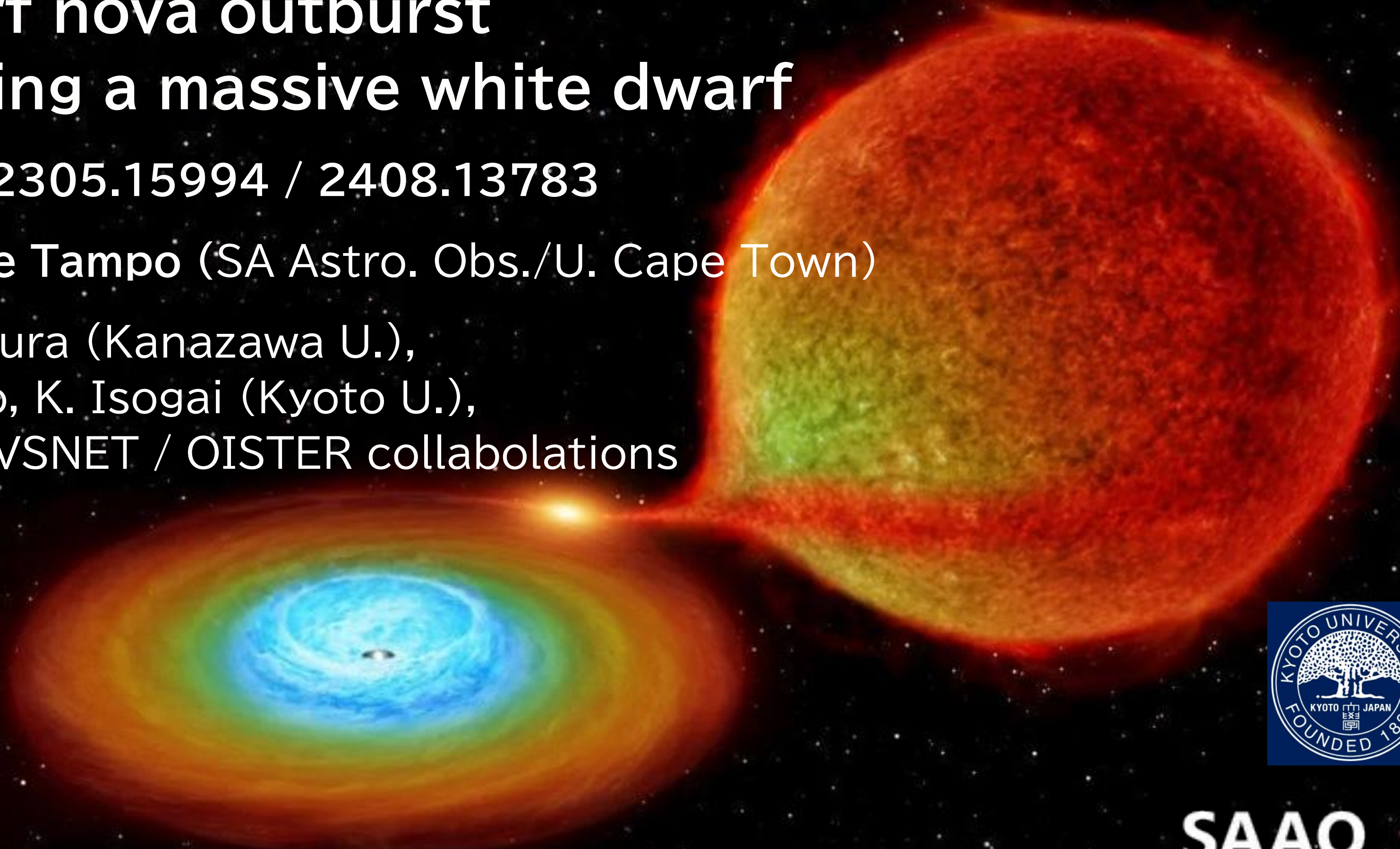
A record-breaking energetic dwarf nova outburst hosting a massive white dwarf

arxiv: 2305.15994 / 2408.13783

Yusuke Tampo (SA Astro. Obs./U. Cape Town)

M. Kimura (Kanazawa U.),
T. Kato, K. Isogai (Kyoto U.),
& VSNET / OISTER collabolations



Cataclysmic variables and dwarf novae

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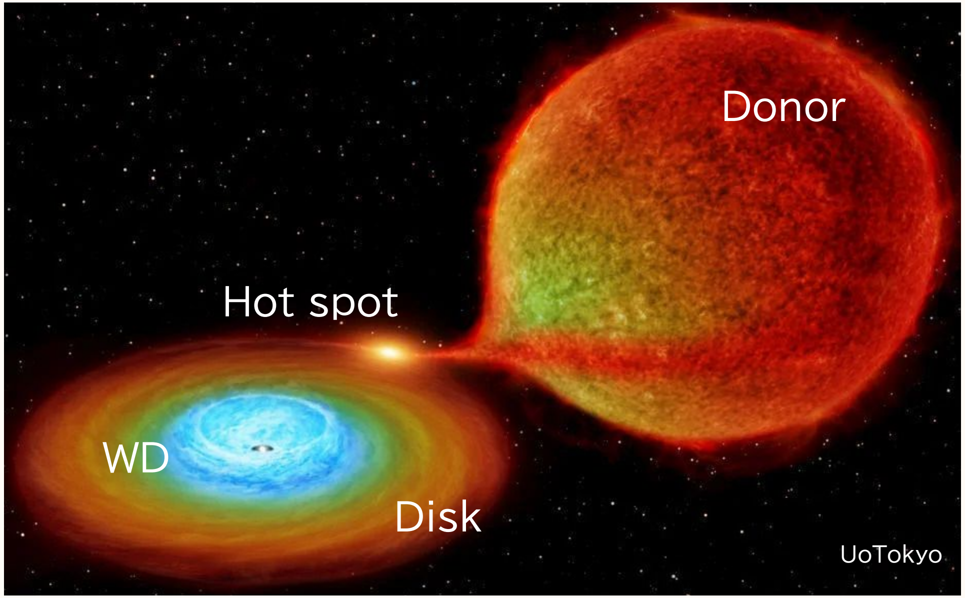

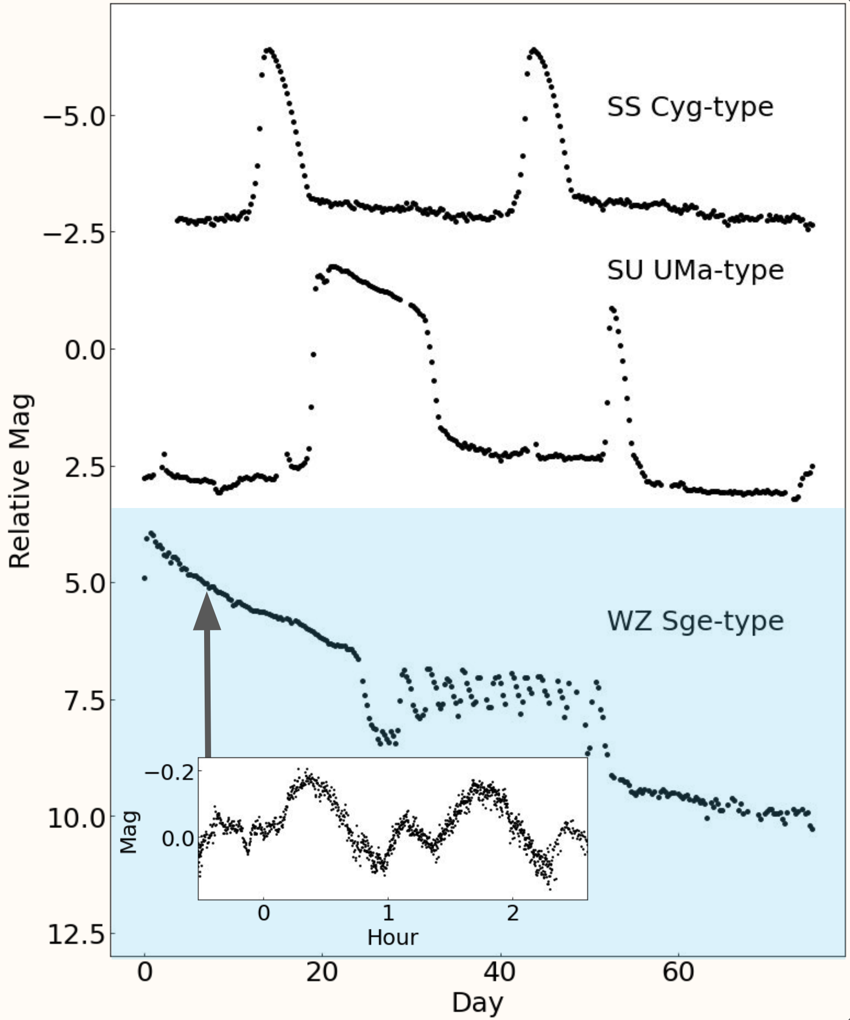

Various amplitude/duration/variations ⋯
: **disk instability model**
(see Osaki 96, Lasota 00)

Established before transient survey era
→ **unique systems from large samples?**

Disk instability model in dwarf nova outbursts

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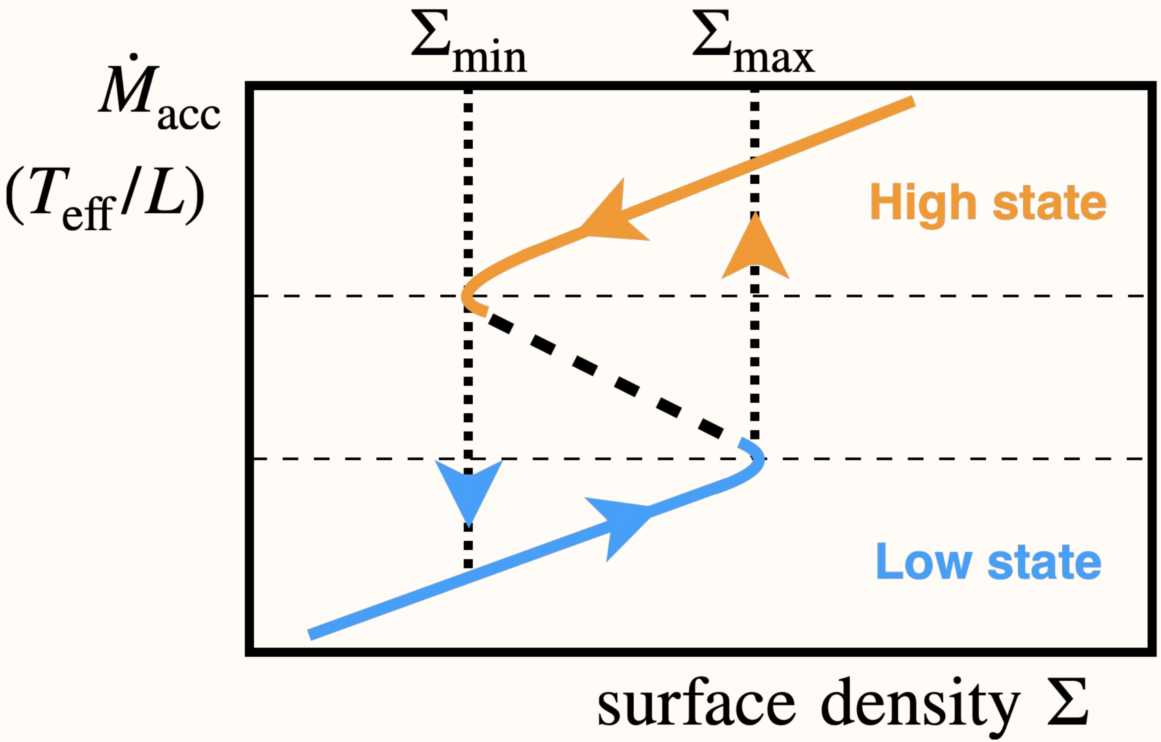
Simplest laboratory of accretion disk physics + many bright systems

Balance b/w viscosity heating & radiation cooling in disk

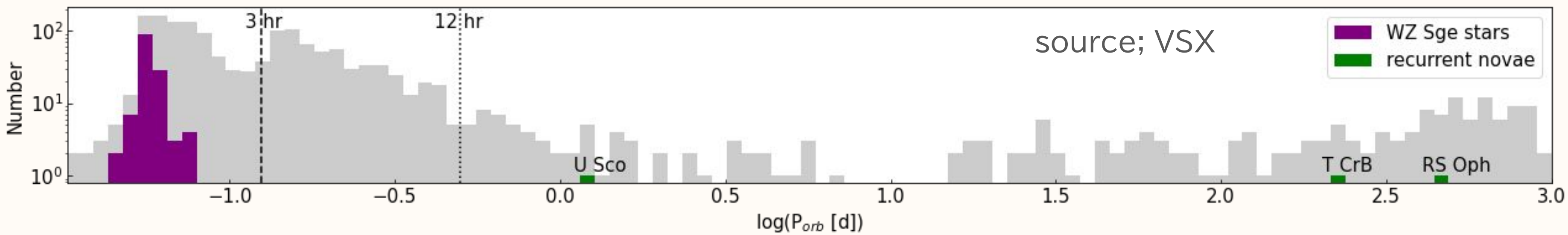
high state : ionized, high viscosity / accretion rate / luminosity

low state : neutral, low viscosity / accretion rate / luminosity

e.g. Osaki 74
Hoshi 79
Mayer+ 81



CV binary evolution – progenitor of SN Ia / AIC?



CV w/ MS donor

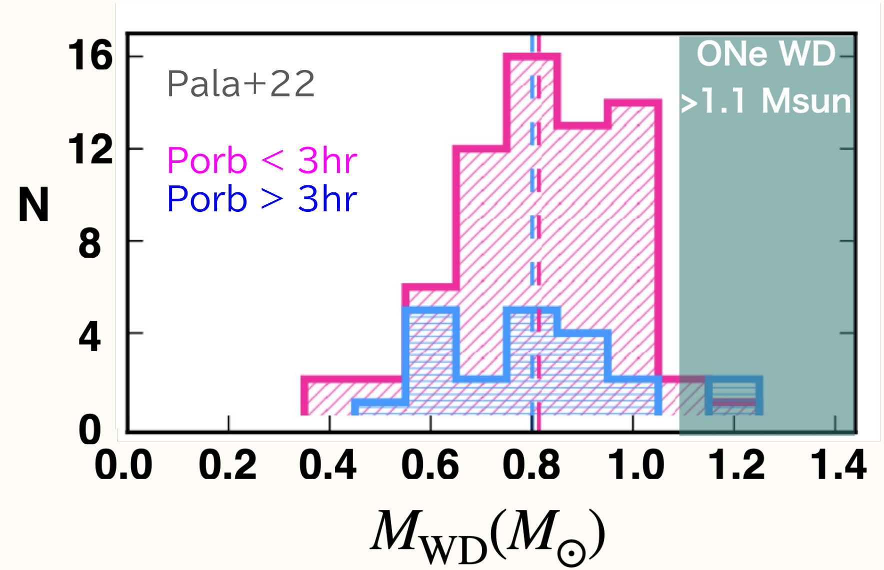
Sub-giant / giant donor → thermal timescale

Standard CV evolve to shorter Porb
due to angular momentum loss

- no evidence of WD mass growth
- no confirmed massive WD system

Not likely a progenitor of
- **SN Ia**
- **accretion induced collapse**

***Long Porb system could be a progenitor



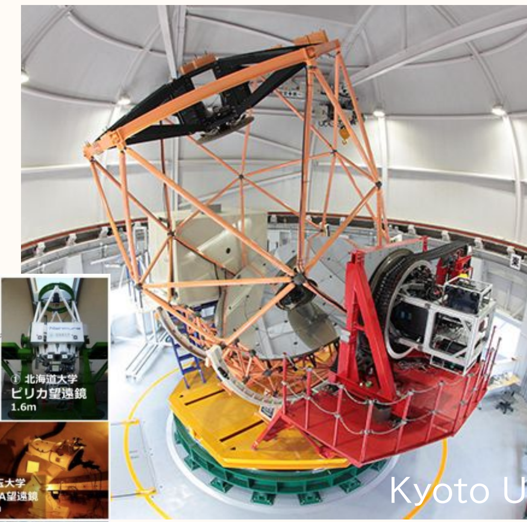
MASTER OT J030227.28+191754.5

12-mag transient as a possible optical counterpart of the IceCube neutrino event
- ~22 mag UV/optical source in GALEX/SDSS → Galactic source?

Zhirkov+21 ATel #15067

Optical observations (PI: YT – arxiv 2408.13783)
- Seimei 3.8m telescope in Japan
- VSNET: pro + amateur variable star collabolation
- OISTER: small-mediam telescope network in Japan

X-ray observations (PI: M. Kimura – arxiv 2305.15994)
- NICER
- NuSTAR



J0302 – overall optical light curve

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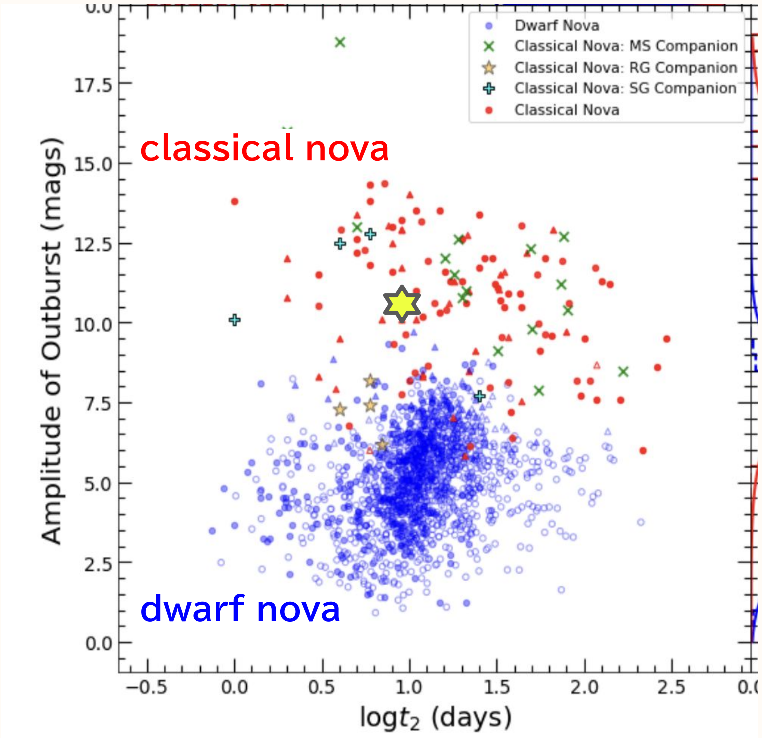
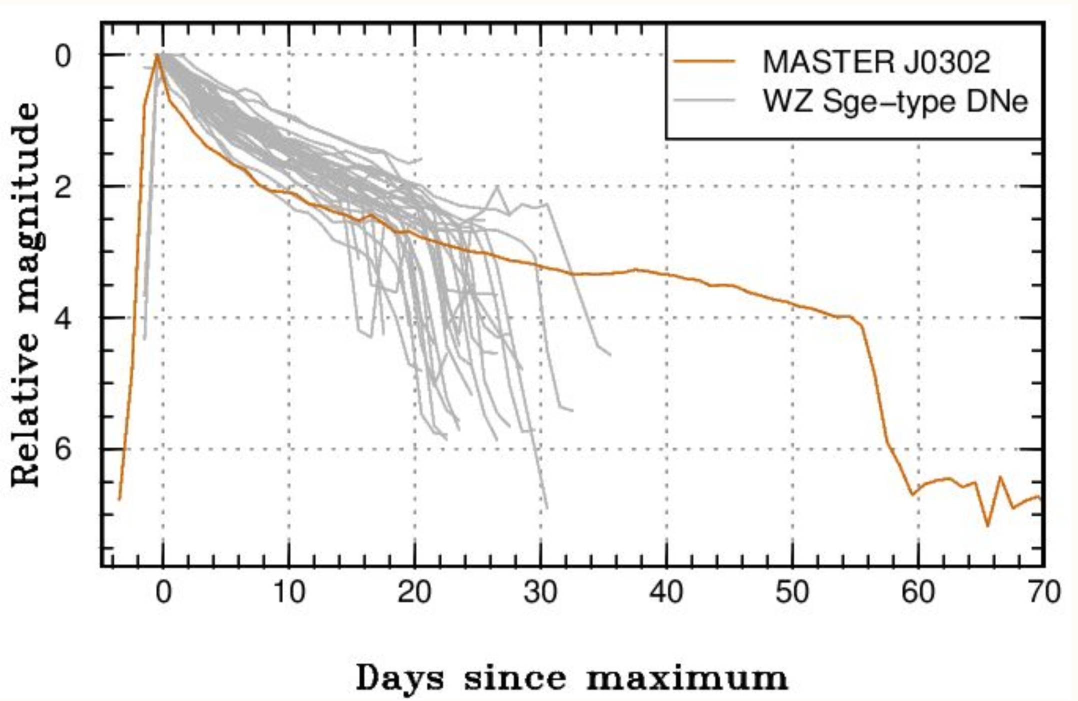
10.2 mag amplitude & 60 d duration (~7 mag amplitude at discovery)
: classical nova? extreme dwarf nova? or anything exciting?



Kawash+21



J0302 as a WZ Sge-type dwarf nova

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Double-peaked emission lines → disk origin
Early & ordinary superhumps → WZ Sge-type DN

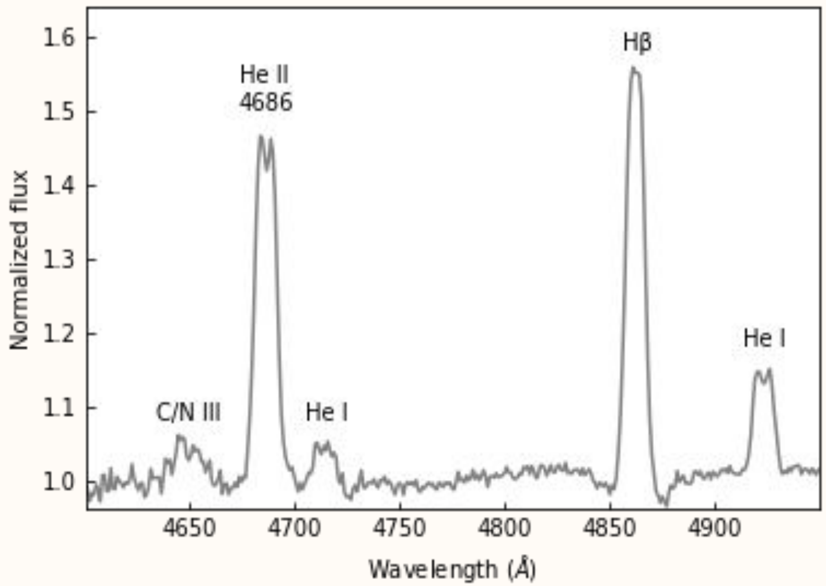
} not a neutrino source – BL Lac AGN activity?

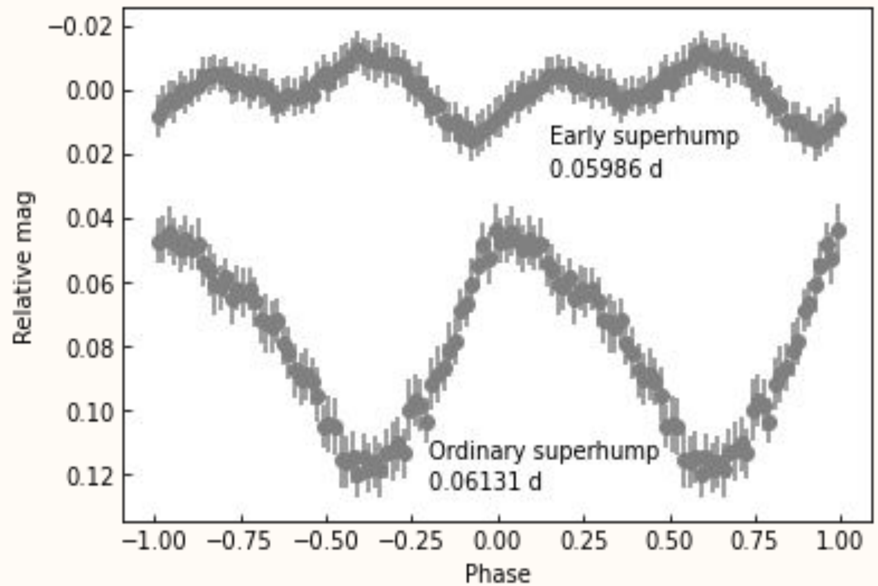
Paiano+21; ATel 15085

Orbital period = 0.05986 d (86.2 min)
Mass ratio (M_2/M_WD)= 0.063(1)

For WZ Sge stars; Kato 15

Except its outburst amplitude & duration,
very typical binary parameters and behaviours as a WZ Sge-type DN





J0302 outburst in X-rays

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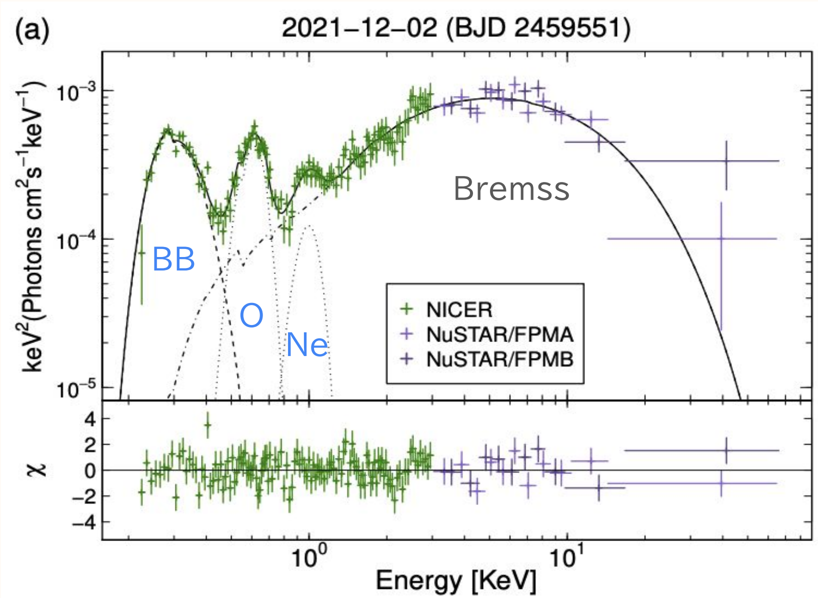

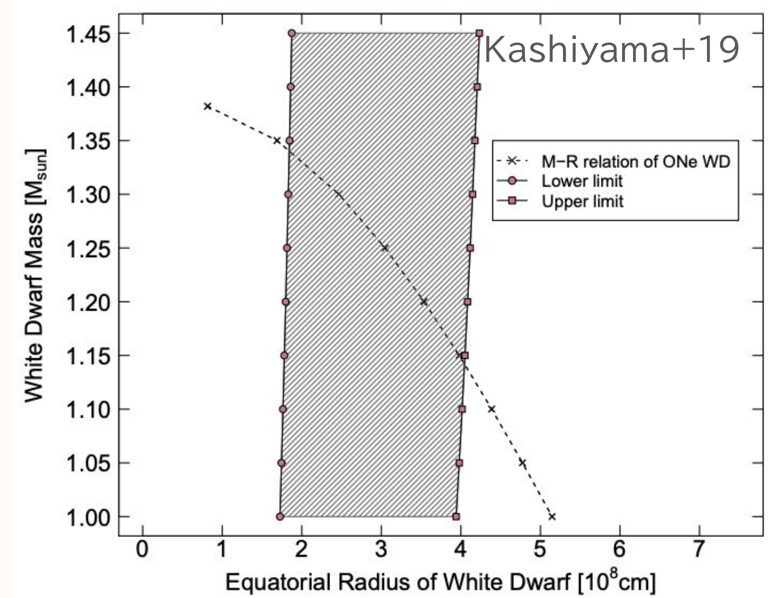

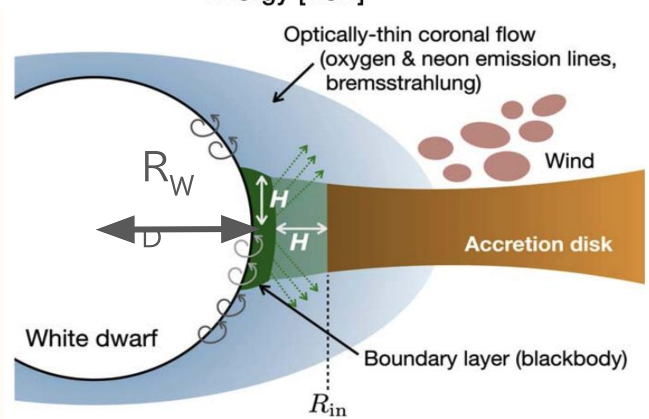

ONe WD

WD radius: $(2.9 \pm 1.1) \times 10^8$ cm

WD mass: 1.15–1.34 M☉

First short Porb & massive-WD CV!

Open question: its binary evolution?

Possible outburst scenario of J0302

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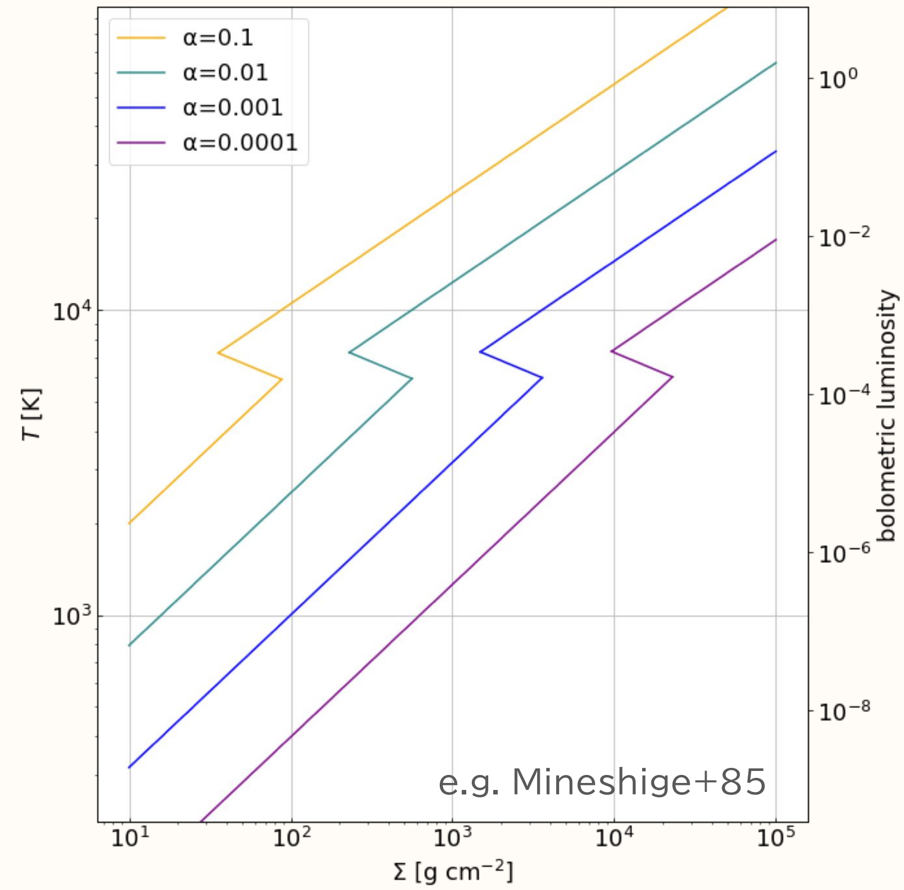
Massive WD + larger disk → brighter disk
: just ~0.35 mag

Poorly-estimated distance + standard disk
suggest **~10^{-6} M⊙/yr** at peak
→ x 100 higher than others!

Lower viscosity in quiescence is the key?

- **larger disk density** to trigger an outburst
  → longer duration
- **higher accretion rate** at outburst
  → larger amplitude



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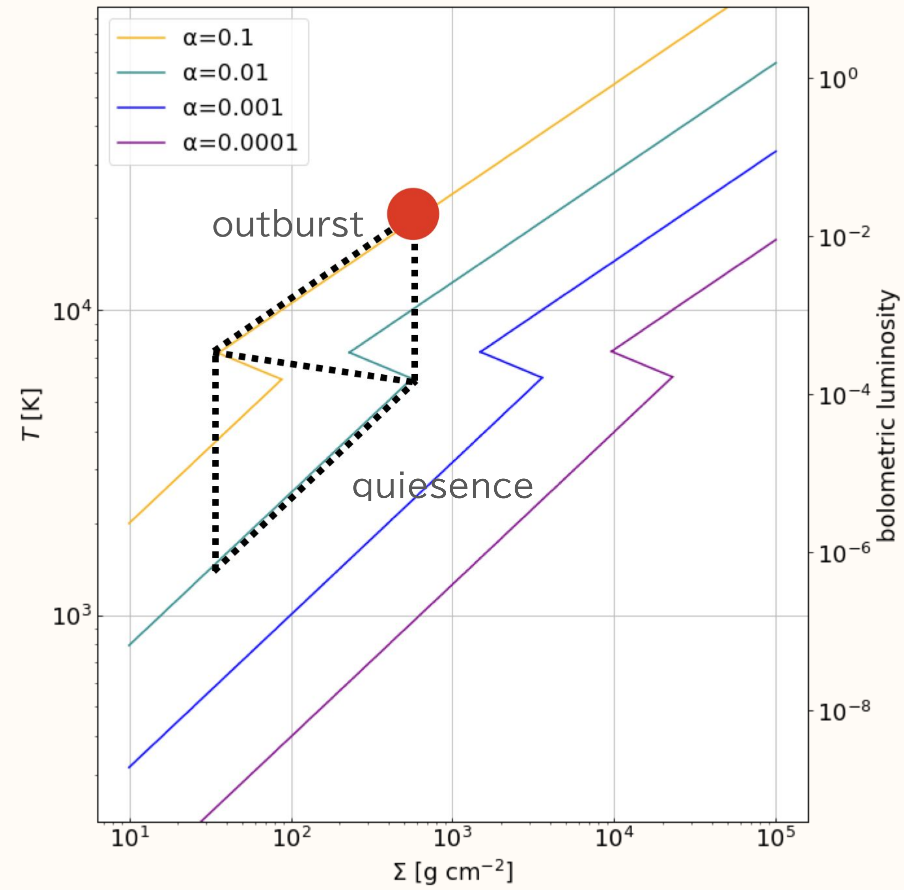

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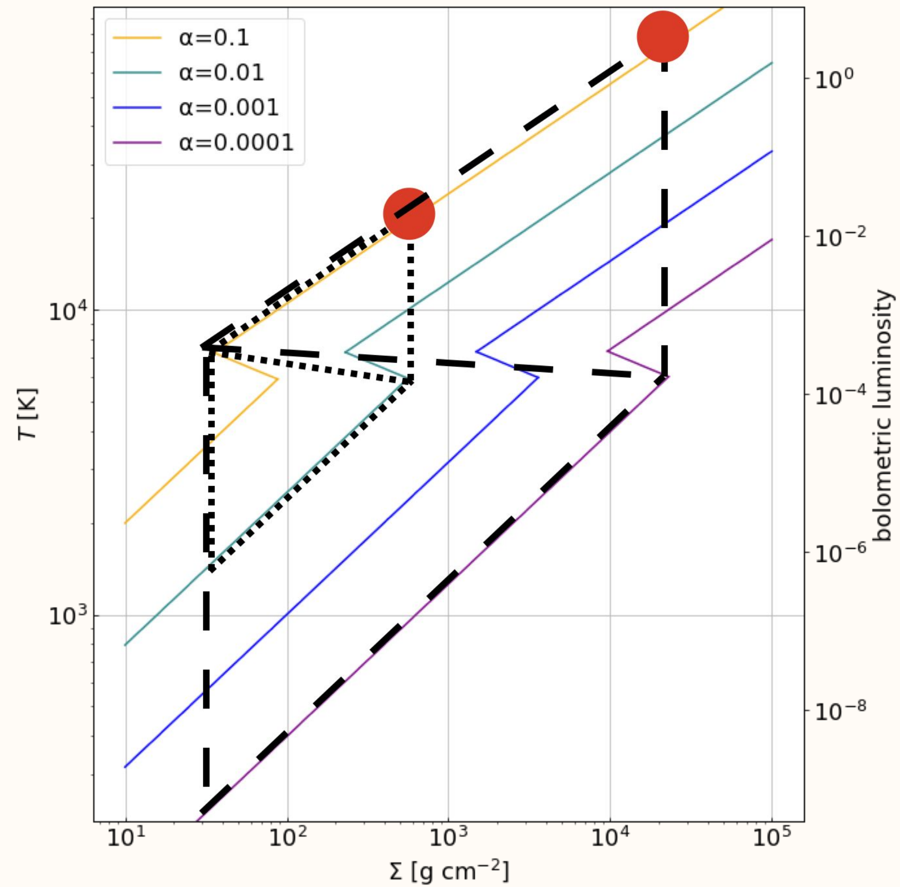

Fate of J0302 – possible AIC progenitor?

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Near-chandrasekhar & ONe WD

⇒ new channel to

: accretion induced collapse progenitor?

: millisecond pulsar?

1 / ~300 known period-bouncing DNe

x space density of CV ~10^{-6} pc^{-3}

x accretion time scale ~Gyr

⇒ **10^{-5} events yr^{-1} $galaxy^{-1}$**

←→ theoretically expected MSP birth rate via AIC

in sub-giant/giant donor star CVs; thermal-timescale mass transfer

: $10^{-4 - -5}$ events yr^{-1} $galaxy^{-1}$ (e.g. Harley+10)

Summary & future works

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MASTER OT J030227.28+191754.5

: 10.2-mag amplitude & 60-d duration dwarf nova outburst → most energetic

From X-ray observations

: likely **> 1.15 $M_\odot$ and ONe WD system**

Large disk around a massive WD cannot explain the outburst

: **quiescence disk viscosity is a key**?

Possible new channel to AIC and MSP

Future works

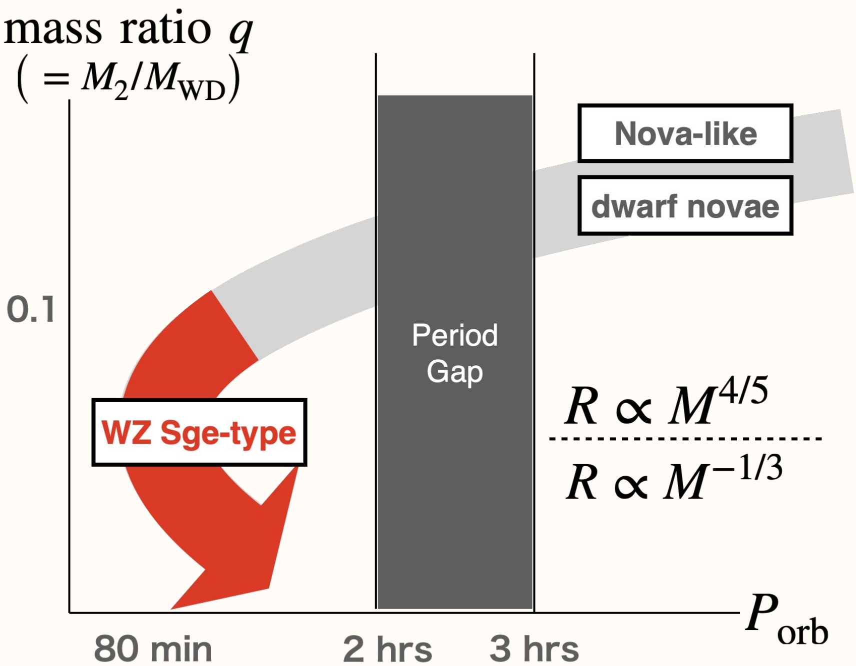
- Quiescence observations to establish its binary parameter, 23 mag tho
- Detailed light curve simulation(s)
- Binary evolution model for J0302

Binary evolution in cataclysmic variables

Toward shorter orbital period
: due to angular momentum loss

Period bounce at ~80 min
: degenerated secondary

(e.g. Knigge+11)

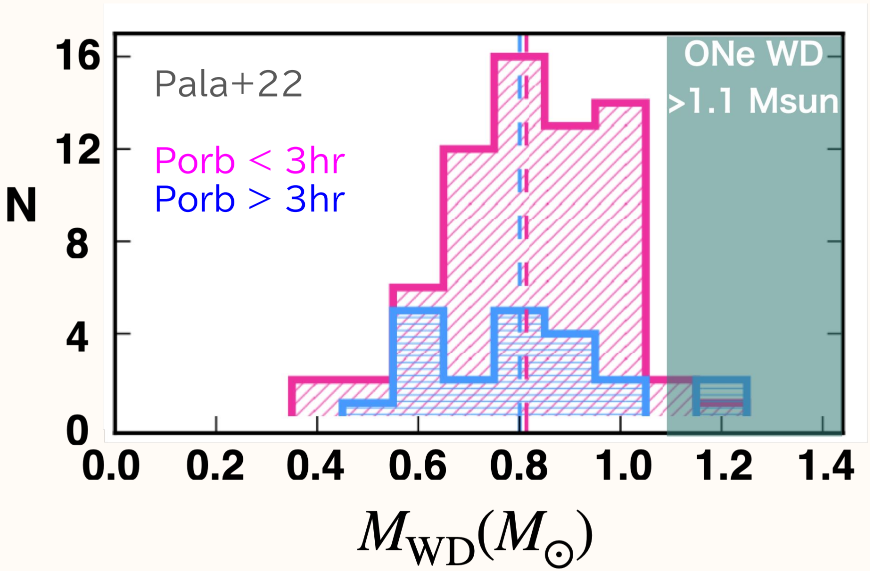


DNe will explode as a SN Ia?

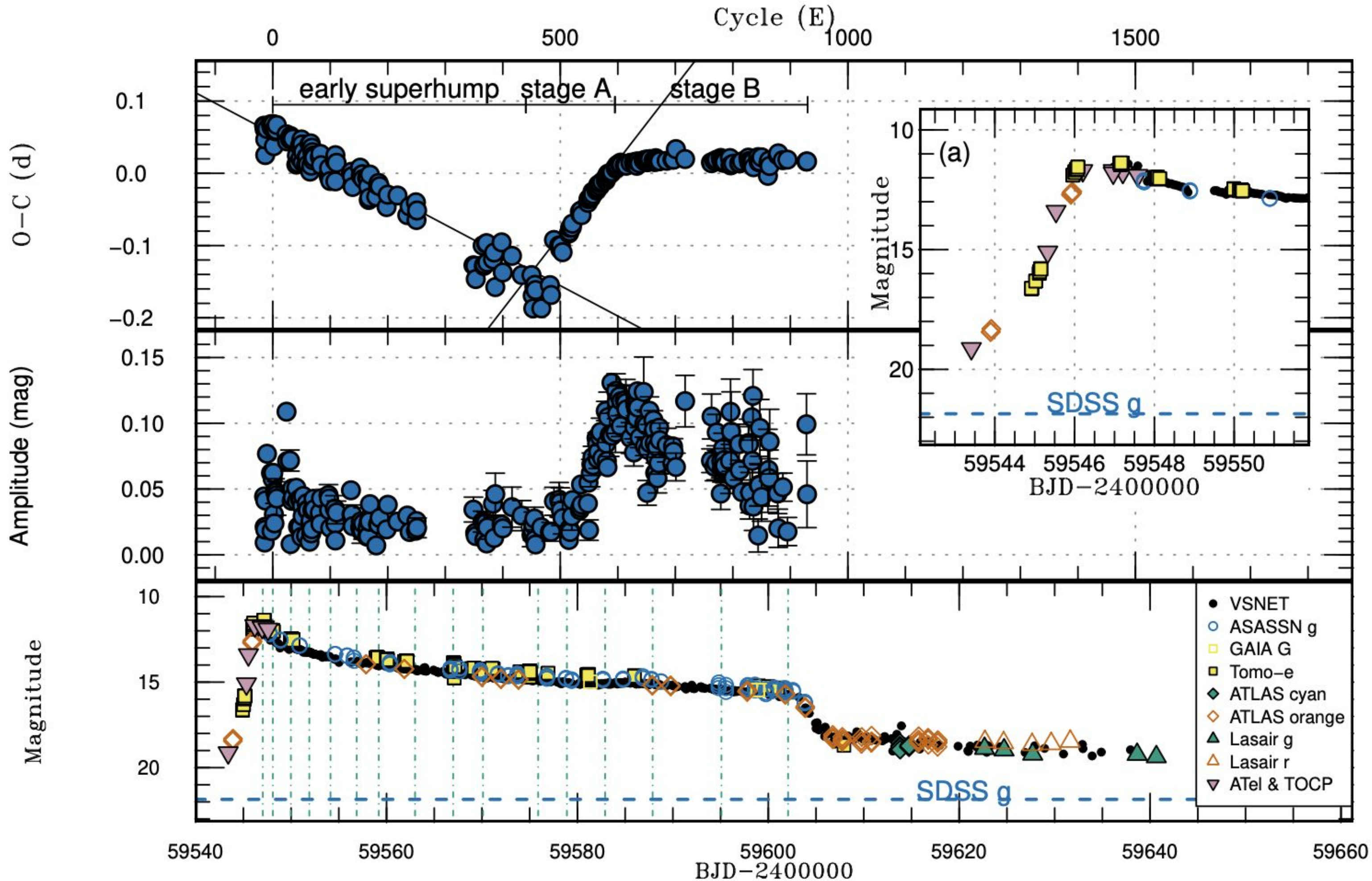
No evidence of WD mass growth
: mass ejection via classical novae

(Zorotovic+11, Pala+22)

Not likely a progenitor of SNe Ia …



Back-ups


Cycle (E)
0
500
1000
1500
early superhump
stage A
stage B
O−C (d)
0.1
0.0
−0.1
−0.2
(a)
Magnitude
10
15
20
SDSS g
59544
59546
59548
59550
BJD−2400000
Amplitude (mag)
0.15
0.10
0.05
0.00
Magnitude
10
15
20
VSNET
ASASSN g
GAIA G
Tomo−e
ATLAS cyan
ATLAS orange
Lasair g
Lasair r
ATel & TOCP
SDSS g
59540
59560
59580
59600
59620
59640
59660
BJD−2400000

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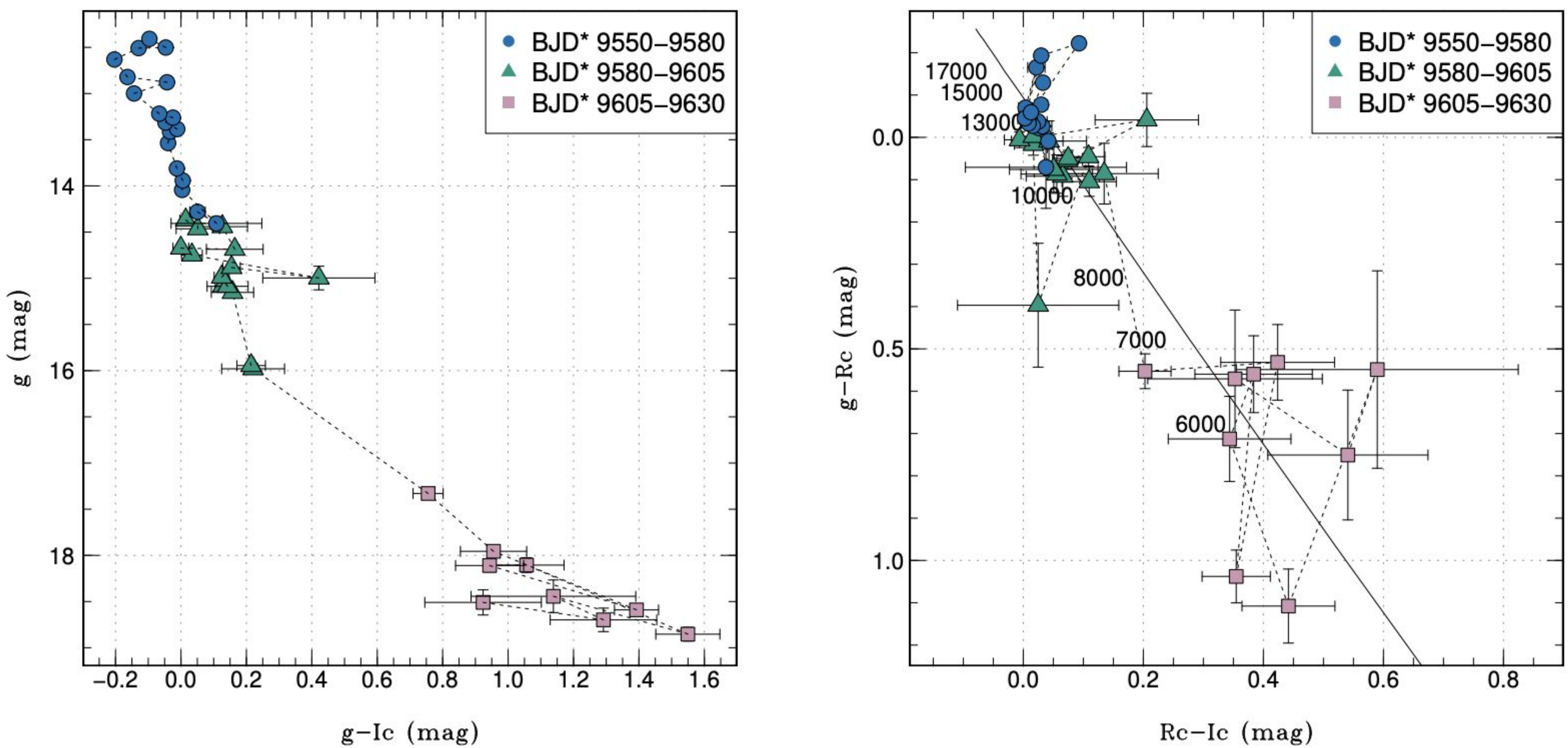
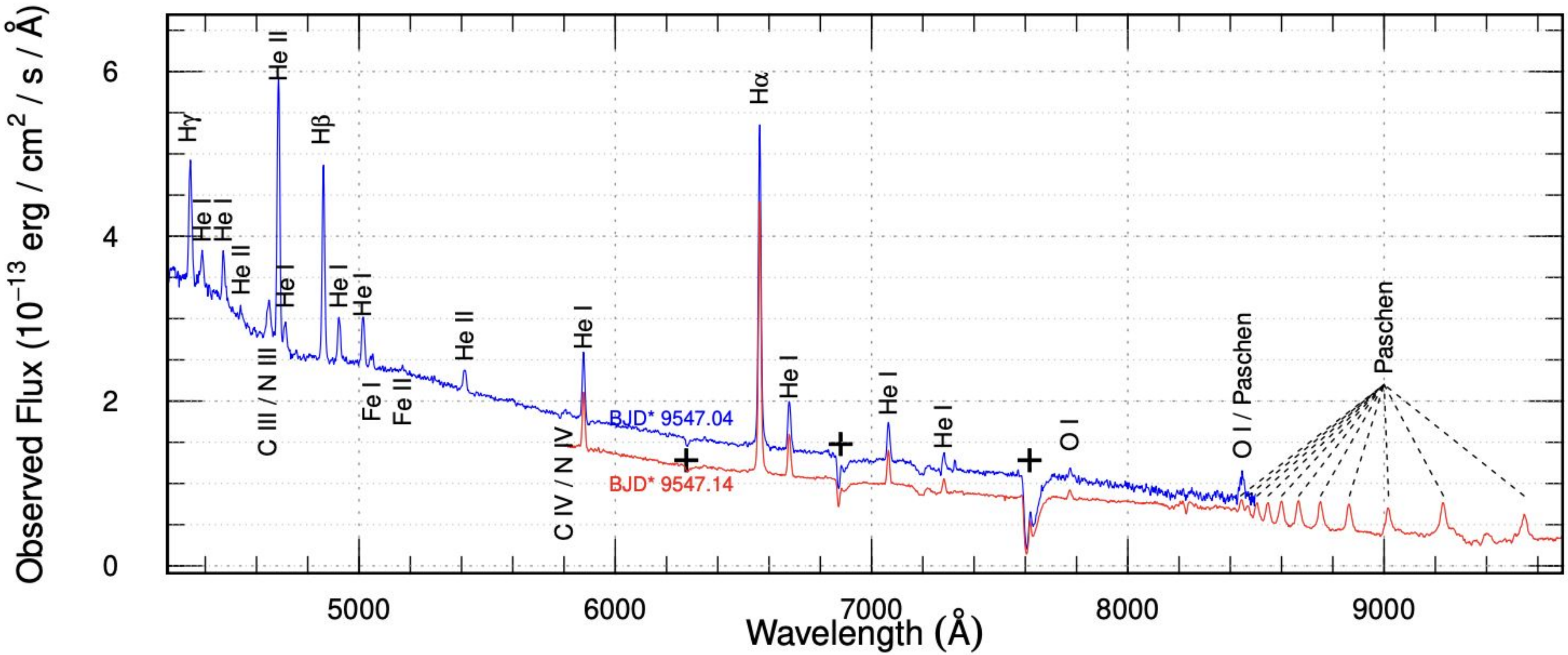


Back-ups


Observed Flux (10^{-13} erg / cm^2 / s / Å)
Wavelength (Å)
0
2
4
6
5000
6000
7000
8000
9000
Hγ
He I
He I
He II
He II
He I
C III / N III
Hβ
He I
He I
Fe I
Fe II
He II
C IV / N IV
He I
BJD* 9547.04
BJD* 9547.14
Hα
He I
He I
He I
O I
O I / Paschen
Paschen

Back-ups

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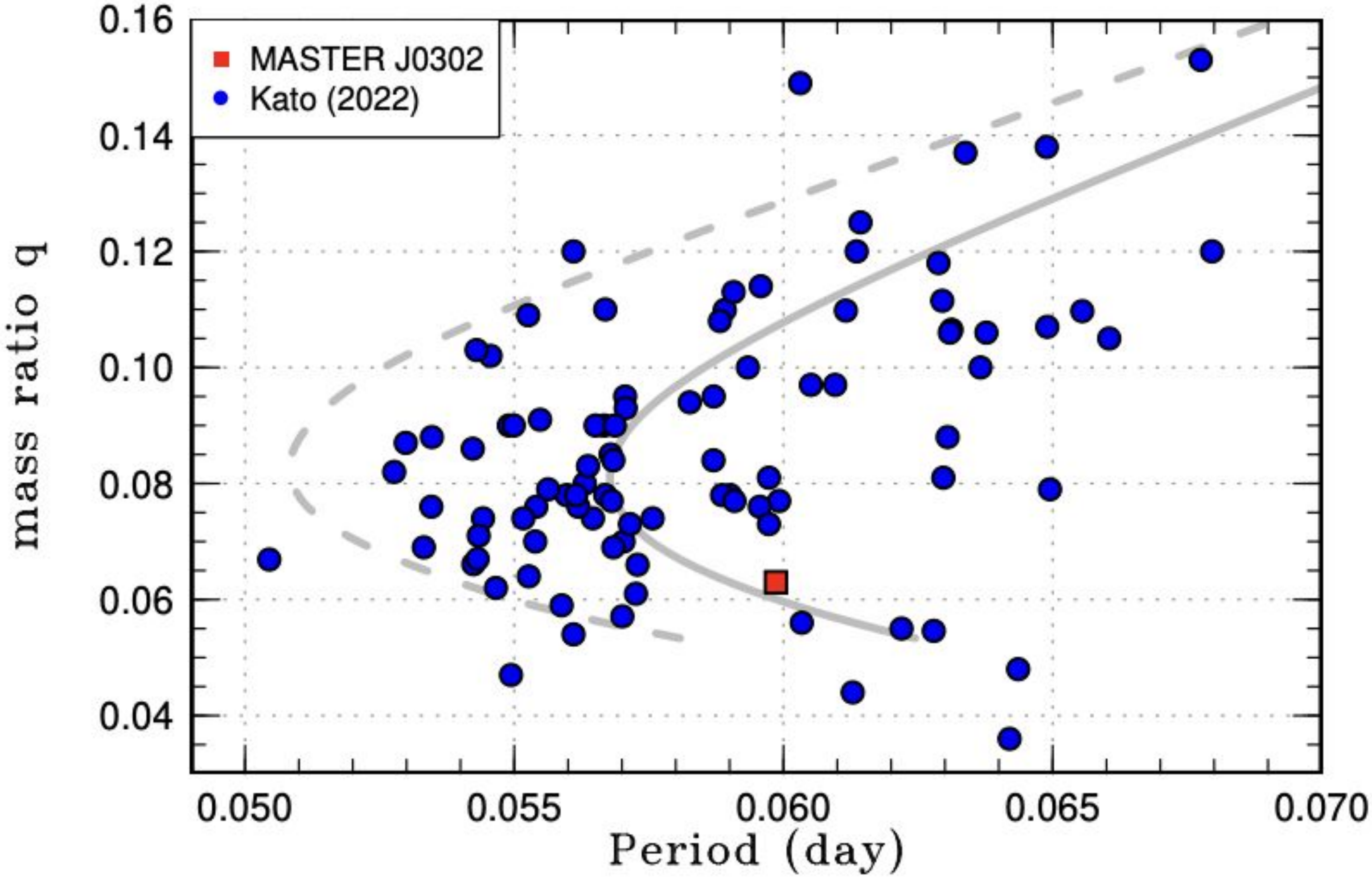

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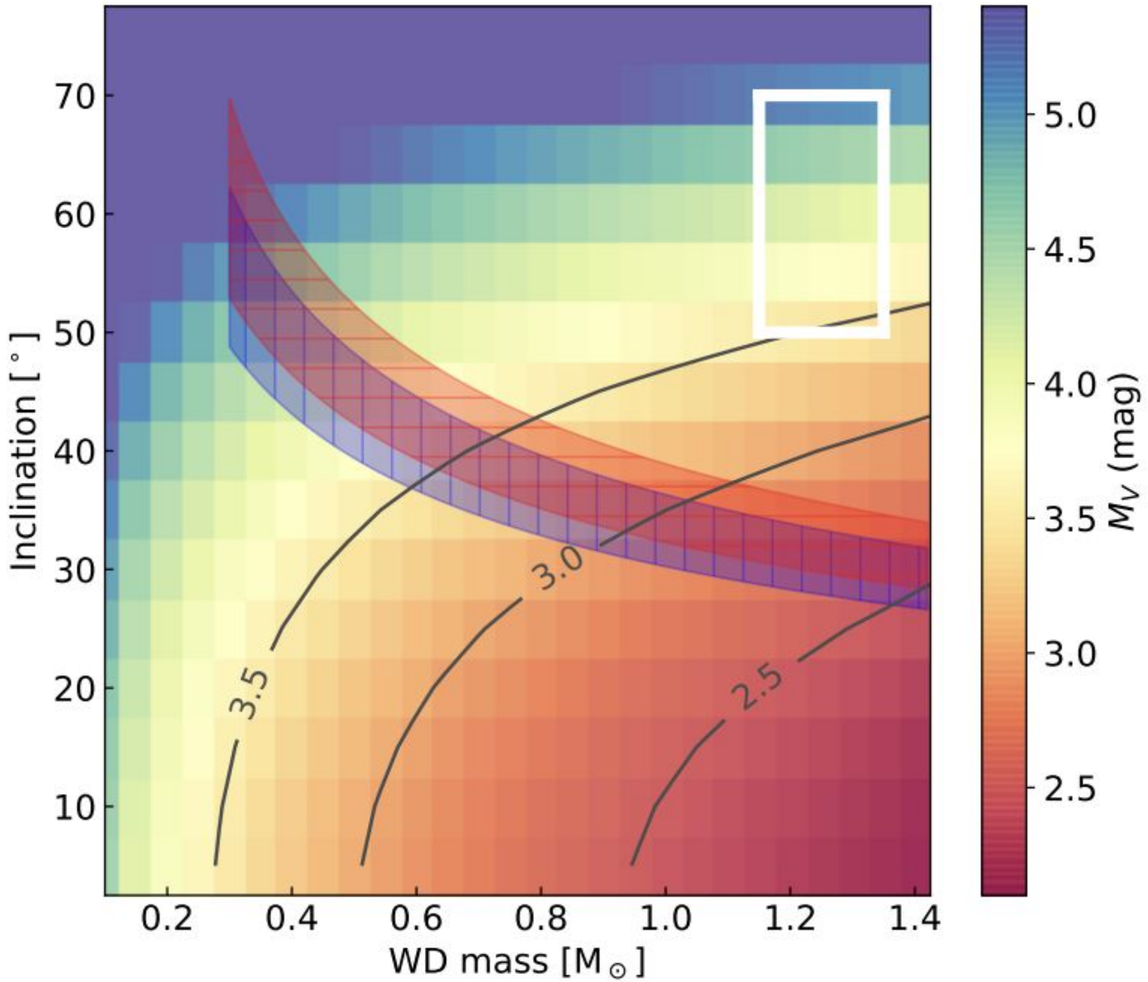

Back-ups

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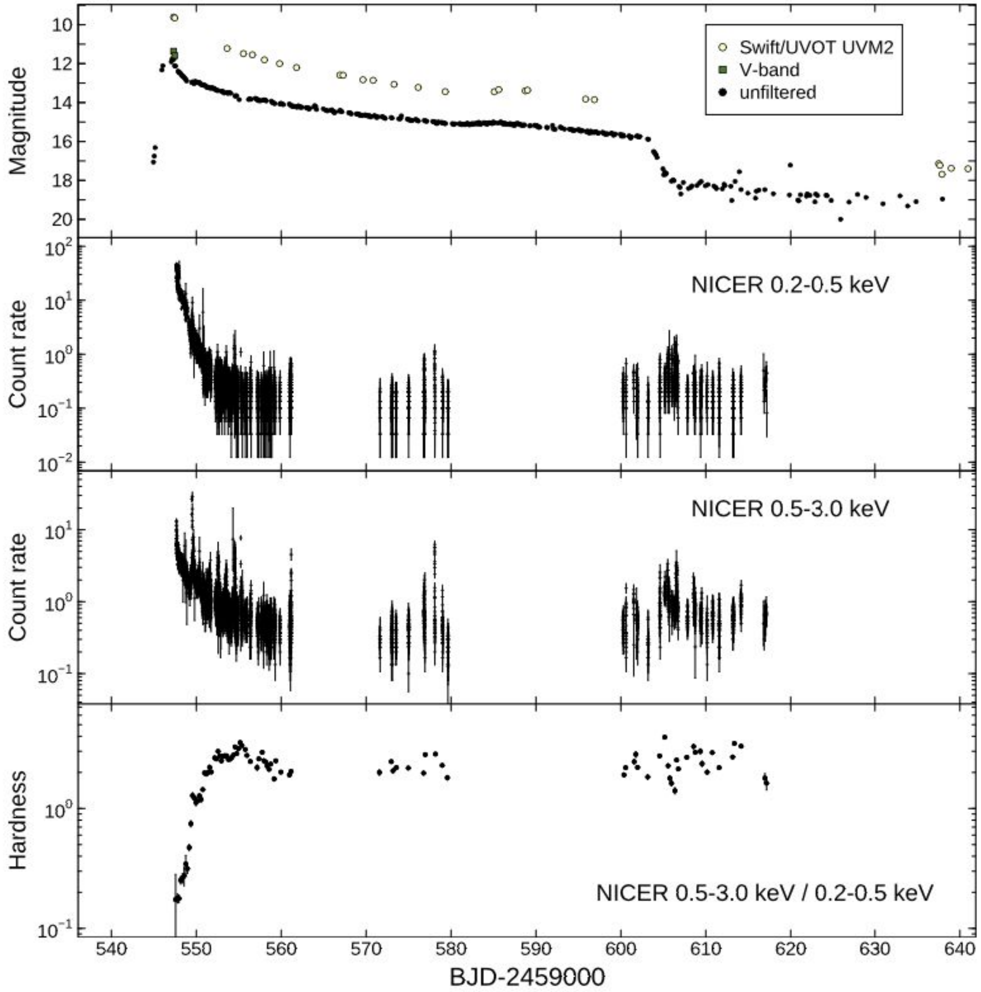


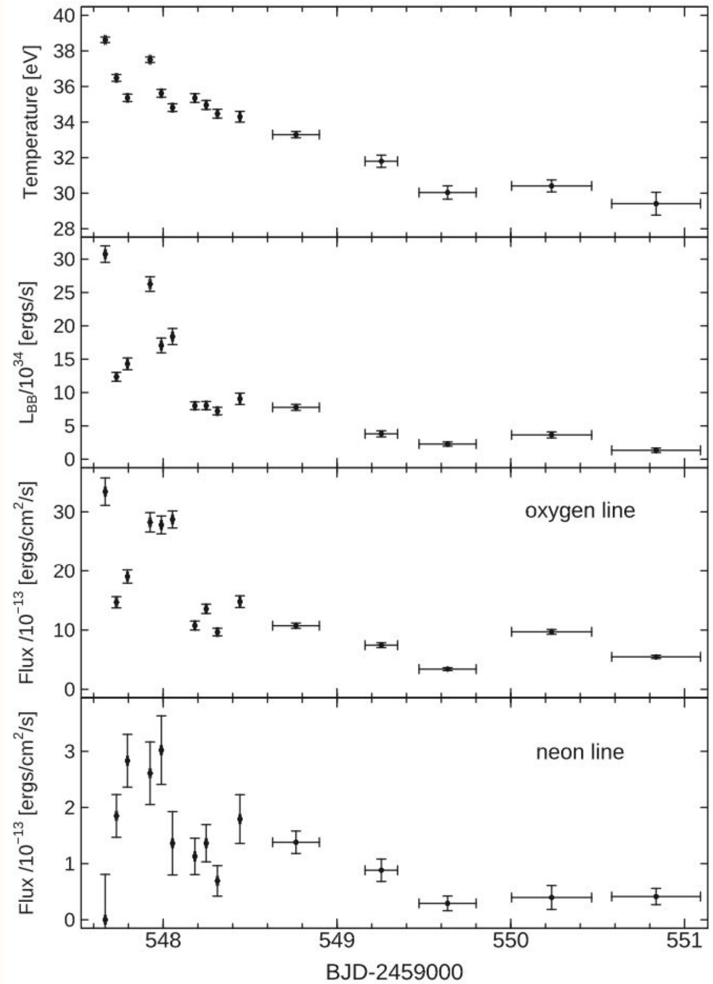
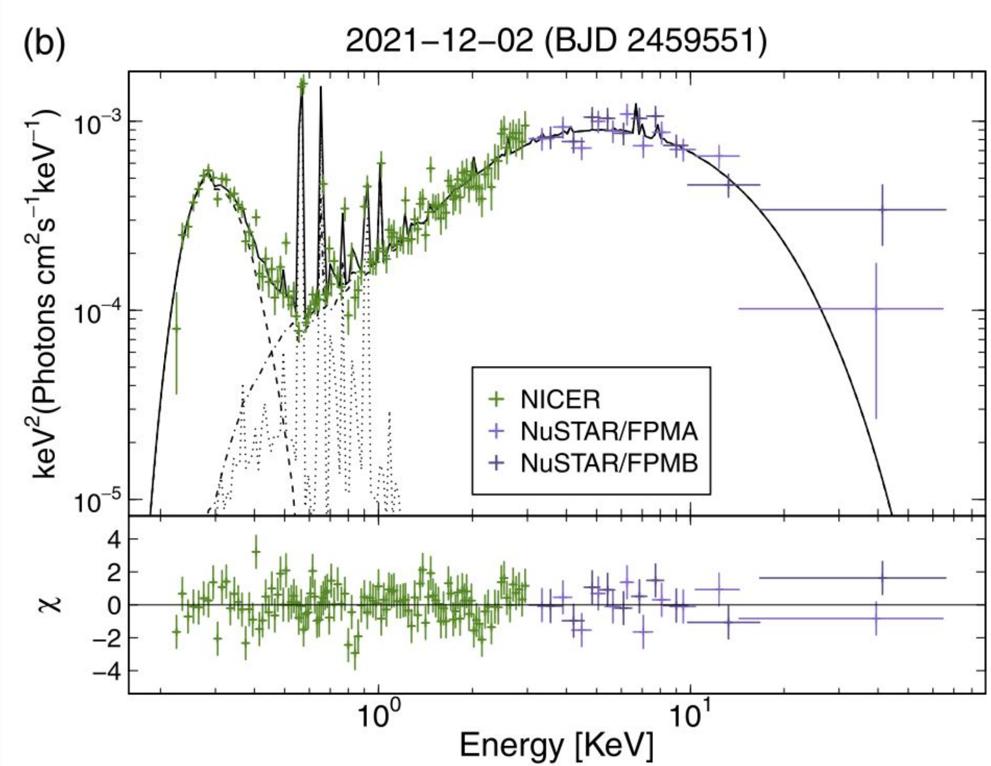


Table 1

Best-fit Parameters for Models of (a) `Tbabs*pcfabs*(bbody+Gaussian+Gaussian+bremsstrahlung)` and (b) `Tbabs*pcfabs*(bbody+vapec+vapec)` in the Simultaneous Spectral Model Fitting of the Simultaneous NICER and NuSTAR Observation Data of MASTER J0302 on BJD 2,459,551 (2021 December 2)

Model	Parameter	(a)	(b)
pcfabs	N_H [a]	$2.7^{+1.0}_{-1.7}$	$1.7^{+1.1}_{-0.6}$
	f [b]	$0.62^{+0.05}_{-0.09}$	$0.61^{+0.06}_{-0.07}$
bbody	T_{BB} [c]	$30^{+1.0}_{-0.5}$	30 ± 1.1
	L_{BB} [e]	1.5 ± 0.4	$1.3^{+0.5}_{-0.3}$
Gaussian 1	E_1 [d]	0.59 ± 0.006	⋯
	σ_1 [f]	$6.0^{+1.0}_{-0.7} \times 10^{-2}$	⋯
	N_1 [g]	$7.4^{+1.3}_{-1.5}$	⋯
Gaussian 2	E_2 [d]	0.98 ± 0.03	⋯
	σ_2 [f]	$5.5^{+3.0}_{-2.9} \times 10^{-2}$	⋯
	N_2 [g]	$5.0^{+7.7}_{-2.2} \times 10^{-1}$	⋯
vapec 1	kT_1 [h]	⋯	$0.18^{+0.01}_{-0.01}$
	Z_O [i]	⋯	$5.8^{+5.9}_{-3.1}$
	Z_{Ne} [k]	⋯	$12^{+12}_{-6.8}$
	Z_{Fe} [j]	⋯	$\leqslant 0.34$
	N_1 [l]	⋯	$1.3^{+1.4}_{-0.6} \times 10^{-4}$
bremsstrahlung	T_{bremss} [h]	$6.7^{+1.0}_{-0.9}$	⋯
	N_3 [m]	$8.6^{+1.0}_{-0.9} \times 10^{-4}$	⋯
vapec 2	kT_2 [h]	⋯	$6.3^{+0.9}_{-0.8}$
	N_2 [l]	⋯	$1.5^{+0.6}_{-0.4} \times 10^{-3}$
χ^2/dof		1.08	1.14



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GCN Circular 31126

Subject IceCube-211125A: IceCube observation of a high-energy neutrino candidate track-like event
Date 2021-11-25T16:13:00Z (3 years ago)
From Cristina Lagunas Gualda at DESY <cristina.lagunas@desy.de>

The IceCube Collaboration (http://icecube.wisc.edu/) reports:

On 21/11/25 at 06:22:21.56 UT IceCube detected a track-like event with a moderate probability of being of astrophysical origin. The event was selected by the ICECUBE_Astrotrack_Bronze alert stream. The average astrophysical neutrino purity for Bronze alerts is 30%. This alert has an estimated false alarm rate of 1.973 events per year due to atmospheric backgrounds. The IceCube detector was in a normal operating state at the time of detection.

After the initial automated alert (https://gcn.gsfc.nasa.gov/notices_amon_g_b/135936_74588253.amon), more sophisticated reconstruction algorithms have been applied offline, with the direction refined to:

Date: 21/11/25
Time: 06:22:21.56 UT
RA: 43.59 (+ 3.13 - 2.71 deg 90% PSF containment) J2000
Dec: 22.59 (+ 1.54 - 2.53 deg 90% PSF containment) J2000

We encourage follow-up by ground and space-based instruments to help identify a possible astrophysical source for the candidate neutrino.

There are two Fermi-LAT 4FGL sources inside the 90% localization region. The nearest source is 4FGL J0248.0+2232, located at RA 42.01 deg and Dec 22.54 deg (J2000), at a distance of 1.46 degrees from the best-fit location.

The IceCube Neutrino Observatory is a cubic-kilometer neutrino detector operating at the geographic South Pole, Antarctica. The IceCube realtime alert point of contact can be reached at roc@icecube.wisc.edu

Optical spectroscopy of 4FGLJ0258.1+2030: possible counterpart of the two neutrino events IceCube-191231A and IceCube-211125A

ATel #15085; *Simona Paiano (INAF/OAR, INAF/IASF-PA) , Aldo Treves (Universitaâ€ dellâ€ Insubria, INAF/OABrera), Renato Falomo (INAF/OAPD), Paolo Padovani (ESO), Paolo Giommi (ASI), Riccardo Scarpa (IAC, Universidad de la Laguna)*
*on **5 Dec 2021; 11:07 UT***
Credential Certification: Simona Paiano (simona.paiano@inaf.it)

Subjects: Optical, Gamma Ray, Neutrinos, Blazar

Post

A plausible association inside the error box of the two neutrino events, IceCube-191231A (GCN#26620) and IceCube-211125A (GCN#31126), is the gamma-ray source 4FGLJ0258.1+2030 (MG3J025805+2029). After the second event the associated radio source was detected at a substantially higher flux densities than listed in the RFC catalog (ATEL#15706). The source was proposed as a BL Lacertae object in the BZCAT catalog (Massaro et al., Ap&SS, 357, 75). On 2020 October 08, we obtained an optical spectrum in the range 5000 - 7700 Ang (average S/N ~ 60) of the target (observed g = 21.0, apparent and corrected for extinction r = 17.6) at the Gran Telescopio Canarias (10.4 m), using the spectrograph OSIRIS (exposure time = 9000 sec). The spectrum is severely reddened due to galactic extinction (E(B-V)=1.1). The dereddened optical spectrum (see below for the link to the spectrum) is characterized by a featureless continuum described by a power-law shape that confirms the BL Lac classification of the target. No emission lines with Equivalent Width EW > 0.8 Ang are found. From the absence of the absorption lines of the host galaxy, assumed to be a giant elliptical of M(R) -22.9 (Sbarufatti et al., 2005, ApJ, 635, 173), we obtain the redshift lower limit (see details in Paiano et al, 2017, ApJ, 837, 144) of z > 0.3. The spectrum is available in the spectroscopic database ZBLLAC (https://web.oapd.inaf.it/zbllac/).

4FGLJ0258p2030_GTC_spectrum