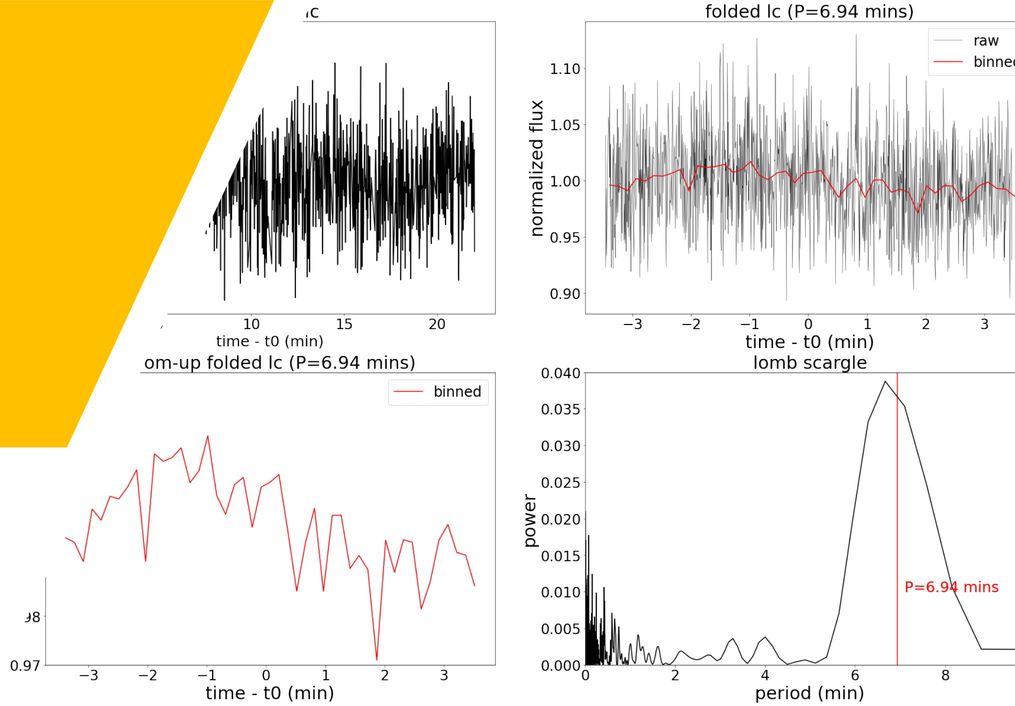
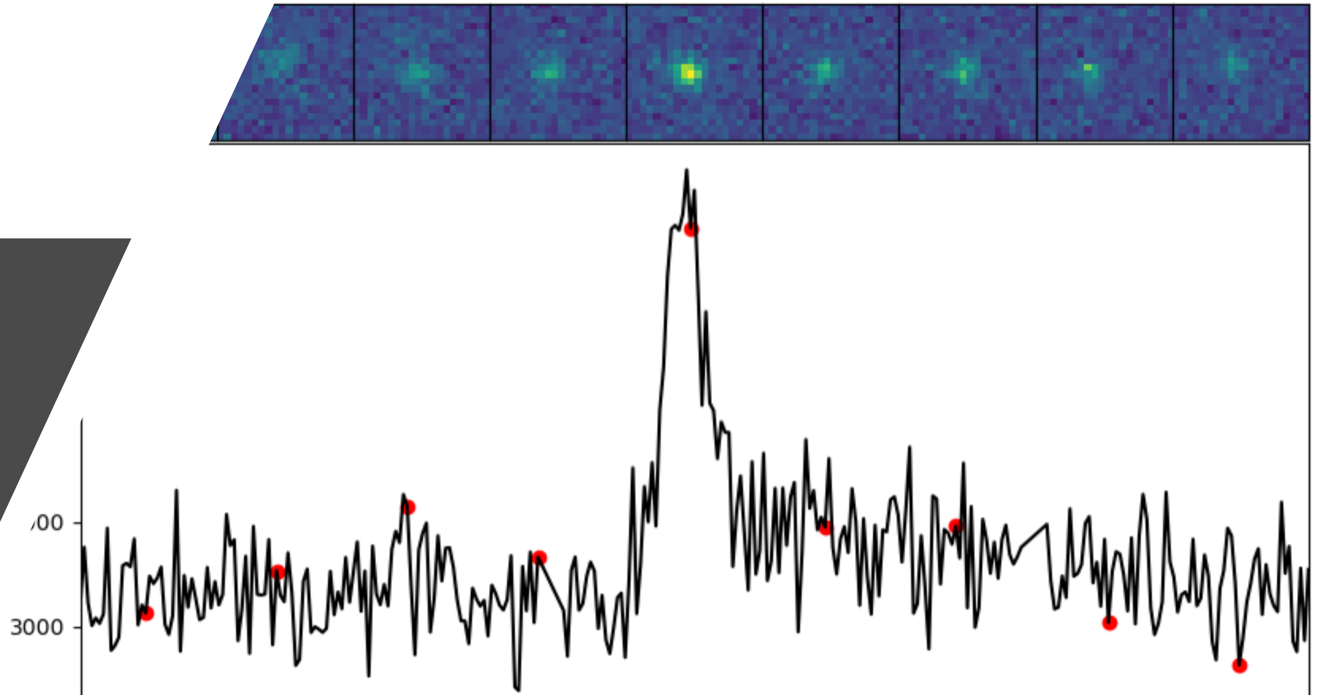


Outflows from Dwarfs

Kazumi Kashiyama (U. of Tokyo)



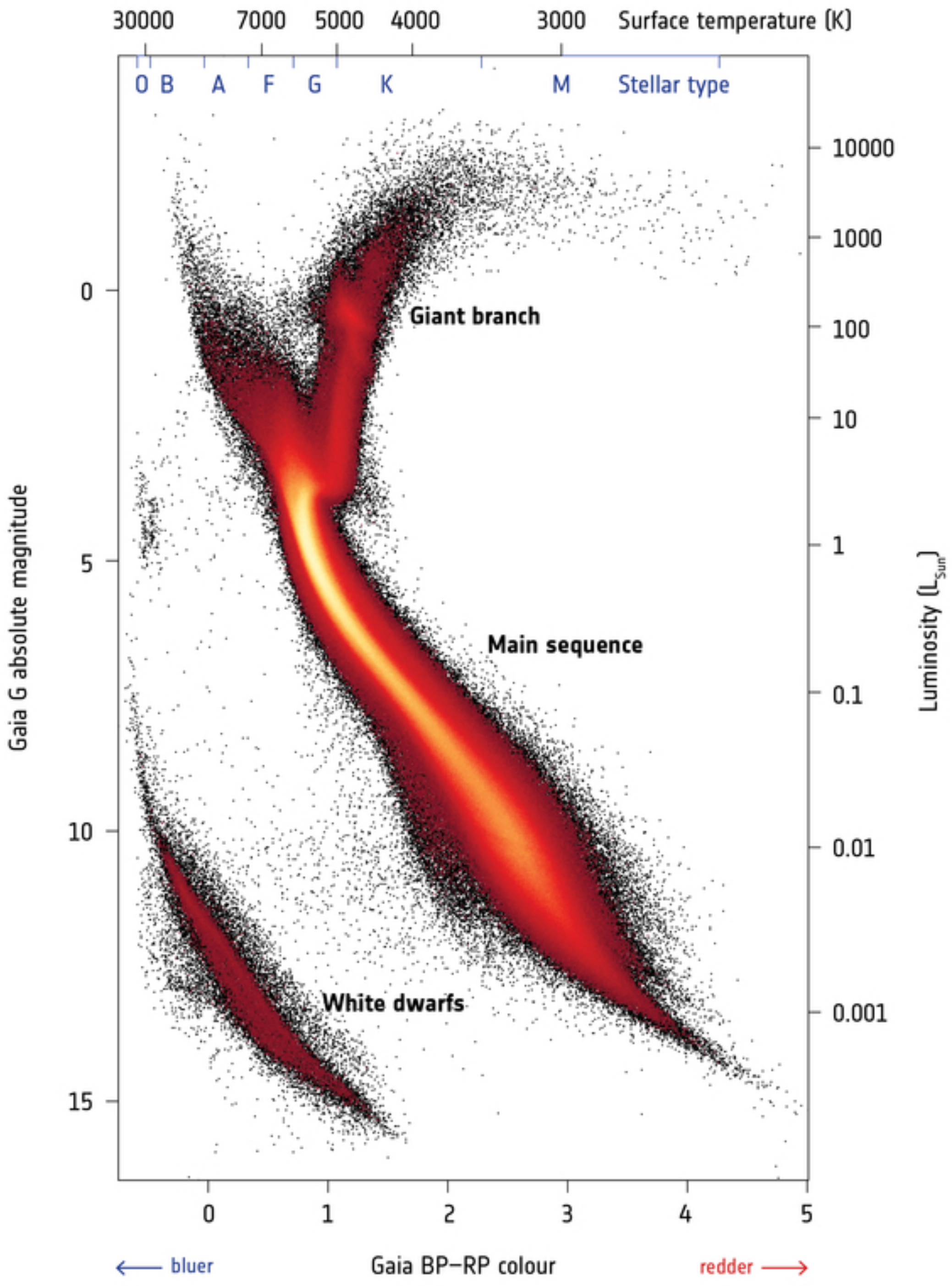
based on collaboration and discussion with

Masataka Aizawa, Kojiro Kawana, and the HeSO team,

Toshikazu Shigeyama, Kotaro Fujisawa, Takatoshi Ko, Daichi Tsuna,

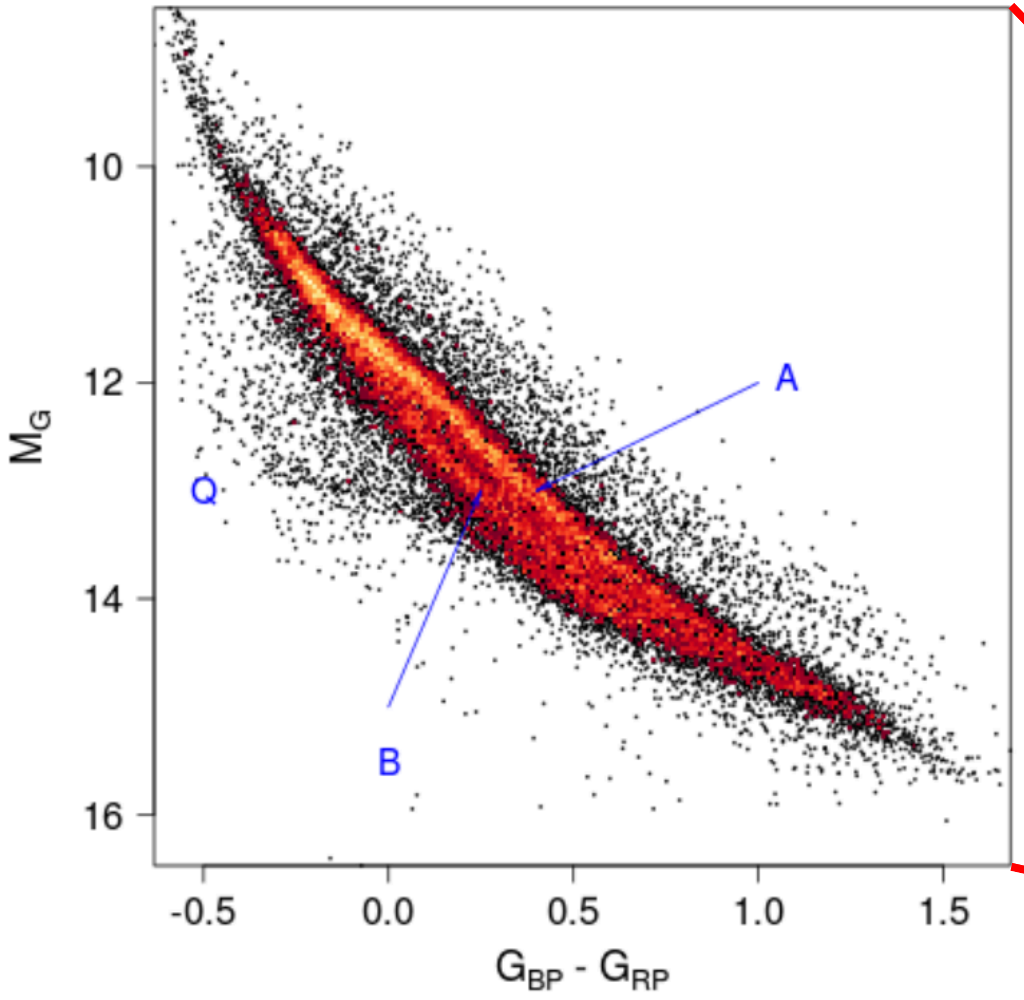
Shota Kisaka, Shuta Tanaka, and Teruaki Enoto

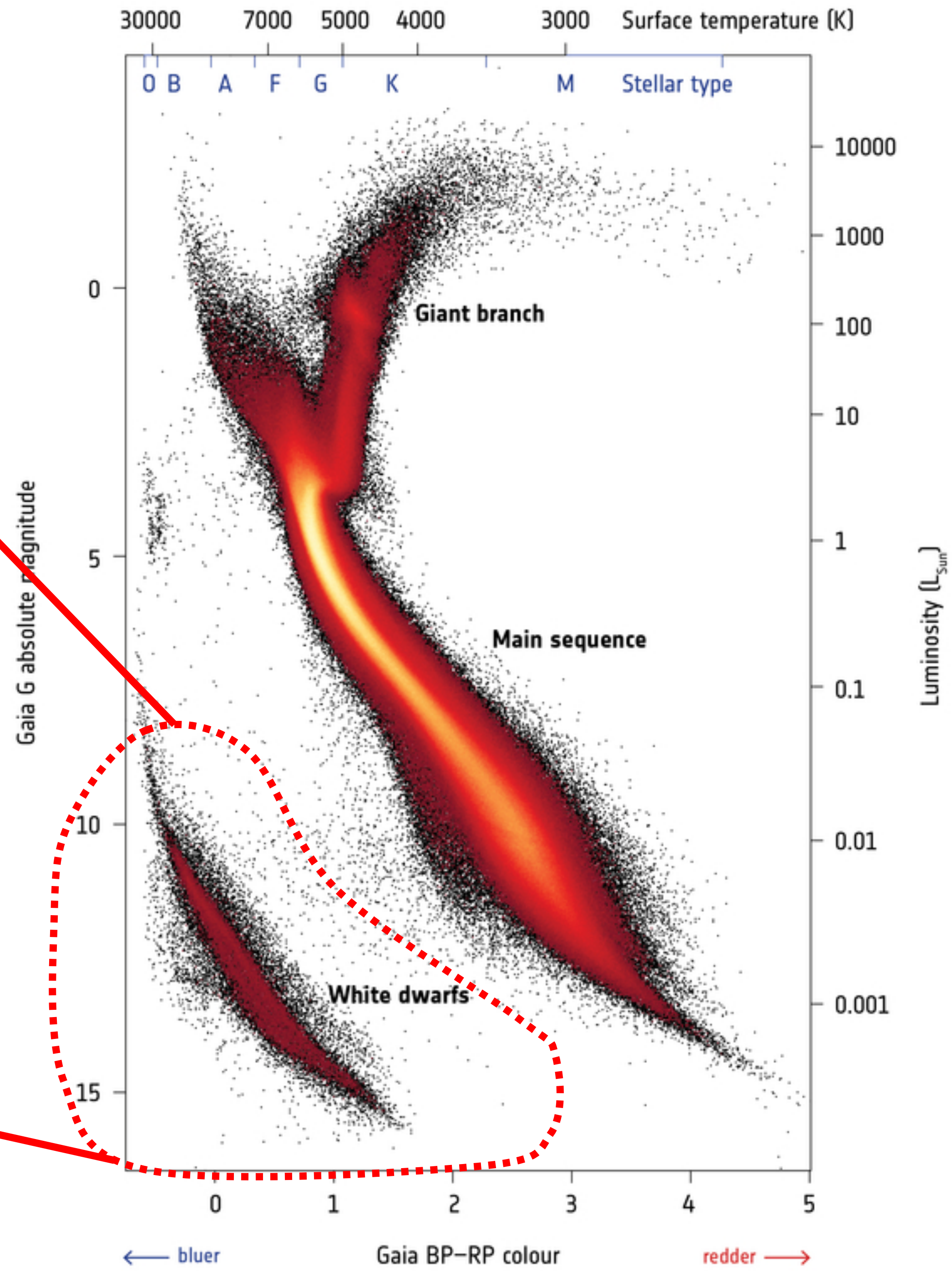
0. Introduction



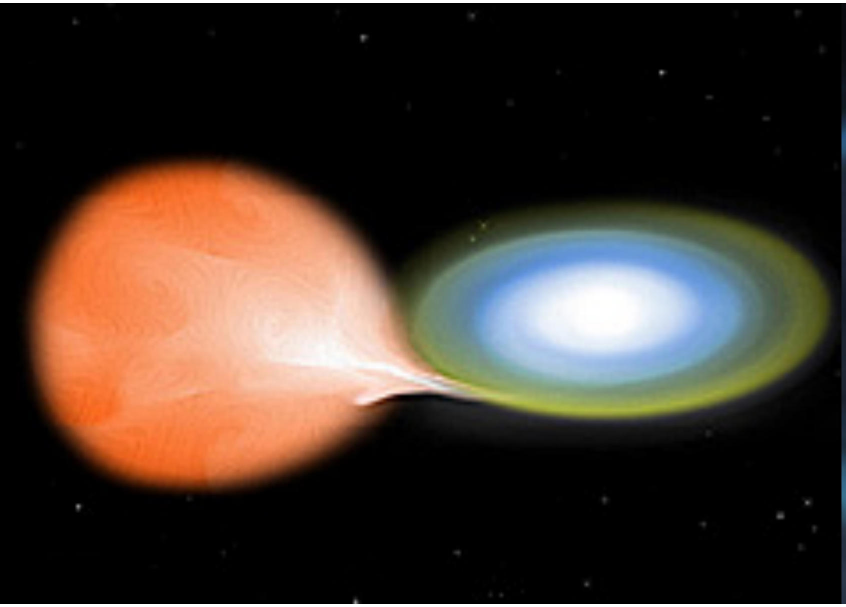
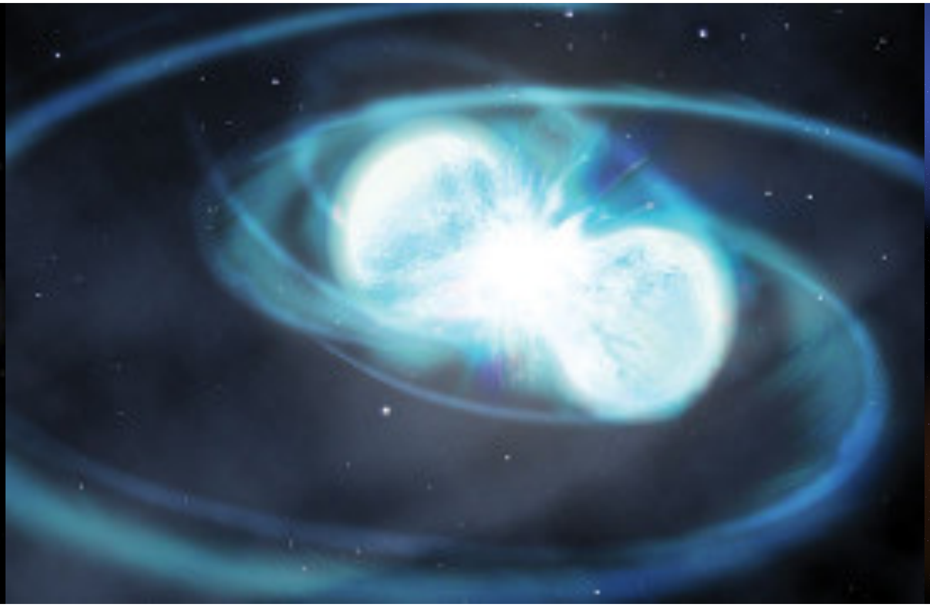
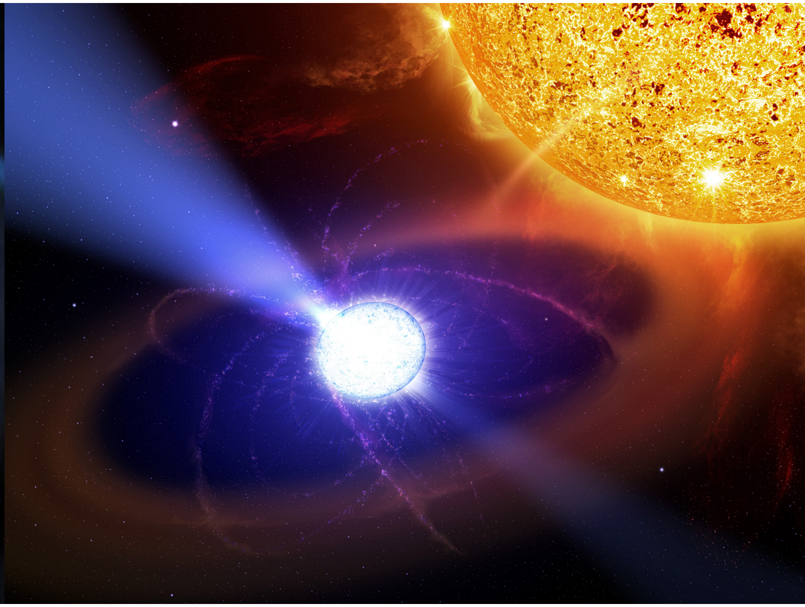
30000
7000
5000
4000
3000
Surface temperature (K)
O
B
A
F
G
K
M
Stellar type
10000
1000
100
10
1
0.1
0.01
0.001
Luminosity (L_{Sun})
0
5
10
15
Gaia G absolute magnitude
Giant branch
Main sequence
White dwarfs
0
1
2
3
4
5
← bluer
Gaia BP−RP colour
redder →

White dwarfs (WDs)

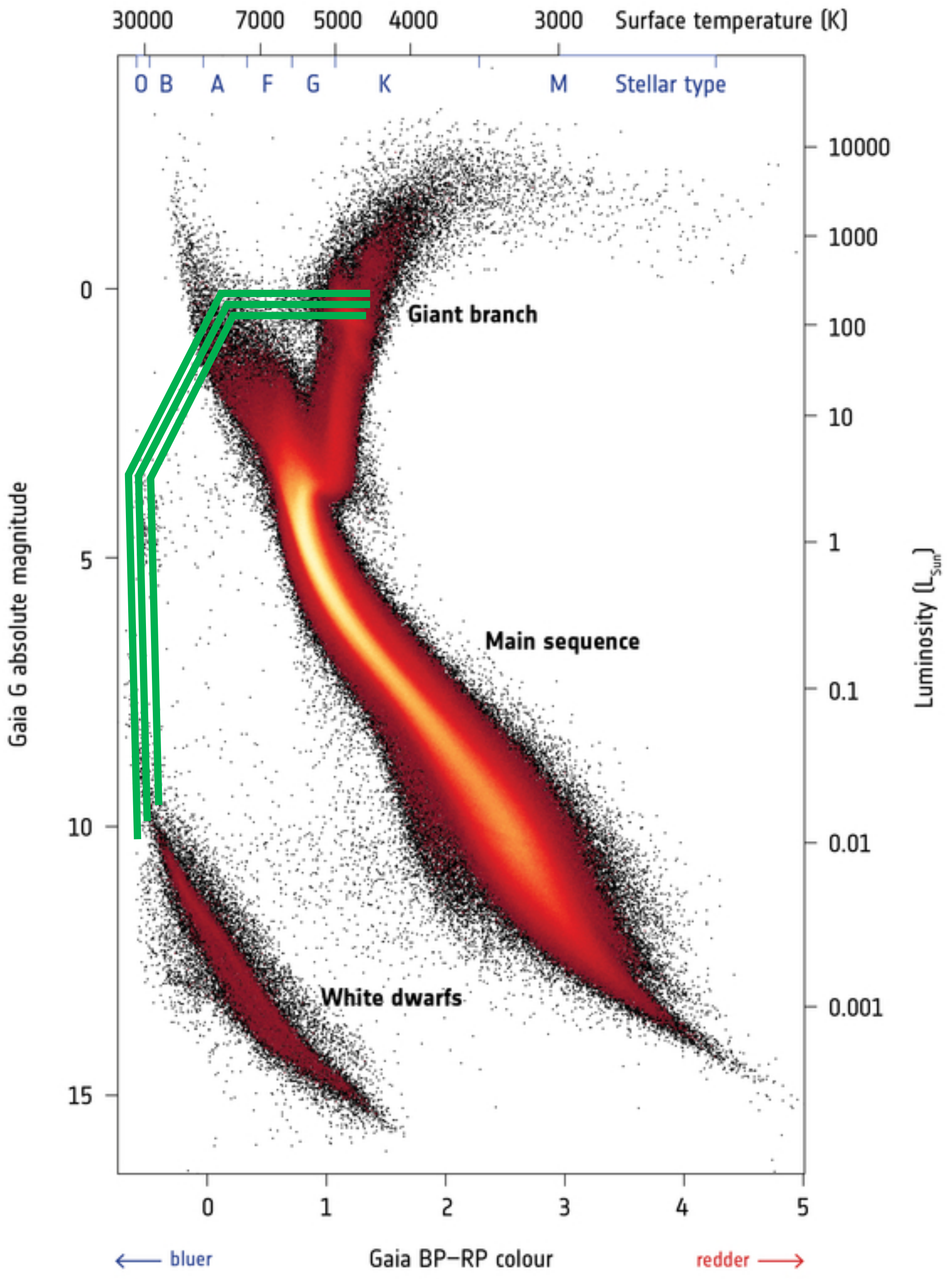




Outflows from white dwarfs

Proto-WDs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Surface temperature (K)
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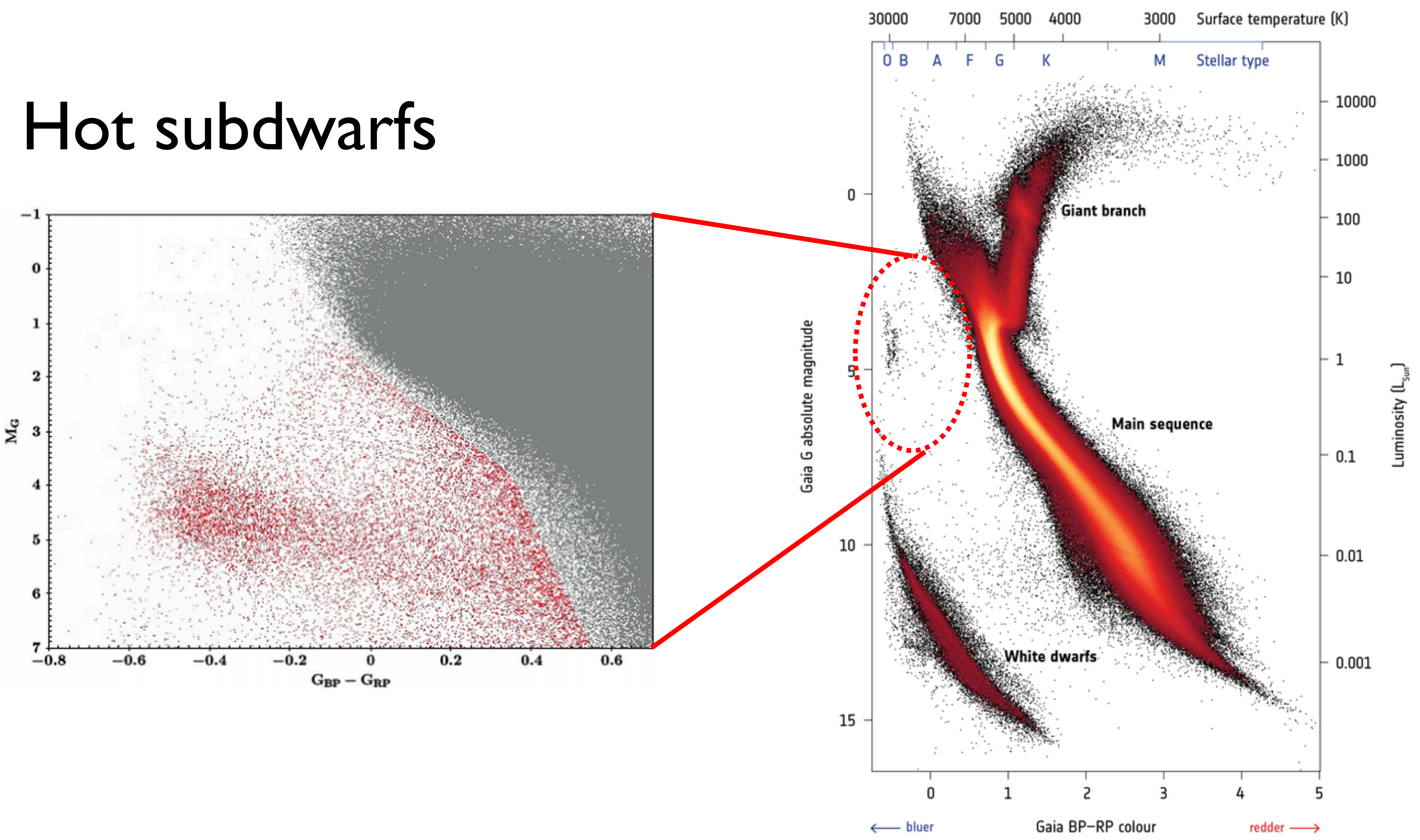
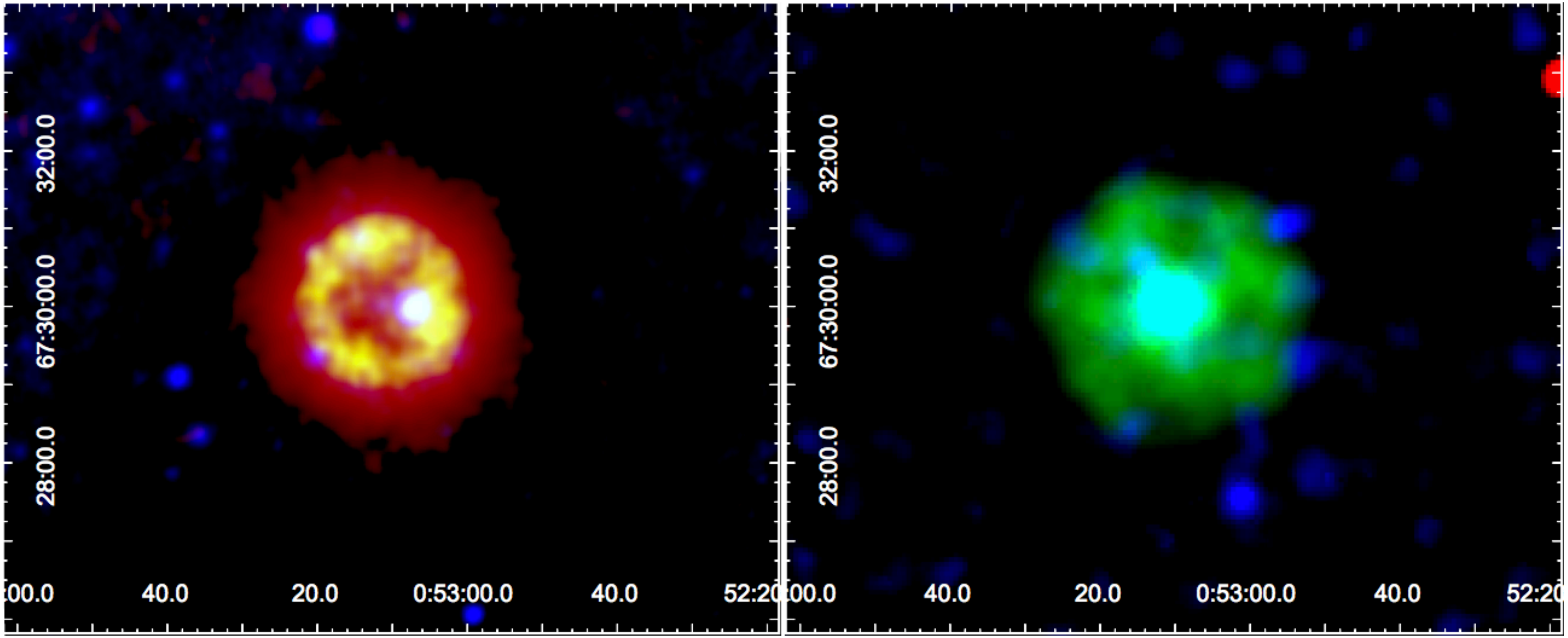
Gaia G absolute magnitude
Giant branch
Main sequence
White dwarfs
0
1
2
3
4
5
← bluer
Gaia BP−RP colour
redder →

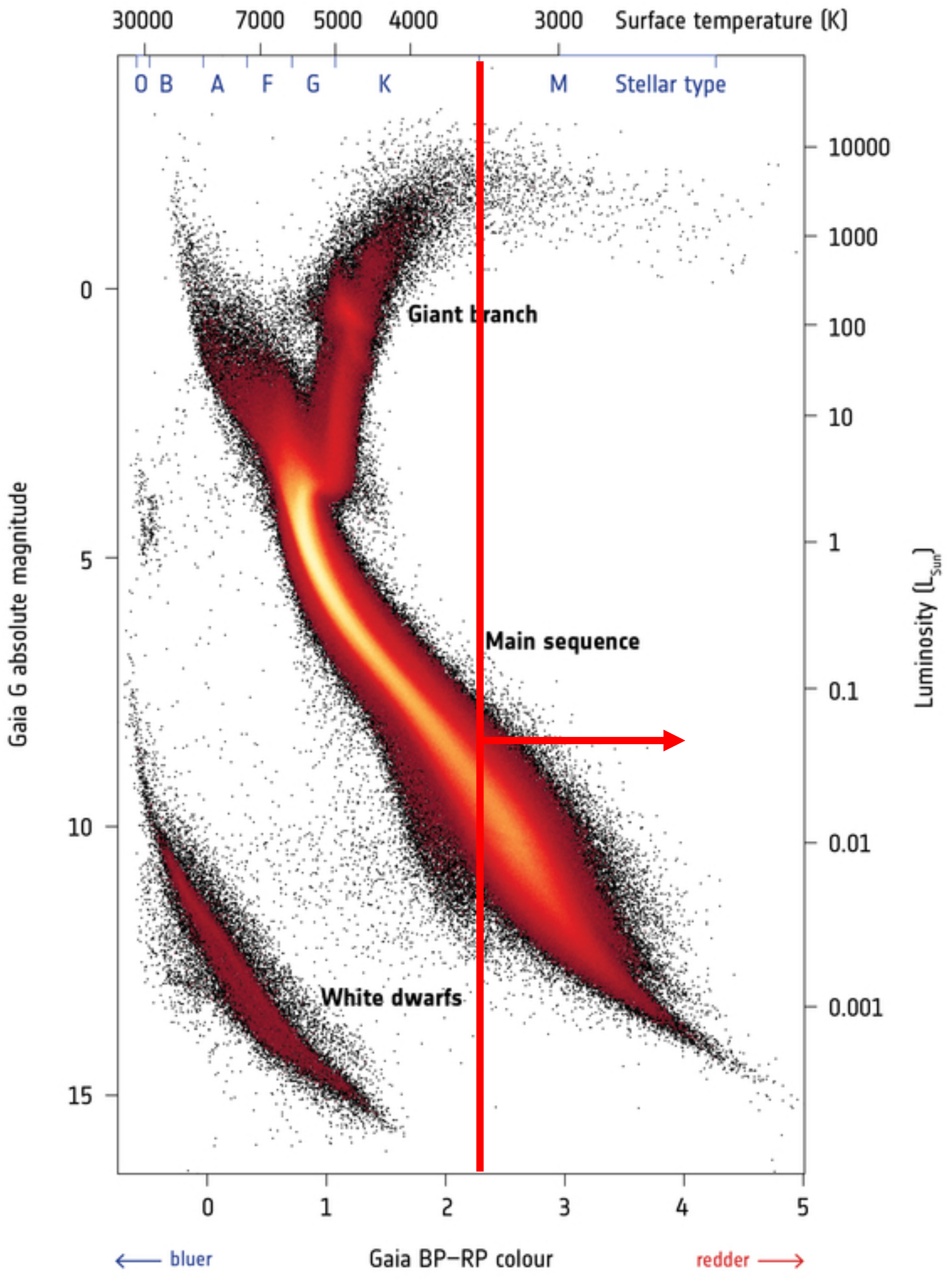
Hot subdwarfs



Outflows from proto-WDs



M dwarfs



30000
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Giant branch
Main sequence
White dwarfs
0
1
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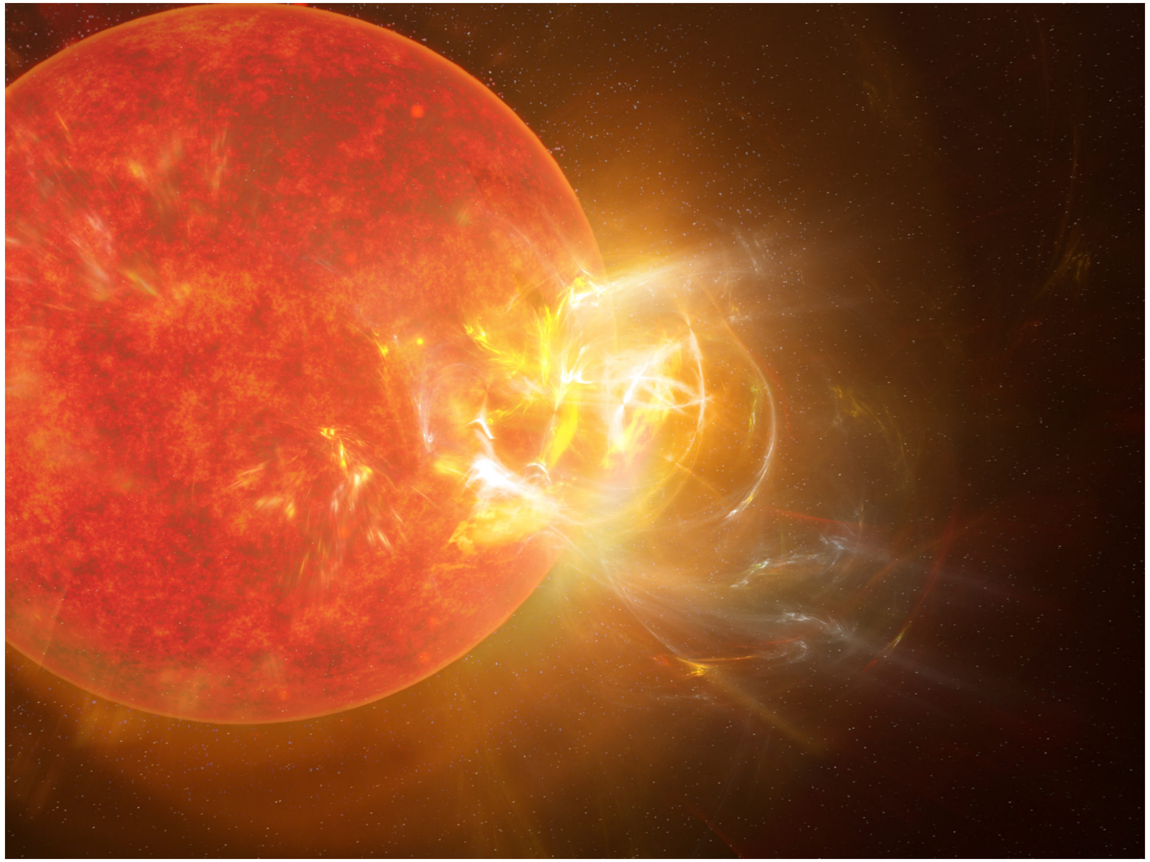
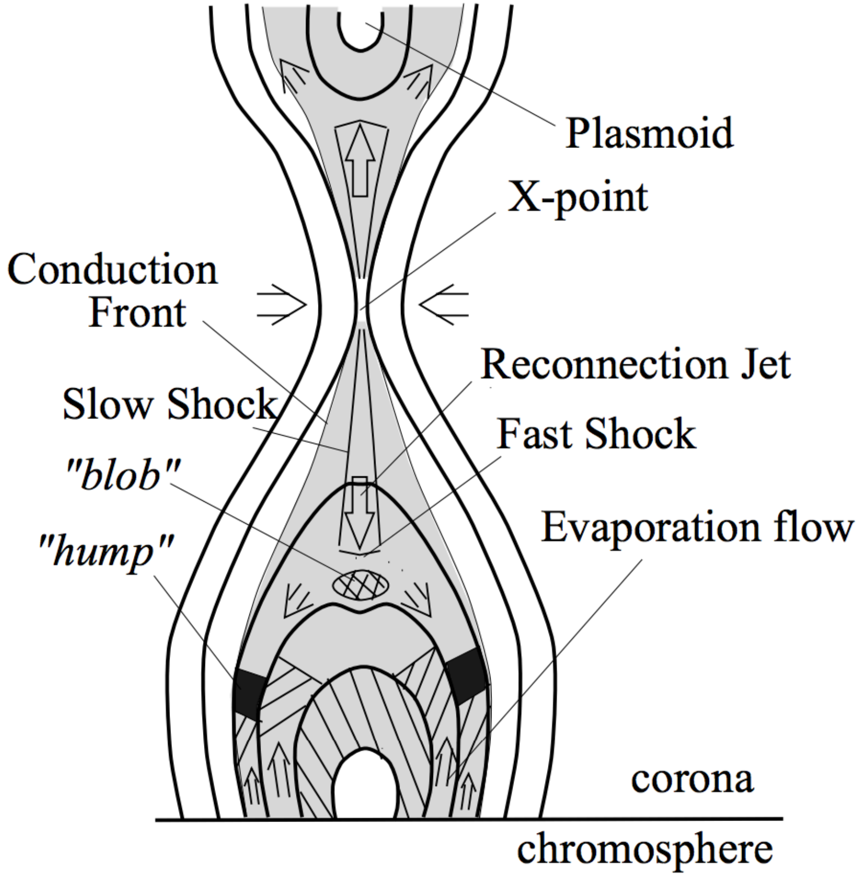
bluer
Gaia BP−RP colour
redder

Outflows from M dwarfs





Explorations in the sub-hr time domain

MAGIC

Swift

ZTF

ASKAP CSIRO

H.E.S.S.

Fermi Gamma-ray Space Telescope

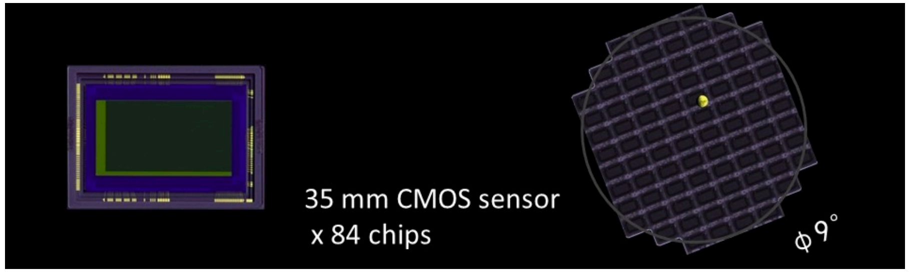
TESS

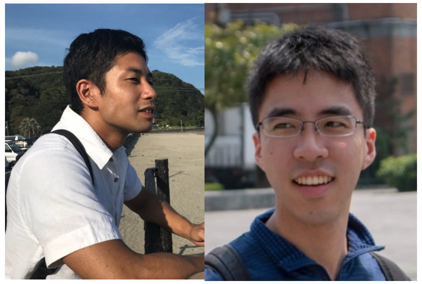
chime/frb

...

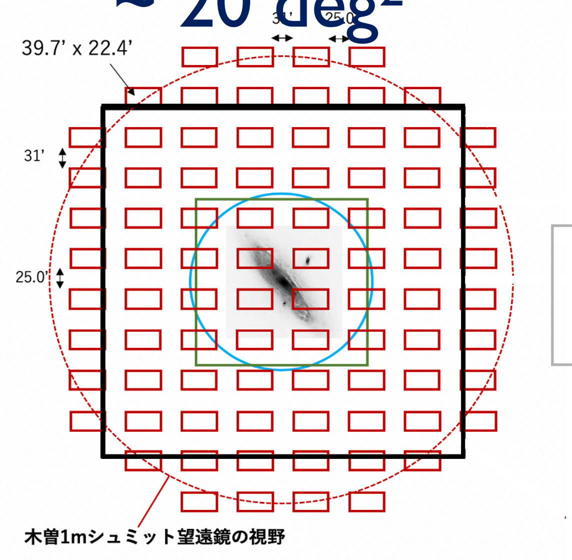
Hertz Spinning Object (HeSO) Survey

TOMO-E GOZEN



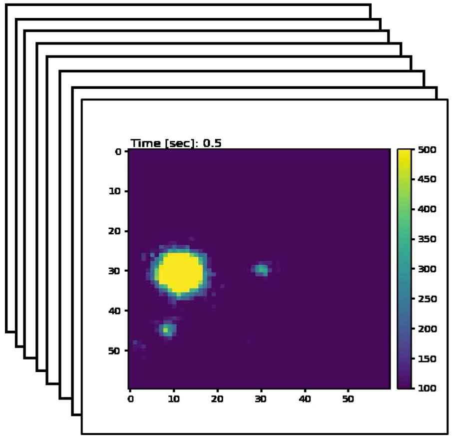


~ 20 deg^2



2 frame/sec

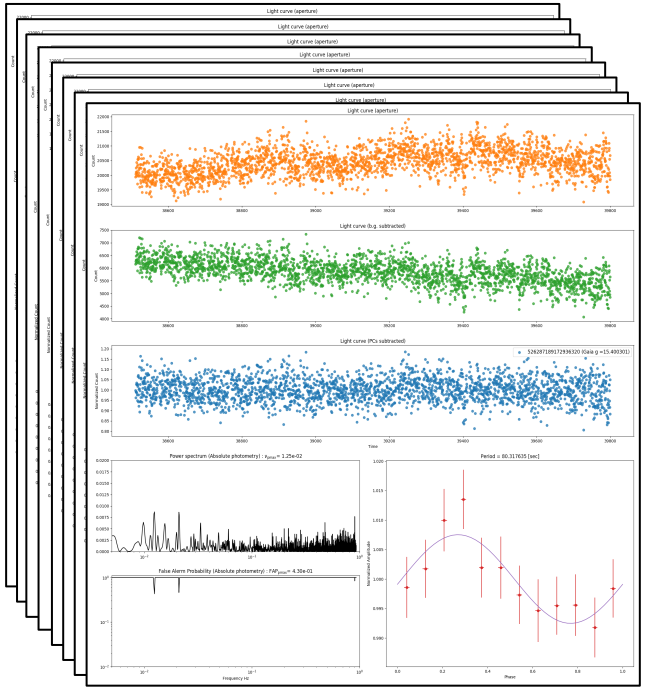
~ 50 TB/night



Gaia-catalog based source id.

~10^5 objects per FoV

with M_g< 19 mag



PCA detrending

Outflows from Dwarfs

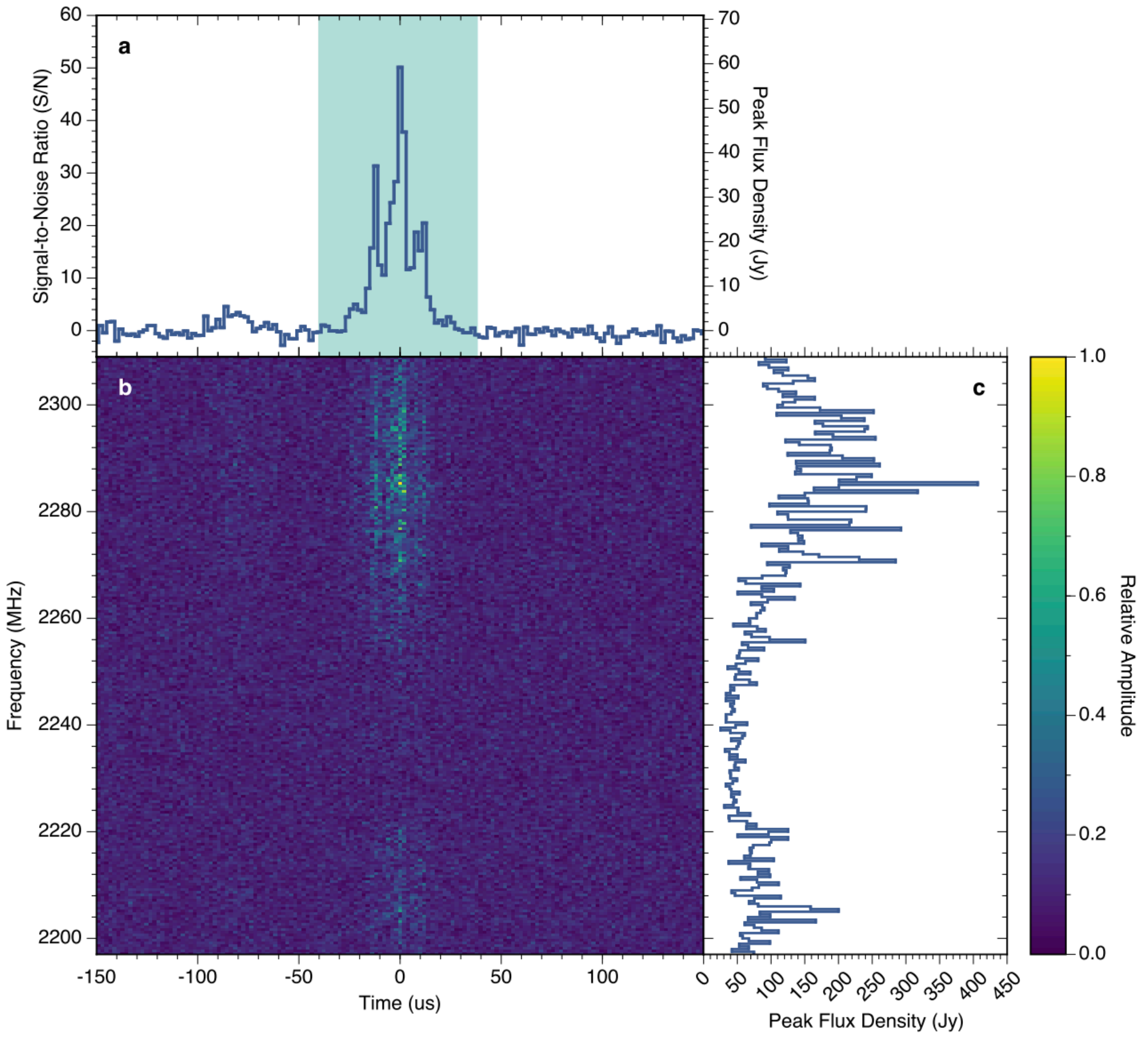
1. ***Ultra fast outflow***

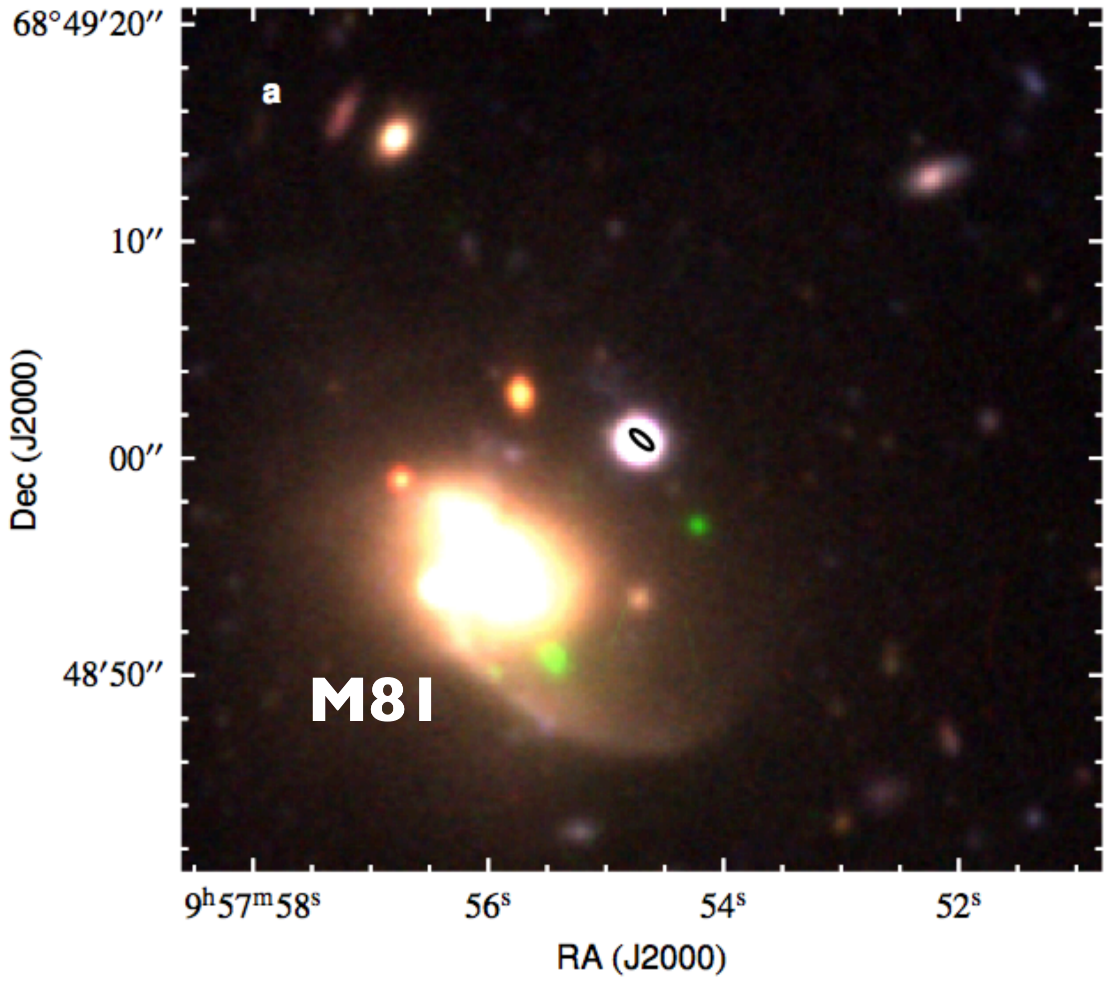
2. ***Coherent plasma outflow***

3. ***"Classical" outflow***

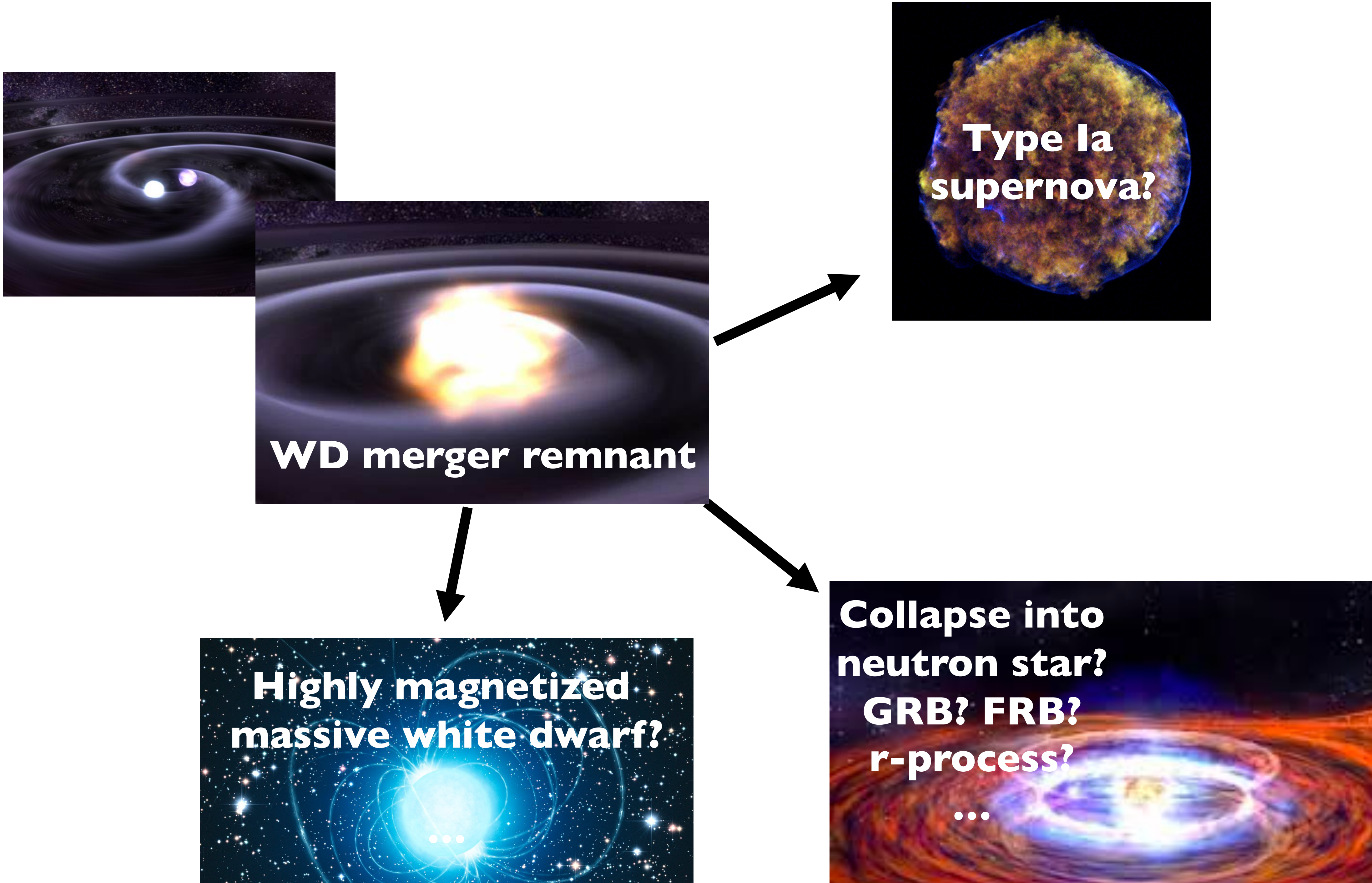
1. ultra-fast outflows

A repeating FRB source in a globular cluster

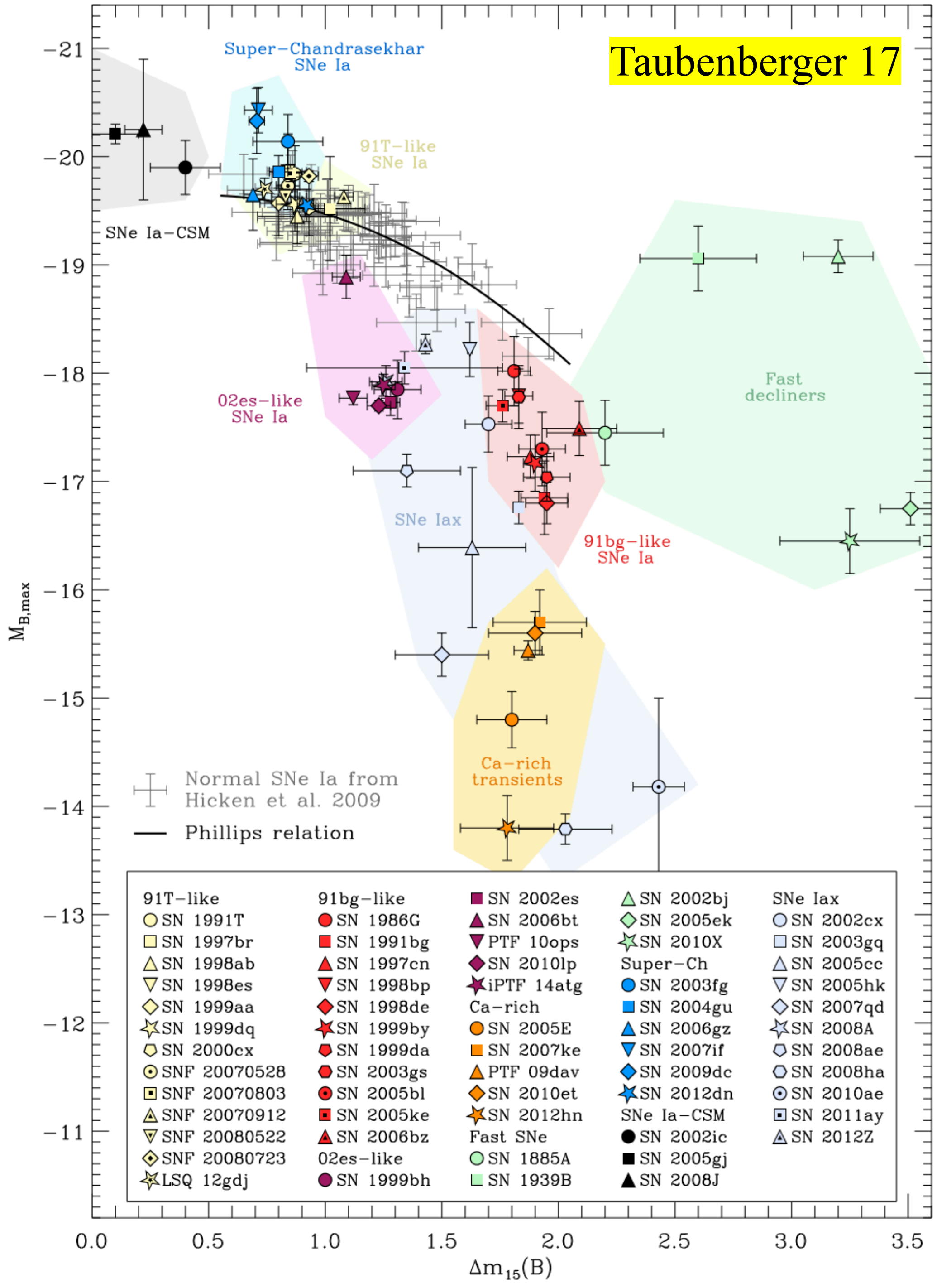




Kirsten et al. 21; Nimmo et al. 21;…

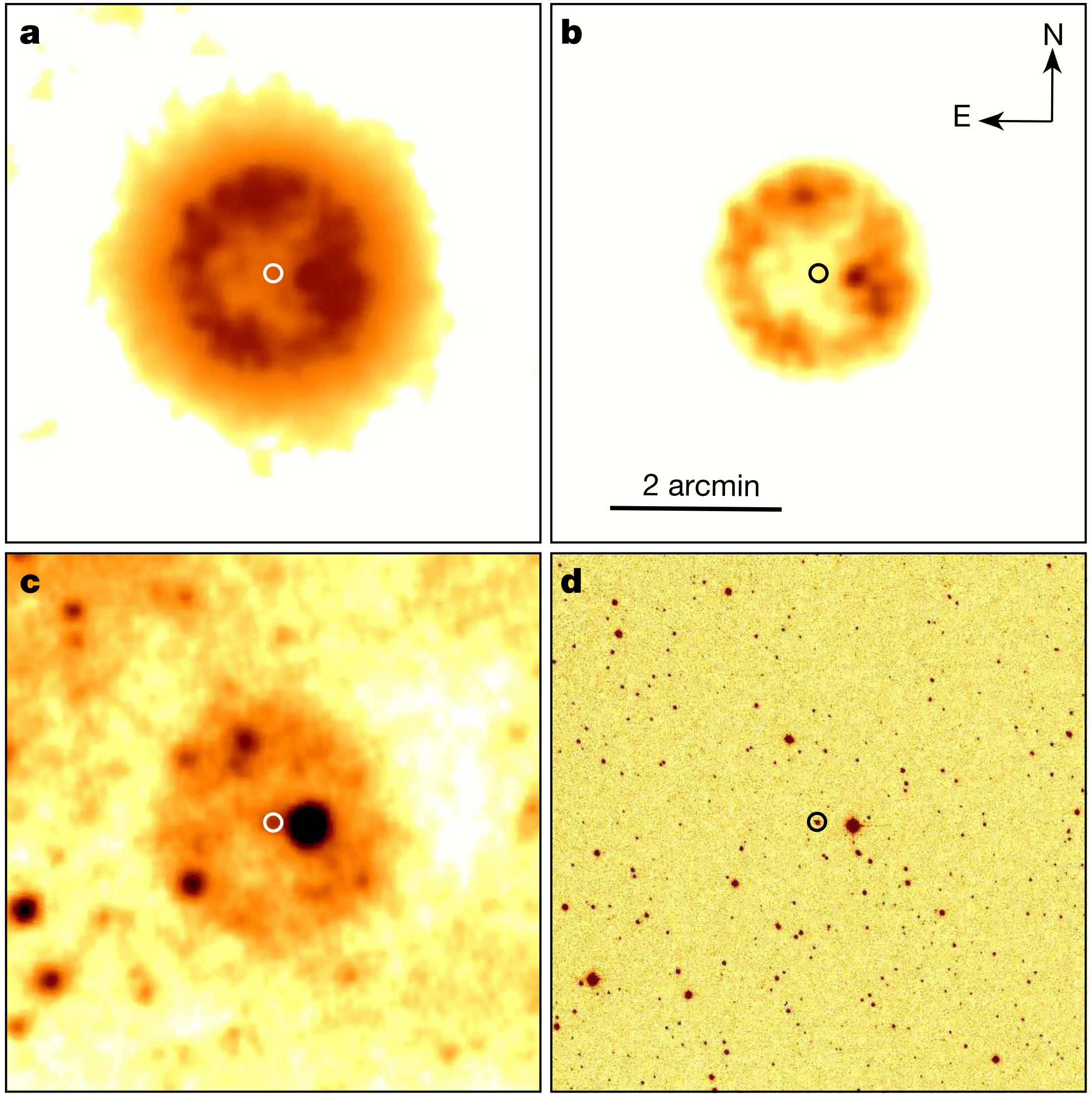

WD merger remnant
Type Ia supernova?
Highly magnetized massive white dwarf?
...
Collapse into neutron star?
GRB? FRB?
r-process?
...

Diversity in thermonuclear explosions

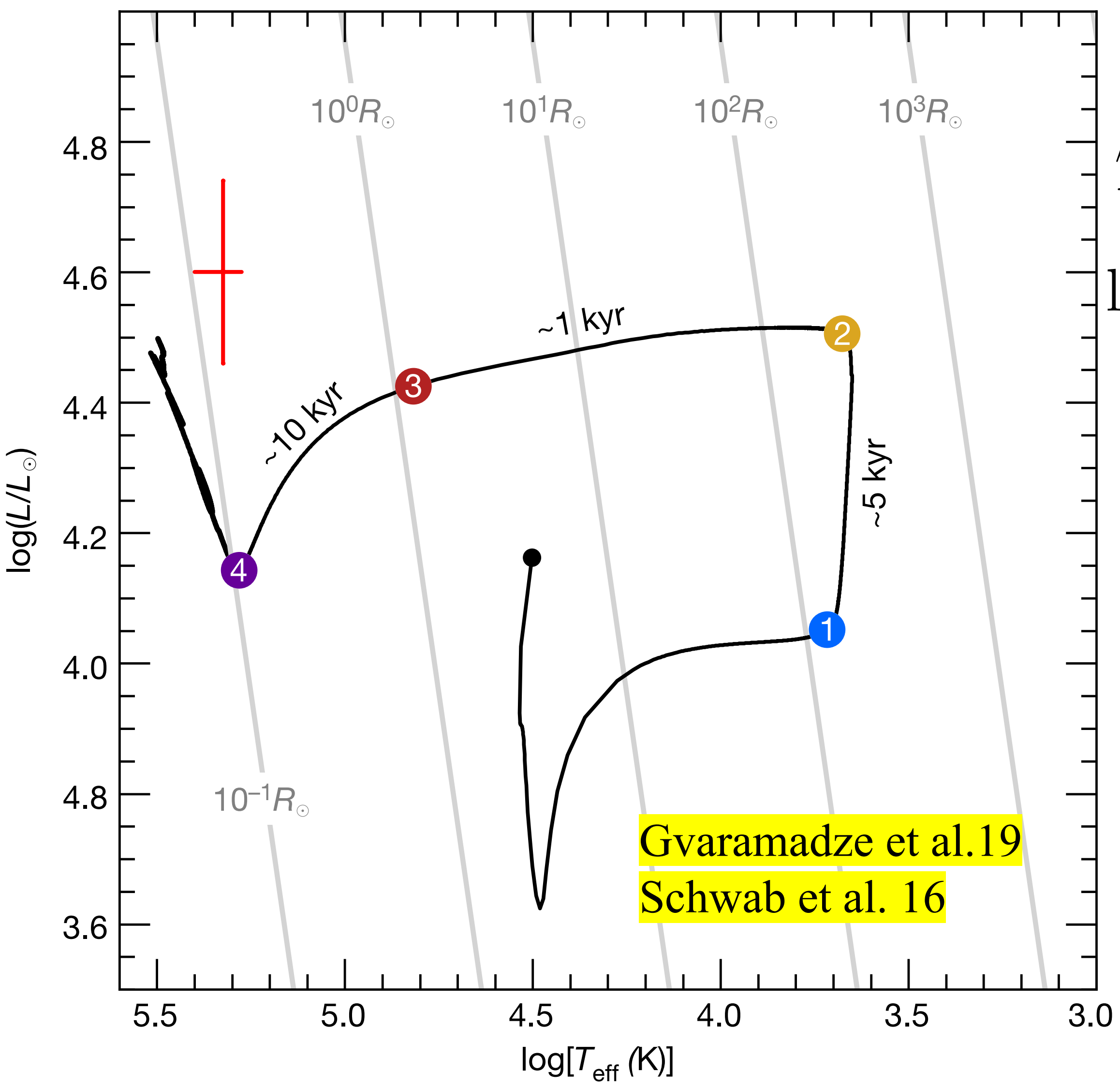


Gvaramadze et al.19

A pale blue dot in an infra nebula WS35 (= J005311)



The pale blue dot on the HR diagram



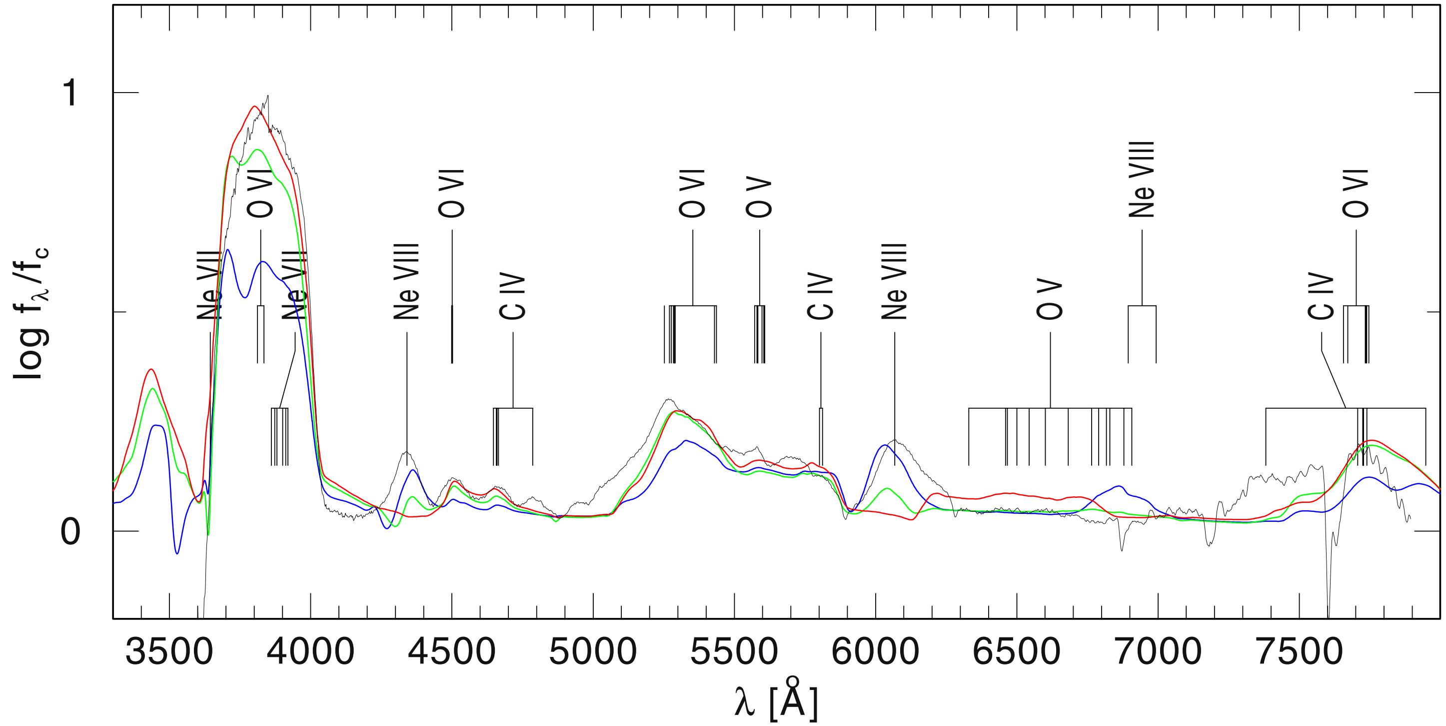
$$T_{\rm eff} = 211,000^{+40,000}_{-23,000}\,\mathrm{K}$$

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

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

Ne enriched C/O dominated outflow

Gvaramadze et al.19



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

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

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

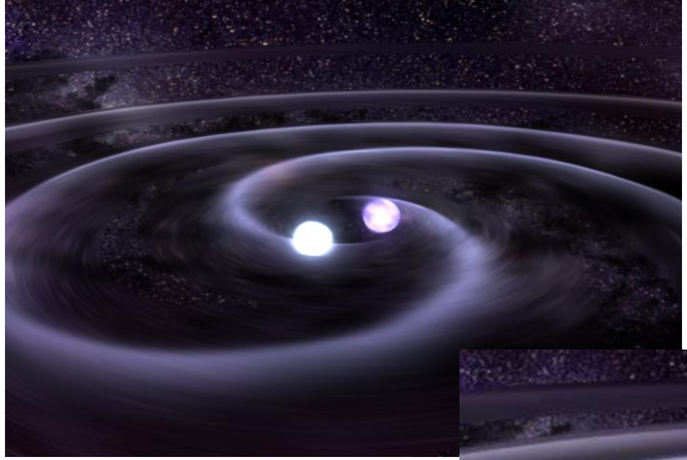
Line width & height ⇨

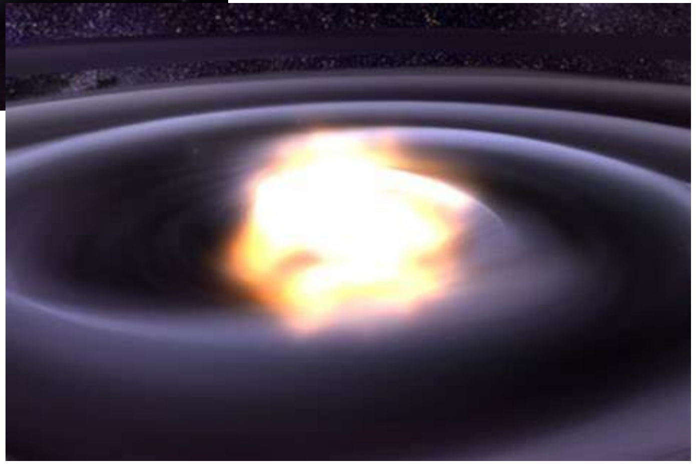
$$\dot{M} = (3.5 \pm 0.6) \times 10^{-6}\, M_{\odot}\,\mathrm{yr}^{-1}$$

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

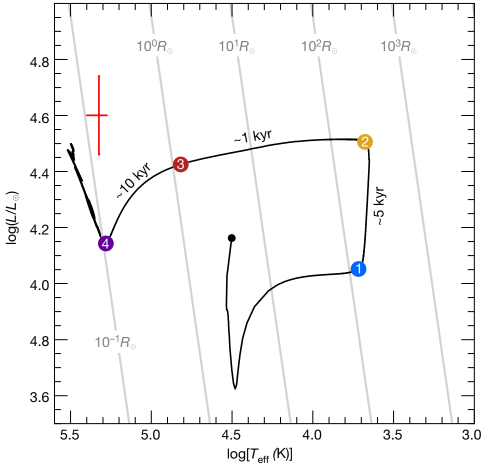
A white dwarf merger product with a super-Chandrasekhar mass?

Gvaramadze et al.19

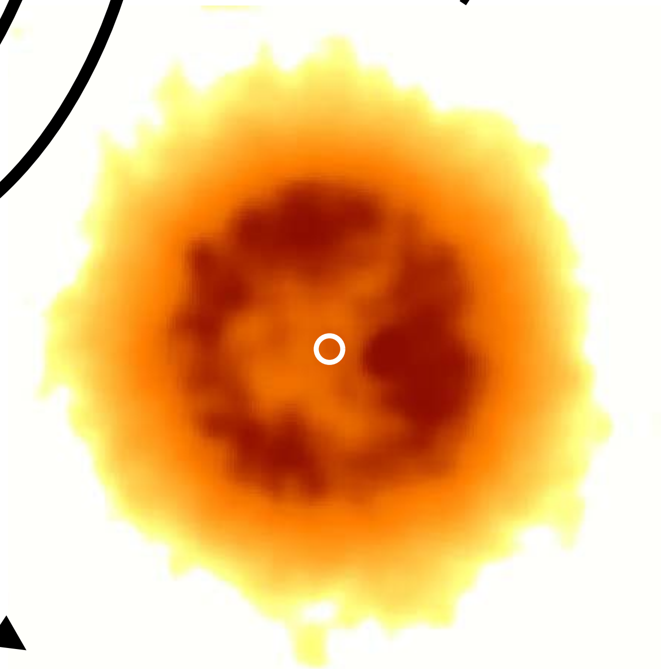




time



~10 kyr

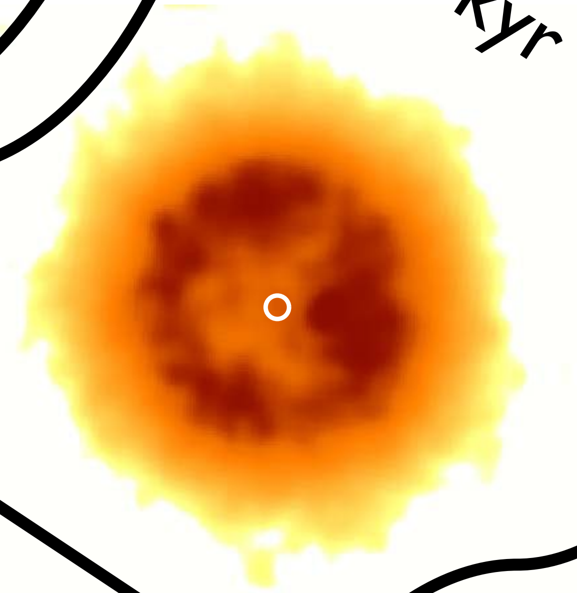


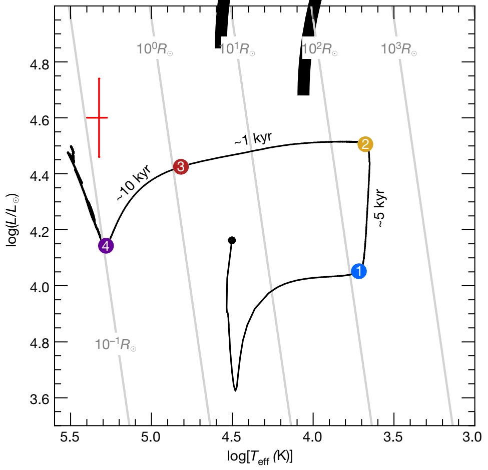
will finally collapse into a neutron star?

Gvaramadze et al.19

time

~10 kyr

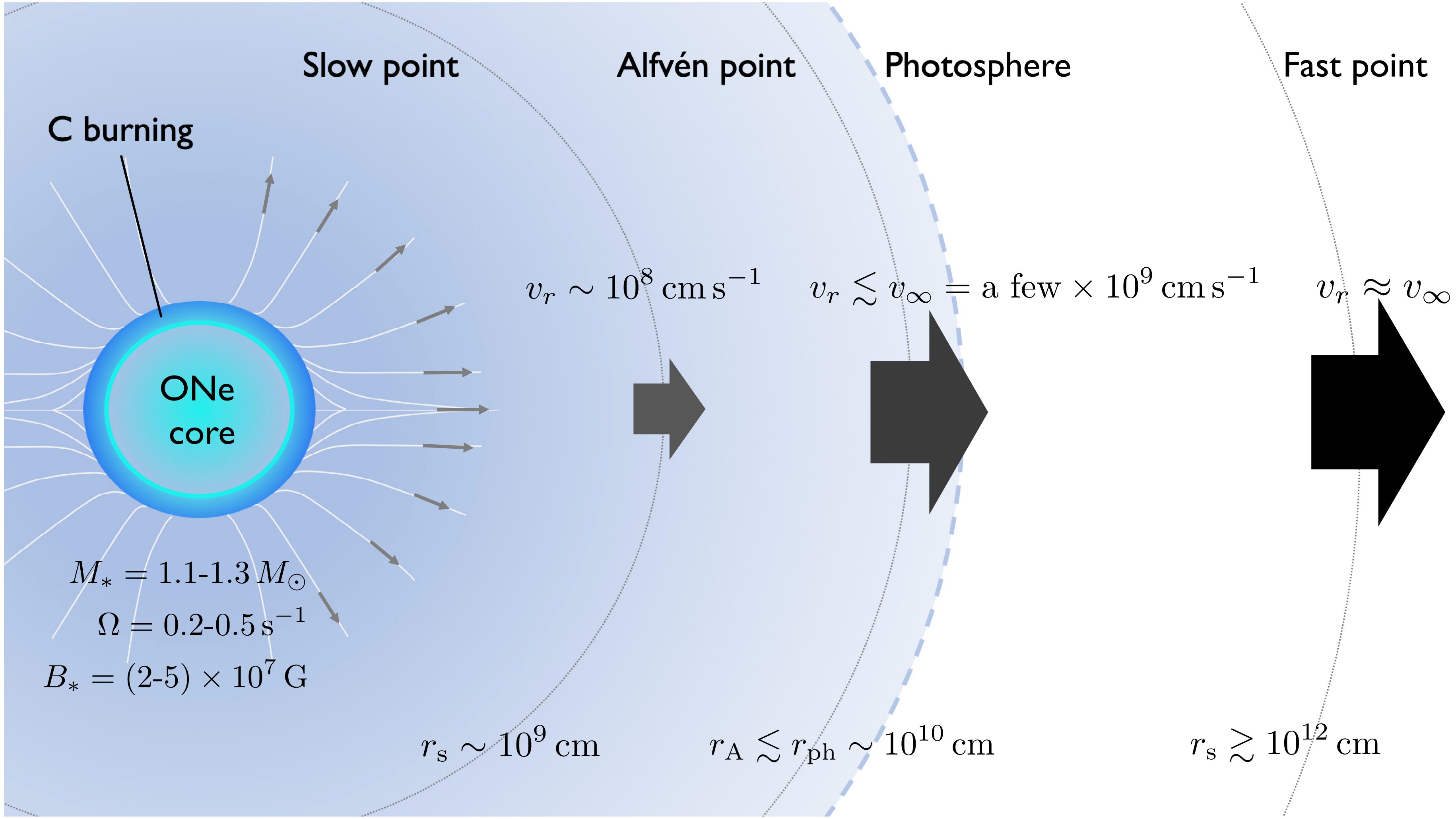




a few kyr

Probably not!

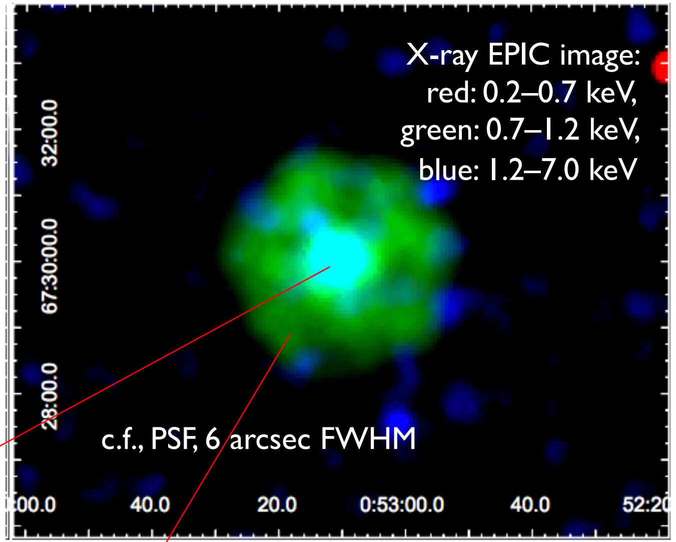
a new outflow solution (Waver-Davis x Kato-Hachisu) Kashiyama, Fujisawa, Shigeyama 19

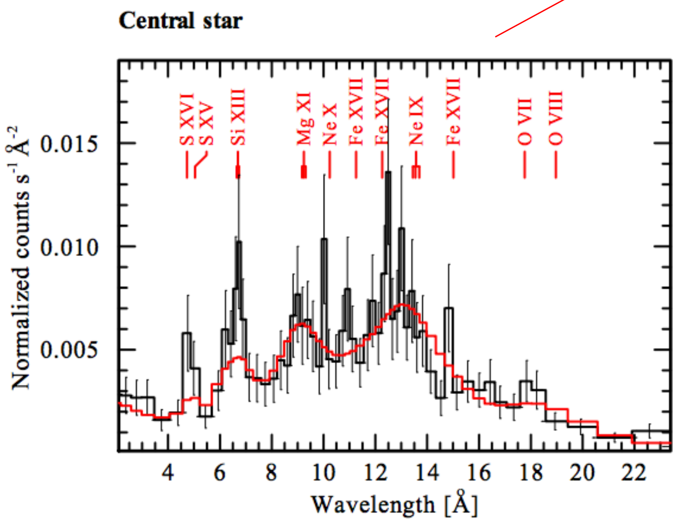


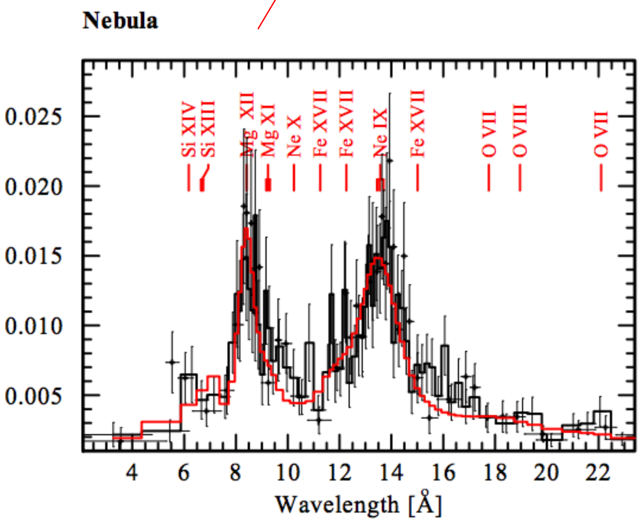
X-ray observations of WD J005311

"Both the central star and the nebula
are detected in X-rays, heralding
the WD merger products as
a new distinct type of strong X-ray sources."

Oskinova et al. 20



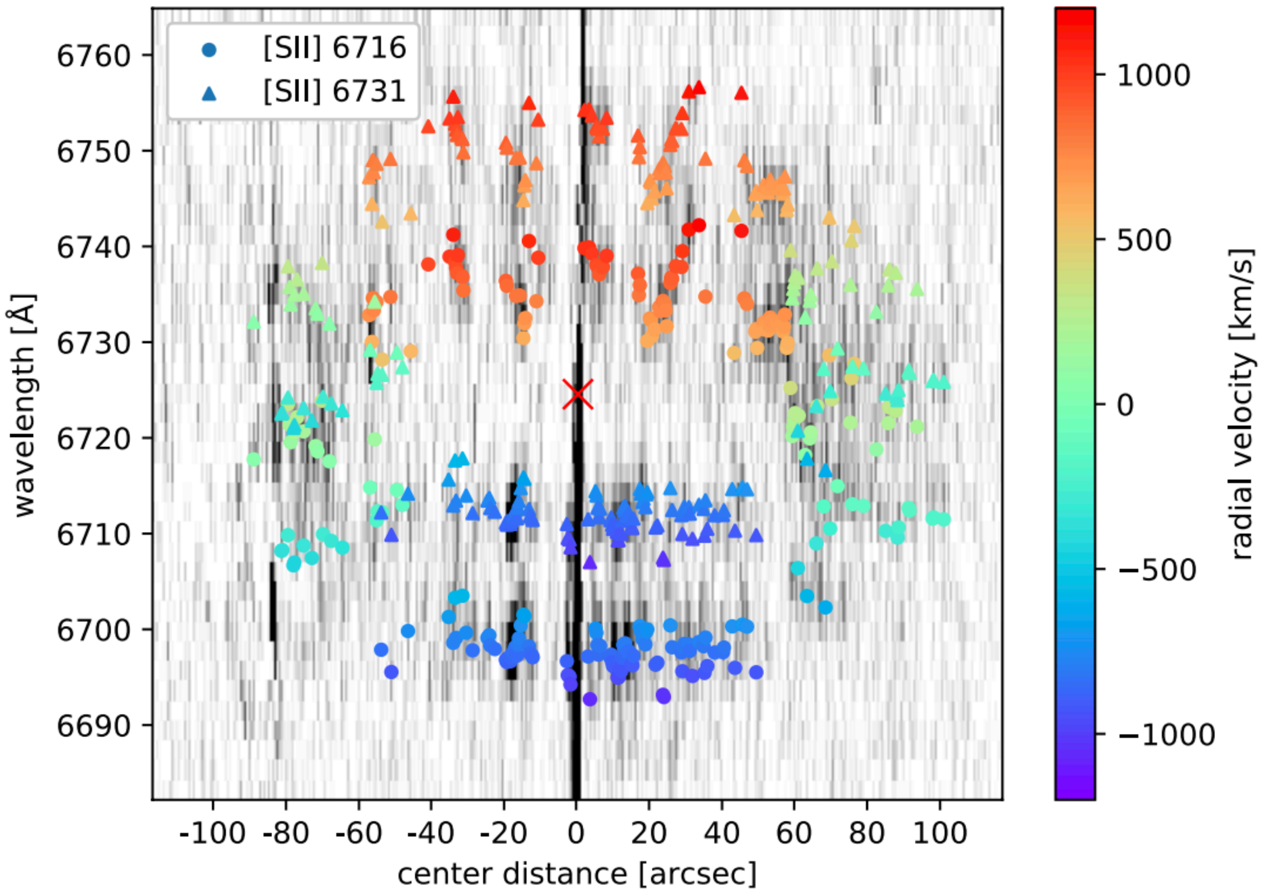




Large neon, magnesium, silicon, and sulfur enrichment of the central star and the nebula

Long slit observations with OSIRIS

on board the 10-m GranTeCan (GTC) telescope



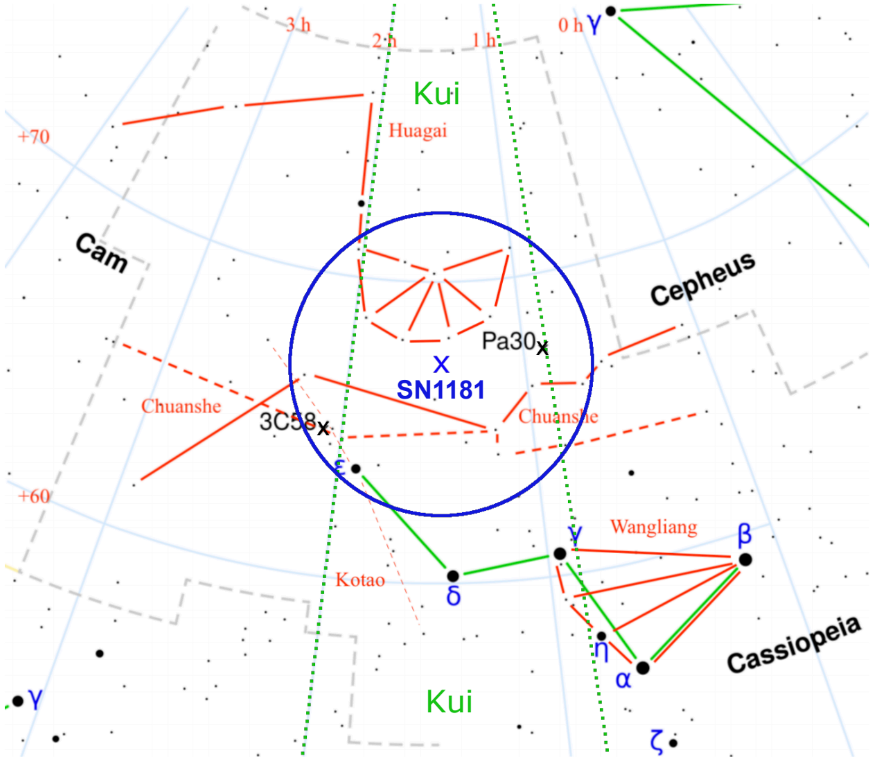
Ritter et al. 21

an expansion velocity of ~ a few 1000 km/s is inferred, which is consistent with type Iax SNe

SN 1181 → IRAS 00500+6713?

the youngest Galactic supernova
without a firmly confirmed remnant

Ritter et al. 21

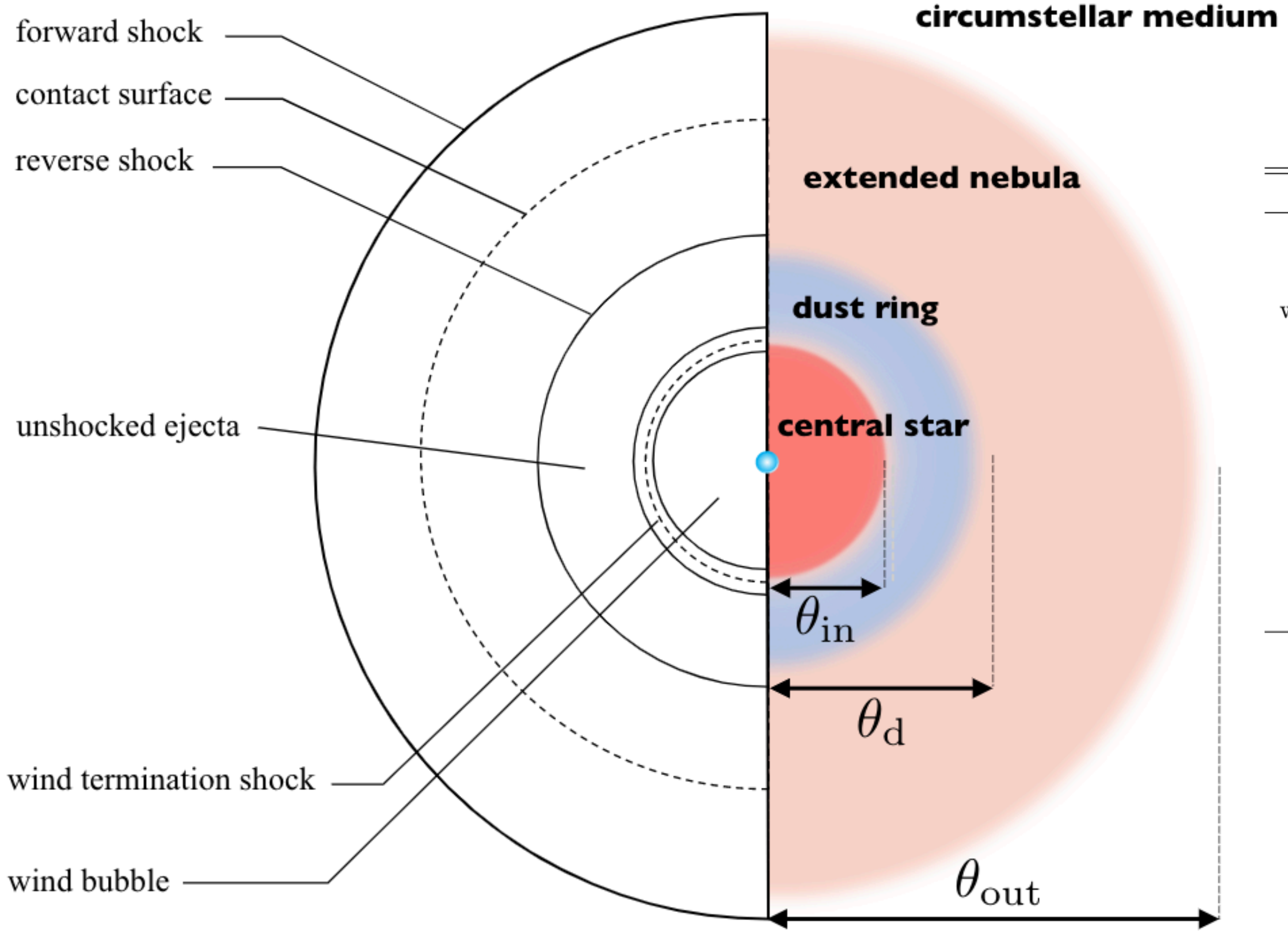


「吾妻鏡」
"治承五年六月廿五日（1181年8月7日）
庚午 戌尅 客星見艮方"

- ✓ The magnitude of SN 1181 is not known
- ✓ it was compared to Saturn
- ✓ $m_V \sim -0.5$ to $+1.0$?
- ✓ $M_V \sim -14$ to -12.5?
- ✓ sub-luminous supernovae?

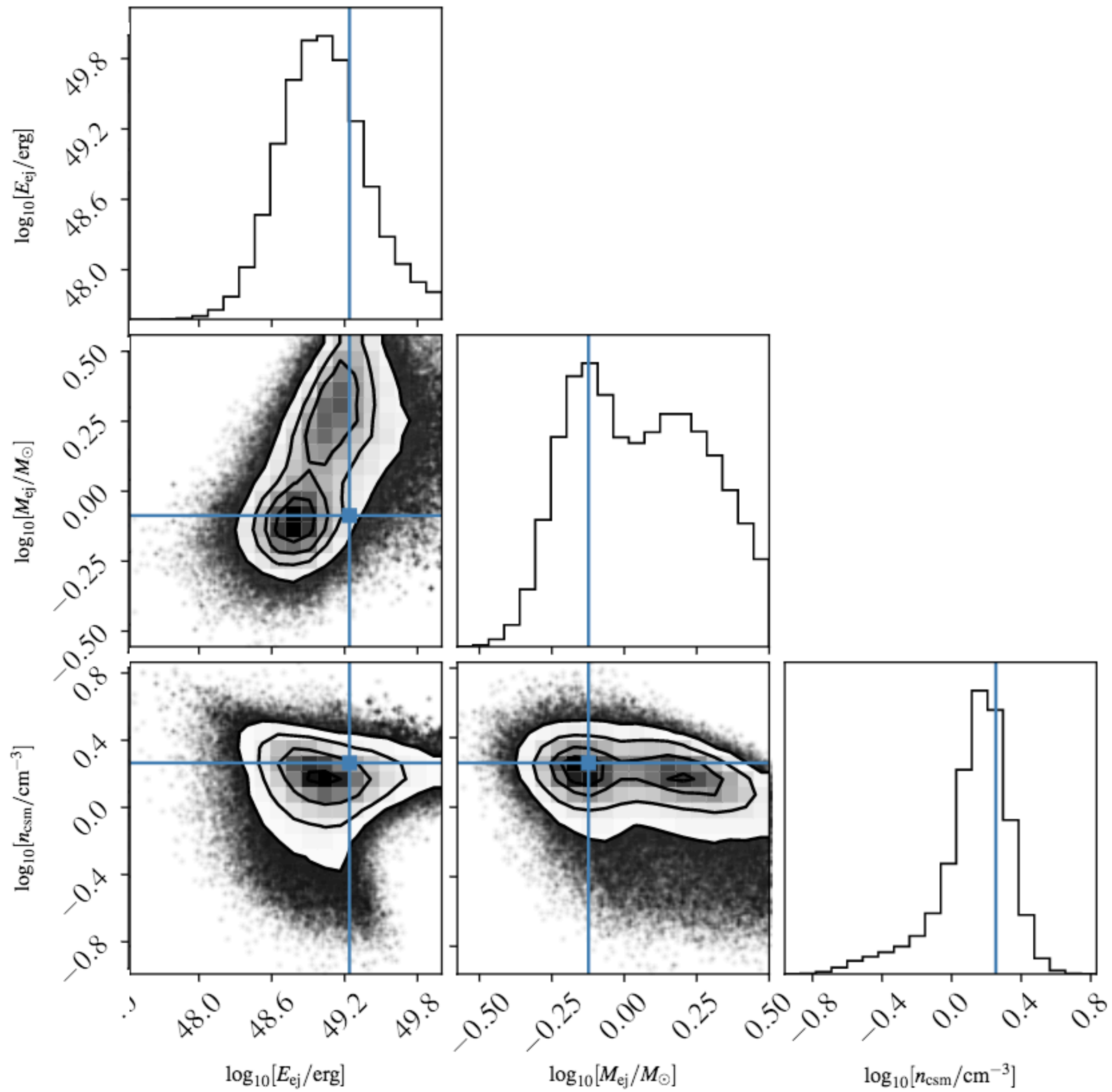
- ✓ remained visible for 185 days
- ✓ 4.5 - 6 mag of fading over this period?

A dynamical model for IRAS 00500+6713



model parameters			reference
distance	d [kpc]	$2.46^{+0.157}_{-0.157}$	Gaia Collaboration et al. (2021)
wind mass loss rate	$\dot{M}_w$ [$M_\odot$/yr]	3.5×10^{-6}	Gvaramadze et al. (2019)
wind kinetic luminosity	L_w [erg s^{-1}]	2.7×10^{38}	Gvaramadze et al. (2019)
angular size	θ_{in} [arcsec]	25^{+5}_{-5}	Oskinova et al. (2020)
	θ_{out} [arcsec]	120^{+24}_{-24}	Oskinova et al. (2020)
	θ_d [arcsec]	60^{+12}_{-12}	Ritter et al. (2021)
expansion velocity	v_d [km s^{-1}]	1100^{+100}_{-100}	Ritter et al. (2021)
emission measure	$EM_{in,1}$ [10^{53} cm^{-3}]	$1.3^{+0.63}_{-0.63}$	Oskinova et al. (2020)
	$EM_{in,2}$ [10^{53} cm^{-3}]	$0.50^{+0.063}_{-0.063}$	Oskinova et al. (2020)
	$EM_{out,1}$ [10^{56} cm^{-3}]	$1.64^{+0.57}_{-0.57}$	Oskinova et al. (2020)
	$EM_{out,2}$ [10^{54} cm^{-3}]	$2.0^{+0.44}_{-0.44}$	Oskinova et al. (2020)

A dynamical model for IRAS 00500+6713



$$t_{\mathrm{age}} = 640^{+130}_{-130}\,\mathrm{yr}$$

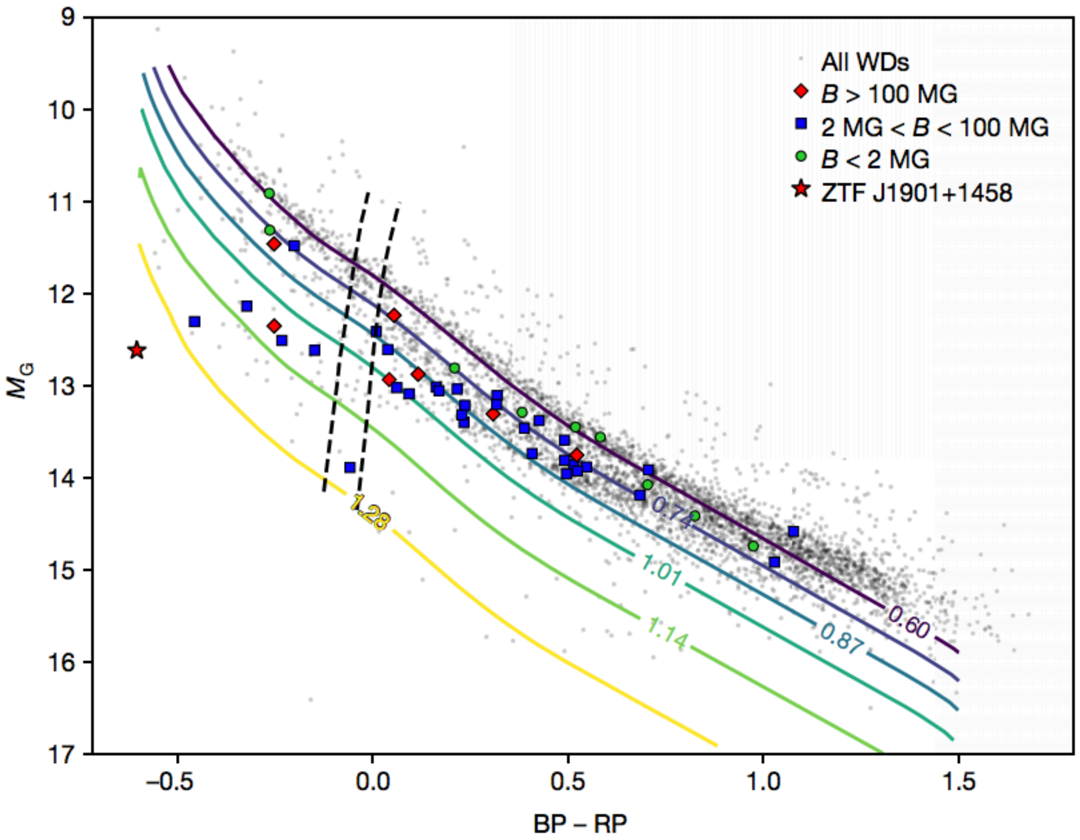
$$\log_{10}[E_{\mathrm{ej}}/\mathrm{erg}] = 48.9^{+0.3}_{-0.3}$$

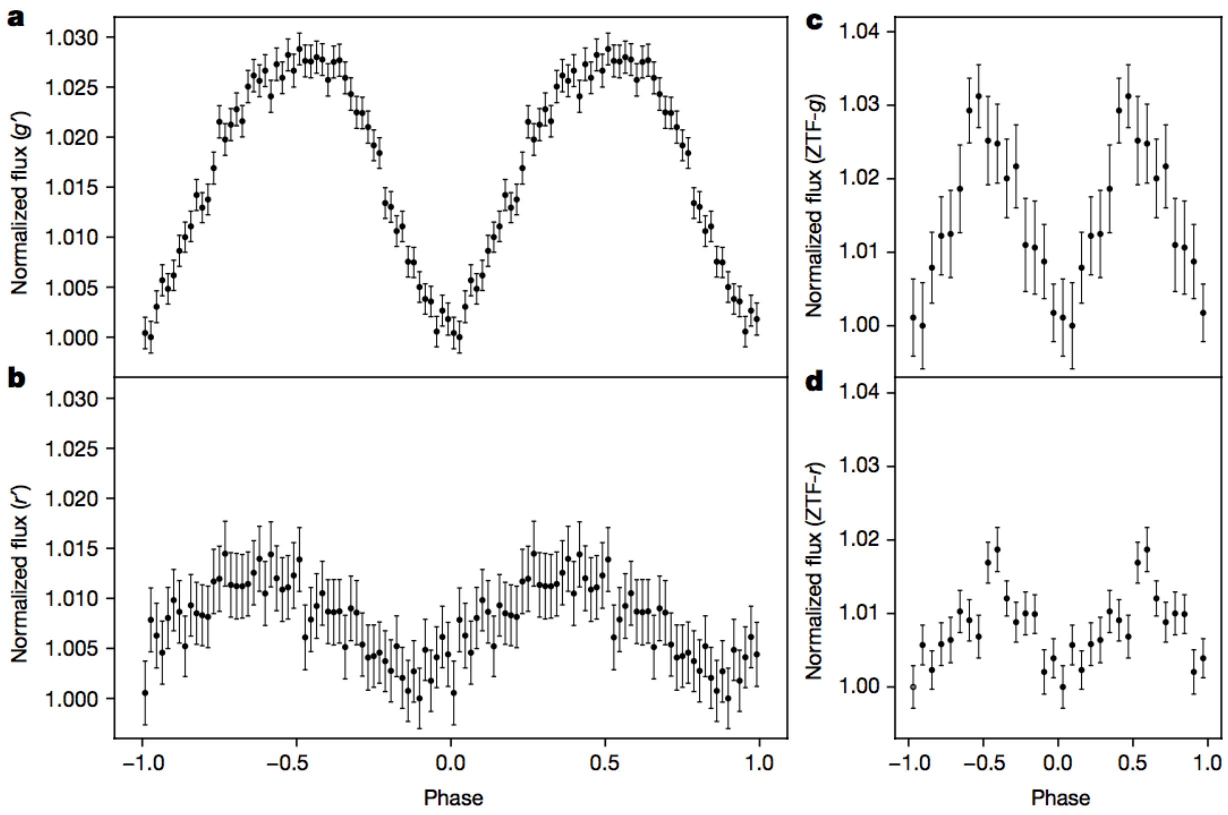
$$\log_{10}[M_{\mathrm{ej}}/M_{\odot}] = -0.2^{+0.2}_{-0.2}$$

"Merger of a massive WD binary system with a total mass of > 1.4 Msun accompanied by an SN Iax like event, but not SN 1181"

c.f., ZTF J190132.9+145808.7

Caiazzo et al. 21





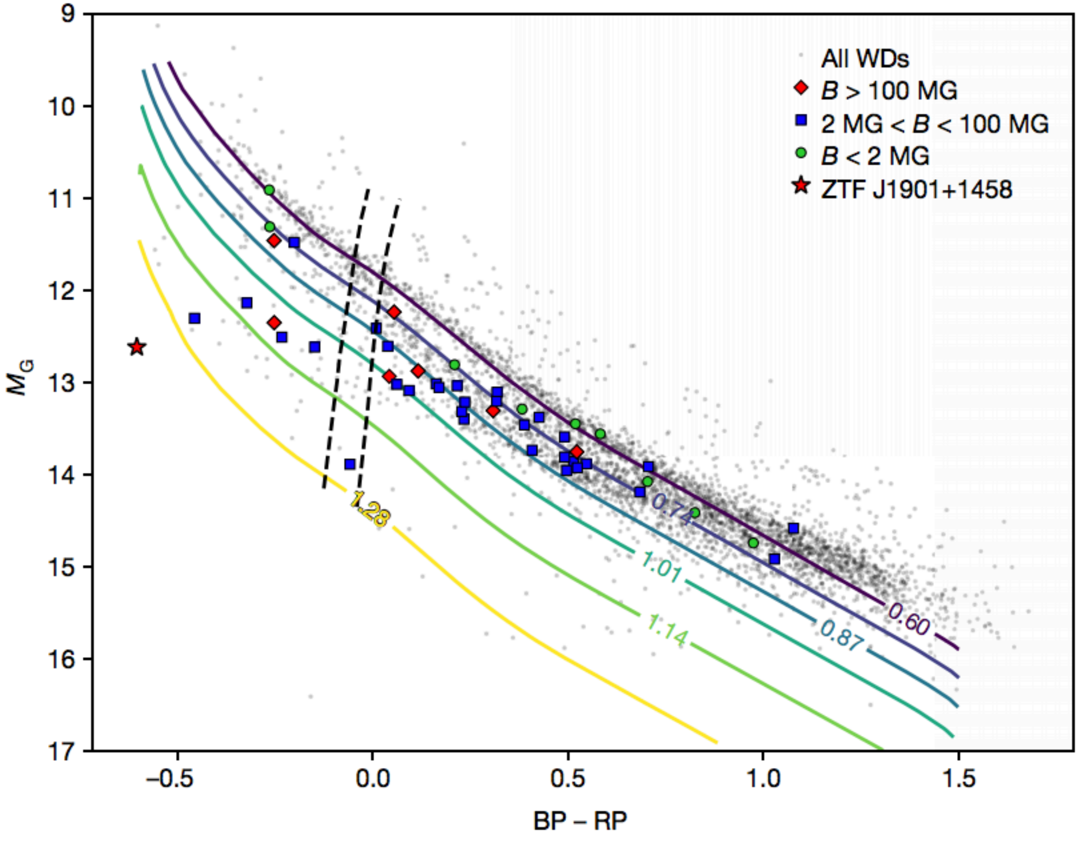
$R = 2140^{+160}_{-230}$ km, $M = 1.327\text{-}1.365\ M_\odot$

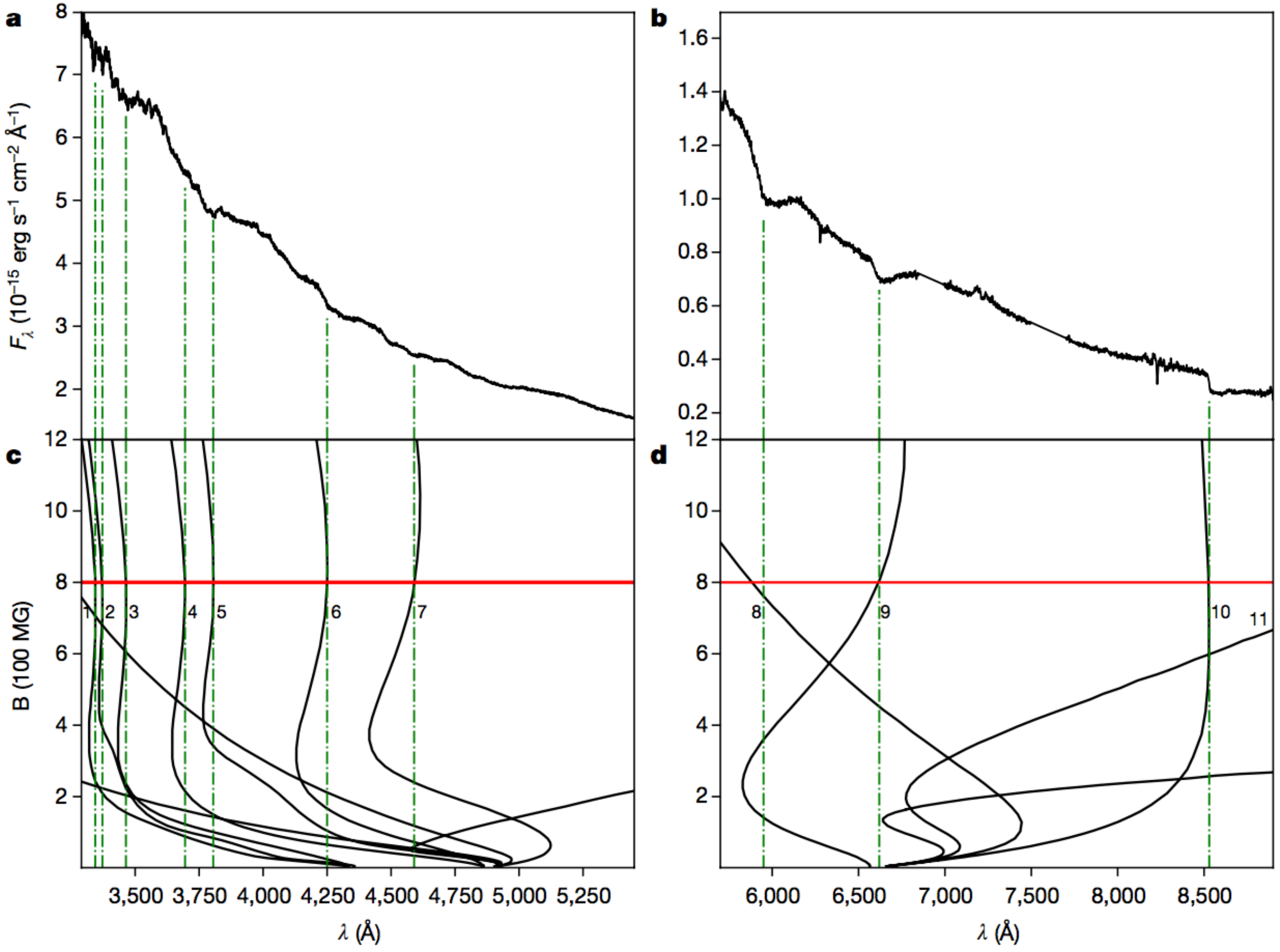
$T_{eff} = 46{,}000$ K, $t_{cool} = 10\text{-}100$ Myr

$P = 6.97$ min

c.f., ZTF J190132.9+145808.7

Caiazzo et al. 21





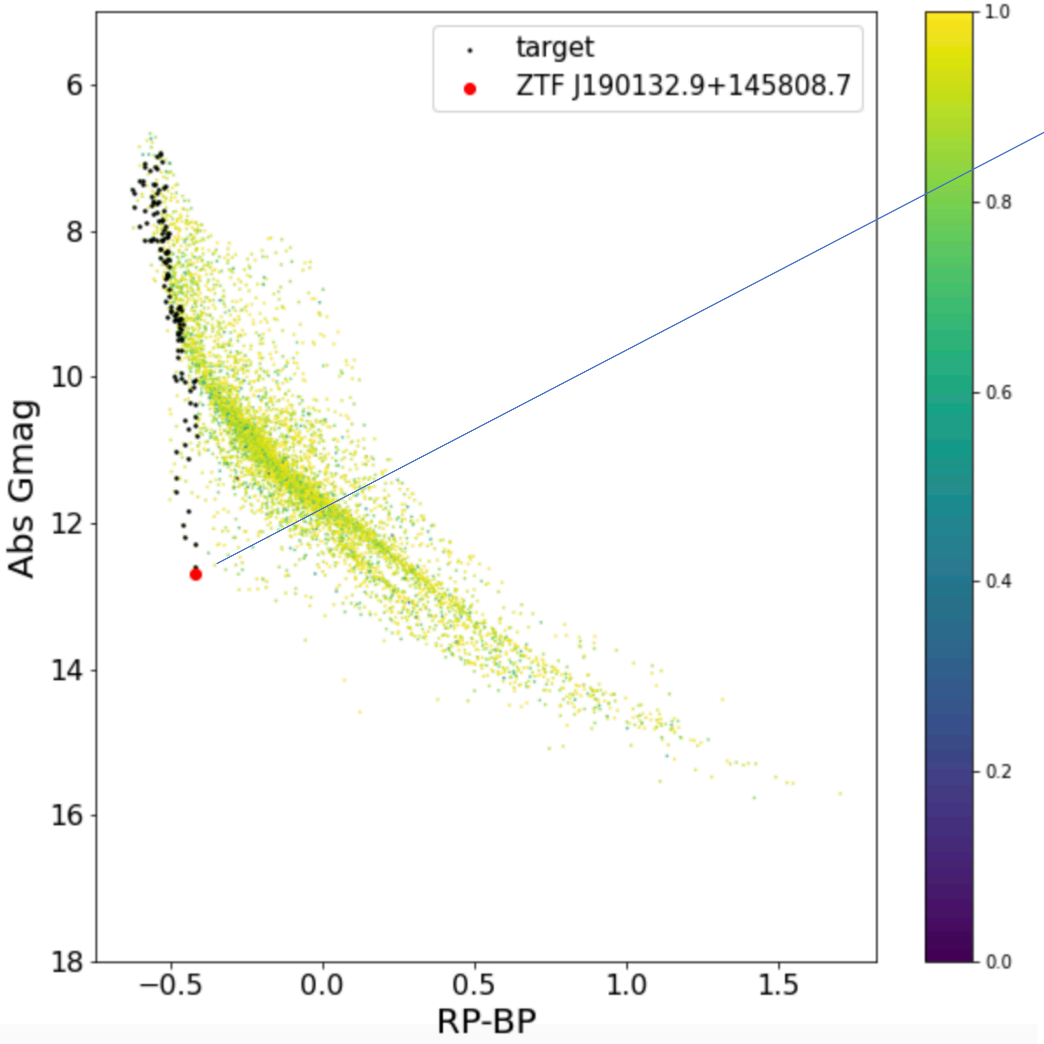
$R = 2140^{+160}_{-230}$ km, $M = 1.327$-$1.365\ M_\odot$

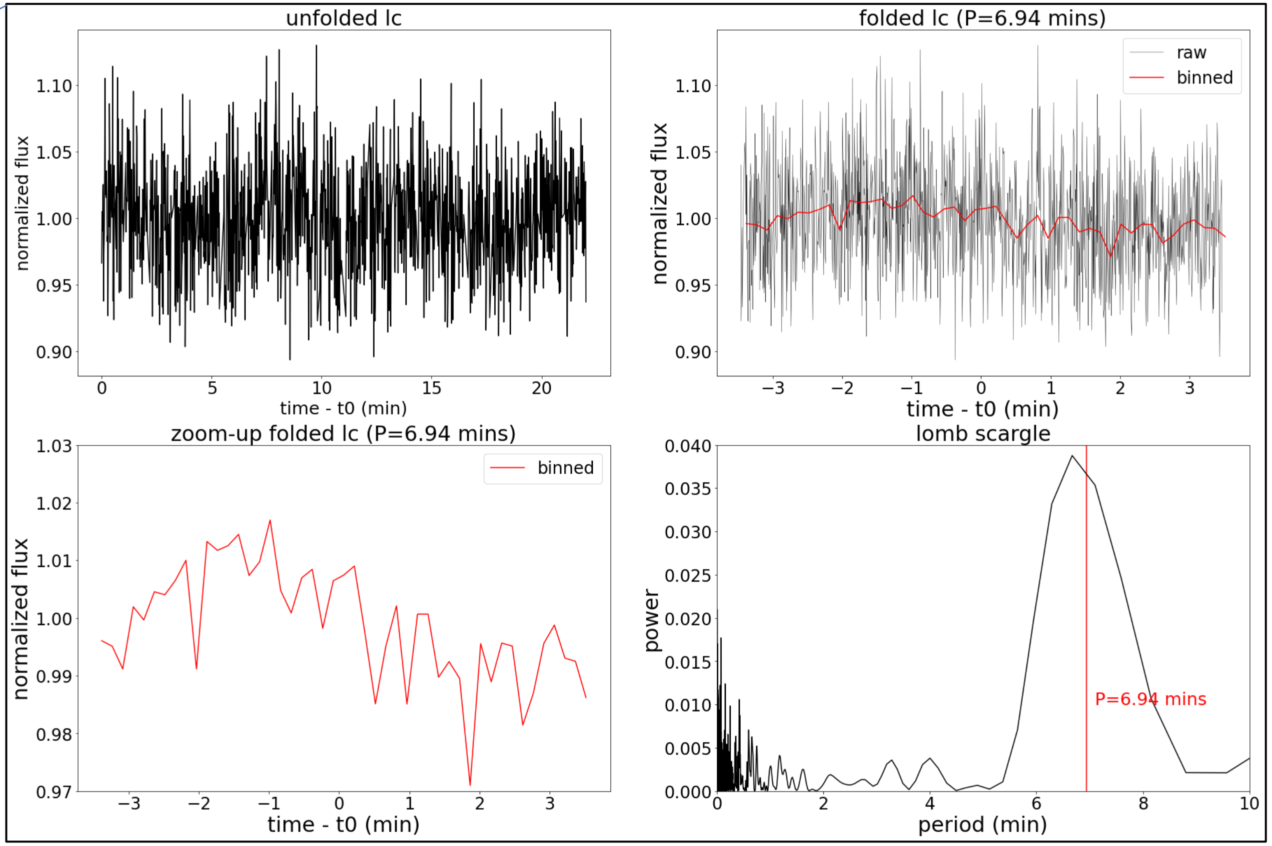
$T_{\rm eff} = 46{,}000$ K, $t_{\rm cool} = 10$-100 Myr

$B = 6$-9×10^8 G

c.f., HeSO survey 2021

✓ (blindly) detect and confirm the signal from ZTF J190132.9+145808.7

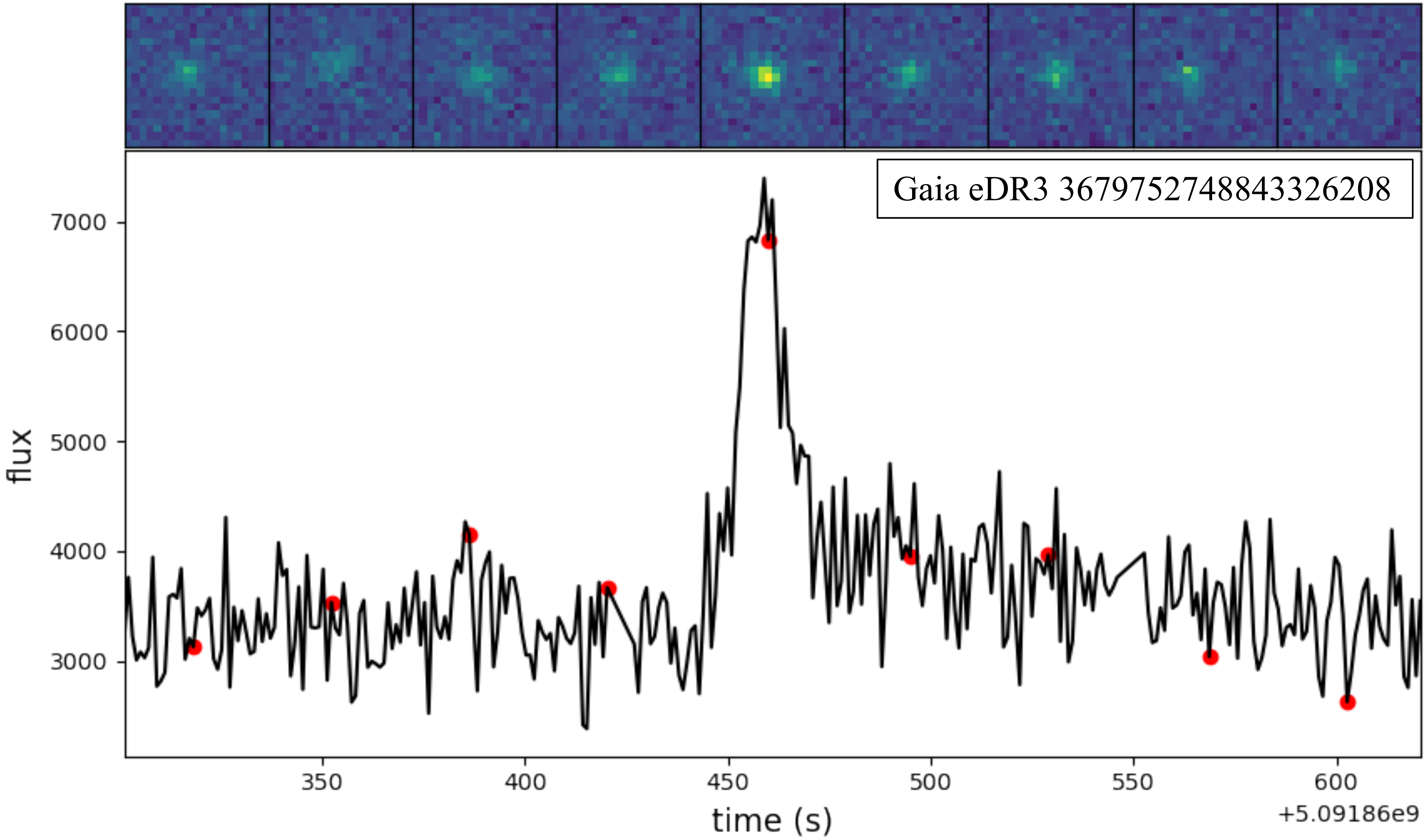




2. Coherent plasma outflows

c.f., HeSO survey 2021

✓ A few 10 sec flare from an M dwarf (M* = 0.16 Msun, Teff = 3094 K)



c.f.,

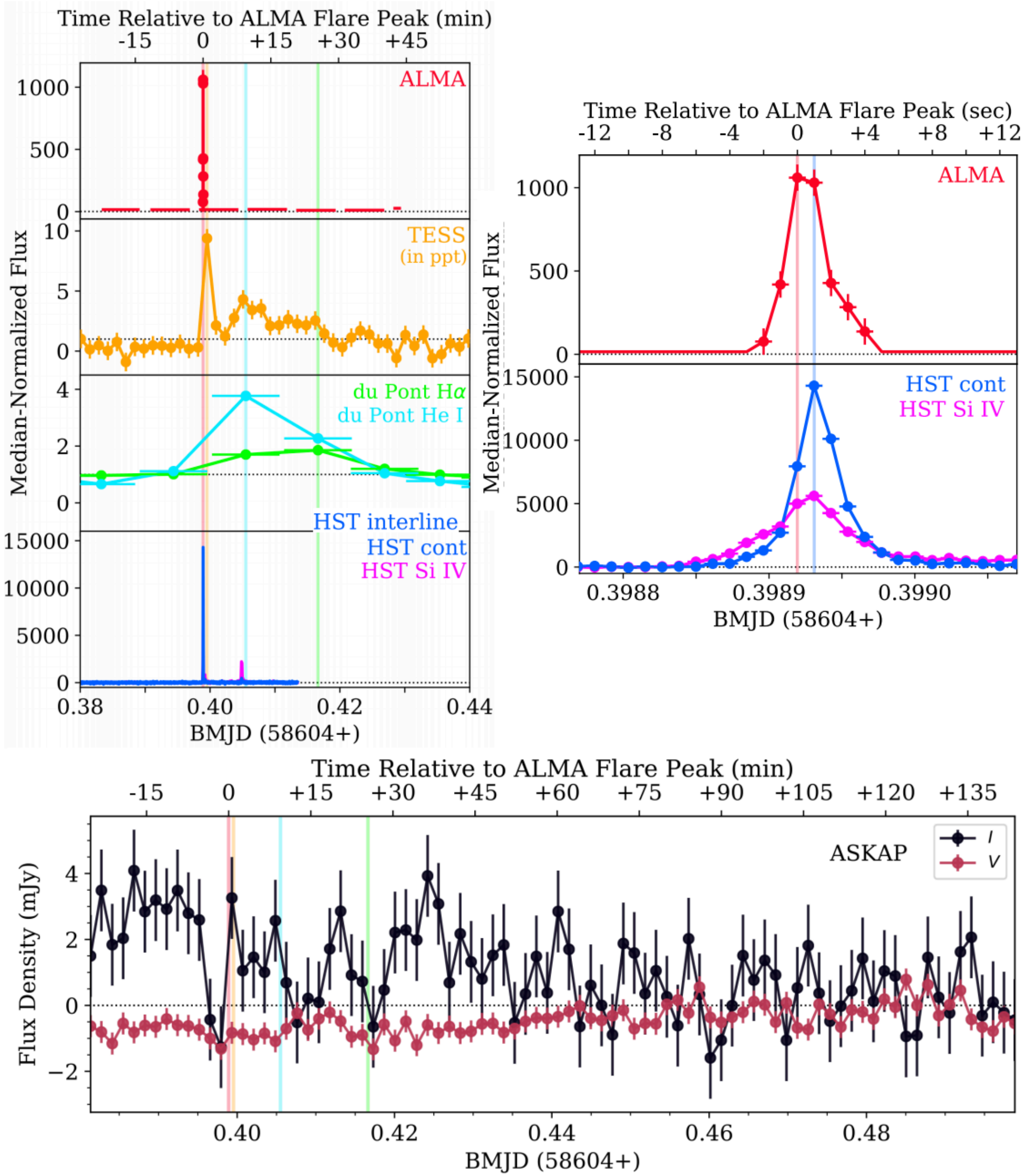
The Astrophysical Journal Letters, 911:L25 (9pp), 2021 April 20 https://doi.org/10.3847/2041-8213/abf14c

Discovery of an Extremely Short Duration Flare from Proxima Centauri Using Millimeter through Far-ultraviolet Observations

Meredith A. MacGregor[1], Alycia J. Weinberger[2], R. O. Parke Loyd[3], Evgenya Shkolnik[3], Thomas Barclay[4,5], Ward S. Howard[6], Andrew Zic[7,8], Rachel A. Osten[9,10], Steven R. Cranmer[1,12], Adam F. Kowalski[1,11], Emil Lenc[8], Allison Youngblood[12], Anna Estes[1], David J. Wilner[13], Jan Forbrich[13,14], Anna Hughes[15], Nicholas M. Law[6], Tara Murphy[7], Aaron Boley[15], and Jaymie Matthews[15]

Abstract

We present the discovery of an extreme flaring event from Proxima Cen by the Australian Square Kilometre Array Pathfinder (ASKAP), Atacama Large Millimeter/submillimeter Array (ALMA), Hubble Space Telescope (HST), Transiting Exoplanet Survey Satellite (TESS), and the du Pont Telescope that occurred on 2019 May 1. In the millimeter and FUV, this flare is the brightest ever detected, brightening by a factor of >1000 and >14,000 as seen by ALMA and HST, respectively. The millimeter and FUV continuum emission trace each other closely during the flare, suggesting that millimeter emission could serve as a proxy for FUV emission from stellar flares and become a powerful new tool to constrain the high-energy radiation environment of exoplanets. Surprisingly, optical emission associated with the event peaks at a much lower level with a time delay. The initial burst has an extremely short duration, lasting for <10 s. Taken together with the growing sample of millimeter M dwarf flares, this event suggests that millimeter emission is actually common during stellar flares and often originates from short burst-like events.



c.f.,

The Astrophysical Journal, 905:23 (13pp), 2020 December 10 https://doi.org/10.3847/1538-4357/abca90

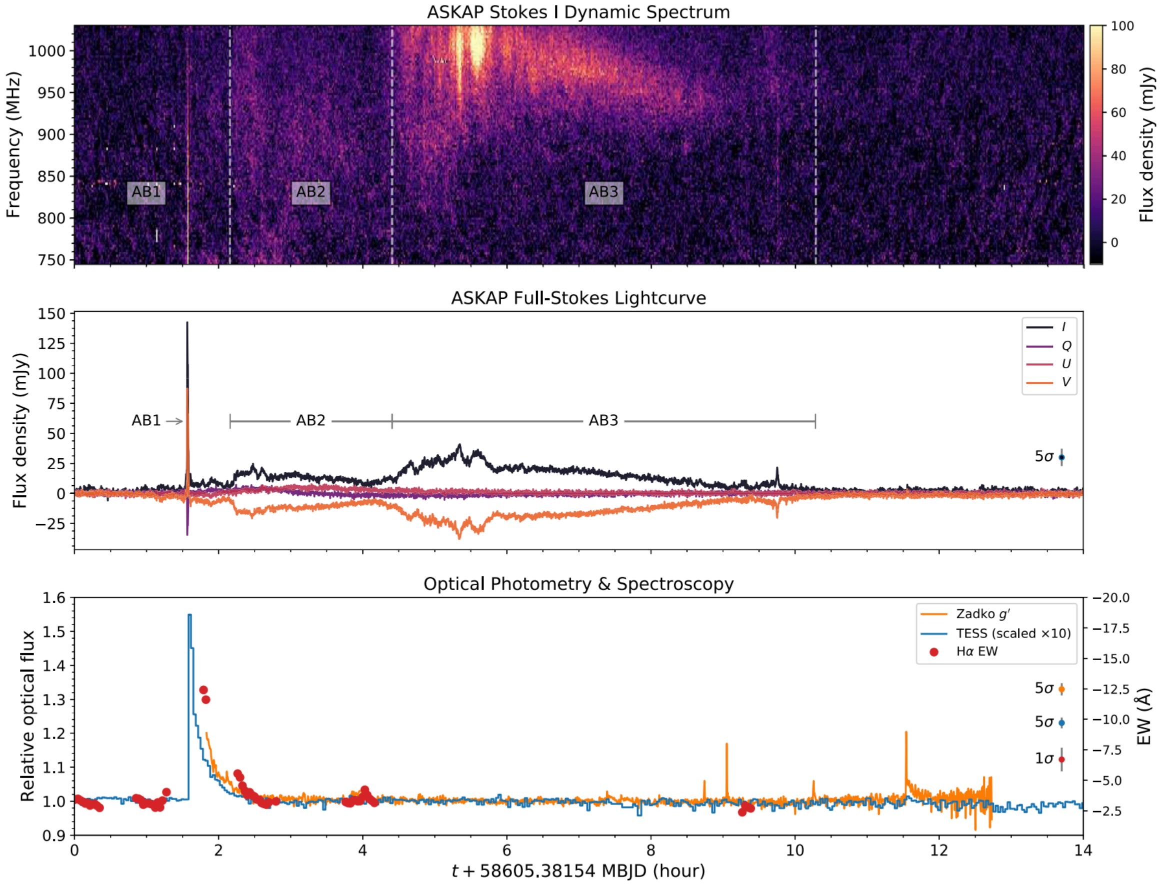
CrossMark

A Flare-type IV Burst Event from Proxima Centauri and Implications for Space Weather

Andrew Zic[1,2], Tara Murphy[1,3], Christene Lynch[4,5], George Heald[6], Emil Lenc[2], David L. Kaplan[7], Iver H. Cairns[8], David Coward[9], Bruce Gendre[9], Helen Johnston[1], Meredith MacGregor[10], Danny C. Price[11,12], and Michael S. Wheatland[1]

Abstract

Studies of solar radio bursts play an important role in understanding the dynamics and acceleration processes behind solar space weather events, and the influence of solar magnetic activity on solar system planets. Similar low-frequency bursts detected from active M-dwarfs are expected to probe their space weather environments and therefore the habitability of their planetary companions. Active M-dwarfs produce frequent, powerful flares which, along with radio emission, reveal conditions within their atmospheres. However, to date, only one candidate solar-like coherent radio burst has been identified from these stars, preventing robust observational constraints on their space weather environment. During simultaneous optical and radio monitoring of the nearby dM5.5e star Proxima Centauri, we detected a bright, long-duration optical flare, accompanied by a series of intense, coherent radio bursts. These detections include the first example of an interferometrically detected coherent stellar radio burst temporally coincident with a flare, strongly indicating a causal relationship between these transient events. The polarization and temporal structure of the trailing long-duration burst enable us to identify it as a type IV burst. This represents the most compelling detection of a solar-like radio burst from another star to date. Solar type IV bursts are strongly associated with space weather events such as coronal mass ejections and solar energetic particle events, suggesting that stellar type IV bursts may be used as a tracer of stellar coronal mass ejections. We discuss the implications of this event for the occurrence of coronal mass ejections from Proxima Cen and other active M-dwarfs.



@FRB 2021

ID LB02: A MeerTRAP discovery of a 76-s radio pulsar: A potential ULPM
Kaustubh Rajwade, University of Manchester
A: Recorded B: Live

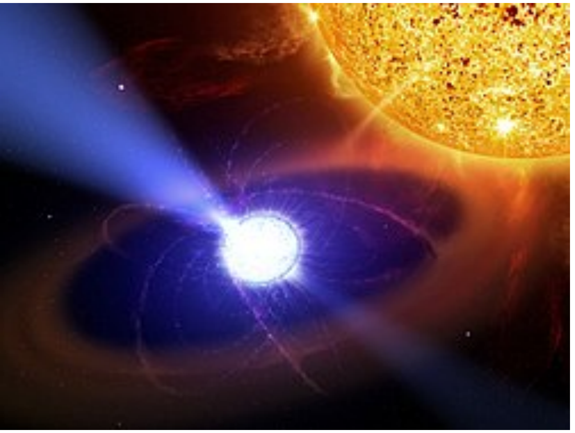
Detailed studies of spectro-ten
physical connection between F
can be produced by highly r
Long-Period Magnetars (ULPI
76-second period neutron star
period radio emitting neutron st
multi-wavelength follow-up obs
source. The single pulses of I
features including partial nulli
periodicities discovered in a s
MTP0013 on the P-Pdot diagra
producing FRB like emission.

ID134: An ultra-long period magnetar with high-fluence radio emission
Natasha Hurley-Walker, Curtin University / ICRAR

One leading theory on the generation of FRBs is that they are produced by magnetars, and the detection of two FRBs from the Galactic Centre magnetar has helped strengthen this connection. However FRBs have also been detected in globular clusters, which should not host young magnetars, only older magnetars below the “death line”. The known population of magnetars typically rotates with periods of seconds to tens of seconds, but due to spin down these should be vastly outnumbered by older, “ultra-long period” (ULP) magnetars. Pulsar-like radio emission from magnetars is uncommon, with only five examples in the literature, all with 1-10s periods. ULP magnetars would explain many of the emission characteristics of FRBs, such as the quasi-periodic windows of emission, but were thought to be impossible to observe directly. We have detected the first ULP magnetar; the radio emission is highly polarised and periodic on a timescale of 20 minutes. Its dynamic spectrum shows high-fluence narrow-timescale “spikes” which are unresolved by our data, with fluence on par with the Galactic centre magnetar. I will highlight the object’s main observational features, including its window of appearance, dispersion measure, polarisation attributes, and changes in its pulse profile over time. Along with X-ray and optical observations, these features have allowed us to constrain its physical attributes such as distance, radio luminosity, and likely magnetic field strength. I will conclude with a population estimate and thoughts on how we might best detect further examples, and follow them up to determine if they generate FRBs.

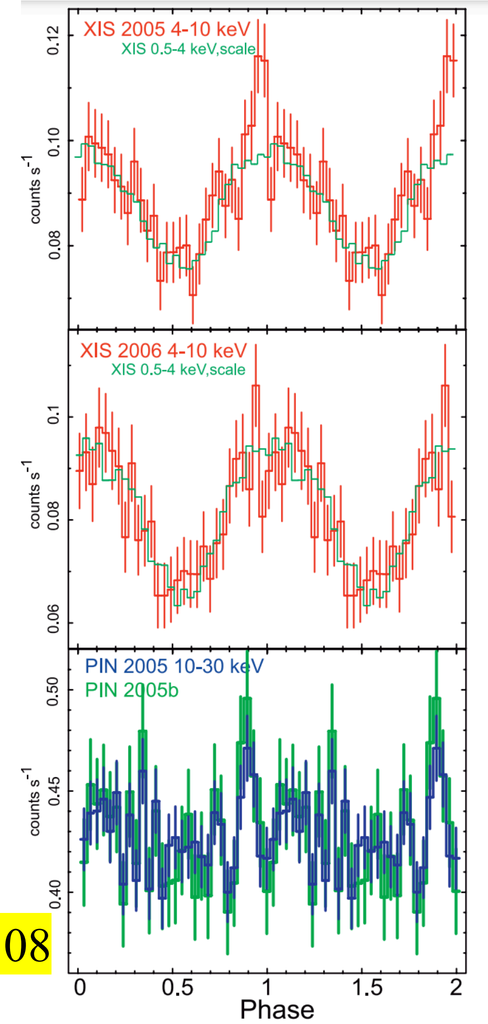
White dwarf "pulsars"

AE aqr



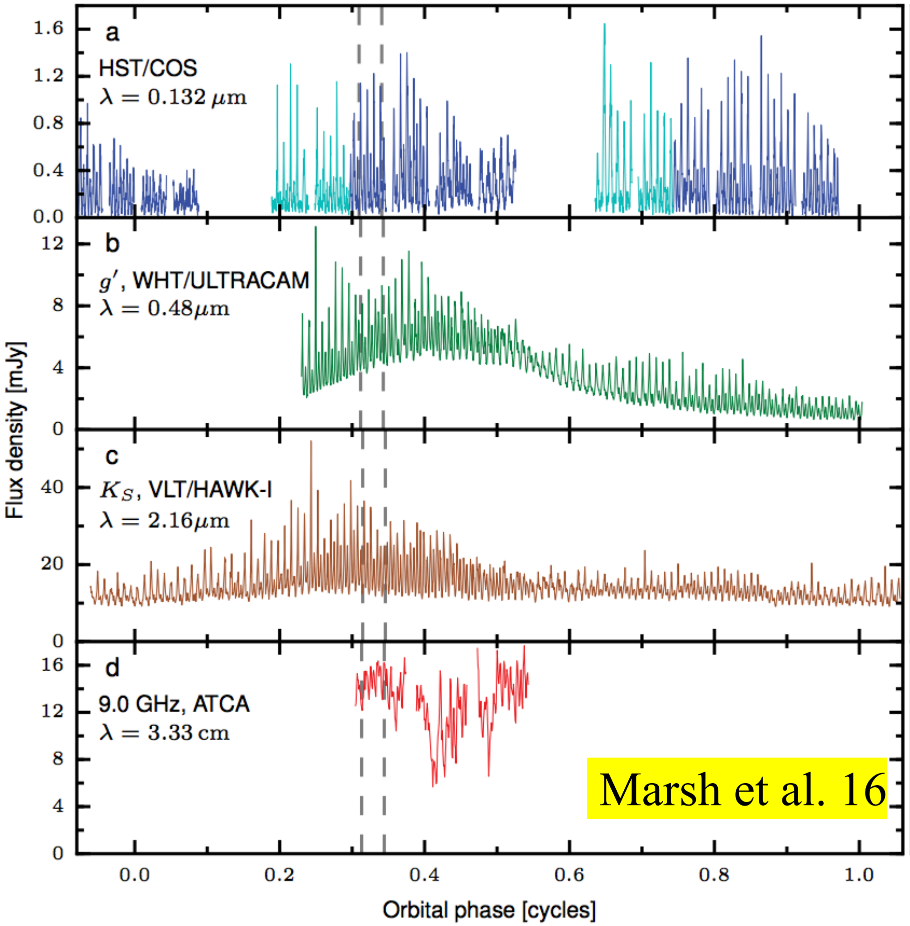
$P = 33.08$ sec

$B = 5e7$ G

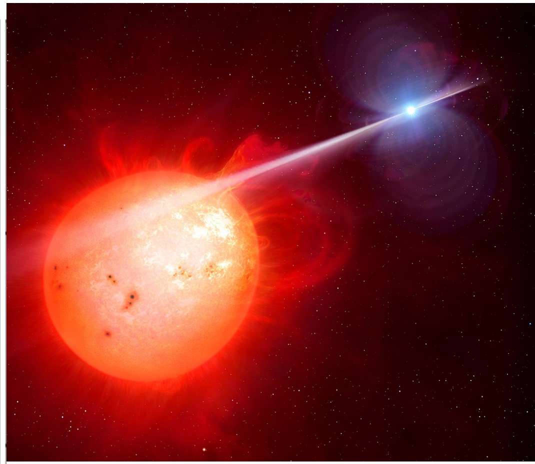


Terada et al. 08

AR sco



Marsh et al. 16

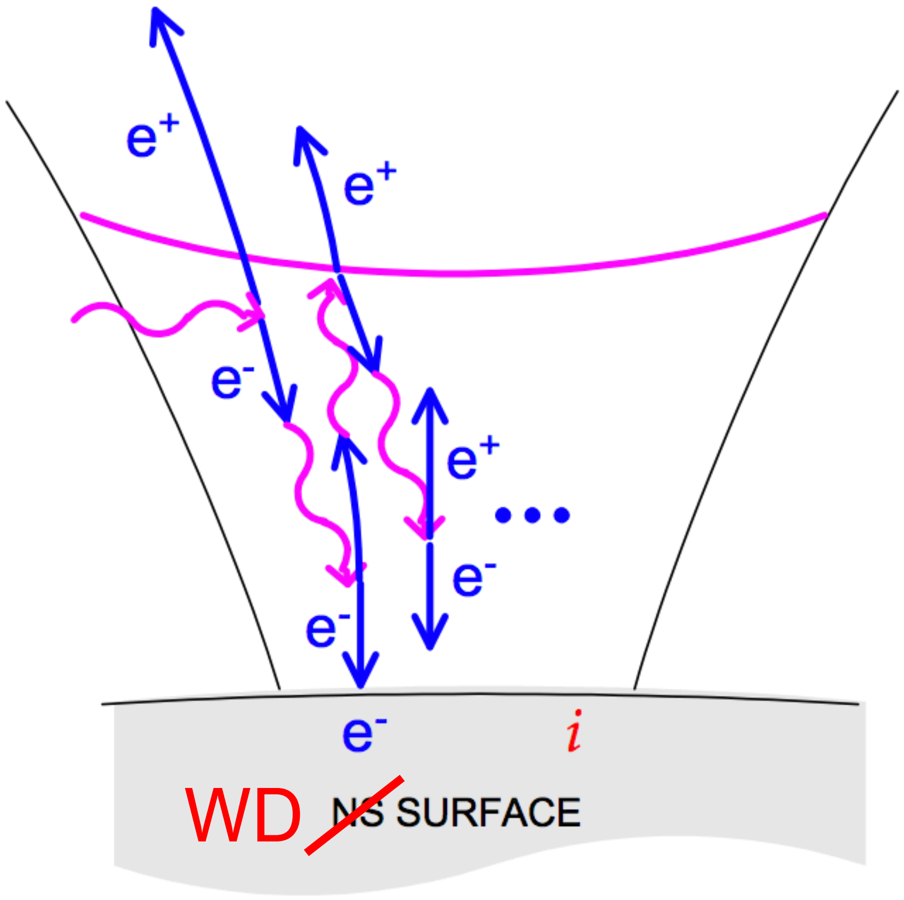


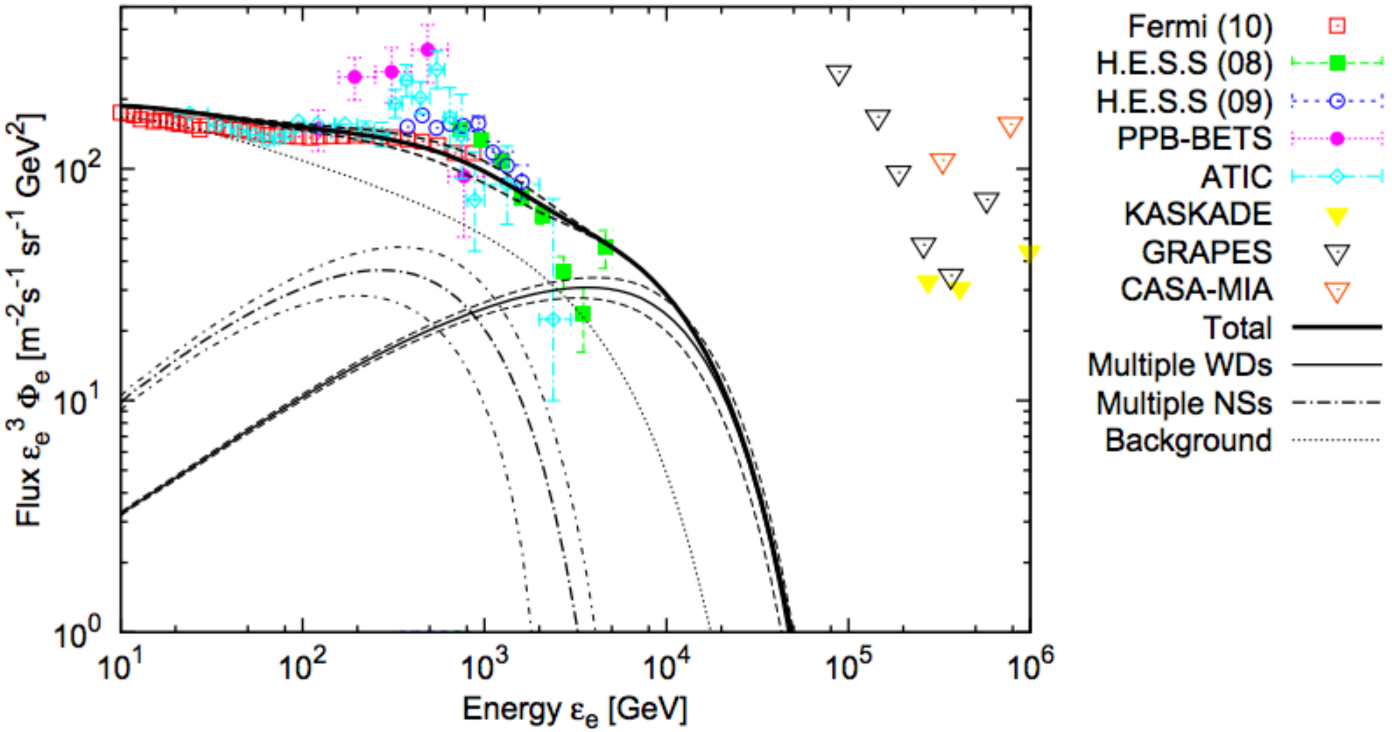
$P = 1.95$ minute

$B = 7.1e8$ G

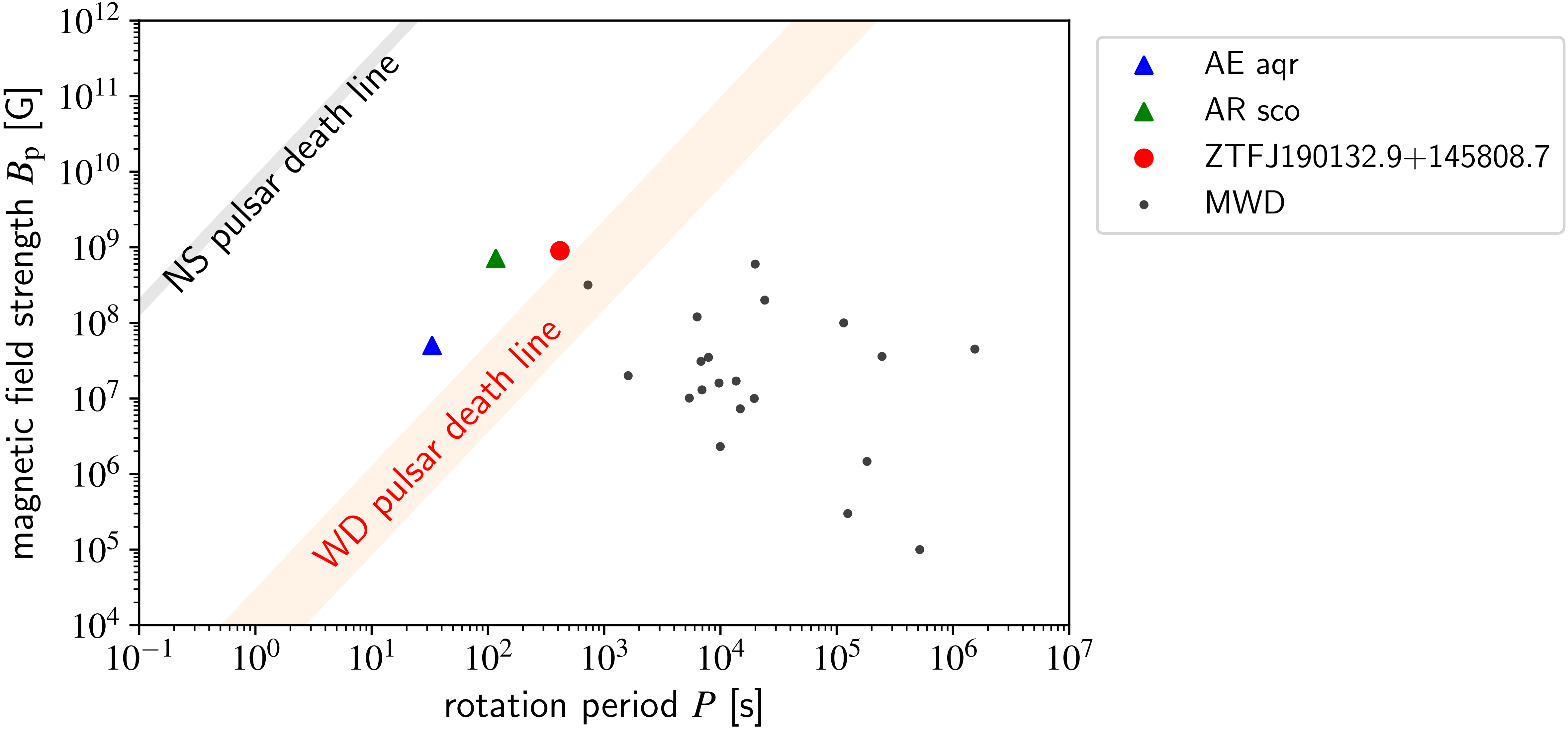
White dwarf "pulsars" as CR e$\pm$ factories

Kashiyama, Ioka, Kawanaka 10

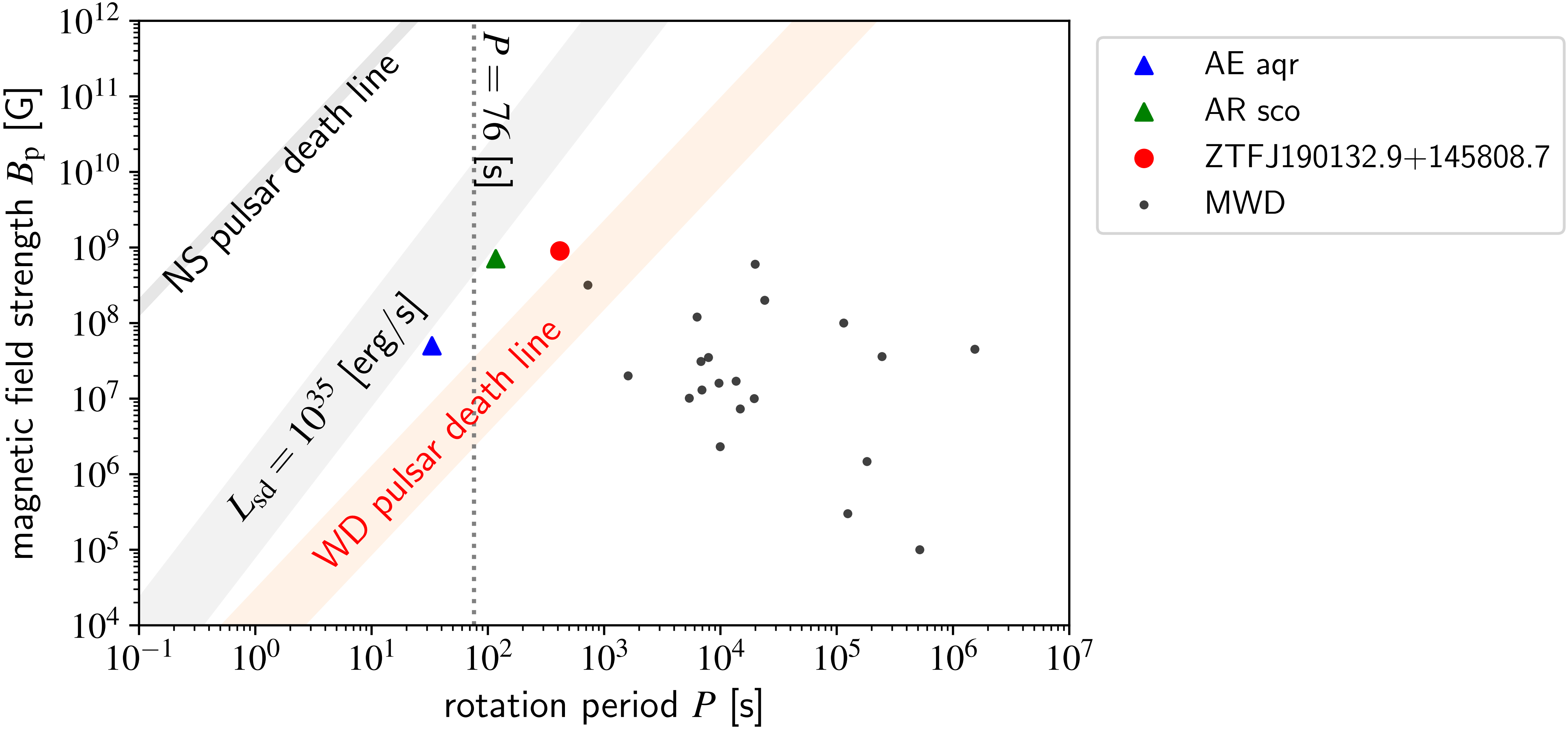




$$\Delta V_{\rm max} = \frac{B_{\rm p}\Omega^2 R^3}{2c^2} \sim 10^{13}\left(\frac{B_{\rm p}}{10^8{\rm G}}\right)\left(\frac{\Omega}{0.1{\rm s}^{-1}}\right)^2\left(\frac{R}{10^{8.7}{\rm cm}}\right)^3 {\rm Volt}$$

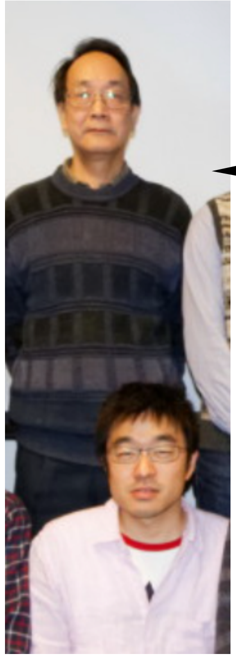


magnetic field strength B_p [G]
rotation period P [s]
NS pulsar death line
WD pulsar death line
AE aqr
AR sco
ZTFJ190132.9+145808.7
MWD



NS pulsar death line
$L_{\rm sd} = 10^{35}$ [erg/s]
WD pulsar death line
$P = 76$ [s]
magnetic field strength $B_{\rm p}$ [G]
rotation period P [s]
10^{12}
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
AE aqr
AR sco
ZTFJ190132.9+145808.7
MWD

~ 10 yrs ago



太陽では同じこと起きてないでしょ？

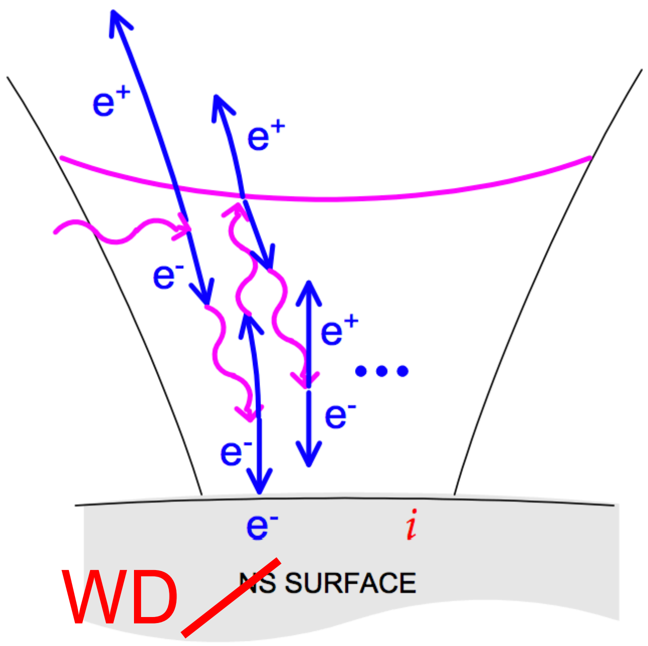
Local sources must have been detected in radio.

Revisiting white dwarf pulsar : pair formation

VACUUM GAP

$T_s < T_{e,i}$

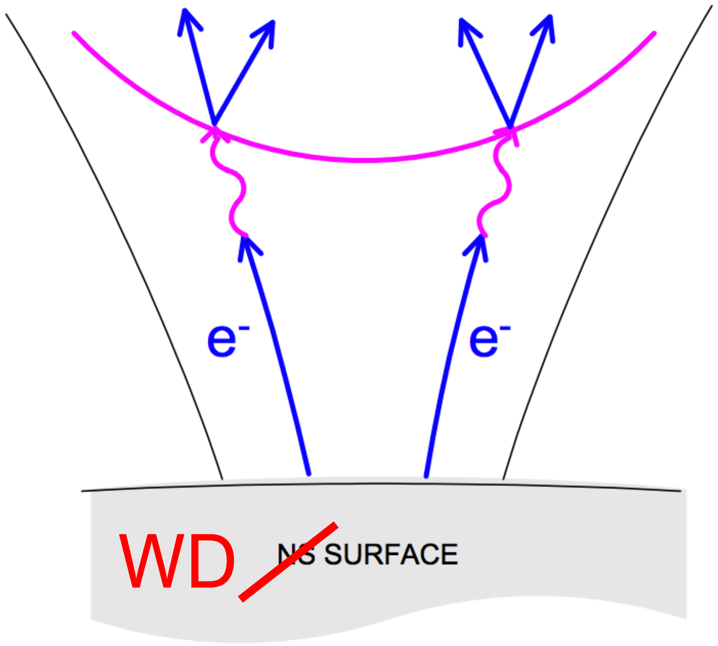
$\Omega \bullet B < 0$



SPACE CHARGE "GAP"

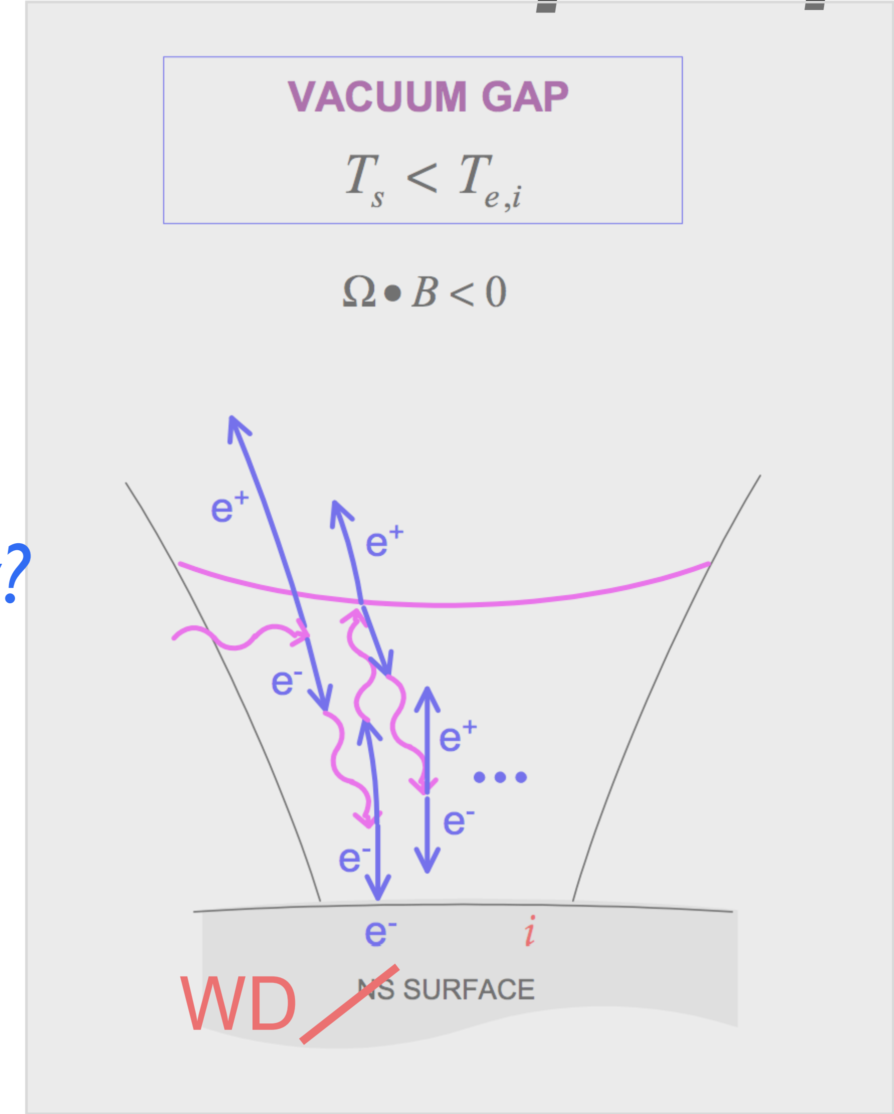
$T_s > T_{e,i}$

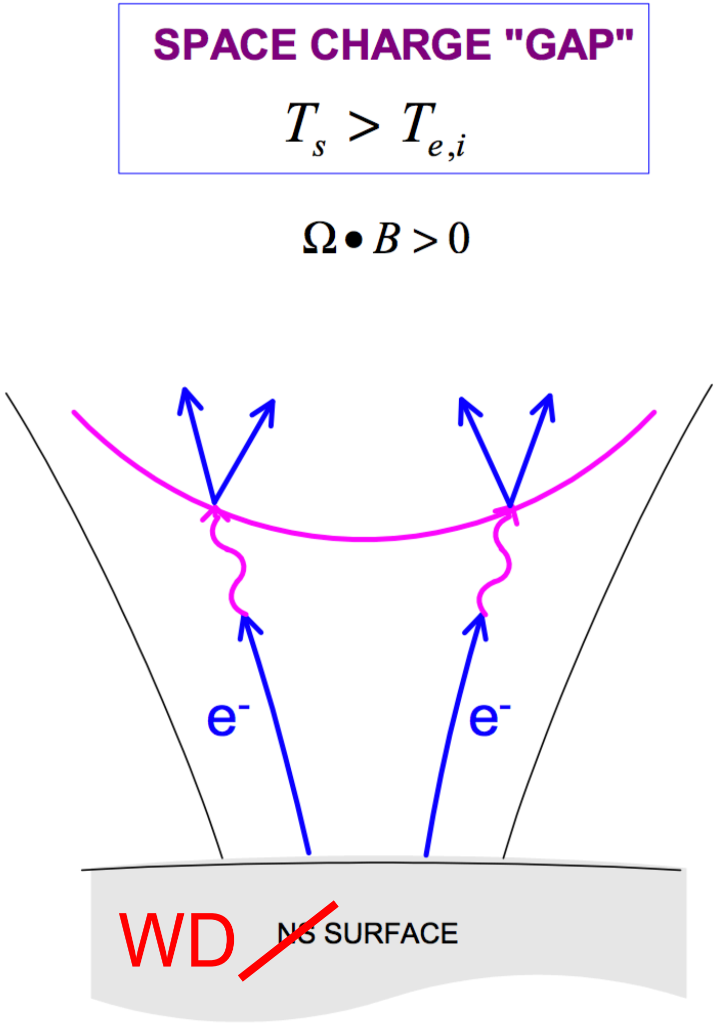
$\Omega \bullet B > 0$



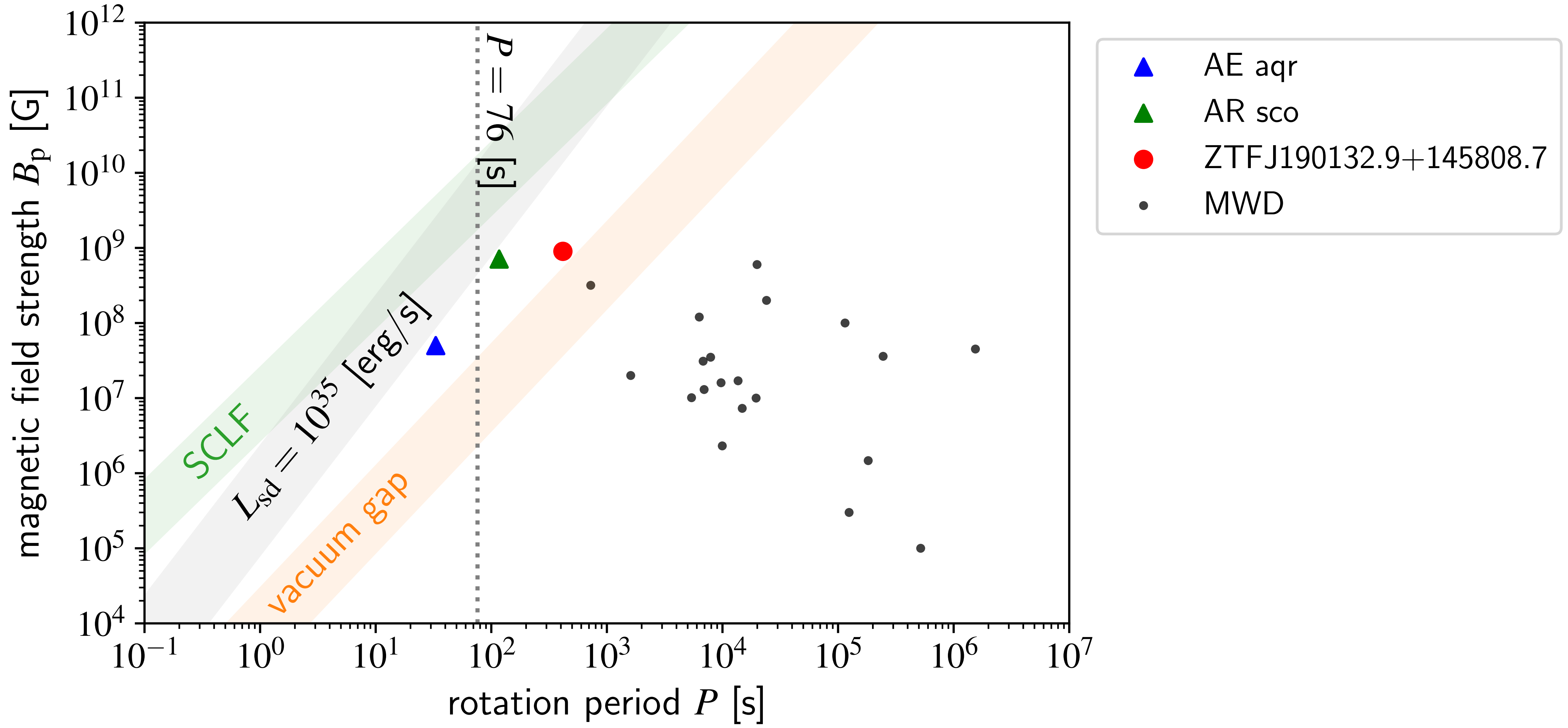
Revisiting white dwarf pulsar : pair formation

less likely?



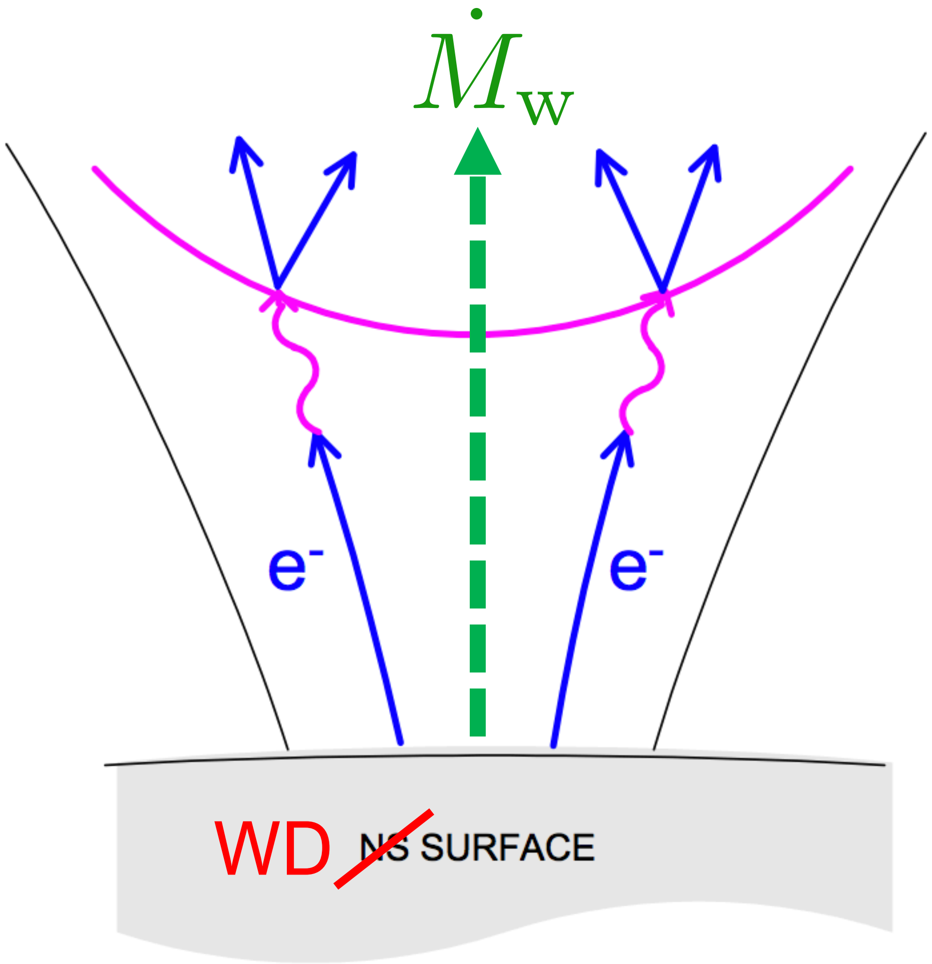


more likely?



magnetic field strength B_p [G]
rotation period P [s]
$P = 76$ [s]
SCLF
$L_{sd} = 10^{35}$ [erg/s]
vacuum gap
AE aqr
AR sco
ZTFJ190132.9+145808.7
MWD

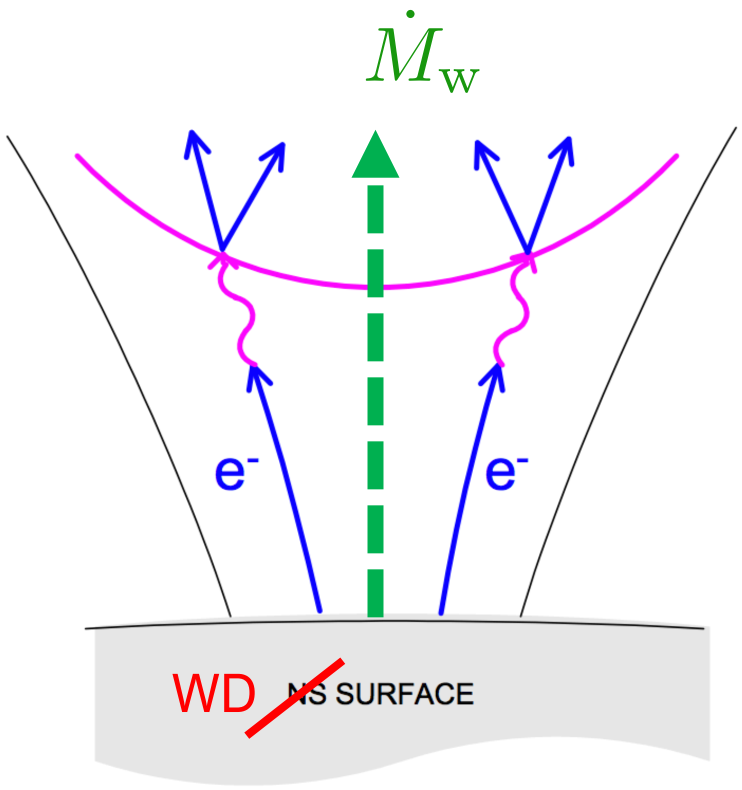
Revisiting white dwarf pulsars : MHD wind or force free magnetosphere?



$$n_{\rm GJ} = \frac{B_* \Omega_*}{2\pi c e} > \frac{\dot{M}_{\rm w}}{4\pi R_*^2 v_{\rm esc} \mu m_{\rm u}}$$

But we have no idea the tiny mass loss rate of the evolved WDs ...

Revisiting white dwarf pulsars : MHD wind or force free magnetosphere?



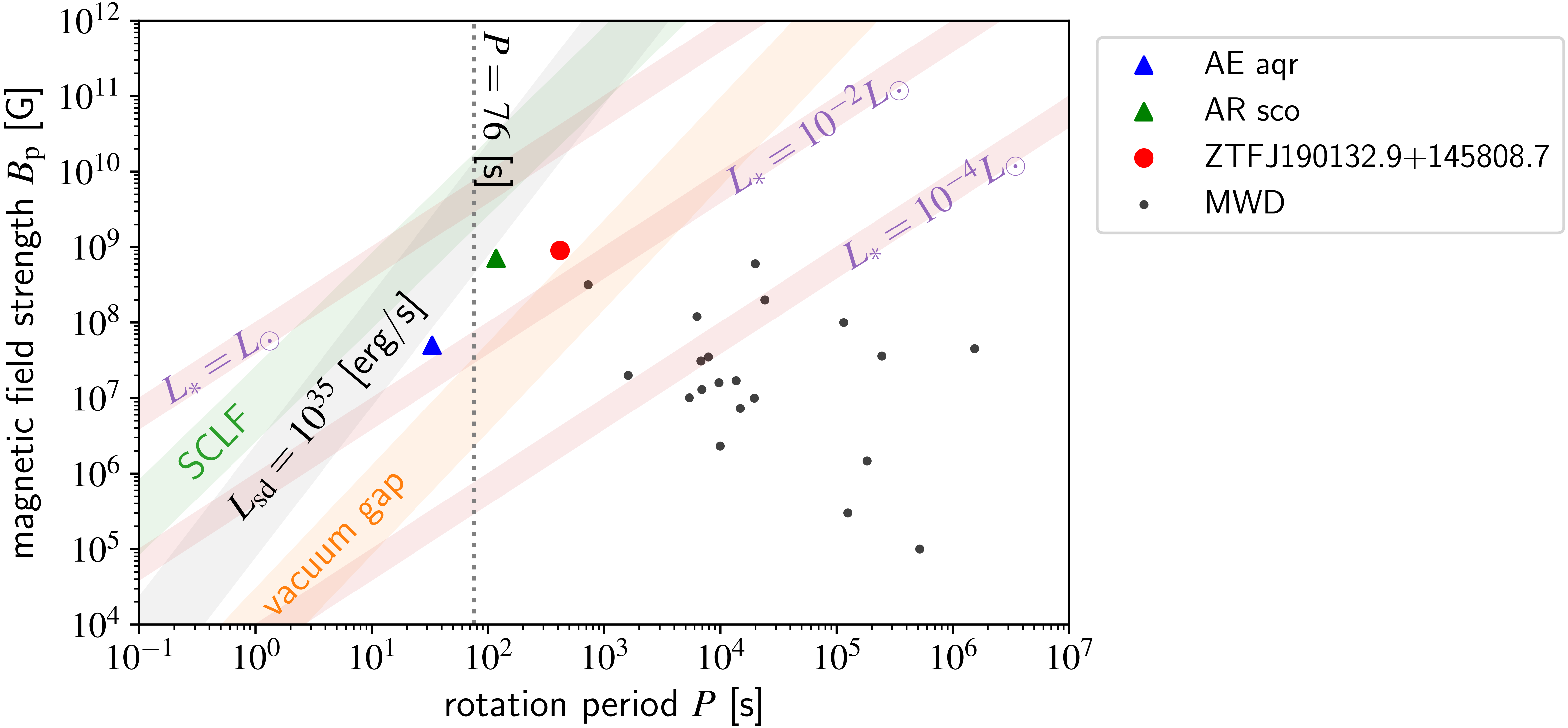
If we assume the same mass loss rate efficiency as our sun, i.e.,

$$\eta \equiv \frac{\dot{M}_\mathrm{w} v_\mathrm{esc}^2}{2L_*} \sim 3 \times 10^{-6}$$

then, the WD pulsar birth condition can be described as

$$n_\mathrm{GJ} = \frac{B_* \Omega_*}{2\pi c e} > \frac{\dot{M}_\mathrm{w}}{4\pi R_*^2 v_\mathrm{esc} \mu m_\mathrm{u}}$$

$$\Longleftrightarrow \quad \left(\frac{B_*}{10^8\,\mathrm{G}}\right)\left(\frac{\Omega_*}{0.1\,\mathrm{s}^{-1}}\right) \gtrsim 24 \left(\frac{\eta}{3\times 10^{-6}}\right)\left(\frac{M_*}{1\,M_\odot}\right)^{-3/2}\left(\frac{R_*}{0.007\,R_\odot}\right)^{-1/2}\left(\frac{L_*}{L_\odot}\right)$$



magnetic field strength B_p [G]
rotation period P [s]
$P = 76$ [s]
$L_* = L_\odot$
$L_* = 10^{-2} L_\odot$
$L_* = 10^{-4} L_\odot$
SCLF
$L_{sd} = 10^{35}$ [erg/s]
vacuum gap
AE aqr
AR sco
ZTFJ190132.9+145808.7
MWD

3. “classical” outflows

[vsnet-alert 26131] Outburst of RS Ophiuchi

KEITH GEARY keithgeary95@gmail.com via vsnet-alert vsnet-alert at ooruri.kusastro.kyoto-u.ac.jp
Mon Aug 9 07:35:21 JST 2021

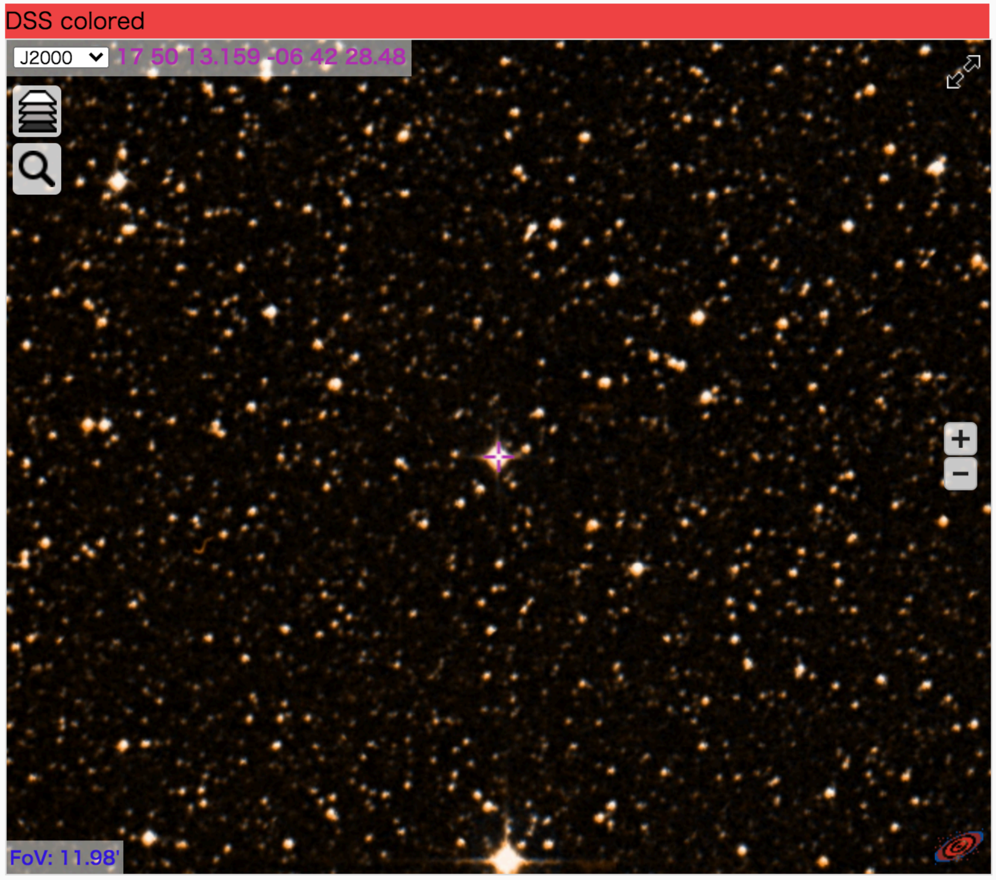
- Previous message (by thread): [vsnet-alert 26130] Re: ASASSN-21pf: new transient (mag. 13.7) in Pegasus
- Next message (by thread): [vsnet-alert 26132] Outburst of RS Ophiuchi
- **Messages sorted by:** [date] [thread] [subject] [author]

Hello CBAT/ all , I wish to report the visual outburst of recurrent nova
RS Ophiuchi as follows:

Current Observation Information: (as of time of sending)

Observer: Keith Geary, 1 Annaghieran Lodge, Killann,Shercock, County Cavan,
Ireland.
Telephone +353(0)429691618, Mobile +353(0)874133227

Place of observation: Dunbratton County Waterford , Ireland
Date and UT of observation: 08 August 2021 2220UT
Object Confirmed Via: Binoculars/DSLR
Estimated Magnitude: 5.0
Observer Location & latitude: 52 16 35N
7.3 degrees West
Limiting magnitude (visual - naked eye): 6.0
Seeing (1 to 5 - best to worst): 3
Charts Used: AAVSO chart X20922HZC
Moon up (phase?): no
Instrument: 20x100mm binoculars
Filters used: none
Object: Recurrent Nova
Constellation: ophiuchus
Contact E-mail Address: keithgeary95 at gmail.com



Fermi-LAT Gamma-ray Detection of the Recurrent Nova RS Oph

ATel #1

& INFN

Subjects

Spectroscopic Follow-up Observation of the 2021 outburst of the recurrent nova RS Ophiuchi

A

Subje

Detection of VHE gamma-ray emission from the recurrent nova RS Ophiuchi with H.E.S.S.

Cr

Subjects: (

NICER X-ray observations of the recurrent nova RS Ophiuchi

ATel #14850; Teruaki En
Observatory of Japan), M
Andrew Fabian (IoA, Camb
(NASA/GSFC), Zaven A
Institute for Astrophysics
Maryland, CRESS

Credential Certifi

Subjects: X-ray, Nova

AMI-LA, e-MERLIN and MeerKAT radio detections of RS Oph in outburst

ATel #14849; *David Williams (JBCA/Manchester), Tim O'Brien (JBCA/Manchester), Patrick Woudt (UCT), Miriam Nyamai (UCT), Dave Green (MRAO, Cambridge), David Titterington (MRAO, Cambridge), Rob Fender (Oxford), Greg Sivakoff (U. Alberta)*

*on **11 Aug 2021; 19:59 UT***

Credential Certification: Tim O'Brien (tim.obrien@manchester.ac.uk)

Subjects: Radio, Nova

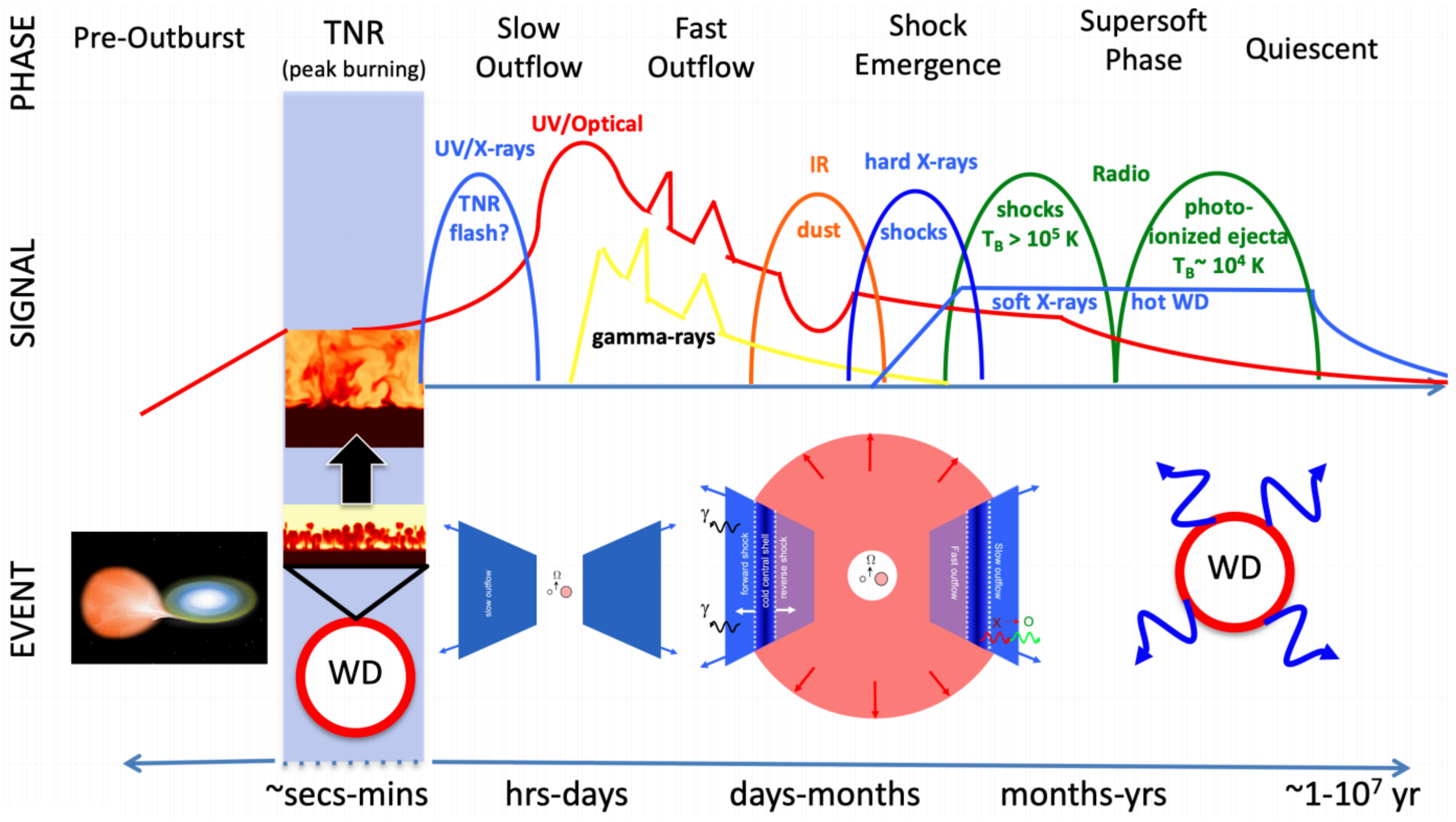
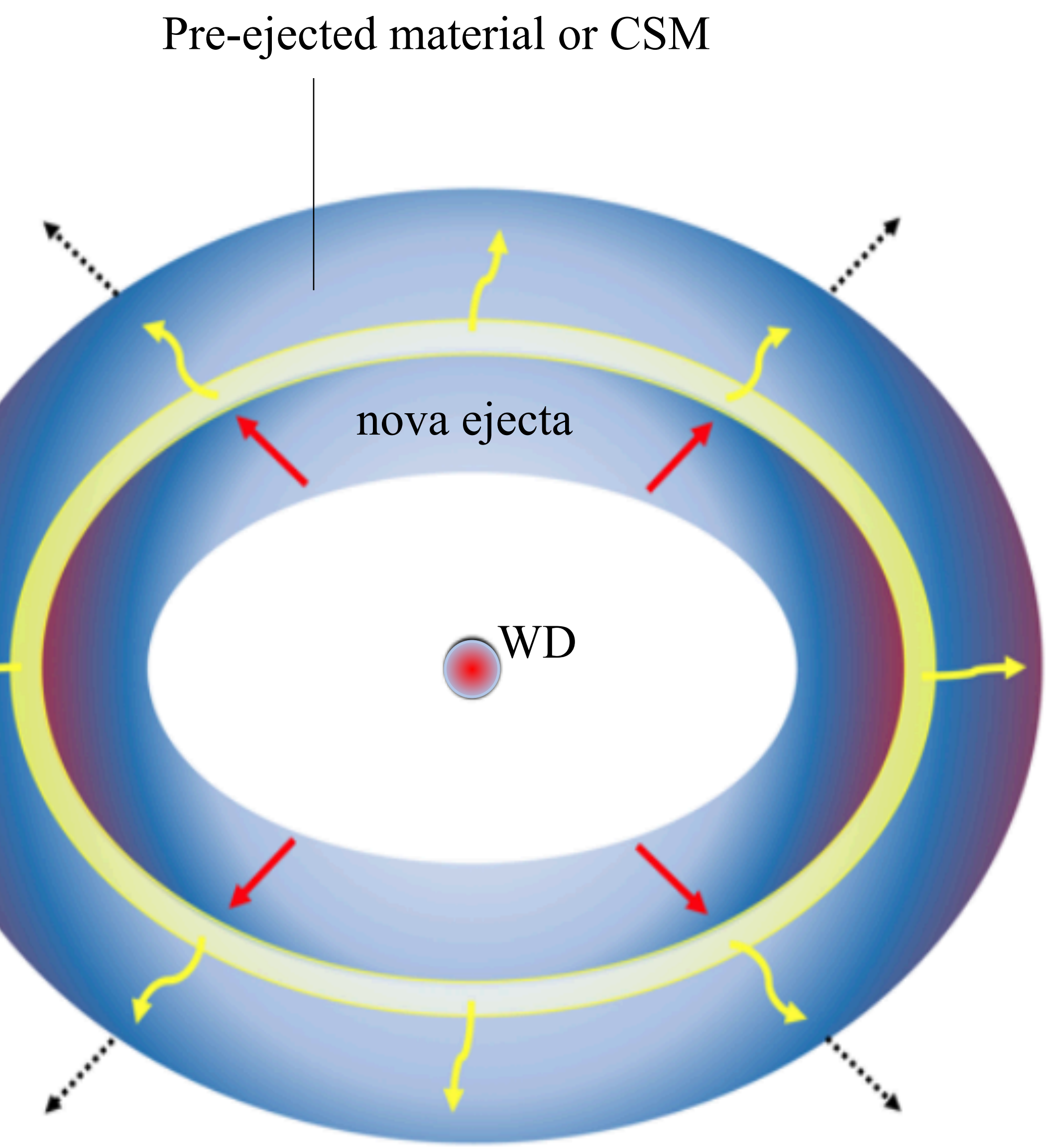
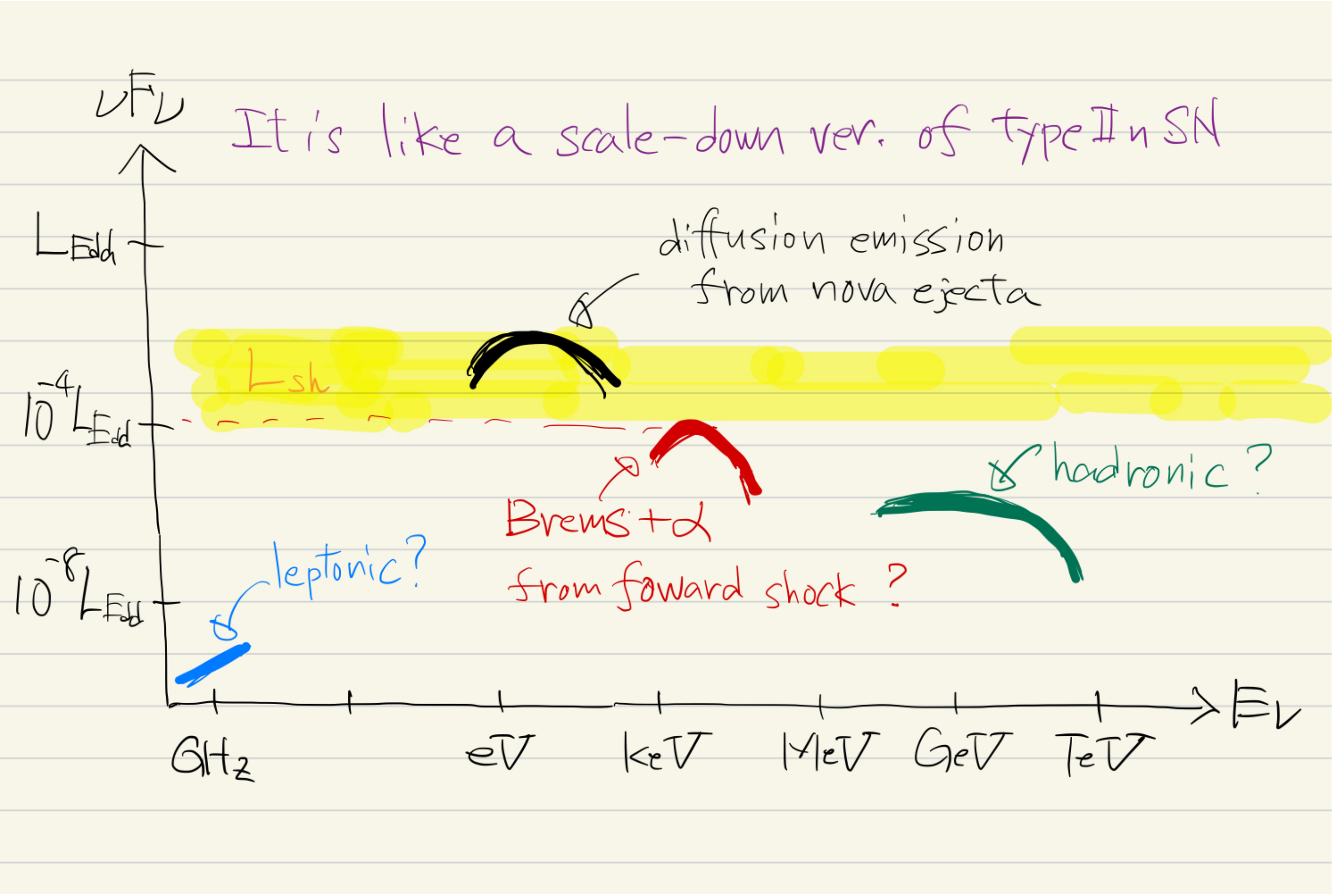


Figure taken from Chomiuk et al. 2020



@ a few days after the eruption



$$L_{\rm sh} \approx \frac{\dot{M}_{\rm w}}{2v_{\rm w}} v_{\rm ej}^3 \rightarrow L_X, L_\gamma, L_{\rm radio}$$

$$L_X \rightarrow {\rm EM} \sim 4\times 10^{56}\,{\rm cm}^{-3} \left(\frac{\dot{M}_{\rm w}}{10^{-7}\,M_\odot/{\rm yr}}\right)^2 \left(\frac{v_{\rm w}}{10^7\,{\rm cm/s}}\right)^{-2} \left(\frac{t}{3\,{\rm day}}\right)^{-1} \left(\frac{v_{\rm ej}}{10^8\,{\rm cm/s}}\right)^{-1}$$

$$E_{\rm CR,max} \rightarrow B \sim 0.33\,{\rm G} \left(\frac{v_{\rm ej}}{10^8\,{\rm cm/s}}\right)^{-2} \left(\frac{t}{3\,{\rm day}}\right) \left(\frac{E_{\rm CR,max}}{10\,{\rm TeV}}\right)$$

$$\text{or} \quad \epsilon_B \sim 0.01 \left(\frac{\dot{M}_{\rm w}}{10^{-7}\,M_\odot/yr}\right)^{-1} \left(\frac{v_{\rm w}}{10^8\,{\rm cm/s}}\right) \left(\frac{v_{\rm ej}}{10^8\,{\rm cm/s}}\right)^{-4} \left(\frac{E_{\rm CR,max}}{10\,{\rm TeV}}\right)^2$$

$$L_\gamma \rightarrow \xi_{\rm CR} \gtrsim 3 \left(\frac{\dot{M}_{\rm w}}{10^{-7}\,M_\odot/{\rm yr}}\right)^{-2} \left(\frac{v_{\rm w}}{10^7\,{\rm cm/s}}\right)^2 \left(\frac{t}{3\,{\rm day}}\right) \left(\frac{v_{\rm ej}}{10^8\,{\rm cm/s}}\right)^{-1}$$

Summary :
Outflows from Dwarfs

- ***Ultra fast outflow***
  - ✓ White dwarf merger remnants
    - A repeating FRB in a globular cluster
    - IRAS 00500+6713

- ***Coherent plasma outflow***
  - ✓ Ultra short duration flares from M dwarfs
  - ✓ Revisiting white dwarf pulsar
    - ~ 7min rotating strongly magnetized massive WD discovered by ZTF
    - Coherent radio emission from 76 sec & 1000 sec rotators?

- ***"Classical" outflow***
  - ✓ Nova ejecta and multiwavelength emission
    - Recent nova event from RS Oph