The Curious Case of the Disappearing (and Appearing) Quasars

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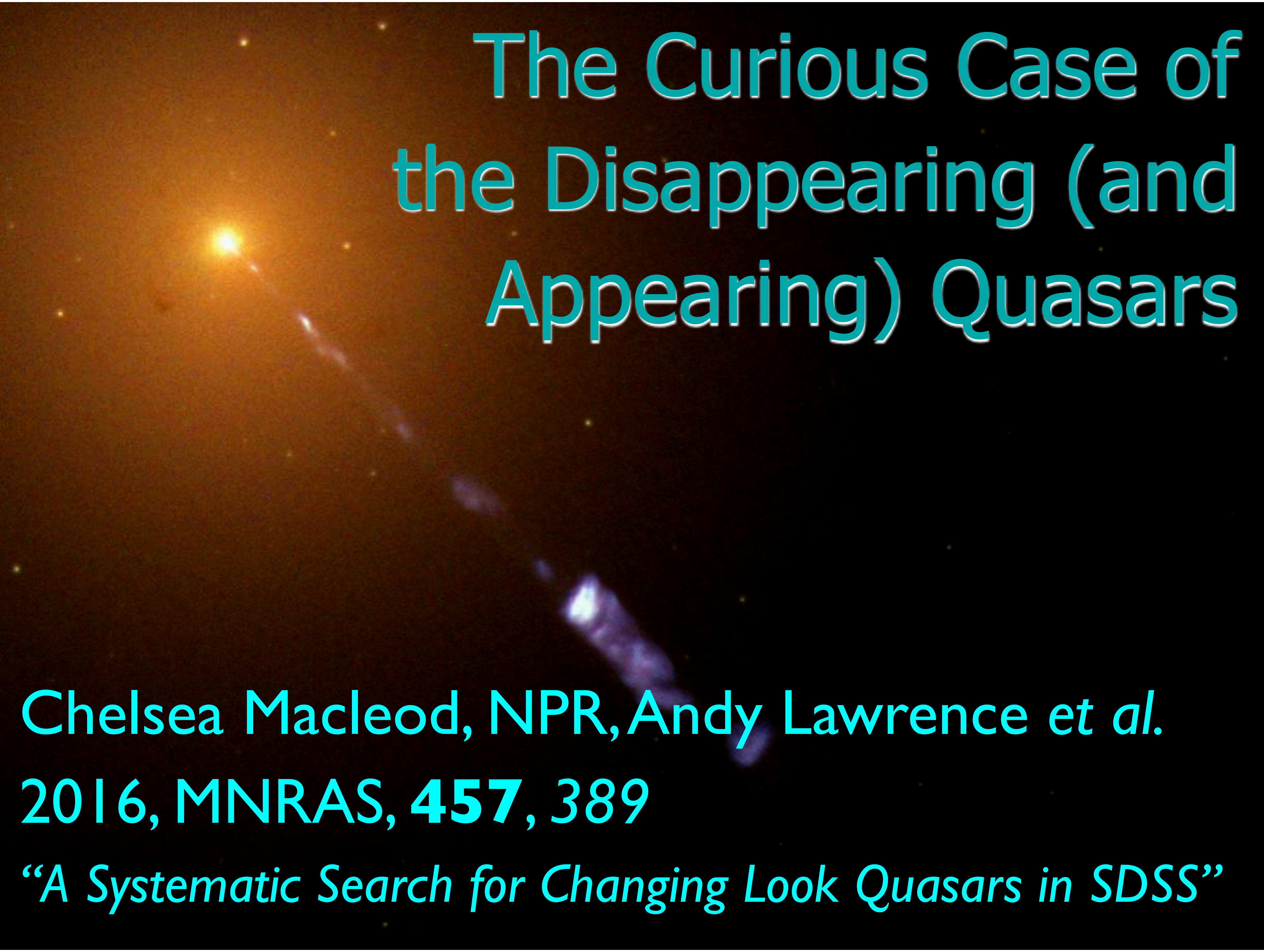

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Chelsea Macleod, NPR, Andy Lawrence *et al.*

2016, MNRAS, **457**, *389*

“A Systematic Search for Changing Look Quasars in SDSS”

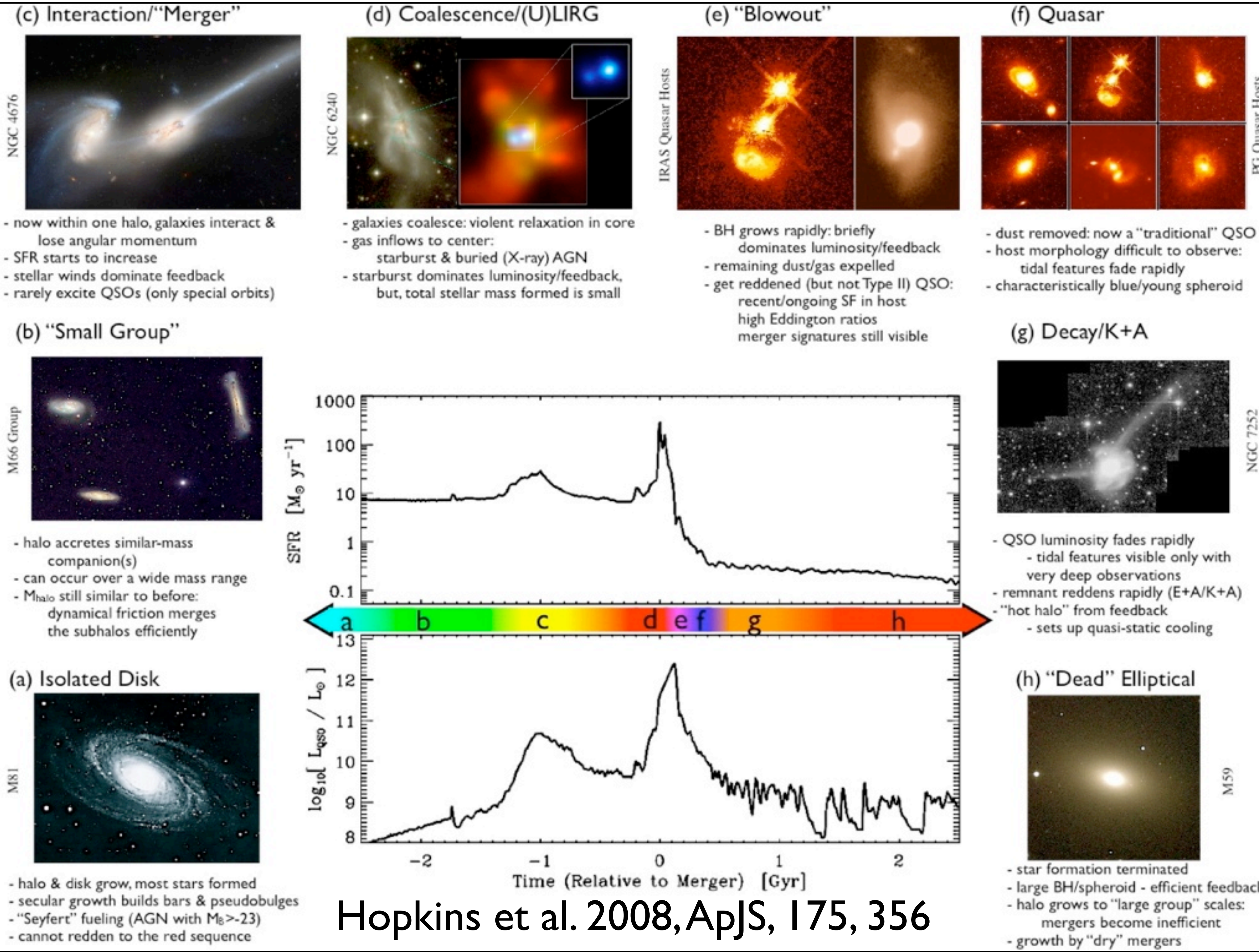
Why you (LBNL) care?

- BOSS, eBOSS, DESI all have QSOs as LSS/BAO tracers: Luminosity (in)dependent bias of QSOs

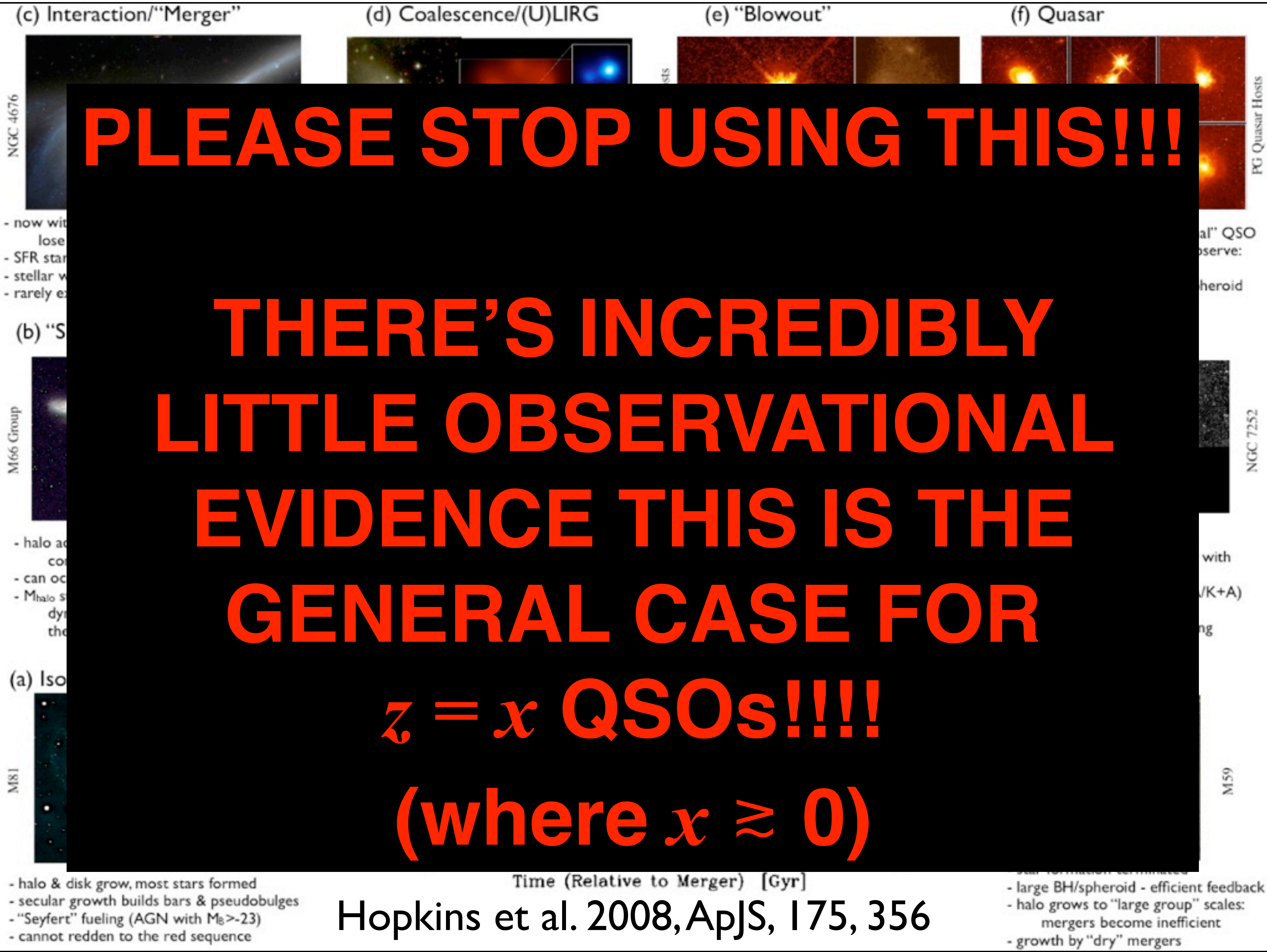
- AGN in DESI ELGs (# ~ same as DESI QSOs)

- QSOs as Standard Candles:
  1. via Reverberation Mapping (e.g. Watson et al., 2014; King et al. 2014, 2015; Shen et al. 2015; Yuan et al., 2015)
  2. via log L_{UV} - L_X relation (e.g. Risaliti & Lusso, 2015)

- Uses BOSS data (over 210 cites to the BOSS QSO catalogues)



Hopkins et al. 2008, ApJS, 175, 356



PLEASE STOP USING THIS!!!

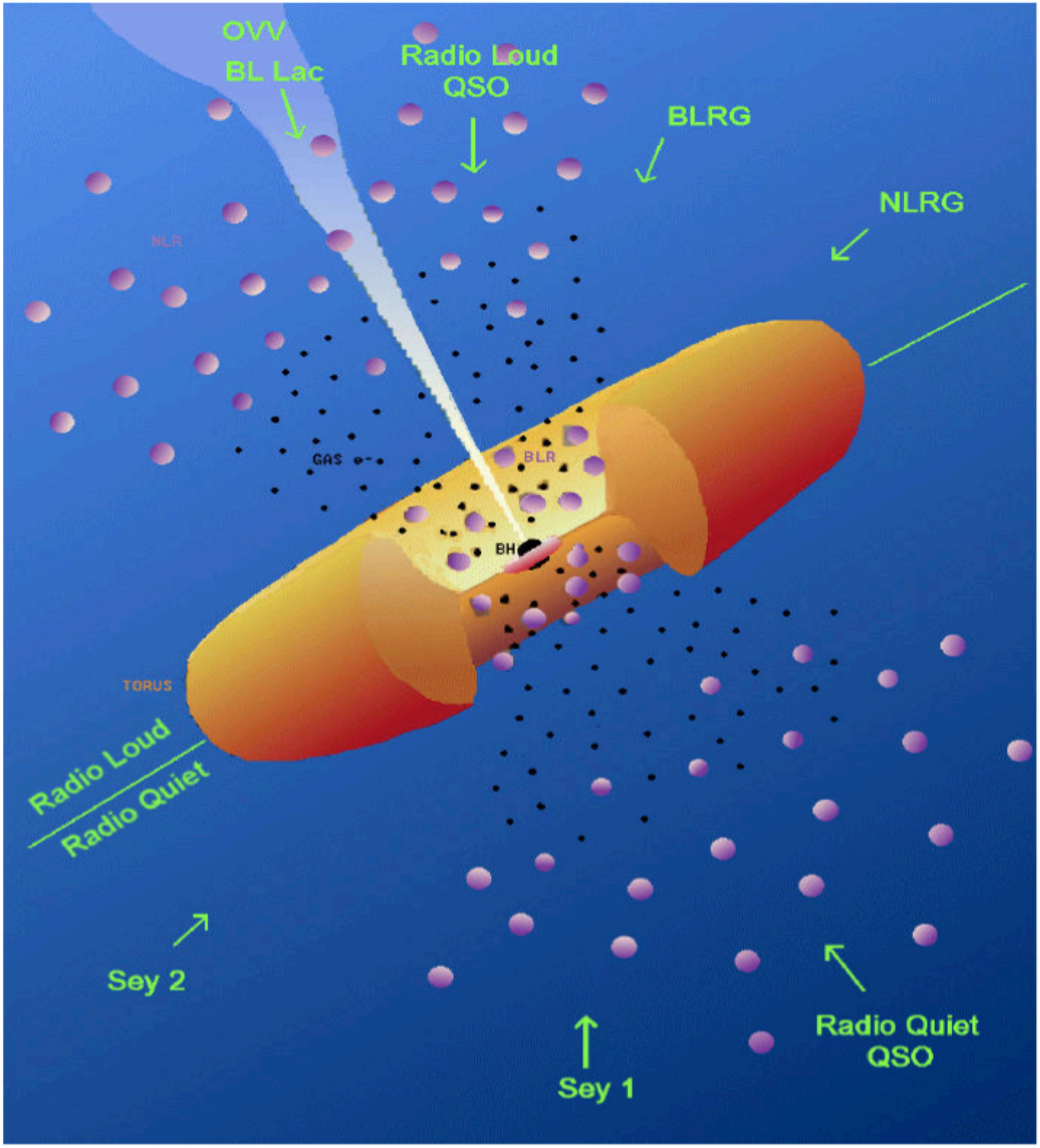
THERE'S INCREDIBLY LITTLE OBSERVATIONAL EVIDENCE THIS IS THE GENERAL CASE FOR $z = x$ QSOs!!!!

(where $x \gtrsim 0$)

Hopkins et al. 2008, ApJS, 175, 356

To add more context than just the slides, the “major merger” hypothesis is a (very) viable idea for the most luminous quasars at the bright(est) end of the quasar luminosity function. However, at the “knee” of the luminosity function, where the most BH mass build-up happens, it is (very) unclear what the main mechanism for BH growth.

As such, and with very little evidence for major mergers powering quasars at $z>0$, this motivational cartoon has to currently be taken with large pinch of salt.



The "AGN Unification Model"

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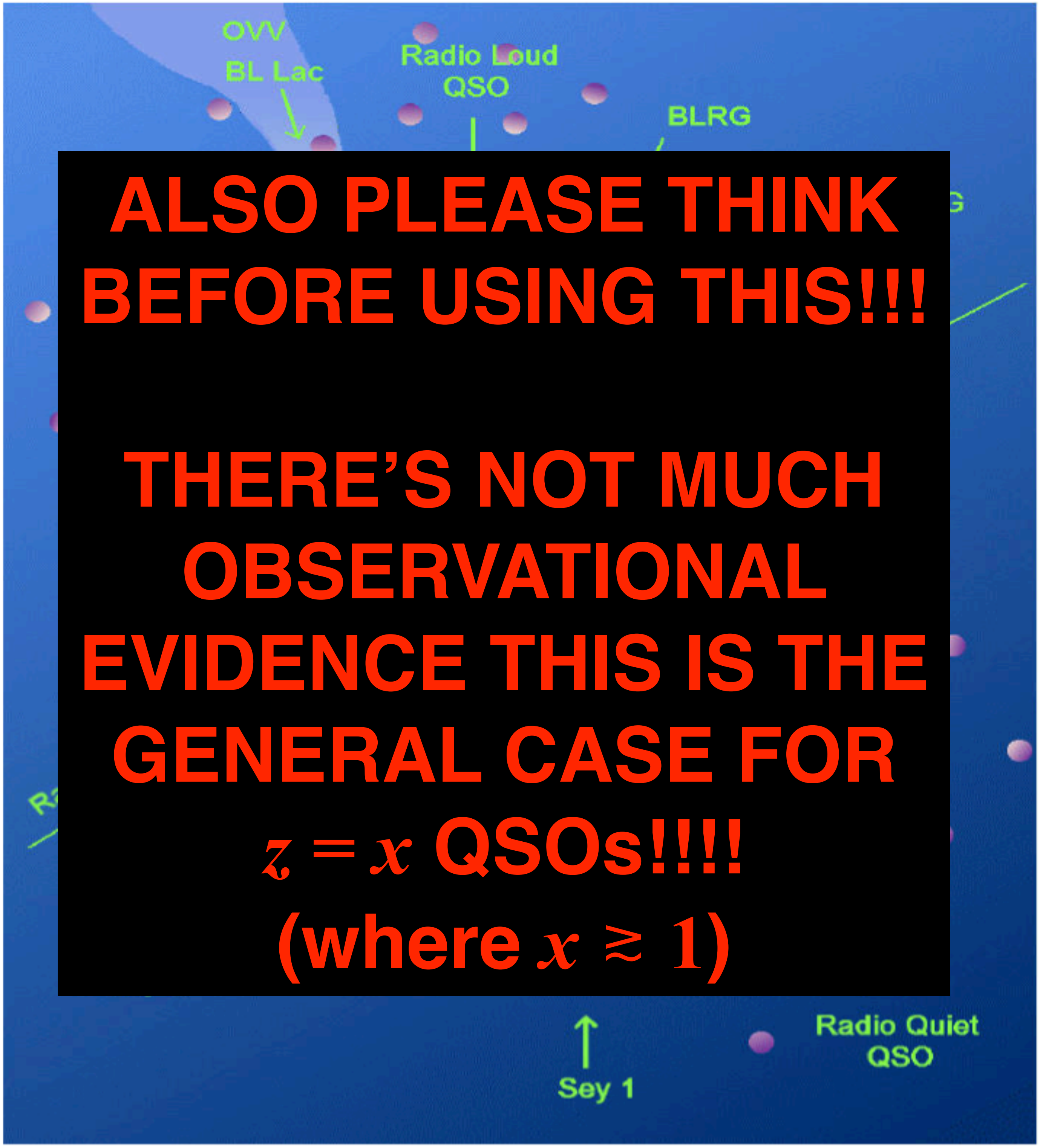

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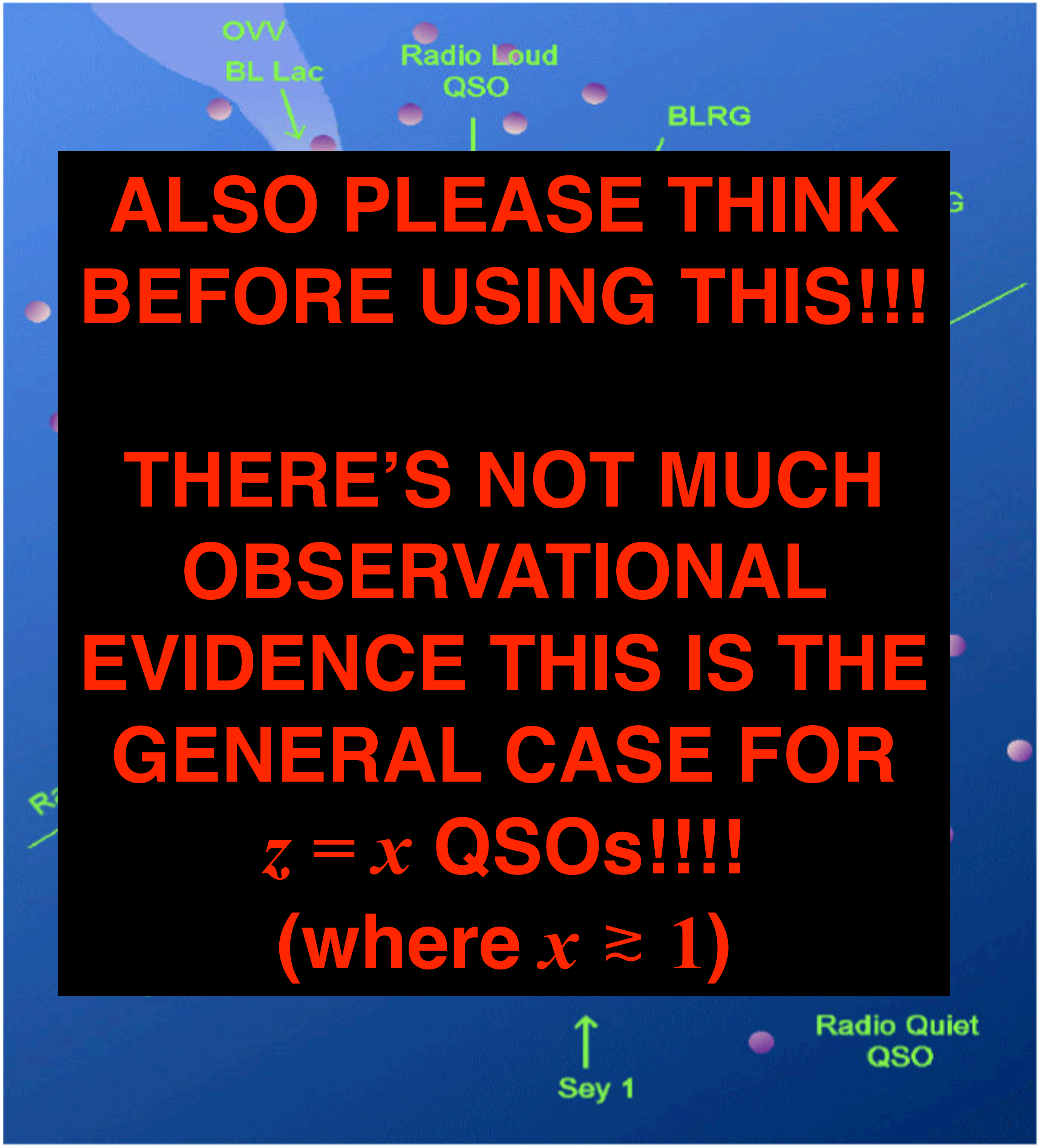

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The "AGN Unification Model"

Basically at odds with "major merger" scenario

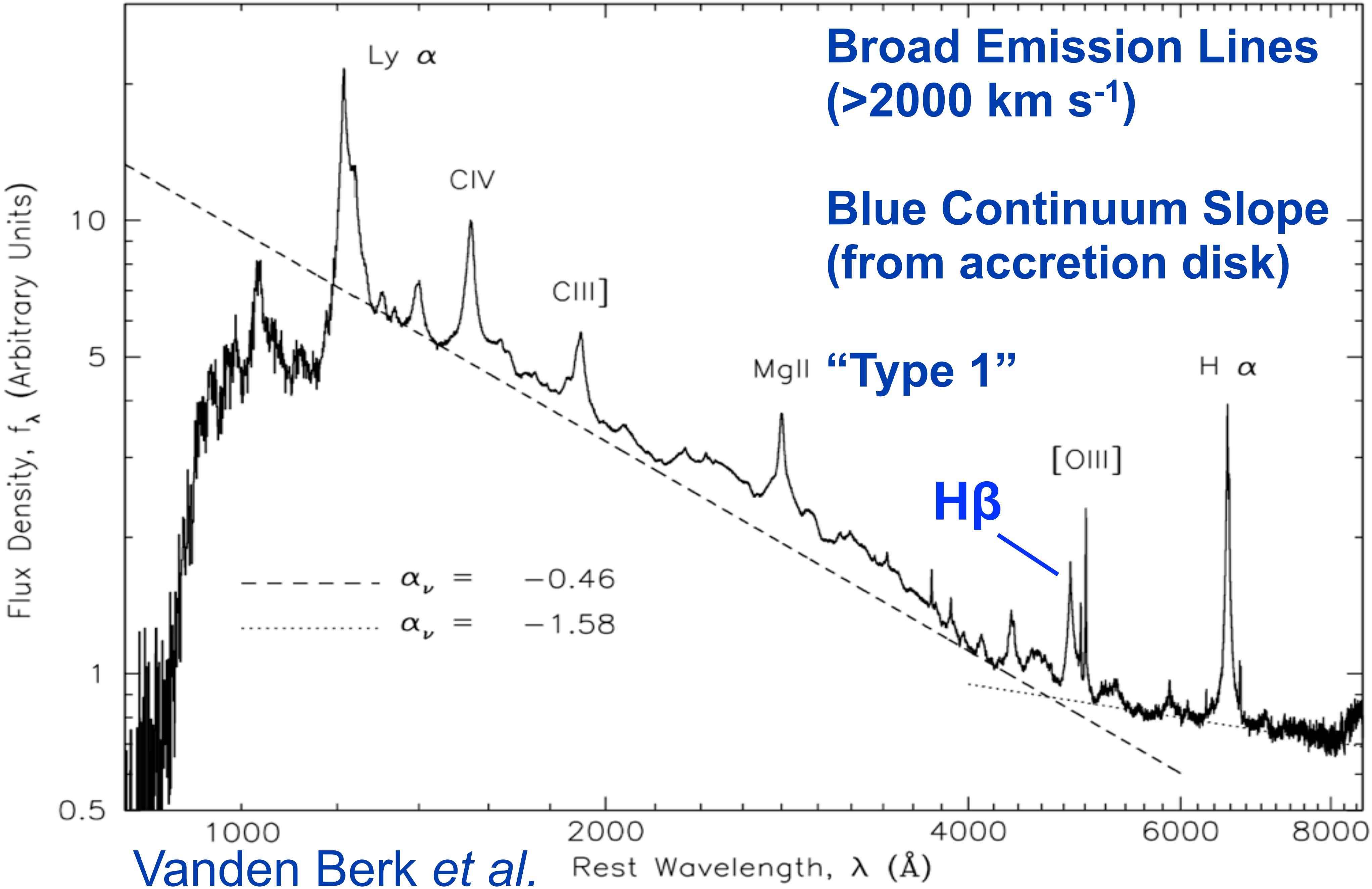
Netzer 2015, *ARAA*, 53, 365 "Revisiting the Unified model of Active Galactic Nuclei"

Again, to add more context than just the slides, the "AGN Unification Picture", is a very good starting point for explaining the range in AGN observed properties.

However, a major outstanding issue is whether these AGN/ Quasars follow an "evolution" (as given in the Hopkins et al. slide) or "orientation" paradigm.

There are fundamental issues still at large with the 'orientation' paradigm, such as the stability and geometry of the obscuring medium, the timescales associated with the many physical processess involved, the "classic problem" of the lack of high-luminosity, high-obscuration objects at z>1, and of course the precise nature of the Broad Line Region. This talk and work begins to directly address this last issue.

Quasar Spectra



Vanden Berk *et al.*
2001, AJ, 122, 549

Why we care about CLQs

“Changing Look Quasars” (CLQs) are defined to be *luminous AGN* which are observed to have a dramatic ***appearance***, or ***disappearance***, of their broad emission-line (BEL) component.

CLQs offer a **direct probe** into the physical processes dictating the structure of the AGN broad-line region (BLR), *and do so on year-timescales.*

These timescales can potentially be associated with:

- the ***viscous timescale*** (associated with radial drift time through the accretion disk),
- the ***light crossing timescale*** (critical for reverberation mapping and disk reprocessing) and
- the ***dynamical timescale*** of the BLR.

CLQ "History"

- Appearing Broadlines
  - Markarian 6 (z=0.018 M_i = -20.3; Khachikian & Weedman 1971)

- Vanishing Broadlines
  - NGC 7603 (z=0.0295, M_i ~ -21.7 Tohlin & Osterbrock 1976)

- First Changing Look "Quasar"
  - SDSS J0159+0033 (z=0.31, M_i = -22.7 in SDSS Quasar catalog, Mi<-22.0; LaMassa et al. 2015)

- First `systematic' (a.k.a. non-serendipitous) search
  - Macleod, NPR et al. (2016; z=0.20-0.62).

Sample Selection of CLQ Candidates

- **SDSS DR7Q**: $M_i < -22$, both point sources and resolved objects (Schneider et al. 2010)

- $|\Delta g| > 1.0$ mag among any observations in SDSS and PS-1

Selection	Total #	In S82
SDSS Quasars in DR7Q	105 783	9474
with BOSS spectra	25 484	2304
and $\|\Delta g\| > 1$ mag and $\sigma_g < 0.15$ mag	1011	287
and that show variable BELs	10	7

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- 6348 DR7Q objects have $|\Delta g|$ > 1.0 mag

- We do not consider 3 blazars, radio sources with ~2-3 mag changes over months; see e.g. Ruan et al. 2012.

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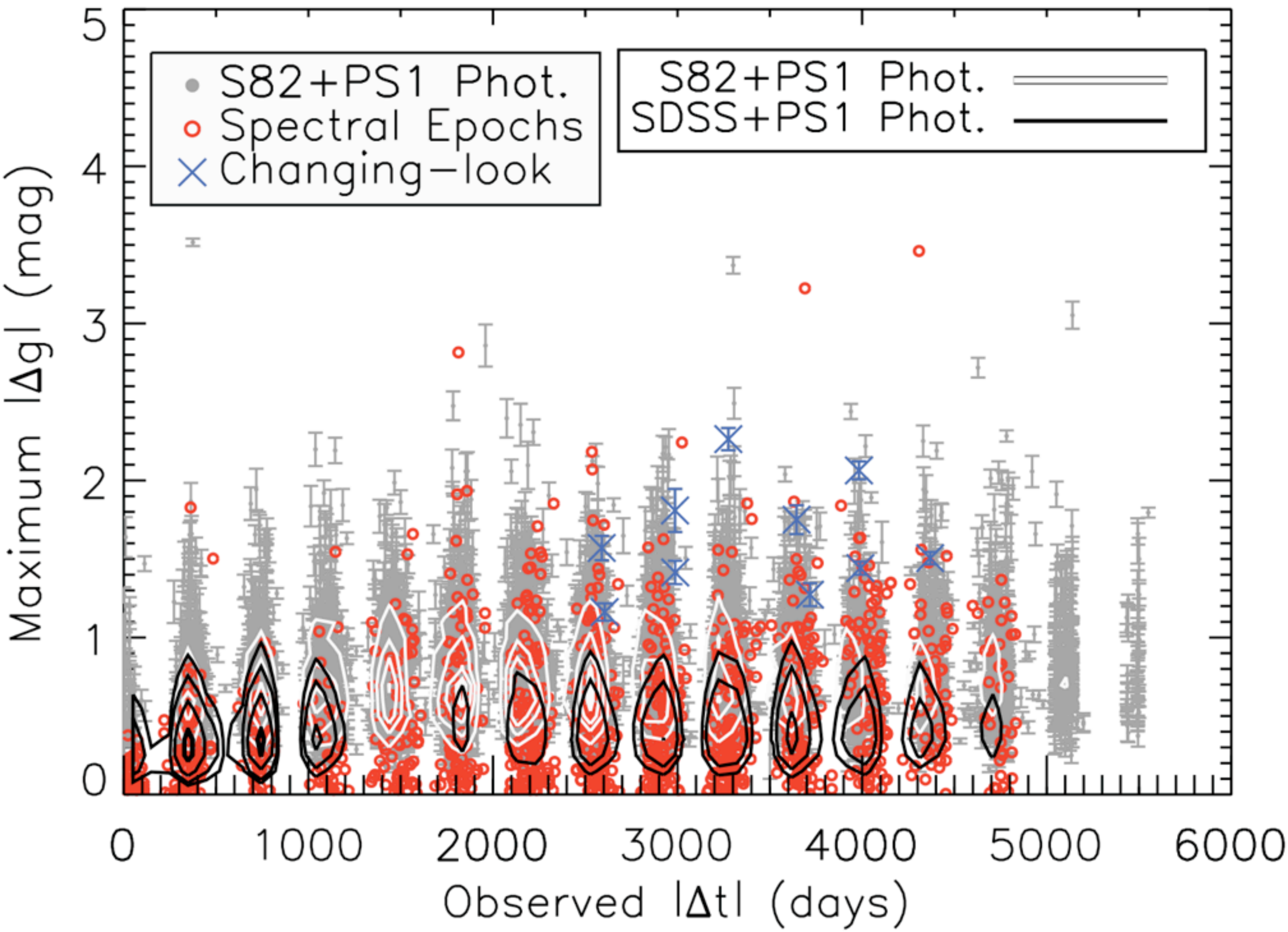

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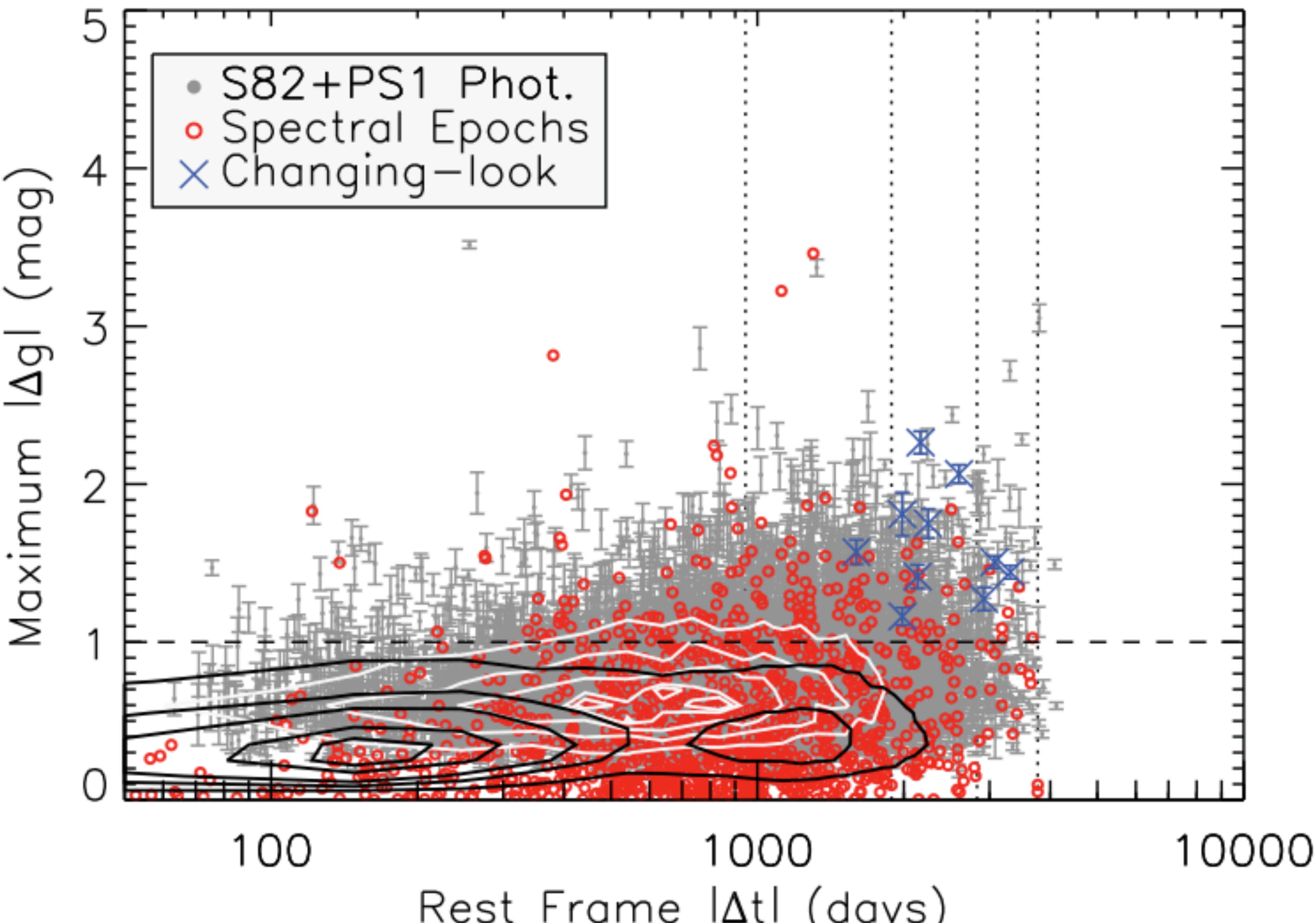

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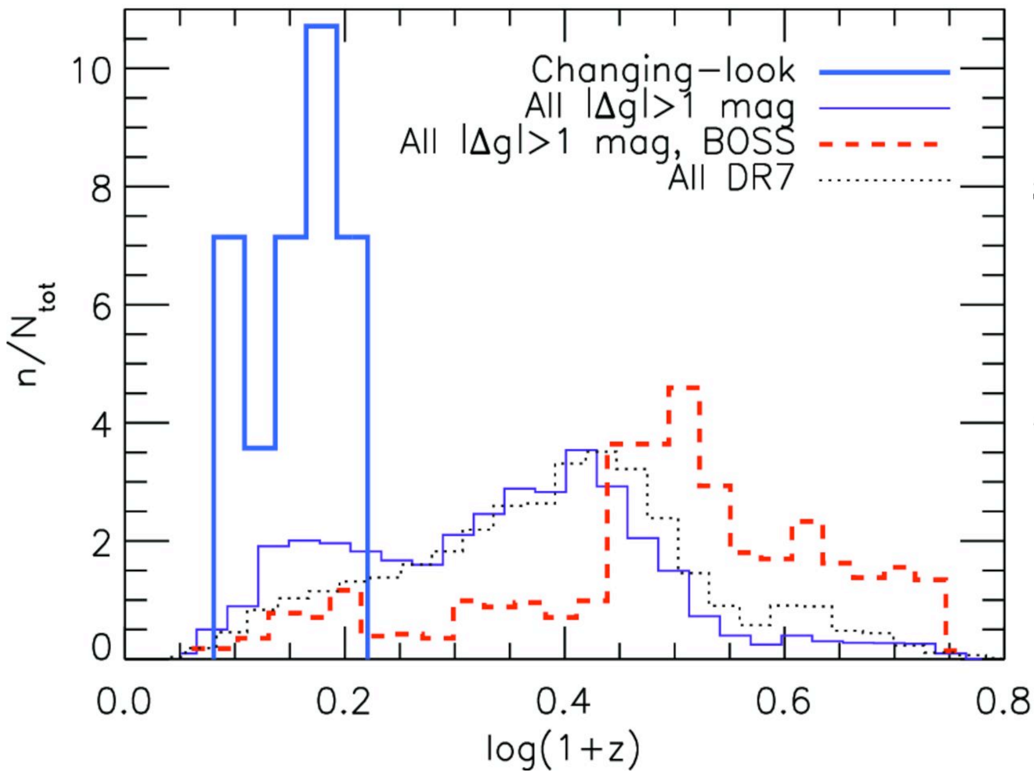
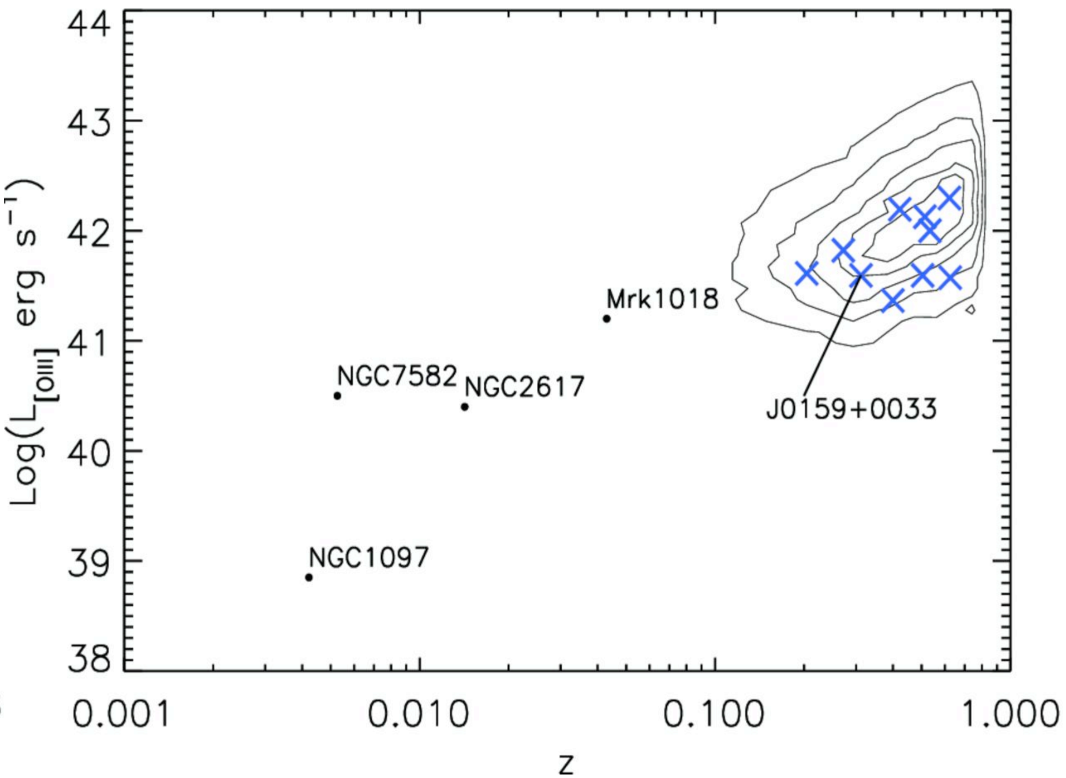
Discovery of 10 CLQs

Name (SDSS J)	z	Max(Δg)	Δt_{RF} (d)	BEL behaviour	(MJD|plate|fibre)$_1$	(MJD|plate|fibre)$_2$	$\lvert\Delta f_\nu\rvert \propto \nu^\beta$
002311.06+003517.5	0.422	-1.50 ± 0.04	3072	Appear	51816|0390|0564	55480|4219|0852	0.04 ± 0.02
015957.64+003310.4	0.312	1.16 ± 0.06	1985	Disappear	51871|0403|0549	55201|3609|0524	0.27 ± 0.02
022556.07+003026.7	0.504	1.81 ± 0.14	1985	Both	52944|1508|0556	55445|3615|0617	0.16 ± 0.03
022652.24−003916.5	0.625	1.75 ± 0.09	2242	Disappear	52641|1071|0281	56577|6780|0339	0.2 ± 0.1
100220.17+450927.3	0.400	1.41 ± 0.07	2134	Disappear	52376|0943|0310	56683|7284|0122	-0.20 ± 0.02
102152.34+464515.6	0.204	1.44 ± 0.04	3313	Disappear	52614|0944|0603	56769|7386|0410	0.175 ± 0.007
132457.29+480241.2	0.272	1.27 ± 0.07	2923	Disappear	52759|1282|0045	56805|7406|0527	0.86 ± 0.02
214613.31+000930.8	0.621	-1.57 ± 0.08	1597	Appear	52968|1107|0358	55478|4196|0774	0.1 ± 0.1
225240.37+010958.7	0.534	-2.06 ± 0.06	2596	Appear	52174|0676|0442	55500|4294|0045	-0.45 ± 0.08
233317.38−002303.4	0.513	-2.26 ± 0.07	2164	Appear	52199|0681|0114	55447|4212|0312	0.75 ± 0.07

Redshift and Luminosity





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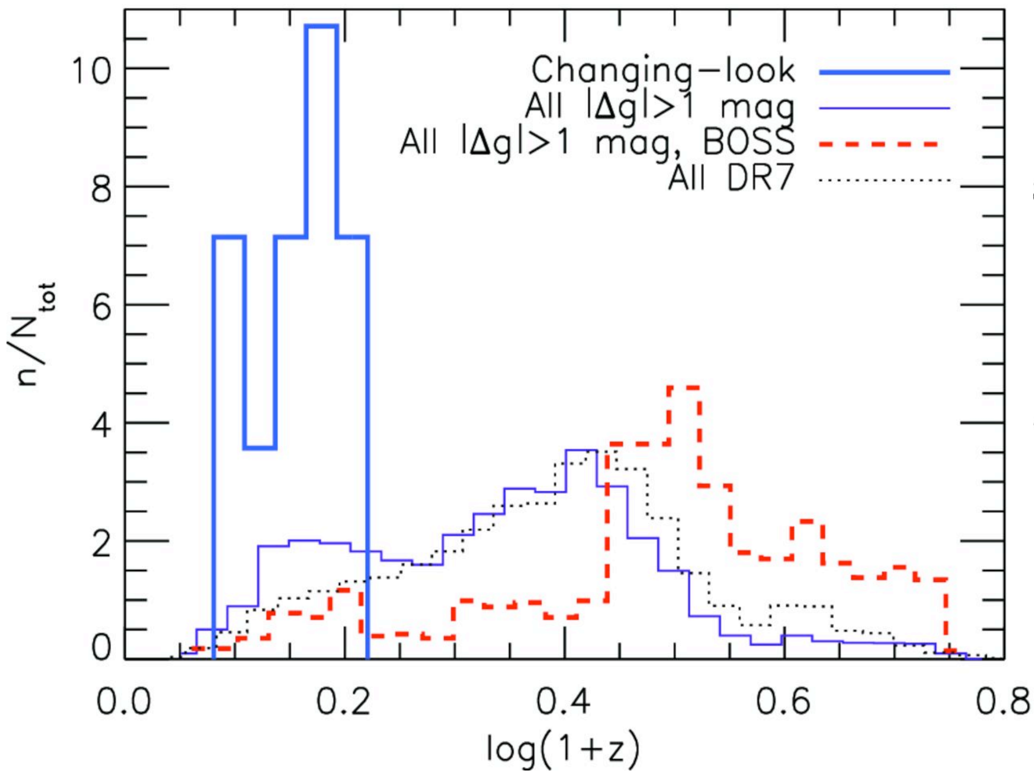
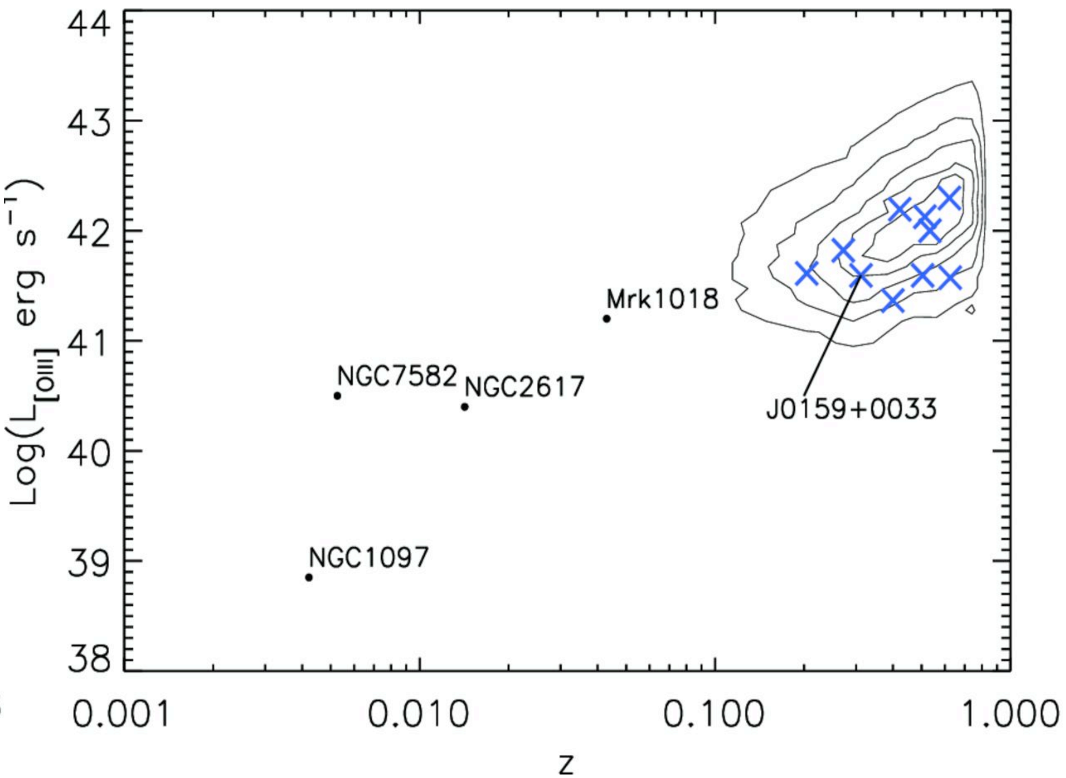


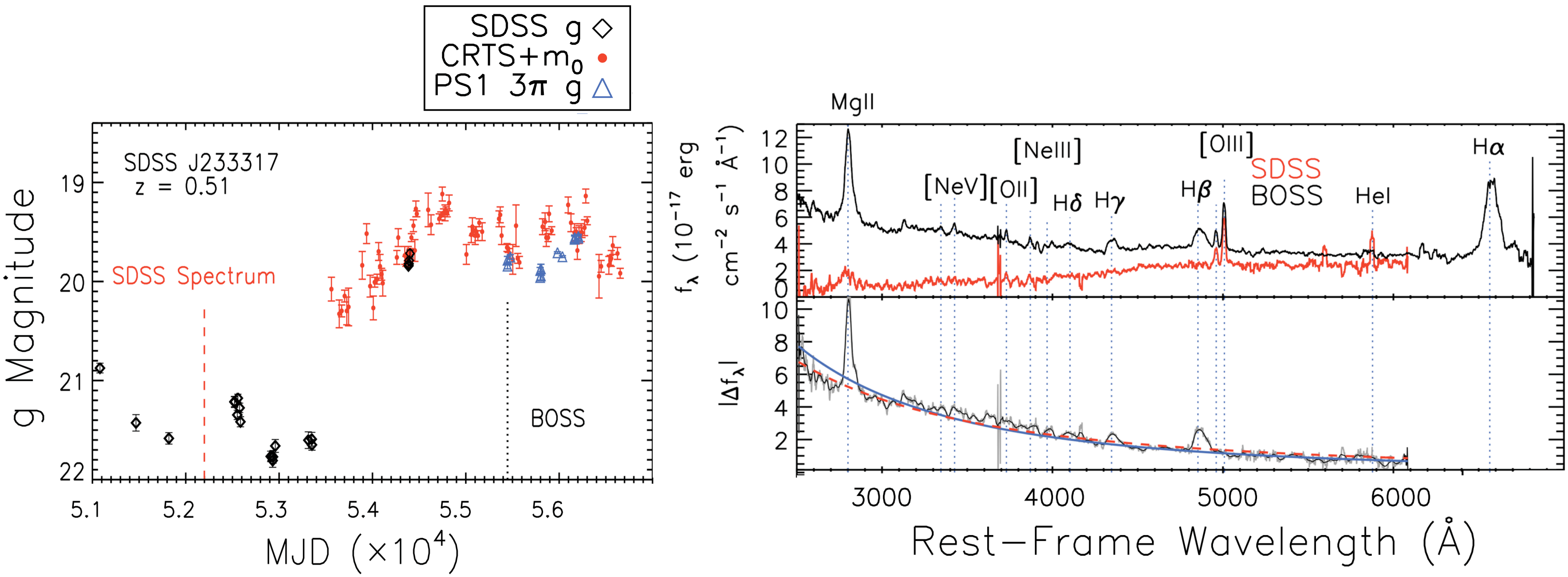


Name (SDSS J)	z	Max($\|\Delta g\|$) (mag)	DR7 QSO?	Found here?
012648.08−083948.0[a]	0.198	0.78 ± 0.03	×	×
015957.64+003310.4[b]	0.312	1.16 ± 0.06	√	√
101152.98+544206.4[c]	0.246	1.51 ± 0.02	√	×
233602.98+001728.7[a]	0.243	1.59 ± 0.13	×	×

Notes. [a]Found by Ruan et al. (2015). [b]Found by LaMassa et al. (2015). [c]Found by Runnoe et al. (2015).

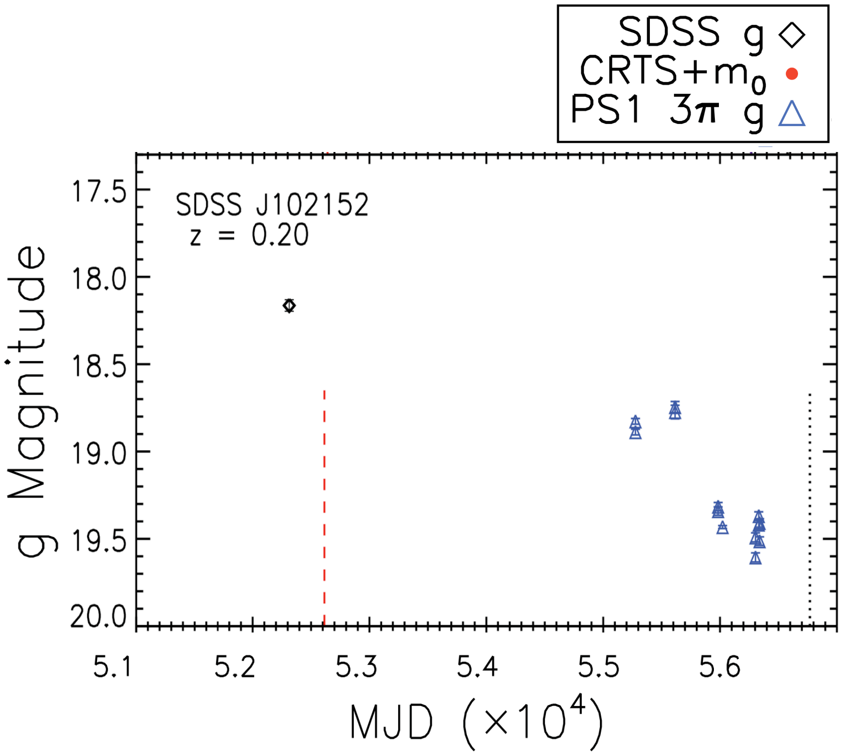
Results (1/5)

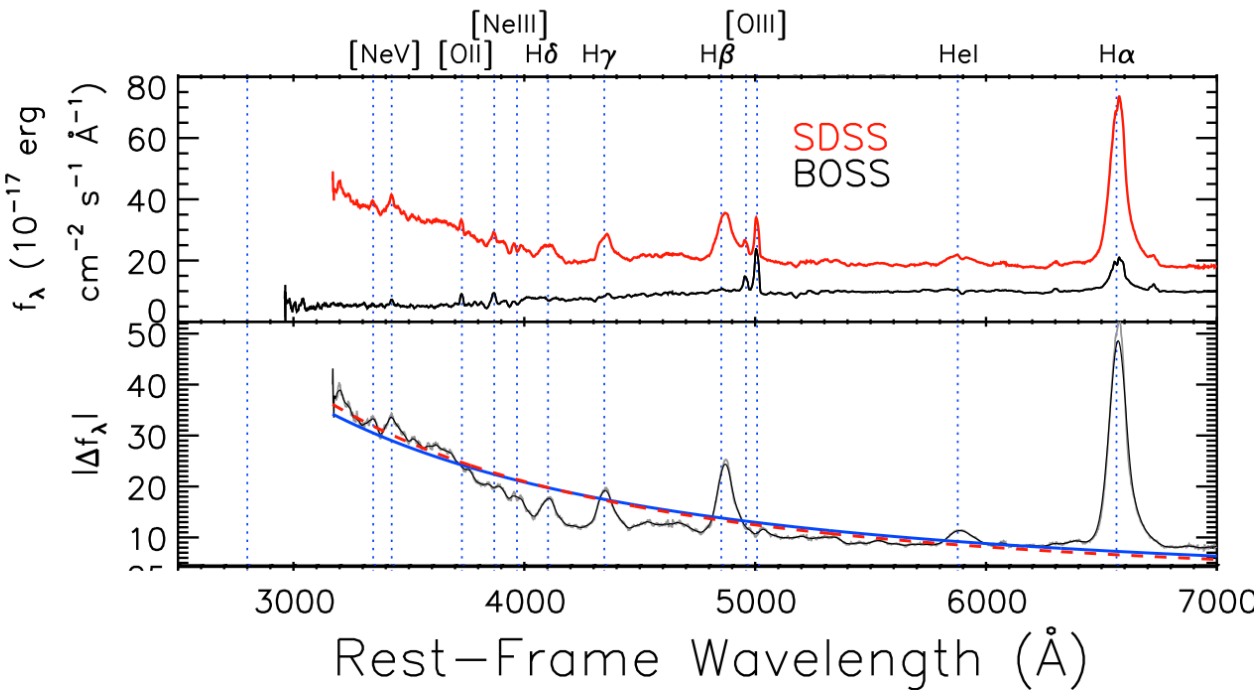
- BEL (dis)appearance associated with large changes in continuum flux.
- 4 with ***emerging*** BELs



Results (2/5)

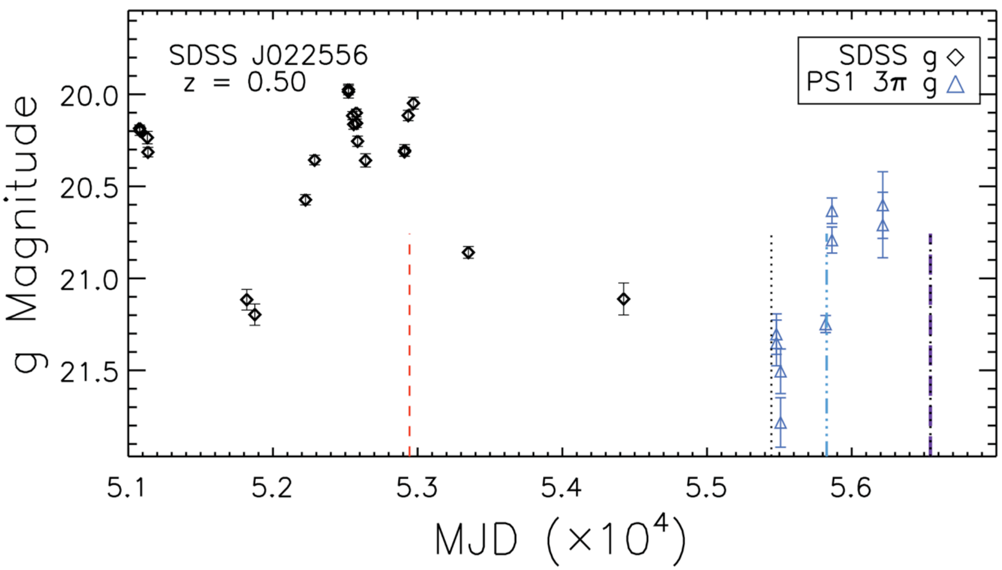
- BEL (dis)appearance associated with large changes in continuum flux.
- 4 with ***emerging*** BELs
- 5 with ***disappearing*** BELs

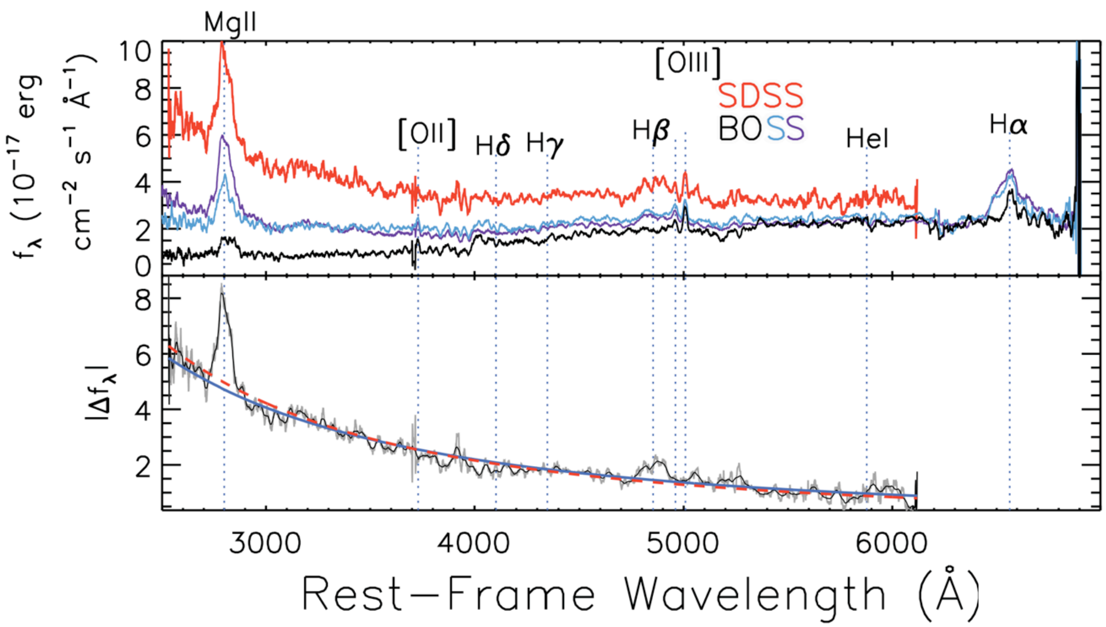




Results (3/5)

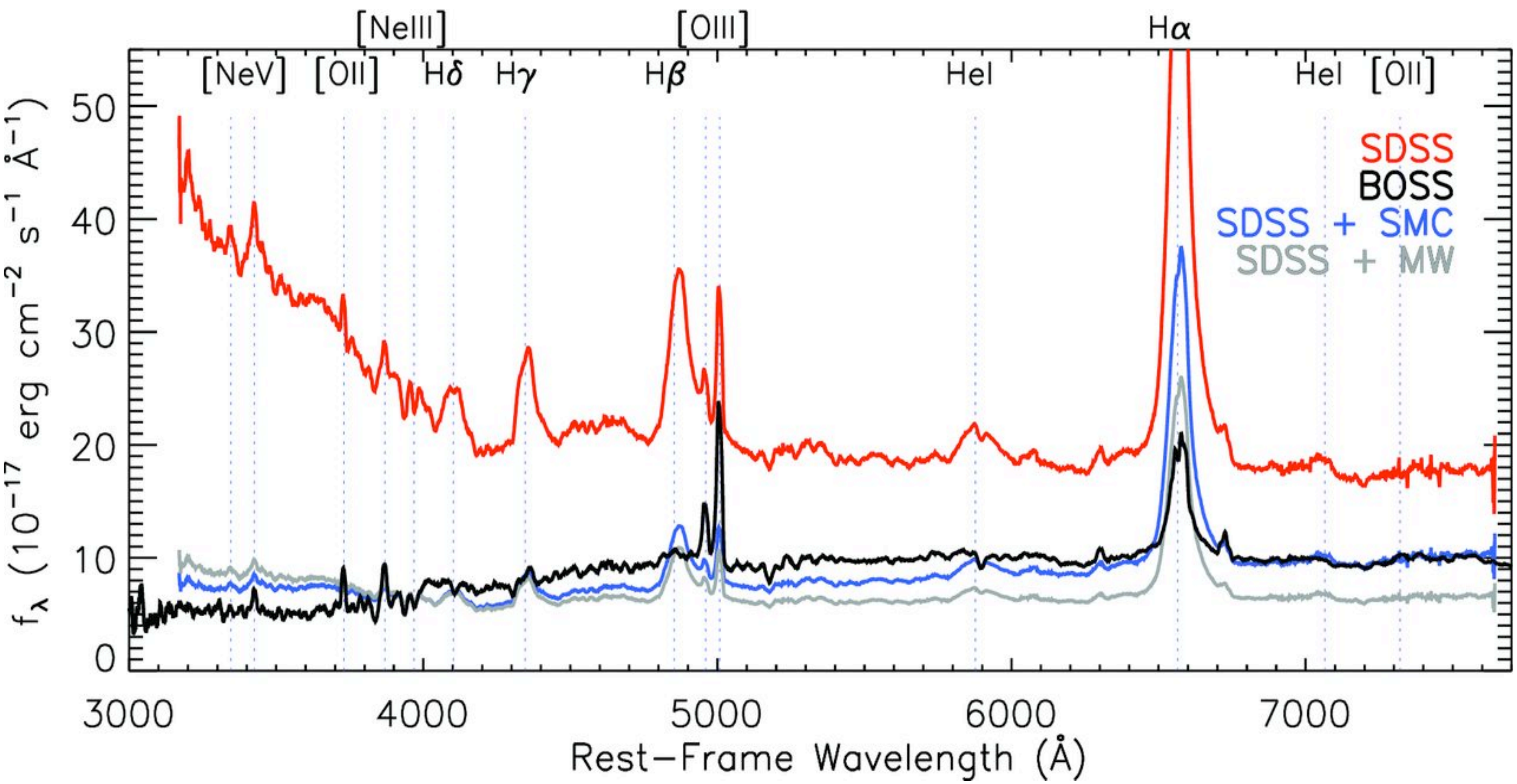
- BEL (dis)appearance associated with large changes in continuum flux.
- 4 with ***emerging*** BELs
- 5 with ***disappearing*** BELs
- One with ***both*** emerging and vanishing BELs





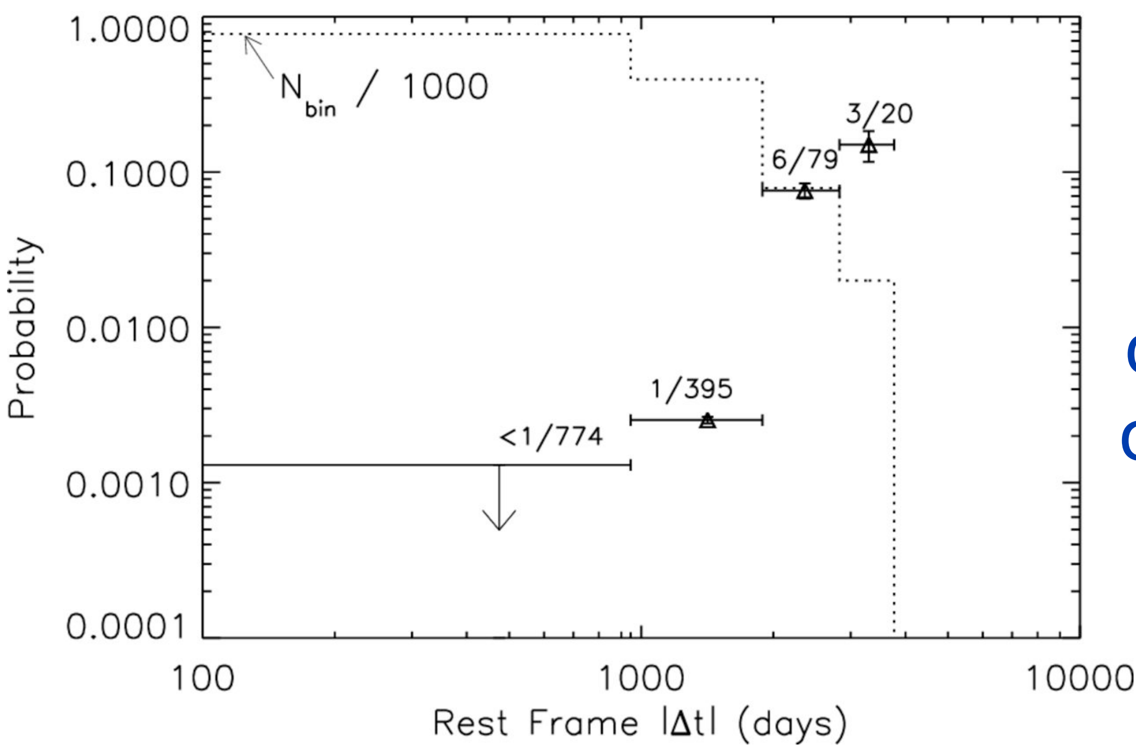
Results (4/5)

- BEL (dis)appearance associated with large changes in continuum flux.
- 4 with ***emerging*** BELs
- 5 with ***disappearing*** BELs
- One with ***both*** emerging and vanishing BELs
- Simple obscuration cannot account for BEL changes



Results (5/5)

- BEL (dis)appearance associated with large changes in continuum flux.
- 4 with ***emerging*** BELs
- 5 with ***disappearing*** BELs
- One with ***both*** emerging and vanishing BELs
- Simple obscuration cannot account for BEL changes
- Timescales shorter than expected for accretion rate changes in the optical emitting region



" >15% of strongly variable luminous quasars display changing-look BEL features on rest-frame time-scales of 8-10 years. "

(Very low level) Interpretation

- "Difference spectra" consistent with $f_\nu \propto \nu^{1/3}$ suggesting **variable** component has an *SED similar to an accretion disk*

- Simple *dust obscuration models* (e.g. MW, SMC) **ruled out**

- Light Curves and narrow emission ***not*** consistent with Tidal Disruption Events (TDE short, sharp event)

- Light Curves ***not*** consistent with e.g. (clumps of) dust crossing timescales ($t_{\mathrm{cross,\ dust}}$ OoM too long)

- ***Potentially*** due to change in ***accretion rates***; but needs some thought into e.g. "disc reprocessing" mechanisms

Next Steps and Conclusions

- Light curve analysis ***plus*** spectroscopy ***very powerful tool;*** very efficient at finding CLQs.

- 10 (9) objects out of ~6350 (99) with $|\Delta g|$ > 1.0 mag (and $|\Delta t|$ > 1000 days) are CLQs

- ***Potentially*** due to change in ***accretion rates***; but needs some thought into e.g. “disc reprocessing” mechanisms

- ***WHT*** time in 2016A,B and Long-Term Status; just finished first run, ***with first new CLQ discovered at the weekend!!***

- TDSS, DESI, “After Sloan 4” etc. will clean up

- BH Major merger rates... ;-)