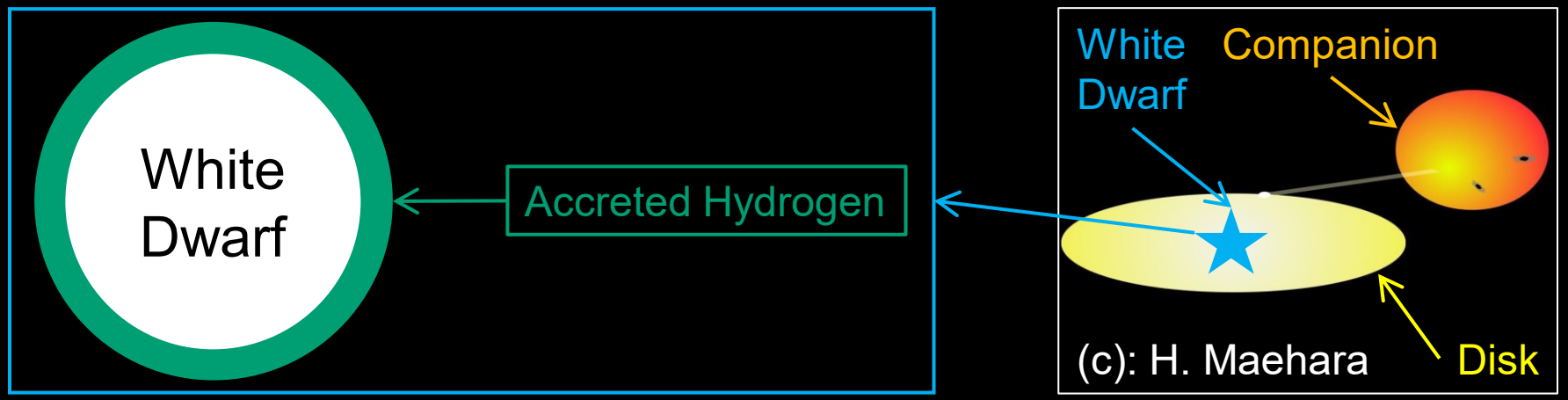
広視野・高頻度サーベイと京都大学せいめい望遠鏡による新星初期の観測可能性

2023-05-31 Kenta Taguchi (Kyoto University)

Mechanism of (Classical) Novae: Thermonuclear Runaway

- Binary of a white dwarf (WD, primary star) & a late (companion) star.
- H gas from companion accretes to form an envelope on the WD surface.



- The amount of accreted gas ↗ → T & ρ ↗

  → Nuclear Reaction (Thermonuclear Runaway, TNR) suddenly occur to lead nova.

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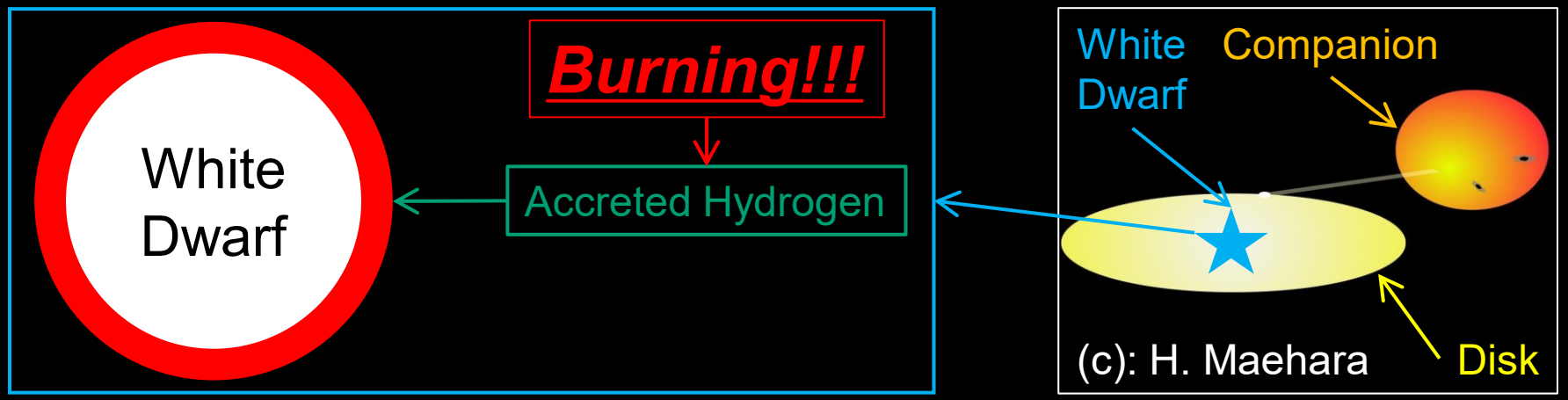

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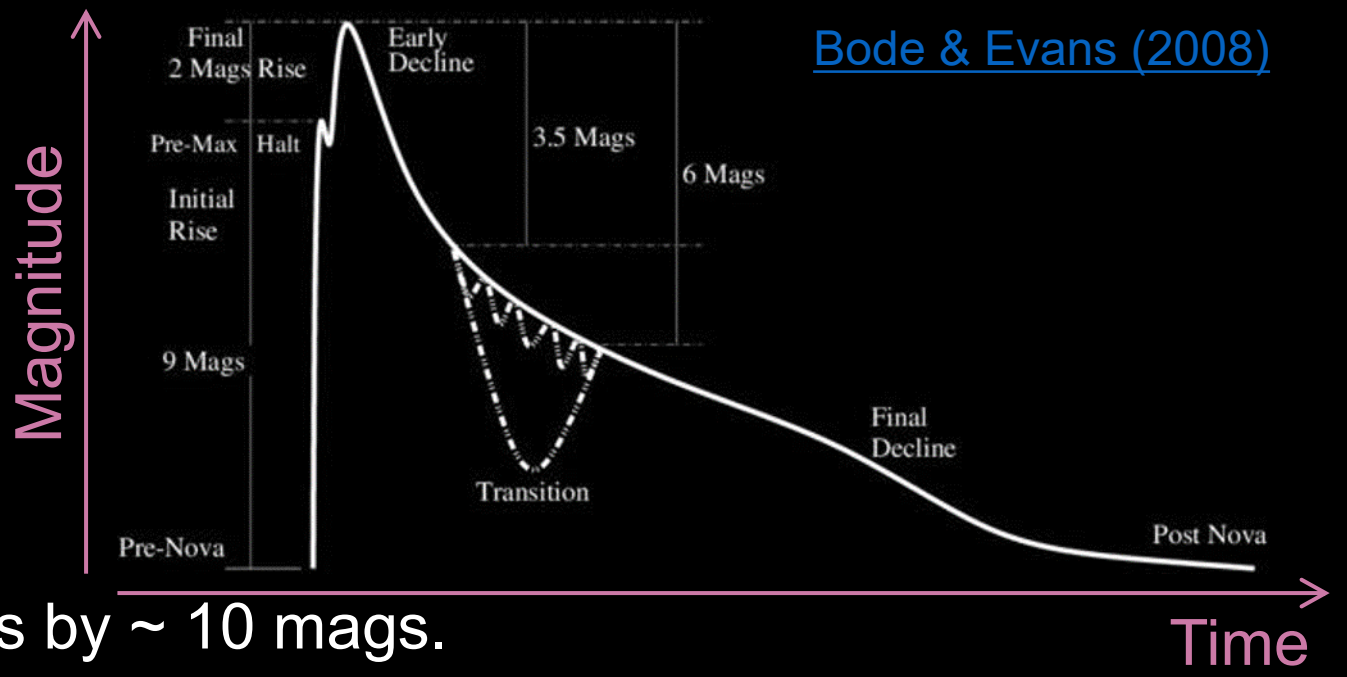
The Nova Lightcurve in Optical Wavelengths

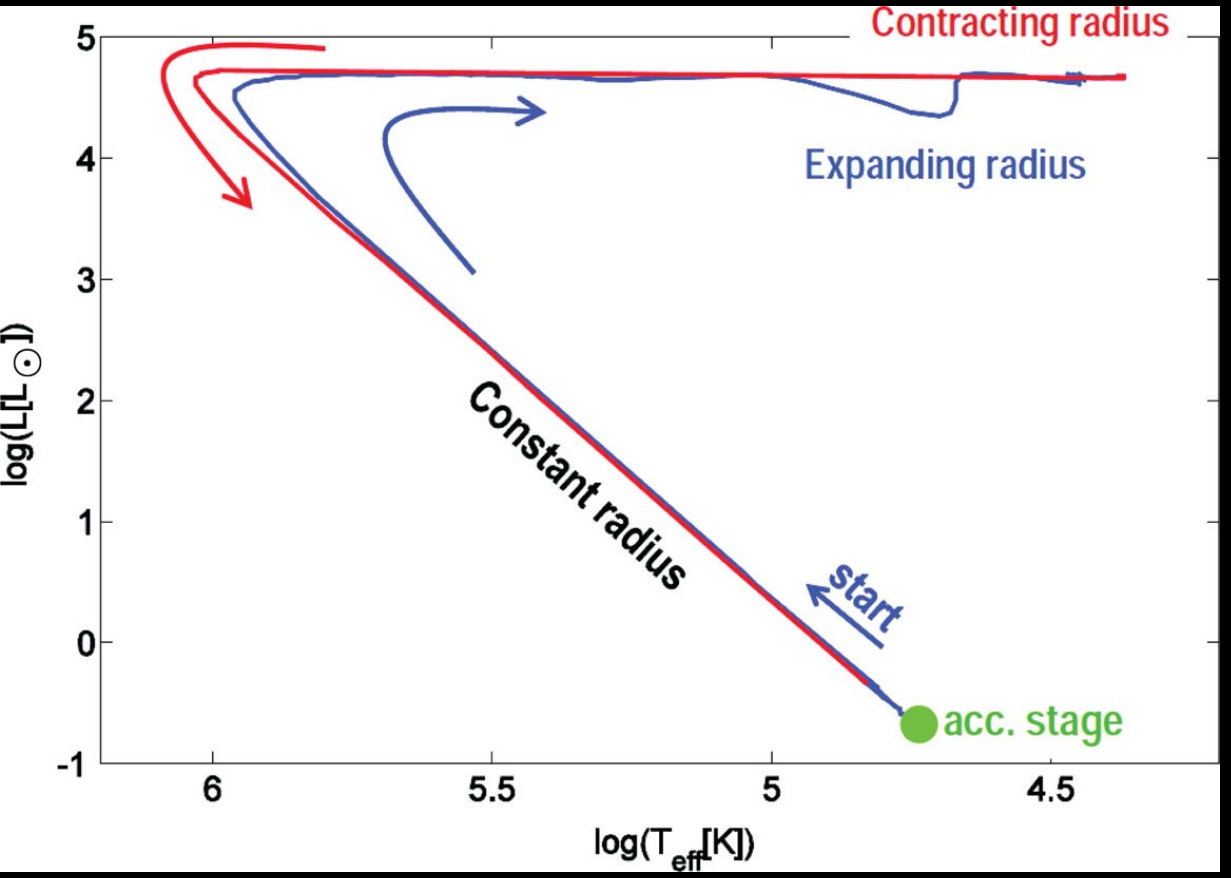


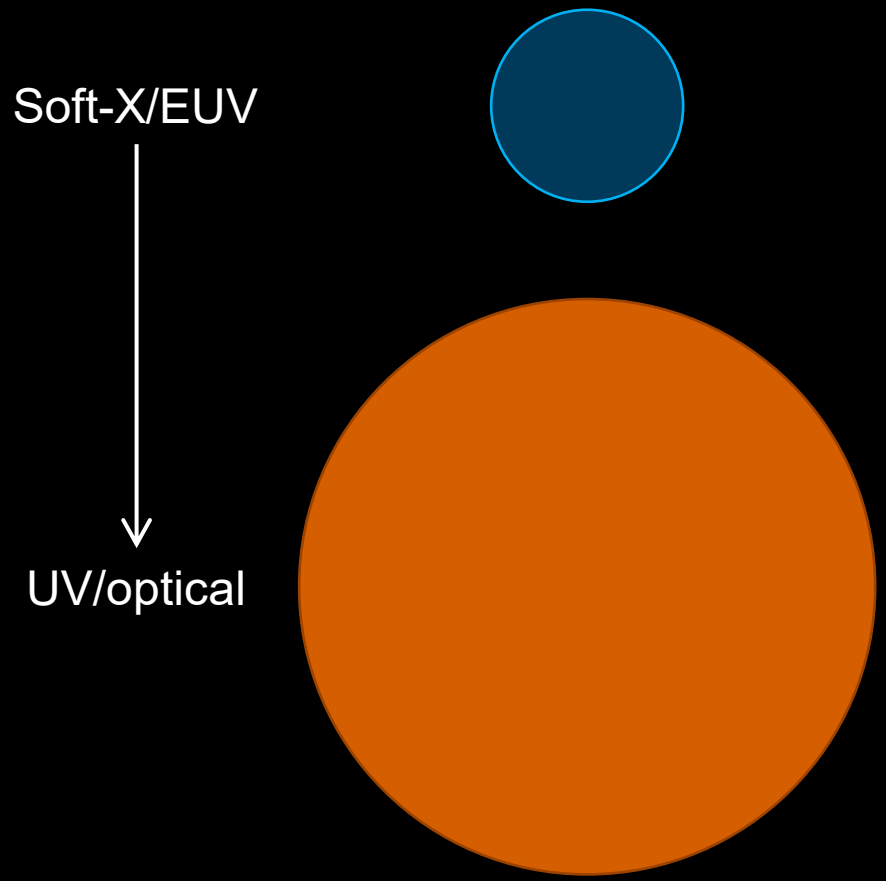
Bode & Evans (2008)

- Typically brightens by ~ 10 mags.
- Sudden (~ hours – a day) initial rise.
  - In some “extremely slow novae” ($\lesssim$ 3%), takes $\gtrsim$ years.
- Gradually fades for a week (“fast novae”) – 100 years (“slow novae”).
  - Fast (slow) novae host massive (light) WDs.

Novae in the HR Diagram (e.g., Hillman et al. 2014; Kato, Saio, Hachisu 2017)

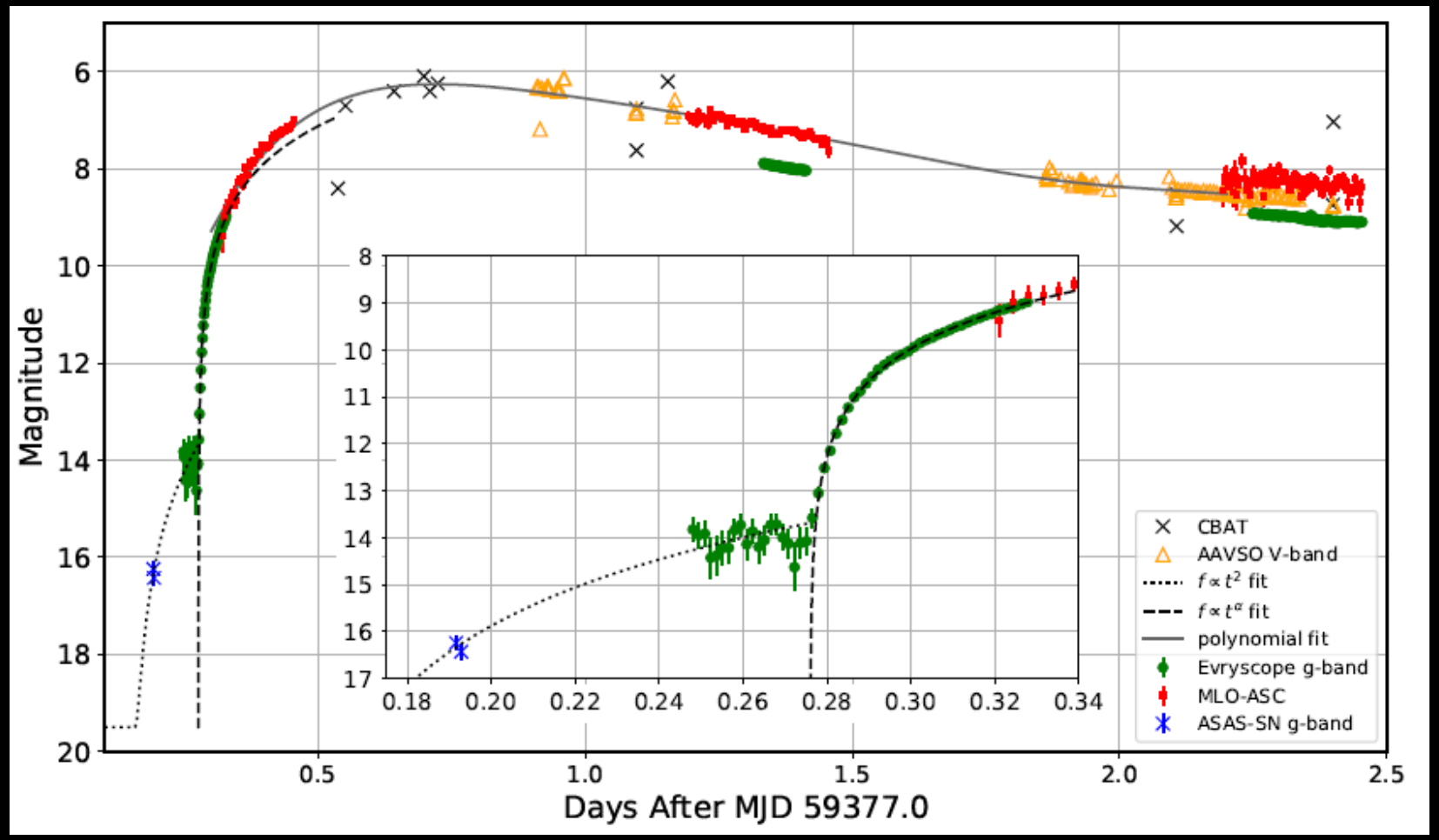
- Theoretically, initial brightening is attributed to an "expanding photosphere".
  - After luminosity reaches Eddington, the envelope expands driven by radiation.





2-min Cadence Light Curve of Nova V1674 Her (Quimby et al., arXiv:2107.05763)

- Physical meaning?



Importance of Initial Brightening Phase in Novae

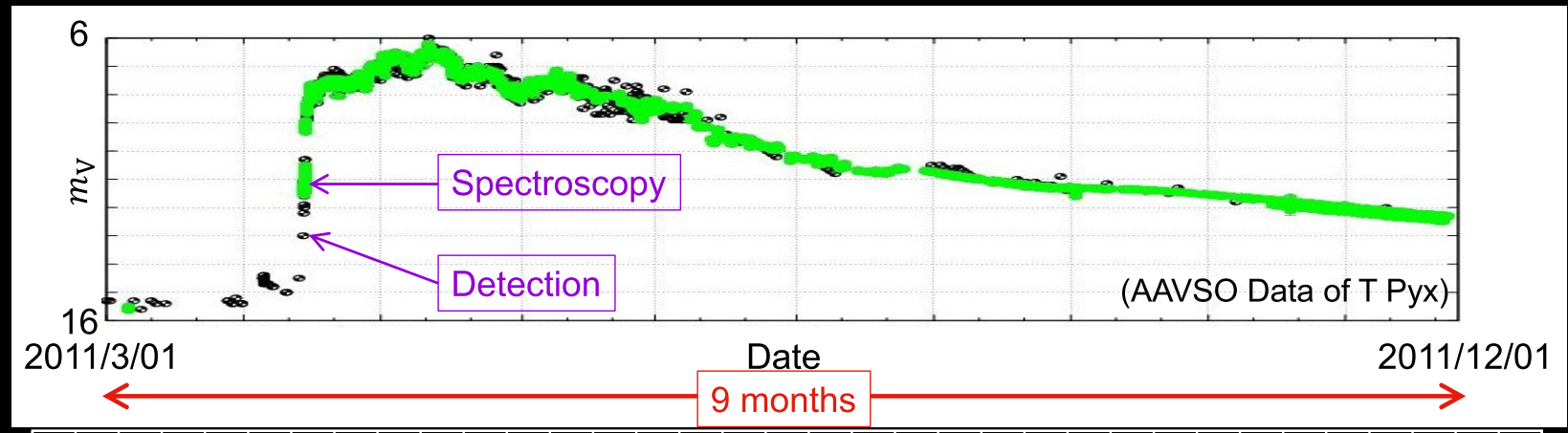
- The ejecta has not expanded so much.
  → The system may have not been “polluted” by the nova ejecta.
  → Possible key to research on the progenitor accretion stage.
- ρ and T would be higher than the maximum light.
  - Some lines could only be seen in initial phase.
    → New abundance estimation.
- Time-evolution of T & ρ → limitation on hydrodynamics models of novae.

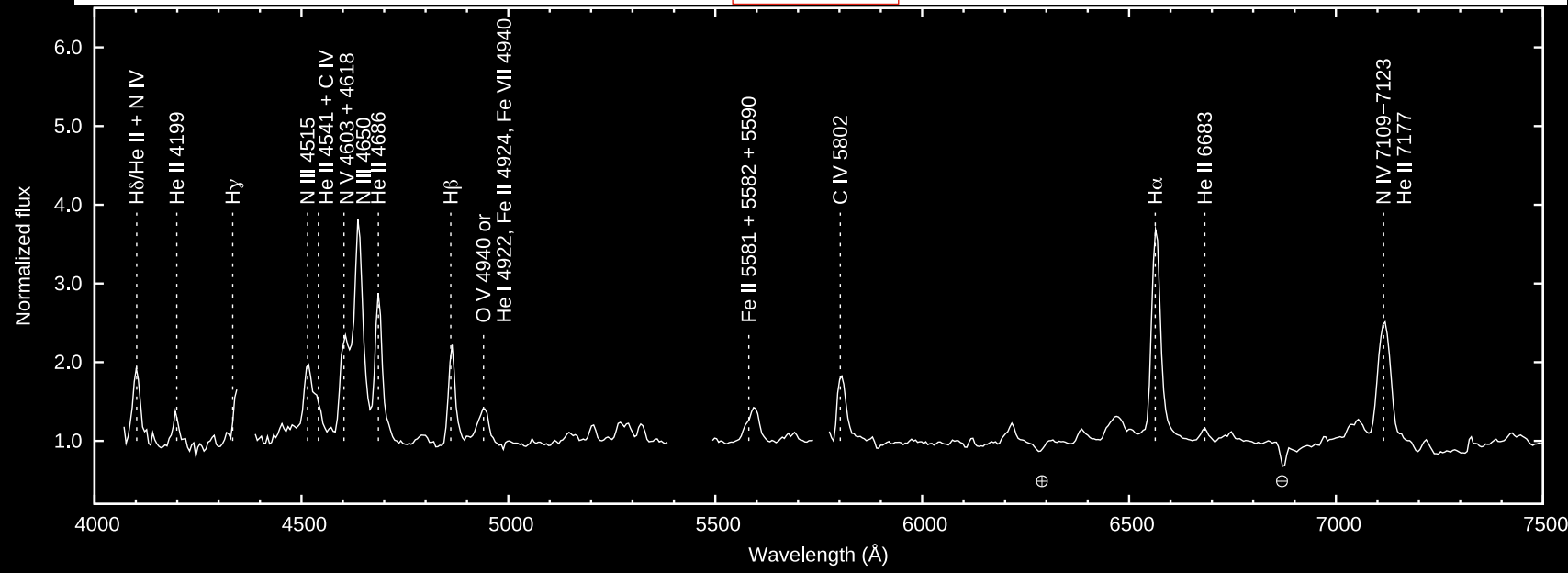
- However, ***taking spectra in the initial brightening phase is difficult!***
  - There is only 1 example before our work: T Pyx in 2011 (Arai et al. 2015)

T Pyx in 2011 (Arai et al. 2015)

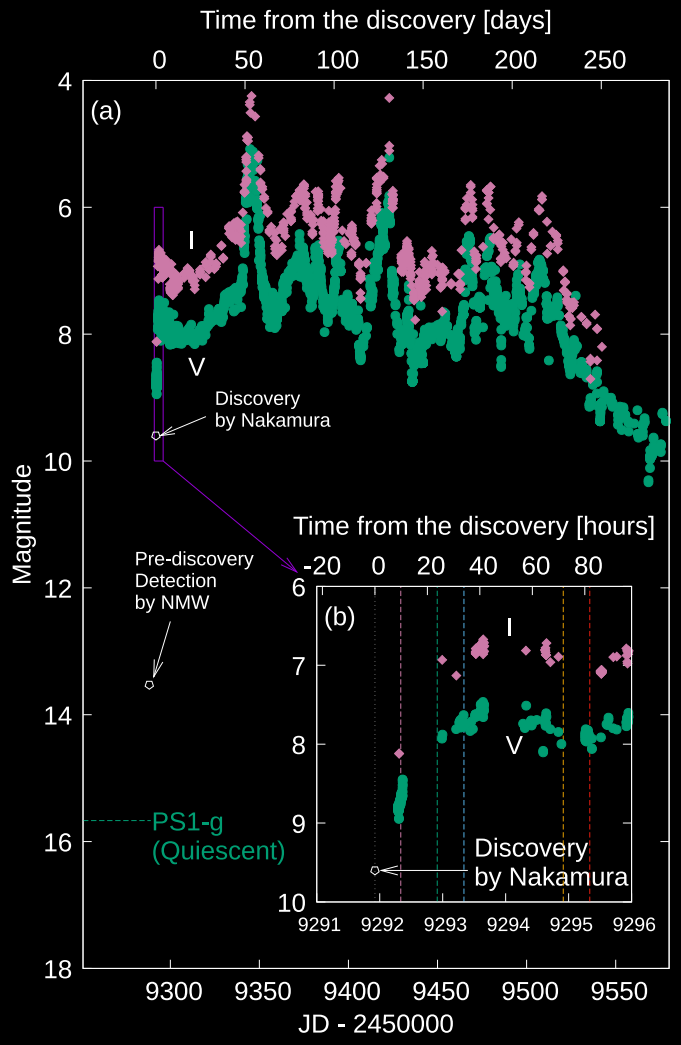
- Nova spectrum only 4.56 hours after discovery.

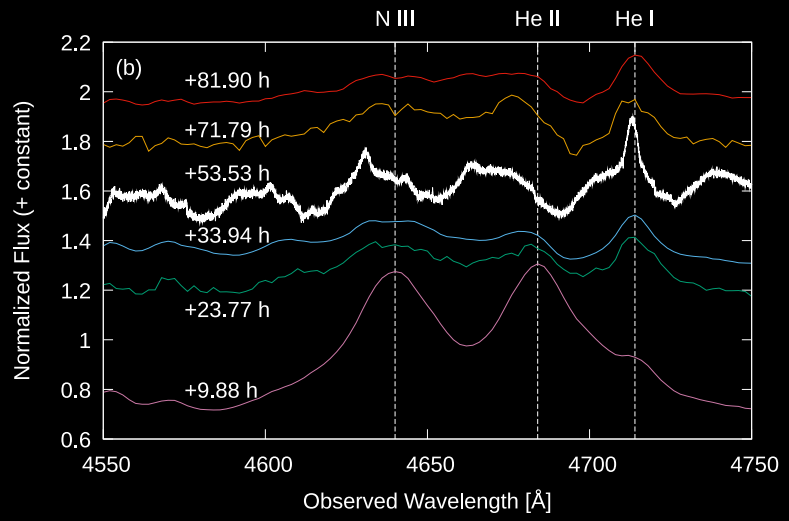
- Different from optical maximum
  - No absorption
  - Highly-ionized emission
    (He II, N III/IV/V, C IV, ...)
  → “Wolf-Rayet-like”

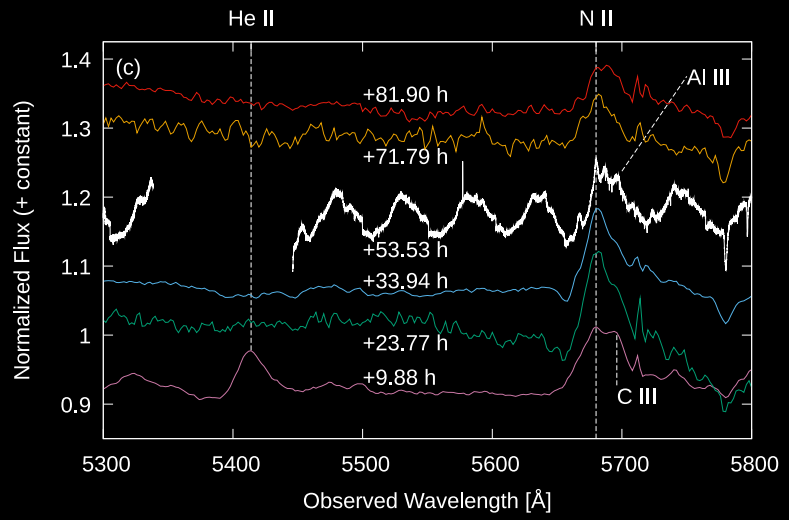




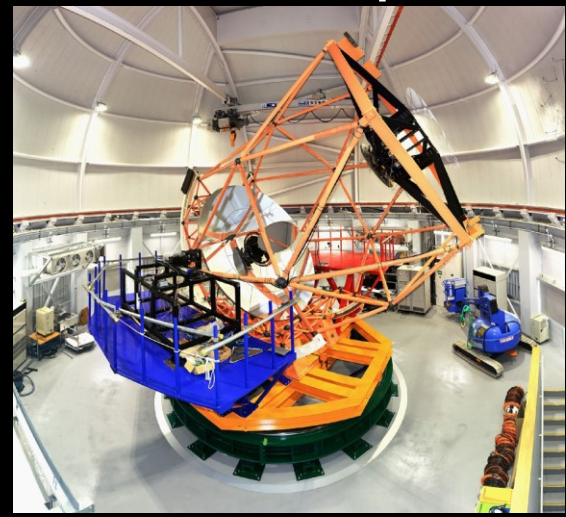
V1405 Cas in 2021 (Taguchi et al., in revision)





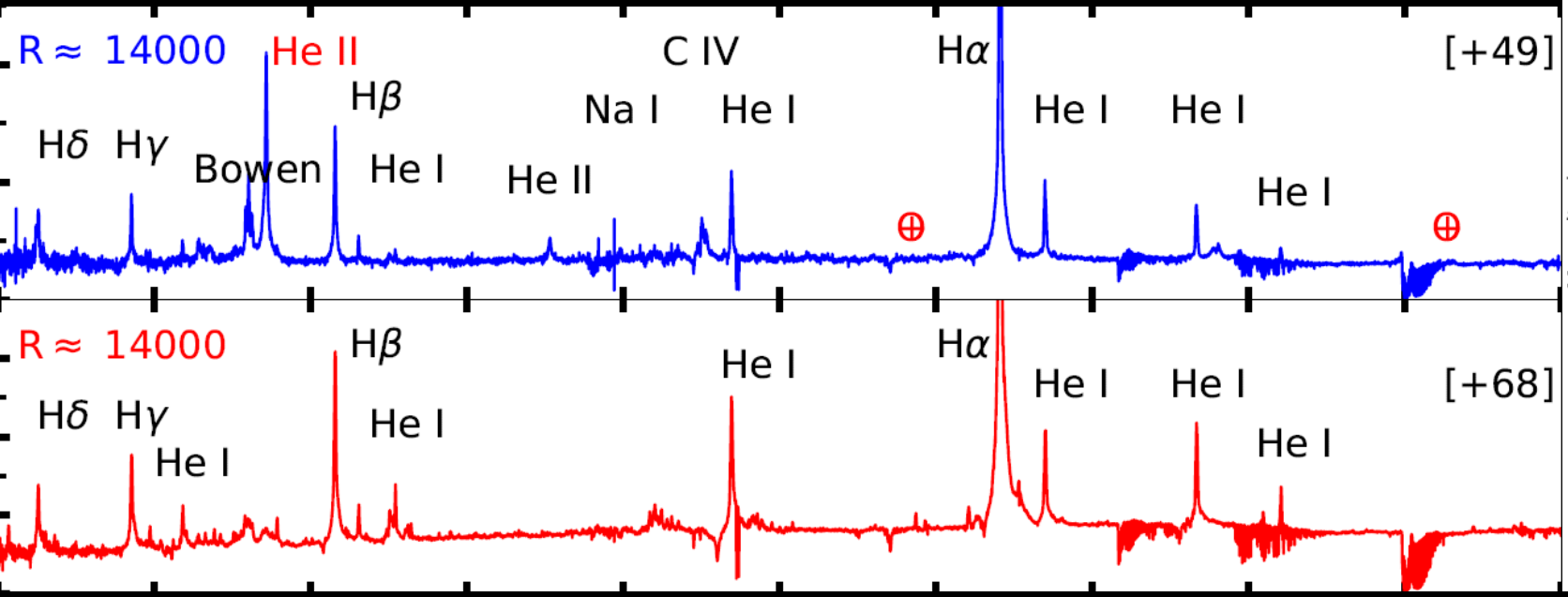


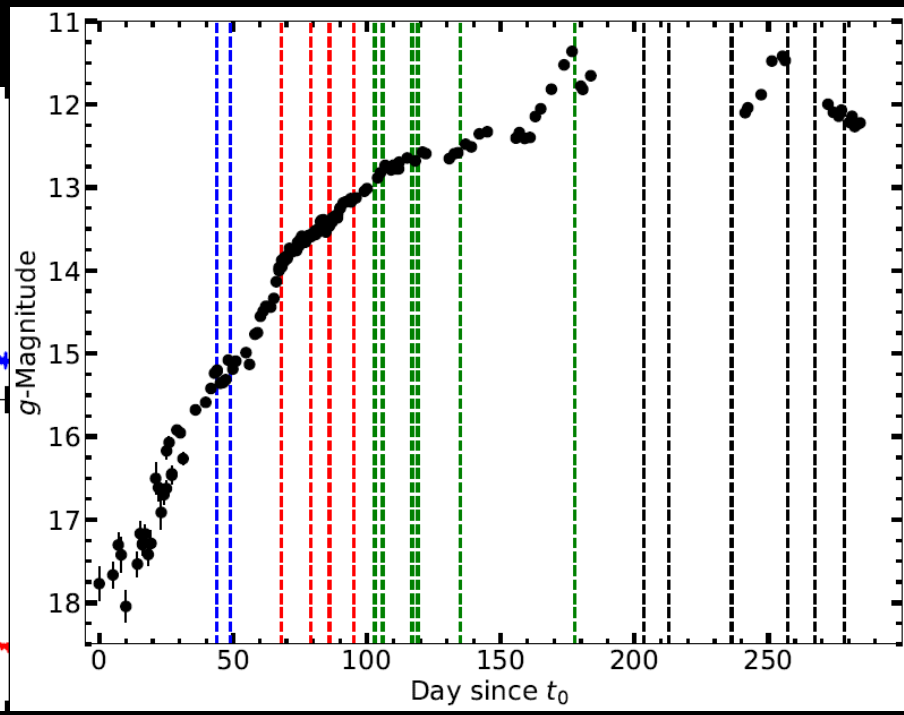
- Only within the discovery day, He II, N III, C III are strongly detected.
- Our initial spectrum was taken by Seimei Telescope.



Gaia22alz in 2022 (Aydi et al., arXiv:2304.04306)

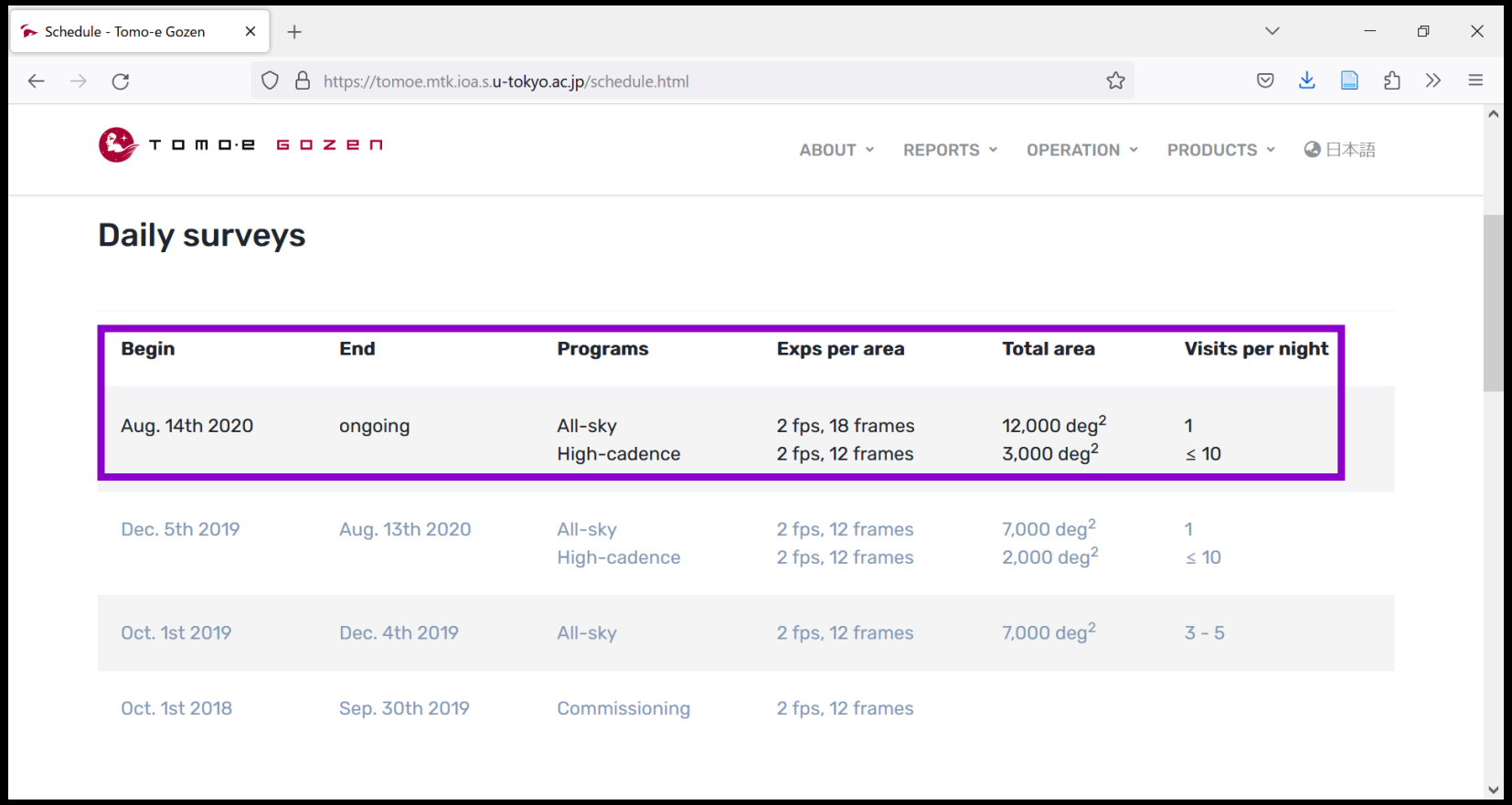
- This is “extremely slow” (***outlier***) symbiotic nova.
- He II, Bowen, C IV only in the “early-rise” phase.





Number of Samples

- The “12000 deg^2, 3000 deg^2” survey has been running for almost 3 yrs.
  - Enough number of sample novae to check the “efficiency” of Tomo-e.



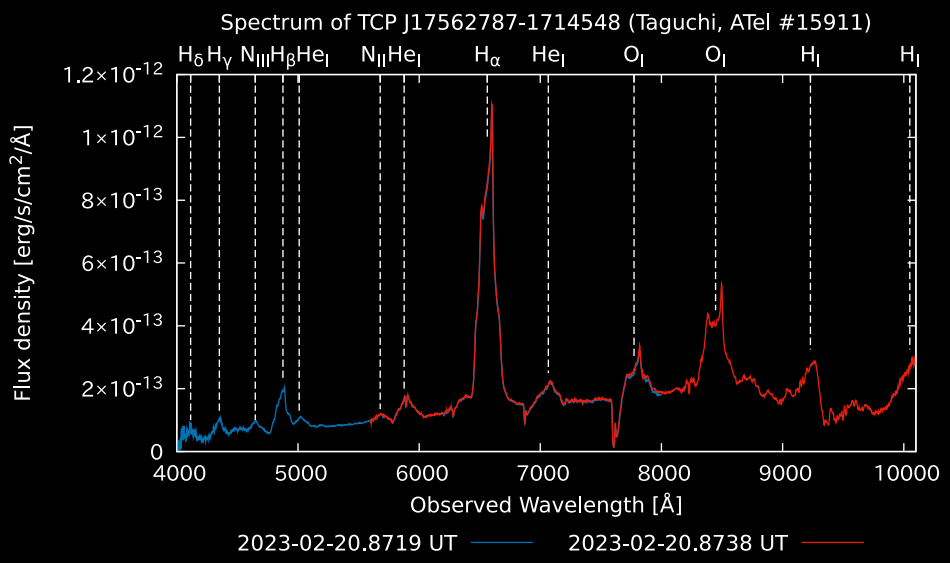
Begin	End	Programs	Exps per area	Total area	Visits per night
Aug. 14th 2020	ongoing	All-sky High-cadence	2 fps, 18 frames 2 fps, 12 frames	12,000 deg^2 3,000 deg^2	1 ≤ 10
Dec. 5th 2019	Aug. 13th 2020	All-sky High-cadence	2 fps, 12 frames 2 fps, 12 frames	7,000 deg^2 2,000 deg^2	1 ≤ 10
Oct. 1st 2019	Dec. 4th 2019	All-sky	2 fps, 12 frames	7,000 deg^2	3 - 5
Oct. 1st 2018	Sep. 30th 2019	Commissioning	2 fps, 12 frames		

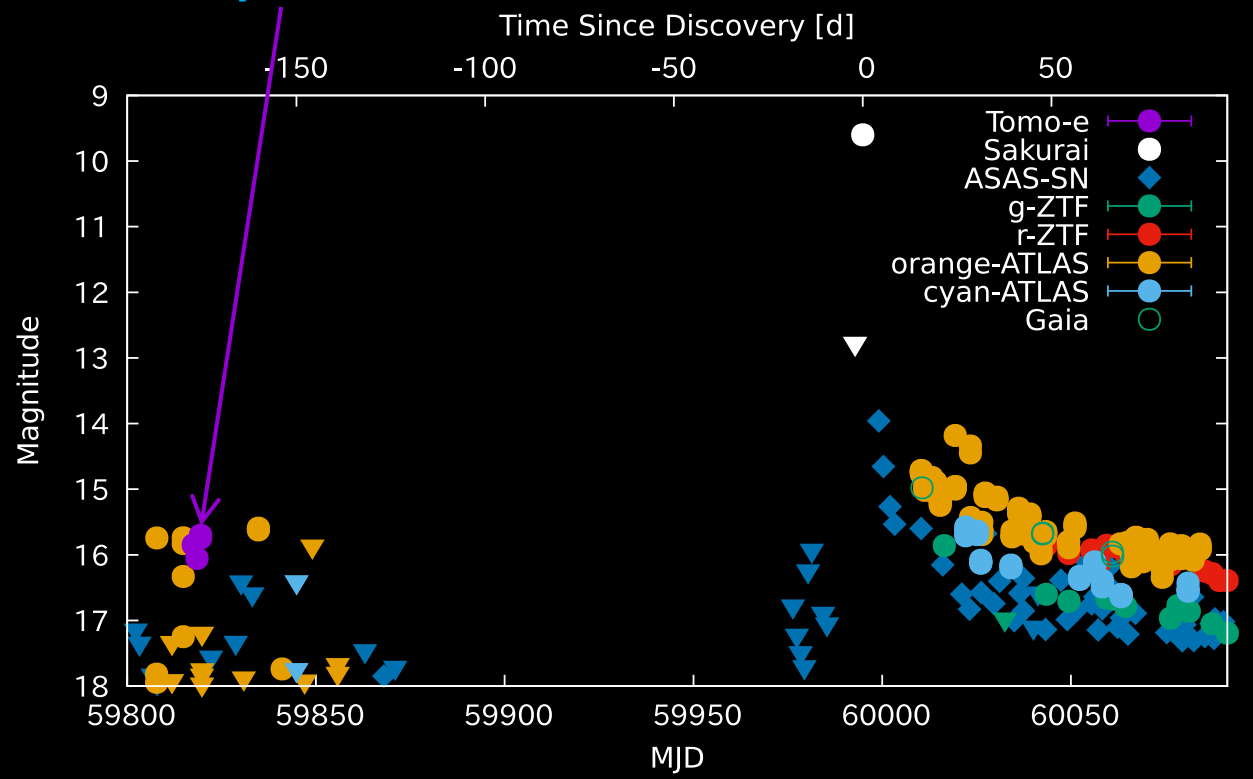
Galactic Novae Discovered in 2023

- Observable from Tomo-e:
  - ❀V6596 Sgr (= AT 2023fnd, classified by Taguchi, ATel #15911)
  - Gaia23azk (= AT 2023ctx)
  - PGIR23gjp (= AT 2023gde)
- Too south:
  - V1716 Sco
  - ❀V6597 Sgr = TCP J17583414-2652300 (→ classified by Taguchi, ATel #16038)

V6596 Sgr = AT 2023fnd (x_x)

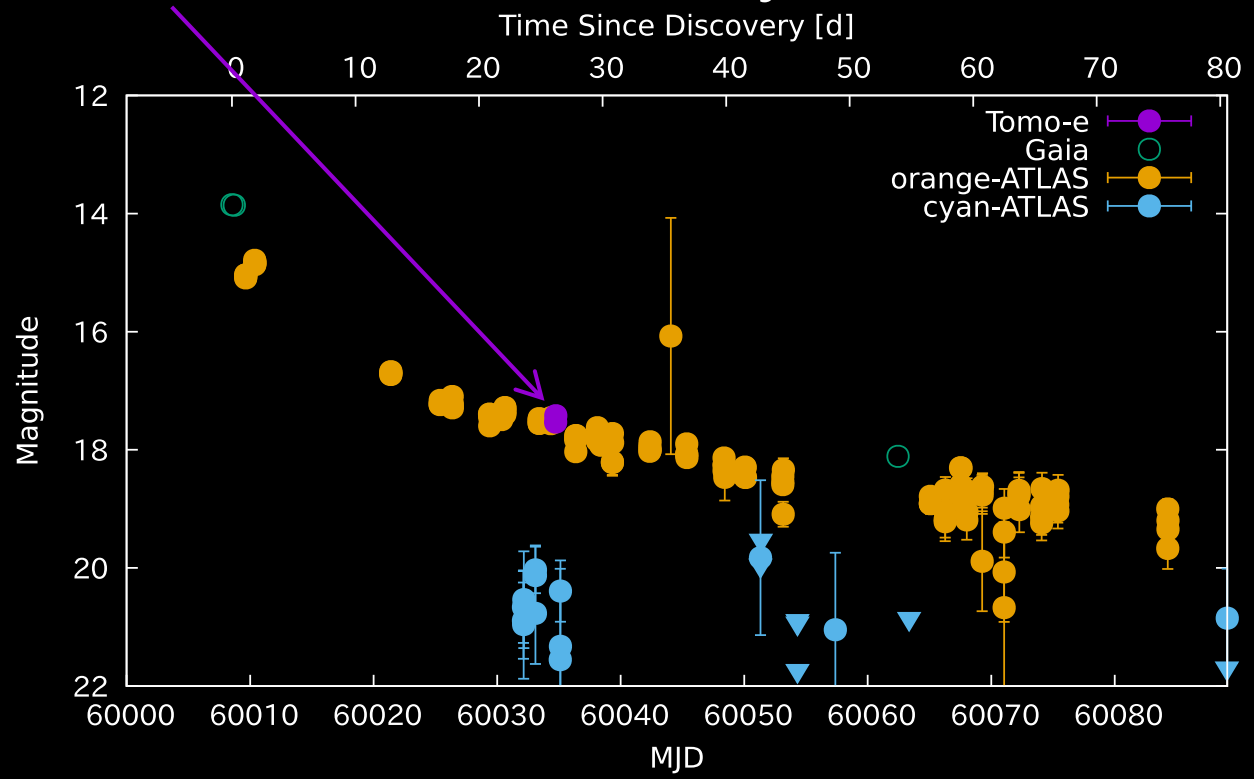
- Discovered by Yukio Sakurai at 9.6 mag on 2023-02-19.82
  → Spectrum on 2023-02-20.87 (Taguchi, ATel #15911)
- **Tomo-e** detected only quiescence in the previous season.





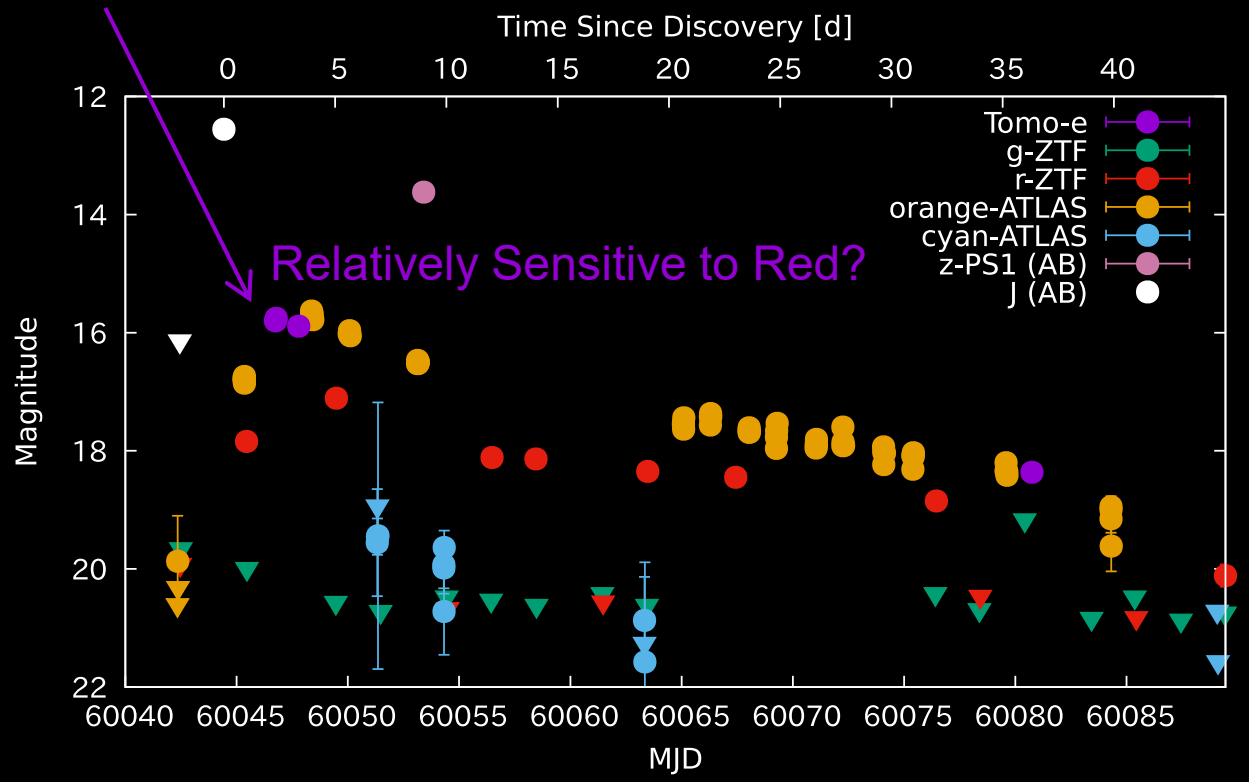
Gaia23azk = AT 2023ctx (˙-˙)

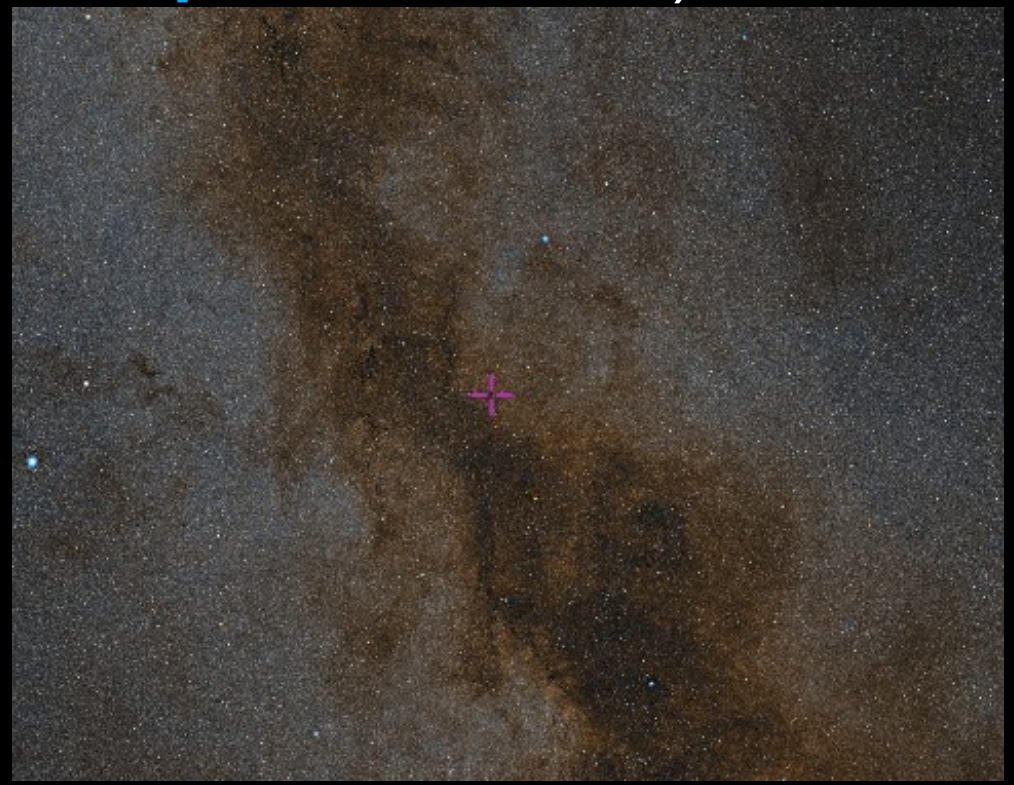
- Discovered by Gaia on 2023-03-05.54 after the seasonal break.
  → classified by Strader et al. (Atel #15956)
- **Tomo-e** detected 26 days after the discovery.



PGIR23gjp = AT 2023gde (^o^)

- Discovered by Palomar Gattini-IR survey at J = 12.555 on 2023-04-10.43
  → Data sent to TNS on 2023-04-19.14 & Atel #15993.
- **Tomo-e** Detected on 2023-04-12.75 UT (**pre-report detection**)!!.





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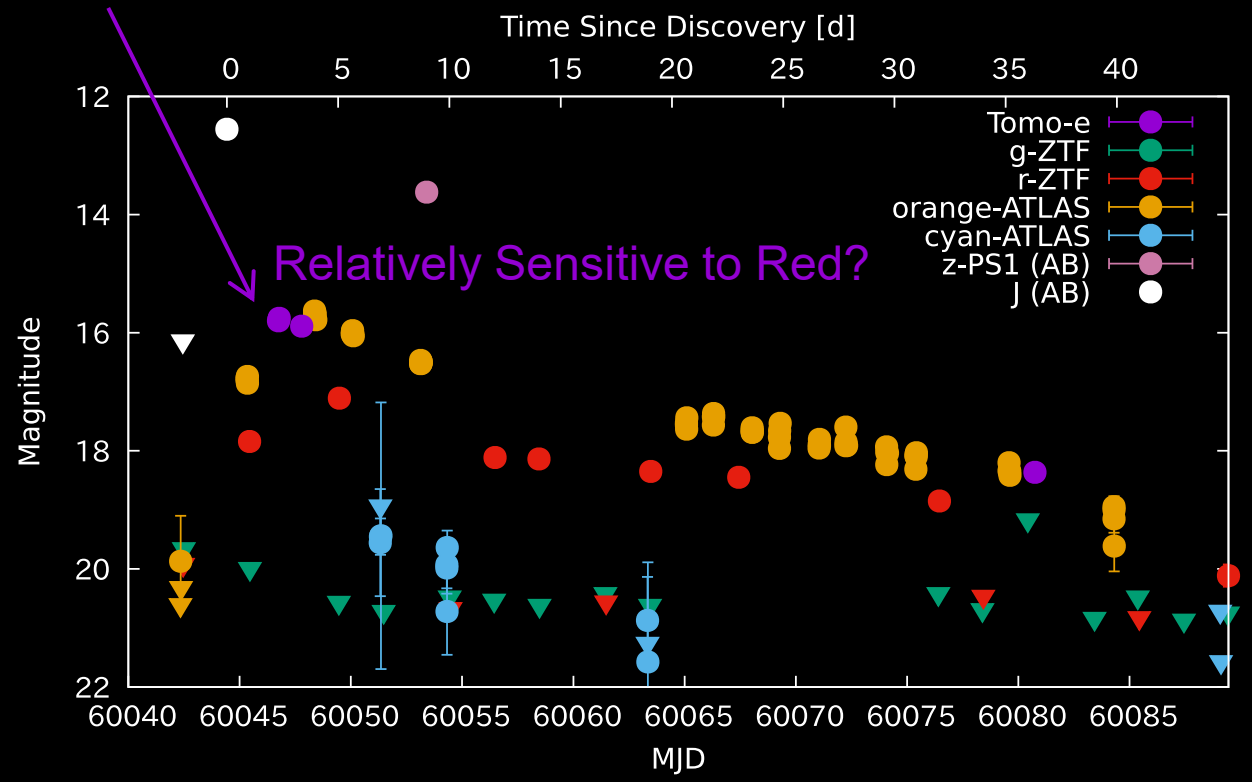


Schmidt Symposium 2022

(昨年度の非公開スライド)

How can I contribute to community?

Galactic Novae Discovered in 2023

- Observable from Tomo-e:
  - 🏵V6596 Sgr (= AT 2023fnd): only previous season. (x_x)
  - Gaia23azk (= AT 2023ctx): 26 days after the discovery. (˙-˙)
  - ***PGIR23gjp (=*** AT 2023gde***): 2 days after discovery (pre-report detection).*** (^o^)
- Too south:
  - V1716 Sco
  - 🏵V6597 Sgr = TCP J17583414-2652300 (→ classified by Taguchi, ATel #16038)

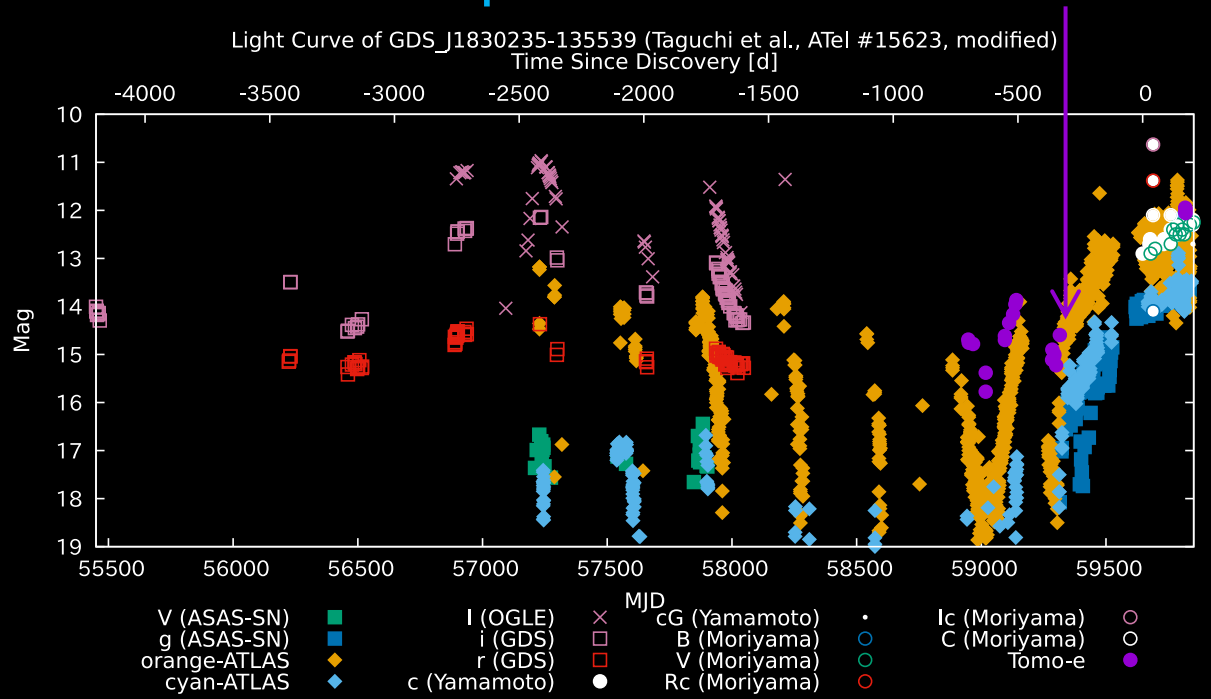
List of Galactic Novae in 2022/2023 (🎆: discovered by Japanese Amateurs)

- 2023 (3 of 5 are observable from Tomo-e):
  - 🎆V6596 Sgr (= AT 2023fnd): only previous season. (x_x)
  - Gaia23azk (= AT 2023ctx): 26 days after the discovery. (˙-˙)
  - ***PGIR23gjp (=*** AT 2023gde***): 2 days after discovery (pre-report detection).*** (^o^)

- 2022 (4 of 10 are observable from Tomo-e):
  - 🎆GDS_J1830235-135539: Tomo-e may have detected initial phase (^o^)
  - PGIR22gjh: No data (dec = –19.37). (x_x)
  - 🎆U Sco: No data (dec = –17.87). (x_x)
  - PGIR22akgylf: 12 days after the discovery. (˙-˙)

GDS_J1830235-135539 (^o^)

- M. Yamamoto found its brightening on 2022-03-08.824.
  → Spectroscopy on 2022-09-20.43 (Taguchi et al., ATel #15623)
- Outburst seems have started end of 2021-03.
  - Tomo-e has 6 points between 2021-03-10 and 2021-04-10 (ignition?).



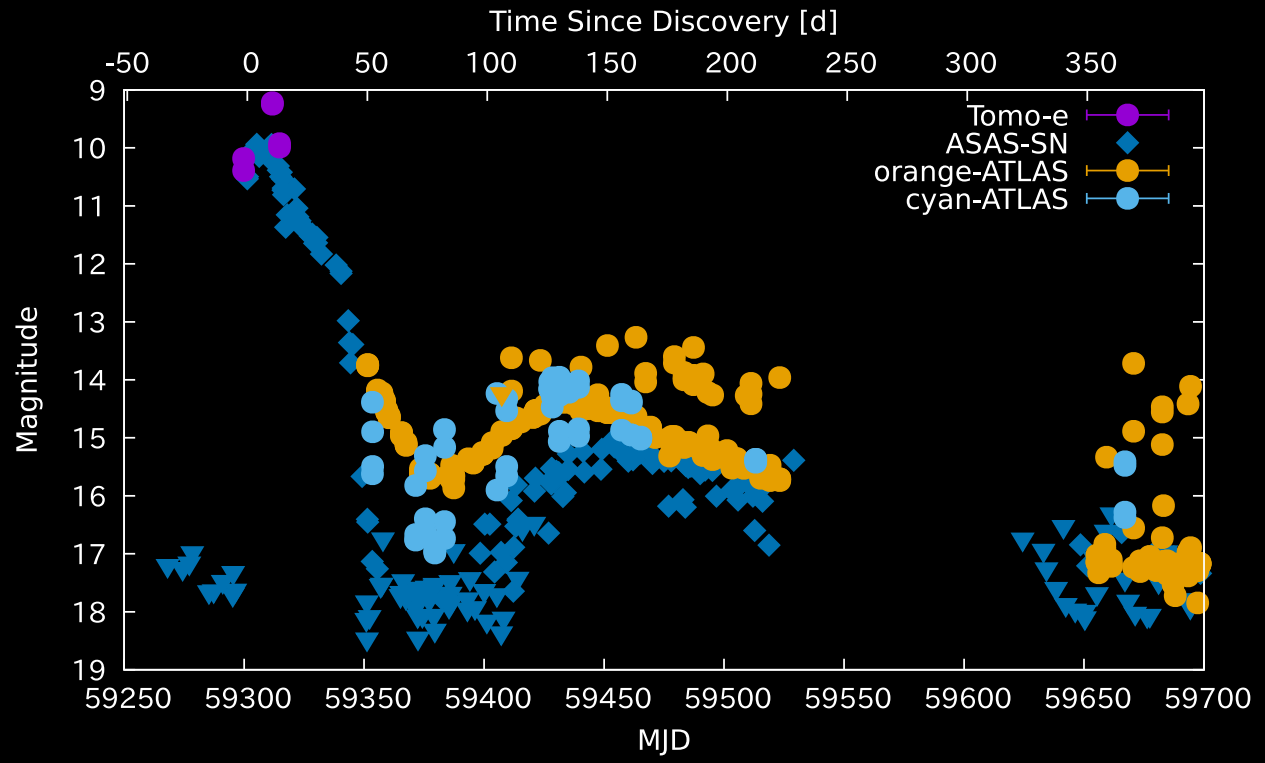
List of Galactic Novae in 2020/2021 (🎌: discovered by Japanese Amateurs)

- 2021 (7 of 18 are observable from Tomo-e)
  - RS Oph: no data during outburst. (x_x)
  - 🎌V606 Vul: no Tomo-e data in 2021. (x_x)
  - 🎌V1674 Her: no Tomo-e data in 2021. (x_x)
  - Gaia21cpb: No Tomo-e data points. (x_x)
  - V2030 Aql: 1 point 13 days after the discovery. (˙-˙)
  - ***V6594 Sgr: 2 pre-discovery (2 days before) points!! (^o^)***
  - 🎌V1405 Cas: 27 days after the discovery. (˙-˙)

- 2020 (after 14th, Aug, 1 of 3 is observable from Tomo-e)
  - 🎌V1112 Per: Tomo-e detected 2.6 days after the discovery. (˙-˙)

V6594 Sgr = AT 2021hej (^o^)

- Discovered by ASAS-SN on 2021-03-25.29.
  - Independent discovery by Nishimura on 25.76 and Nakamura on 25.80.
- Tomo-e have data points (high-cadence?) *two days before the discovery!!*



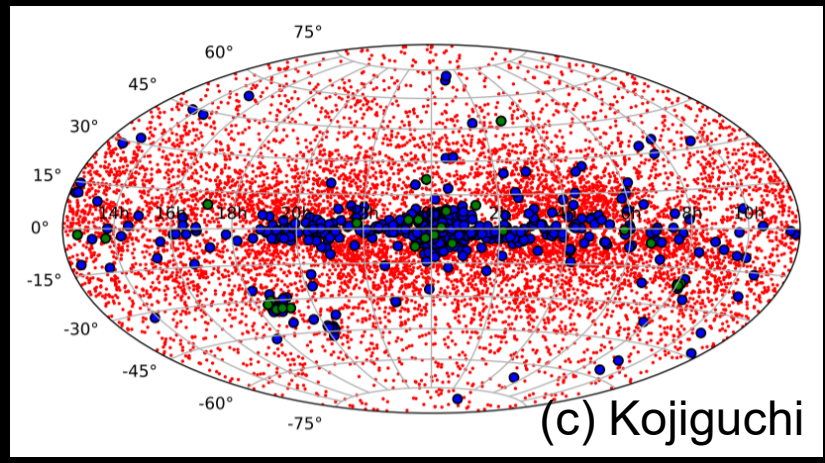
Statistics

- 15 of 36 novae have dec > –20 deg (Tomo-e observable).
- 3 of 15 are (^o^).
  - Except the symbiotic (very slow) one, the other 2 are not 🎌.
- Japanese amateurs are strong (🎌 are about 25–30% of all novae)
- ***We (I) should check the real-time Tomo-e data more carefully!***

	(^o^)	(˙-˙)	(x_x)	South	Total (🎌)
2020 (since 14th, Aug.)	0	1	0	2	3 (2)
2021	1	2	4	11	18 (4)
2022	1	1	2	6	10 (2)
2023	1	1	1	2	5 (2)
Total	3	5	7	21	36 (10)

How to Survey Further Novae?

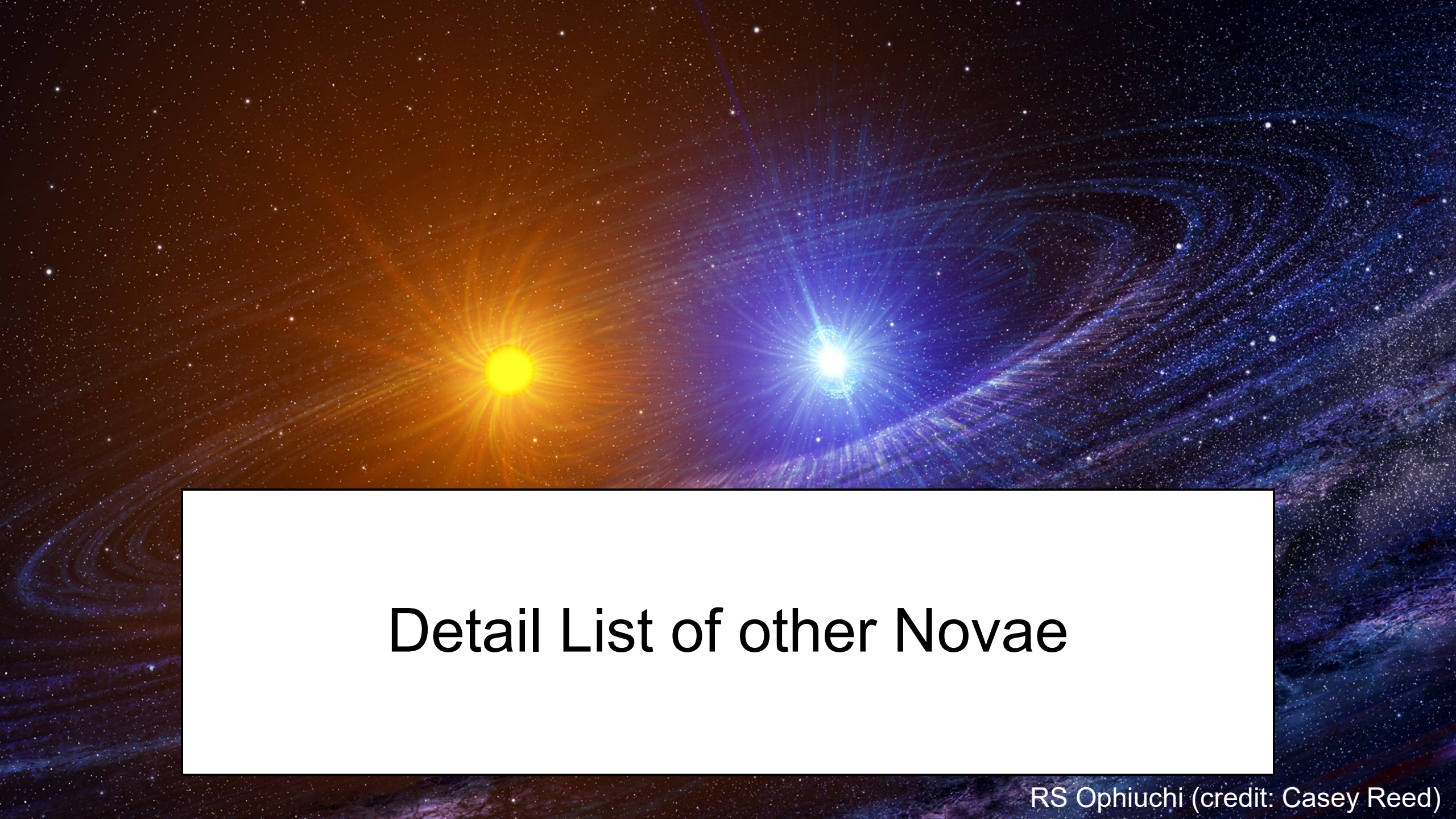
- Nova are **concentrated on the Galactic plane**.
- Usually discovered "brighter than supernovae".
  - Detectable in nautical/astronomical twilight.



Positions (in Galactic coordinate) of
Dwarf nova, Nova, Recurrent Nova

- Additional to daily surveys, Galactic center (dec < –20 deg) in evening?
  - Queue?
  - Reduction/Subtraction/Detection?
  - Database?
  - Follow-up (Okayama?) in the same night.

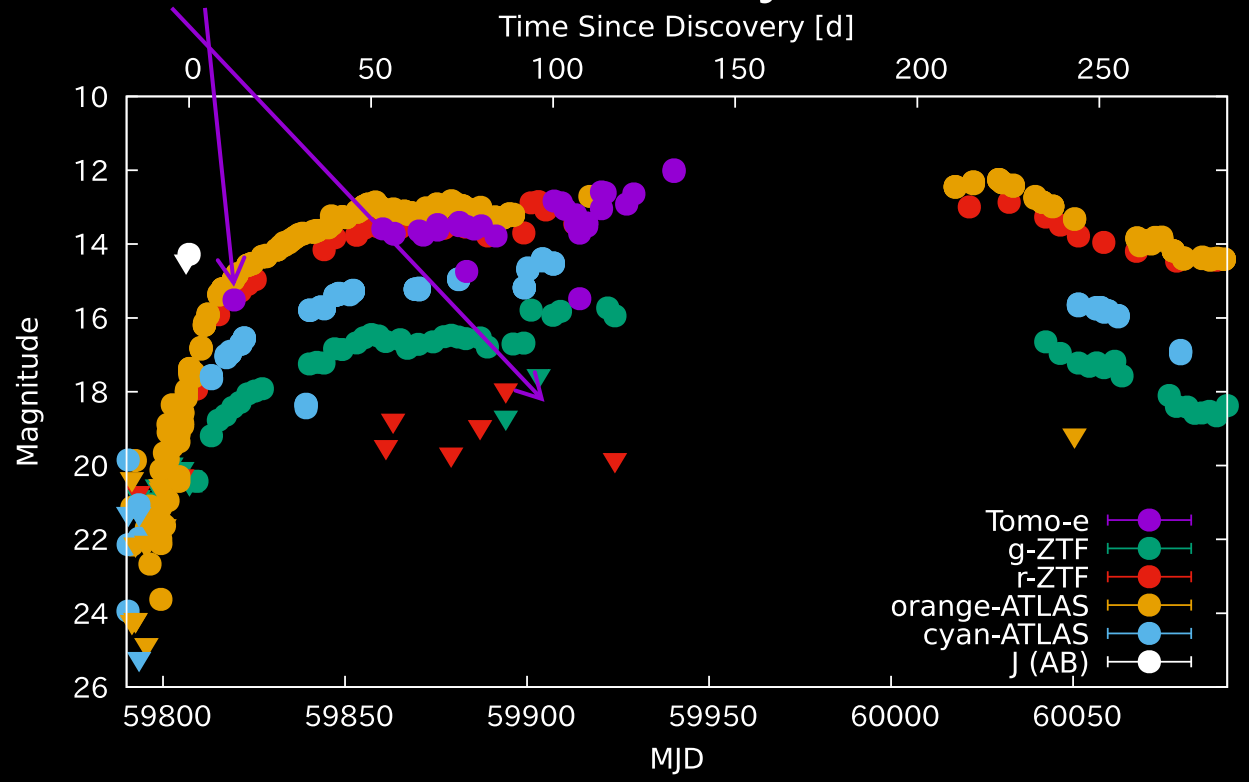
Detail List of other Novae



RS Ophiuchi (credit: Casey Reed)

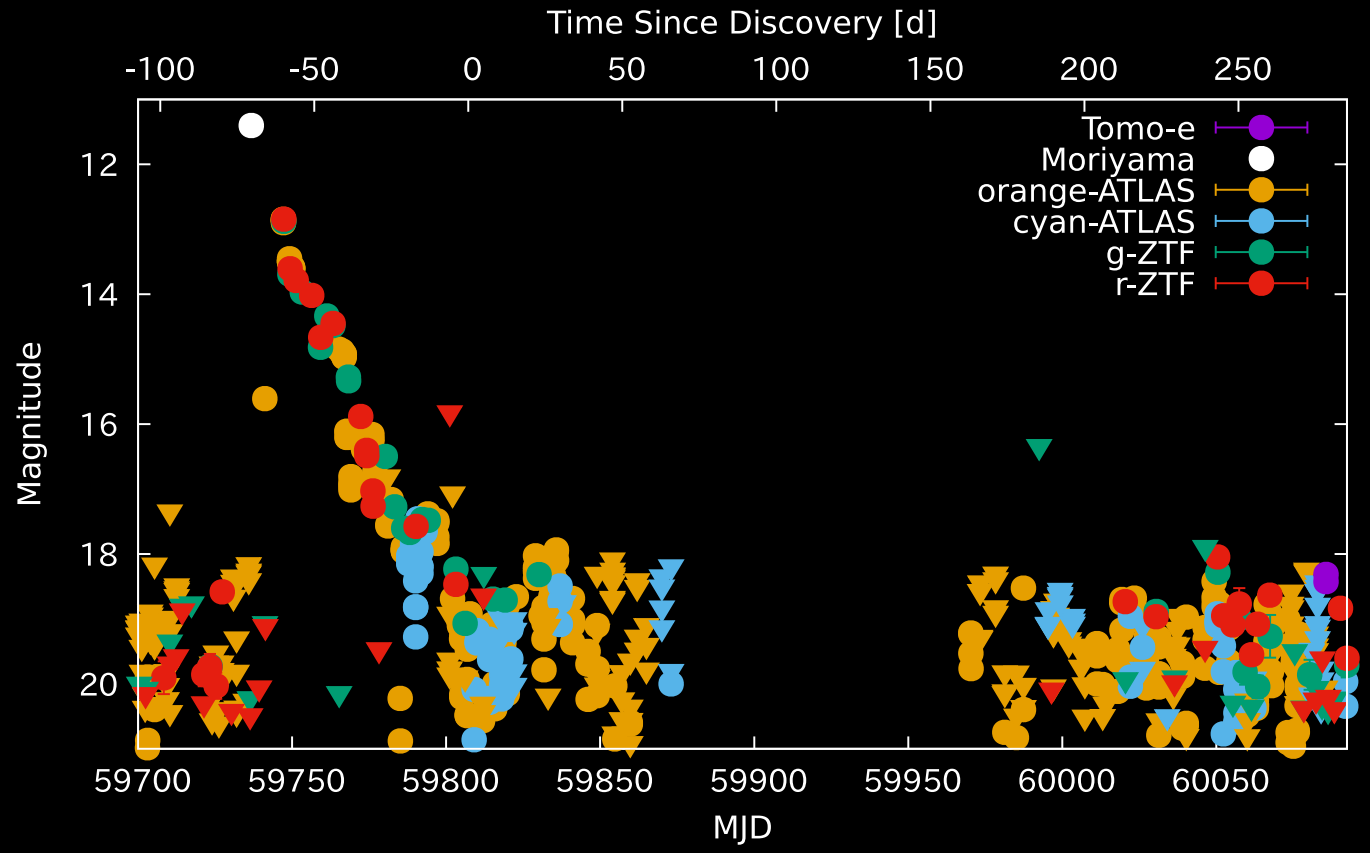
PGIR22akgylf = AT 2022sfe (˙-˙)

- Discovered by Palomar Gattini-IR survey at J = 12.28 on 2022-08-16.19
  → Data sent to TNS 10 days after that.
- **Tomo-e** detected 12 days after the discovery.



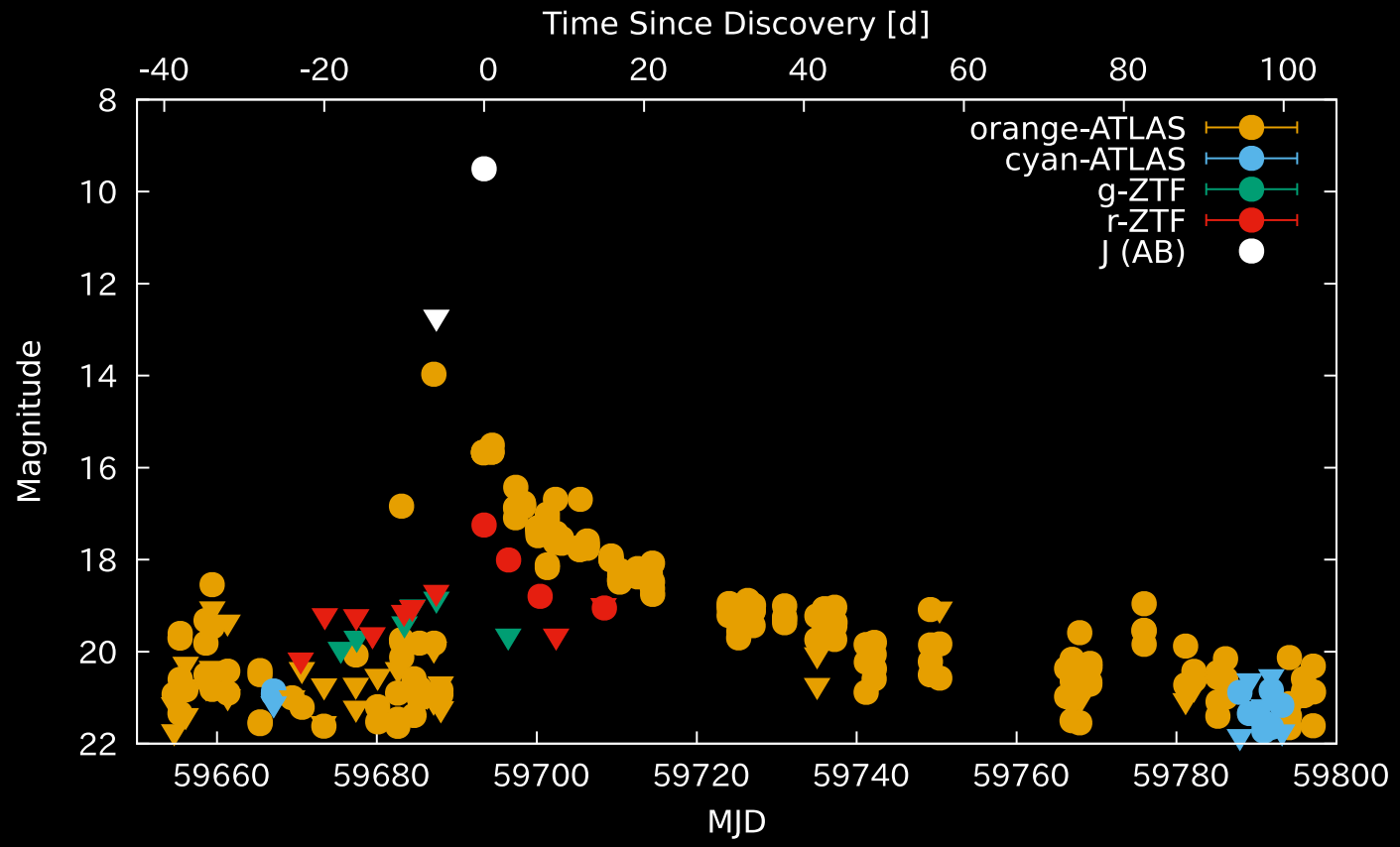
U Sco (x_x)

- Discovered by M. Moriyama at 11.4 mag on 2022-06-06.720
- No Tomo-e Data points on 2022 (probably due to the low dec, –17.87).



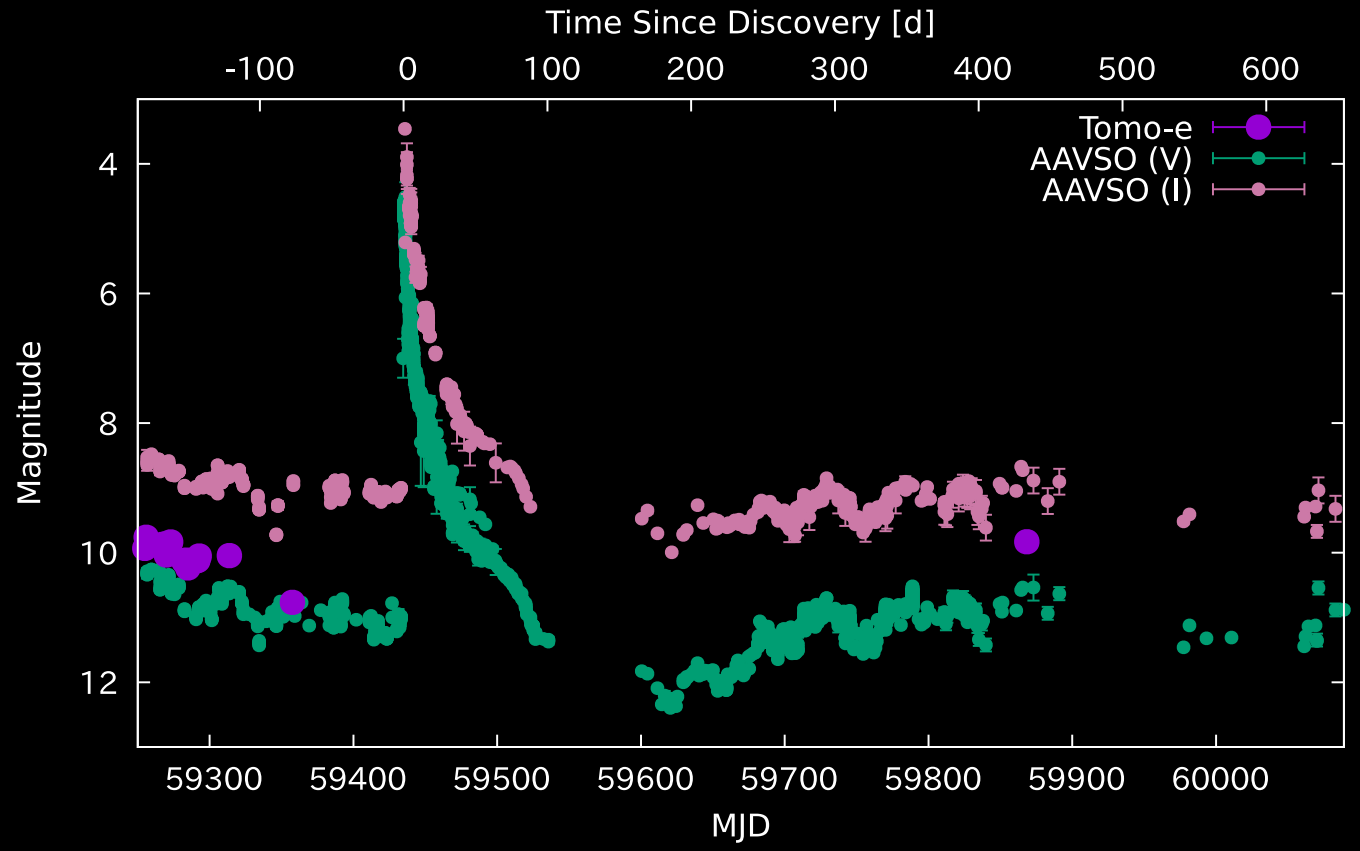
PGIR22gjh = AT 2022iev (x_x)

- Discovered by Palomar Gattini-IR survey at J = 9.505 on 2022-04-24.41
- Tomo-e: No data (probably due to the low dec, –19.37).



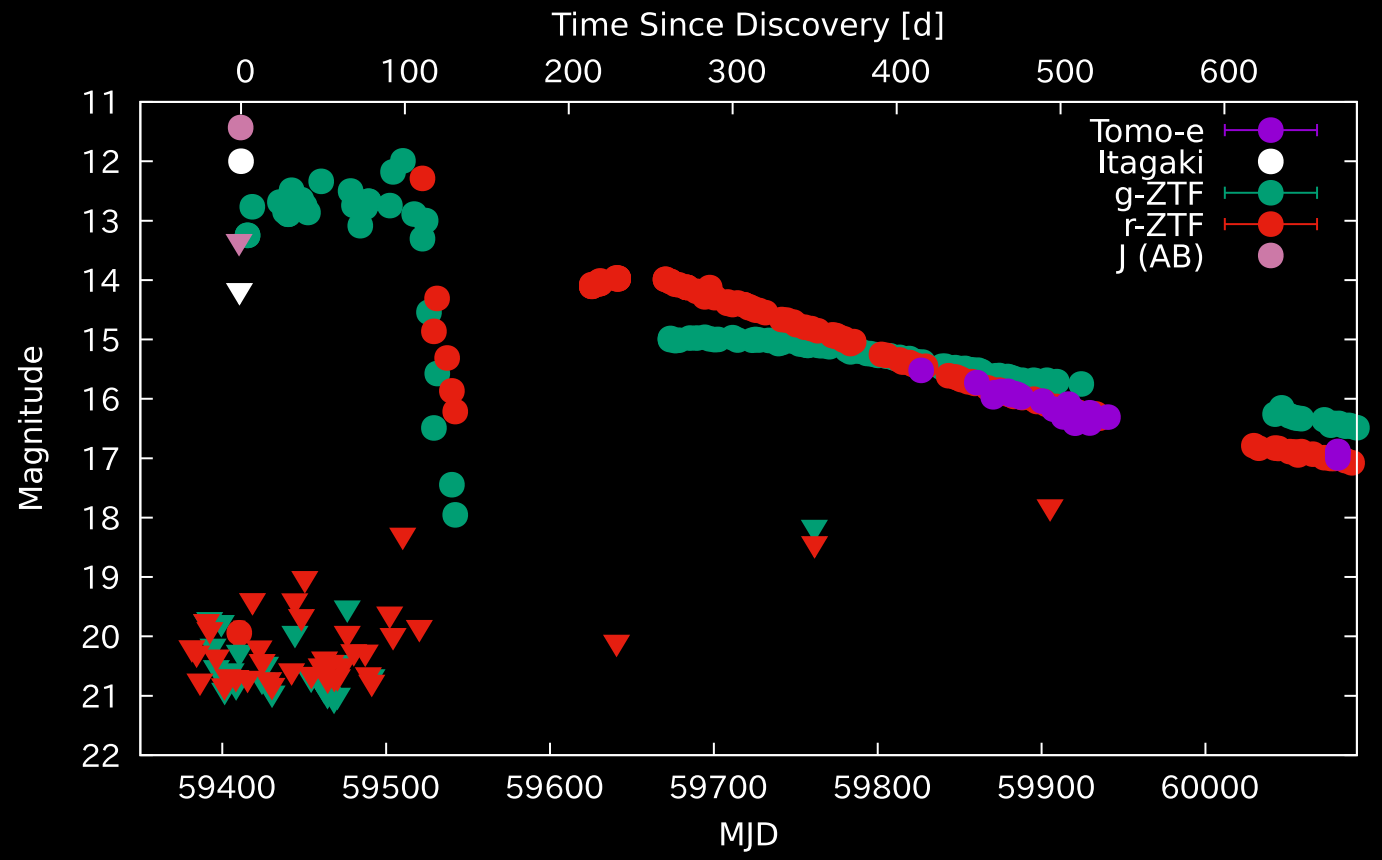
RS Oph (x_x)

- Discovered by E. Muyllaert on 2021-08-08.91 after the 15-years interval.
- No Tomo-e data points between 2021-05-23 and 2022-10-16.



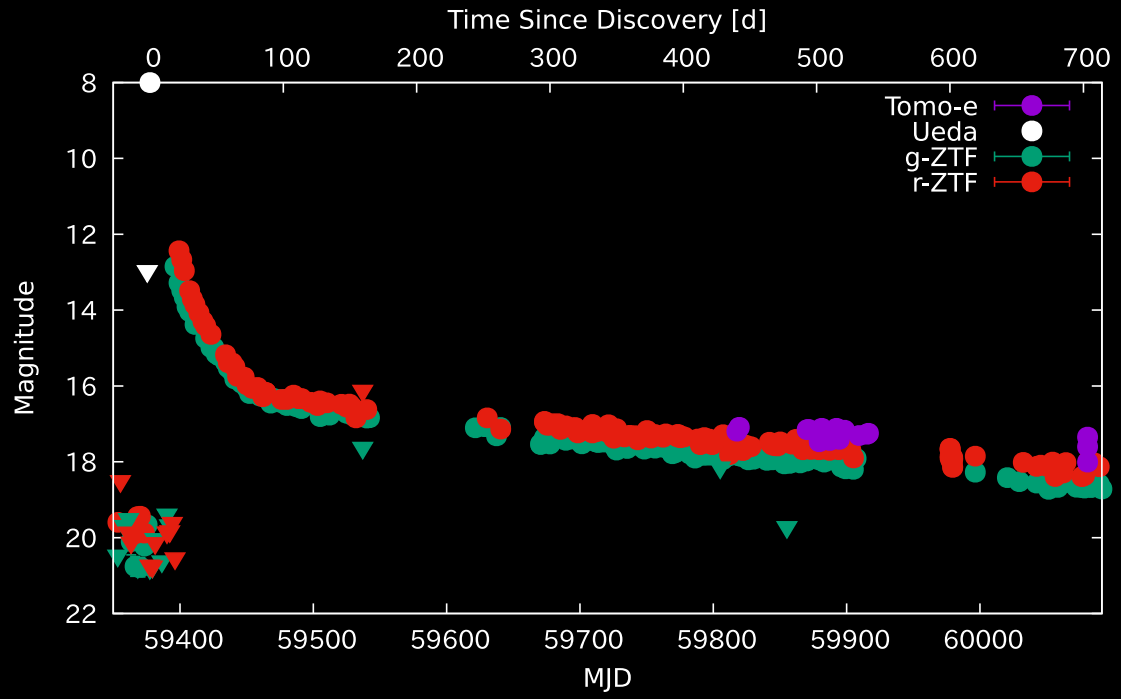
V606 Vul = AT 2021twr (x_x)

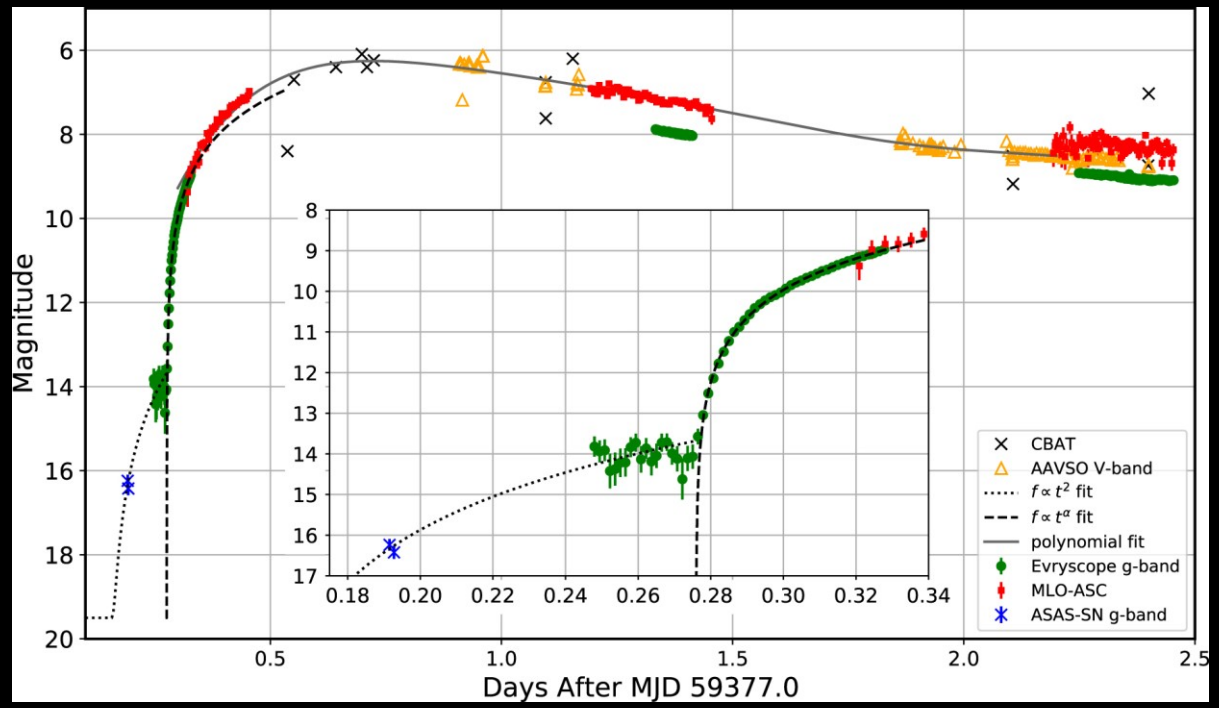
- Discovered by K. Itagaki on 2021-07-16.475.
- No Tomo-e data points in 2021.



V1674 Her (x_x)

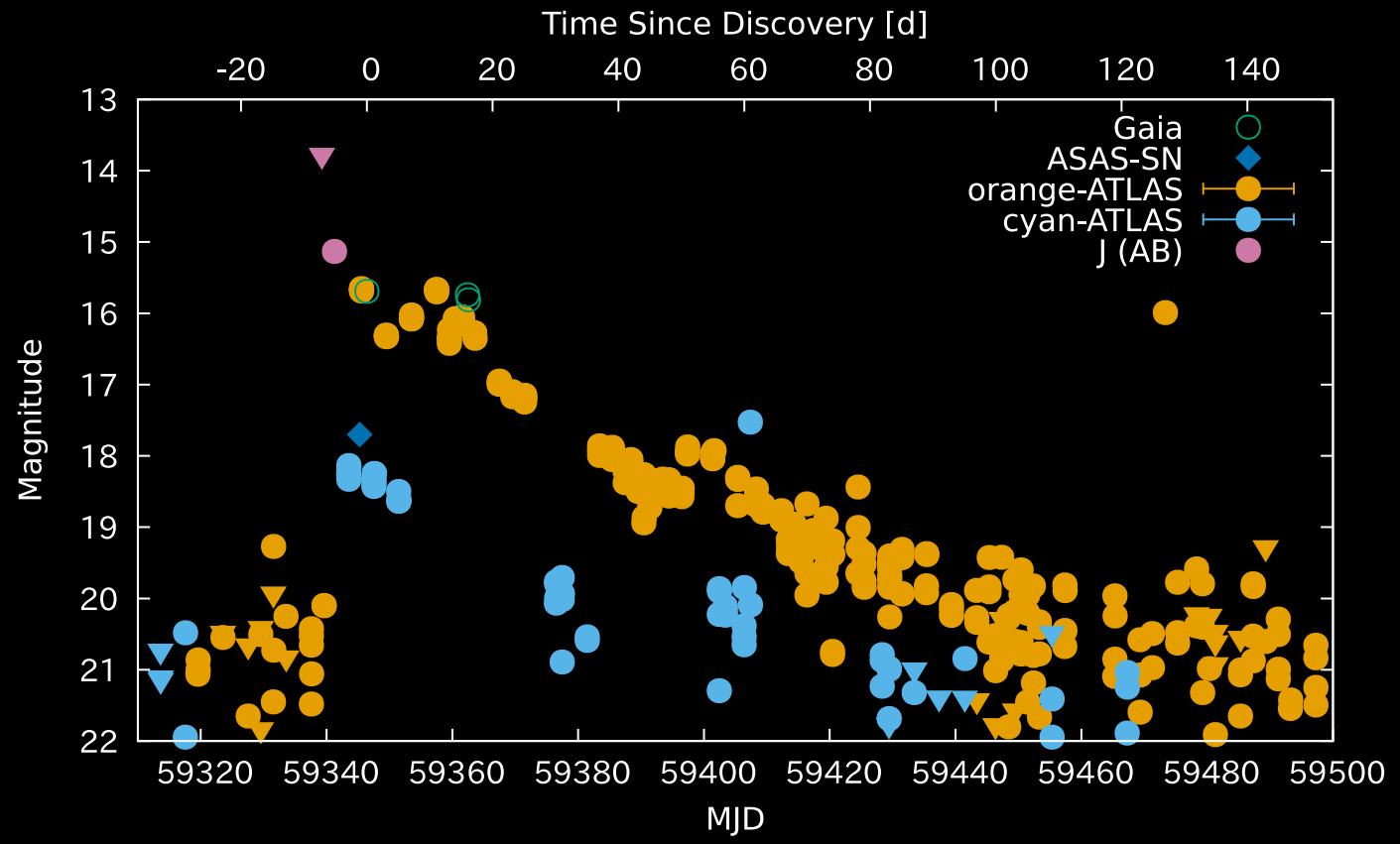
- Discovered by S. Ueda on 2021.06.12.537.
  - Pre-discovery detection (2-min cadence) by Quimby et al., arXiv:2107.05763
  - One of the “fastest nova” ever recorded.
- No Tomo-e data on 2021.





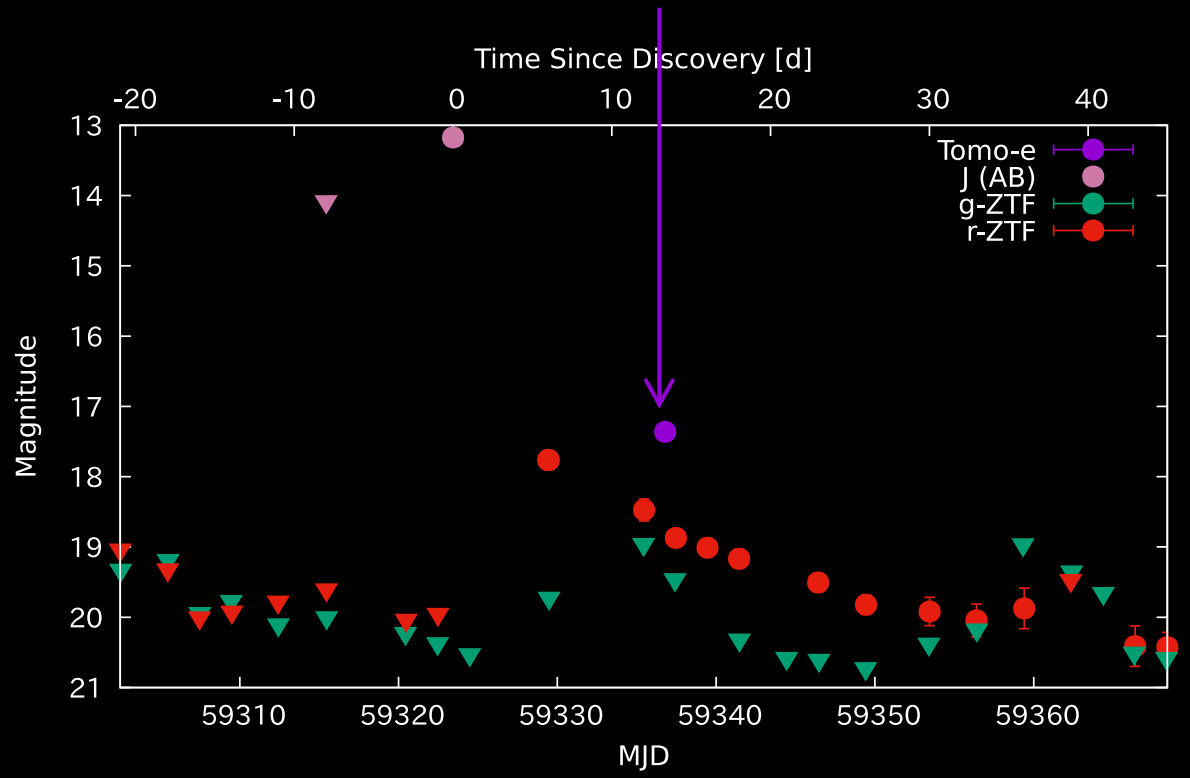
Gaia21cpb = AT 2021nwn (x_x)

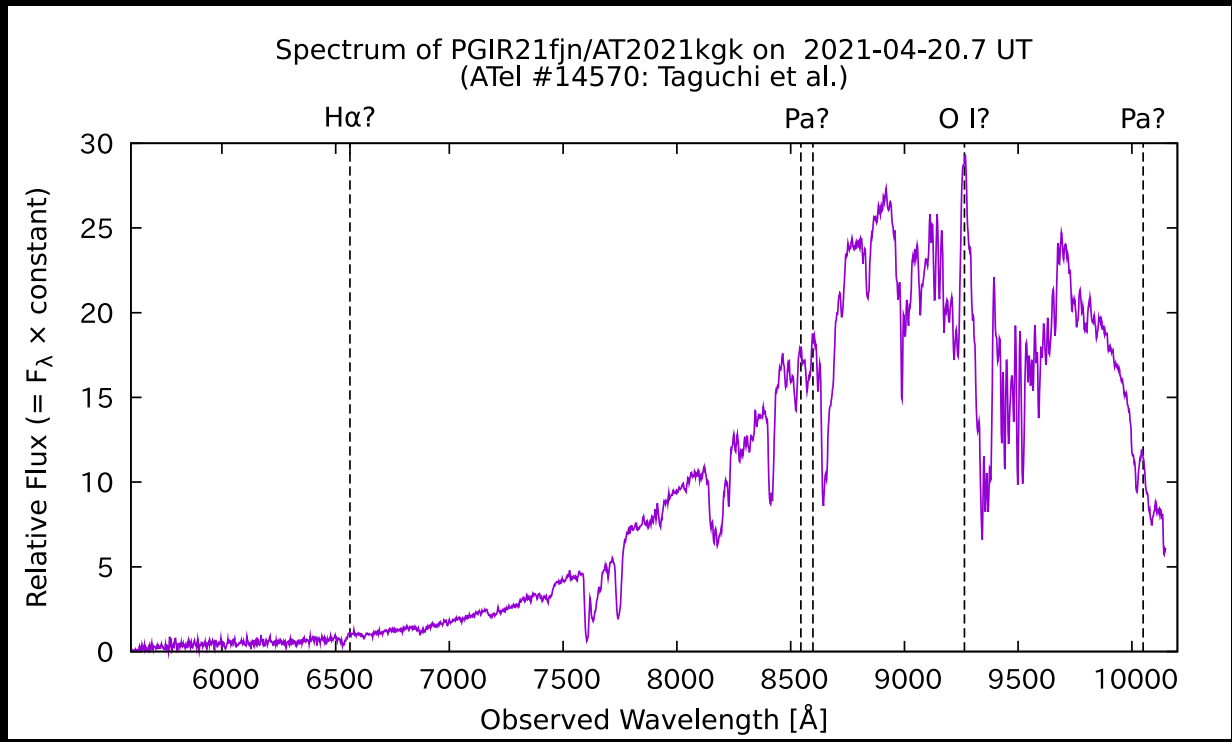
- Discovered by Gaia on 2021-05-12.40.
- No Tomo-e data points.



V2030 Aql = AT 2021kgk (˙-˙)

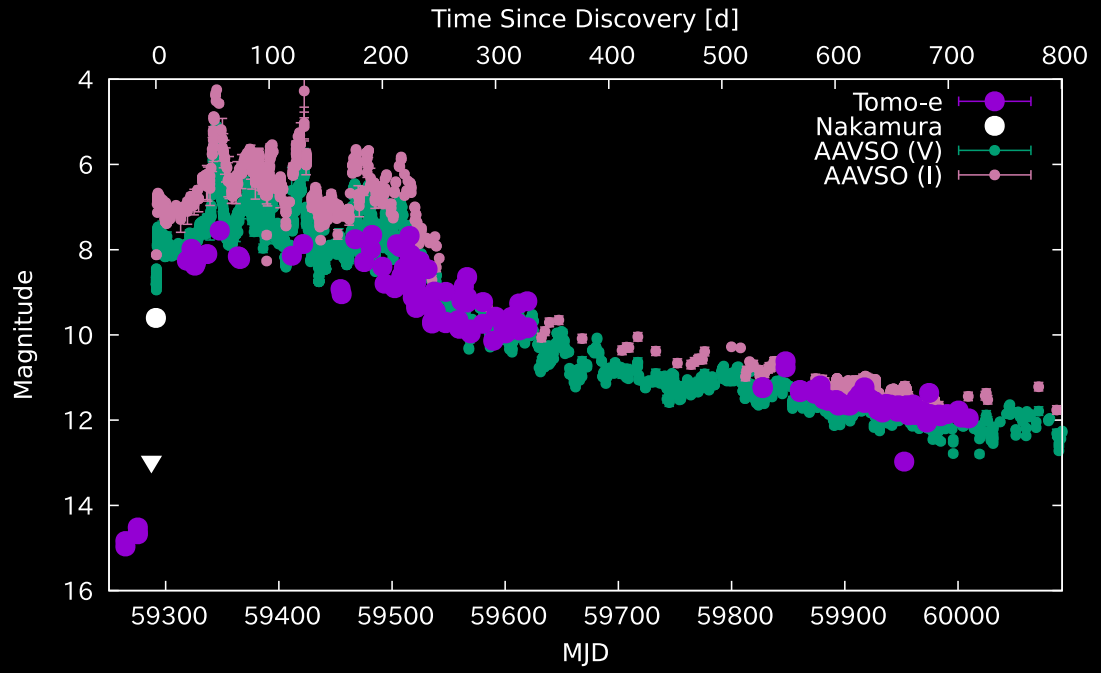
- Discovered by Palomar Gattini-IR survey on 2021-04-19.43 (ATel #14567)
  - "Reddened" spectra by Soria+ (ATel #14567, 14574) & Taguchi+ (ATel #14570)
- Tomo-e has 1 data point (13 days after the discovery).



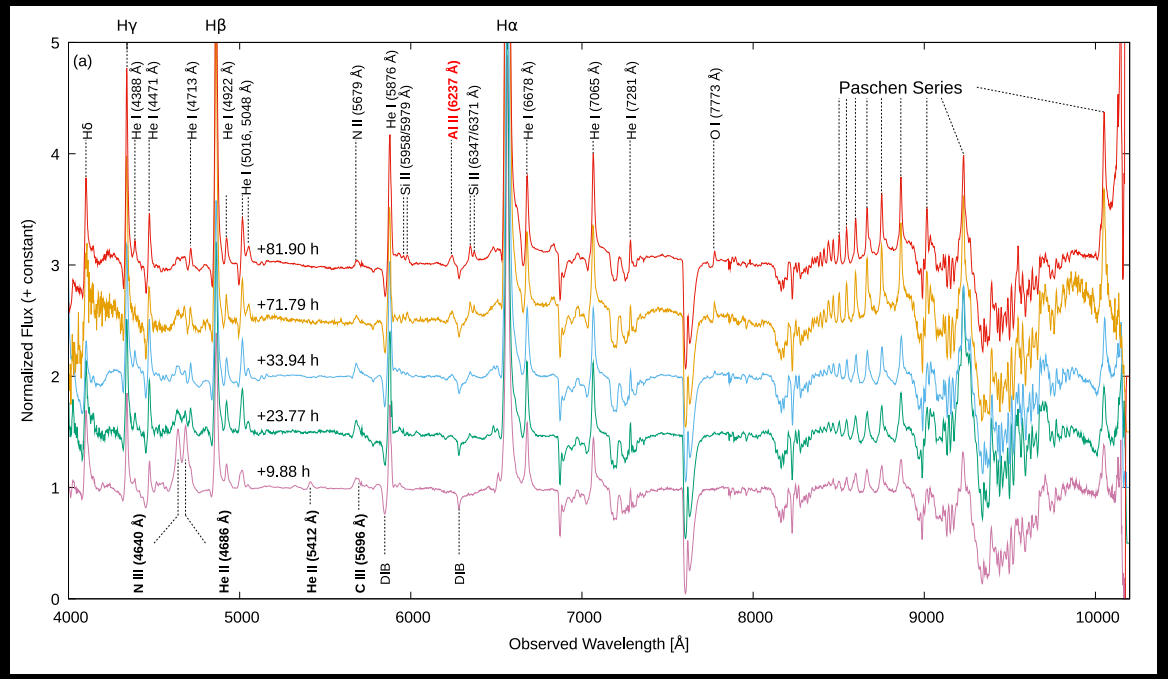


V1405 Cas (˙-˙)

- Discovered by Y. Nakamura on 2021-03-18.4236 UT.
  → Classified by Maehara et al. (ATel #14471)
- Tomo-e's last pre-outburst detection: 2021-03-02.
- Tomo-e's first outburst detection: 2021-04-14.



Taguchi+ (in revision)



V1112 Per = AT 2020abap (˙-˙)

- Discovered by S. Ueda on 2020-11-25.8071
- Tomo-e's first data on 2021-11-28.4679.