Millinovae: a new class of transient supersoft X-ray sources without a nova eruption

Przemek Mroz et al. (arXiv:2409.17338v1)

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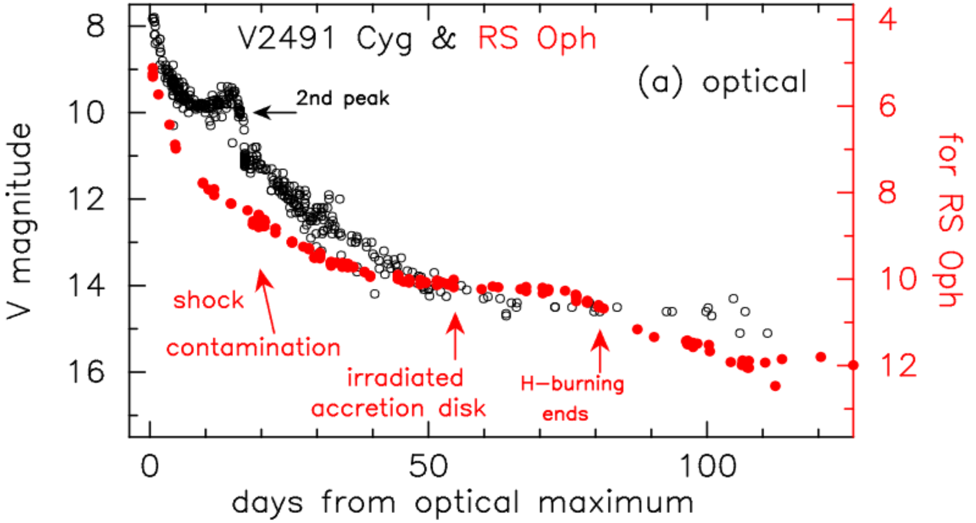
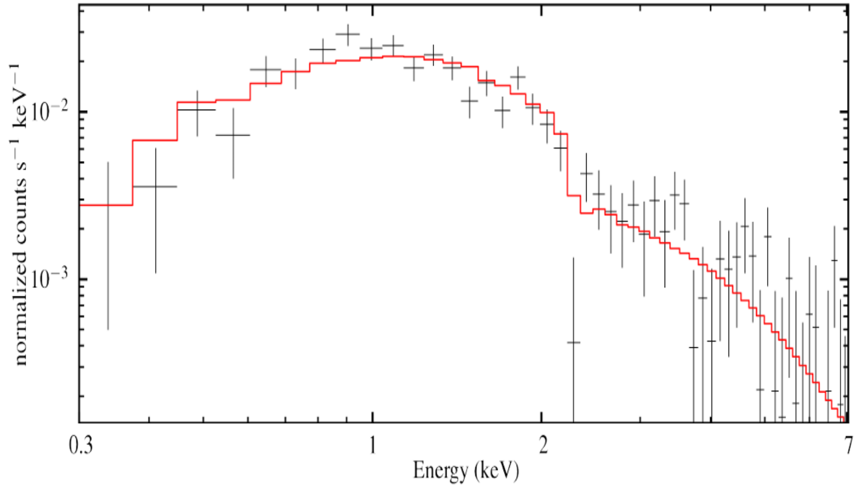
30/09/2024 @SWIFAR, YNU

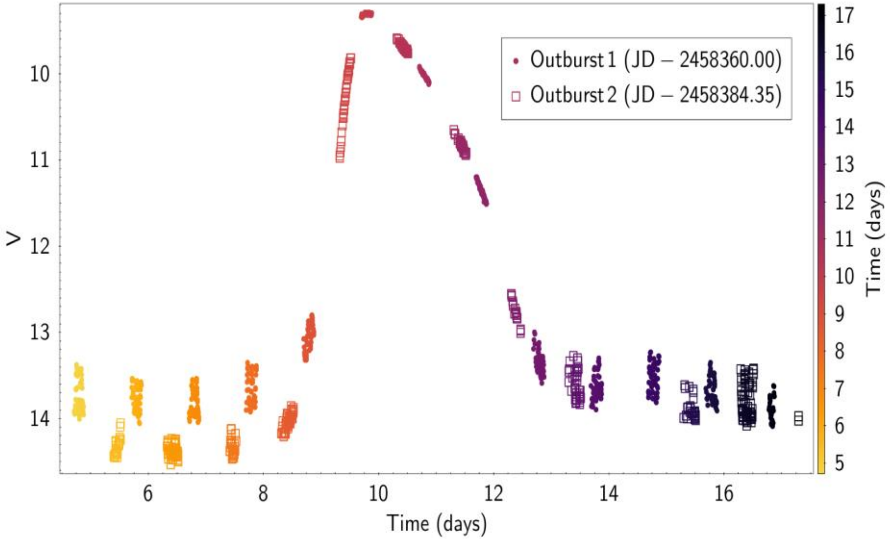
1.Classical novae and dwarf novae

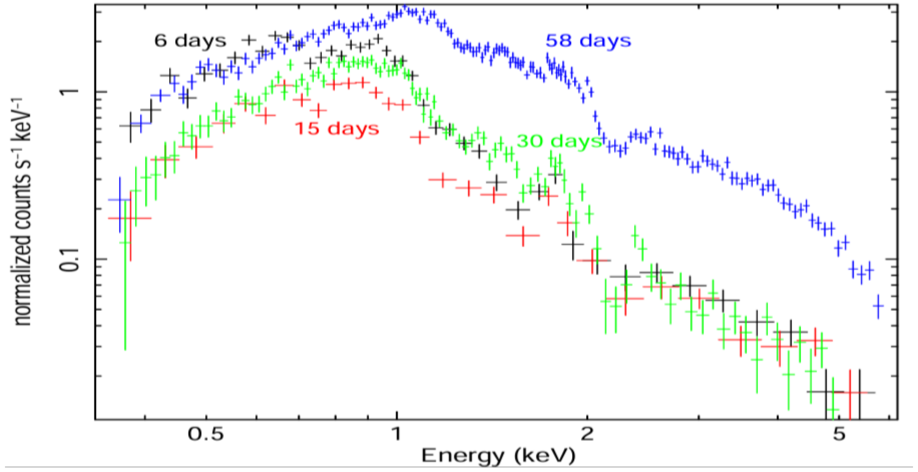
- **Classical novae:**
  - The maximum X-ray luminosity :$10^{36} - 10^{38}$ erg/s
  - Optical absolute magnitude : -6 to -10





- **Dwarf novae:**
  - The maximum X-ray luminosity : $10^{29} - 10^{32}$ erg/s;
  - Optical absolute magnitude : +6 to 0

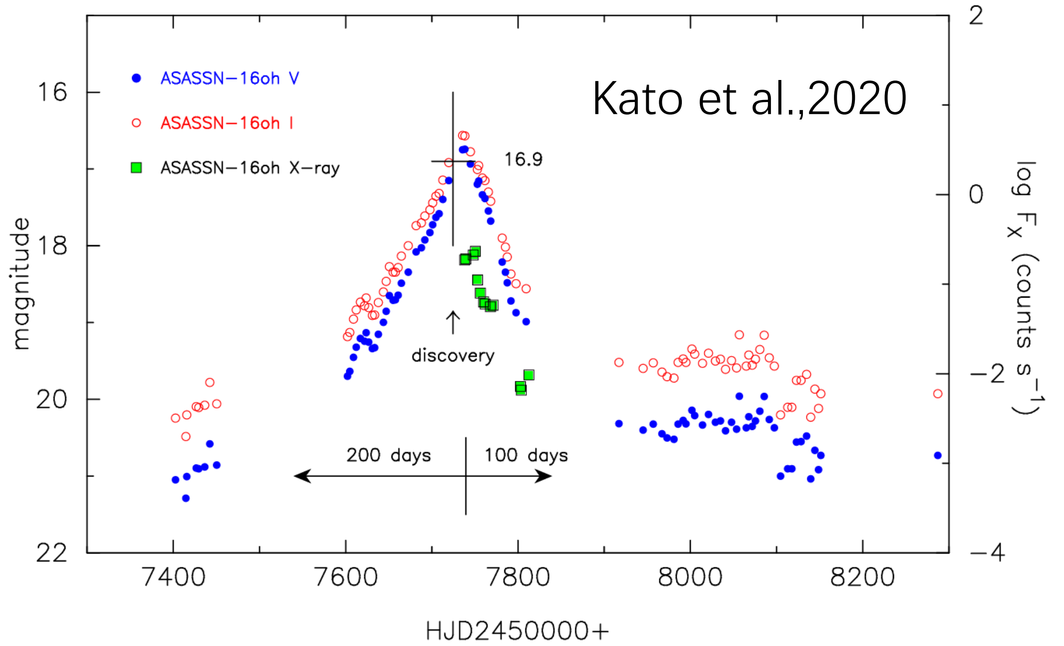


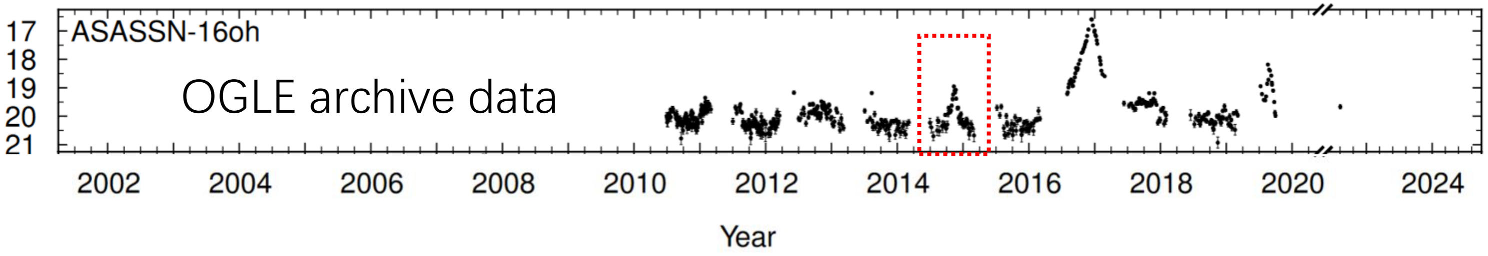


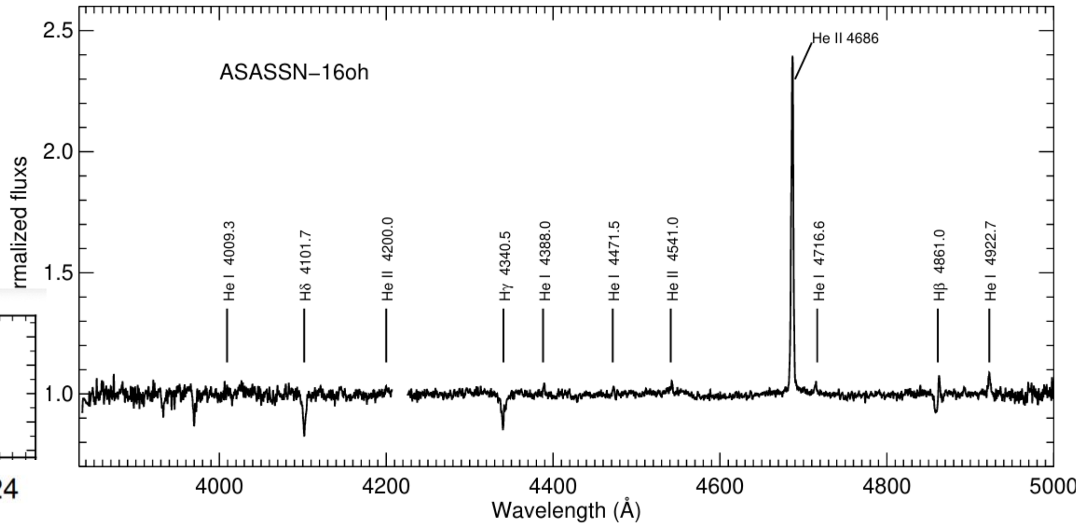
2.Unusual nova: ASASSN-16oh

- **Discovery time** : December 2016
- **Location** : Small Magellanic Cloud (SMC).
- **magnitude** : $m_V = 16.9$ mag
- L_{x-ray}: 6.7×10^{36} erg/s,(900,000K BB), similar to persistent supersoft X-ray sources and classical novae.

- Long time rising (~200days);
- Narrow optical emission lines (FWHM=164km/s)
- Symmetric light curve.



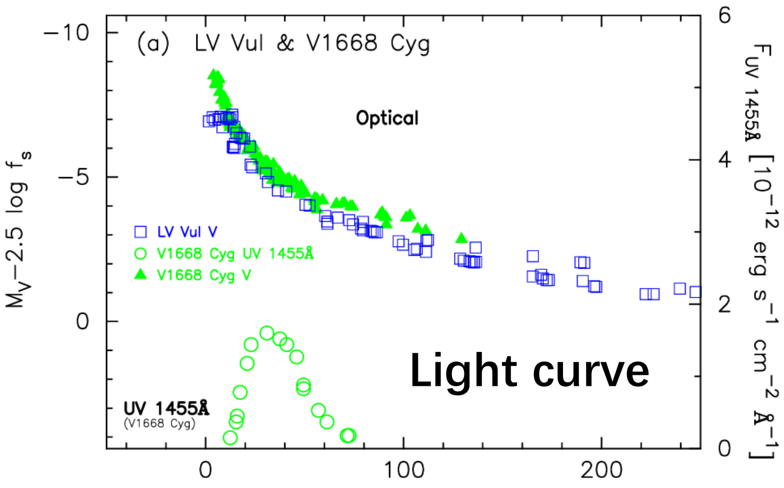


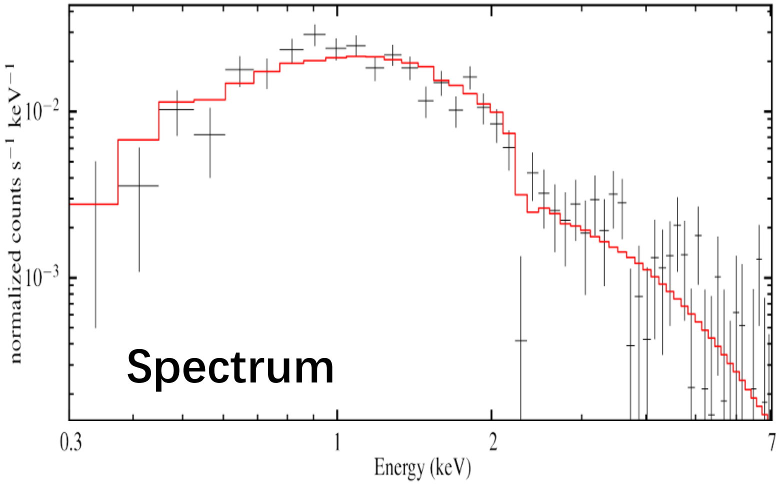


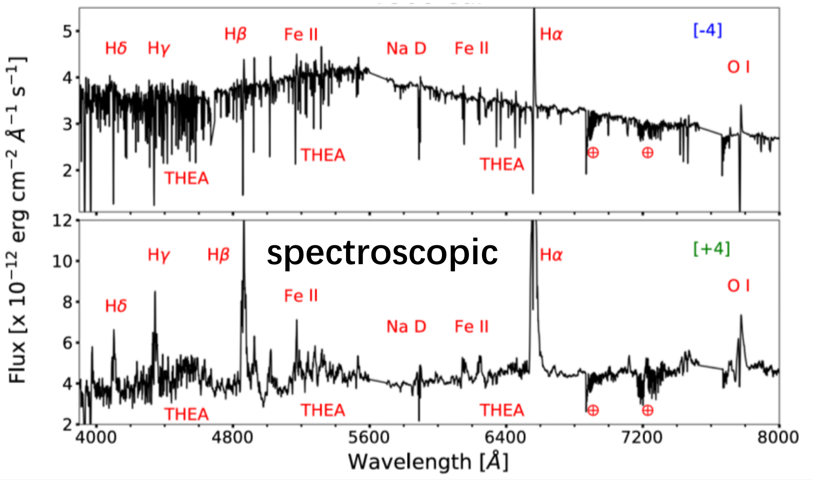
A.F. Rajoelimanana et al.,2017

3. Classical novae VS. ASASSN-16oh

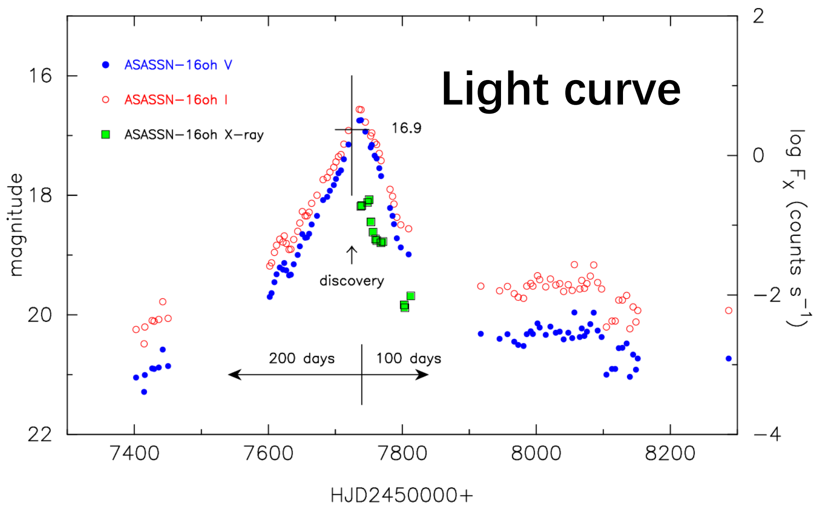
Classical novae

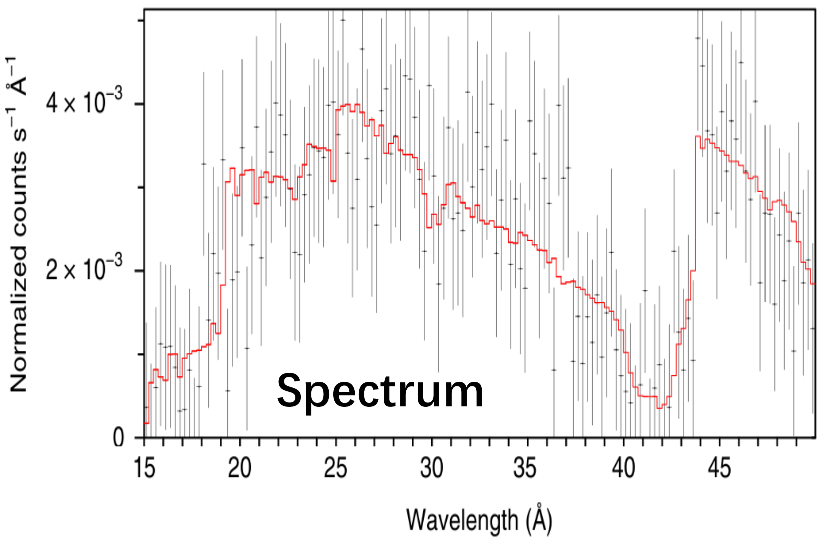


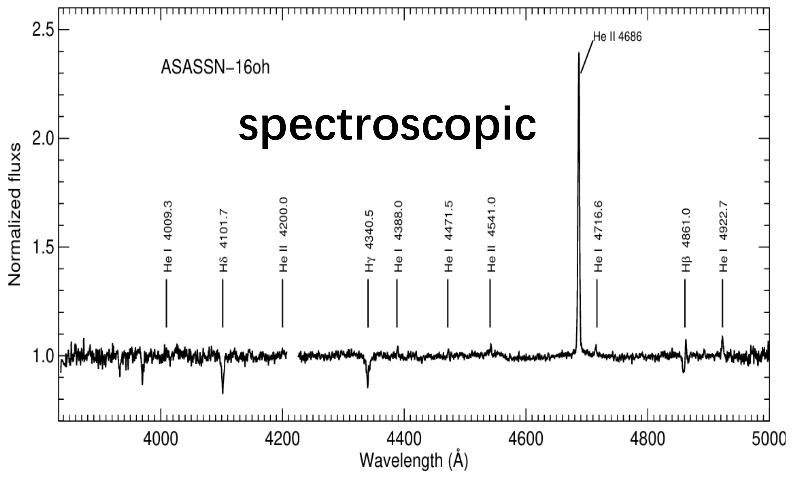




ASASSN-16oh







4.Searching from Magellanic Clouds

① OGLE photometry data: light curves contain at least five consecutive data points magnified with respect to the remaining light curve.
72303 objects : 54996 in LMC, 17307 in SMC;

② Inspection : light curve contains at least one outburst with an amplitude larger than 1 mag and duration between 10 and 600 days.

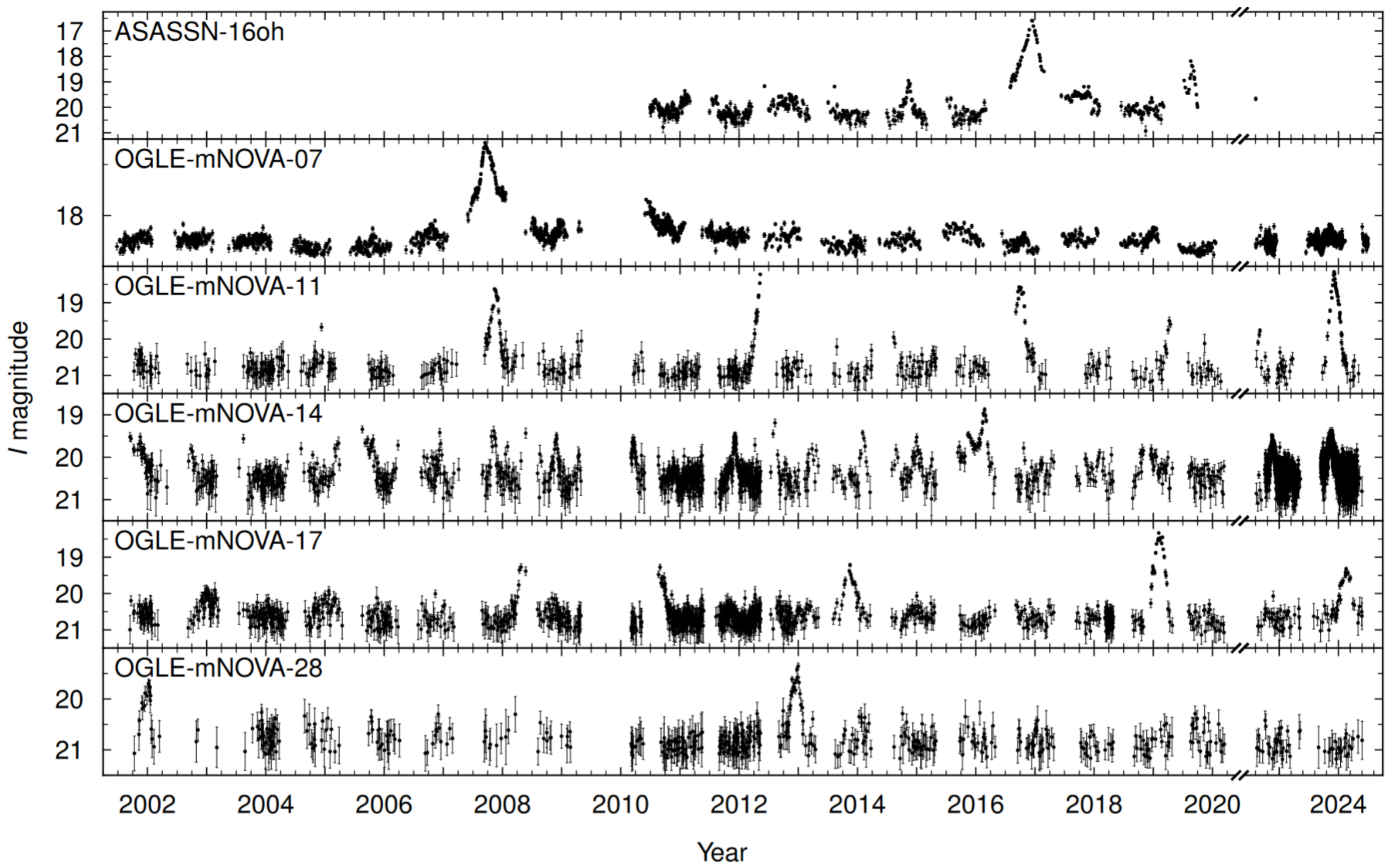
③ Cross-matched with Gaia DR3 data, and removed artifacts
10101 objects, 7412 in LMC, 2689 in SMC;

④ Visually inspected and selected the initial sample of outbursts similar to those of ASASSN-16oh.

⑤ Vetted all the selected objects using additional data including multi-color photometry, Gaia parallaxes and proper motions, and sky images. Then removed objects that could be classified as classical novae, supernovae, and active galactic nuclei.

⑥ Searching results:
22 in LMC , 7 in SMC.

Name	RA	Decl.	I_q	$(V-I)_q$	I_{max}	$(V-I)_{max}$	$E(V-I)$	Comments
OGLE-mNOVA-01	$01^h57^m43^s.64$	$-73°37'32''.5$	20.273 ± 0.016	0.784 ± 0.056	16.595 ± 0.012	0.198 ± 0.008	0.059	ASASSN-16oh
OGLE-mNOVA-02	$00^h20^m40^s.41$	$-75°11'56''.5$	20.981 ± 0.017	1.088 ± 0.058	19.216 ± 0.050	...	0.042	
OGLE-mNOVA-03	$00^h26^m10^s.69$	$-73°34'18''.2$	21.063 ± 0.040	0.502 ± 0.186	19.956 ± 0.055	0.501 ± 0.055	0.028	
OGLE-mNOVA-04	$00^h34^m30^s.23$	$-74°05'40''.3$	21.008 ± 0.025	0.611 ± 0.239	19.706 ± 0.064	...	0.046	
OGLE-mNOVA-05	$00^h50^m08^s.58$	$-69°46'33''.8$	20.745 ± 0.017	0.894 ± 0.068	18.885 ± 0.022	0.420 ± 0.017	0.016	candidate
OGLE-mNOVA-06	$00^h51^m18^s.58$	$-68°54'34''.7$	20.916 ± 0.017	1.051 ± 0.073	19.268 ± 0.029	0.354 ± 0.033	0.011	
OGLE-mNOVA-07	$00^h52^m45^s.30$	$-72°20'07''.5$	18.276 ± 0.010	0.574 ± 0.015	17.301 ± 0.012	0.545 ± 0.008	0.068	
OGLE-mNOVA-08	$04^h51^m40^s.68$	$-68°25'14''.5$	20.197 ± 0.013	0.987 ± 0.019	18.255 ± 0.024	...	0.128	
OGLE-mNOVA-09	$04^h51^m58^s.14$	$-68°30'35''.6$	20.057 ± 0.015	1.428 ± 0.064	19.015 ± 0.046	1.267 ± 0.028	0.122	candidate
OGLE-mNOVA-10	$04^h56^m24^s.20$	$-68°27'31''.5$	20.673 ± 0.026	0.789 ± 0.110	19.586 ± 0.091	0.771 ± 0.128	0.119	
OGLE-mNOVA-11	$04^h59^m56^s.68$	$-67°31'48''.9$	20.884 ± 0.039	1.244 ± 0.129	18.151 ± 0.021	0.420 ± 0.023	0.100	
OGLE-mNOVA-12	$05^h04^m03^s.38$	$-69°33'17''.9$	20.814 ± 0.033	0.776 ± 0.171	19.407 ± 0.029	0.570 ± 0.014	0.083	MACHO-LMC-7
OGLE-mNOVA-13	$05^h06^m17^s.46$	$-70°58'46''.8$	20.096 ± 0.011	0.847 ± 0.018	18.909 ± 0.048	...	0.124	MACHO-LMC-23
OGLE-mNOVA-14	$05^h10^m15^s.41$	$-70°31'43''.6$	20.423 ± 0.018	0.372 ± 0.061	18.847 ± 0.058	0.156 ± 0.091	0.092	
OGLE-mNOVA-15	$05^h12^m44^s.80$	$-69°41'28''.0$	20.790 ± 0.022	0.886 ± 0.078	18.540 ± 0.018	0.478 ± 0.015	0.183	candidate
OGLE-mNOVA-16	$05^h14^m22^s.96$	$-70°56'56''.1$	20.545 ± 0.019	0.327 ± 0.031	19.202 ± 0.045	0.223 ± 0.061	0.072	
OGLE-mNOVA-17	$05^h15^m05^s.58$	$-68°31'07''.2$	20.461 ± 0.015	0.893 ± 0.087	19.312 ± 0.065	0.810 ± 0.027	0.105	
OGLE-mNOVA-18	$05^h15^m17^s.91$	$-70°36'58''.6$	20.366 ± 0.011	0.904 ± 0.018	18.570 ± 0.037	0.756 ± 0.078	0.094	
OGLE-mNOVA-19	$05^h17^m12^s.72$	$-68°49'38''.4$	21.179 ± 0.031	0.838 ± 0.084	19.775 ± 0.037	0.541 ± 0.045	0.102	
OGLE-mNOVA-20	$05^h20^m05^s.81$	$-69°38'31''.0$	19.648 ± 0.011	0.118 ± 0.018	18.259 ± 0.020	0.146 ± 0.024	0.078	
OGLE-mNOVA-21	$05^h25^m58^s.44$	$-69°34'33''.8$	19.886 ± 0.011	0.656 ± 0.017	18.492 ± 0.025	0.498 ± 0.020	0.078	
OGLE-mNOVA-22	$05^h26^m45^s.21$	$-70°29'45''.7$	18.574 ± 0.010	0.580 ± 0.014	17.653 ± 0.015	...	0.139	
OGLE-mNOVA-23	$05^h27^m48^s.98$	$-68°15'44''.6$	21.167 ± 0.047	0.700 ± 0.302	20.006 ± 0.051	0.451 ± 0.029	0.099	
OGLE-mNOVA-24	$05^h28^m25^s.12$	$-70°20'43''.8$	21.032 ± 0.048	0.671 ± 0.094	18.661 ± 0.036	0.487 ± 0.027	0.082	
OGLE-mNOVA-25	$05^h30^m47^s.88$	$-69°54'33''.8$	20.404 ± 0.014	0.428 ± 0.022	19.228 ± 0.080	0.520 ± 0.059	0.060	
OGLE-mNOVA-26	$05^h32^m10^s.63$	$-70°22'09''.5$	20.764 ± 0.027	0.097 ± 0.116	19.366 ± 0.057	-0.023 ± 0.025	0.124	
OGLE-mNOVA-27	$05^h37^m56^s.29$	$-68°48'51''.0$	20.763 ± 0.028	1.010 ± 0.025	19.273 ± 0.069	...	0.263	
OGLE-mNOVA-28	$05^h52^m29^s.30$	$-71°10'29''.9$	20.818 ± 0.023	1.079 ± 0.227	19.439 ± 0.034	0.537 ± 0.055	0.141	
OGLE-mNOVA-29	$05^h53^m41^s.54$	$-70°22'23''.0$	20.747 ± 0.019	0.410 ± 0.027	19.758 ± 0.078	0.655 ± 0.088	0.105	



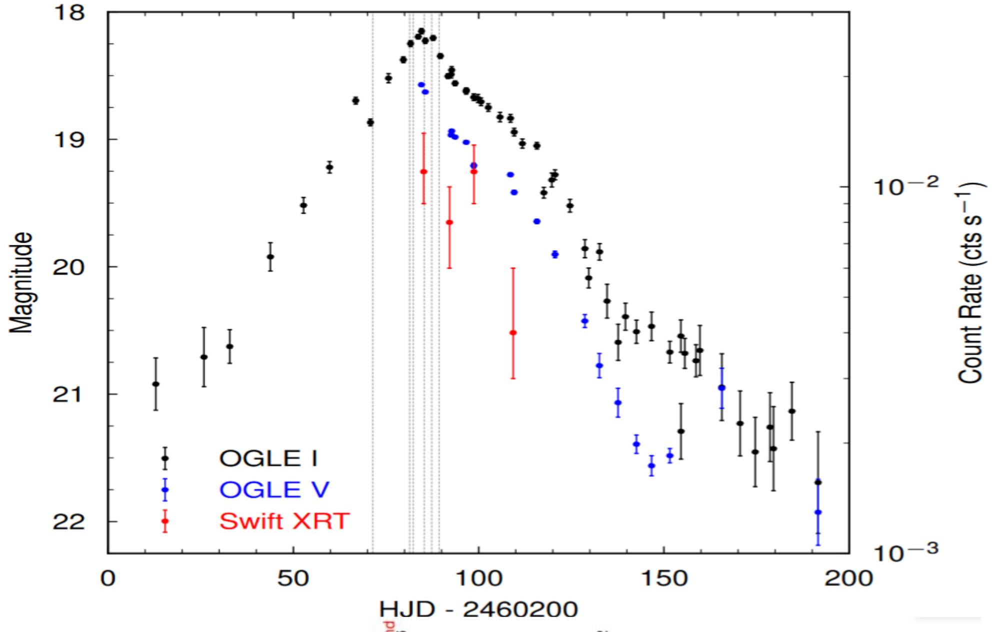
All objects show long-duration (weeks to months), symmetrical (triangle shaped) outbursts with amplitudes in I ranging from 1.0 to 3.7 mag

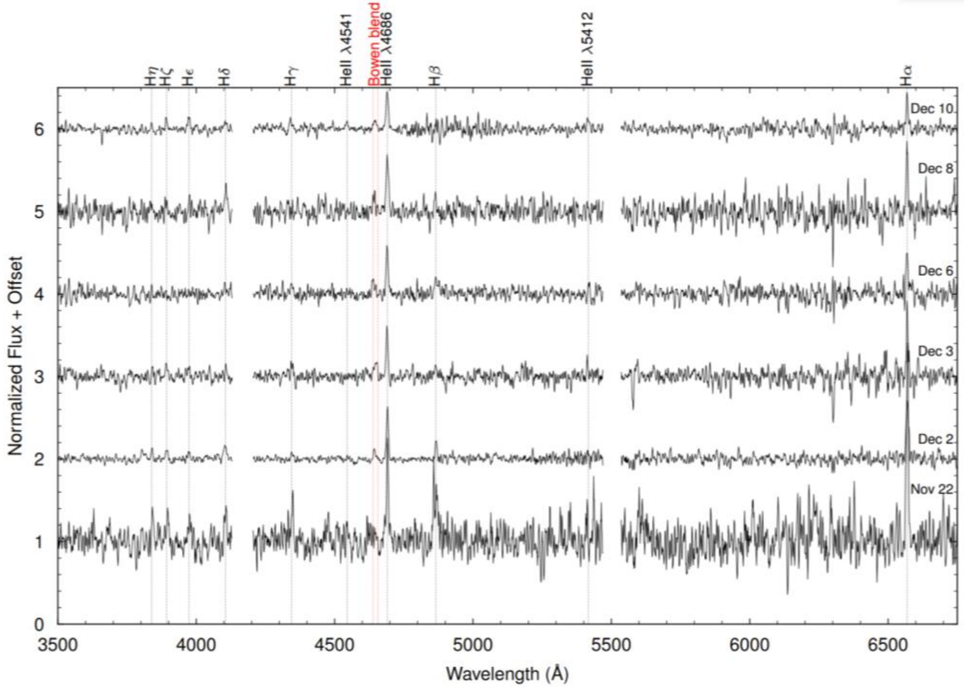
5.Outburst of OGLE-mNOVA-11 (LMC)

- Observation period: 2023 October 15.3 to 26.3
- Peak time: 2023 December 6.1
- Apparent magnitude: I = 18.15 ± 0.02, V = 18.57 ± 0.01
- Absolute magnitude: MI = −0.5 ± 0.1, MV = −0.2 ± 0.1,
- Outburst duration: ~ 120 days
- $L_{X(0.3-10keV)}$: 0.9×10^{35} erg/s or 3.6×10^{35} erg/s;
- Blackbody temperature: $607{,}000^{+160{,}000}_{-130{,}000}$ K.

- Narrow emission lines : FWHM = 247±28 km s−1
- Emission lines are redshifted with velocity of 278.3 ± 4.5 km s−1, close to that of the LMC systemic value (262.2 ± 3.4 km s−1)

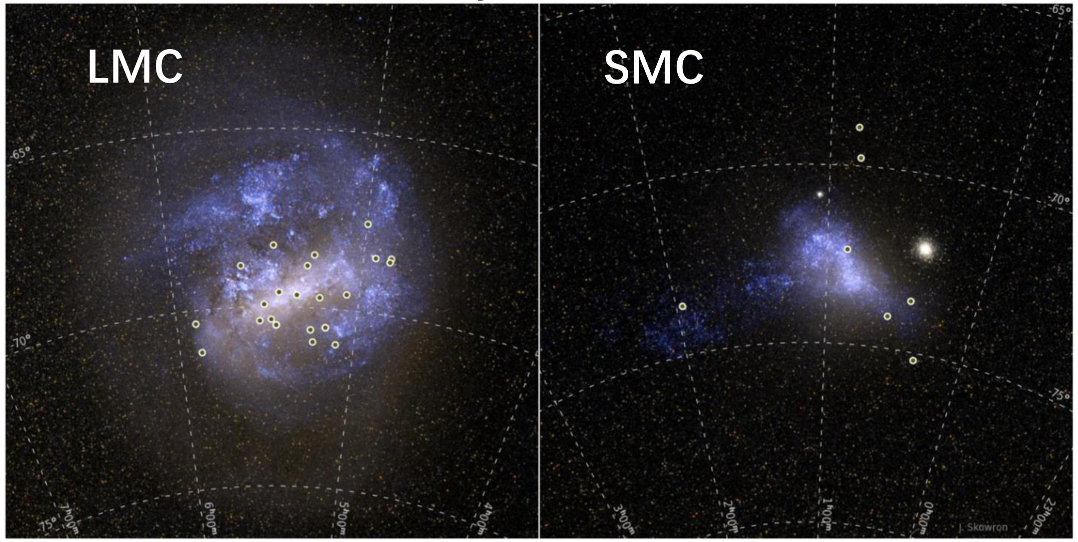
millinovae





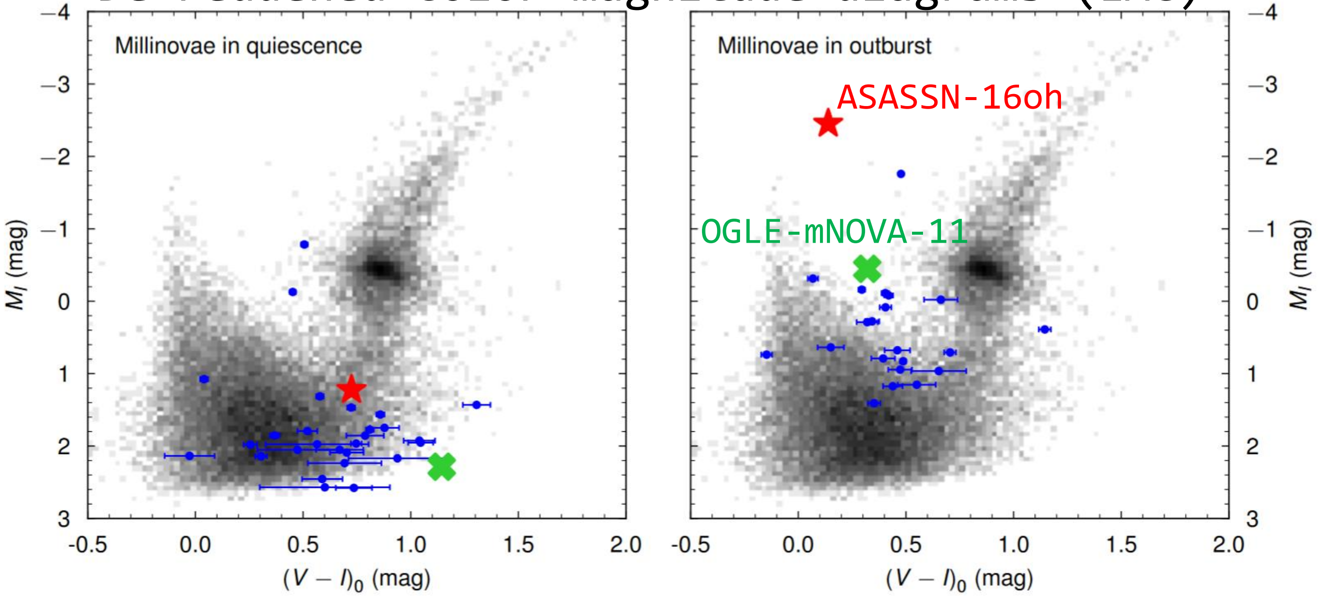
6. Millinovae, population characteristics

The sky location



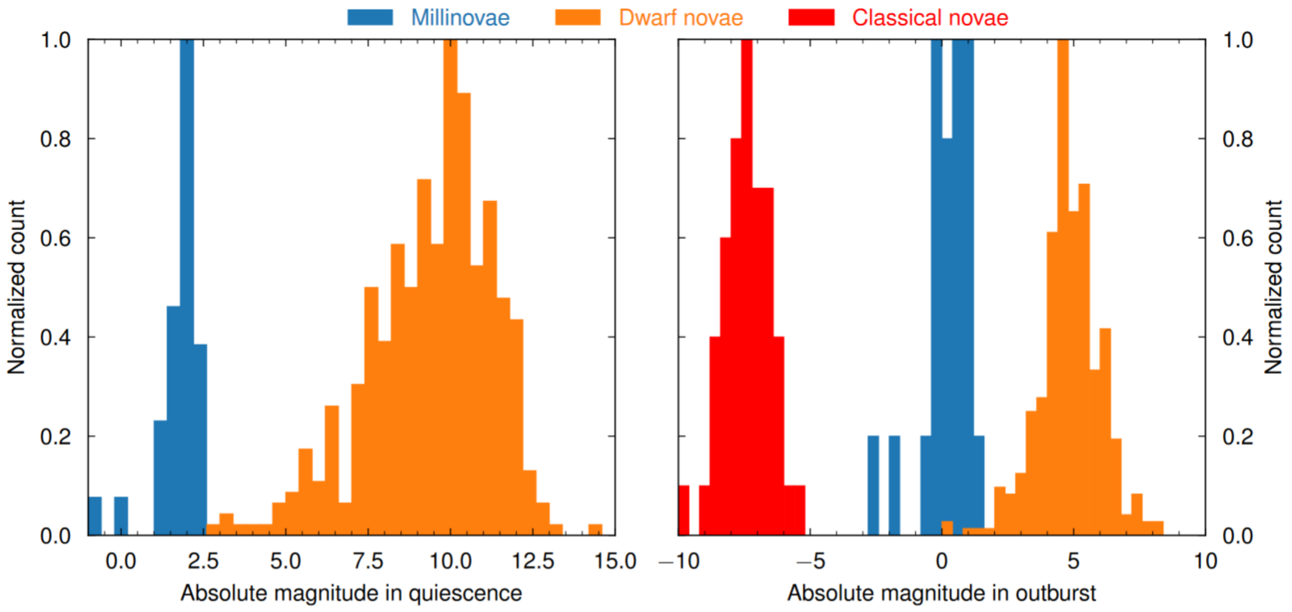
- Most of the selected stars occupy a relatively narrow region.
- Proper motions and radial velocities are measured and consistent with those of stars located in LMC and SMC.

De-reddened color–magnitude diagrams (LMC)

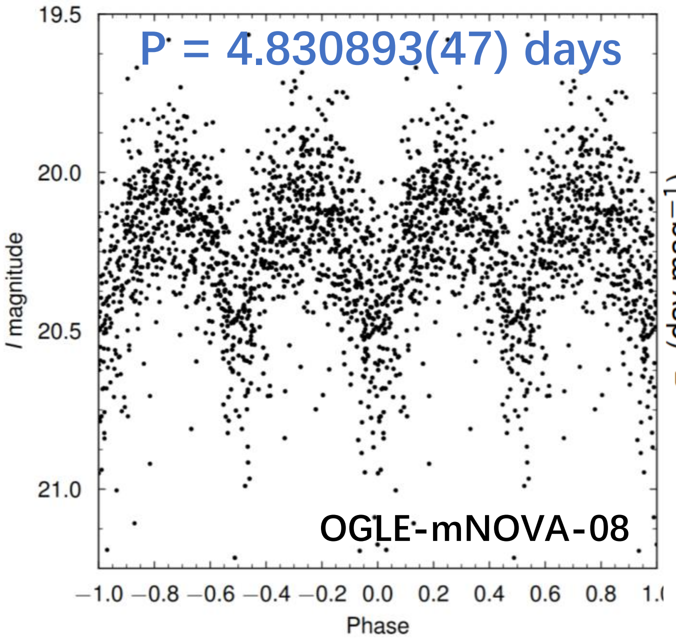


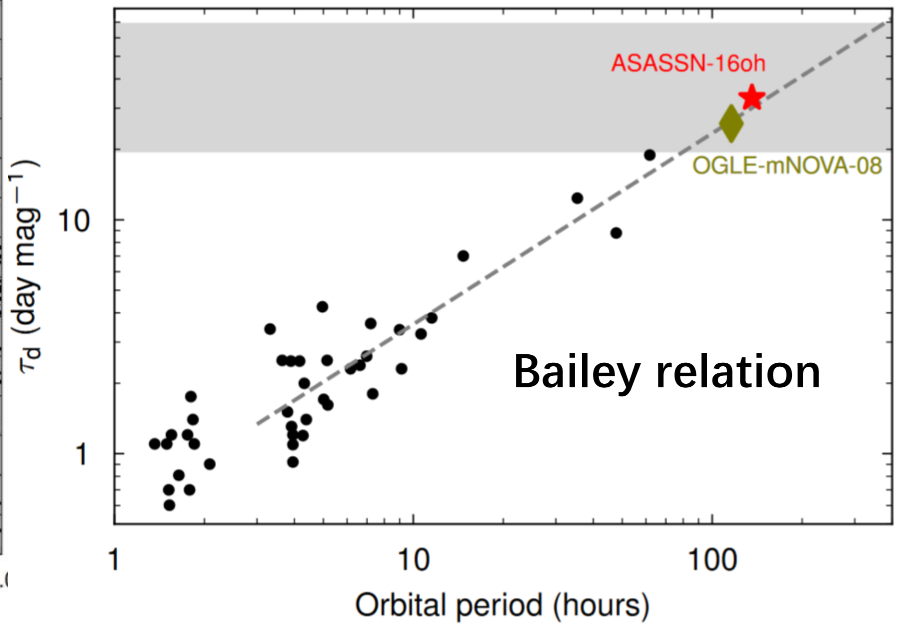
- Occupied region (quiescence) :
  $0.5 \leqslant (V-I)_0 \leqslant 1.0,\ 1.5 \leqslant M_I \leqslant 2.5,$
- Occupied region (outburst) :
  $0.0 \leqslant (V-I)_0 \leqslant 0.5,\ -0.5 \leqslant M_I \leqslant 1.0,$

6. Millinovae, population characteristics



- **Mean absolute magnitudes(quiescence):** $M_I = 1.72 \pm 0.70$ and $M_V = 2.37 \pm 0.80$
- **Mean absolute magnitudes(outburst):** $M_I = 0.18 \pm 0.83$ and $M_V = 0.62 \pm 0.97$
- Eclipsing variability with a 4.830893(47) day period.





Most millinovae have decline rates in the range 20 < τd < 70 day mag−1, which corresponds to orbital periods from 3 to 15 day, assuming that the Bailey relation can be extrapolated to such long periods.

7. Summary

1. Transient ASASSN-16oh is a unusual transient that does not match the classical novae.

2. 29 objects were discovered in MC, which are similar to ASASSN-16oh in LC, X-ray spectrum, narrow emission.

3. OGLE-mNOVA-11 was detected in the near-real-time monitoring of these selected objects and exhibit the same properties with ASASSN-16oh.

4. These 29 objects described in this study, could form a homogeneous group of transient supersoft X-ray sources and dub “millinovae” because their optical luminosities are roughly a thousand times fainter than those of ordinary classical novae.

5. The solution to explaining the properties of millinovae is still unknown.

6. These millinovae found in MC opens an important new route for study, with the added benefit of a well-constrained population in the Magellanic Clouds.

Thanks .