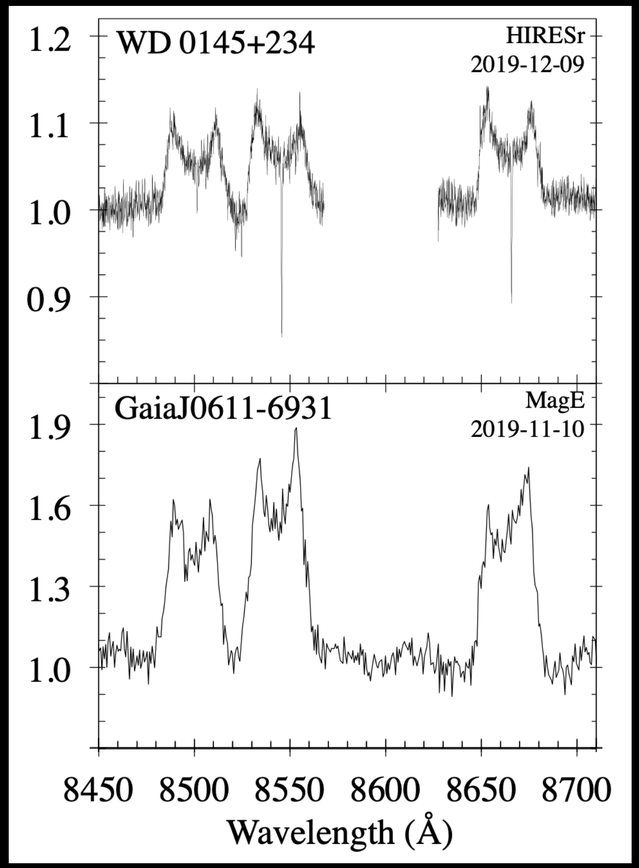
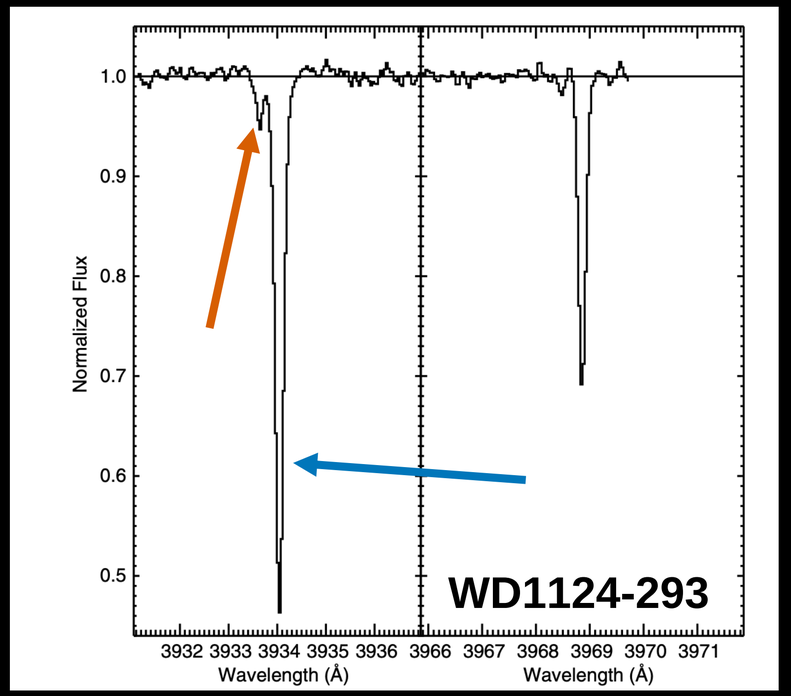


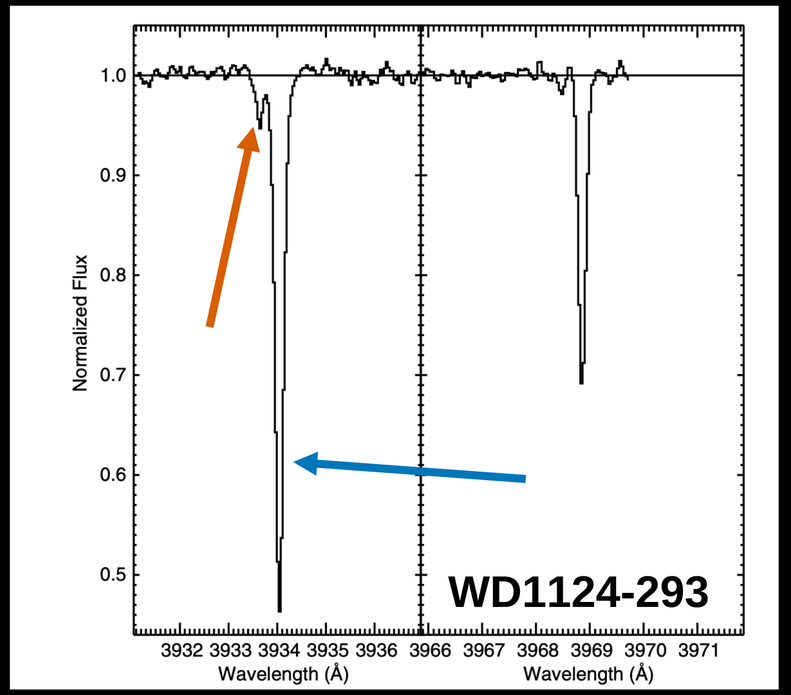
Melis et al. 2020, ApJ 905, 56

… in absorption
With and without dust



Debes et al. 2012, ApJ, 754, 59
Steele et al. 2020, ApJ, accepted

Gaseous absorption



WD photosphere

Circumstellar

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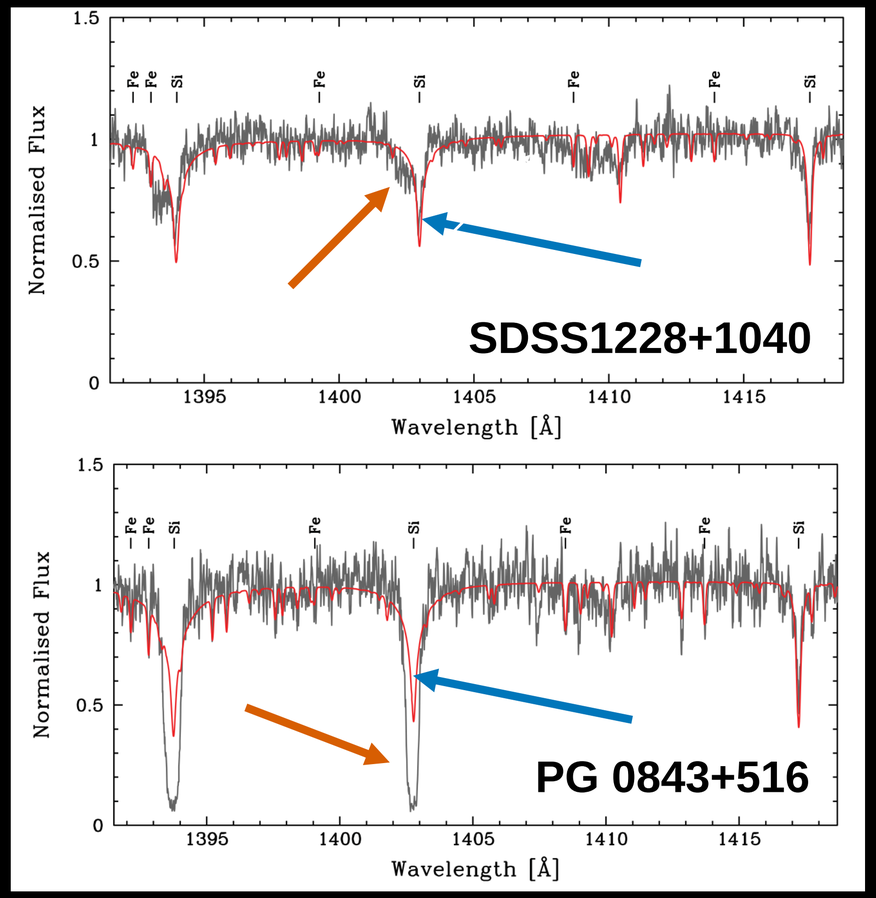
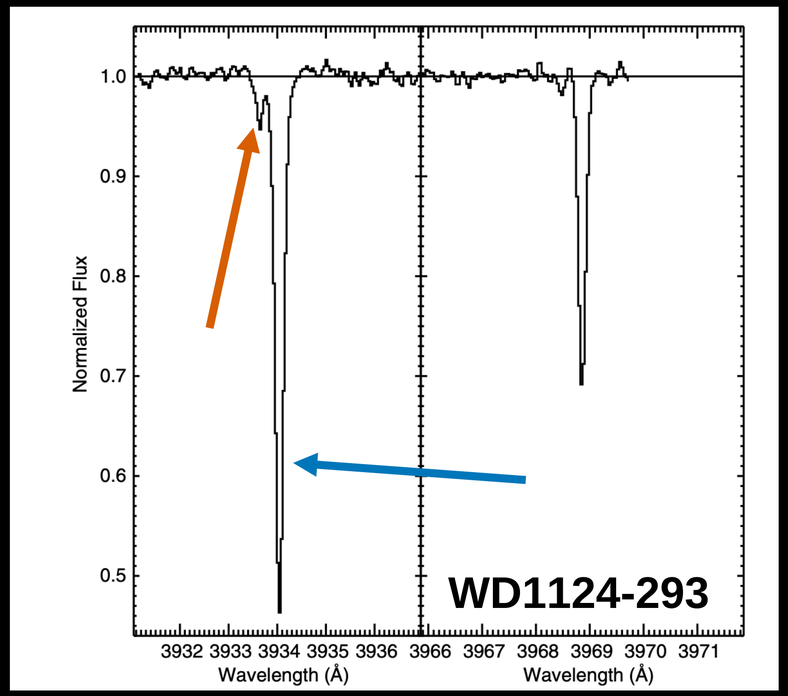


Gänsicke et al 2012, MNRAS, 424, 333



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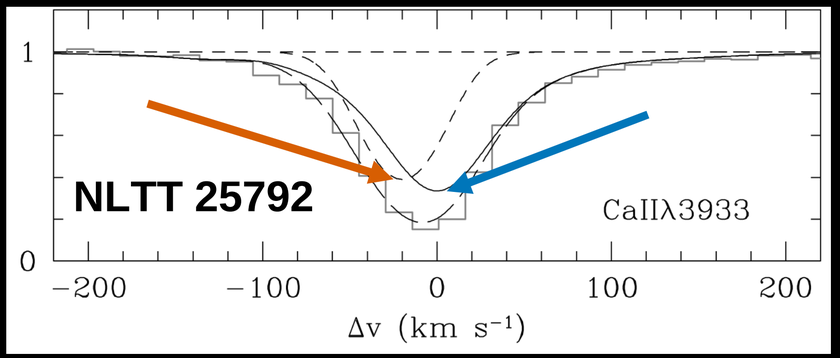
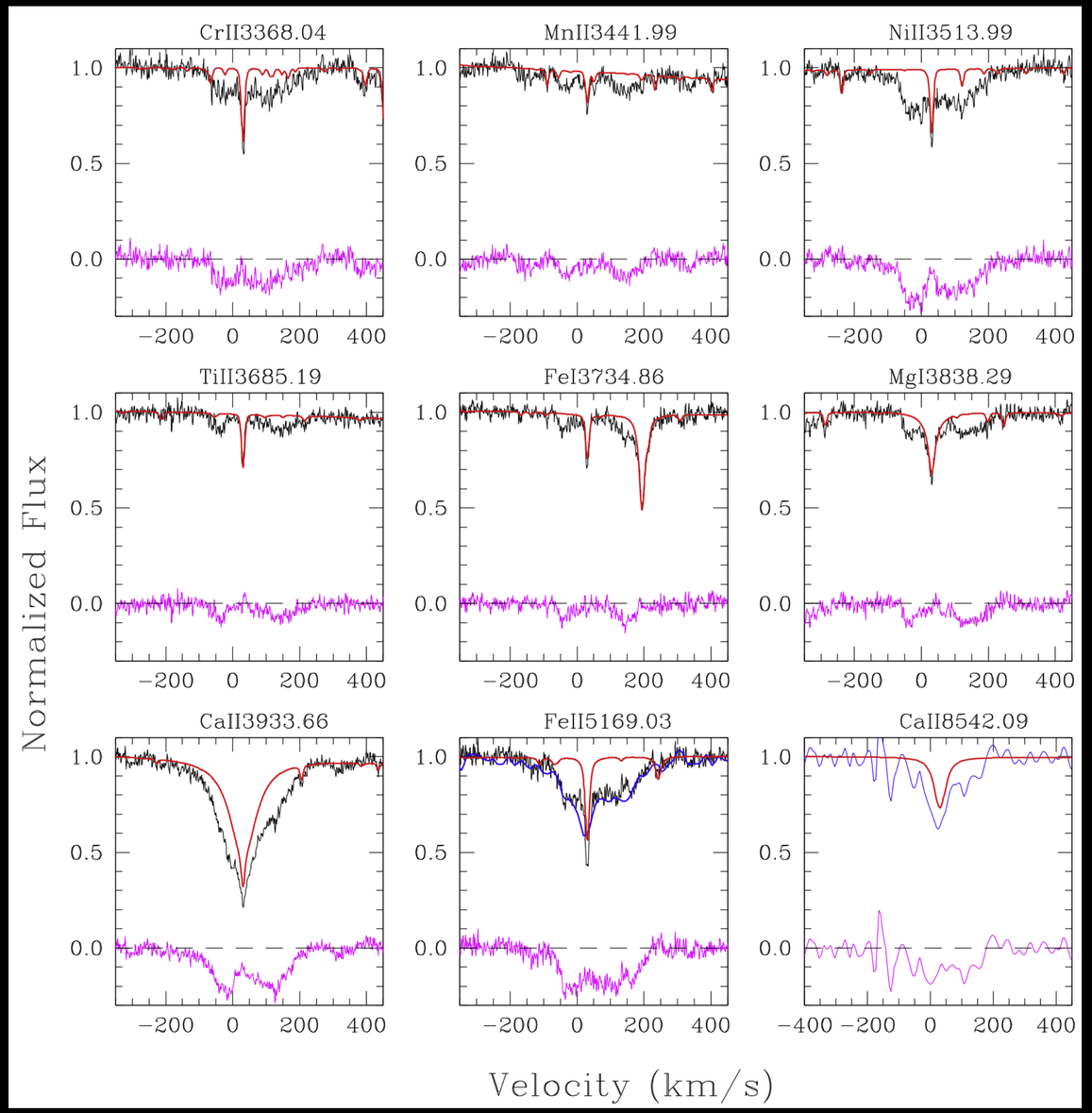


Vennes & Kawka 2013, ApJ, 779, 70

Gaseous absorption - WD1145+017



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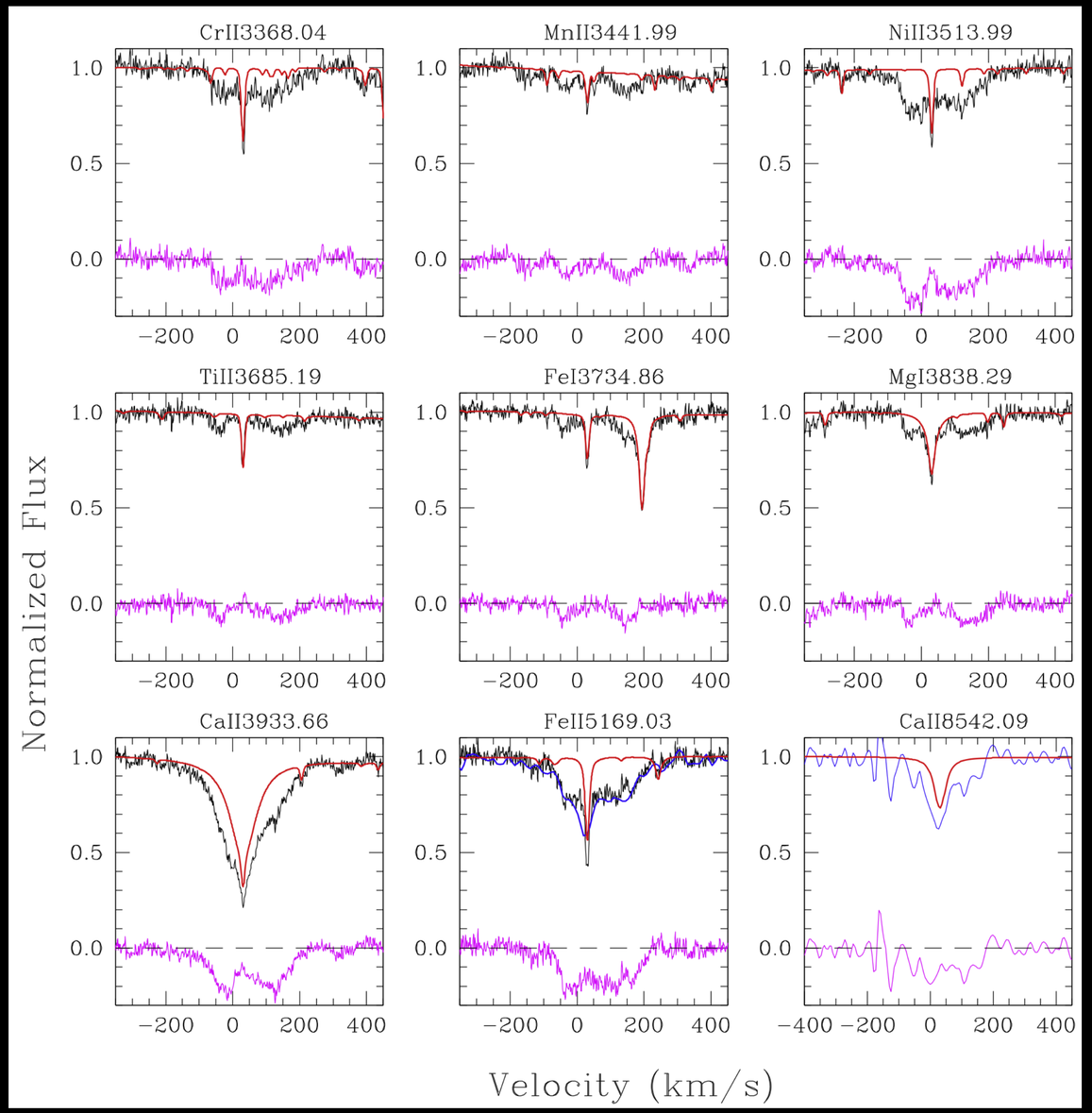
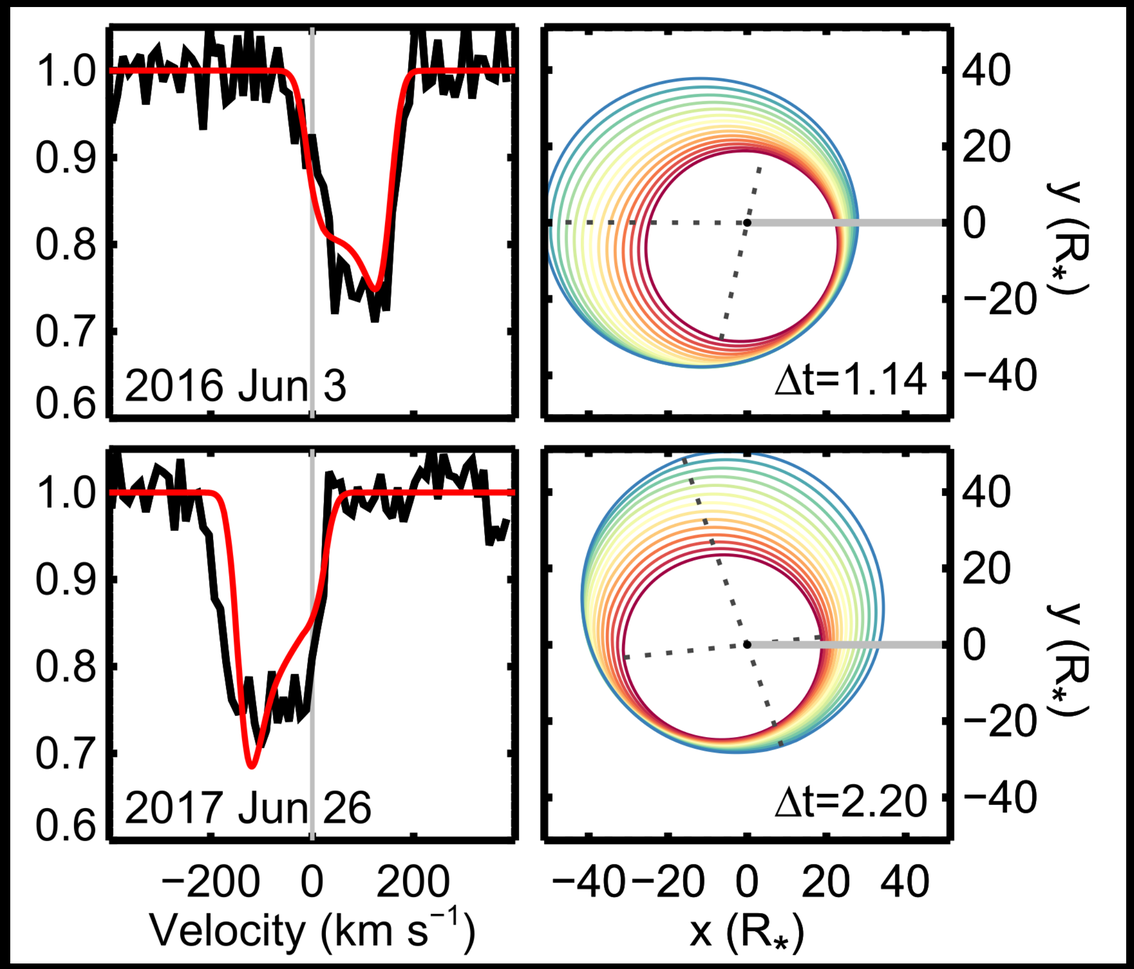
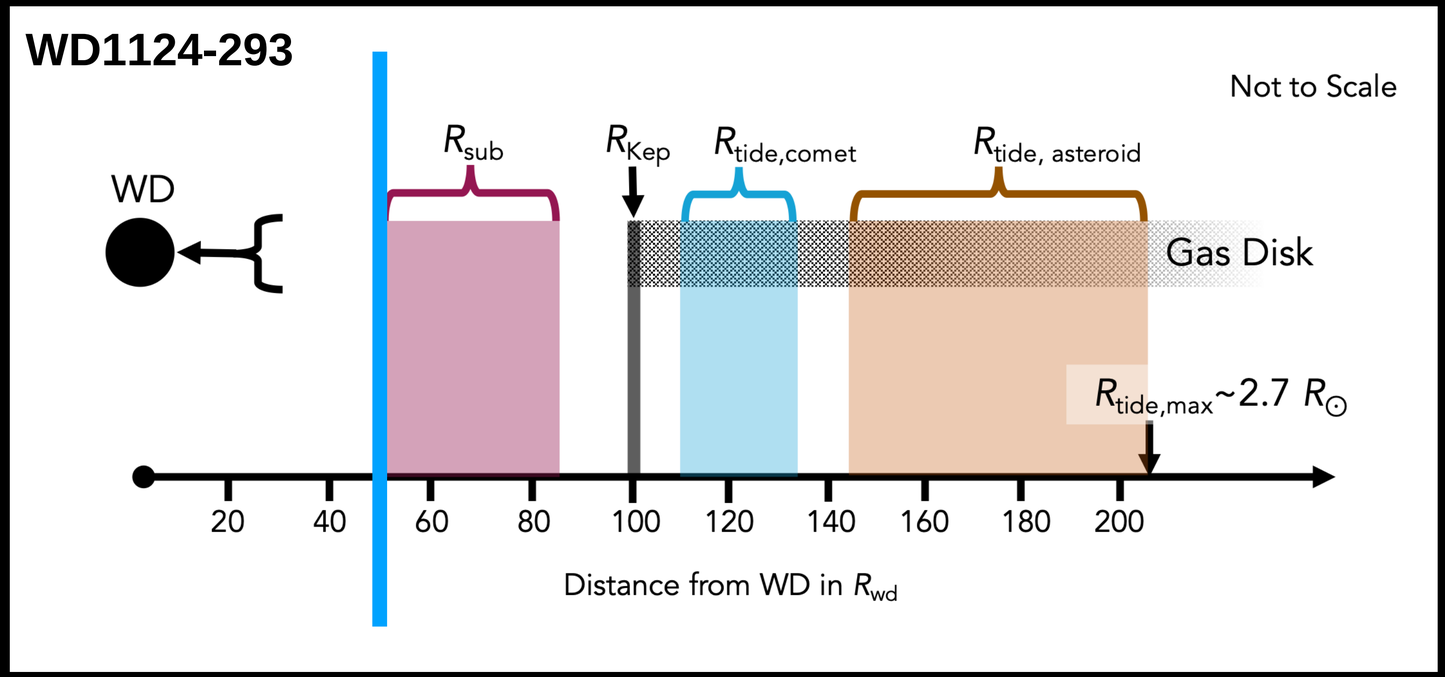


~ 5yr precession period

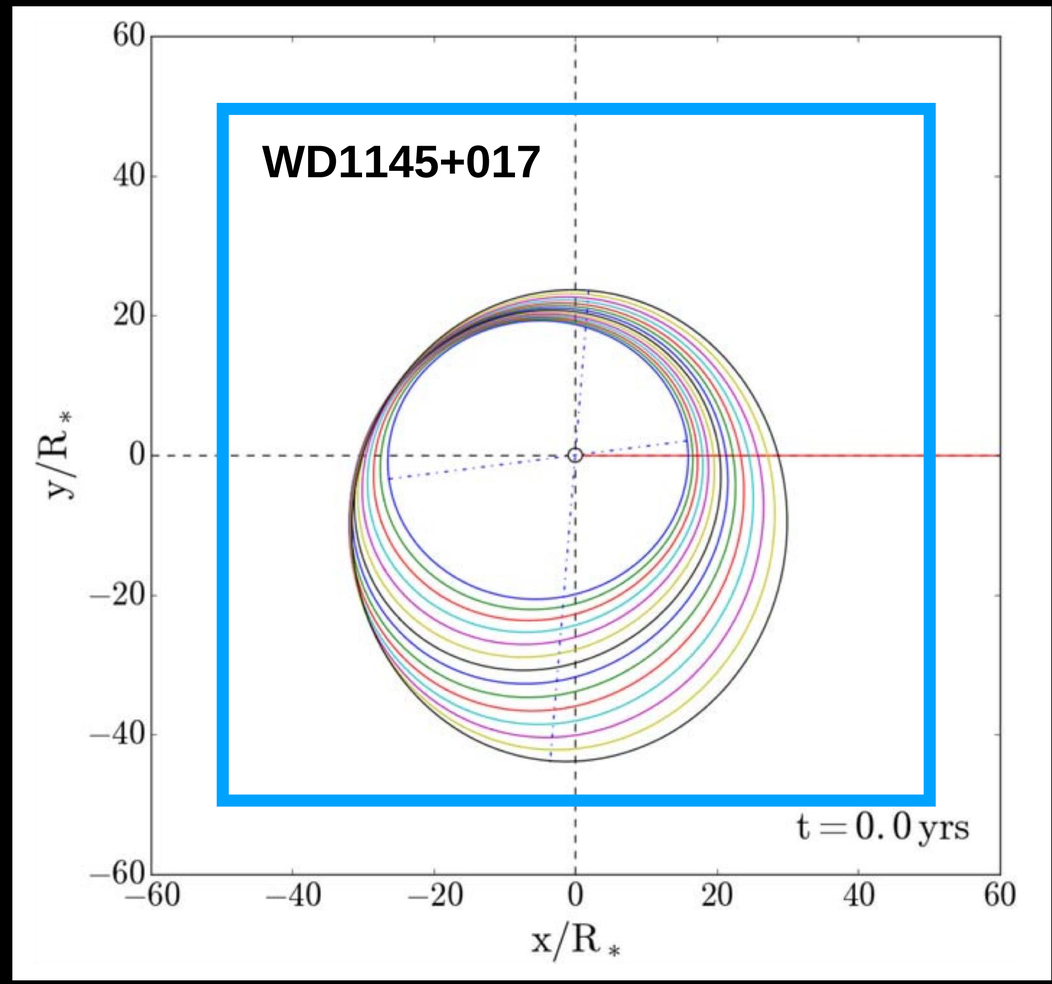


Xu et al. 2016, ApJL, 816, L22
Cauley et al. 2018, ApJL, 852, L22
Fortin-Archambault et al. 2020, ApJ, 888, 47

Gaseous absorption - location



~50R_{WD}



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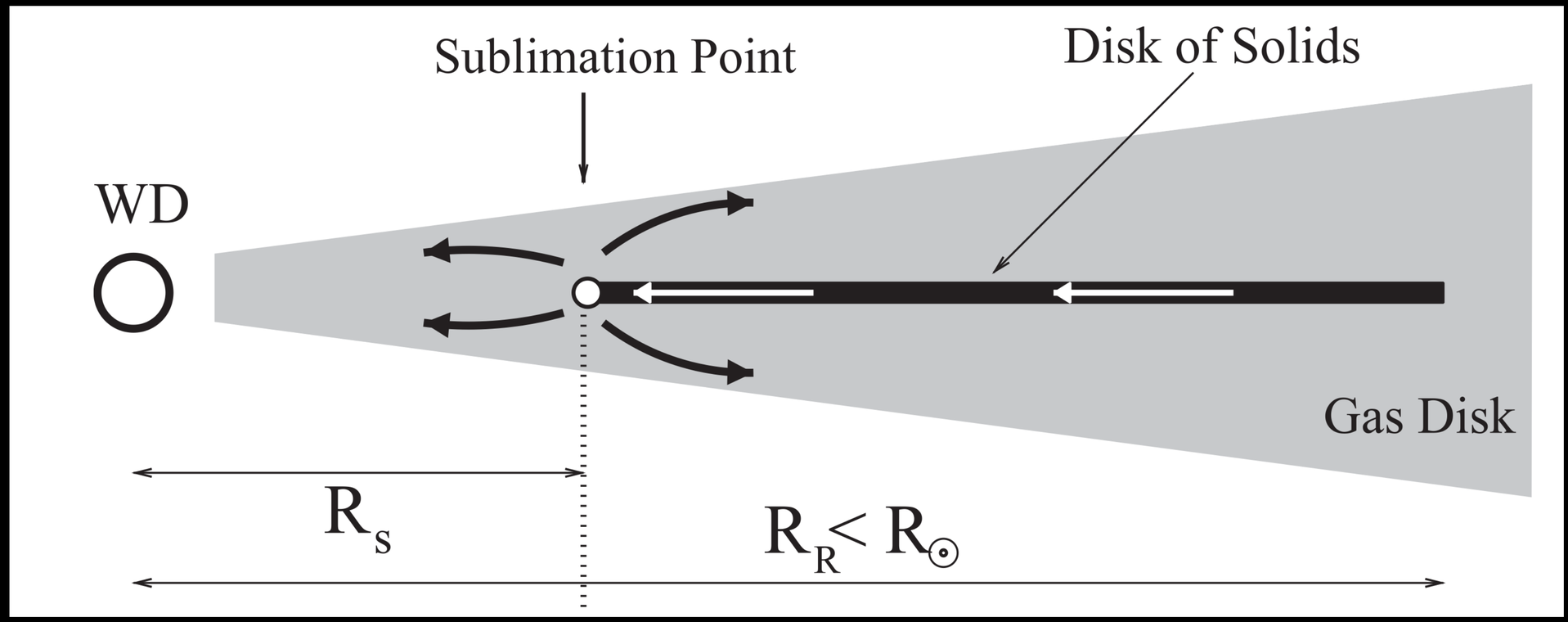
(1) Runaway accretion via sublimation

Rafikov 2011; Metzger et al. 2012



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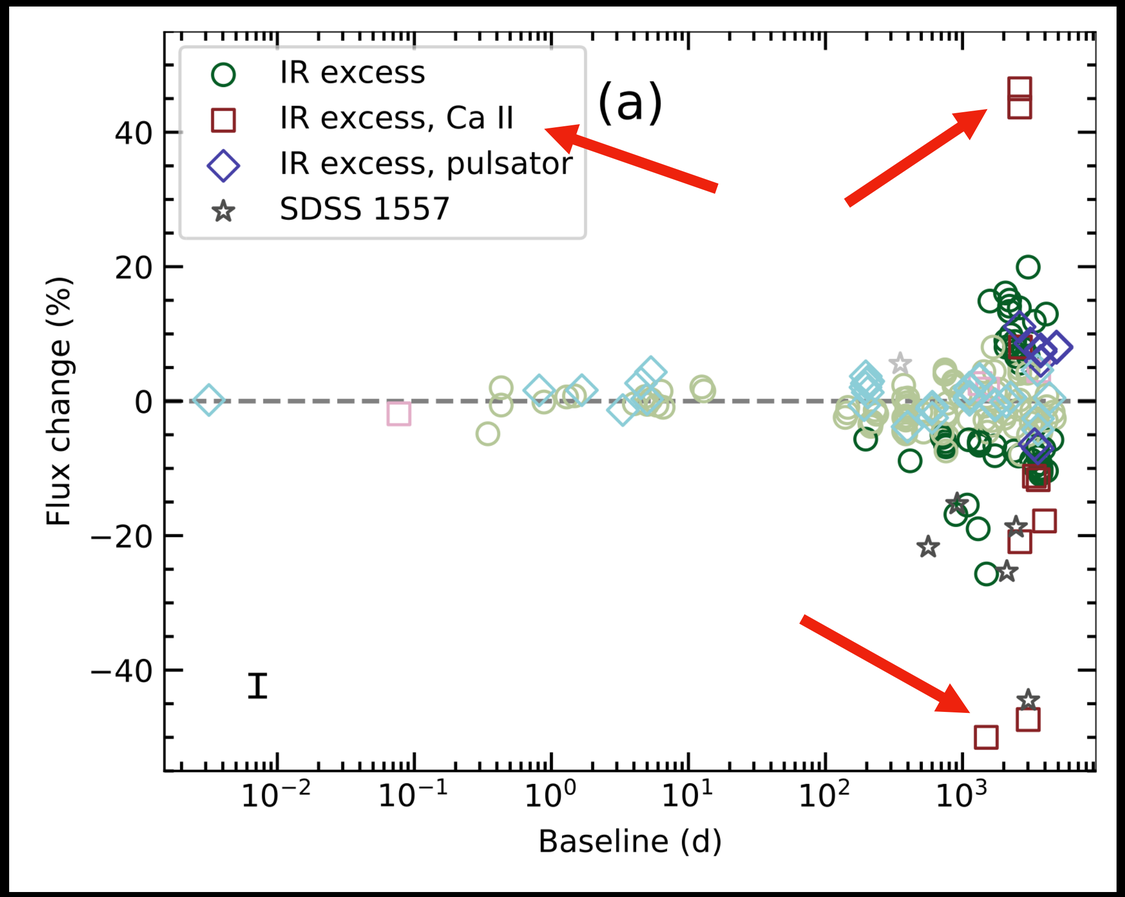

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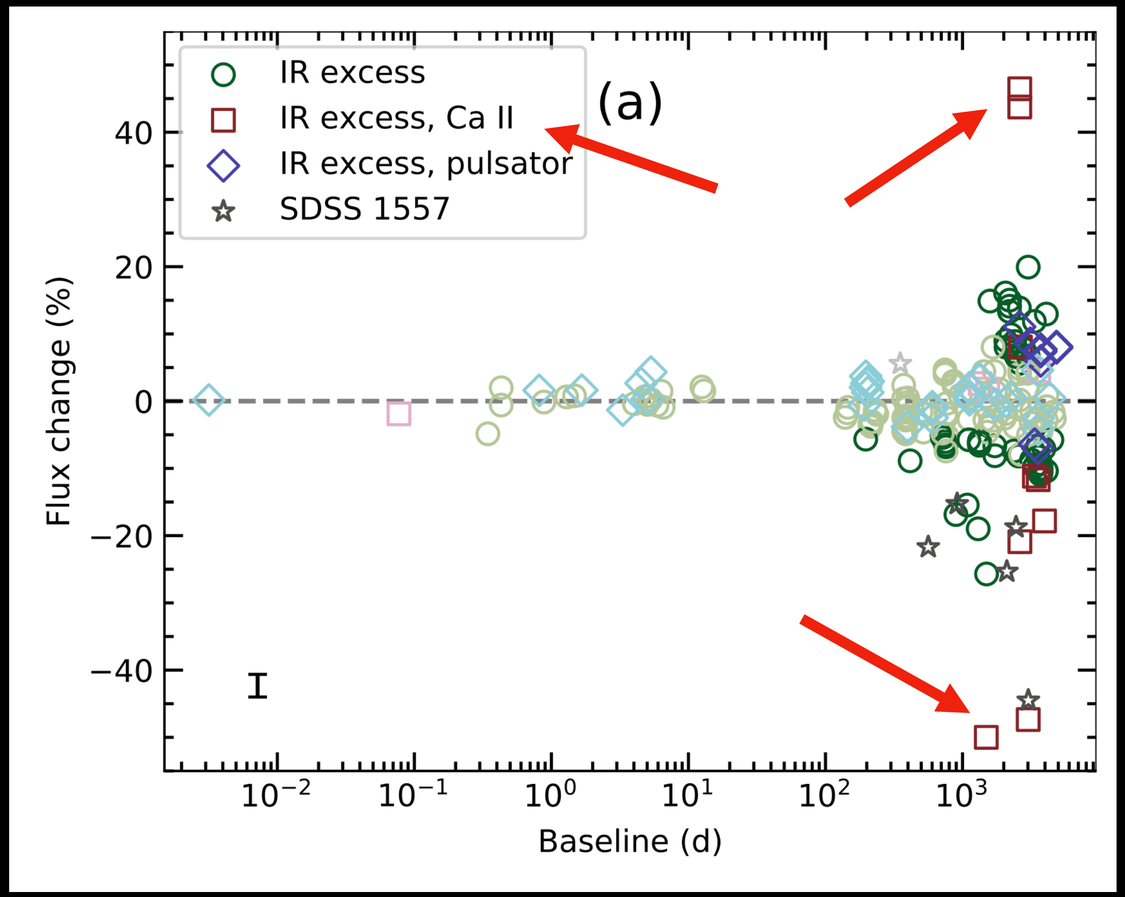

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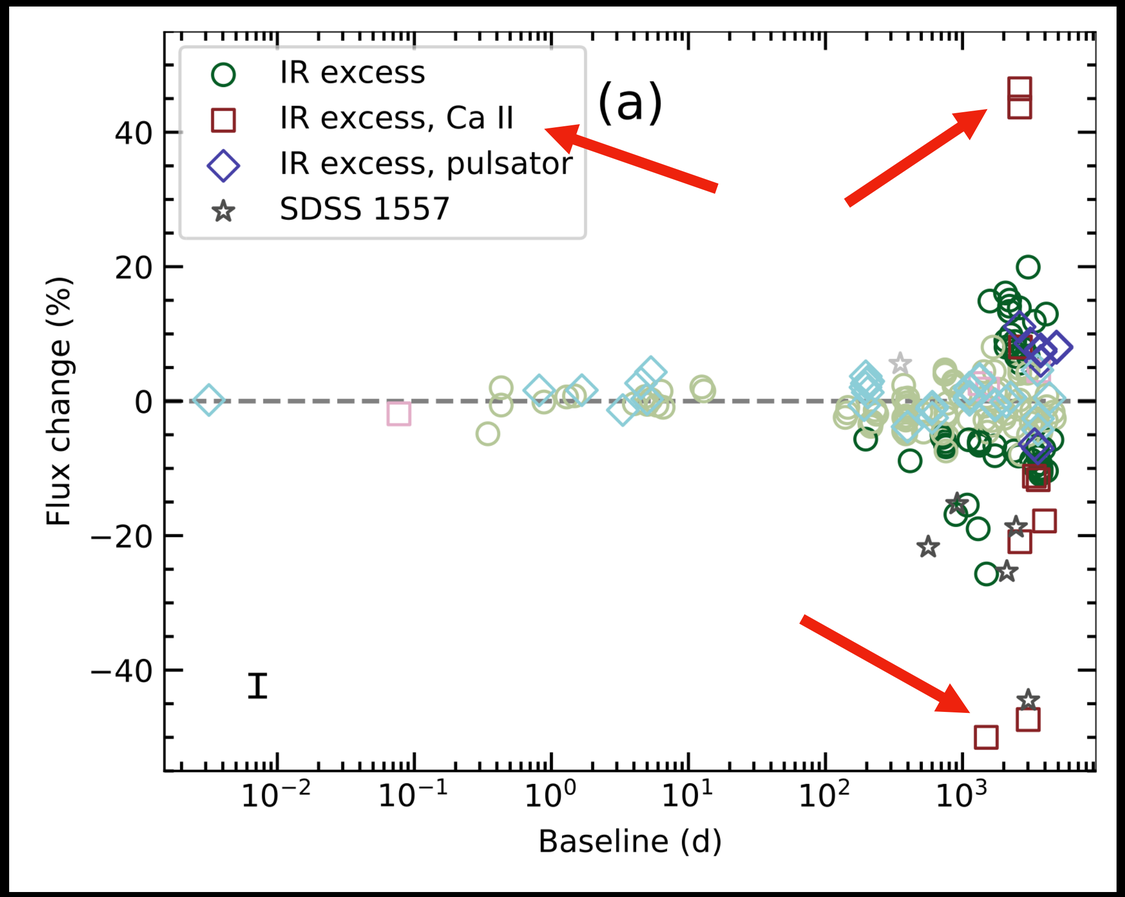
Manser et al. 2019; 2020



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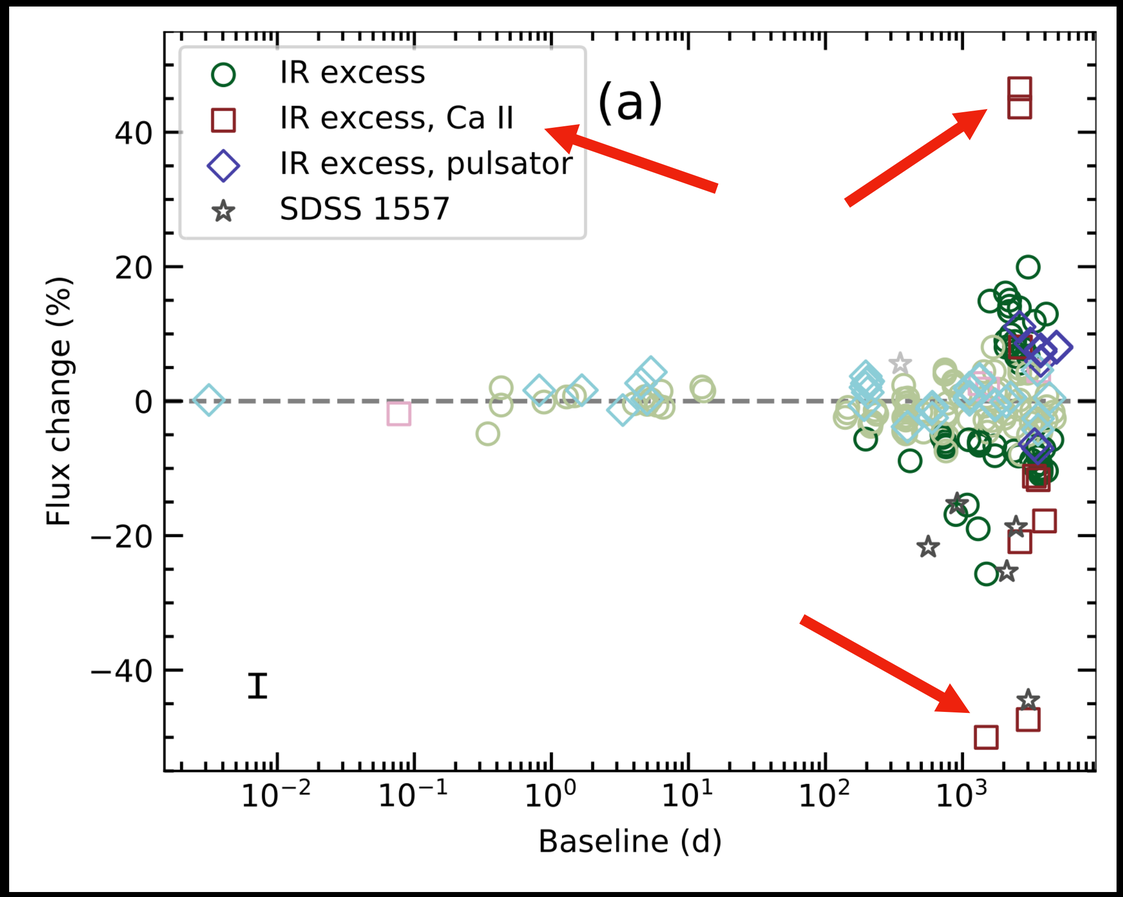
Kenyon & Bromley 2017a;b

(3) Embedded planetesimal

Manser et al. 2019; 2020

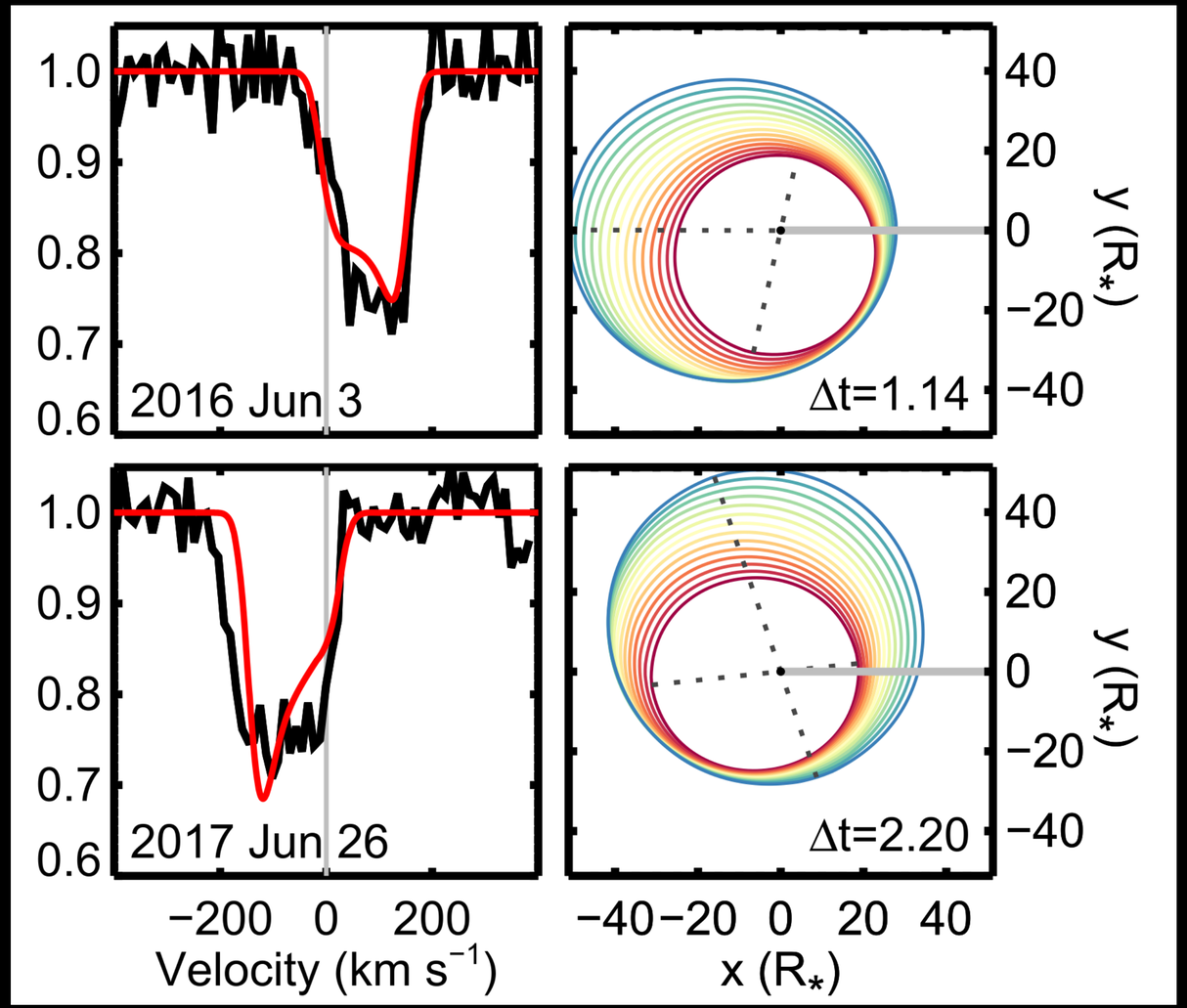
(4) Tidal stream collisions with a pre-existing disc

Malamud et al. 2021



Why do gas discs precess?

WD1145+017



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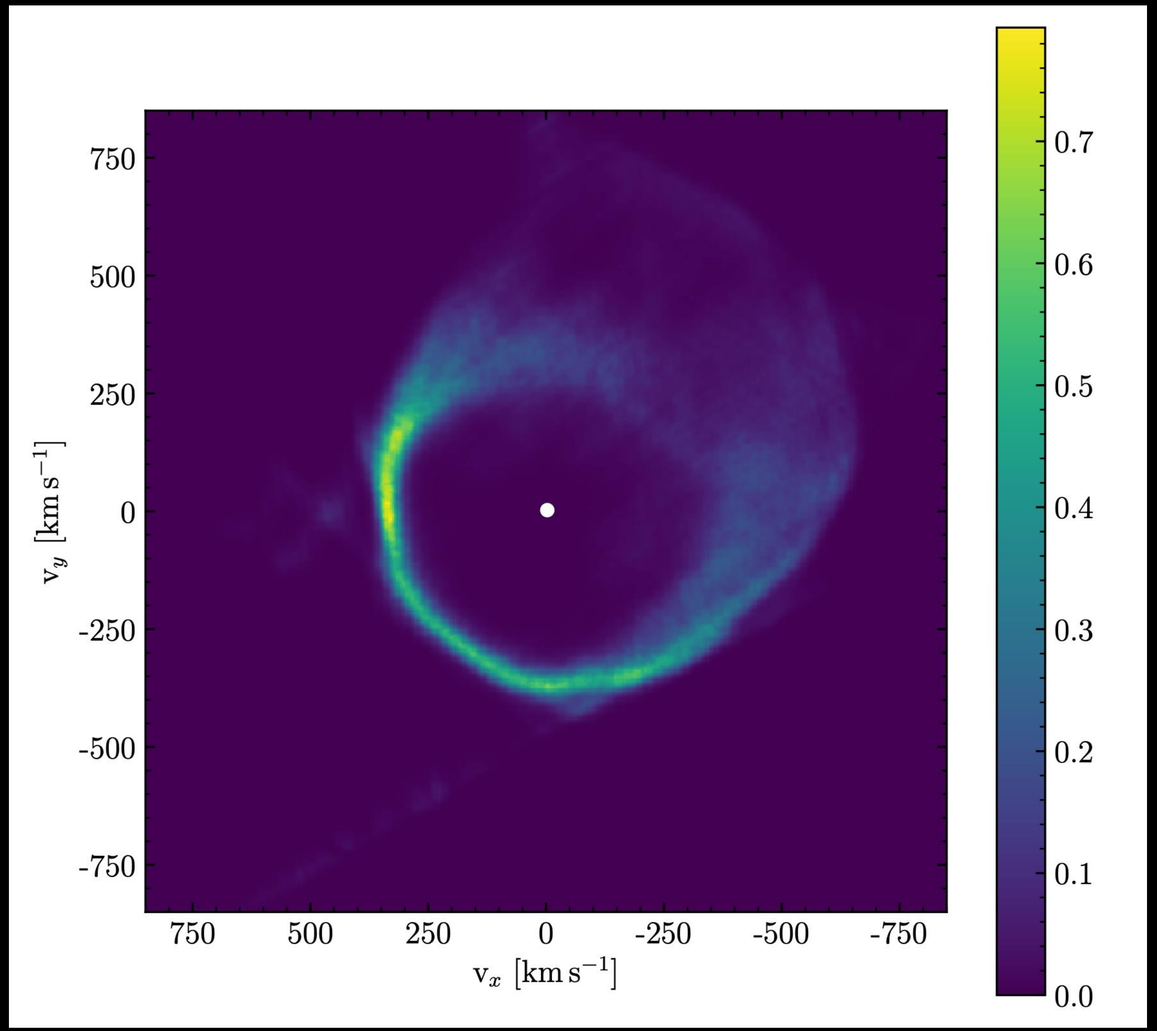

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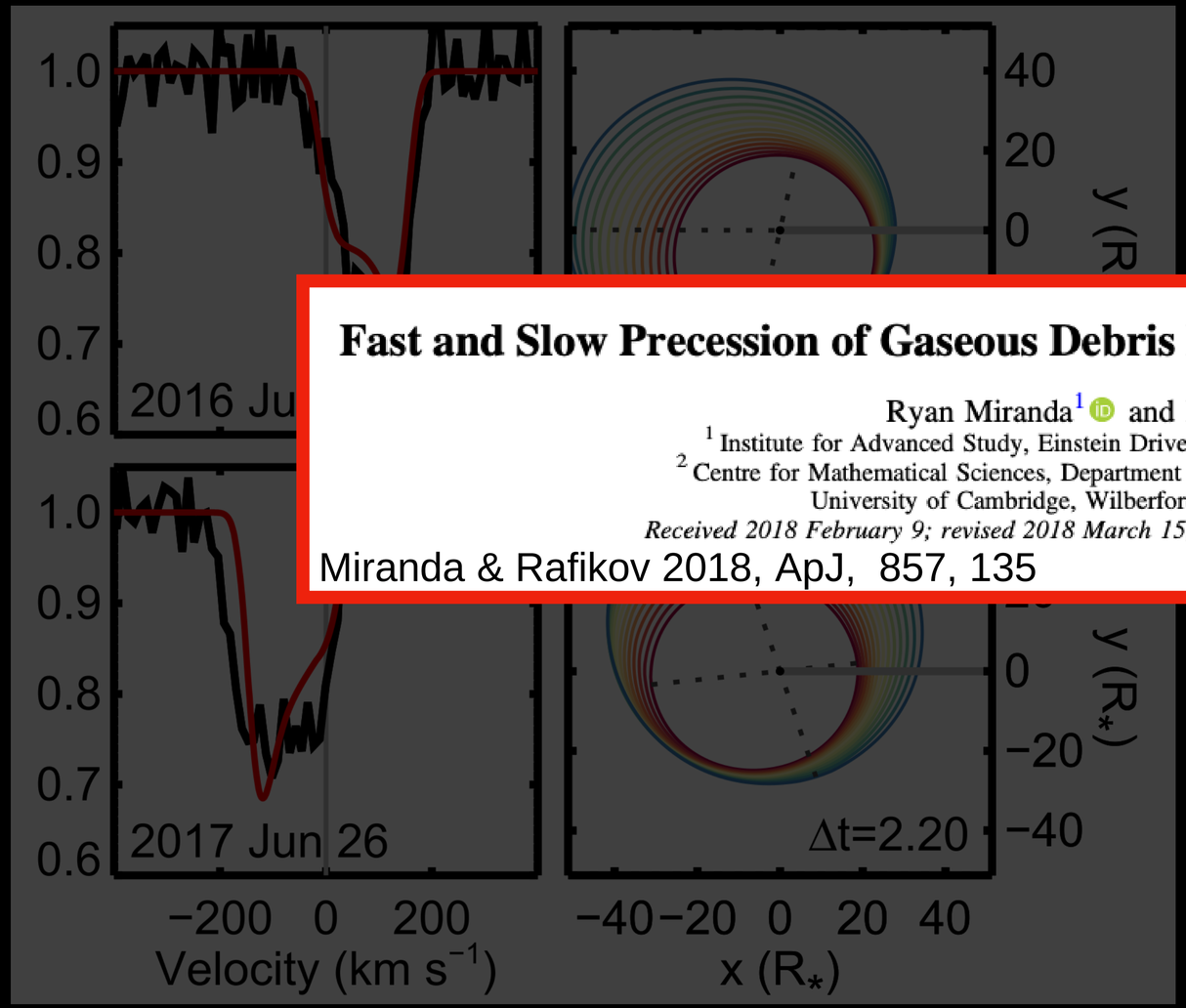
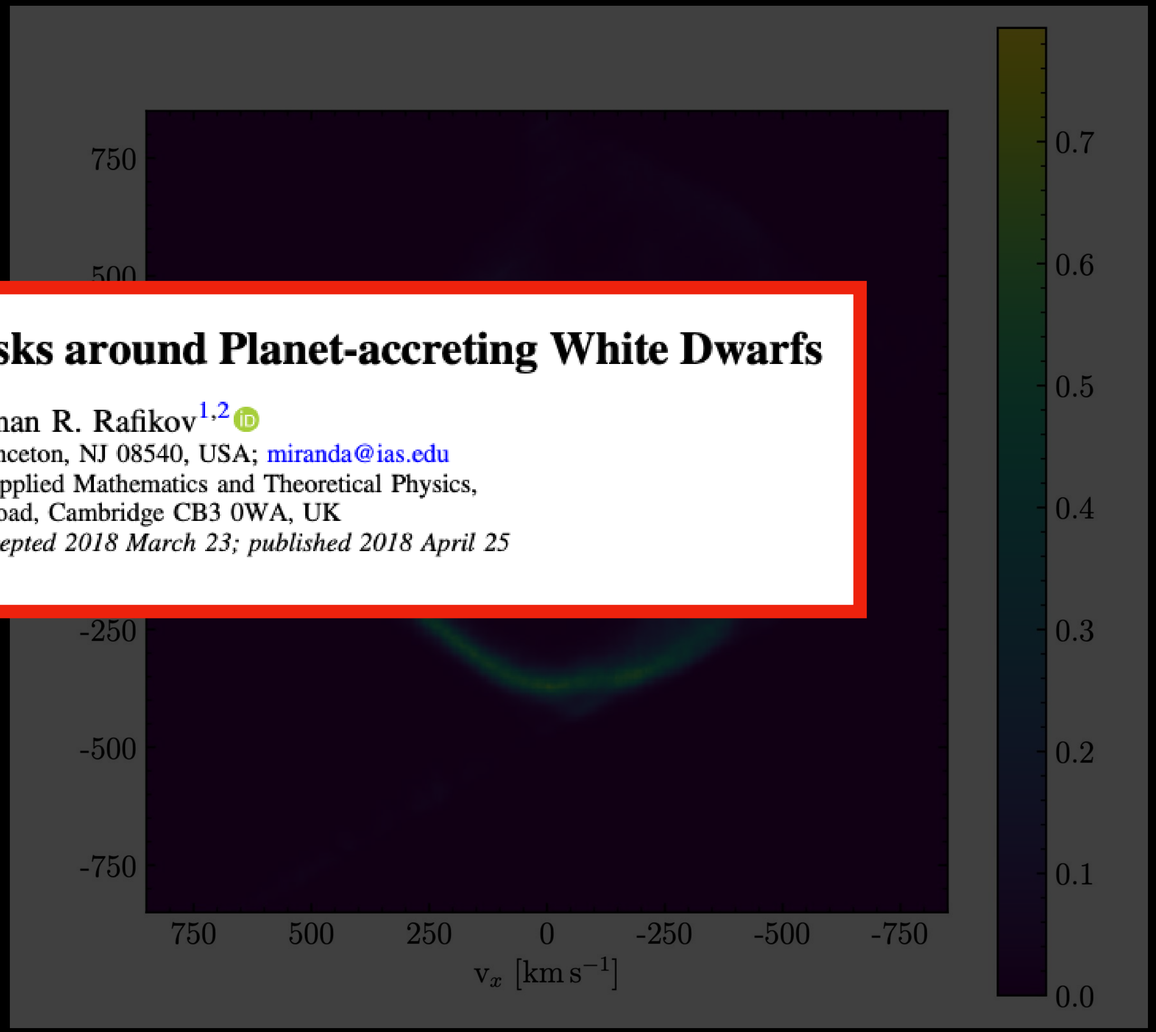


Fast and Slow Precession of Gaseous Debris Disks around Planet-accreting White Dwarfs

Ryan Miranda[1] and Roman R. Rafikov[1,2]
[1] Institute for Advanced Study, Einstein Drive, Princeton, NJ 08540, USA; miranda@ias.edu
[2] Centre for Mathematical Sciences, Department of Applied Mathematics and Theoretical Physics, University of Cambridge, Wilberforce Road, Cambridge CB3 0WA, UK
Received 2018 February 9; revised 2018 March 15; accepted 2018 March 23; published 2018 April 25

Miranda & Rafikov 2018, ApJ, 857, 135



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Looking to the Future

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- Find more! (21 emission, 5 absorption).
- Modelling precession (e.g. Doppler tomography) gives exquisite insight into disc structure and evolution.
- Can be used to explore debris disc generation scenarios.

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- Photoionisation modelling of both CS absorption/emission profiles.

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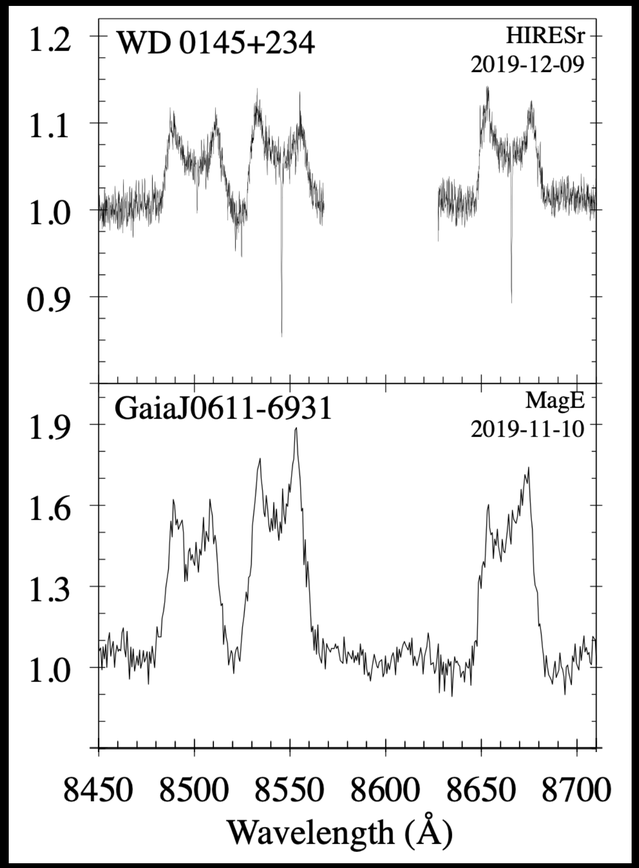
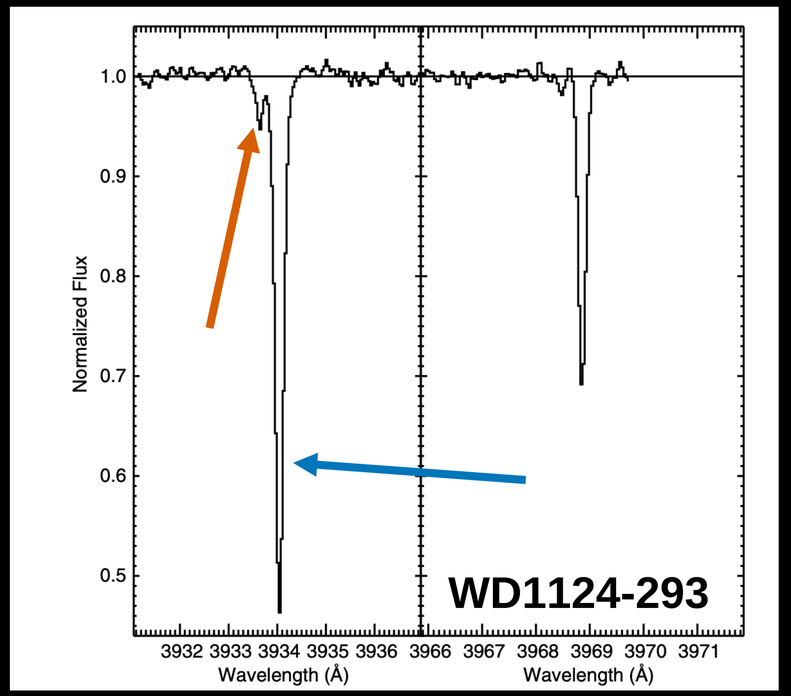
… in emission
Co-orbital with dust



Melis et al. 2020, ApJ 905, 56

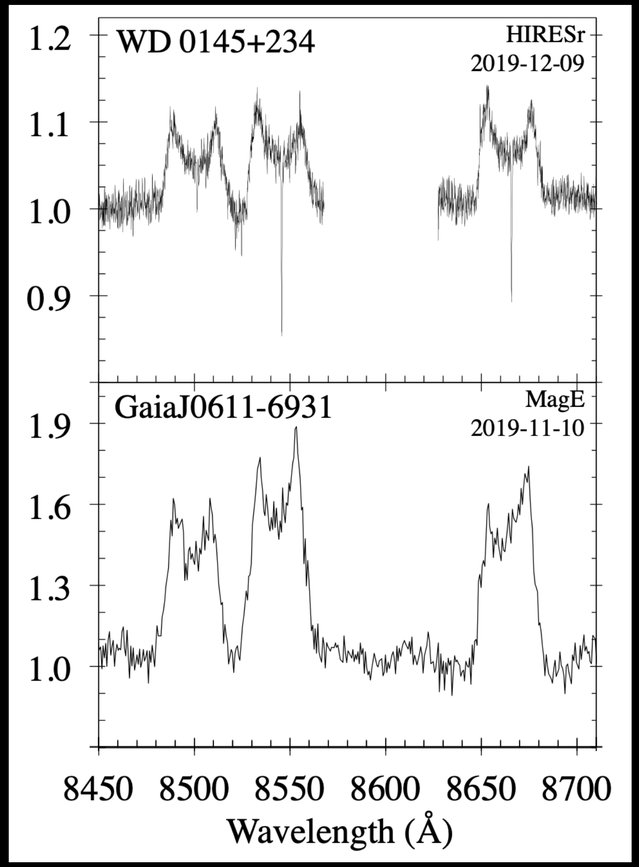
… in absorption
With and without dust



Debes et al. 2012, ApJ, 754, 59
Steele et al. 2020, ApJ, accepted

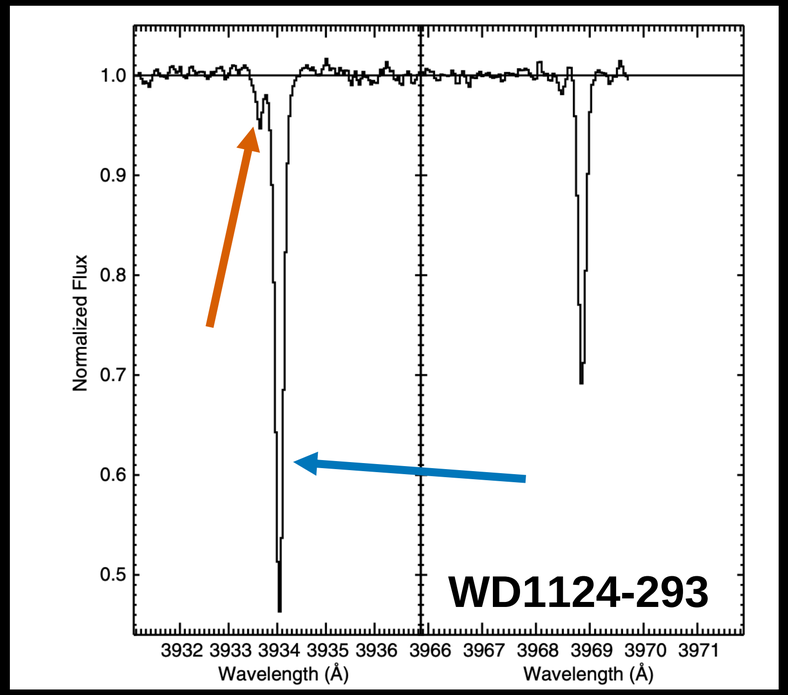
Observed gaseous planetary discs…

… in emission
Co-orbital with dust



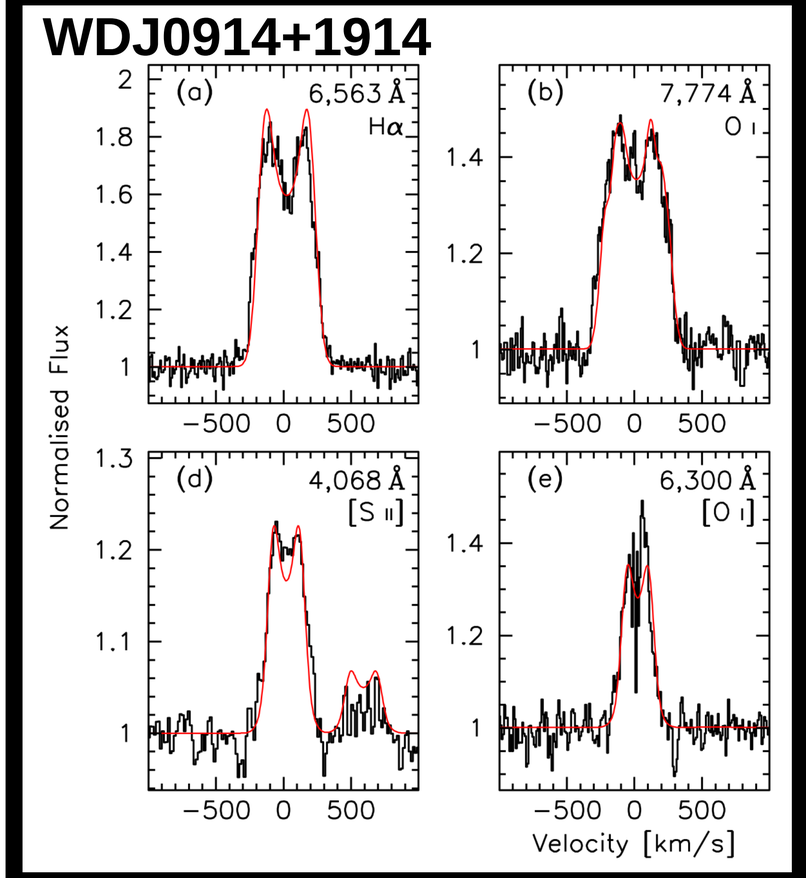
Melis et al. 2020, ApJ 905, 56

… in absorption
With and without dust



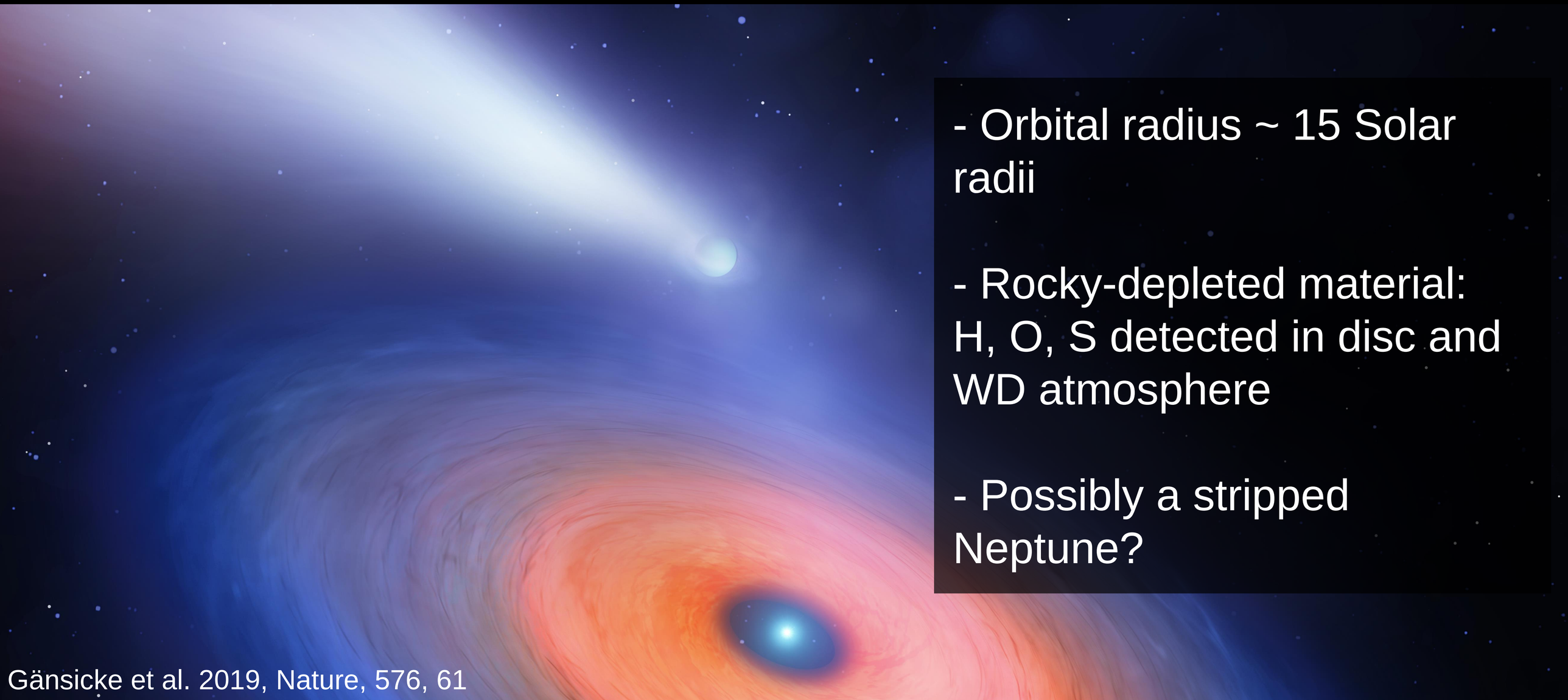
Debes et al. 2012, ApJ, 754, 59
Steele et al. 2020, ApJ, accepted

… in emission
No dust



Gänsicke et al. 2019, Nature, 576, 61

Gaseous emission - Photo-evaporated giant planet atmosphere



- Orbital radius ~ 15 Solar radii

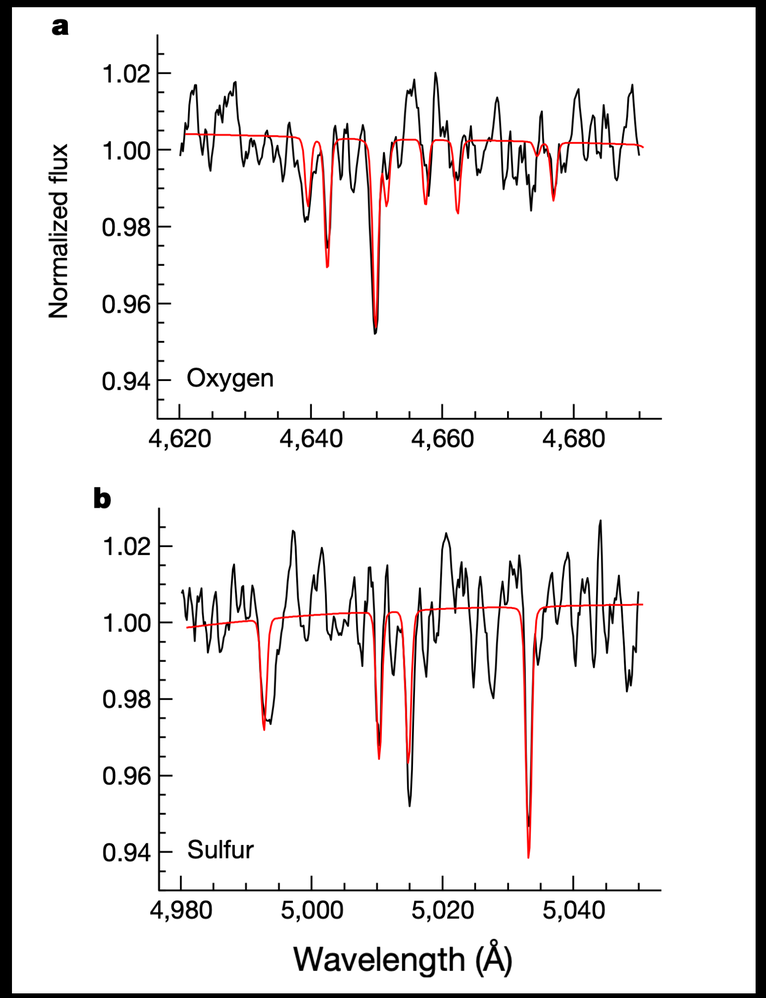
- Rocky-depleted material: H, O, S detected in disc and WD atmosphere

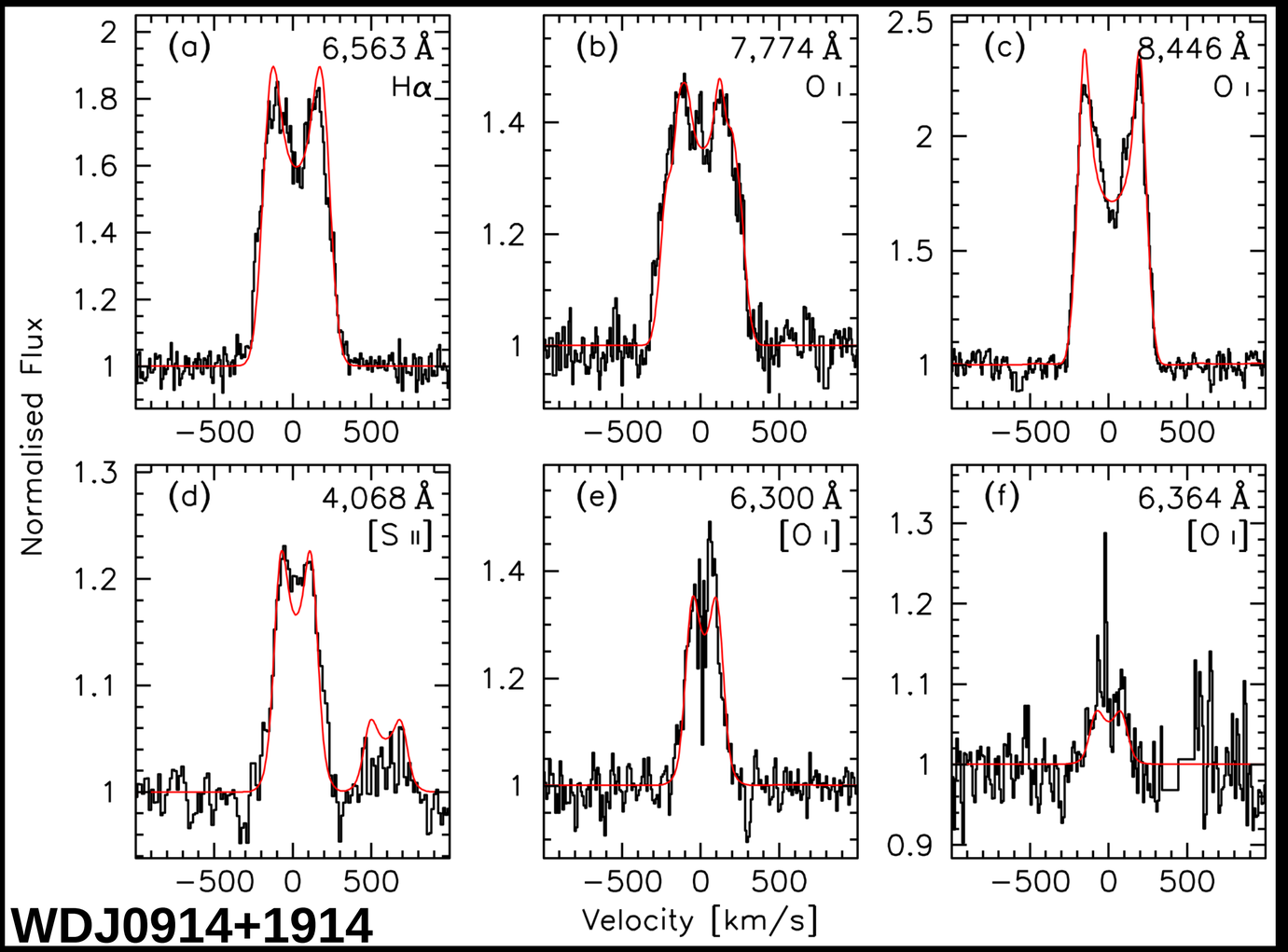
- Possibly a stripped Neptune?

Gänsicke et al. 2019, Nature, 576, 61

Photoionisation model with CLOUDY

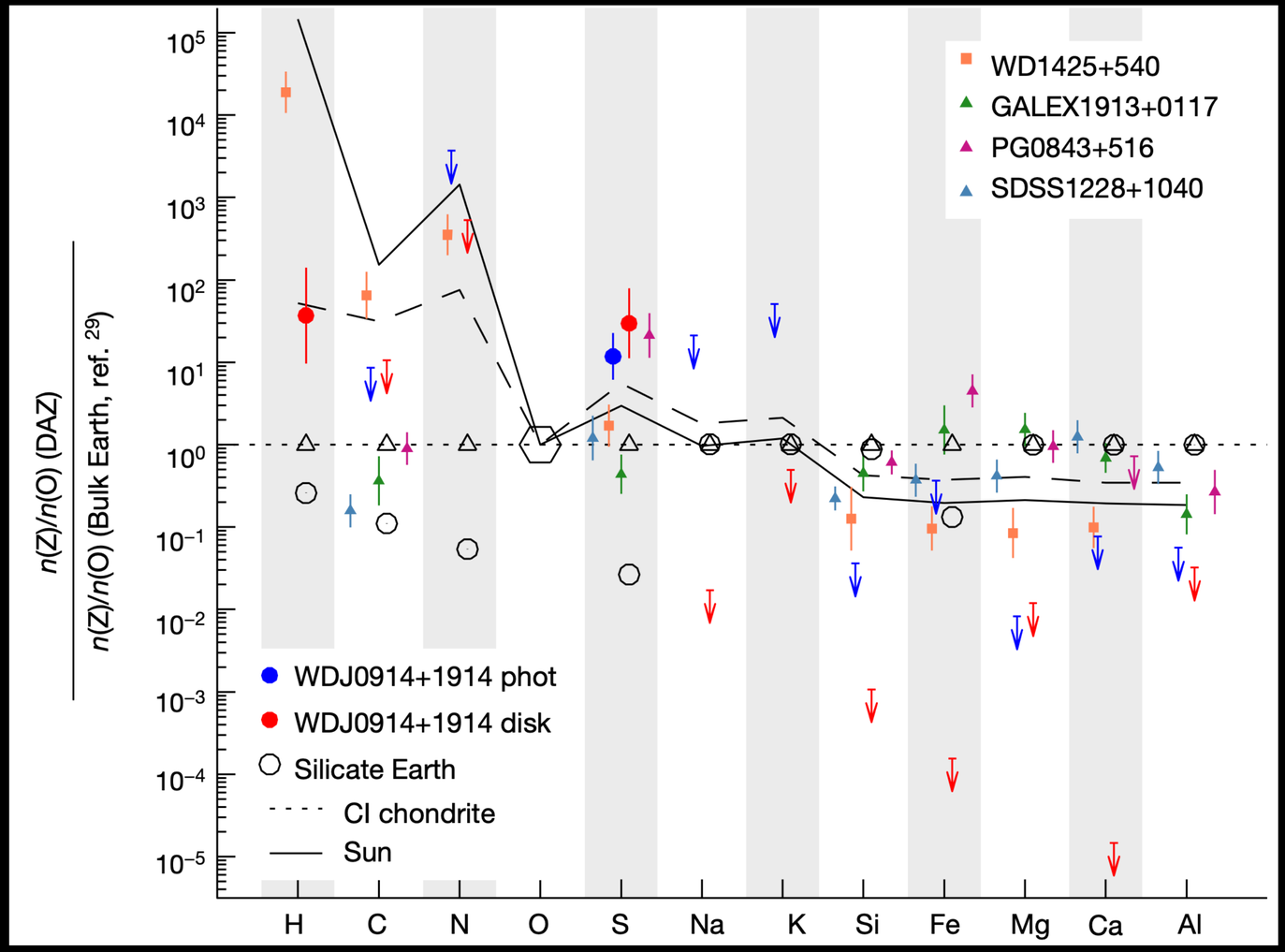
Modelling of white dwarf photosphere and gaseous emission profiles are consistent within factor ~2





Gänsicke et al. 2019, Nature, 576, 61

WDJ0914+1914 - accreting volatile material



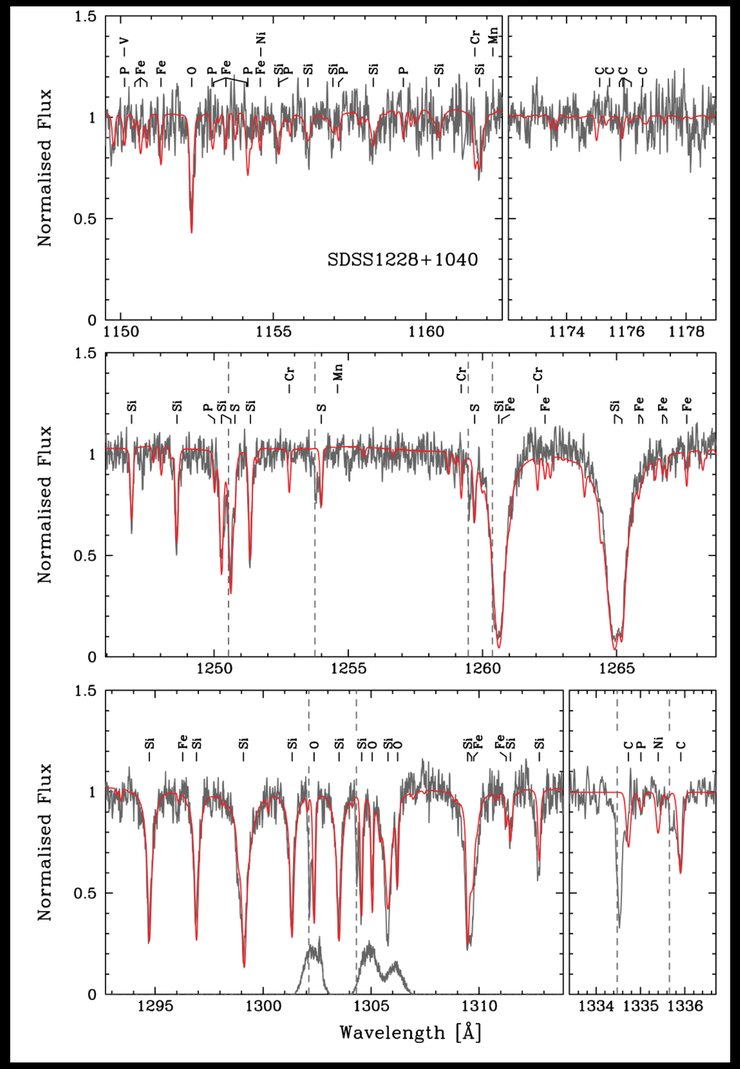
Rocky

Volatile

Gänsicke et al. 2019, Nature, 576, 61

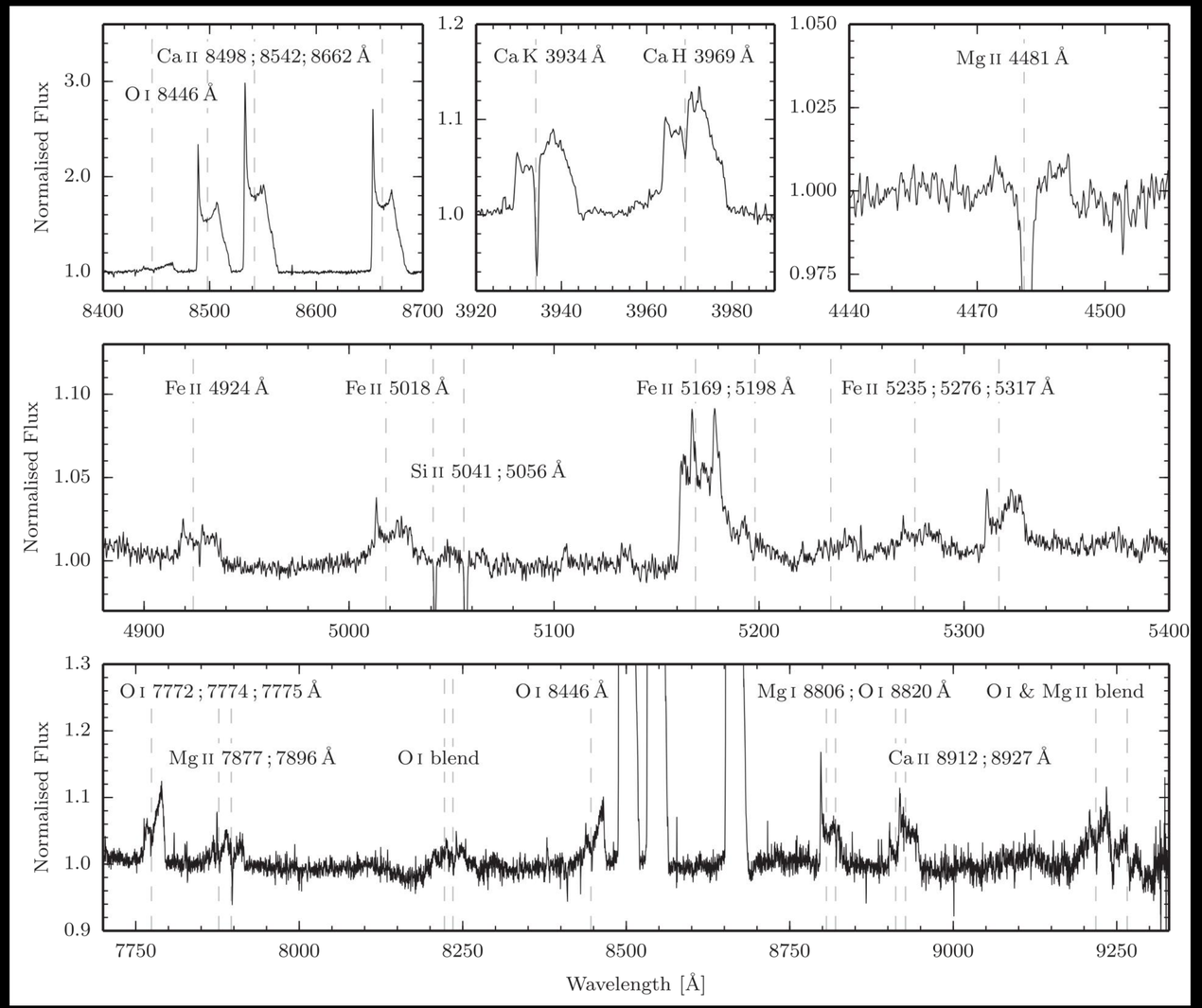
Onto gaseous debris discs? SDSSJ1228+1040

White dwarf atmosphere



Gänsicke et al. 2012, MNRAS, 424, 333

Gaseous debris disc



Manser et al. 2016, MNRAS, 455, 4467

Thanks for listening!