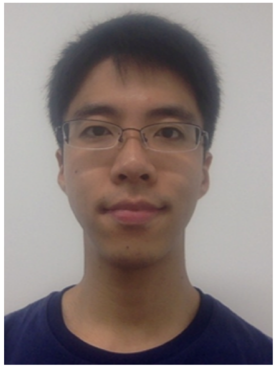
The Hertz Spinning Object Survey

Kazumi Kashiyama (U. of Tokyo)

HeSO

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   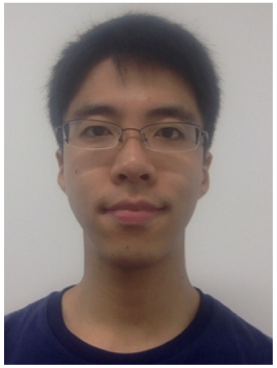 

Searching for yet-to-be-discovered sub-minute variability of white dwarfs

- Spin (close to the mass shedding limit)
  - ✓ (Magnetohydro)dynamics of formation and merger
  - ✓ A new class of high energy source
- (p-mode) oscillation
  - ✓ New asteroseismology to probe the interior
- Tidal disruption (of asteroids)
- Transits (of "habitable" planets)
  - ✓ Future of our solar system?

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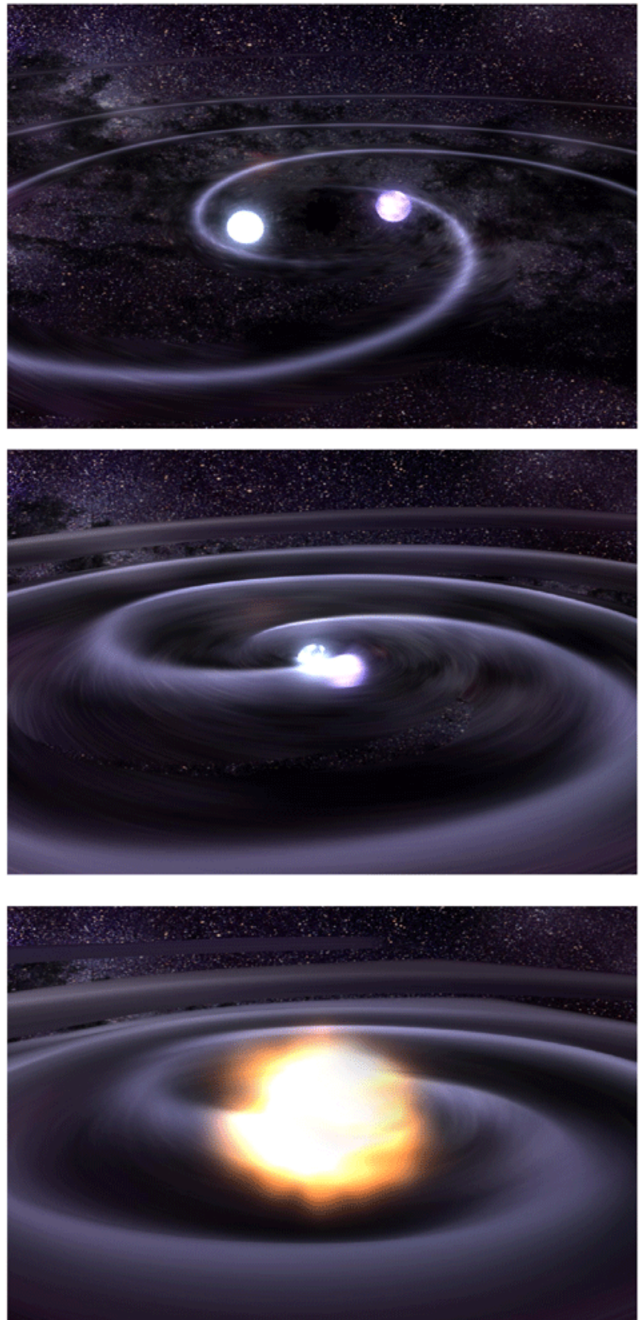
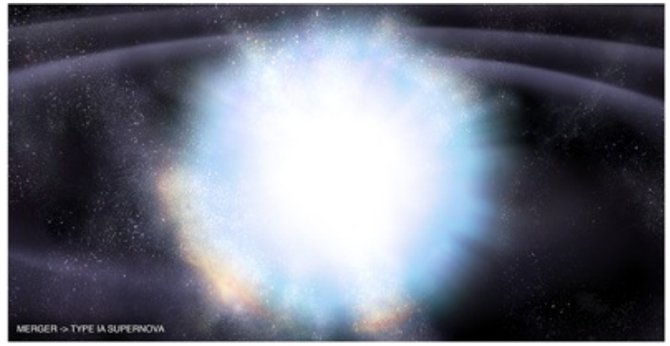
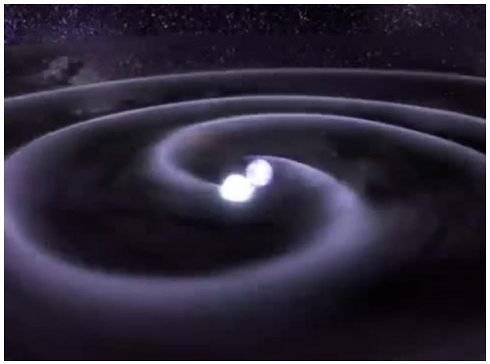


Credit:NASA

Ia SNe?

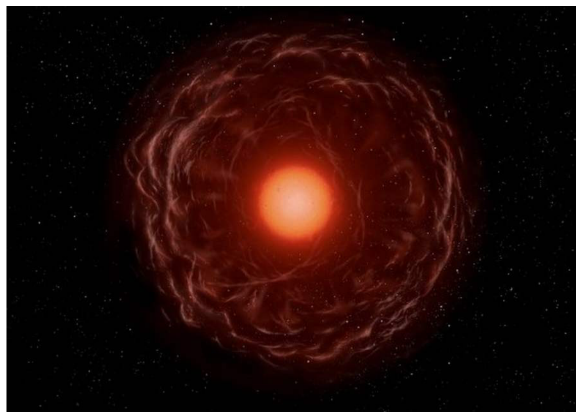


Double WD merger



$\sim 1\ \mathrm{yr}^{-1}\mathrm{gal}^{-1}$

Not found



Debris expansion

(R Coronae Borealis variables?)

Fast-spinning WD?

if @ mass shedding limit

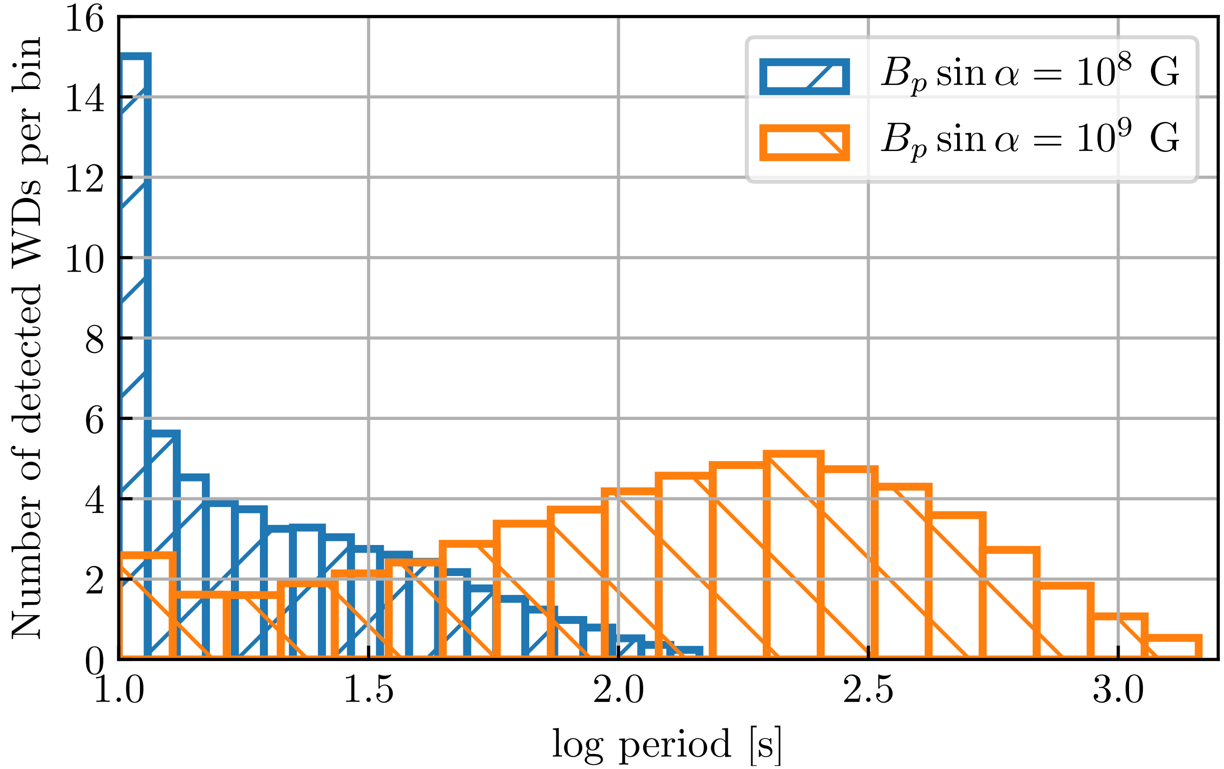
P_{rot} = 1-10 sec

$\sim 10^{50}$erg/100yr

~ 10 % of CCSN

Prospects of the fssWD survey

- Limiting magnitude: g = 19, sky coverage 10,000 deg^2
- f_{fssWD} = 0.3%



Searching for yet-to-be-discovered sub-minute variability of white dwarfs

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Searching for *Yet-to-be-discovered sub-minute variability of WDs*

can be explored with

~1 (10 night x 1000 WDs)

hertz spinning object survey!

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  - ✓ (magnetohydro)dynamics of formation and merger
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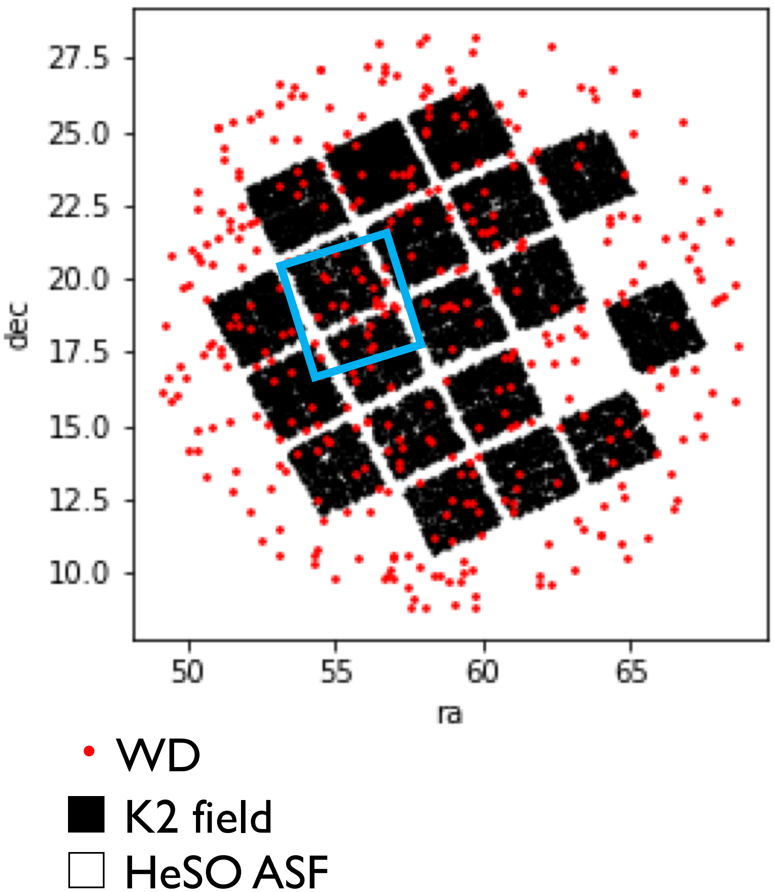
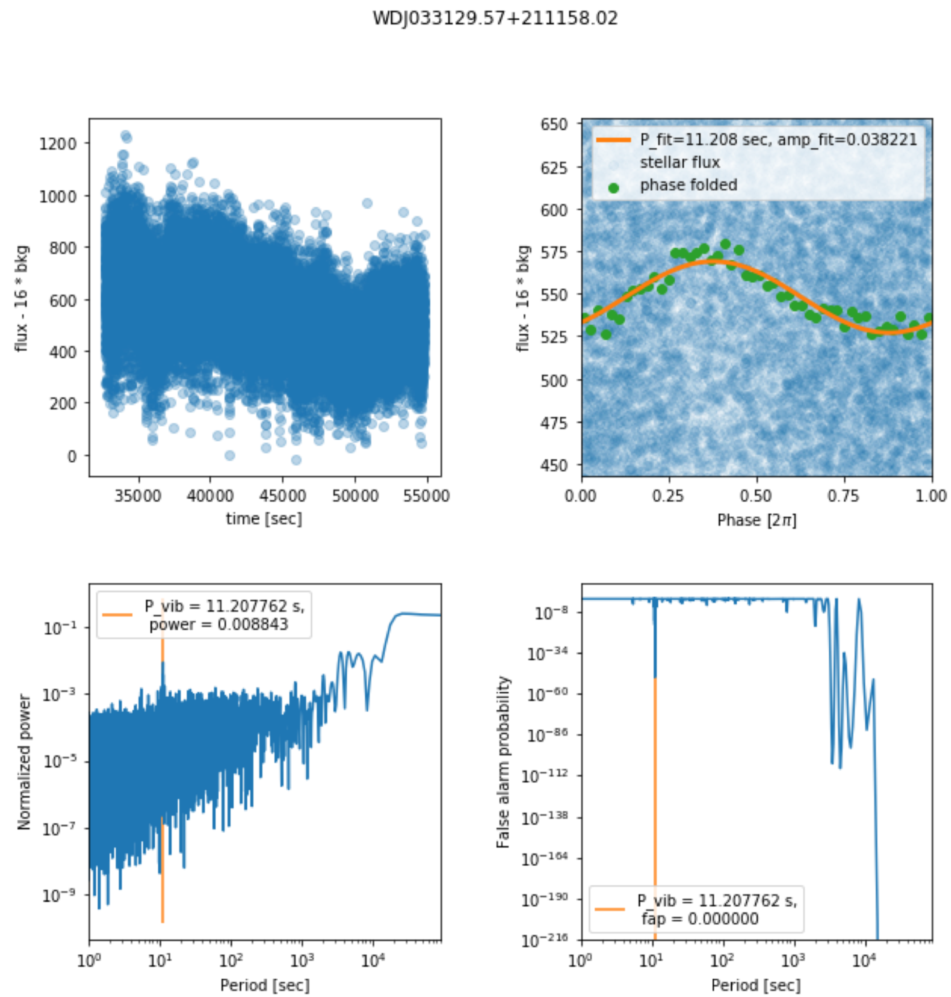
Pipeline Construction, Test Observations Under Way





LETTER

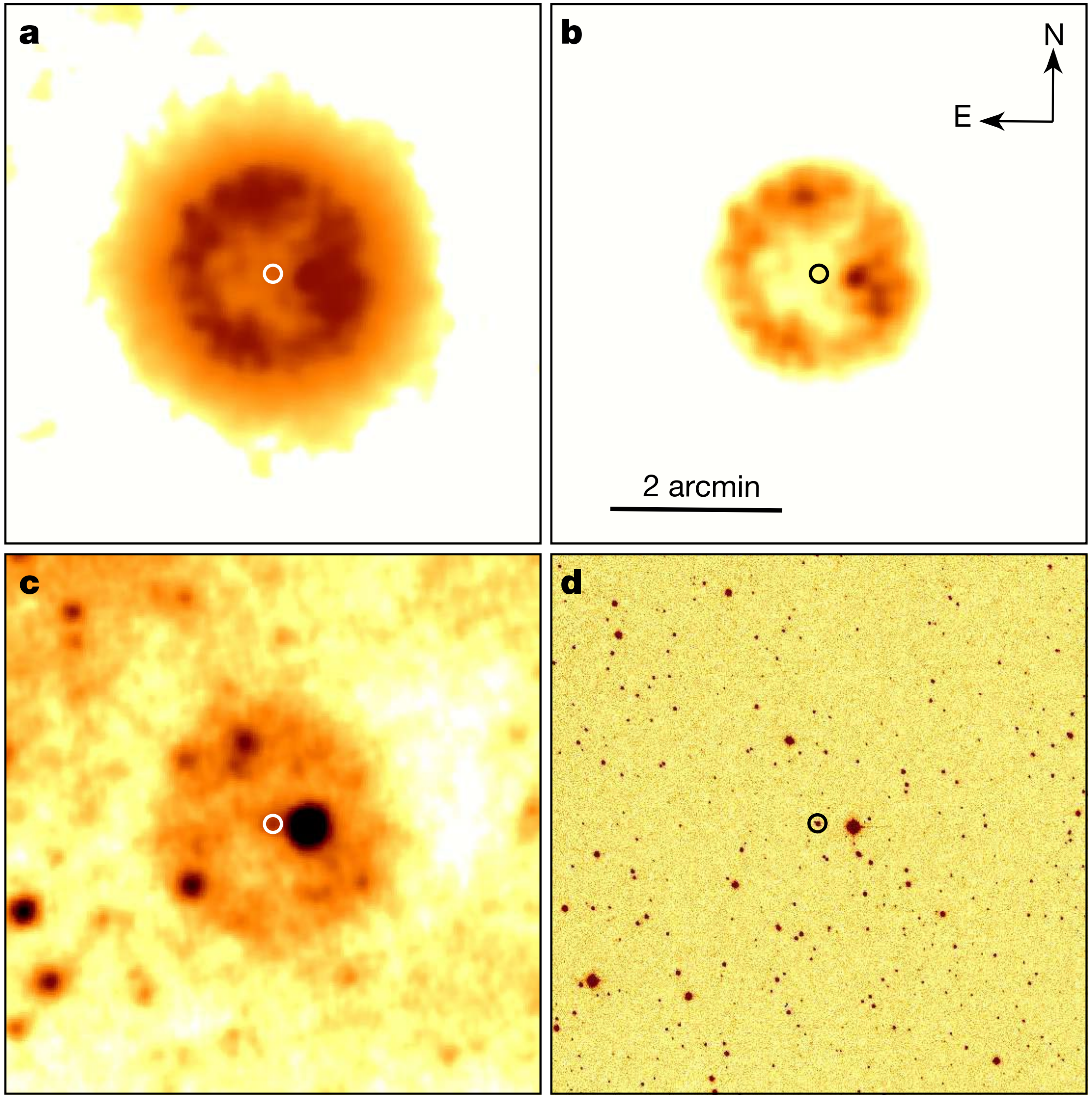
https://doi.org/10.1038/s41586-019-1216-1

A massive white-dwarf merger product before final collapse

Vasilii V. Gvaramadze[1,2,3]*, Götz Gräfener[4]*, Norbert Langer[4,5], Olga V. Maryeva[1,6], Alexei Y. Kniazev[1,7,8], Alexander S. Moskvitin[9] & Olga I. Spiridonova[9]

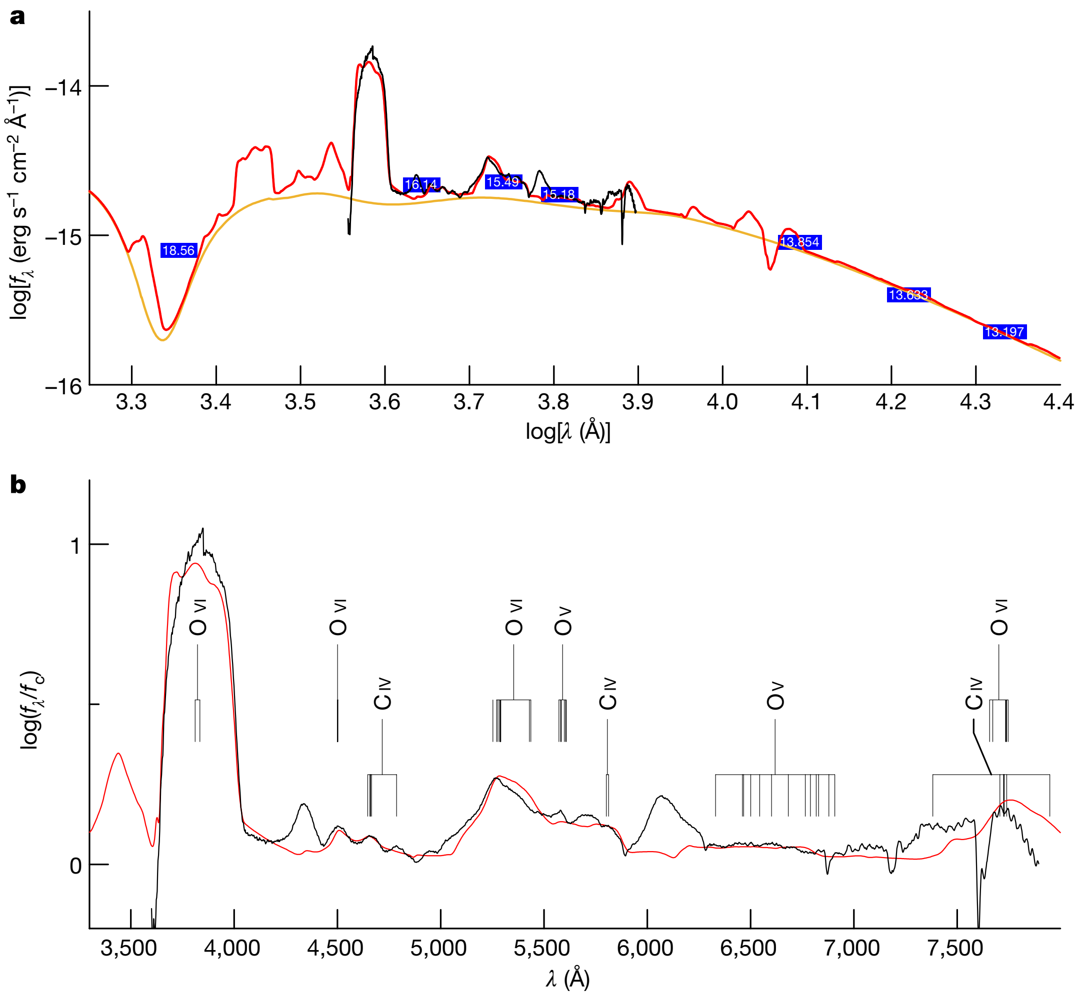
Gravitational-wave emission can lead to the coalescence of close pairs of compact objects orbiting each other[1,2]. In the case of neutron stars, such mergers may yield masses above the Tolman–Oppenheimer–Volkoff limit (2 to 2.7 solar masses)[3], leading to the formation of black holes[4]. For white dwarfs, the mass of the merger product may exceed the Chandrasekhar limit, leading either to a thermonuclear explosion as a type Ia supernova[5,6] or to a collapse forming a neutron star[7,8]. The latter case is expected to result in a hydrogen- and helium-free circumstellar nebula and a hot, luminous, rapidly rotating and highly magnetized central star with a lifetime of about 10,000 years[9,10]. Here we report observations of a hot star with a spectrum dominated by emission lines, which is located at the centre of a circular mid-infrared nebula. The widths of the emission lines imply that wind material leaves the star with an outflow velocity of 16,000 kilometres per second and that rapid stellar rotation and a strong magnetic field aid the wind acceleration. Given that hydrogen and helium are probably absent from the star and nebula, we conclude that both objects formed recently from the merger of two massive white dwarfs. Our stellar-atmosphere and wind models indicate a stellar surface temperature of about 200,000 kelvin and a luminosity of about $10^{4.6}$ solar luminosities. The properties of the star and nebula agree with models of the post-merger evolution of super-Chandrasekhar-mass white dwarfs[9], which predict a bright optical and high-energy transient upon collapse of the star[11] within the next few thousand years. Our observations indicate that super-Chandrasekhar-mass white-dwarf mergers can avoid thermonuclear explosion as type Ia supernovae, and provide evidence of the generation of magnetic fields in stellar mergers.

A pale blue dot in an infra nebula J005311



Gvaramadze et al.19

C/O dominated fairly broad emission lines



Gvaramadze et al.19

$$X_\mathrm{C} = 0.2 \pm 0.1$$

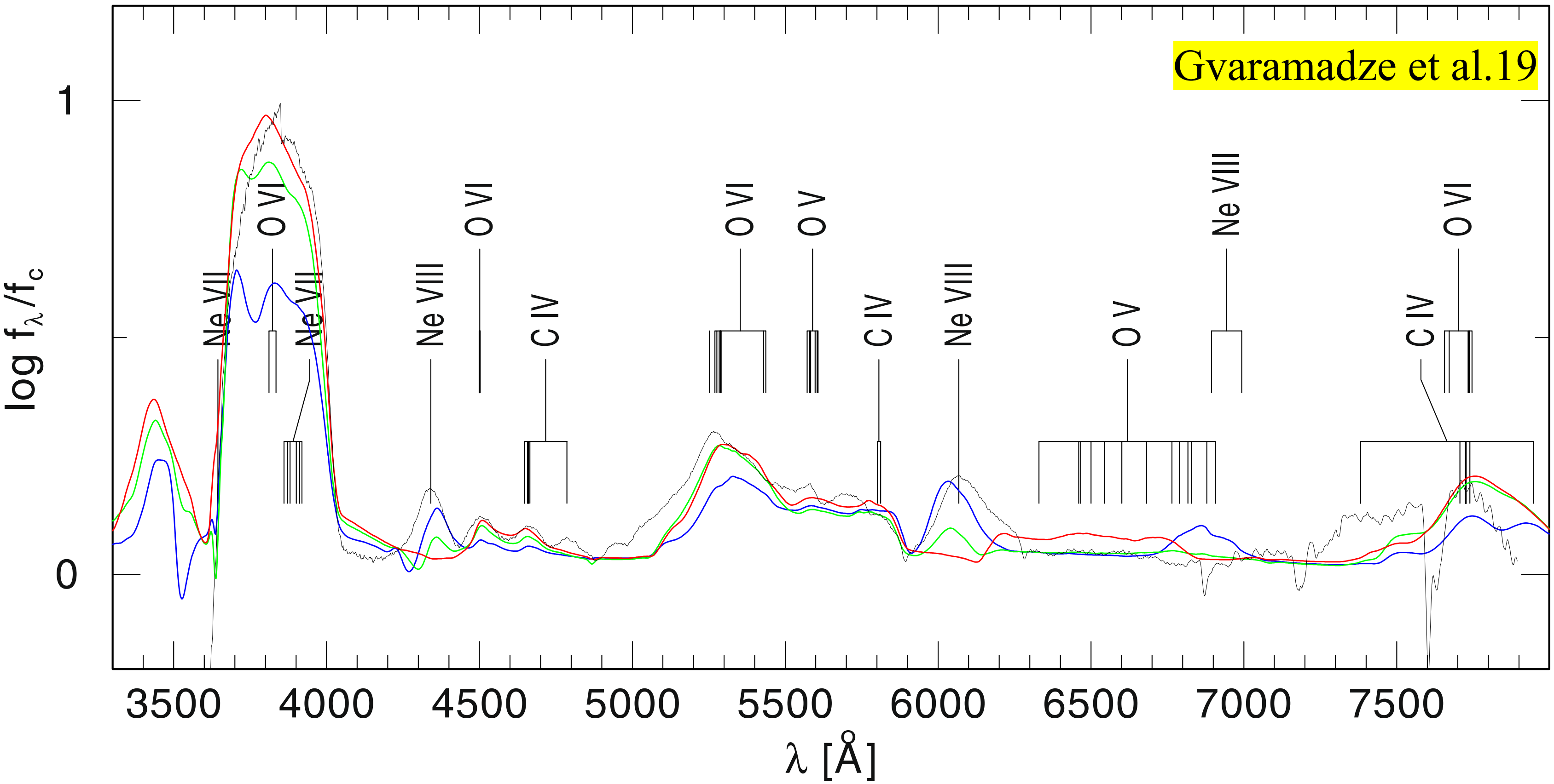
$$X_\mathrm{O} = 0.8 \pm 0.1$$

Line width & height ⇨

$$\dot{M} = (3.5 \pm 0.6) \times 10^{-6}\, M_\odot\, \mathrm{yr}^{-1}$$

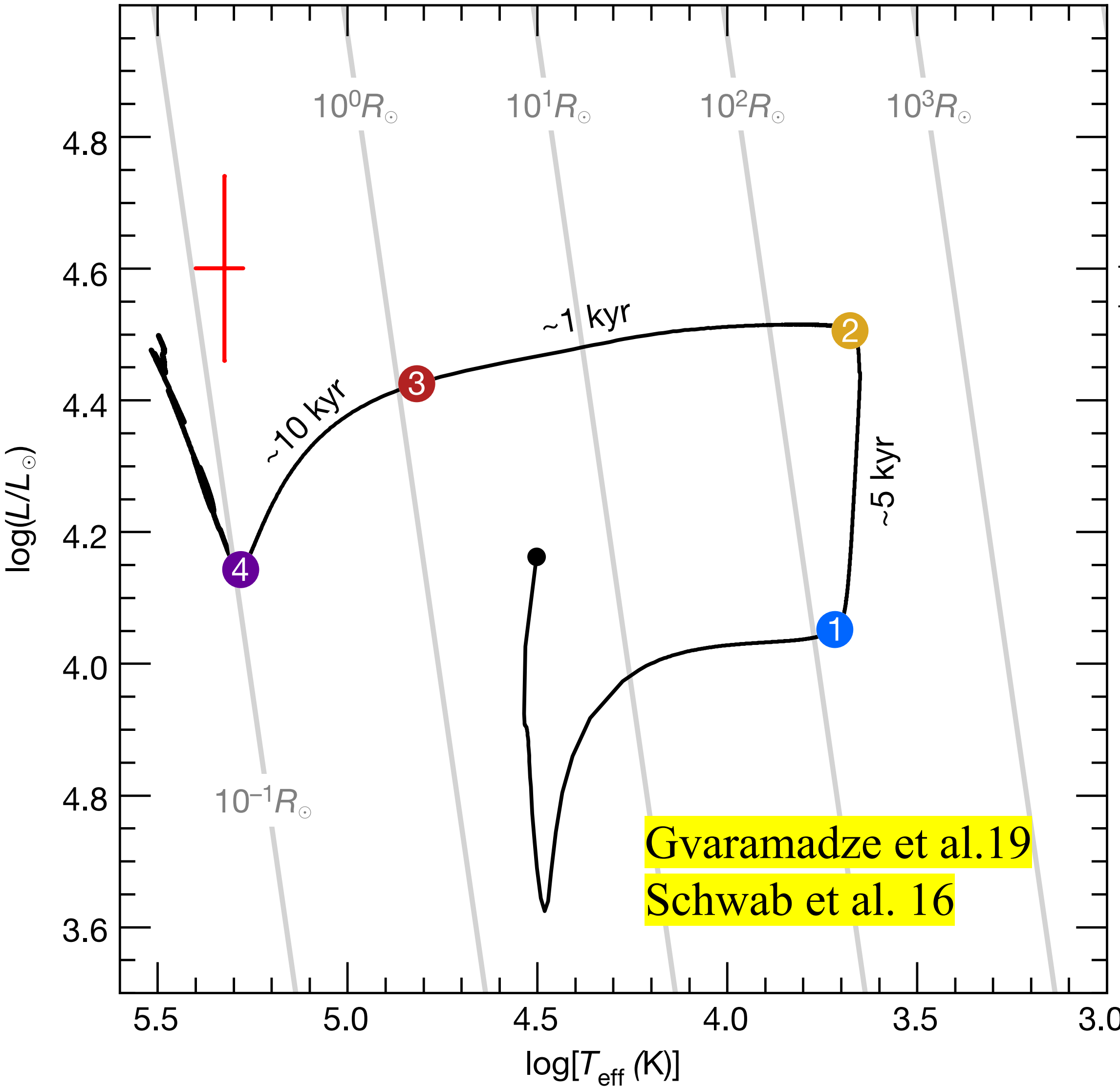
$$v_\infty = 16,000 \pm 1,000\, \mathrm{km\, s}^{-1}$$!?

Neon is also (probably) enriched



$$X_{\rm Ne} = 0.01$$

The pale blue dot on the HR diagram



$$T_{\rm eff} = 211,000^{+40,000}_{-23,000}\,{\rm K}$$

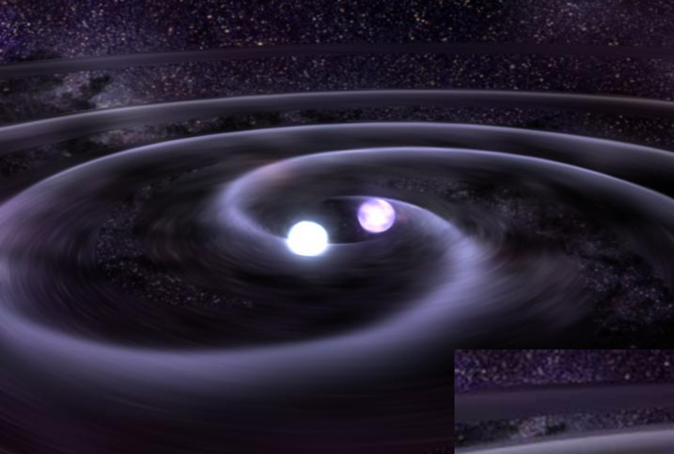
$$\log(L_{\rm rad}/L_\odot) = 4.60 \pm 0.14$$

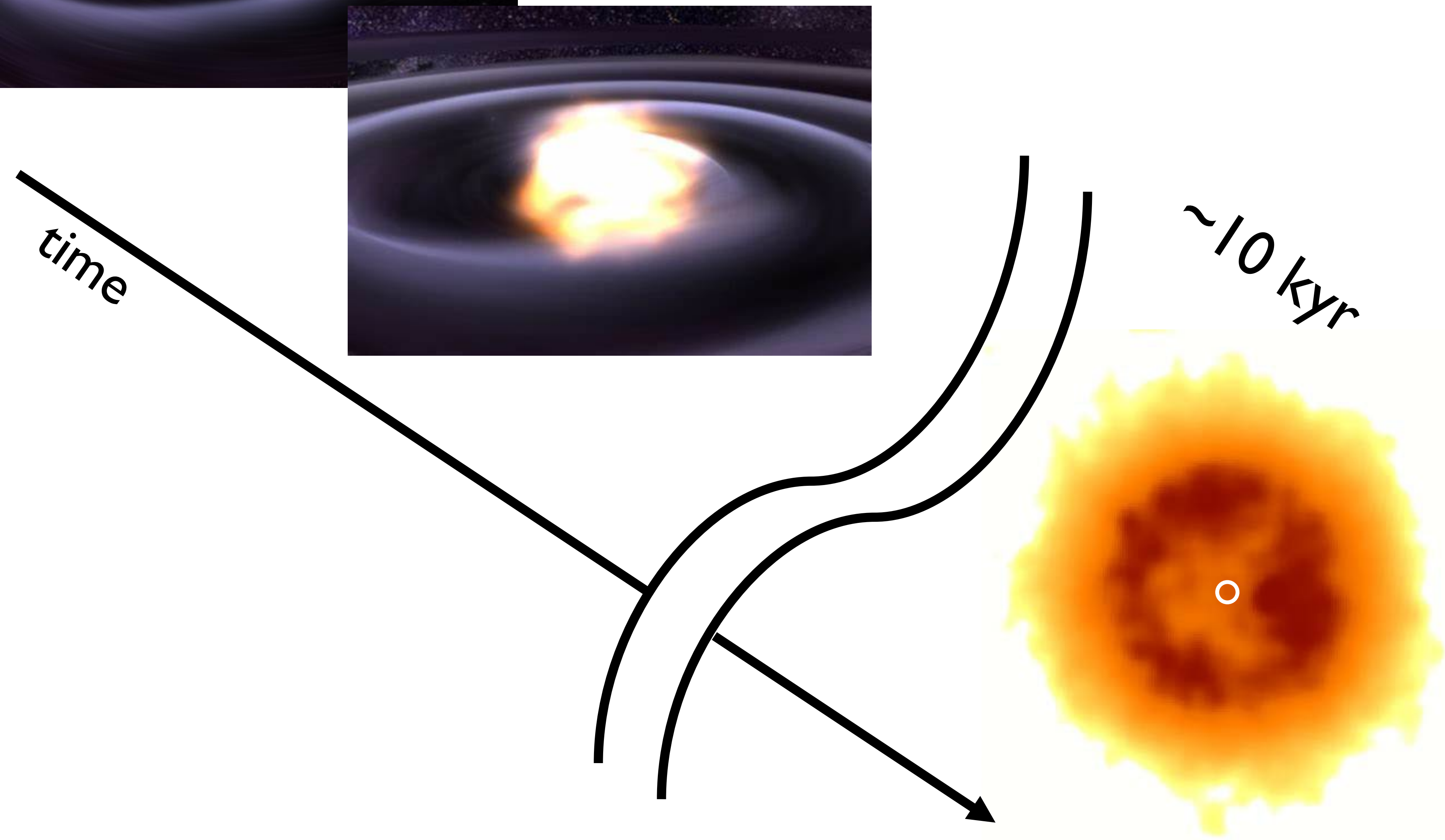
$$r_{\rm ph} = 0.15 \pm 0.04\,R_\odot$$

It looks like nothing but …

a white dwarf merger product with a super-Chandrasekhar mass

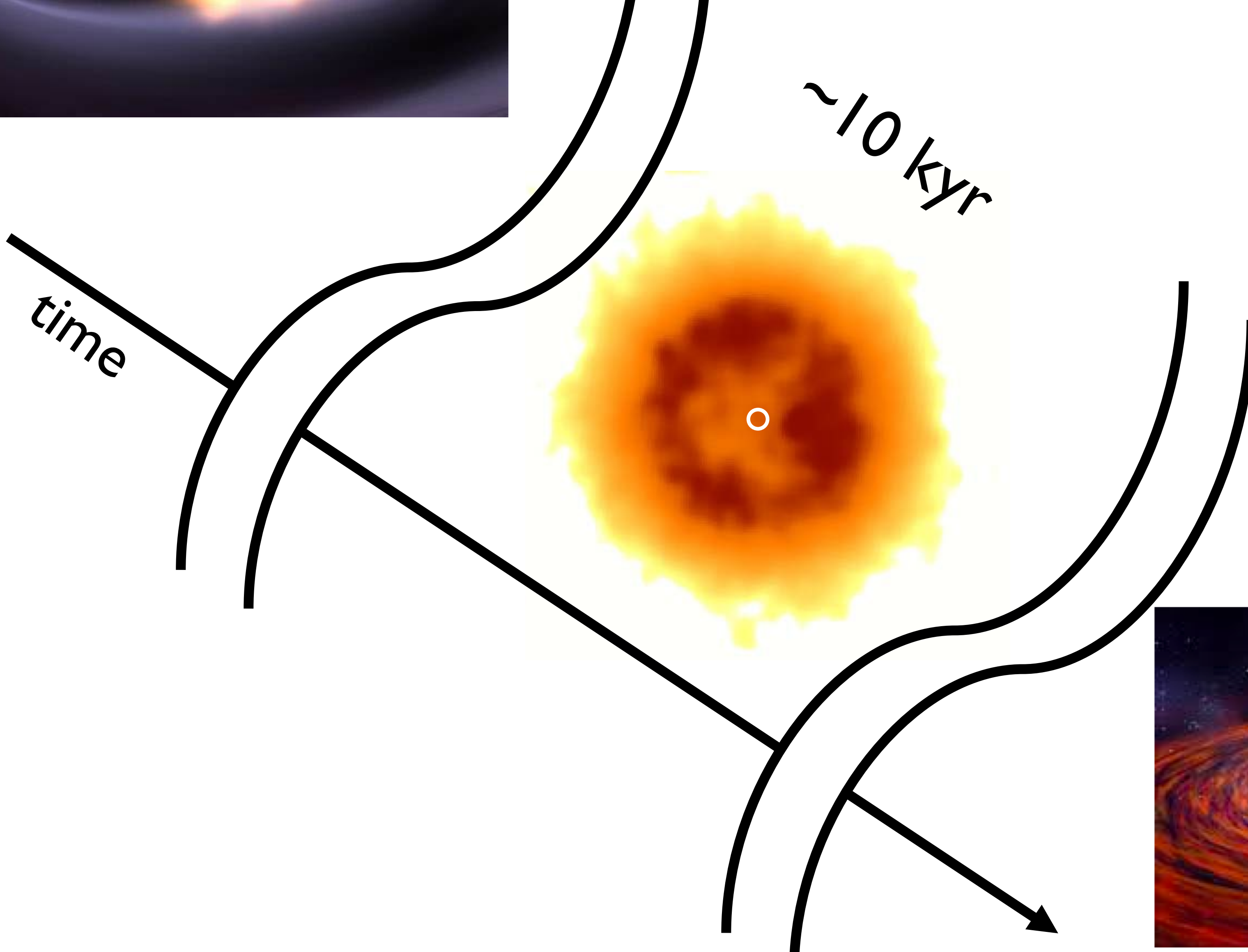
Gvaramadze et al.19





will finally collapse into a neutron star

Gvaramadze et al.19



Q. How can the wind be so fast?

- Radiation pressure?

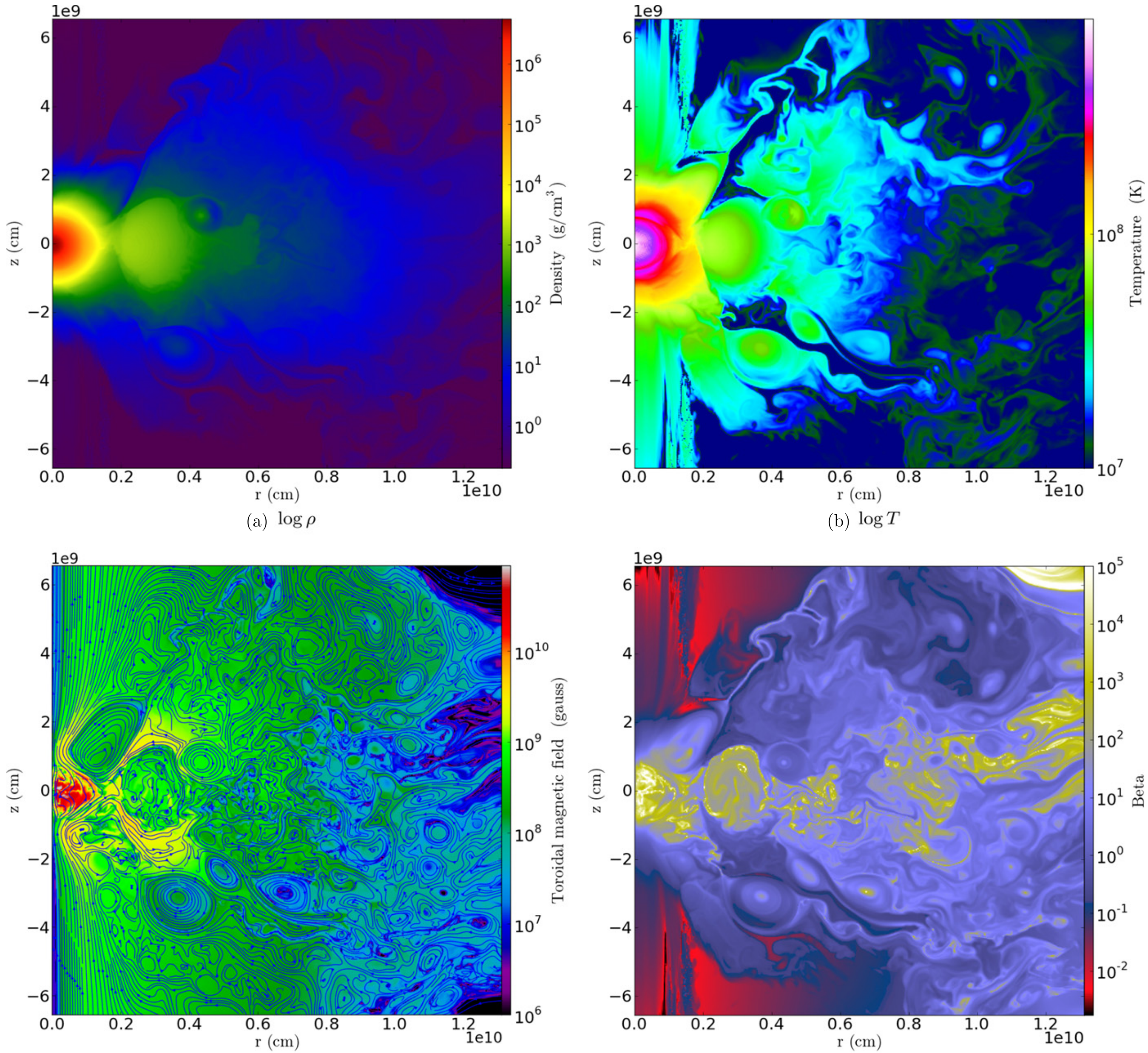
  → wind velocity $\sim$ escape velocity @ photosphere

  $\sim$ O(1,000) km s^{-1} for a ~ solar mass obj.

  << 16,000 km s^{-1} …

- Rotating magnetic field?

  → wind velocity ↑↑ for *a larger B field and a faster spin*



(a) $\log \rho$

(b) $\log T$

(c) Magnetic Field

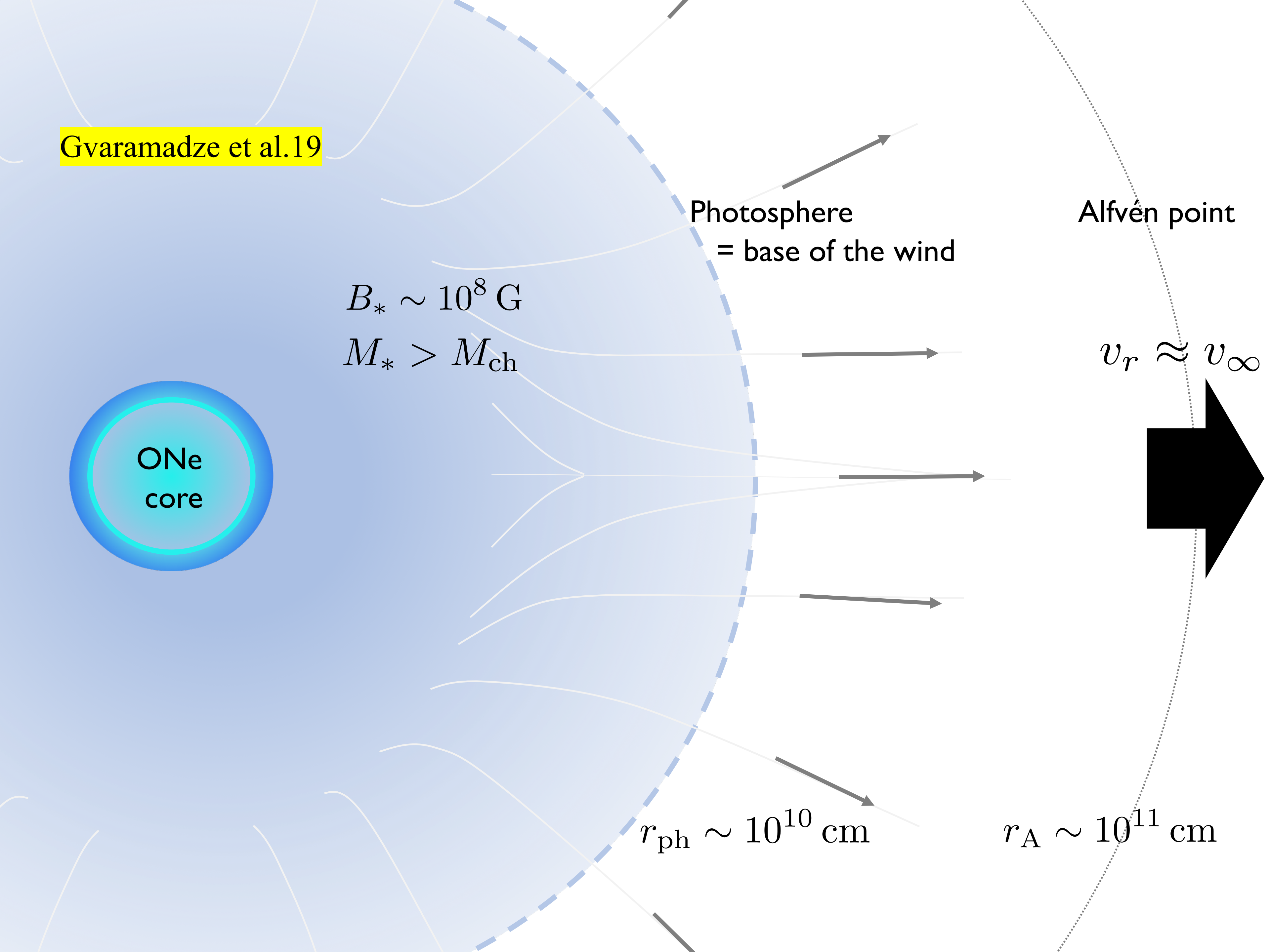
(d) $\log \beta$

Ji et al.13

Gvaramadze et al.19

- *" … this extremely high velocity can be explained in the framework of rotating magnetic wind models."*

- *" We find that a co-rotation speed of 16,000 km s^{-1} at the Alfvén point in J005311, where the inertia force starts to dominate over the magnetic forces, requires an Alfvén radius of about 10 stellar radii (about 1.5$R_{\odot}$), which is achieved with a magnetic field strength of about 10^8 G. "*

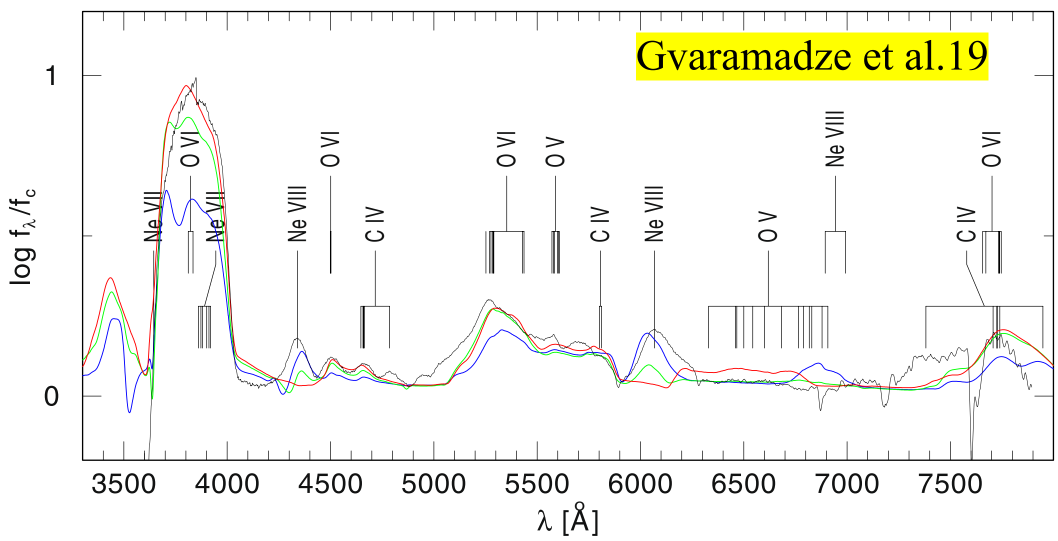


Gvaramadze et al.19
Photosphere
= base of the wind
Alfvén point
$B_* \sim 10^8$ G
$M_* > M_{ch}$
$v_r \approx v_\infty$
ONe
core
$r_{ph} \sim 10^{10}$ cm
$r_A \sim 10^{11}$ cm

???

- If the bulk acceleration occurs beyond the photosphere, a P Cygni profile should be detected, but the emission lines in the observed spectrum lacks blue-shifted absorption components …

→ A sub-photospheric acceleration may be required.



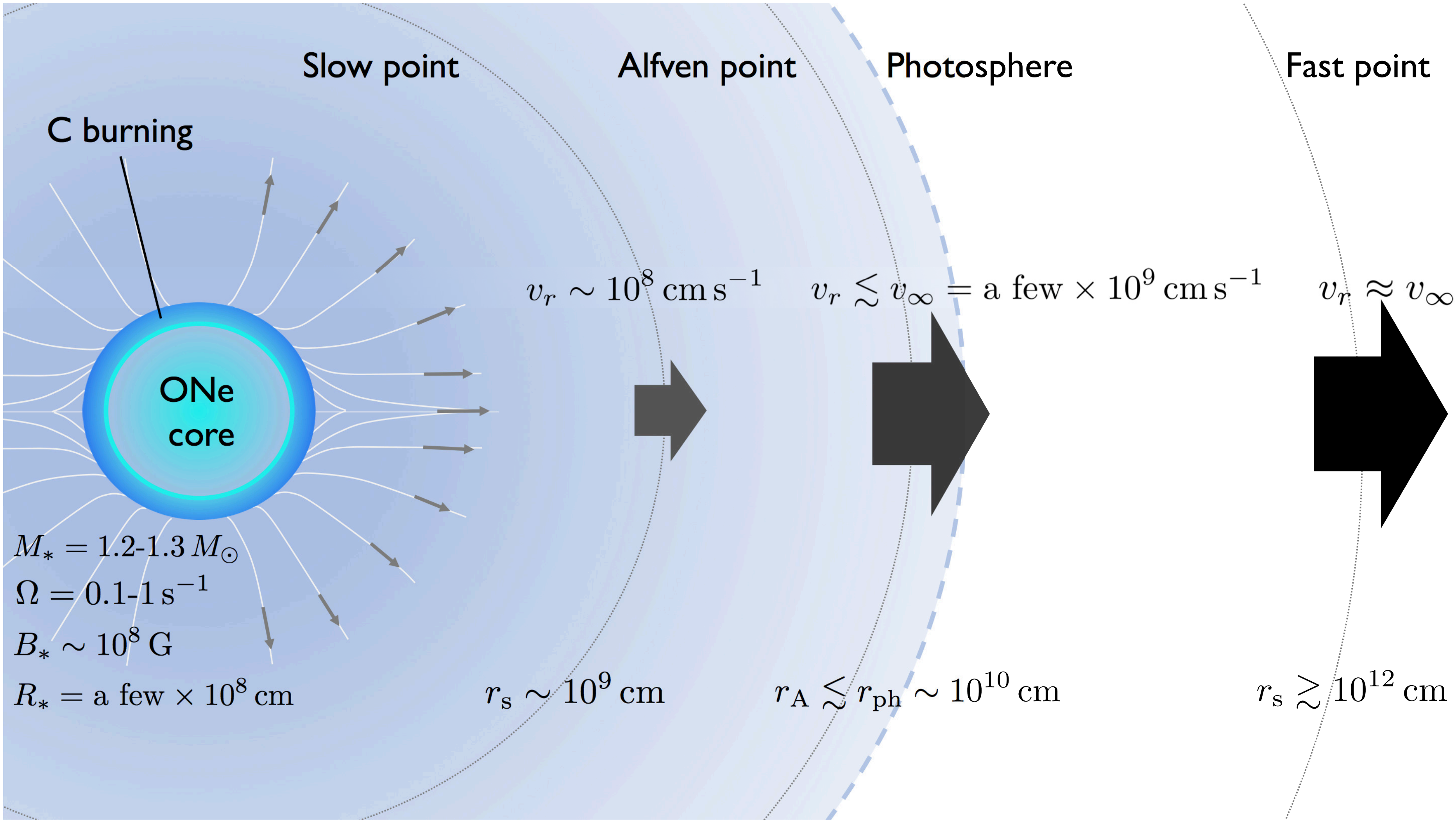
???

- If the bulk acceleration occurs beyond the photosphere, a P Cygni profile should be detected, but the emission lines in the observed spectrum lacks blue-shifted absorption components …

  → A sub-photospheric acceleration may be required.

- **How fast the star rotates?**
- How the wind is launched?
- Does it need to have a super-Chandrasekhar mass?

Kashiyama, Fujisawa, Shigeyama in prep



LETTER

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4月3日 (水)

Kojiro Kawana 13:50
Double WD mergerのremnantらしきmassive WDが見つかったという論文がNatureっぽいフォーマットでarxivに出てましたね
https://arxiv.org/abs/1904.00012v1
Ra ~00h53m, Dec ~+67 deg,　B~16magなのでTomoeでも見えそうですが，彼らの1m望遠鏡 (CCD photometer, Zeiss-1000 telescope)では変動はなかったと報告しています．

> **arXiv.org**
> A massive white-dwarf merger product prior to collapse
> Gravitational wave emission can lead to the coalescence of close pairs of compact objects orbiting each other. For the case of neutron stars such mergers may yield masses above the...

Kojiro Kawana 14:02
結構強いWindが吹いていたという話のようなので，HeSOの観点からはwindで角運動量を失ってしまいHertz spinにはならないという話になるかもしれませんが… （編集済み）

Kazumi Kashiyama 17:23
あ、これ理論の論文やと思ってた。すぐにでも見るべきじゃね？

見れるなら。

Kazumi Kashiyama 17:30
彼らの立場はこいつは最終的にコラプスするやつというもので、それが正しいとすると強くspindownしてるかどうかはサーベイする立場からはあんまり関係ないかも。こいつがsecで回ってて強くspindownしてるphaseがphotometryで受かったらめっちゃおもろい。

@Ryou Ohsawa ということでo3始まってすぐでそんな余裕ないことを承知でお伺いするのですが、こいつ見れないですかね？

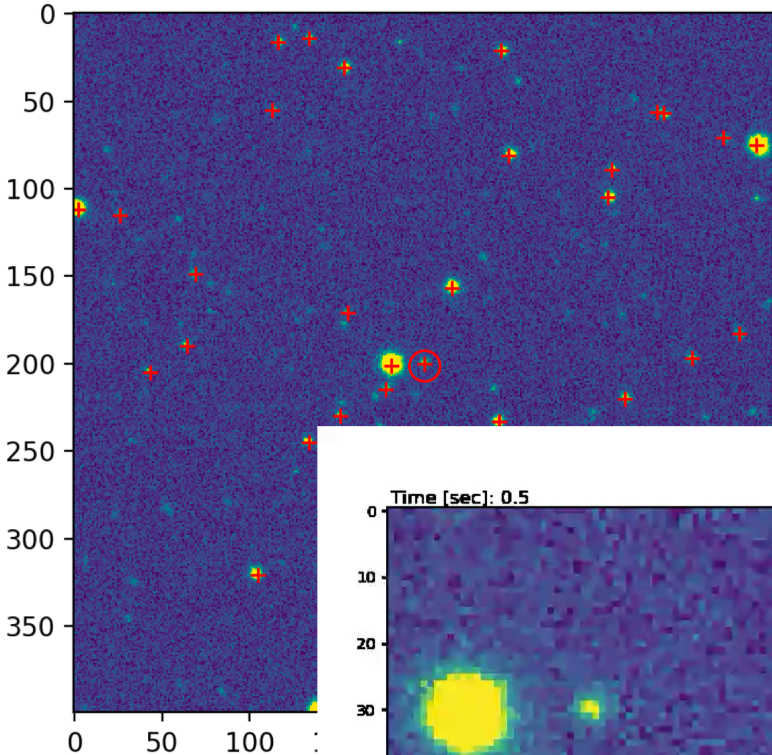
Ryou Ohsawa 17:40
今日ちょうど別の天体を手動で観測するつもりだったので天気に嫌われなければ撮ってみます （編集済み）

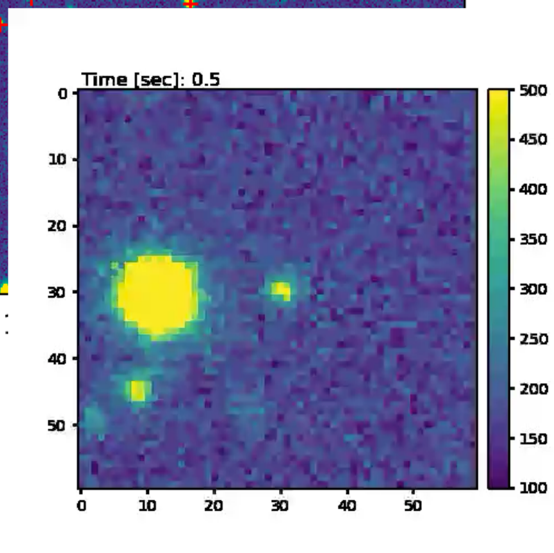
~ sec の変動があるかどうかがわかれば良いという程度でしょうか？

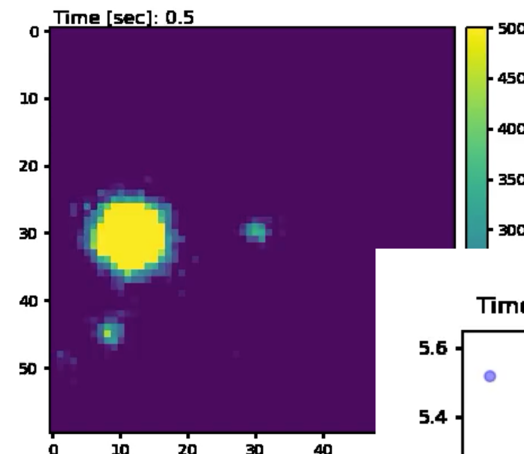
Kazumi Kashiyama 17:42
ありがとうございます！
@Kojiro Kawana 解析の準備や！

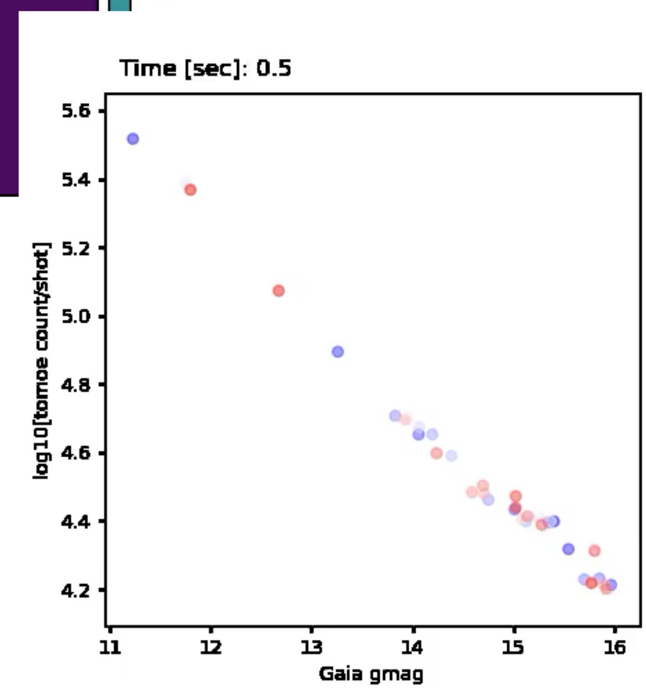
はい。16等なのでそんなに積分時間いらないです。

Ryou Ohsawa 17:43
とりあえず 2 Hz で数分くらい撮ってみますー.



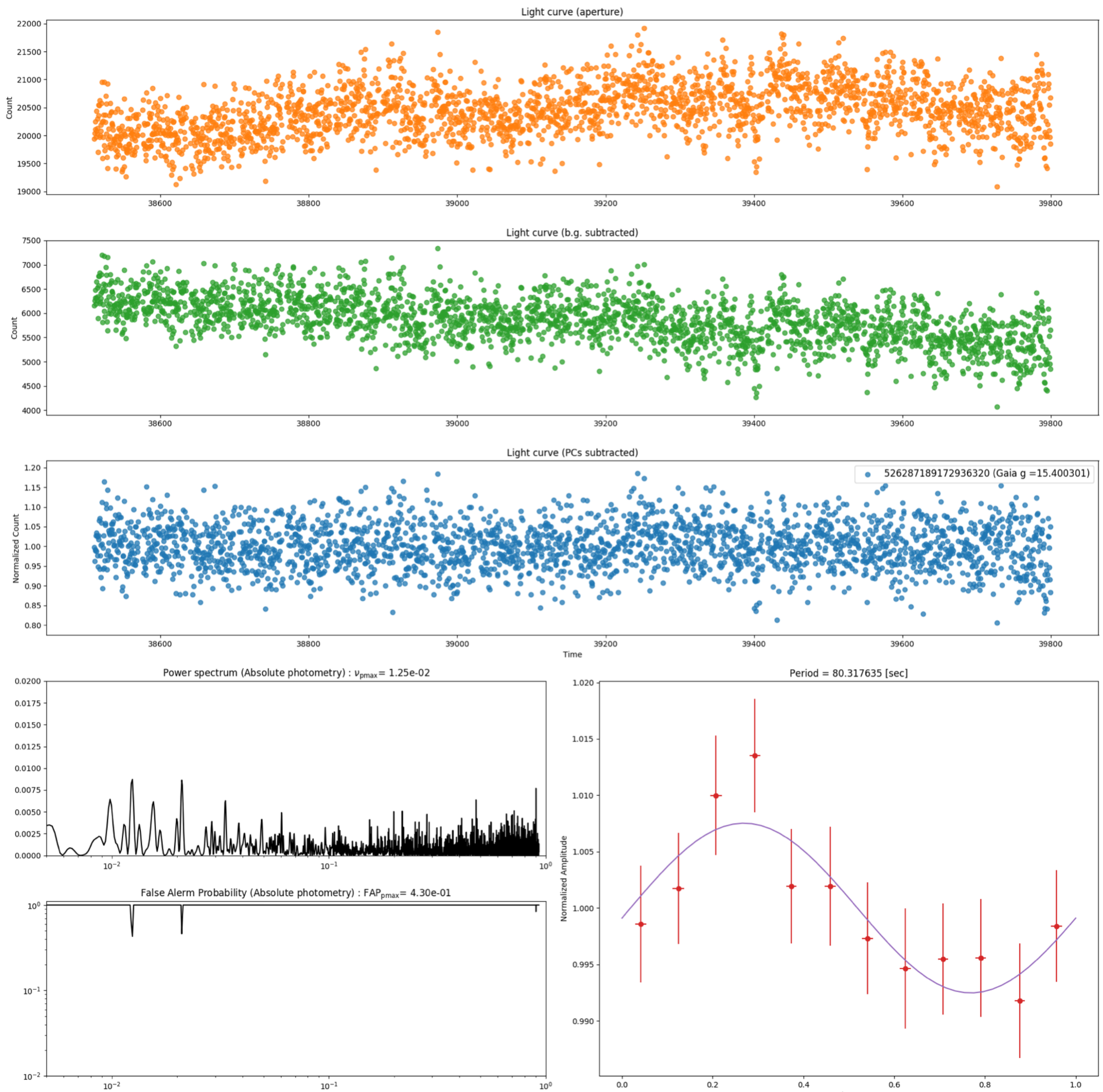






Tomo-e observation of J005311

Timing analysis of J005311



Summary and discussion

- The Hertz Spinning Object Survey
  - **The goal is ~1 (10 night x 1000 WDs)**

- A target observation of J005311-like system will be also interesting.

- Pipeline construction under way.

Appendix

Searching for yet-to-be-discovered sub-minute variability of WDs

- Spin (close to the mass shedding limit)
  - ✓ (Magnetohydro)dynamics of formation and merger
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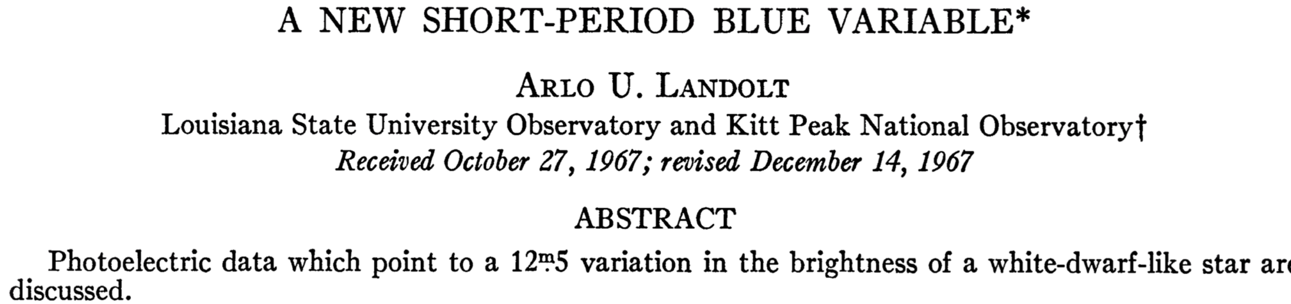
Pulsating white dwarfs

discovered by


A NEW SHORT-PERIOD BLUE VARIABLE*

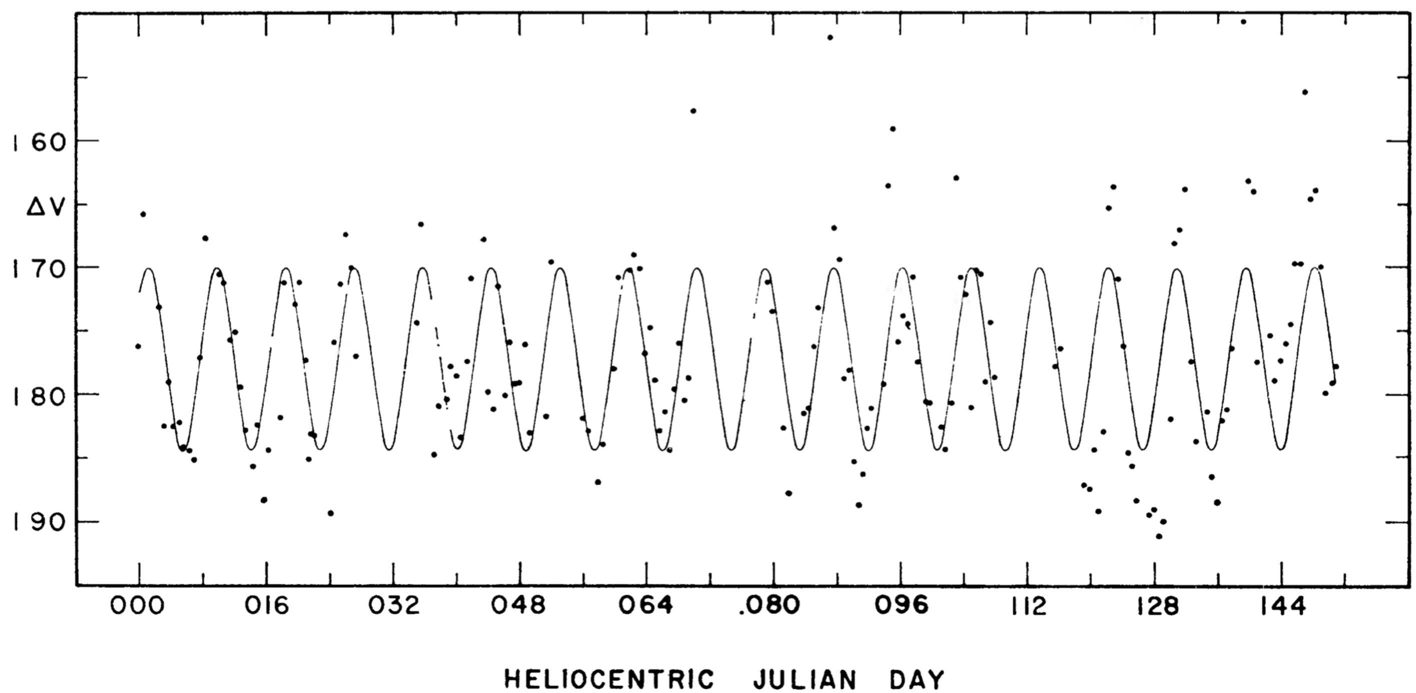
ARLO U. LANDOLT

Louisiana State University Observatory and Kitt Peak National Observatory†

Received October 27, 1967; revised December 14, 1967

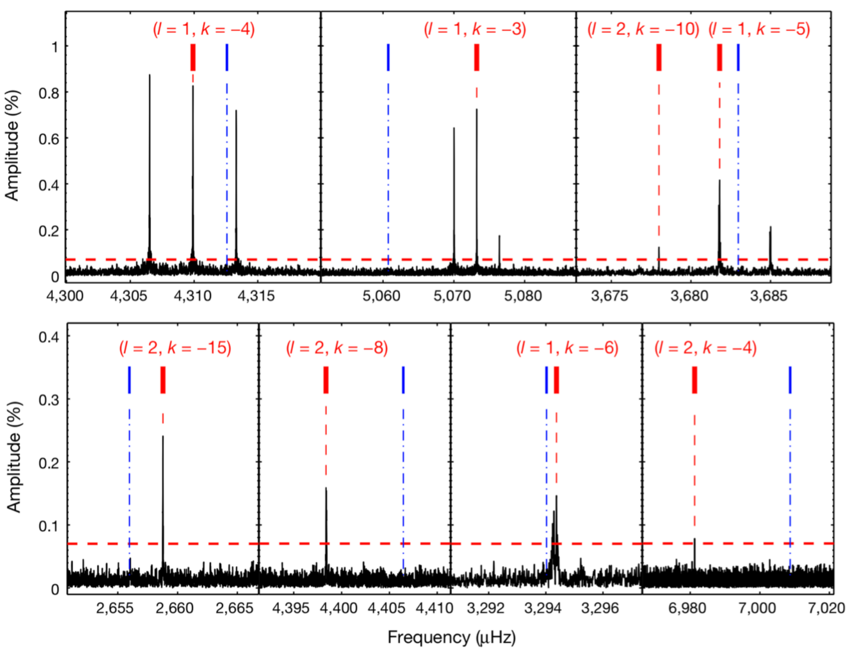
ABSTRACT

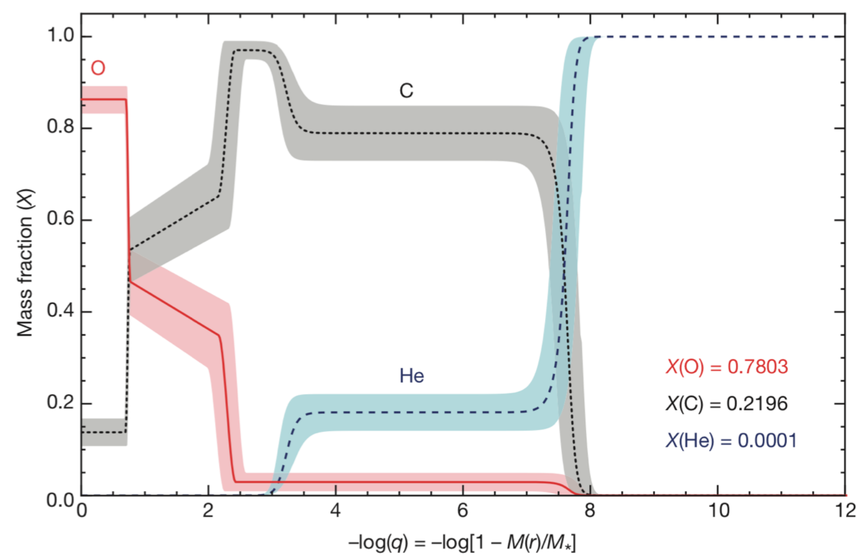
Photoelectric data which point to a 12ᵐ5 variation in the brightness of a white-dwarf-like star are discussed.



Probing the internal structure

e.g., DBV J192904.6+444708 (KIC08626021) using Kepler data Giammichele et al. 18





Radial p-modes also becomes unstable?

e.g., PULSATION PROPERTIES OF DA WHITE DWARFS: RADIAL MODE INSTABILITIES

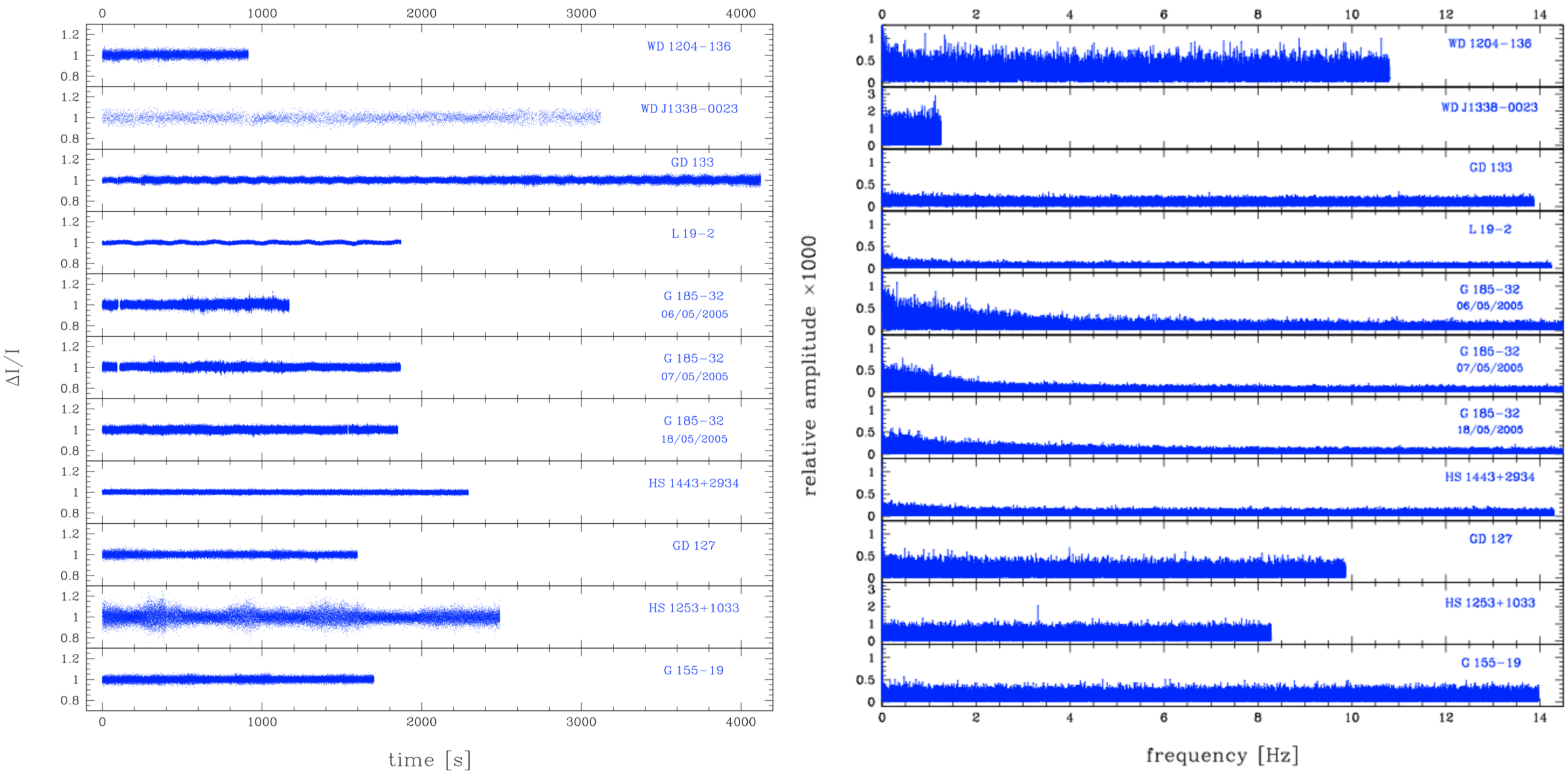
H. SAIO, D. E. WINGET, AND E. L. ROBINSON
McDonald Observatory and Department of Astronomy, University of Texas at Austin
Received 1982 June 2; accepted 1982 August 5

ABSTRACT

We have solved the equations describing linear, nonadiabatic, radial pulsations for models of compositionally stratified, evolving, DA white dwarfs. We find a κ-mechanism, radial mode, instability strip that is caused by the development of a hydrogen partial ionization zone during the evolutionary cooling of our models. Instabilities occur for radial modes with periods, Π, in the range $4 \gtrsim \Pi \gtrsim 0.2$ s, with *e*-folding growth times, τ_e, in the range $2 \times 10^9 \gtrsim \tau_e \gtrsim 8 \times 10^2$ s; the minimum growth times occur in the shortest period unstable modes. Comparison with our previous calculations for nonradial pulsations indicates that the blue edge for the radial instability strip is ~ 1600 K hotter than the blue edge of the theoretical ZZ Ceti instability strip, and further, that the maximum instability occurs at temperatures ~ 600 K hotter than the blue edge of the theoretical ZZ Ceti instability strip. Our results also indicate that the development of this instability strip is insensitive to the mass of the surface hydrogen layer and to uncertainties in the hydrogen opacities. We demonstrate that existing observations of the DA white dwarfs are insufficient to determine if such radial pulsations exist in the DA white dwarfs, and we evaluate the prospects for detecting these pulsations in the future.

But not detected so far.

VLT-ULTRACAM vs 11 WDs



Silvotti et al. 11

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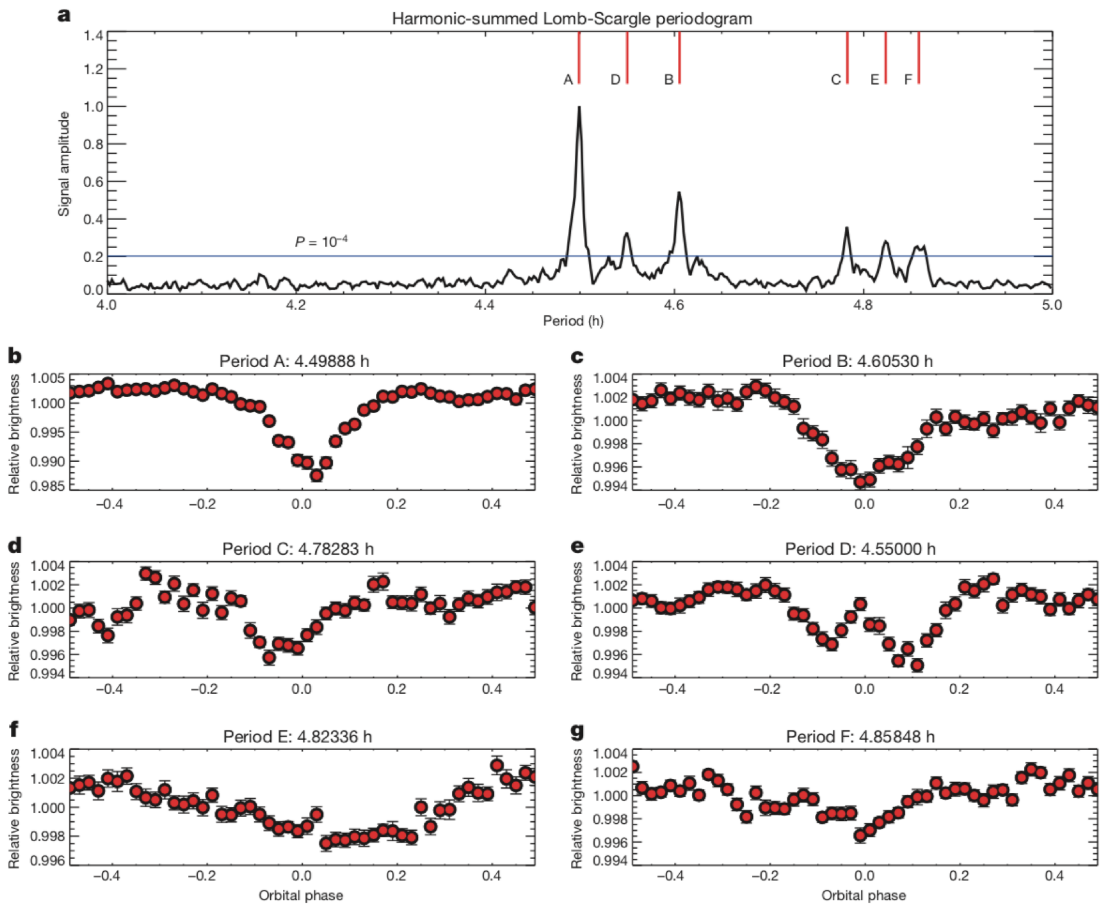
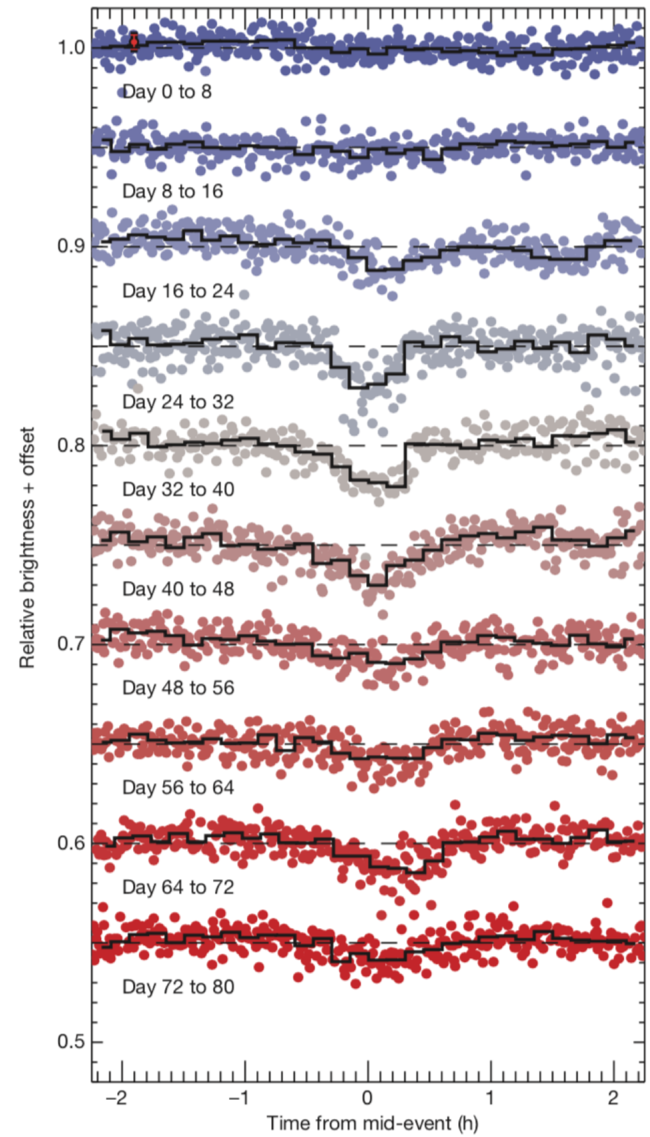
Credit:NASA/ESA/Z. Levy (STScl)

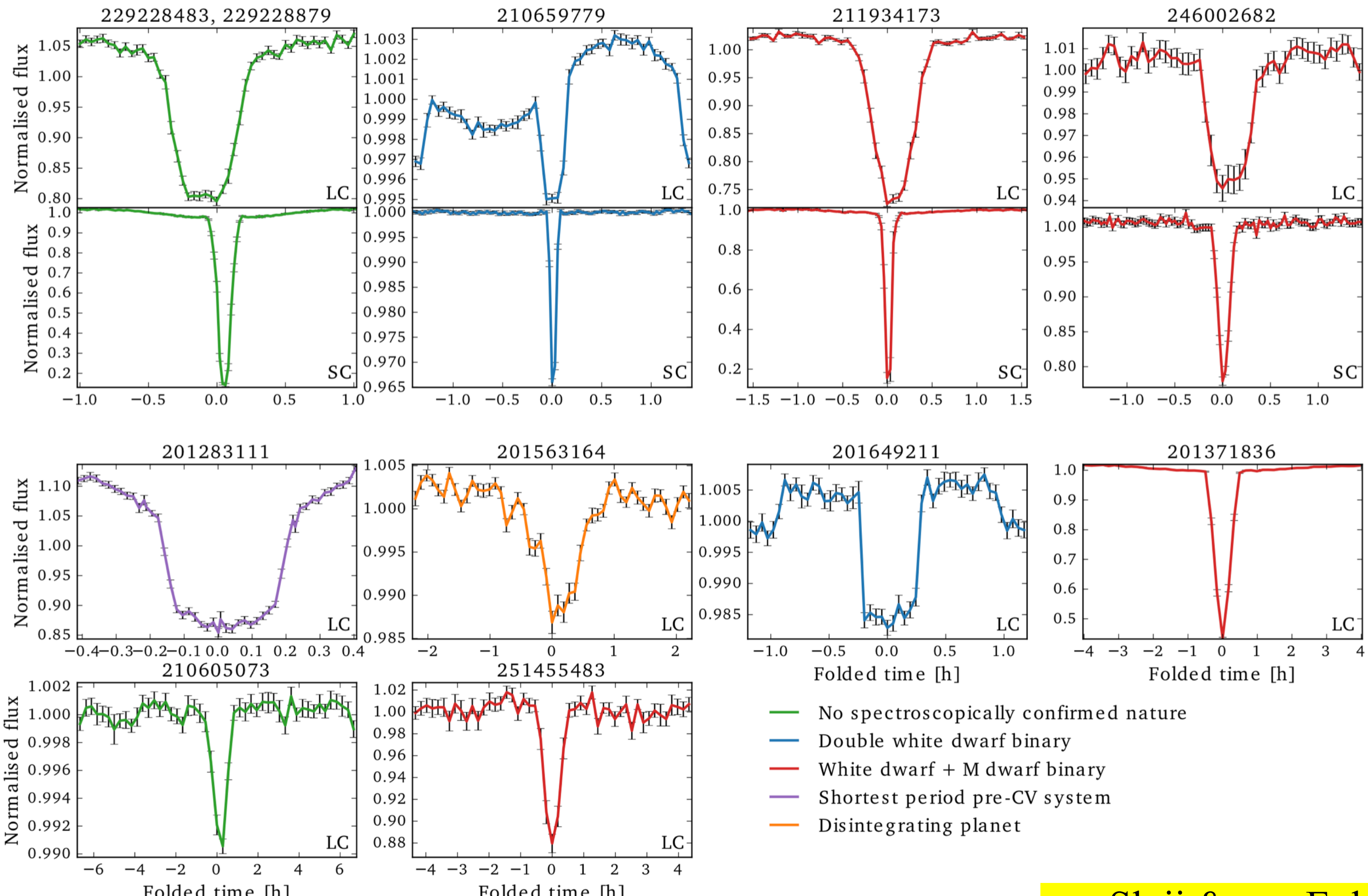
WD1145+1017 with K2





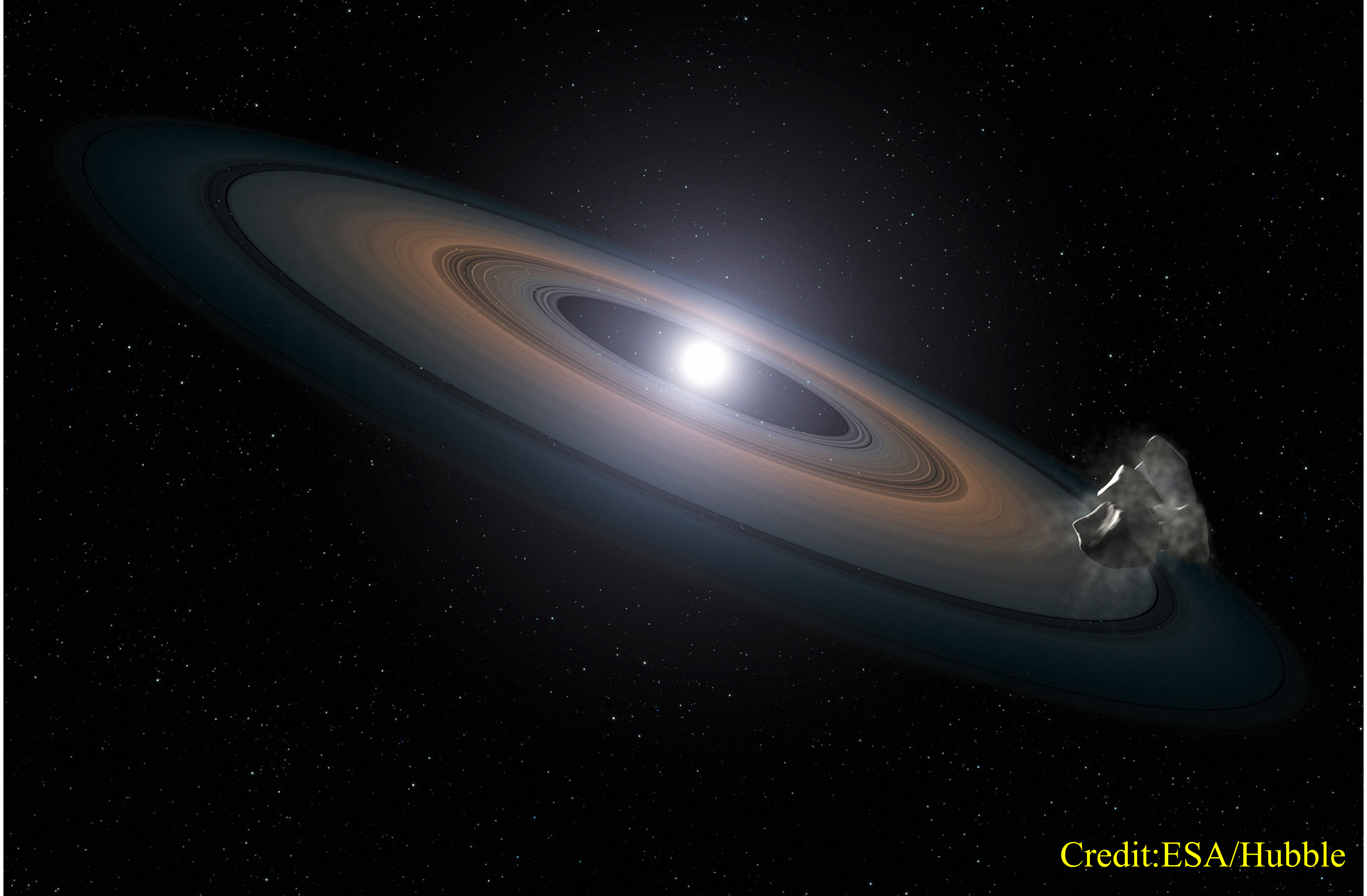
Vanderberg et al. 15

Searching for transiting/eclipsing objects around 1148 WDs with K2



van Sluij & van Eylen 17

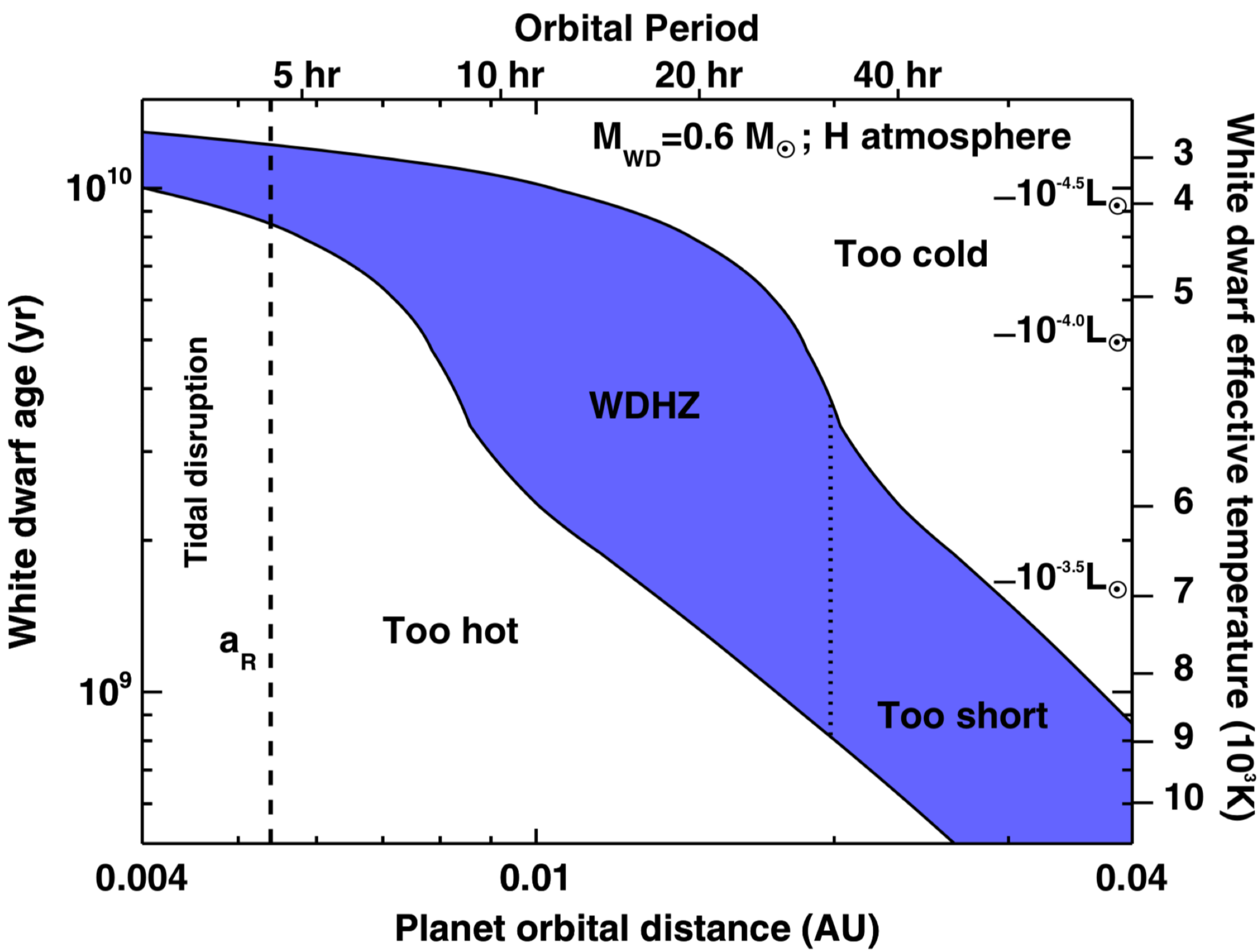
Our far far future …



Credit:ESA/Hubble

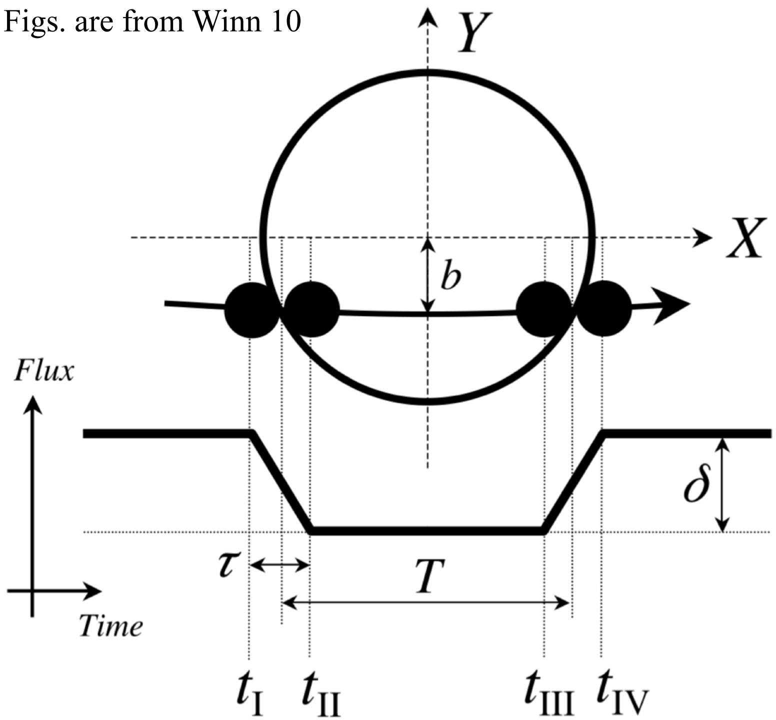
Habitable planets around WDs

Agol 11



Transit signals from WDs

Figs. are from Winn 10



$$p_{tran} \approx \frac{R_*}{a} \sim 1\% \left(\frac{R_*}{0.01 R_\odot}\right)\left(\frac{a}{R_\odot}\right)^{-1}$$

$$T \approx \frac{R_* P}{\pi a} \sim 30s \left(\frac{P}{3h}\right)^{\frac{1}{3}}\left(\frac{\rho_*}{10^6 g/cc}\right)^{-\frac{1}{3}}$$

$$\delta \approx \left(\frac{R_p}{R_*}\right)^2 \sim 1$$