可視光赤外線観測の現状
~アウトフローの観測~

Recent Results of Outflow Observations

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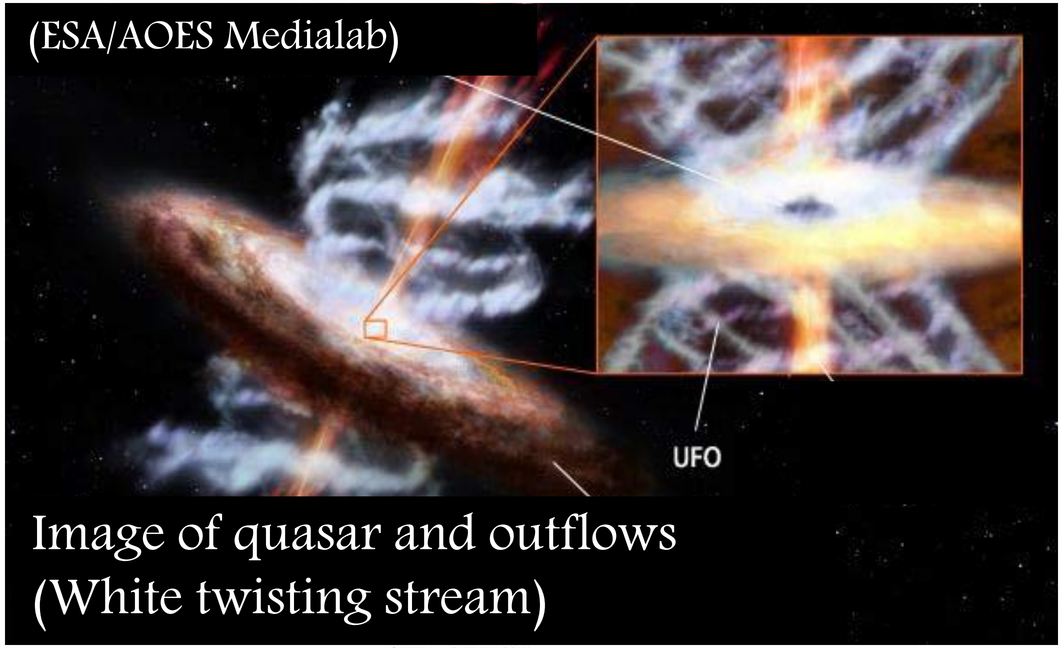
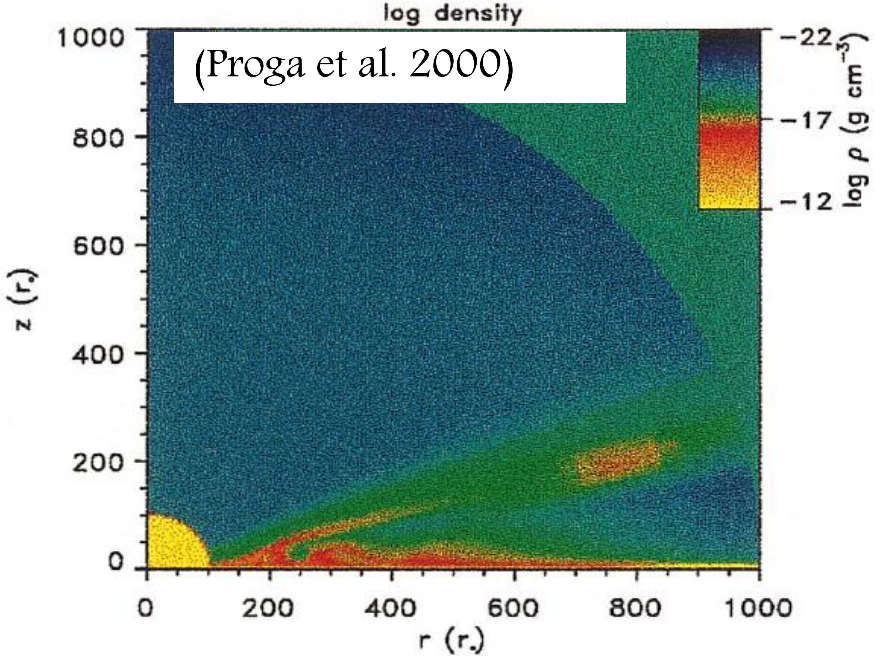
Contents

- Observational evidence of quasar outflows – BALs, mini-BALs, NALs –
- BAL to non-BAL quasar transformations !? (Sameer et al. 2018, arXiv:1810.03625v2)
- BAL quasar at a redshift of 7.02 ! (Wang et al. 2018, arXiv:1810.11925)

Quasar Outflows





Quasar outflows are important element for

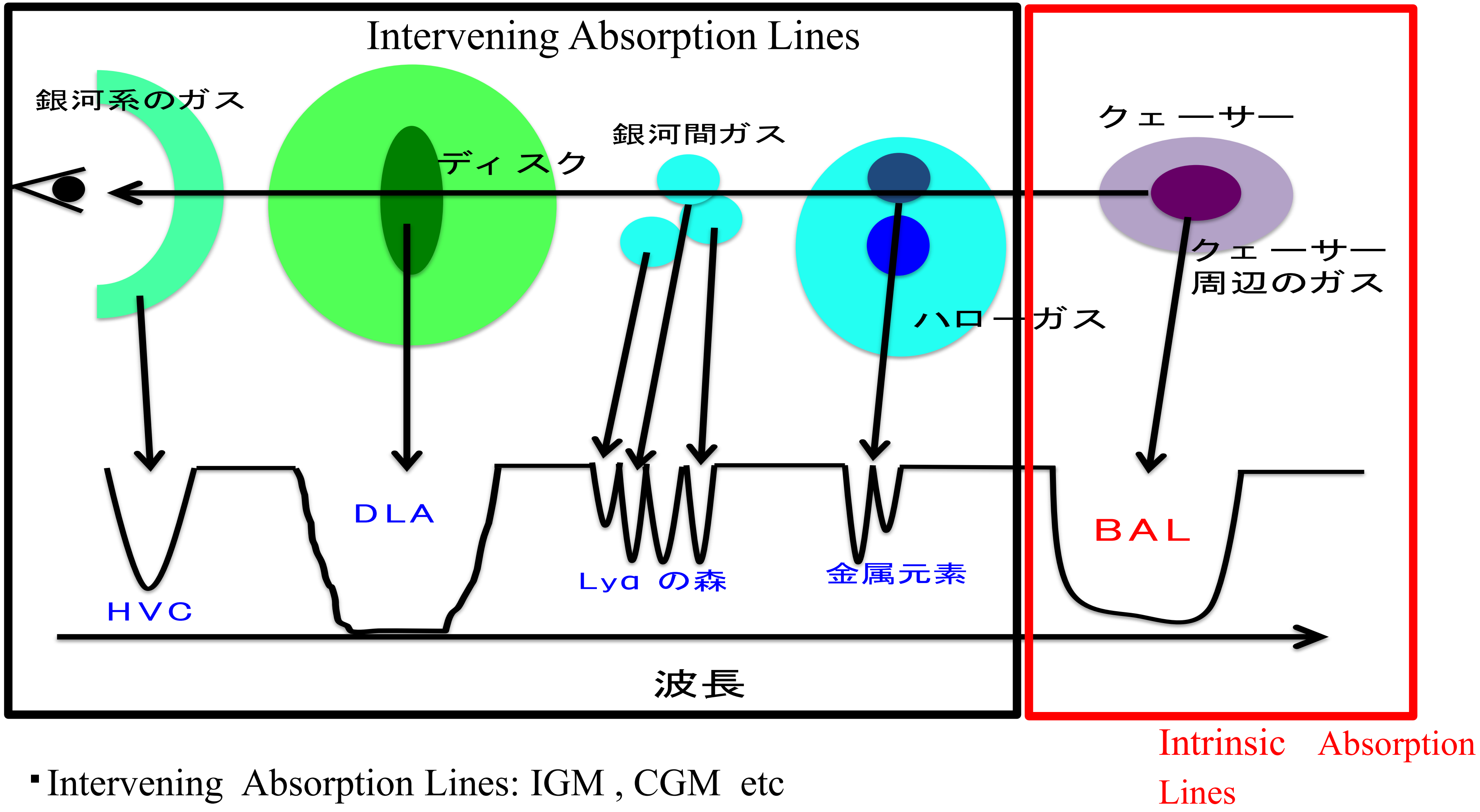
(i) quasar growth,
(ii) chemical evolution for host galaxy and intergalactic space

Mechanisms to launch outflows (candidates)

- Radiation pressure (Proga et al. 2000; Nomura et al. 2012, 2015)
- Magnetic Force (Everett 2005)

Using quasar absorption lines to study ouflows !

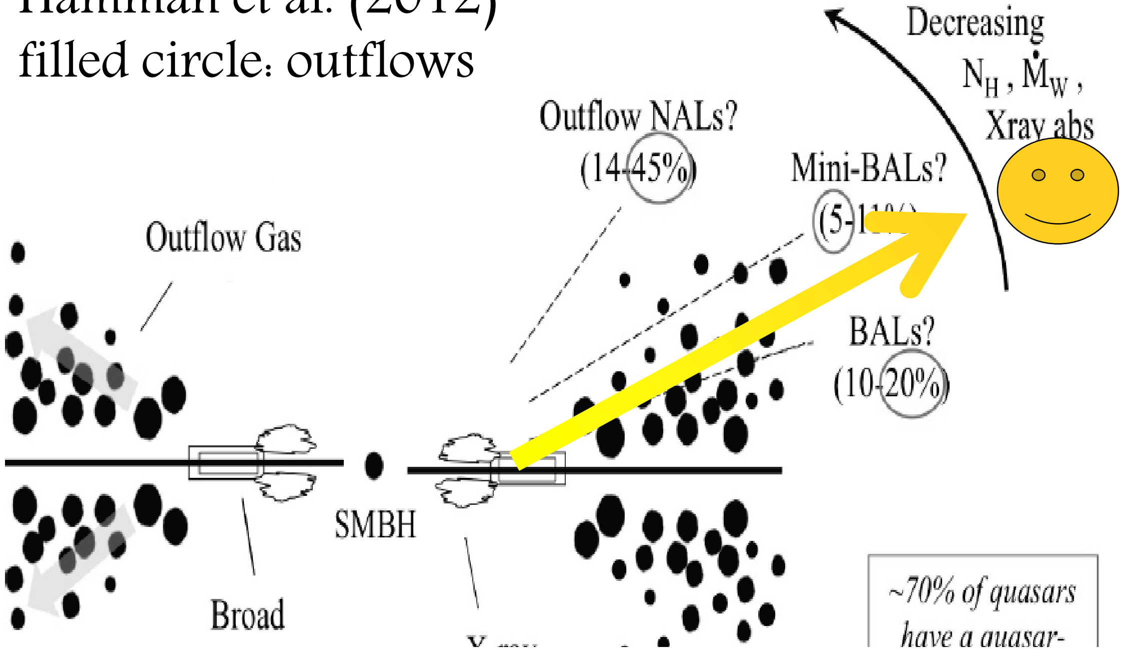
Quasar Absorption Line



- Intervening Absorption Lines: IGM , CGM etc
- Intrinsic Absorption Lines : Outflow Gas

Quasar intrinsic absorption lines: BALs, mini-BALs and NALs

Hamman et al. (2012)
filled circle: outflows

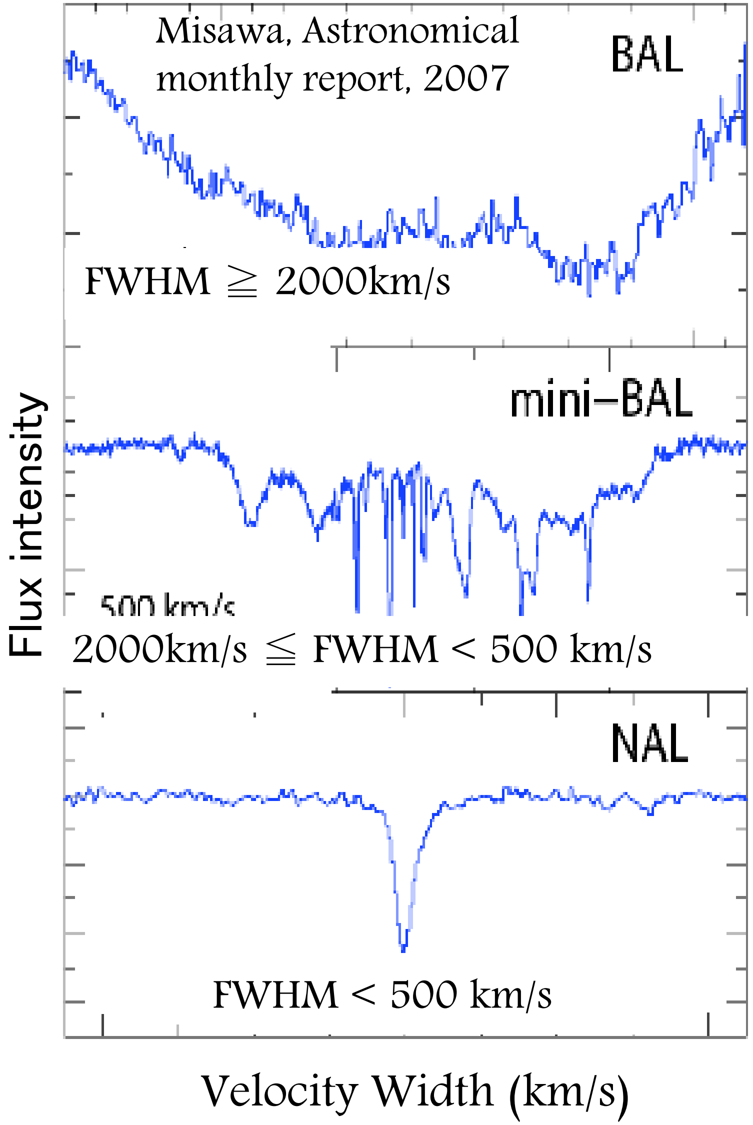


BALs: The main current of outflow study

mini-BALs and NALs: They are attracting attention in recent year

Estimation of physical parameters is possible !

AL via outflows



About Broad Absorption Lines (BALs)

- Definition for BALs: Balnicity Index (Weymann et al. 1991)

normalized spectrum

$$\mathrm{BI} = \int_{v_{\mathrm{min}}}^{v_{\mathrm{max}}} \left(1 - \frac{f(v)}{0.9}\right) C dv$$

1 : Quantity in brackets is continuously greater than zero for more than 2,000 km/s

0: otherwise

- Velocities are usually set to 3,000 and 25,000 km/s

To avoid strong absorption complexes around blueward of C IV emission

To avoid ambiguities with Si IV emission and absorption

- BI(maximum) = 20,000 km/s (=25,000-3,000-2,000) km/s

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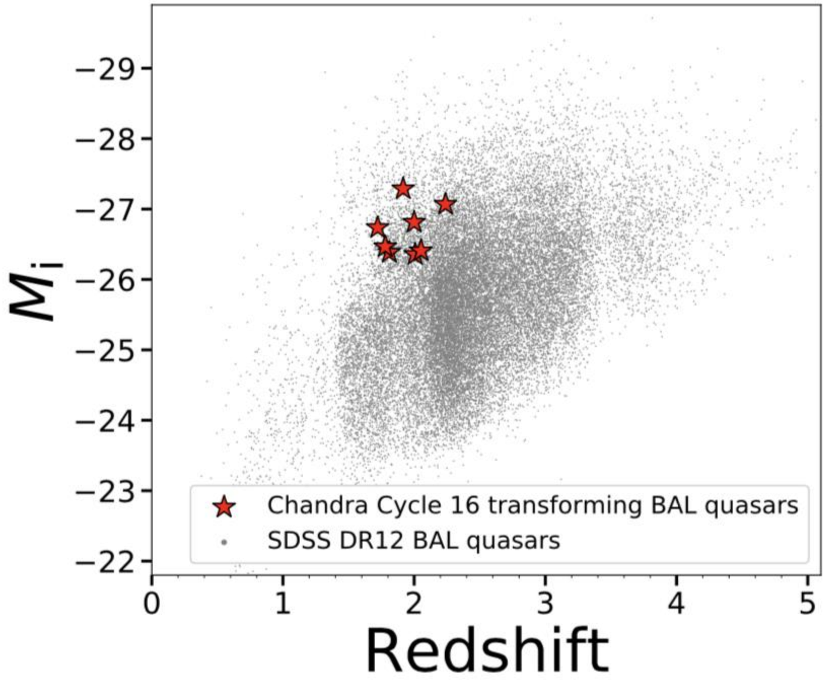
Samerr et al. (2018) : ABSTRACT

- Theme: X-ray and optical/UV study of eight BAL to non-BAL transforming quasars at $z \approx$ 1.7–2.2 over 0.29–4.95 rest-frame years.
- Data:

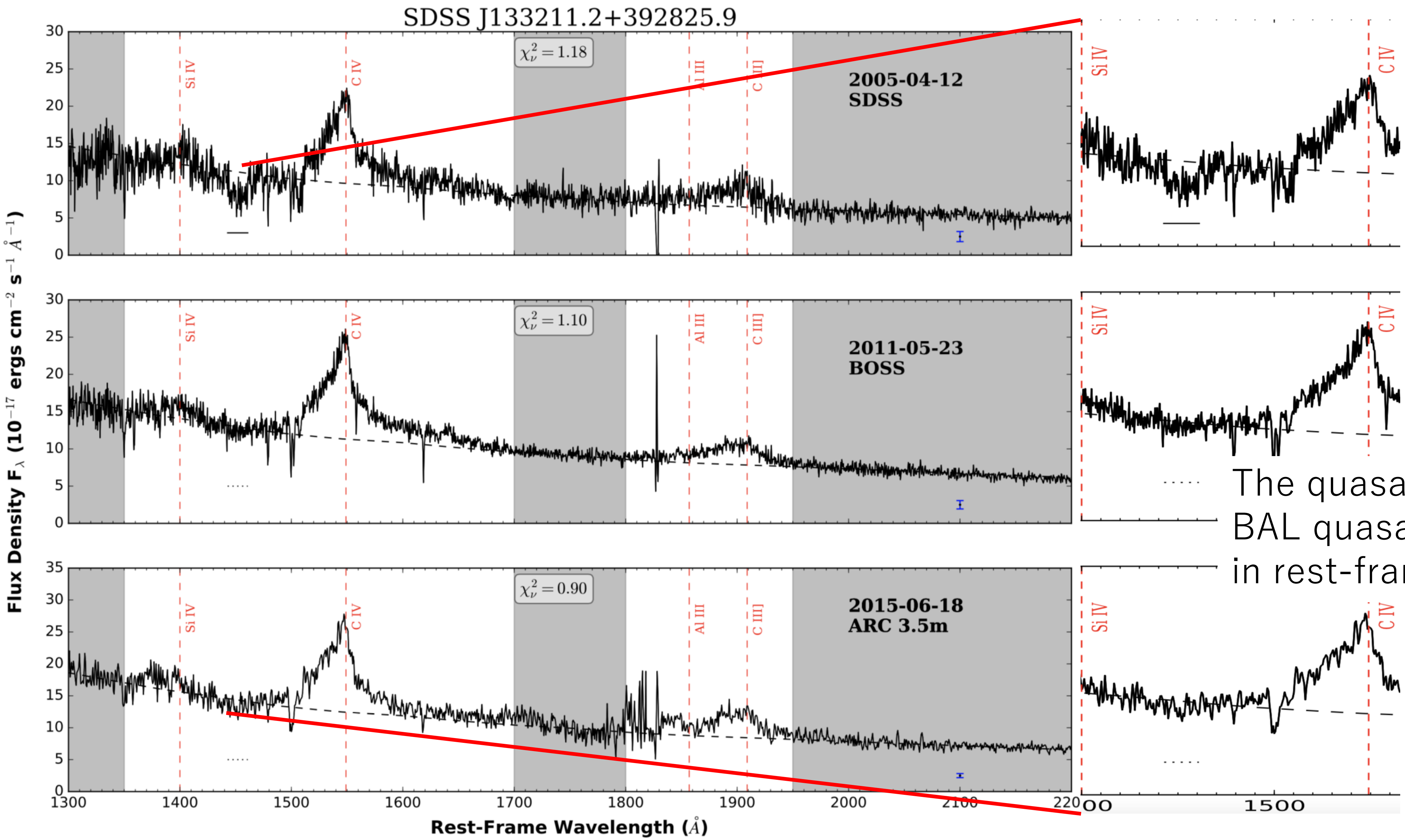
  SDSS, BOSS, Gemini, and ARC 3.5-m (optical), Chandra (X-ray)
- Results:

  New Chandra observations show α_{OX} and $\Delta\alpha_{OX}$ of are consistent with those

- Conclusion: X-ray and optical/UV observation
  - (At least) The X-ray absorbing material moving out of the line-of-sight, leaving an X-ray unabsorbed non-BAL quasar.
  - The UV absorber might have become more highly ionized (in a shielding-gas scenario) or also moved out of the line-of-sight (in a wind-clumping scenario).

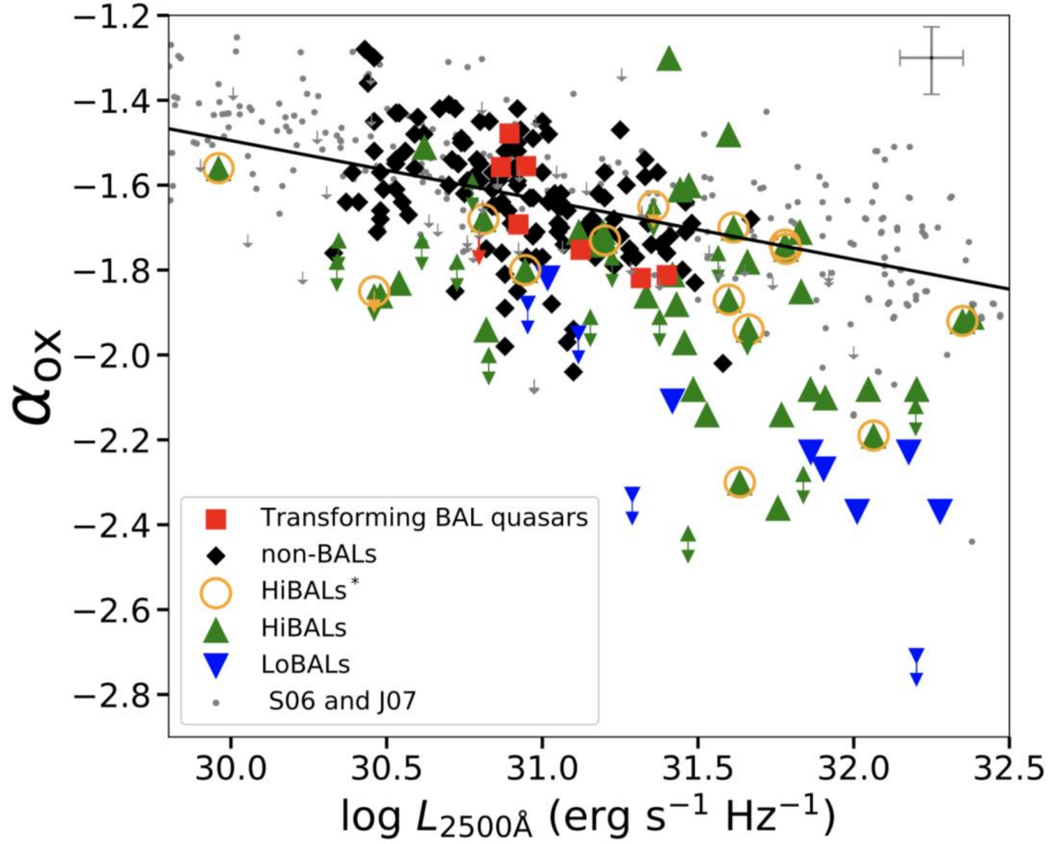


An Example of non-BAL transforming

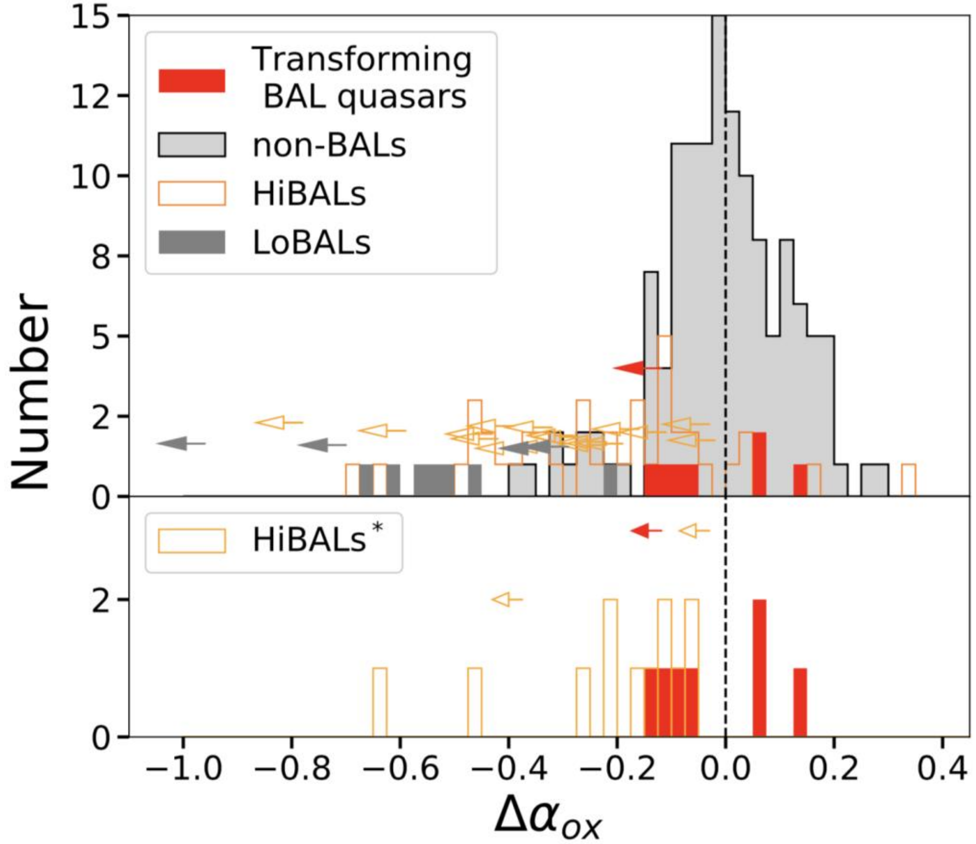


The quasar became a non-BAL quasar within two years in rest-frame !

Comparing X-ray-to-optical power-law slope α_{OX} and $\Delta\alpha_{OX}$



$$\alpha_{\rm ox} = \frac{\log(f_{2\ \rm keV}/f_{2500\ \text{Å}})}{\log(\nu_{2\ \rm keV}/\nu_{2500\ \text{Å}})}$$



$$\Delta\alpha_{\rm ox} = \alpha_{\rm ox(measured)} - \alpha_{\rm ox(expected)}$$

$$\alpha_{\rm ox(expected)} = (-0.140 \pm 0.007) \log(L_{2500\ \text{Å}}) + (2.705 \pm 0.212)$$

X-ray, optical, and radio properties

Object Name (SDSS J)	z	$m_{\rm i}$	$M_{\rm i}$	$N_{\rm H}$	Count Rate	$F_{0.5-2\ \rm keV}$	$f_{2\ \rm keV}$	$\log L_{\rm X}$ (2–10 keV)	$f_{2500\ \rm Å}$	$\log L_{\nu}$ (2500 Å)	α_{ox}	$\Delta\alpha_{ox}(\sigma)$	R
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
074650.59+182028.7	1.92	17.96	−27.36	4.17	$1.63^{+1.27}_{-0.77}$	$0.94^{+0.79}_{-0.53}$	$4.11^{+3.43}_{-2.30}$	44.46	2.24 ± 0.22	31.32 ± 0.10	$-1.82^{+0.10}_{-0.08}$	−0.14(0.89)	<2.17
085904.59+042647.8	1.81	18.74	−26.45	4.11	< 1.0	<0.57	<2.39	<44.18	0.75 ± 0.07	30.80 ± 0.10	<−1.72	<−0.12(0.64)	<4.46
093620.52+004649.2	1.72	18.26	−26.81	3.85	$4.38^{+1.72}_{-1.28}$	$2.51^{+1.24}_{-1.05}$	$10.21^{+5.05}_{-4.27}$	44.77	1.15 ± 0.12	30.95 ± 0.10	$-1.56^{+0.07}_{-0.06}$	0.07(0.41)	<2.94
114546.22+032251.9	2.01	19.01	−26.42	2.19	$2.54^{+0.95}_{-0.71}$	$1.40^{+0.67}_{-0.58}$	$6.31^{+3.02}_{-2.58}$	44.68	0.72 ± 0.07	30.87 ± 0.10	$-1.56^{+0.07}_{-0.06}$	0.06(0.33)	<5.74
133211.21+392825.9	2.05	19.01	−26.46	0.89	$4.31^{+1.17}_{-0.94}$	$2.31^{+0.93}_{-0.86}$	$10.49^{+4.24}_{-3.89}$	44.91	0.75 ± 0.08	30.89 ± 0.10	$-1.48^{+0.06}_{-0.06}$	0.14(0.79)	<5.21
142132.01+375230.3	1.78	18.61	−26.54	0.92	$1.79^{+1.05}_{-0.70}$	$0.96^{+0.63}_{-0.47}$	$3.99^{+2.63}_{-1.96}$	44.38	1.02 ± 0.10	30.92 ± 0.10	$-1.69^{+0.09}_{-0.07}$	−0.07(0.38)	<3.66
152149.78+010236.4	2.24	18.45	−27.22	4.24	$1.39^{+0.92}_{-0.59}$	$0.81^{+0.59}_{-0.42}$	$3.89^{+2.83}_{-2.02}$	44.55	2.04 ± 0.21	31.40 ± 0.10	$-1.81^{+0.09}_{-0.07}$	−0.12(0.79)	<3.96
152243.98+032719.8	2.00	18.56	−26.86	3.81	$1.39^{+0.92}_{-0.59}$	$0.80^{+0.58}_{-0.41}$	$3.57^{+2.60}_{-1.86}$	44.43	1.31 ± 0.13	31.12 ± 0.10	$-1.75^{+0.09}_{-0.07}$	−0.10(0.59)	<3.88

New Chandra Observation

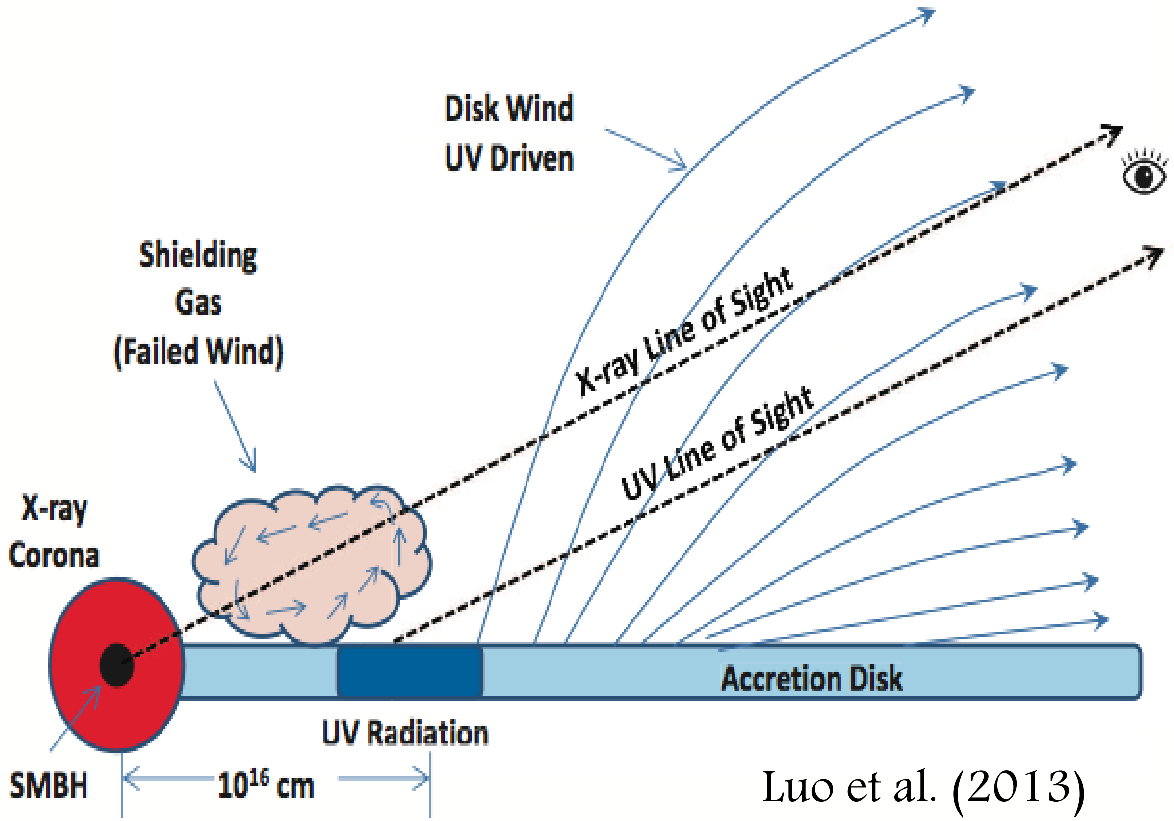
Table 3. ***Chandra*** **observation log and X-ray counts**

Object Name (SDSS J) (1)	ObsID (2)	Date (3)	Exposure Time (ks) (4)	Full-Band Cts. (0.5–8.0 keV) (5)	Soft-Band Cts. (0.5–2.0 keV) (6)	Hard-Band Cts. (2.0–8.0 keV) (7)	Band Ratio (8)	$\Gamma_{\rm eff}$ (9)
074650.59+182028.7	17021	2015 Dec 03	2.54	$9.51^{+4.21}_{-3.04}$	$4.15^{+3.22}_{-1.95}$	$5.46^{+3.50}_{-2.27}$	$1.32^{+1.02}_{-0.69}$	$0.67^{+0.72}_{-0.54}$
085904.59+042647.8	17023	2016 Jan 04	3.92	$3.09^{+2.99}_{-1.69}$	< 4.07	$2.13^{+2.72}_{-1.36}$	> 0.52	< 1.56
093620.52+004649.2	17022	2015 Mar 16	2.61	$13.76^{+4.82}_{-3.67}$	$11.44^{+4.50}_{-3.33}$	$2.15^{+2.72}_{-1.36}$	$0.19^{+0.24}_{-0.13}$	$2.55^{+1.06}_{-0.80}$
114546.22+032251.9	17029	2016 Feb 09	4.91	$16.88^{+5.22}_{-4.08}$	$12.46^{+4.64}_{-3.49}$	$4.30^{+3.27}_{-2.01}$	$0.34^{+0.28}_{-0.18}$	$1.93^{+0.70}_{-0.57}$
133211.21+392825.9	17028	2015 Aug 24	4.83	$25.48^{+6.13}_{-5.02}$	$20.84^{+5.65}_{-4.53}$	$4.35^{+3.27}_{-2.01}$	$0.21^{+0.16}_{-0.10}$	$2.38^{+0.64}_{-0.55}$
142132.01+375230.3	17027	2015 Oct 07	3.49	$7.38^{+3.86}_{-2.66}$	$6.24^{+3.65}_{-2.43}$	< 4.26	< 0.68	> 1.25
152149.78+010236.4	17026	2015 Jun 12	3.73	$6.29^{+3.67}_{-2.46}$	$5.18^{+3.44}_{-2.20}$	< 4.23	< 0.82	> 1.13
152243.98+032719.8	17024	2015 Apr 12	3.73	$11.62^{+4.53}_{-3.37}$	$5.18^{+3.44}_{-2.20}$	$6.56^{+3.71}_{-2.50}$	$1.27^{+0.88}_{-0.61}$	$0.70^{+0.64}_{-0.50}$

Column (1): The SDSS J2000 equatorial coordinates for the quasar. Column (2): *Chandra* observation ID. Column (3): Date of observation of the target with *Chandra*. Column (4): Background-flare cleaned effective exposure time. Columns (5), (6), (7): The X-ray data analysis was carried out using the procedure in Luo et al. (2015). Errors on the X-ray counts were calculated using Poisson statistics corresponding to the 1σ significance level using Gehrels (1986). A source is considered undetected if the $P_{\rm B}$ value, defined via Equation (3) in Section 3.1, in a band is > 0.01, in which case an upper limit on the source counts was derived. Column (8): Band ratio is the hard band to soft band ratio. Column (9): The effective power-law photon index, $\Gamma_{\rm eff}$.

Consideration about ancillary mechanism

Are ionization states in outflows influenced by changing optical thickness of X-ray shielding gas observed by X-ray !?



Luo et al. (2013)

Eight transforming BAL quasars show no evidence for intrinsic X-ray absorption

→ X-ray absorbing material moving out of the line-of-sight !

Generally, BAL quasars show strong intrinsic X-ray absorption

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- BAL quasar at a redshift of 7.02 (Wang et al. 2018, arXiv:1810.11925)

Wang et al. (2018) : ABSTRACT

- Theme: The discovery of a luminous quasar at $z = 7.021$, DELS J003836.10– 152723.6 (hereafter J0038–1527), selected using photometric data.
- Photometric data :

  DESI Legacy imaging Survey (DELS), Pan-STARRS1 (PS1) imaging Survey,

  WISE mid-infrared all-sky survey

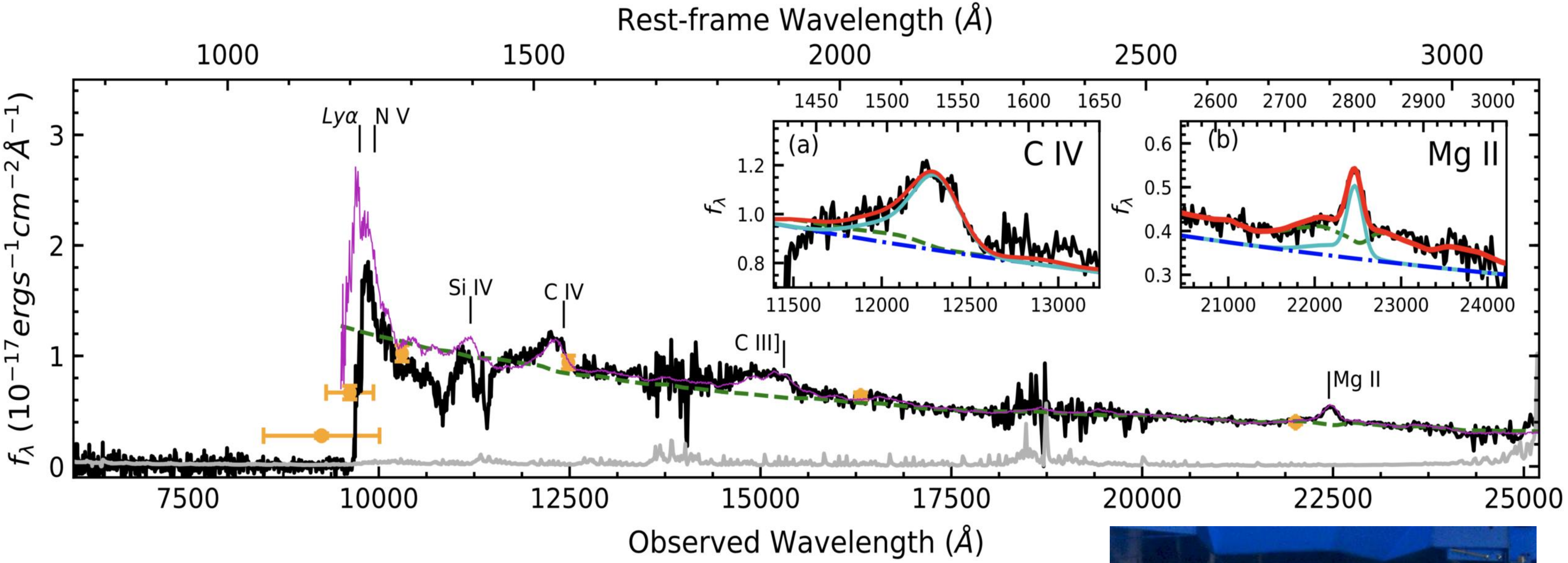
- J0038–1527 is the most luminous quasar known at z > 7 ($L_{Bol}=5.6\times10^{13}L_{\odot}$)

  Eddington ratio of 1.25±0.19

  Outflow velocity = 0.08c to 0.14c → extremely high velocity !!

- J0038–1527 is the first quasar found at the epoch of reionization with such strong outflows ! → These contribute the growth of the most massive galaxies !

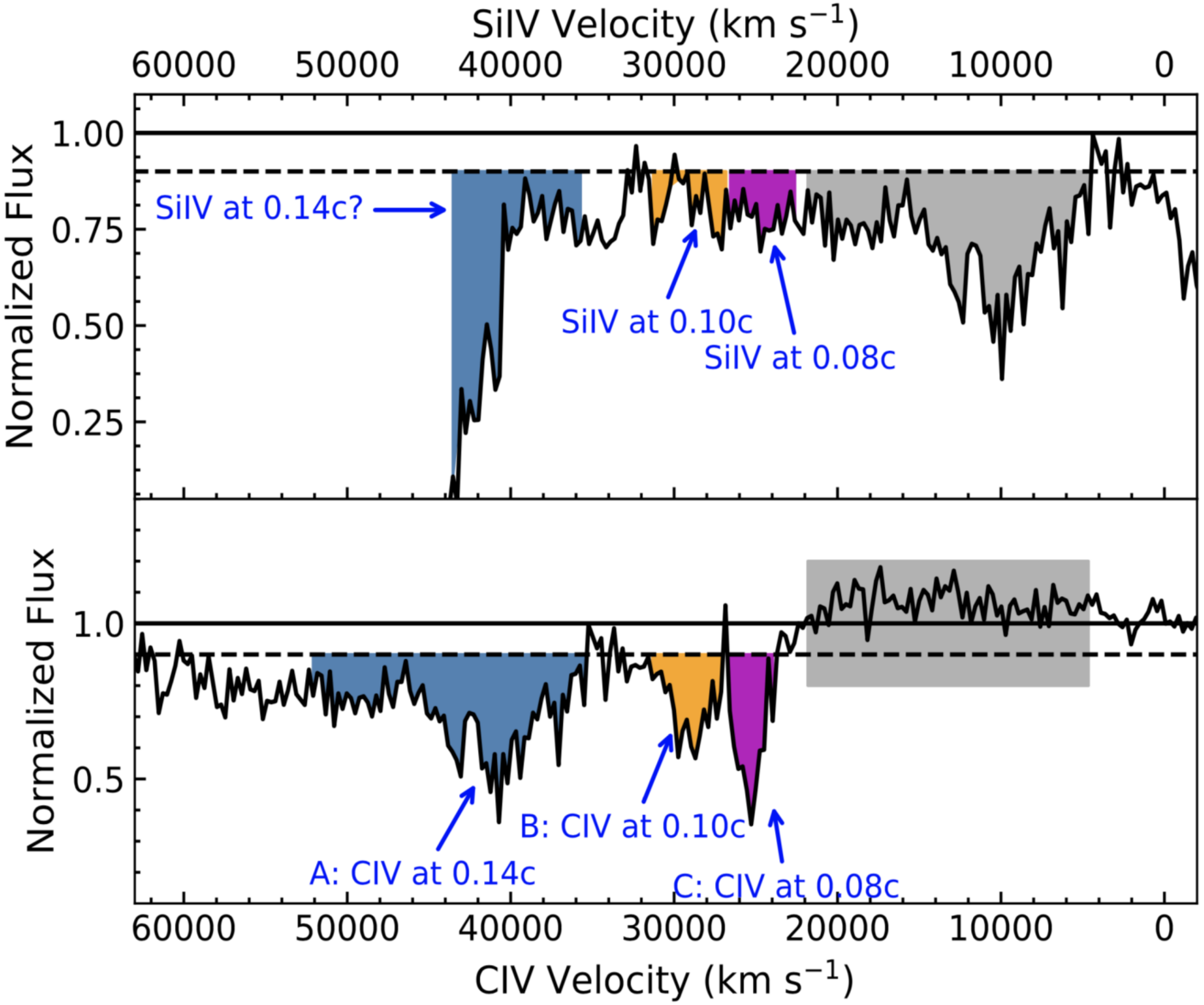
Spectrum of J0038–1527



Gemini/GNIRS, with a total exposure time of 4.2 hours

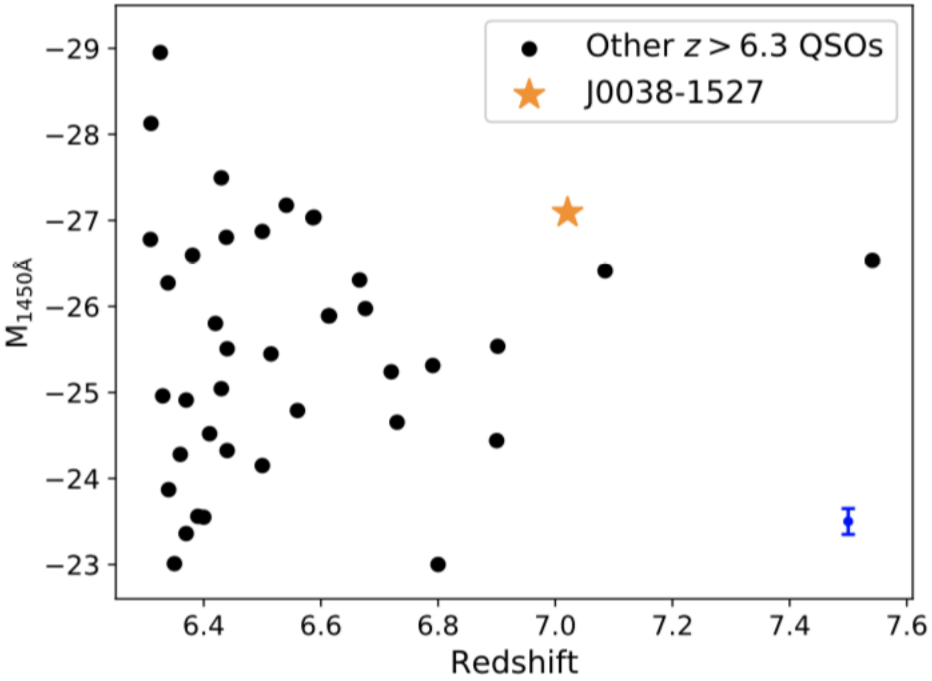
GNIRS ©Gemini

Normalized spectrum and BALs with extremely high velocity



- Normalized spectrum of J0038–1527
- The quasar has three absorption systems at 0.14c, 0.10c, and 0.08c !
- BI = 3400 km/s (A), 890 km/s (B), 1010 km/s (C) for CIV BAL

Derived Parameters of J0038–1527



- J0038-1527 has high Eddington-ratio.

$z_{\rm MgII}$	7.025±0.005
$z_{\rm CIV}$	6.939±0.008
α_λ	−1.54±0.05
$\Delta_{\rm v_{CIV}-v_{MgII}}$ (km s^{-1})	3400±411
FWHM$_{\rm MgII}$ (km s^{-1})	2994±140
EW$_{\rm MgII}$ (Å)	16.5±1.0
FWHM$_{\rm CIV}$ (km s^{-1})	8728±452
EW$_{\rm CIV}$ (Å)	18.1±1.4
$\lambda L_{3000Å}$ (erg s^{-1})	4.19×10^{46}
$L_{\rm Bol}$ (erg s^{-1})	2.16×10^{47}
$M_{\rm BH}$ ($M_\odot$)	$(1.33\pm0.25)\times10^{9}$
$L_{\rm Bol}/L_{\rm Edd}$	1.25±0.19

Summary of the two studies

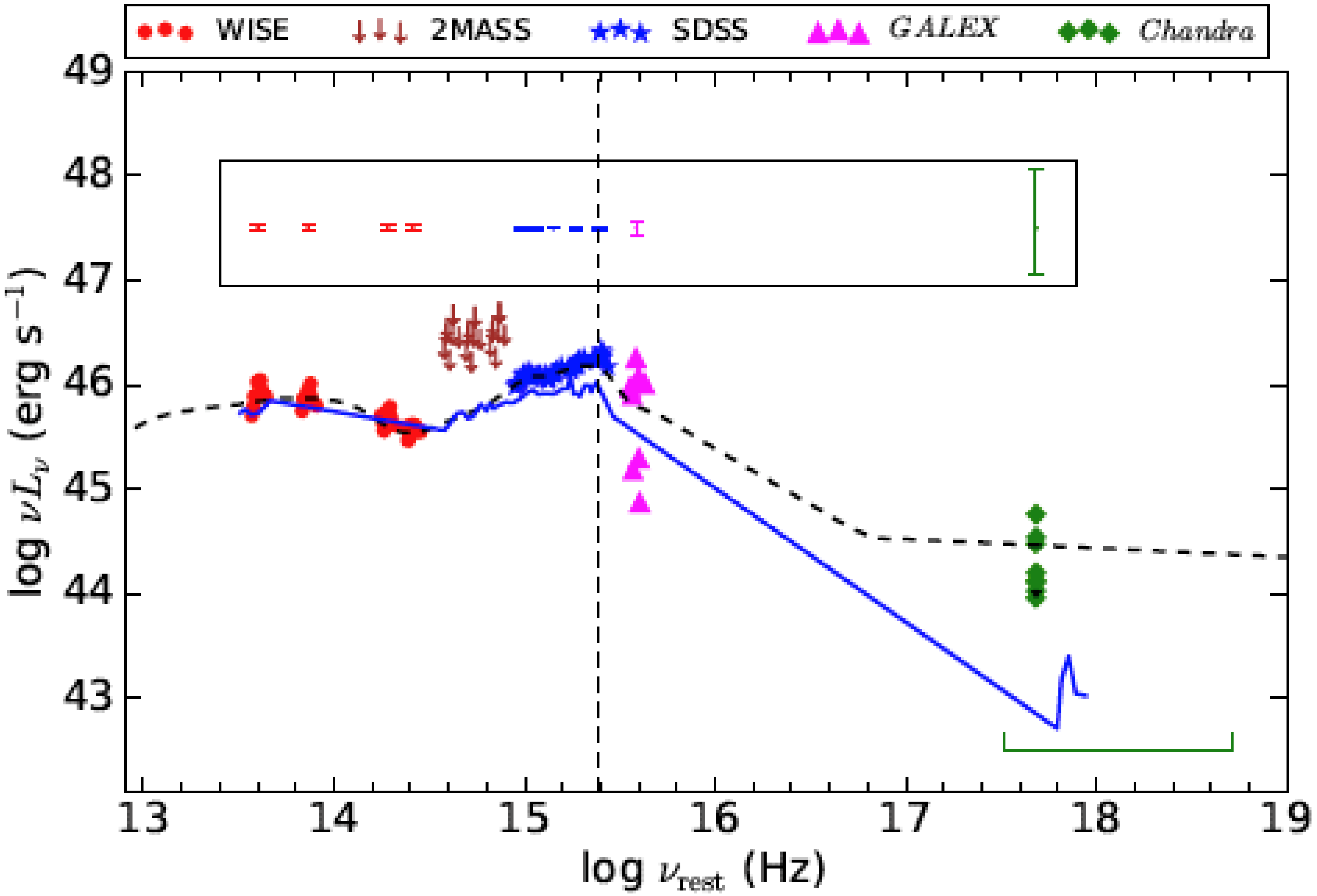
- Conclusion: X-ray and optical/UV observation
  - (At least) The X-ray absorbing material moving out of the line-of-sight, leaving an X-ray unabsorbed non-BAL quasar.
  - The UV absorber might have become more highly ionized (in a shielding-gas scenario) or also moved out of the line-of-sight (in a wind-clumping scenario).

Sameer et al. (2018)

- J0038–1527 is the most luminous quasar known at z > 7 (L_{Bol}=5.6×10^{13} $L_{\odot}$)
  - Eddington ratio of 1.25±0.19
  - Outflow velocity = 0.08c to 0.14c → extremely high velocity !!
- J0038–1527 is the first quasar found at the epoch of reionization with such strong outflows ! → These contribute the growth of the most massive galaxies !

Wang et al. (2018)

Appendix I : SED (Samerr et al. 2018)



Appendix II : CIV Emission Blueshift (Wang et al. 2018)