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Discovery of Changing-look AGNs via Mid-infrared variability

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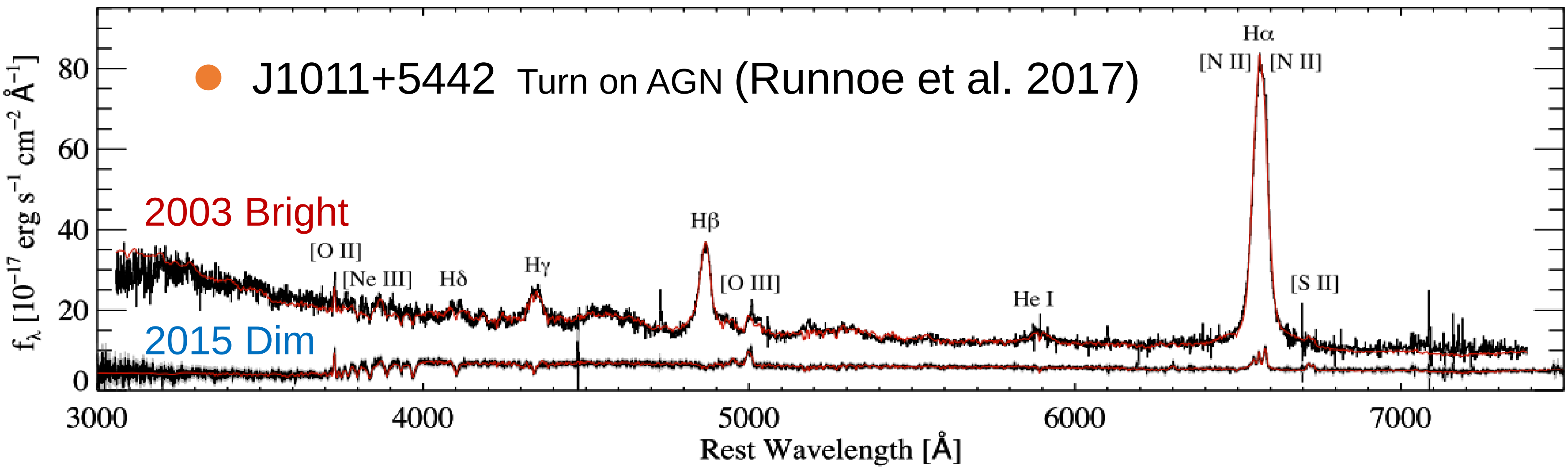
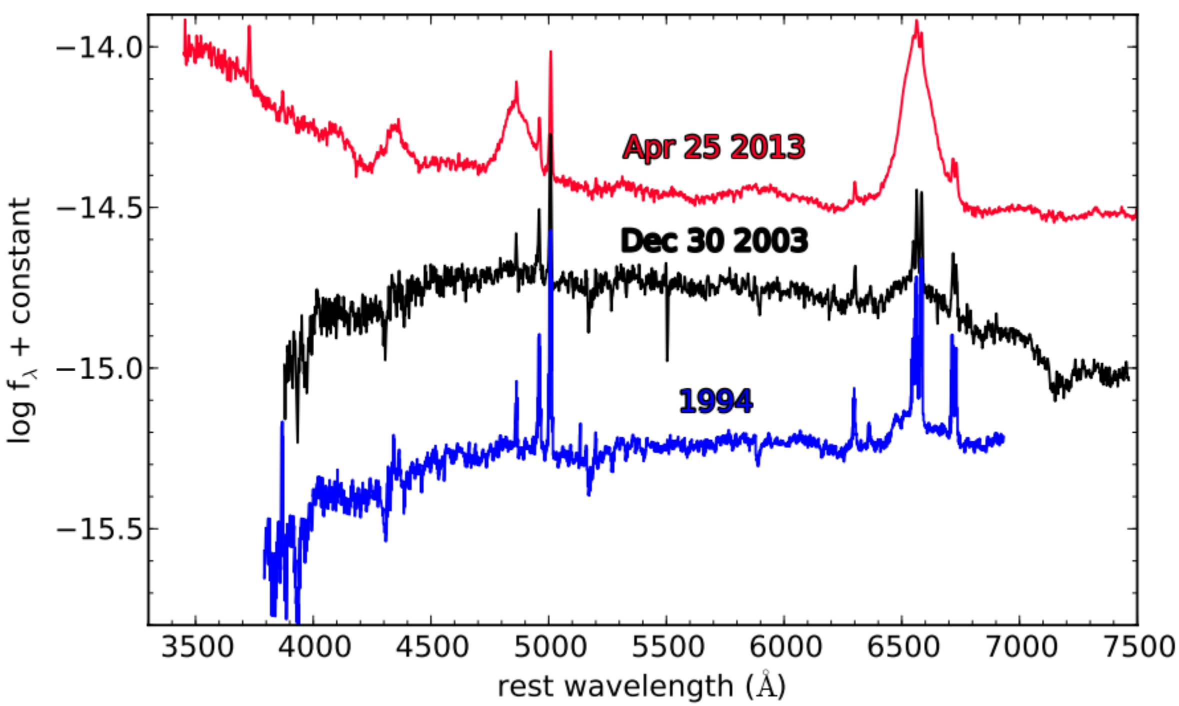
Outline

- Introduction
  a. Background of changing-look (CL) AGNs
  b. A brief review of previous results
- Our work
  a. Mid-Infrared variability of CL AGNs
  b. Searching for CL AGNs
- Conclusion & Future work

Background---What is Changing look (CL) AGN?

- J1011+5442 Turn on AGN (Runnoe et al. 2017)





- NGC 2617（Shappee et al. 2014）
- From 2003 to 2013 , emerging broad Hβ

Background --- Discovery of CL ANGs

- Once serendipitously discovered in nearby AGNs:
  - Mrk 6 (Khachikian & Weedman 1971)
  - NGC 7603 (Tohline & Osterbrock 1976)
  - NGC 4151、3C390.3 (Penston & Perez 1984)
  - Mrk1018 (Cohen et al. 1986; Goodrich et al. 1989; McElroy et al. 2016)
  - Mrk 993 (Tranetal.1992)
  - NGC 1097 (Storchi-Bergmannetal. 1993)
  - ……
  - Mrk 590 (Denney et al. 2014) ,
  - NGC 2617 (Shappee et al. 2014)
- LaMassa et al. (2015) reported the first CL quasar (J015957.64+003310.5, z=0.31, L_{bol} >10^{44} erg/s)
- So far >50 CL AGNs have been reported (e.g., Ruan et al. 2016; MacLeod et al. 2016,2019; Gezari et al. 2017;Yang et al 2018; Sheng et al 2019)

Background --- Changing-look **scenarios**

- **Three possible explanations**
  - Some CL AGNs might be Tidal Disrupted Events

(no TDE-like light curve, no strong HeII emission line)

  - Variation in obscuration

  - Intrinsic accretion rate change (**more prefered)**

Mid-infrared Variability of Changing-look AGNs

- Mainstream model：

1) variation in obscuration

2) variation accretion rate

- Motivation:
- Infrared emission is produced by dust heated by the UV
- Infrared emission is much less sensitive to dust extinction
- Torus is much larger than broad line region

WISE (Wide-field Infrared Survey Explorer ; Wright et al. 2010)

W1 : 3.4μm, *W2* : 4.6μm, mid-infrared (MIR) photometric data

Mid-infrared Variability of Changing-look AGNs
(Sheng et al. 2017, ApJ, 846, L7)

- **Collected all the changing-look AGNs in literature**

Additional optical data:

- V-band light curves: Catalina Real-time Transient Survey (CRTS)
- S82 photometric data, SDSS g-band

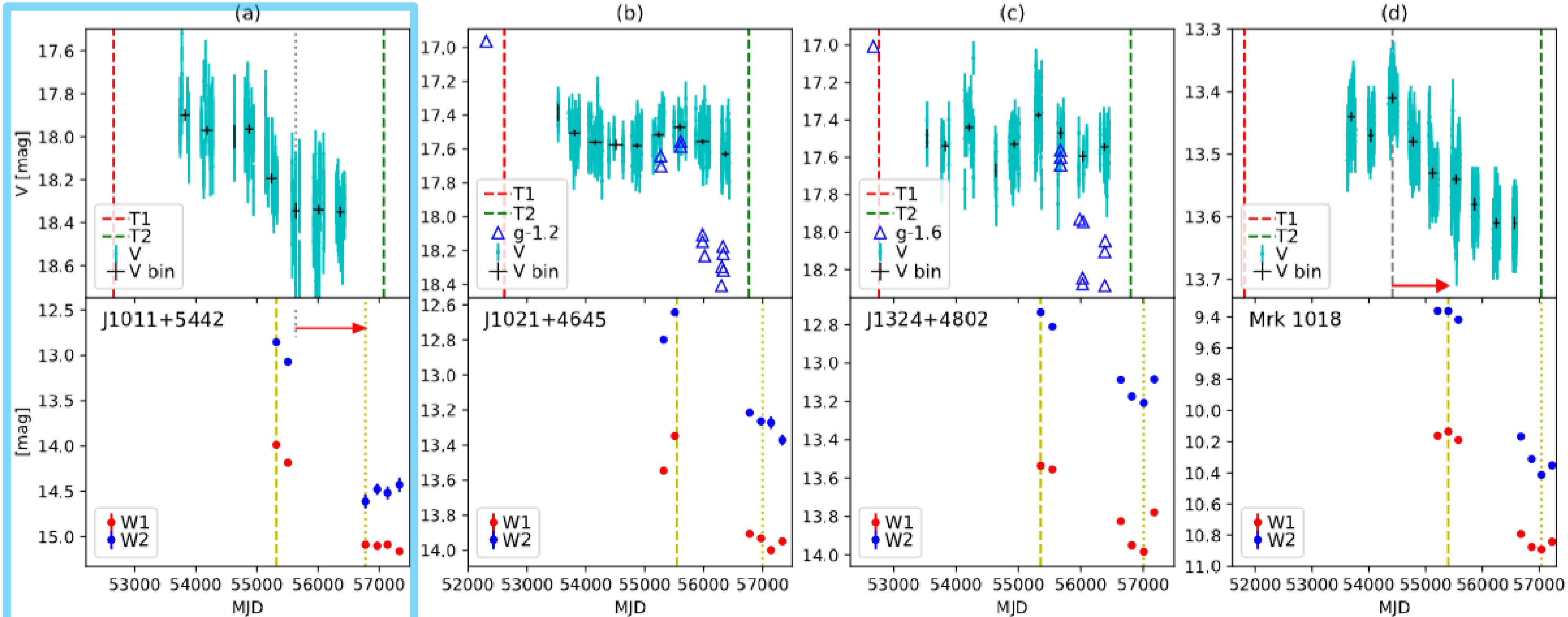
Selection crtiteria: → 24 AGNs

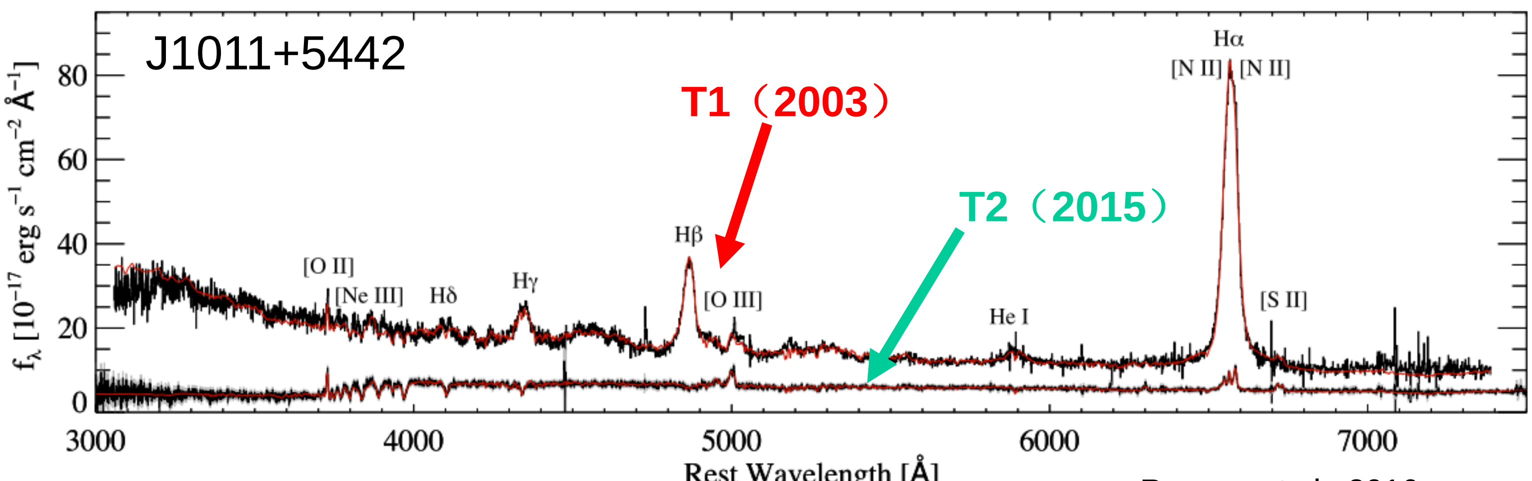
- Exclude immediate types
- Large variation in infrared bands (>0.4 mag)
- No source contamination within 6”

  (angular resolution of WISE)

} 24 →10 AGNs

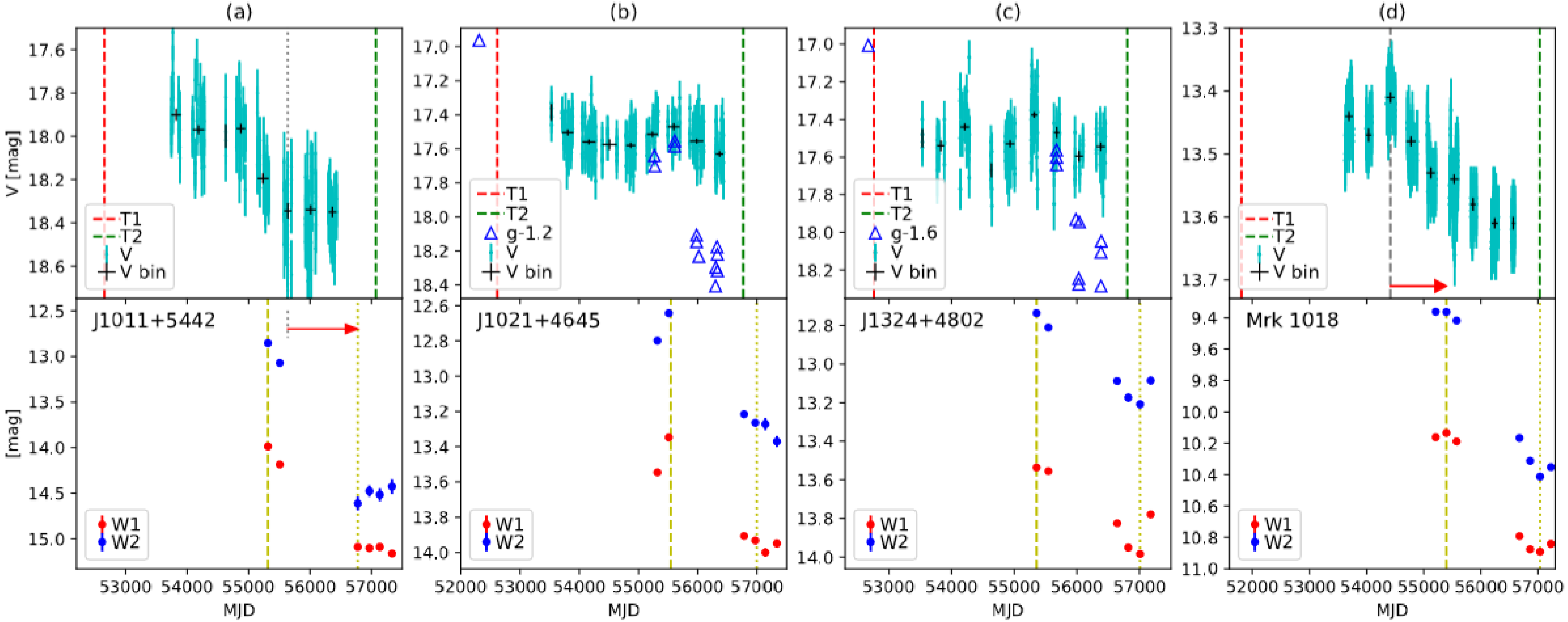
Turn-off（4 objects）





Runnoe et al.. 2016

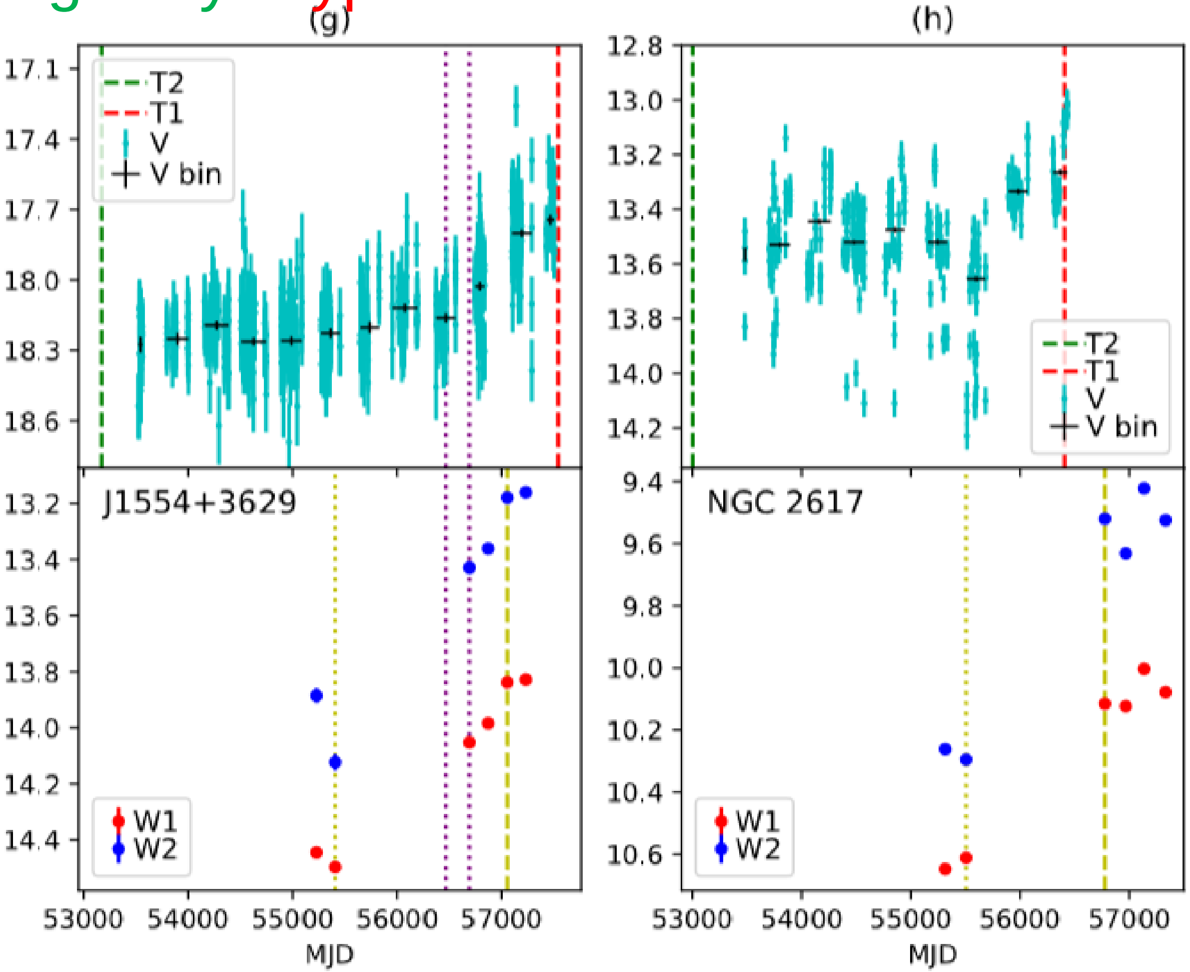
Turn-off（4 objects）

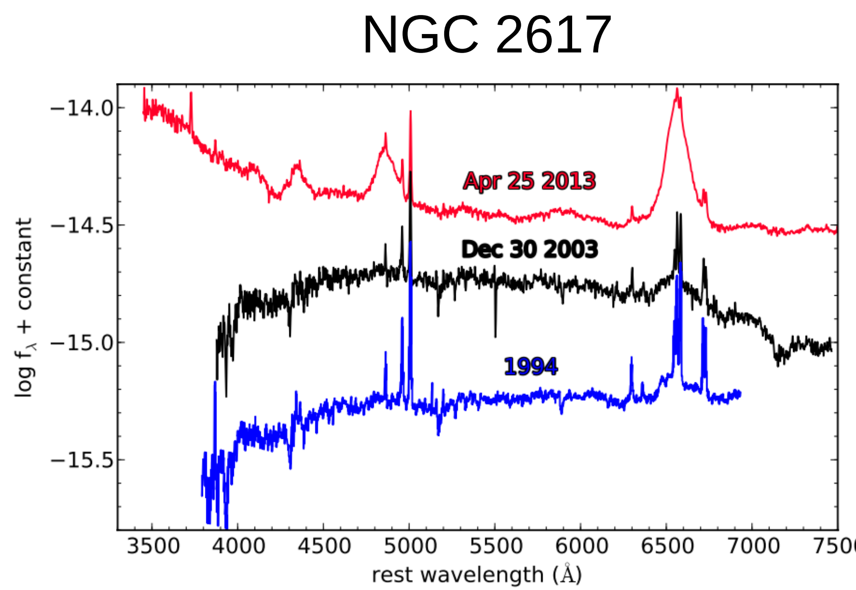


- turn-off → decrease in mid-infrared light curve (LC)
- time-scale: 4~5 years

Turn-on（6 objects）

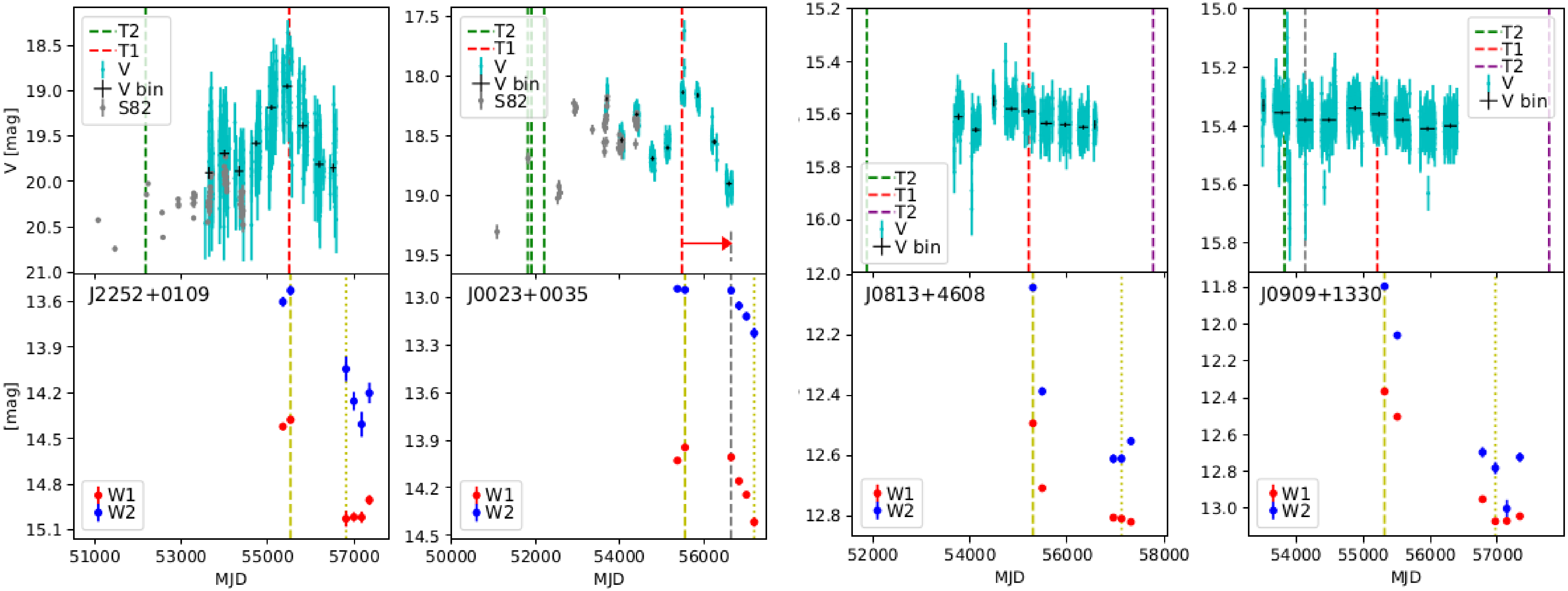
galaxy Type 1 AGN

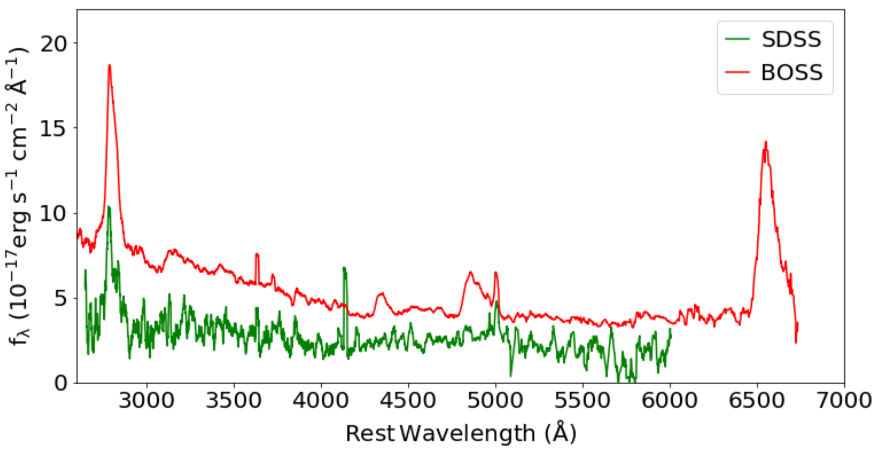




- turn-on → uprise in mid-infrared LC
- time-scale: 4~5 years

Turn-on （second transtion？）

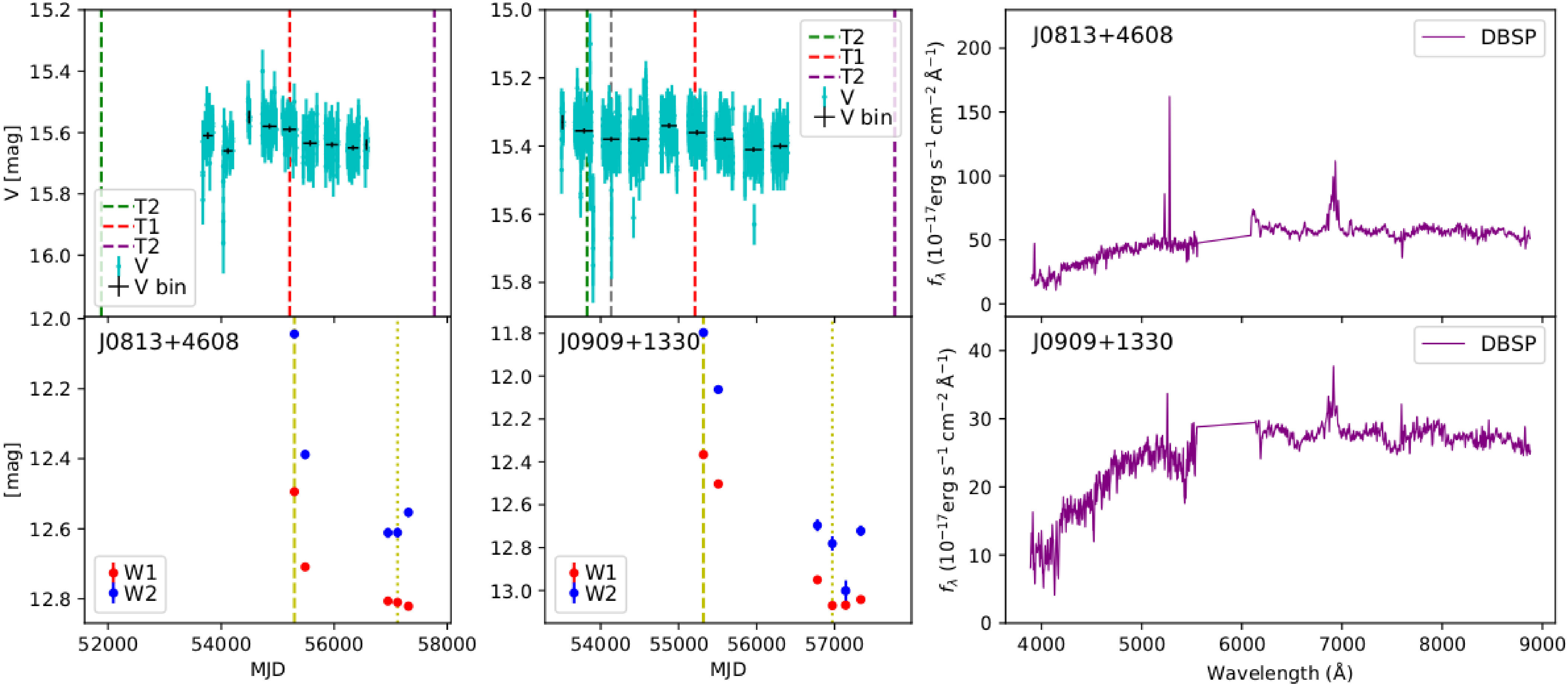




- time-scale 3~5 year
- turn-on, but W1 and W2 decrease
- BELs disappeared again？

Second transition

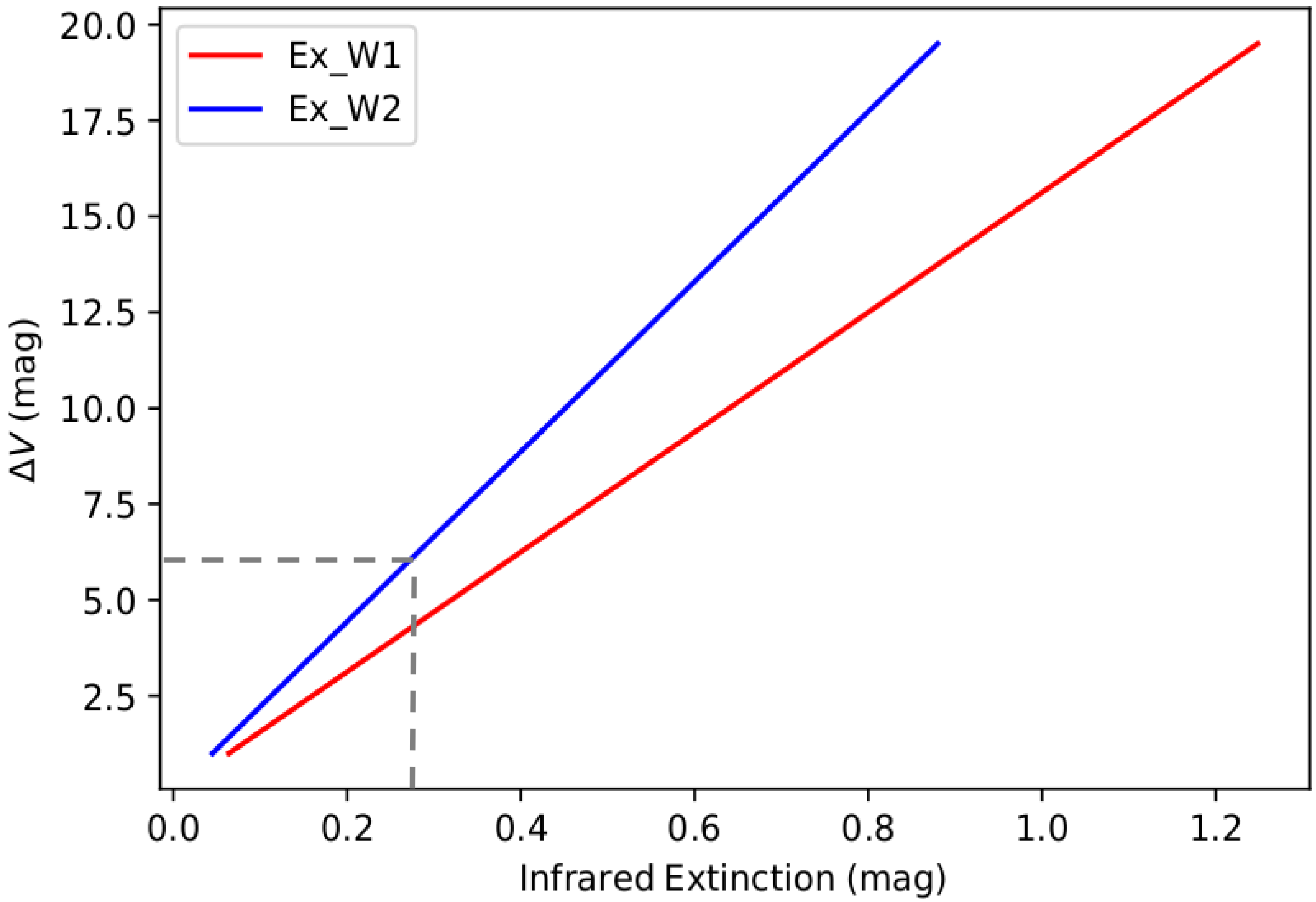
DBSP spectra on Jan. 2017



- We confirmed that they changed back to Type1.9
- The other two were confirmed by Macleod et al. (2019)

Discussion --- exclude extinction

- infrared variation --> optical variation
- J0023+00351: ΔW1=0.41，ΔW2=0.27，need ΔV~6 mag

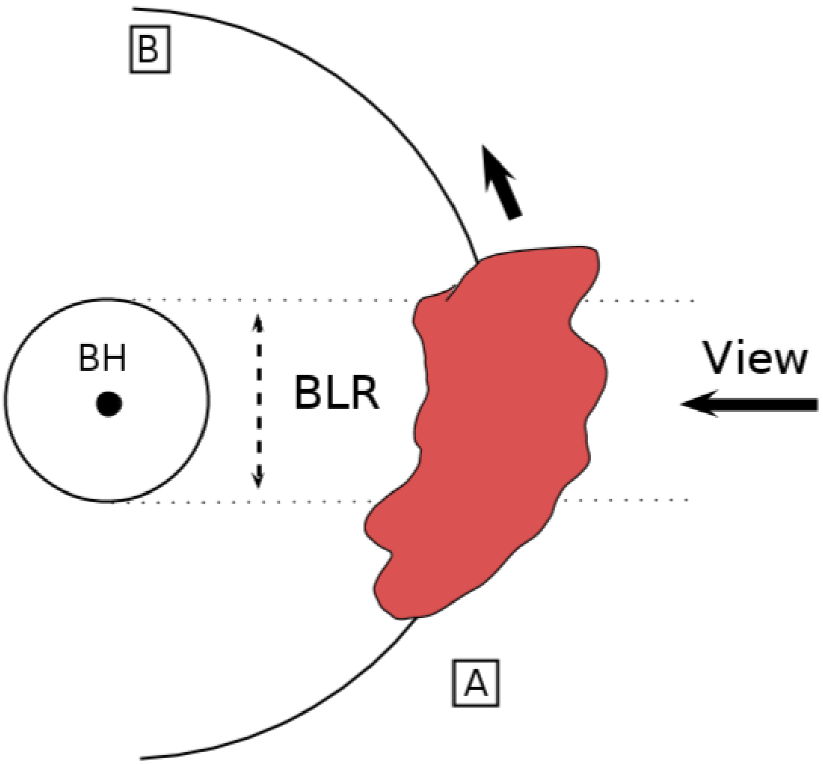


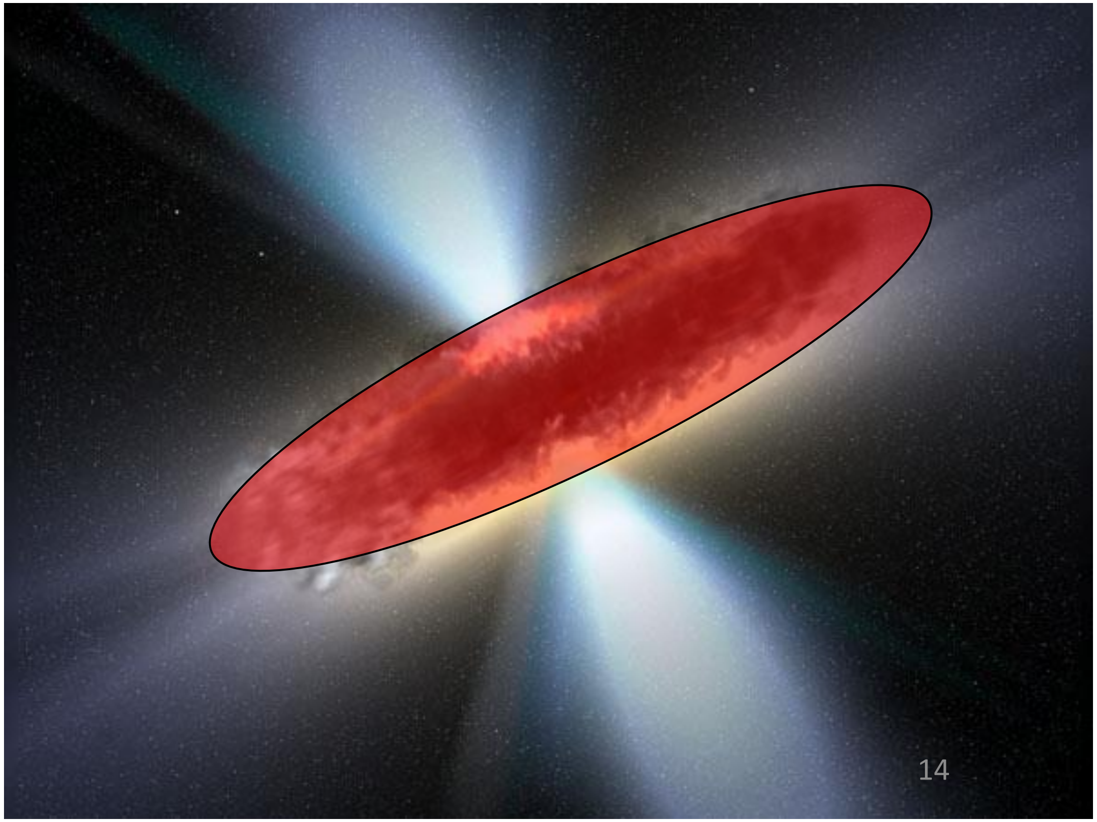
F99 extinction model (Fitzpatrick et al. 1999)

Discussion --- investigate the dynamical timescale

$$R_{\rm sub} \simeq 0.5 \left[\frac{L_{\rm bol}}{10^{44}\ {\rm erg\ s^{-1}}}\right]^{1/2} \left[\frac{1800{\rm K}}{T_{\rm sub}}\right] {\rm pc}$$

$$t_{\rm cross} = 0.073 \left[\frac{r_{\rm orb}}{1{\rm lt-day}}\right]^{3/2} M_8^{-1/2} \arcsin\left[\frac{r_{\rm src}}{r_{\rm orb}}\right]\ {\rm yr}$$





Discussion --- Excluded the obscuration model

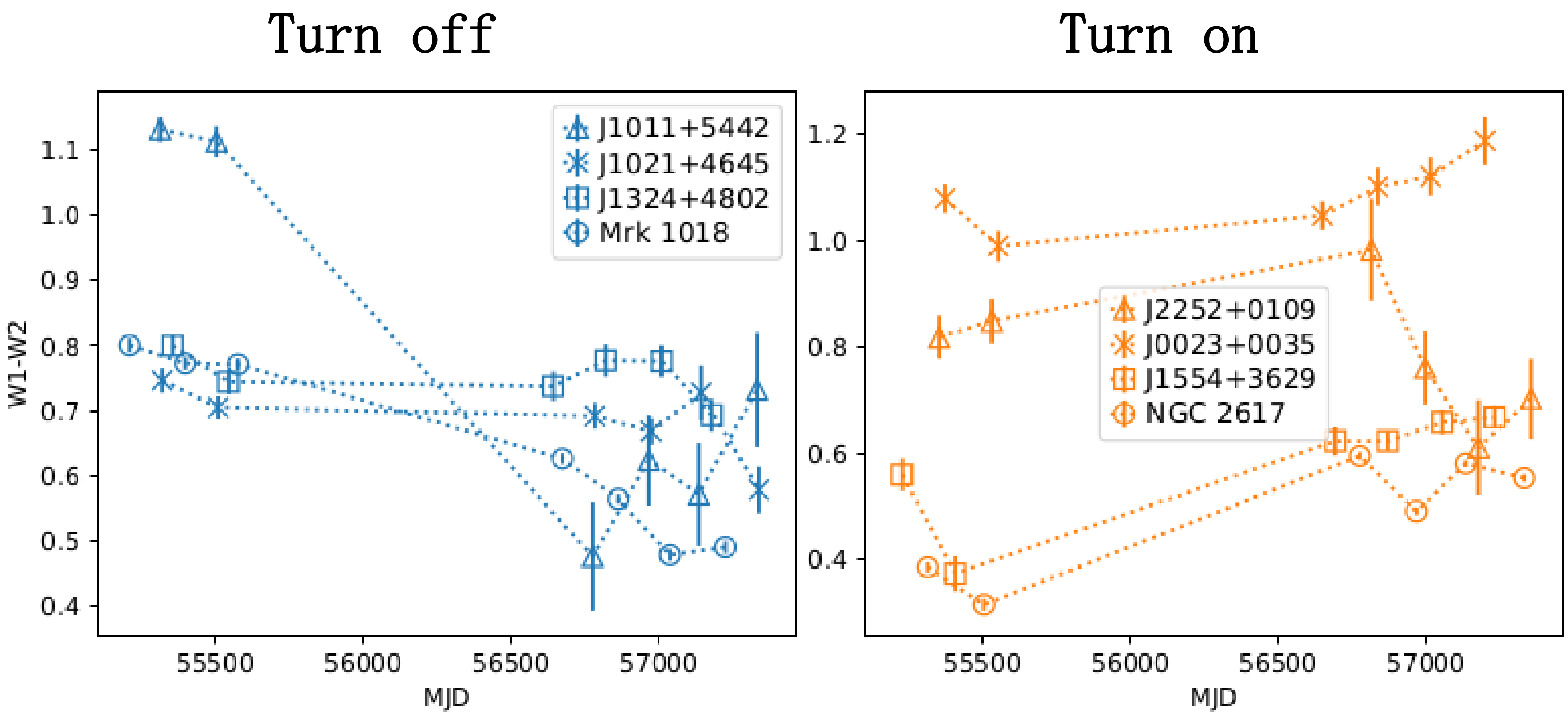
$$R_{\rm sub} \simeq 0.5 \left[\frac{L_{\rm bol}}{10^{44}\ {\rm erg\ s^{-1}}}\right]^{1/2} \left[\frac{1800{\rm K}}{T_{\rm sub}}\right] {\rm pc}$$

$$t_{\rm cross} = 0.073 \left[\frac{r_{\rm orb}}{1{\rm lt-day}}\right]^{3/2} M_8^{-1/2} \arcsin\left[\frac{r_{\rm src}}{r_{\rm orb}}\right] {\rm yr}$$

(1) Name	(8) t_{cross} (yr)	(9) ΔT (yr)
J002311.06+003517.5	28.95	4.51
J101152.98+544206.4	69.96	4.00
J102152.34+464515.6	36.16	4.01
J132457.29+480241.2	43.11	4.53
J155440.25+362952.0	60.61	4.51
J225240.37+010958.7	34.93	3.52

cross time is much larger than the observed

Discussion --- Mid-infrared color change



- (W1-W2) variation might be good method to find CL AGNs

Searching for CL AGNs via Mid-infrared variation

- AGN： $W1$-$W2$ >0.8
- galaxy： $W1$-$W2$ <0.5

→ from Type 1 Type 2

- Data： specObj-dr14、Dr7， Dr12， Dr14 QSO catelogs

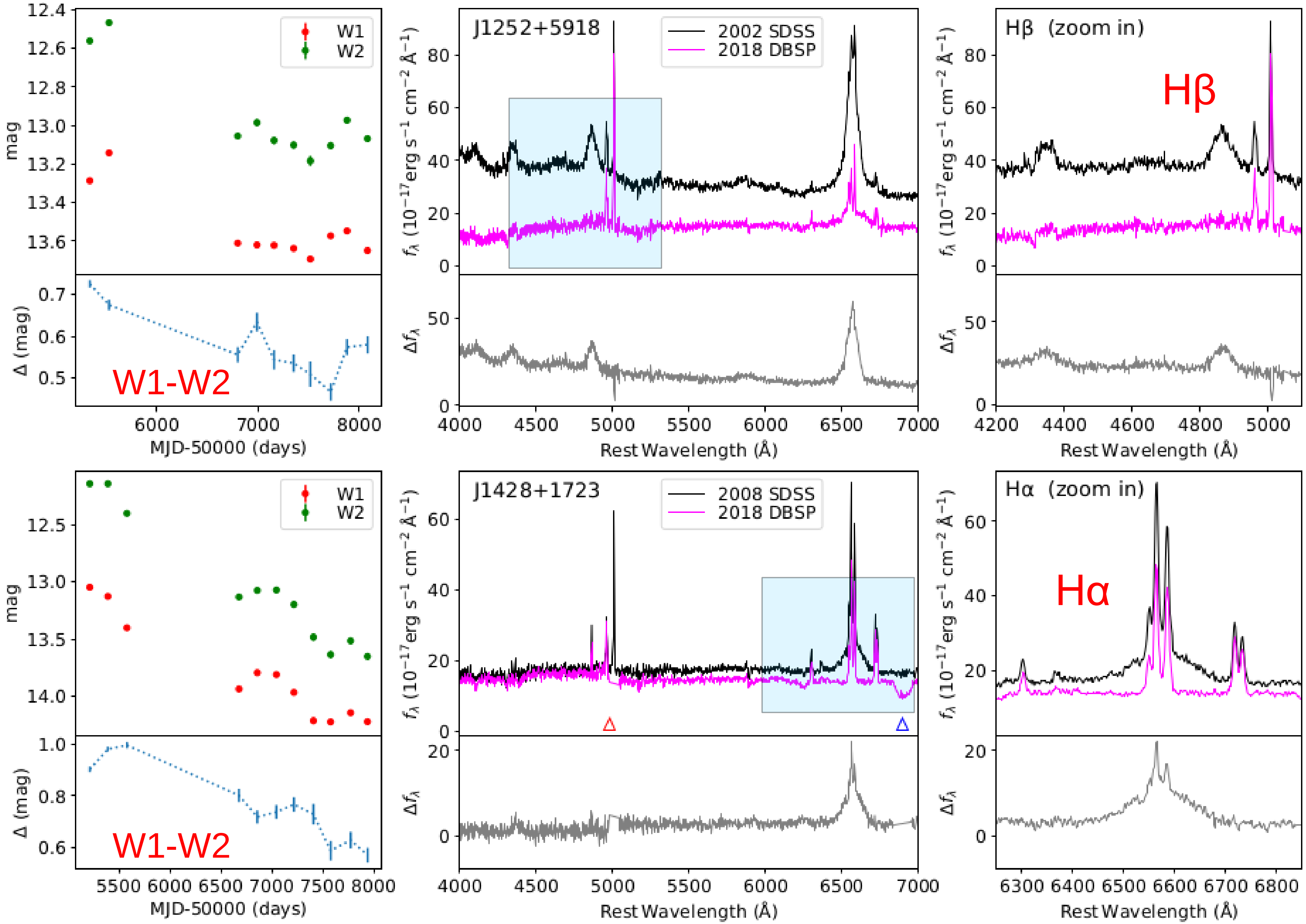
- sample seletion criteria：
  - redshift < 0.5（cover Hβ 、Hα），64167 objects
  - $\Delta W1$ *or* $\Delta W2$ >0.4 mag at 5σ
  - *min(W1-W2)* > 0.8 excluded

→ ~400

Follow up spectroscopic observation

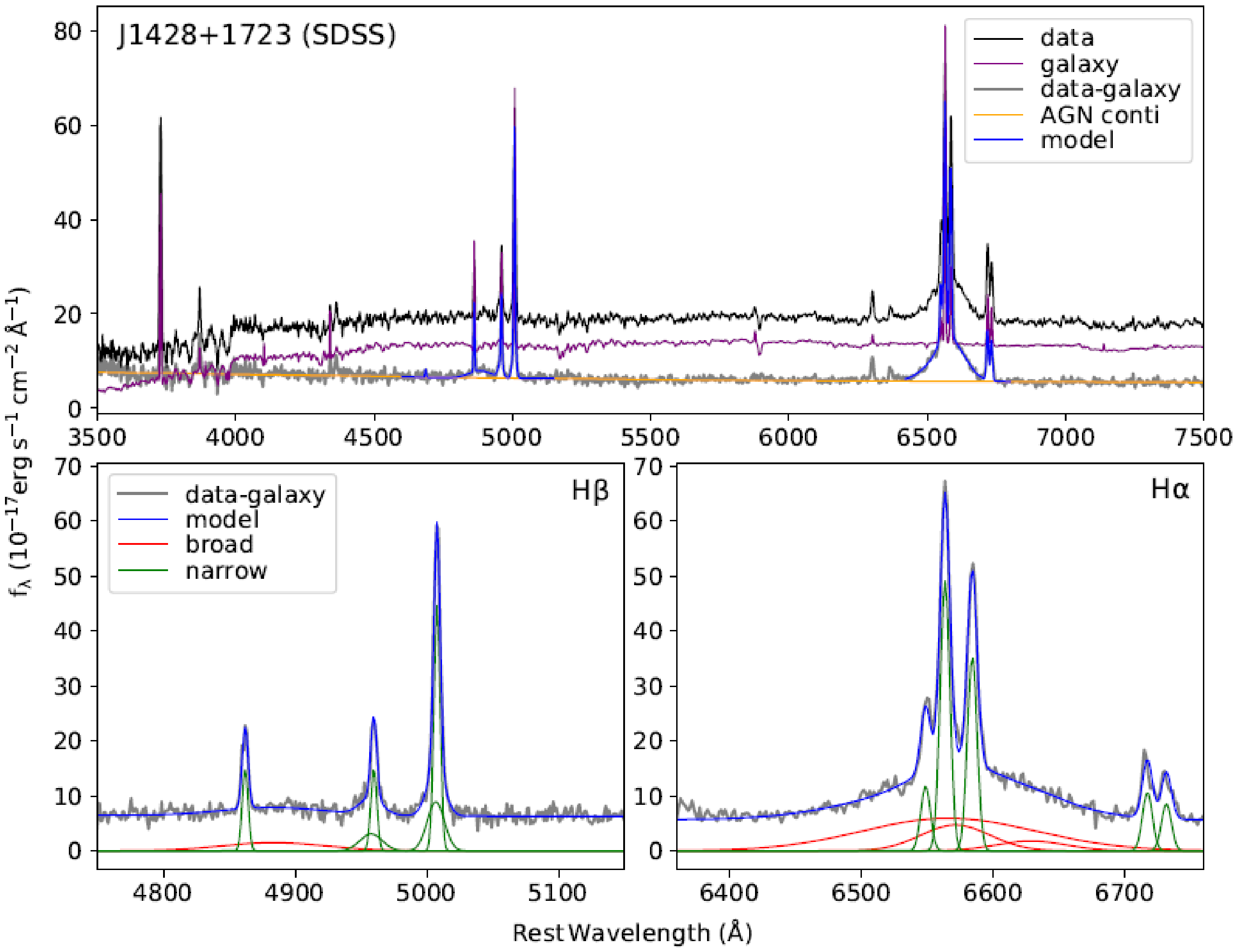
- We followed 7 candidates which are bright and proper for observation.
- Finally, 6 new CL AGNs are identified (see Sheng et al. 2019)

- 2018/06/06，Palomar Hale 5m DBSP：
  - J1307+4506、 J1428+1723 、J1627+5419
- 2018/06/12~06/13，Lick Shane：
  - J1252+5918、 J1317+1024、J1549+1121、J1713+2736



- tansition time scale 4~6 years

Decomposition example（J1428+1723）



- We use the PyQSOFit（Guo et al. 2018; Shen et al. 2019) to make decomposition of each spectrum

Results

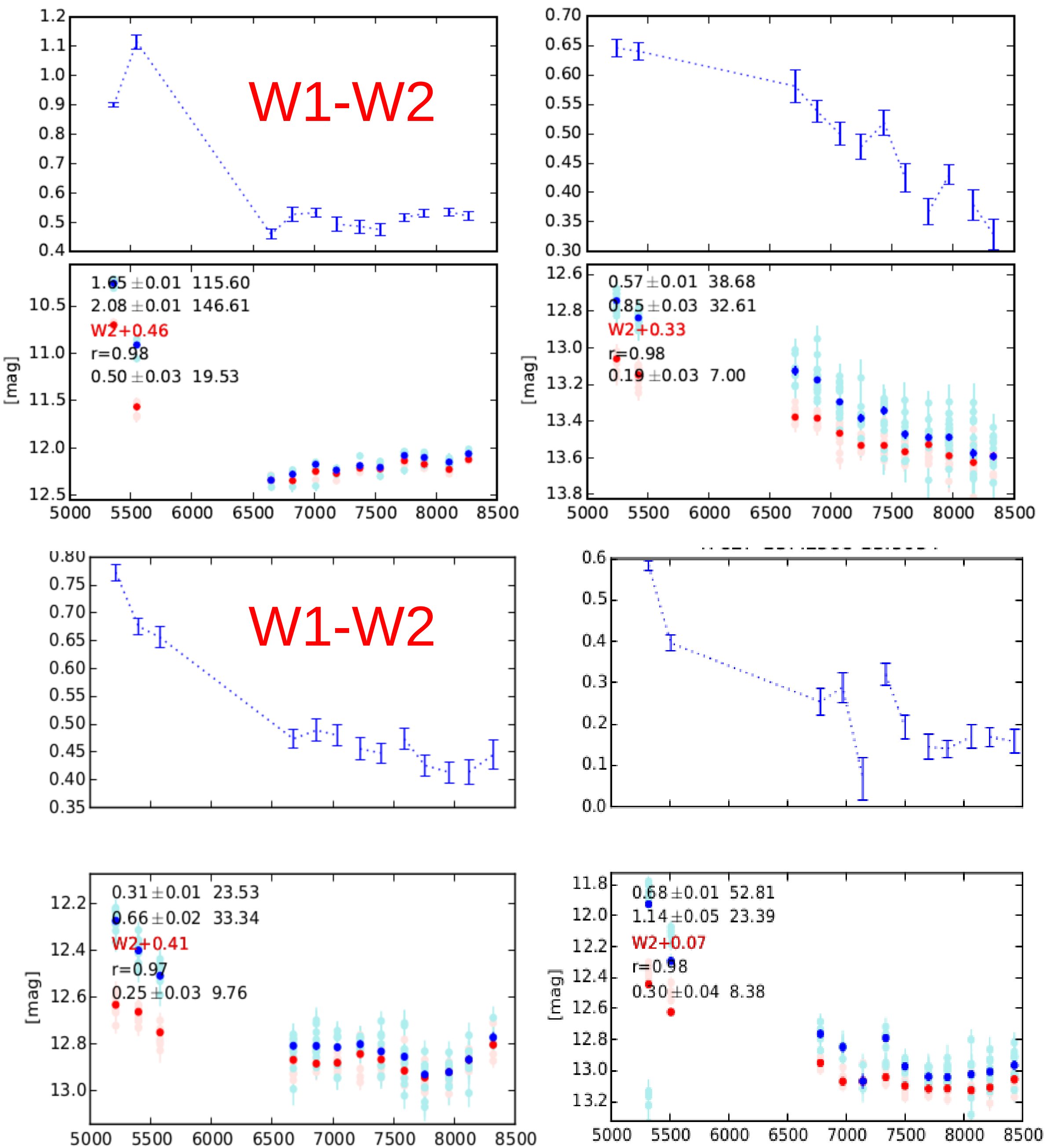
6 new CL AGNs are identified
(Sheng et al .2019 arXiv:1905.02904)

Type Transition

(1) Name	(7) $L_{H\beta,1}$ (10^{41}erg s^{-1})	(8) $L_{H\beta,2}$ (10^{41}erg s^{-1})	(9) $L_{H\alpha,1}$ (10^{41}erg s^{-1})	(10) $L_{H\alpha,2}$ (10^{41}erg s^{-1})	(11) T1	(12) T2
J125258.72+591832.7	10.524±0.177	1.011±0.298	23.987±0.184	3.884±0.122	1	1.9
J130716.99+450645.3	0.165±0.022	0	0.707±0.069	0	1.8	2
J131737.93+102427.7	8.779±0.462	0.265±0.798	33.255±0.790	-	1	1.9
J142846.71+172353.1	0.414±0.108	0	3.611±0.152	0	1.8	2
J154953.60+112148.3	0.028±0.019	0 ±0.012	1.005±0.014	0.306±0.041	1.9	1.9
J162752.18+541912.5	10.686±0.756	0	78.948±2.899	28.011±1.880	1	1.9
J171353.85+273626.8	15.615±1.307	3.621±0.619	23.494±1.281	-	1	1.8

- The result with the minimum reduced χ2 is adopted as the best fit.
- Cutting on the signal-to-noise >3 sigma for detecting broad emission lines

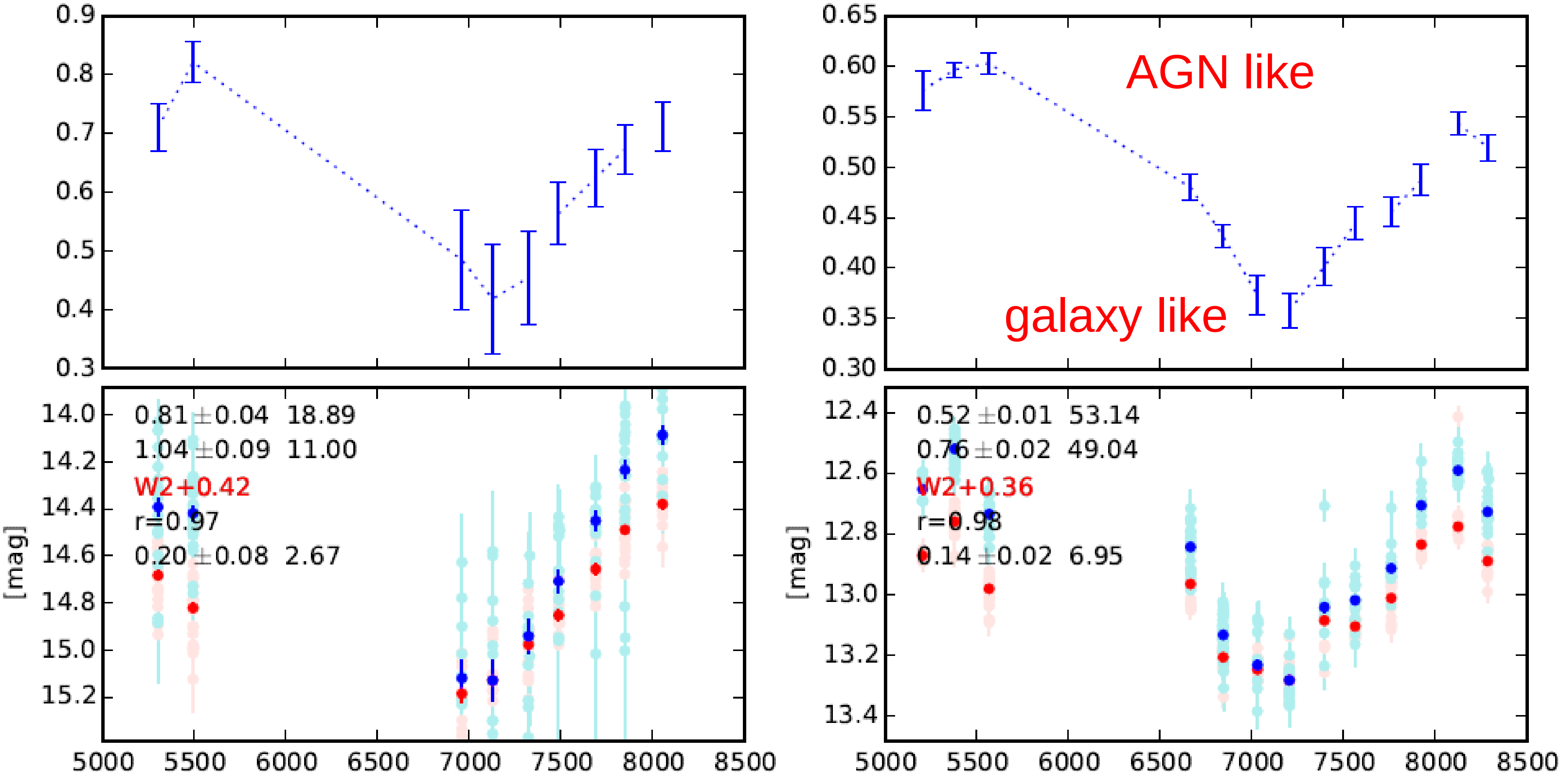
Candidates of Turn off AGNs?



AGN-like color to galaxy-like color

large decrease tendency

Reversible mid-infrared color change



changing look AGNs?
time scale is also ~5 years

Challenges（time-scale of CL）

Viscous timescale in standard thin-disk（$\alpha \sim 0.1$，$\mathrm{H} = 0.01r$，Netzer 2013）：

$$t_{vis} \simeq \frac{200 M_8}{\sqrt{T/10^4}} \frac{r}{r_g} \text{ yr}$$

- For typical optical region：100r_g， tvis$\sim 10^4$ years
- Changing look timescale: less than 10 years

➢ Much shorter than theoretical prediction

Models to address the CL time-scale problem

- X-binary-like accretion (Ruan et al. 2019 arXiv:1903.02553);

- Magnetically elevated accretion (Dexter & Begelman 2019);

- Narrow transition zone between the standard disk and inner advection dominated accretion flow (Śniegowska & Czerny 2019 arXiv:1904.06767) →NGC 1566

Summary

- We find a large mid-infrared variation in 10 CL AGNs
  - Exclude the extinction or obscuration.
  - The 10 CL AGNs likely due to variation of accretion rate
- We predicted 4 CL AGNs have reversible change between Type 1 and Type 2 and confirmed two of them
- We proposed a (might be efficient) method to select a large sample of CL candidates and find 6 new CL AGNs

Future work

- Apply the mid-infrared color selection method to galaxy sample

→ turn on AGNs

→ focus on high redshift (accretion rate) turn on AGN

Thank you !