

The Curious Case of the Disappearing (and Appearing) Quasars

Nic Ross

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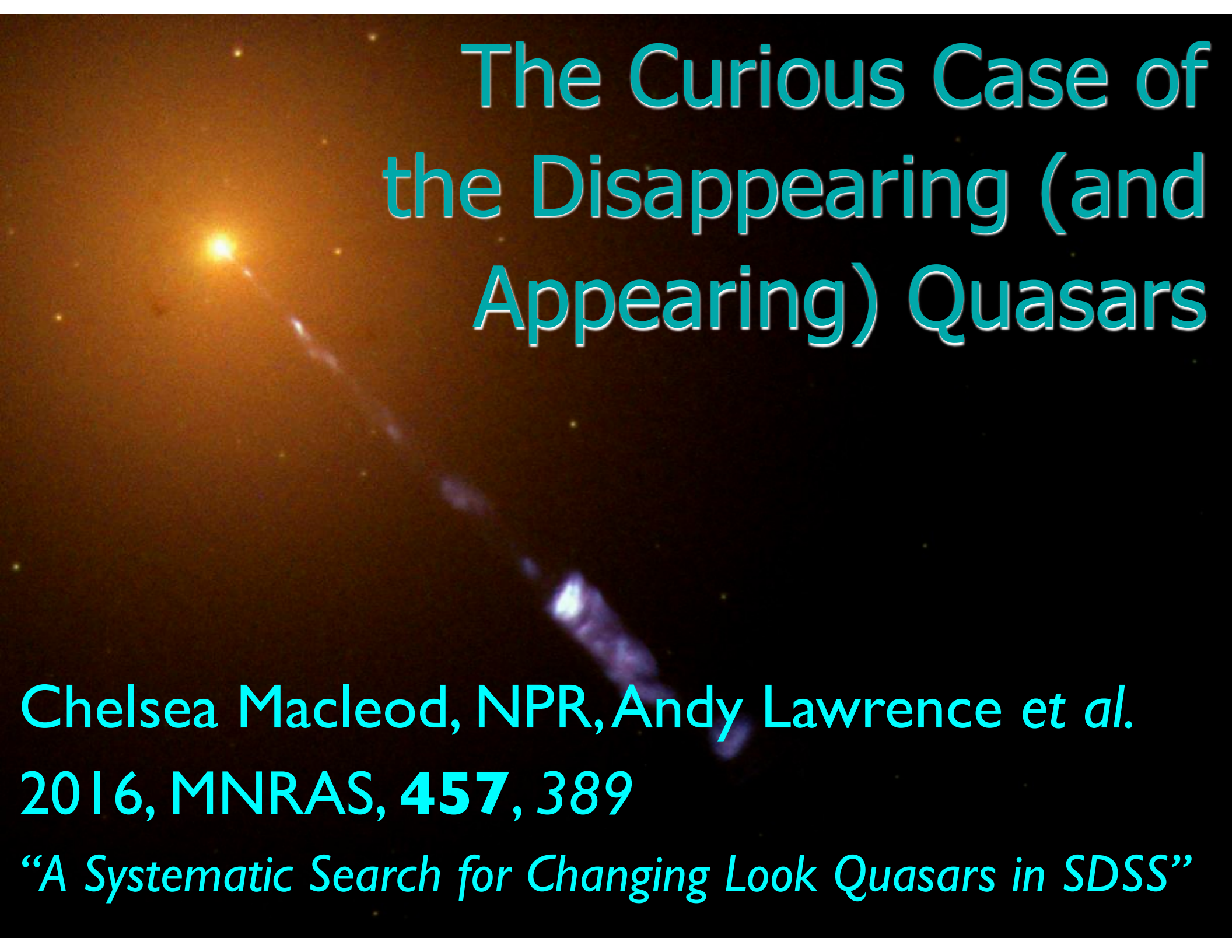
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Chelsea Macleod, NPR, Andy Lawrence *et al.*

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)

(c) Interaction/"Merger"



- now within one halo, galaxies interact & lose angular momentum
- SFR starts to increase
- stellar winds dominate feedback
- rarely excite QSOs (only special orbits)

(b) "Small Group"



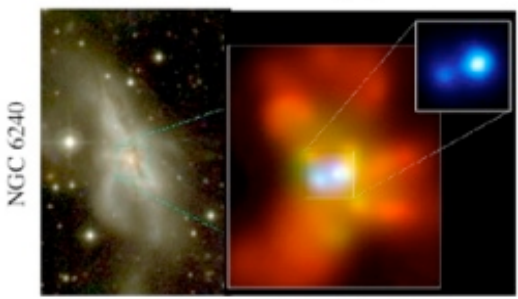
- halo accretes similar-mass companion(s)
- can occur over a wide mass range
- M_{halo} still similar to before: dynamical friction merges the subhalos efficiently

(a) Isolated Disk



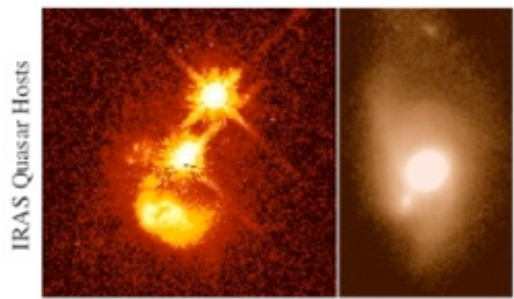
- halo & disk grow, most stars formed
- secular growth builds bars & pseudobulges
- "Seyfert" fueling (AGN with $M_{\text{BH}} > 23$)
- cannot redden to the red sequence

(d) Coalescence/(U)LIRG



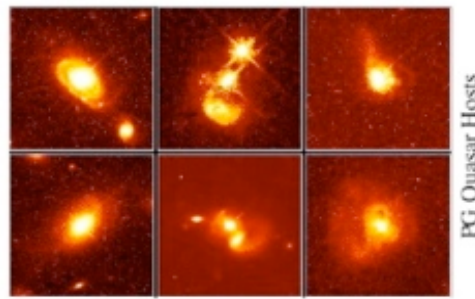
- galaxies coalesce: violent relaxation in core
- gas inflows to center: starburst & buried (X-ray) AGN
- starburst dominates luminosity/feedback, but, total stellar mass formed is small

(e) "Blowout"



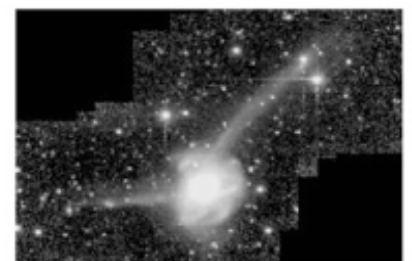
- BH grows rapidly: briefly dominates luminosity/feedback
- remaining dust/gas expelled
- get reddened (but not Type II) QSO: recent/ongoing SF in host
- high Eddington ratios
- merger signatures still visible

(f) Quasar



- dust removed: now a "traditional" QSO
- host morphology difficult to observe: tidal features fade rapidly
- characteristically blue/young spheroid

(g) Decay/K+A

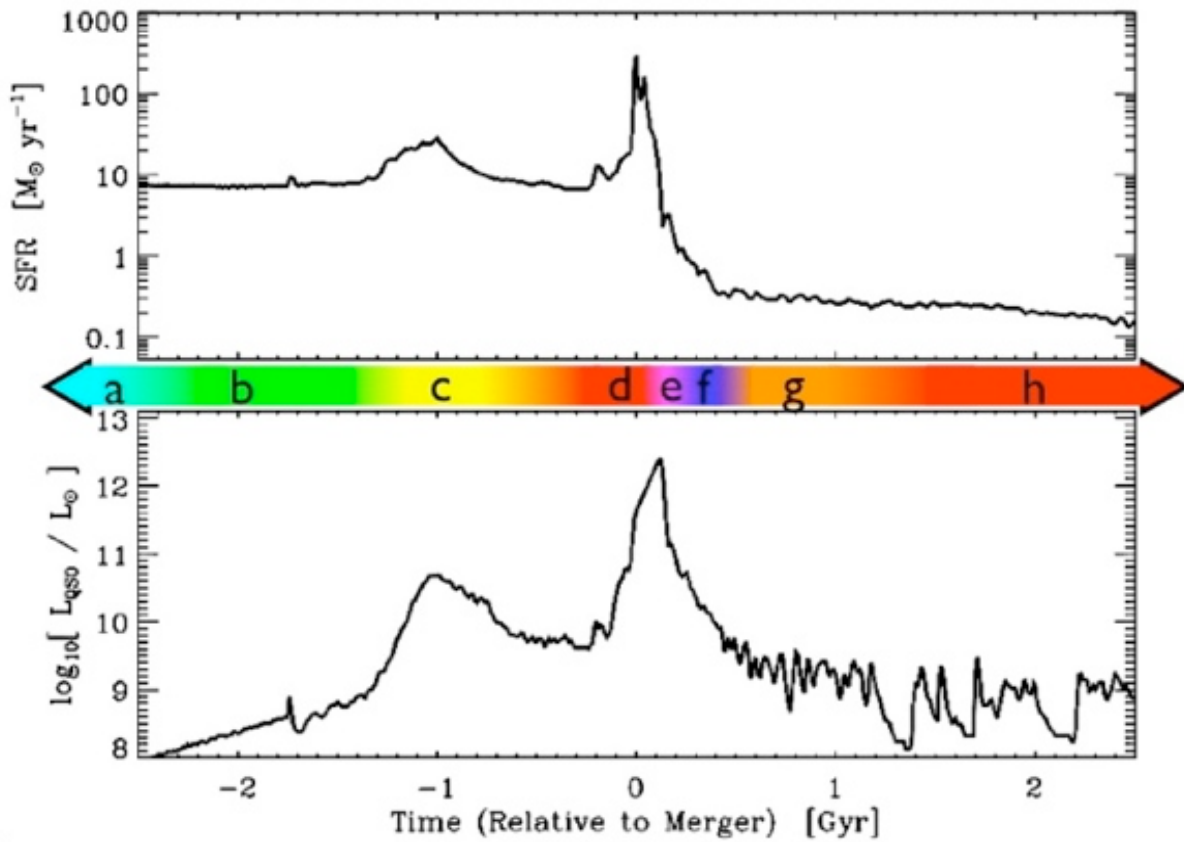


- QSO luminosity fades rapidly
- tidal features visible only with very deep observations
- remnant reddens rapidly (E+A/K+A)
- "hot halo" from feedback
- sets up quasi-static cooling

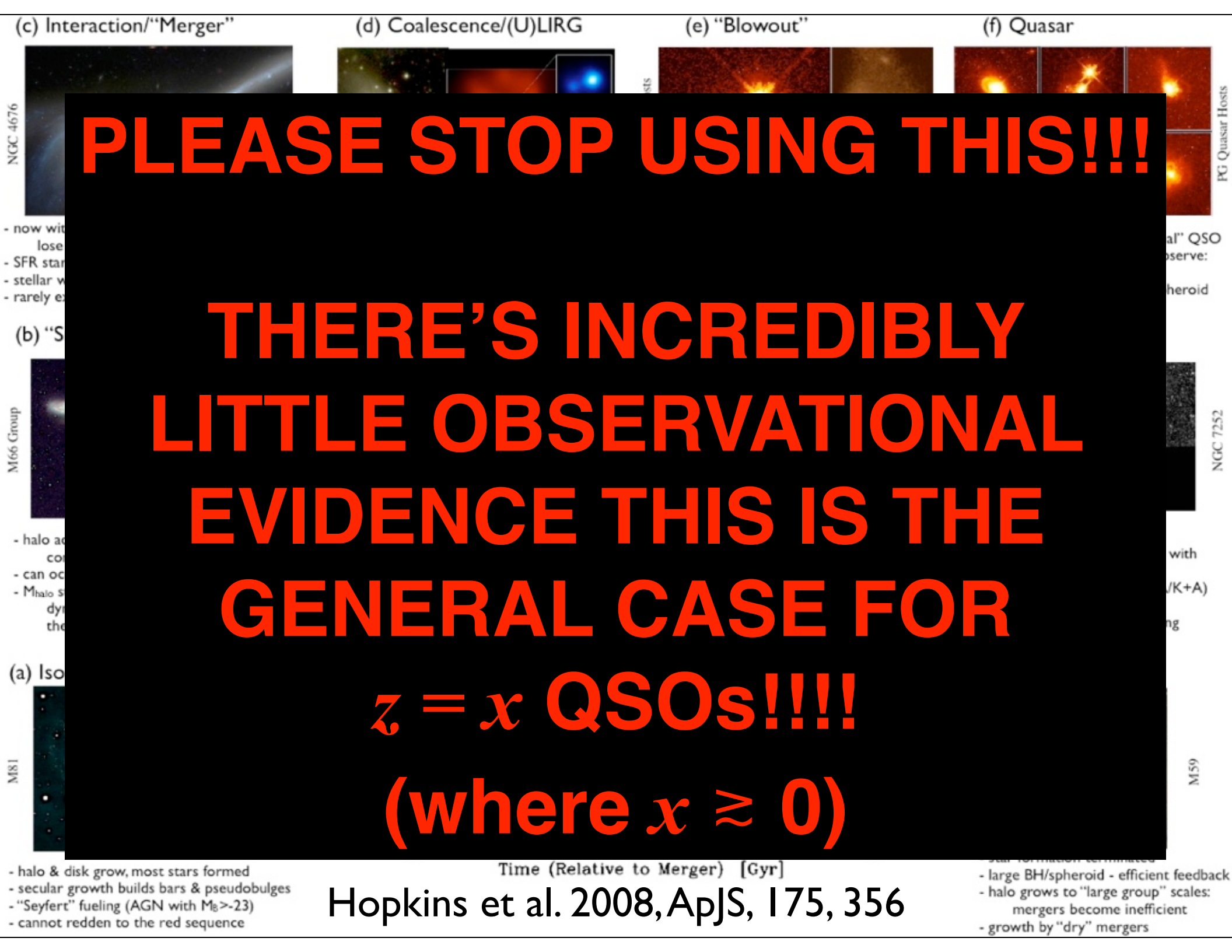
(h) "Dead" Elliptical



- star formation terminated
- large BH/spheroid - efficient feedback
- halo grows to "large group" scales: mergers become inefficient
- growth by "dry" mergers



Hopkins et al. 2008, ApJS, 175, 356



PLEASE STOP USING THIS!!!

THERE'S INCREDIBLY
LITTLE OBSERVATIONAL
EVIDENCE THIS IS THE
GENERAL CASE FOR

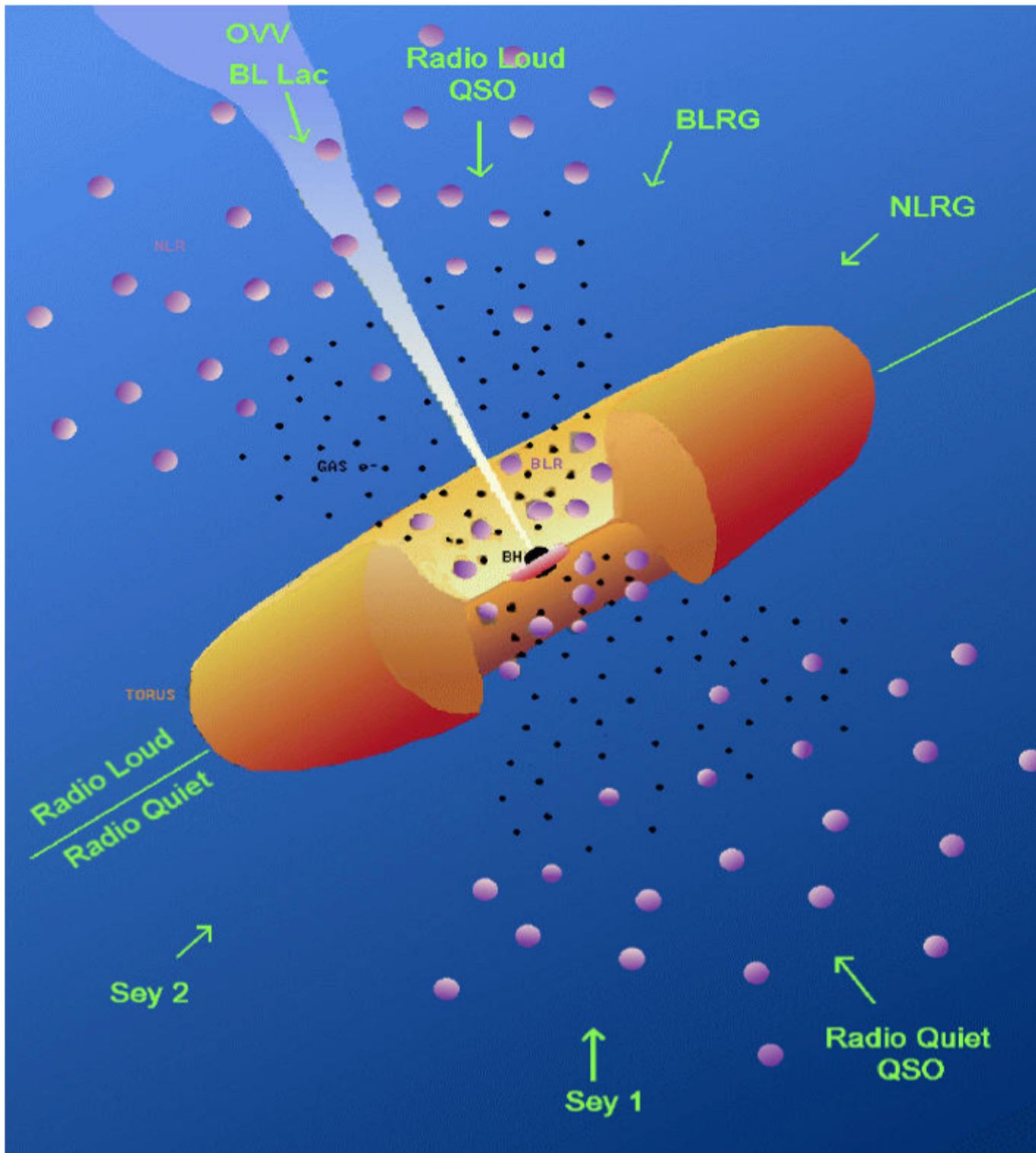
$z = x$ QSOs!!!!

(where $x \gtrsim 0$)

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”



The “AGN Unification Model”

**ALSO PLEASE THINK
BEFORE USING THIS!!!**

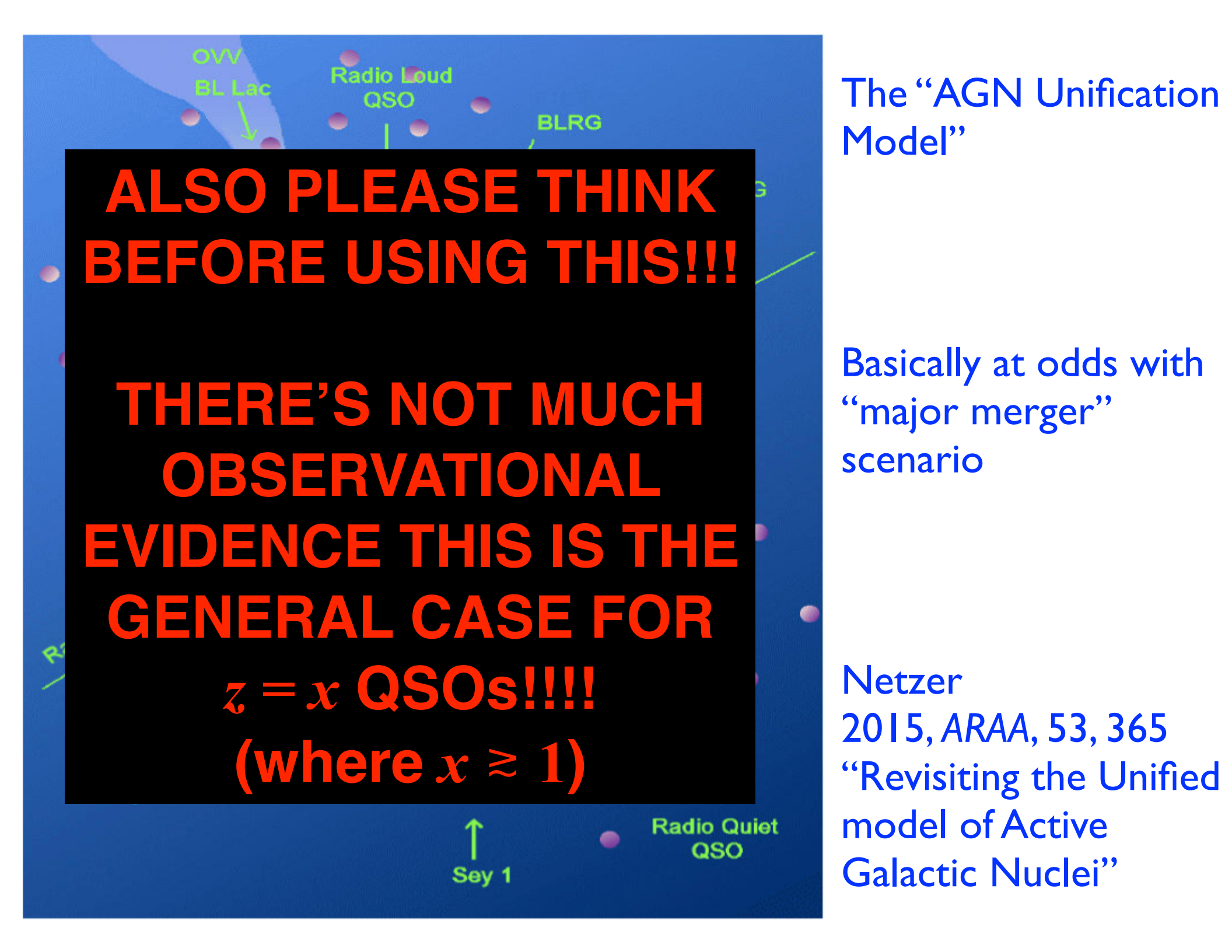
**THERE'S NOT MUCH
OBSERVATIONAL
EVIDENCE THIS IS THE
GENERAL CASE FOR**

$z = x$ QSOs!!!!

(where $x \gtrsim 1$)

↑
Sey 1

Radio Quiet
QSO

The background of the slide features a blue field with several purple dots representing galaxies. Labels in green text include 'OVV' and 'BL Lac' at the top left, 'Radio Loud QSO' at the top center, 'BLRG' at the top right, 'Sey 1' at the bottom center with an upward arrow, and 'Radio Quiet QSO' at the bottom right. A large black rectangle with orange text is centered on the slide.

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**$z = x$ QSOs!!!!
(where $x \gtrsim 1$)**

The “AGN Unification Model”

Basically at odds with
“major merger”
scenario

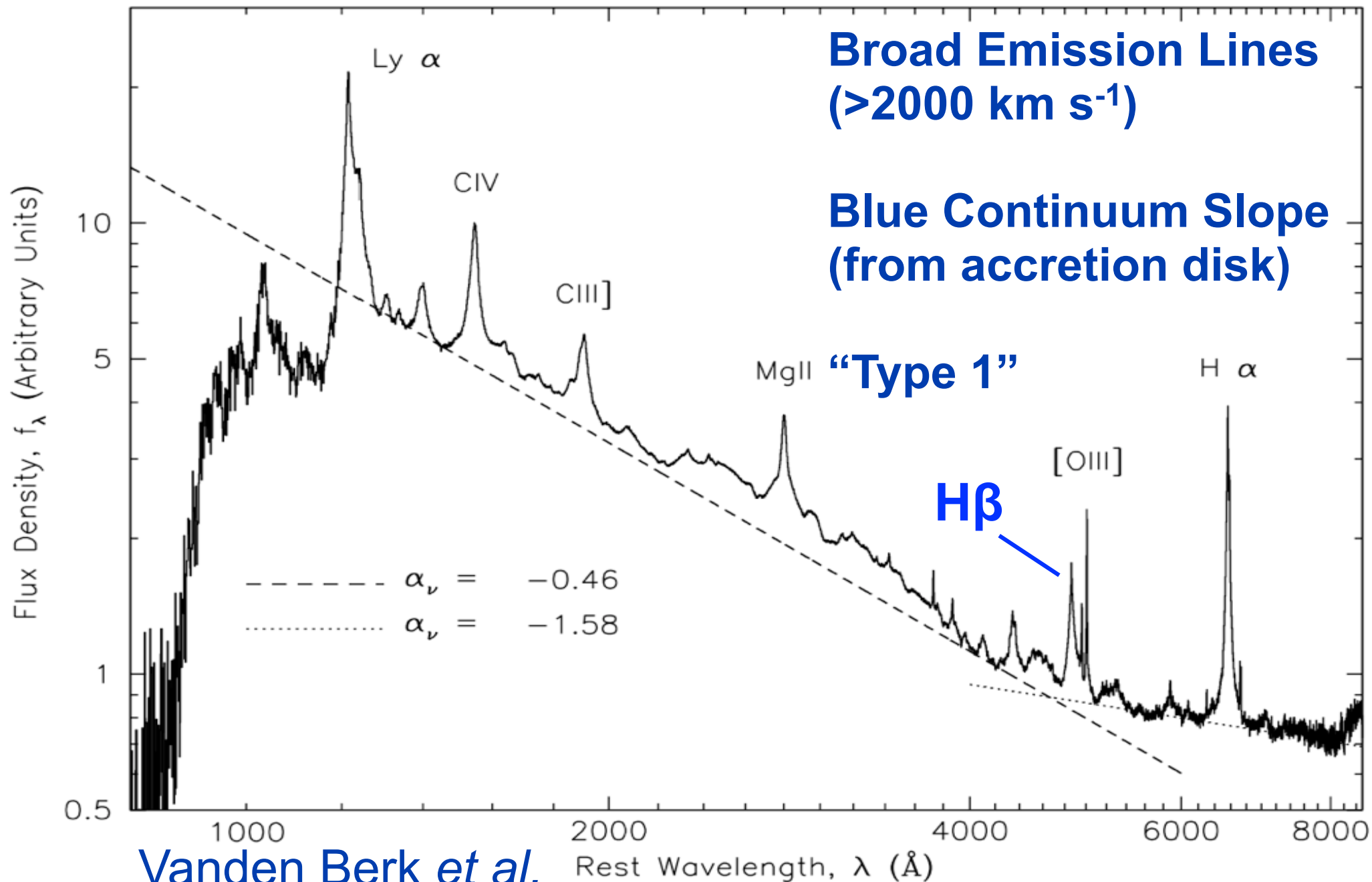
Netzer
2015, ARAA, 53, 365
“Revisiting the Unified
model of Active
Galactic Nuclei”

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 processes 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 ($z=0.0295$, $M_i \sim -21.7$ Tohlin & Osterbrock 1976)
- First Changing Look “Quasar”
 - SDSS J0159+0033 ($z=0.31$, $M_i = -22.7$ in SDSS Quasar catalog, $M_i < -22.0$; 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

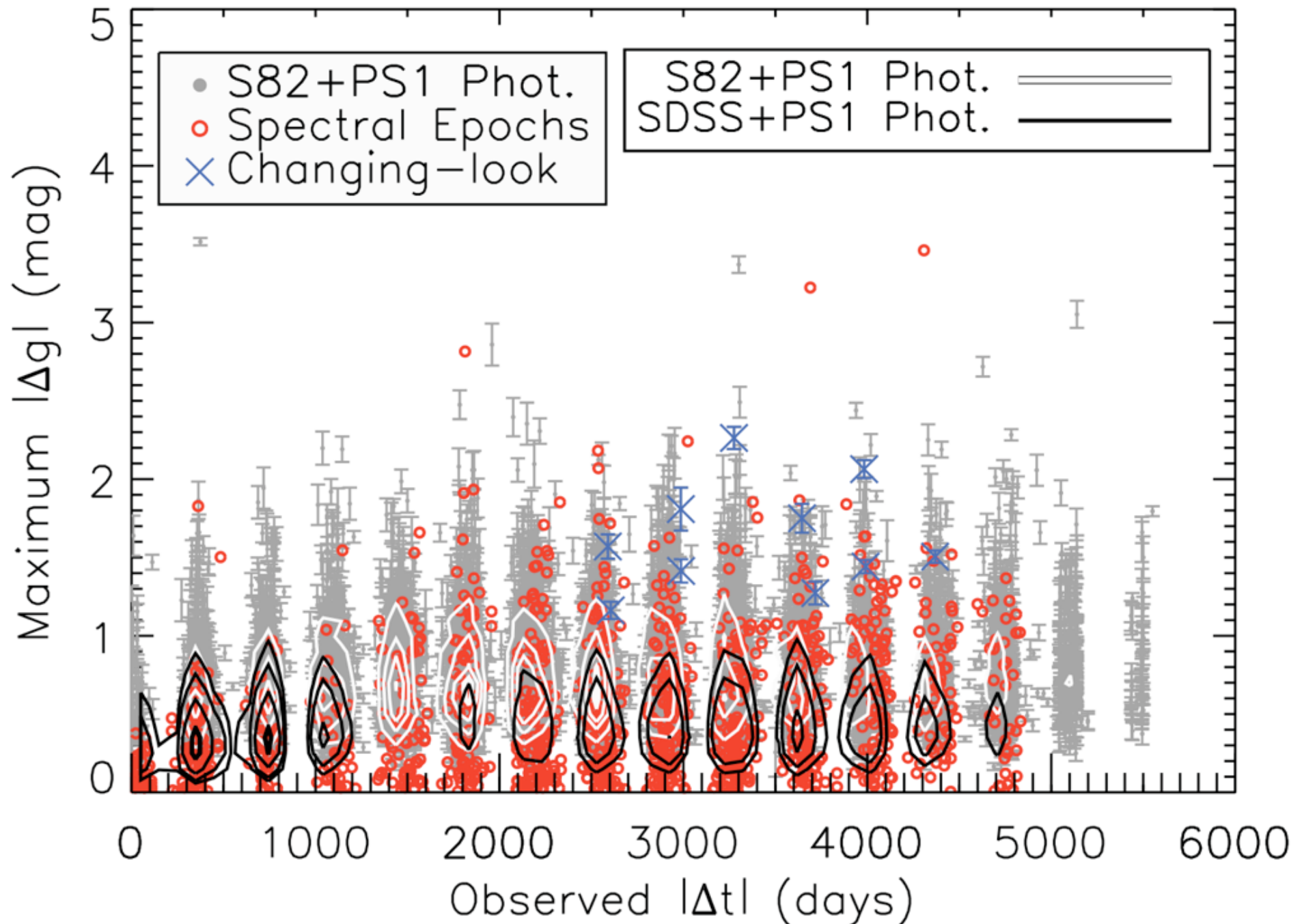
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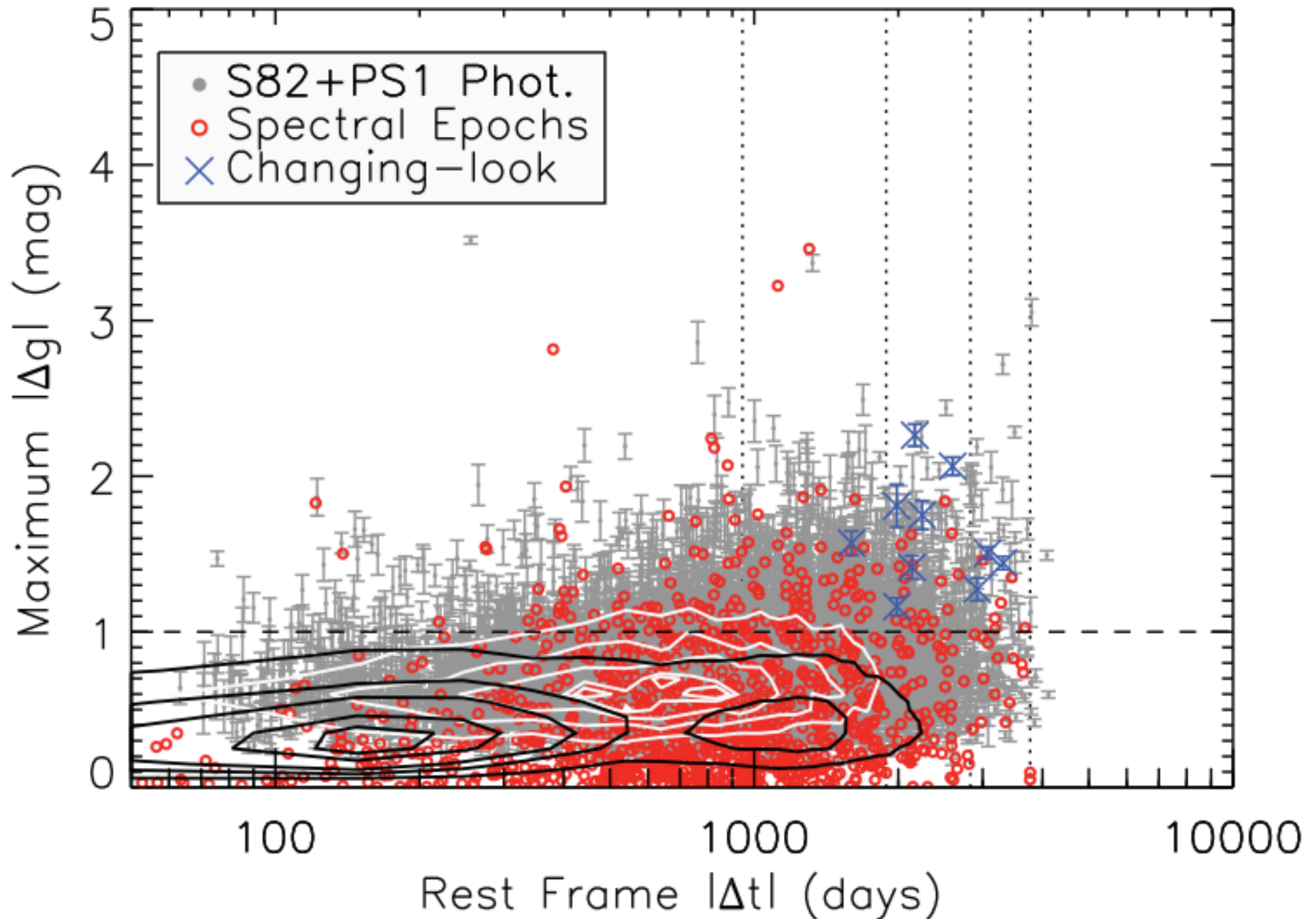
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- 6348 DR7Q objects have $|\Delta g| > 1.0$ mag
- We do not consider 3 blazars, radio sources with ~ 2 -3 mag changes over months; see e.g. Ruan et al. 2012.

Sample Selection of CLQ Candidates



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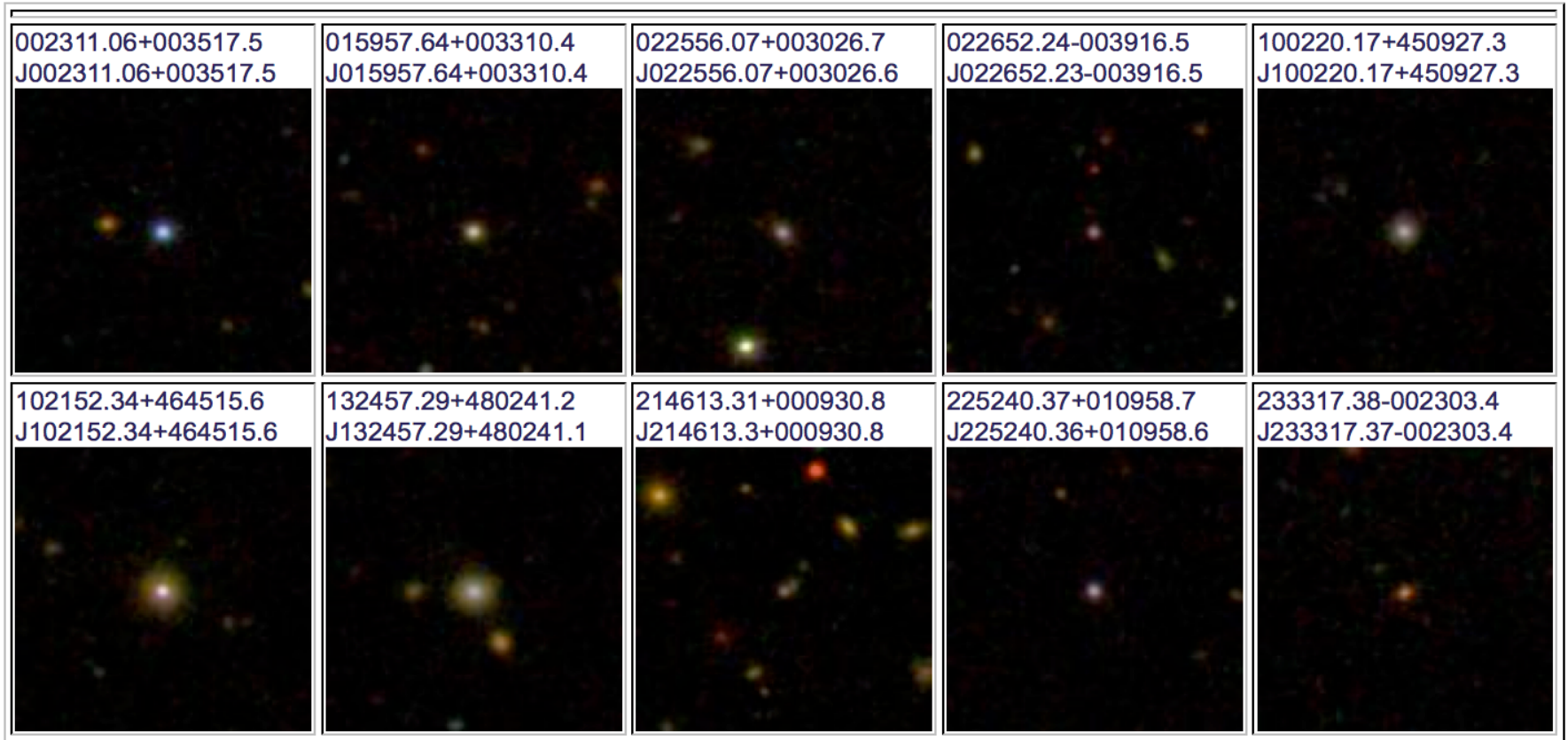
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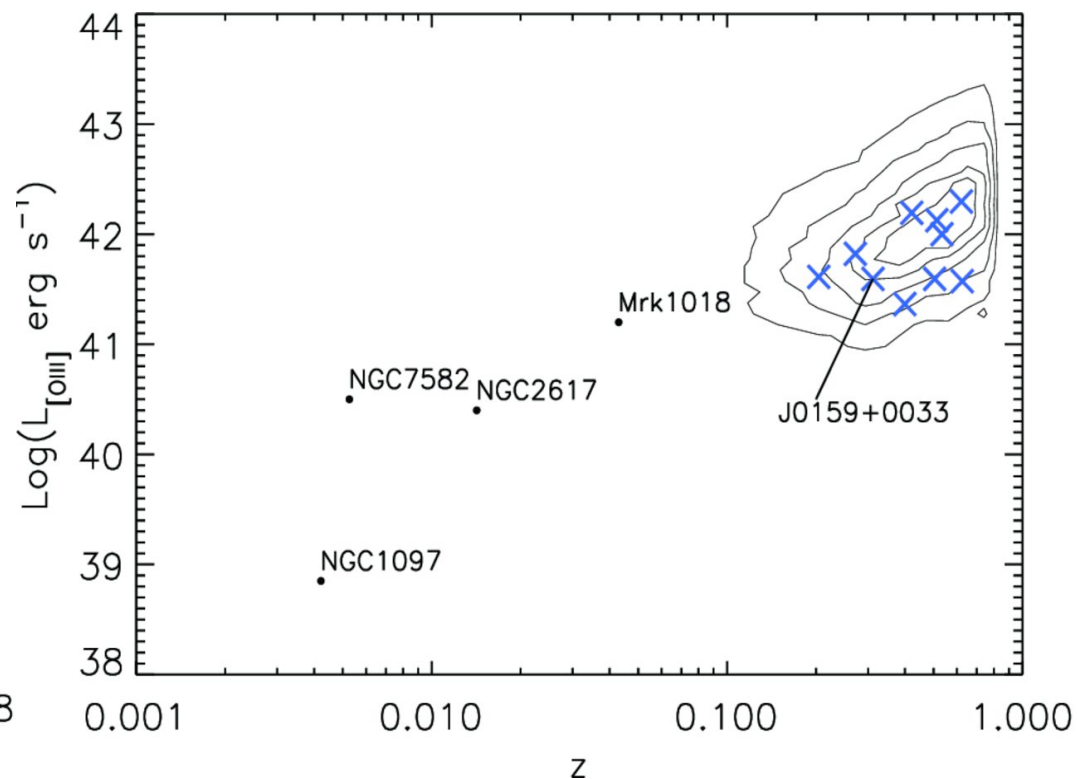
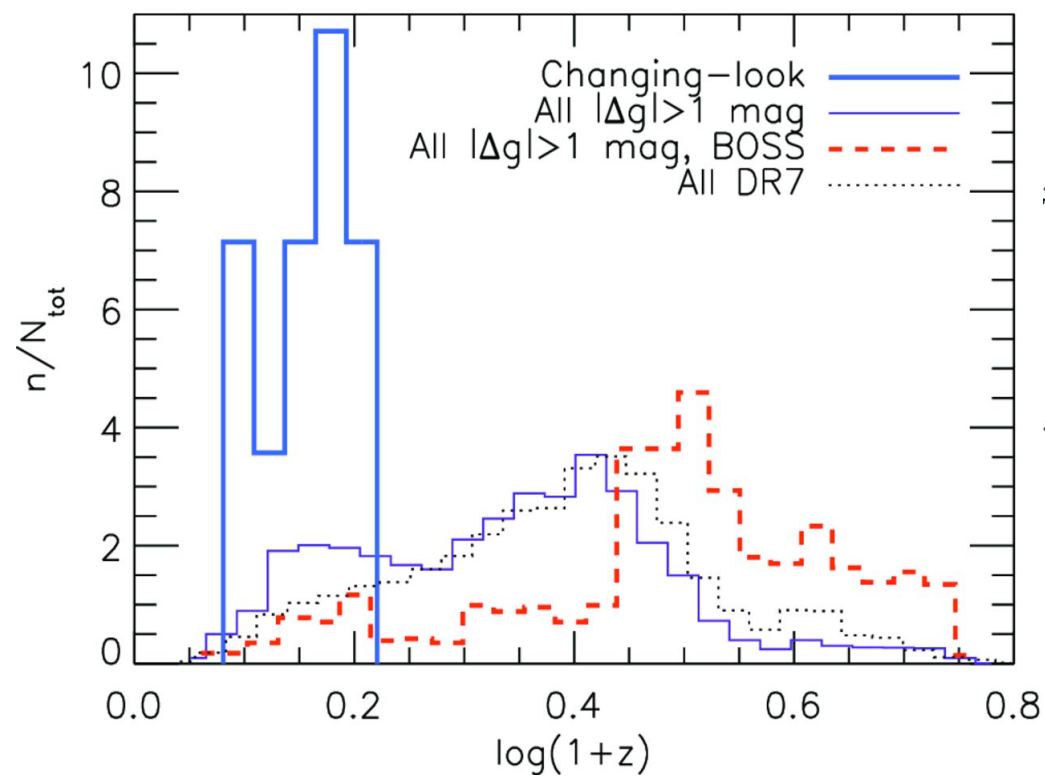
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Discovery of 10 CLQs

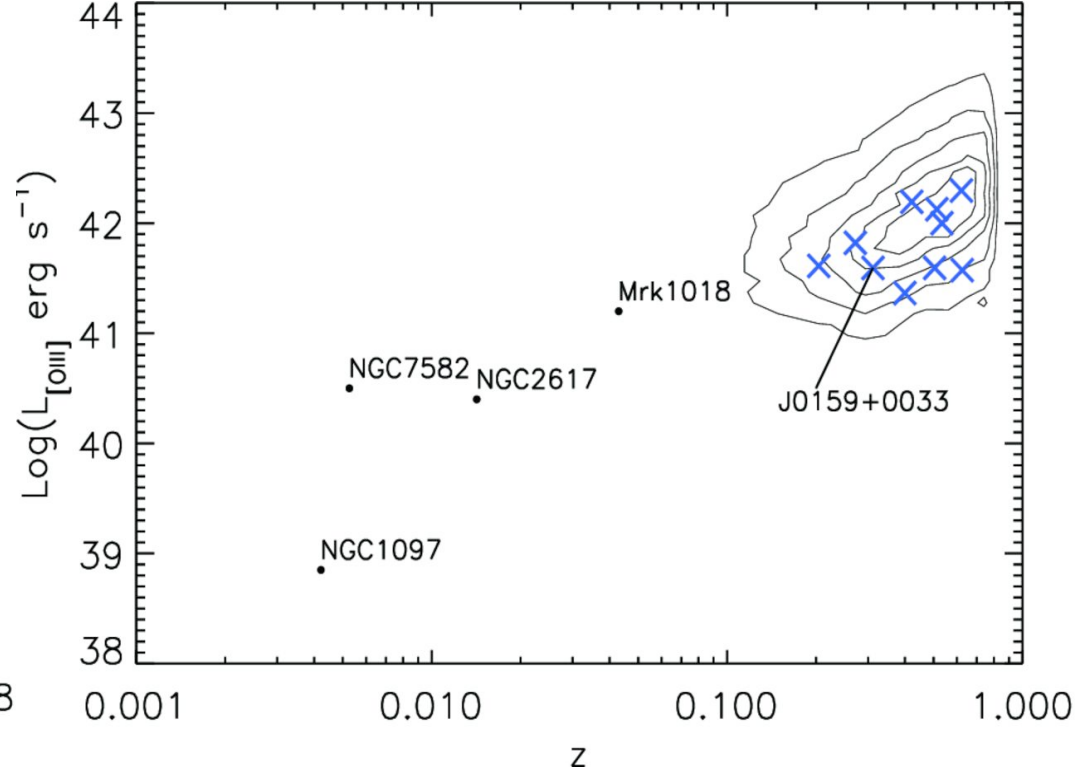
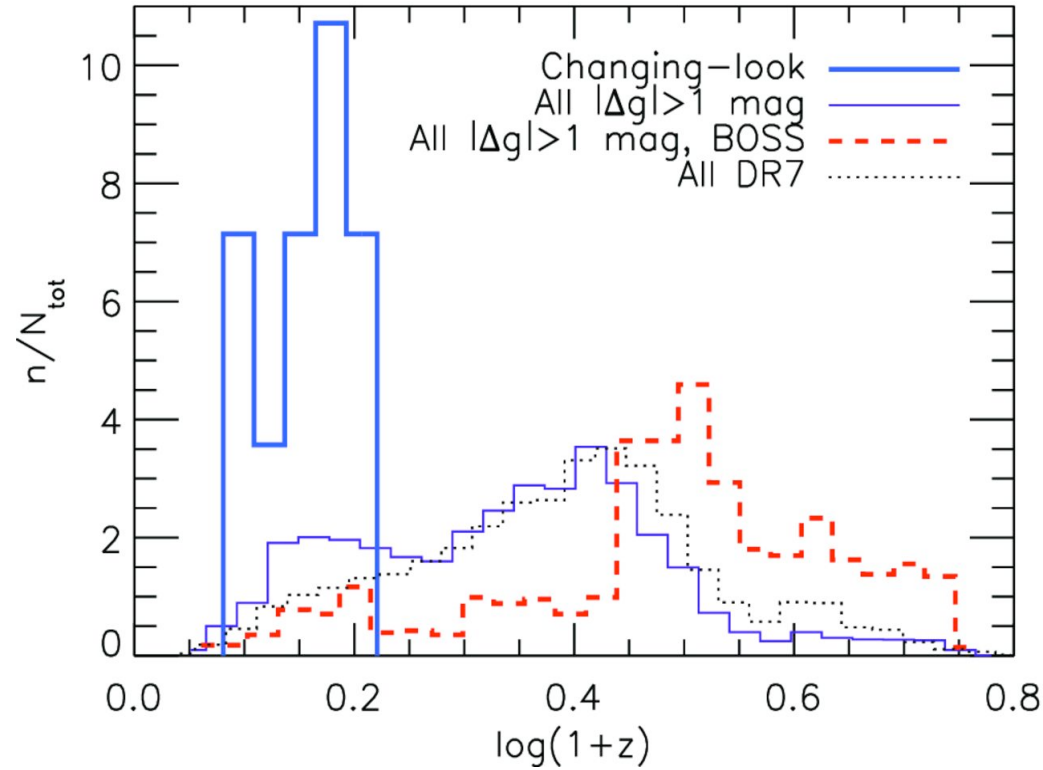
Name (SDSS J)	z	Max(Δg)	Δt_{RF} (d)	BEL behaviour	(MJD plate fibre) ₁	(MJD plate fibre) ₂	$ \Delta f_\nu \propto \nu^\beta$
002311.06+003517.5	0.422	-1.50 ± 0.04	3072	Appear	51816 0390 0564	55480 4219 0852	0.04 ± 0.02
015957.64+003310.4	0.312	1.16 ± 0.06	1985	Disappear	51871 0403 0549	55201 3609 0524	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



Redshift and Luminosity

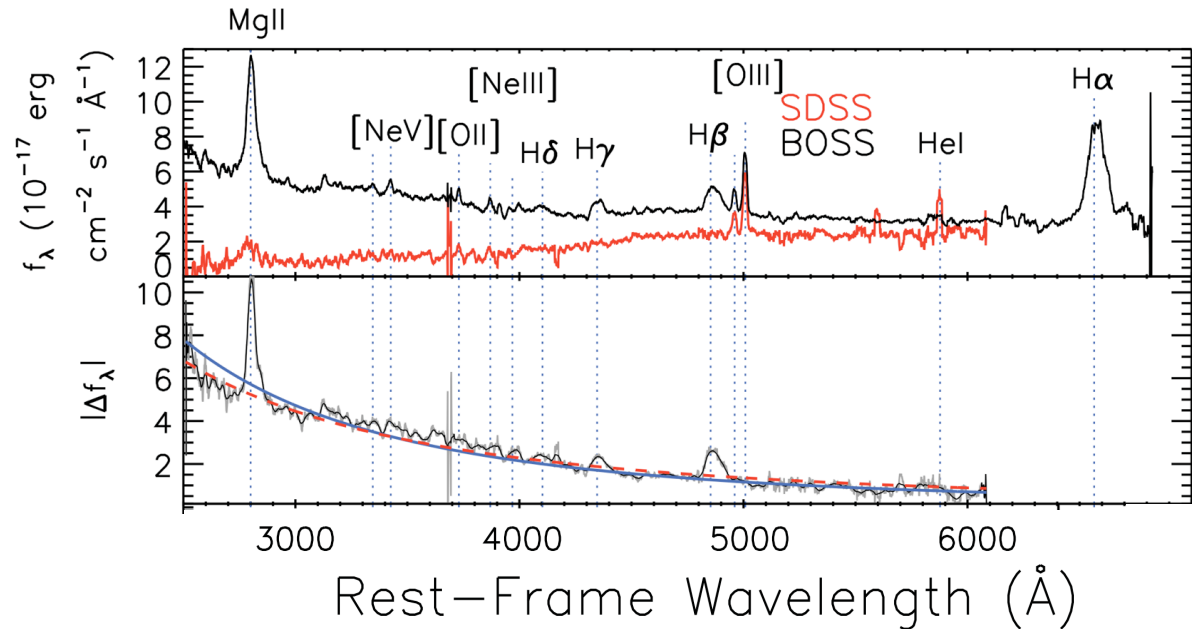
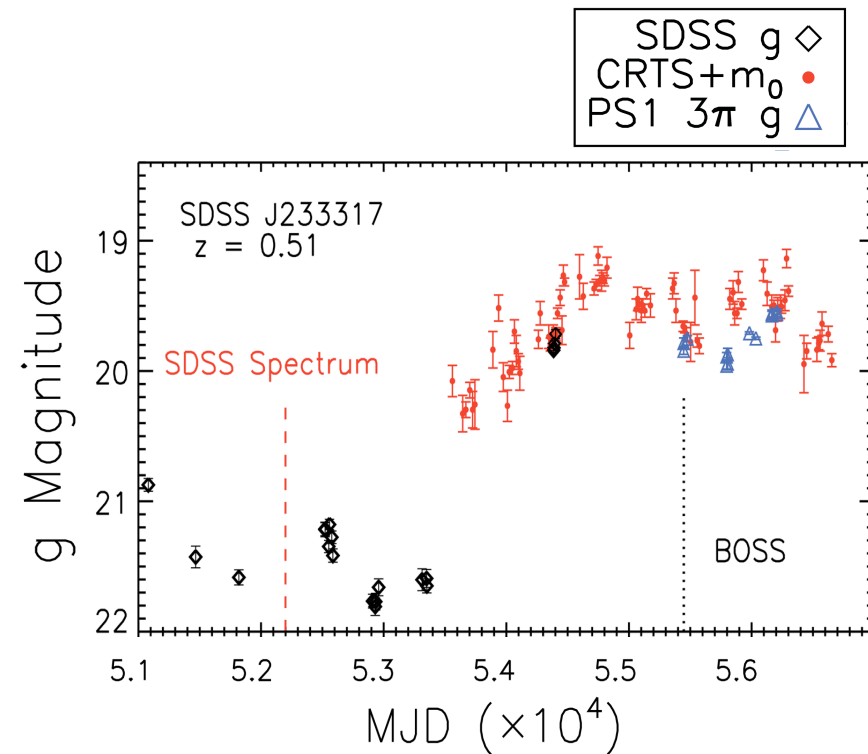


Name (SDSS J)	z	Max($ \Delta g $) (mag)	DR7 QSO?	Found here?
012648.08−083948.0 ^a	0.198	0.78 ± 0.03	×	×
015957.64+003310.4 ^b	0.312	1.16 ± 0.06	✓	✓
101152.98+544206.4 ^c	0.246	1.51 ± 0.02	✓	×
233602.98+001728.7 ^a	0.243	1.59 ± 0.13	×	×

Notes. ^aFound by Ruan et al. (2015). ^bFound by LaMassa et al. (2015).
^cFound by Runnoe et al. (2015).

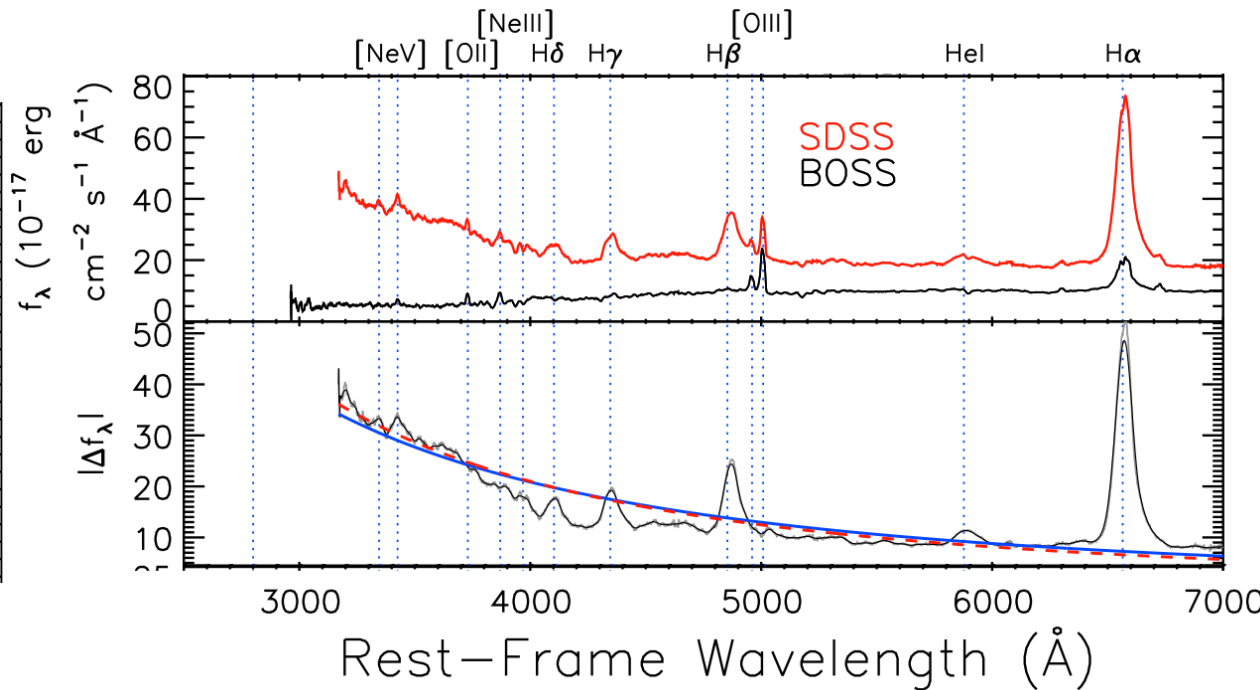
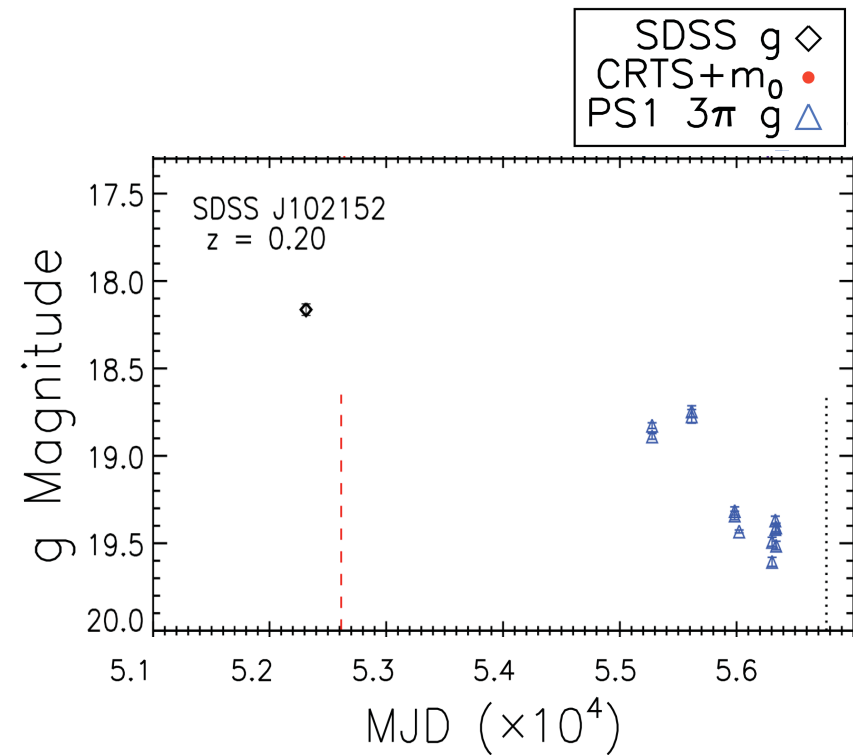
Results (1/5)

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



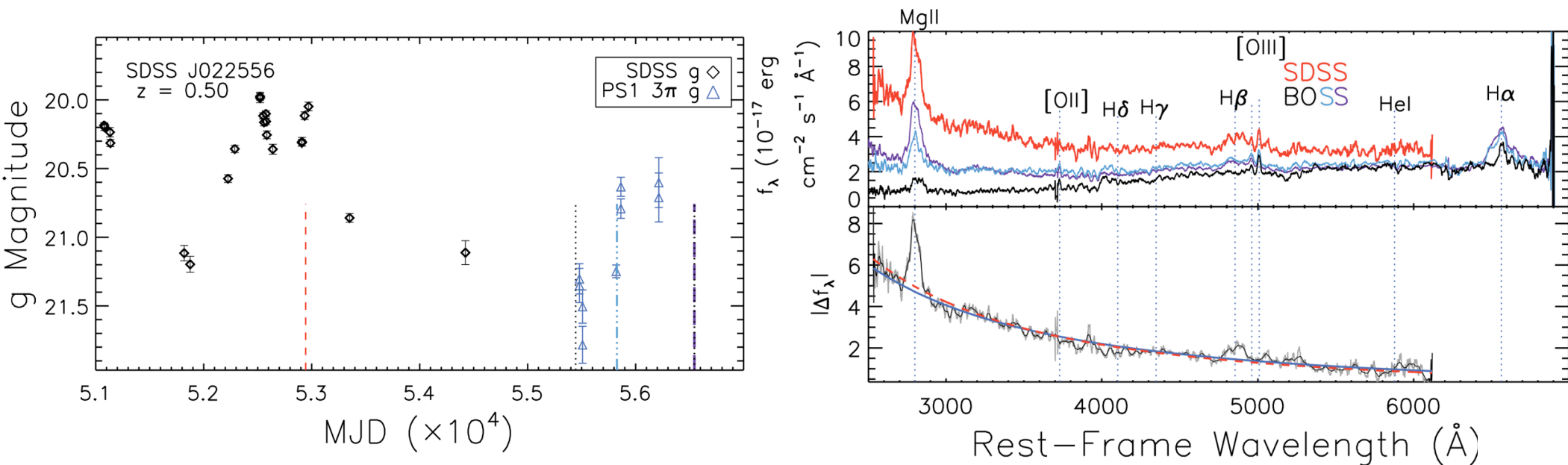
Results (2/5)

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



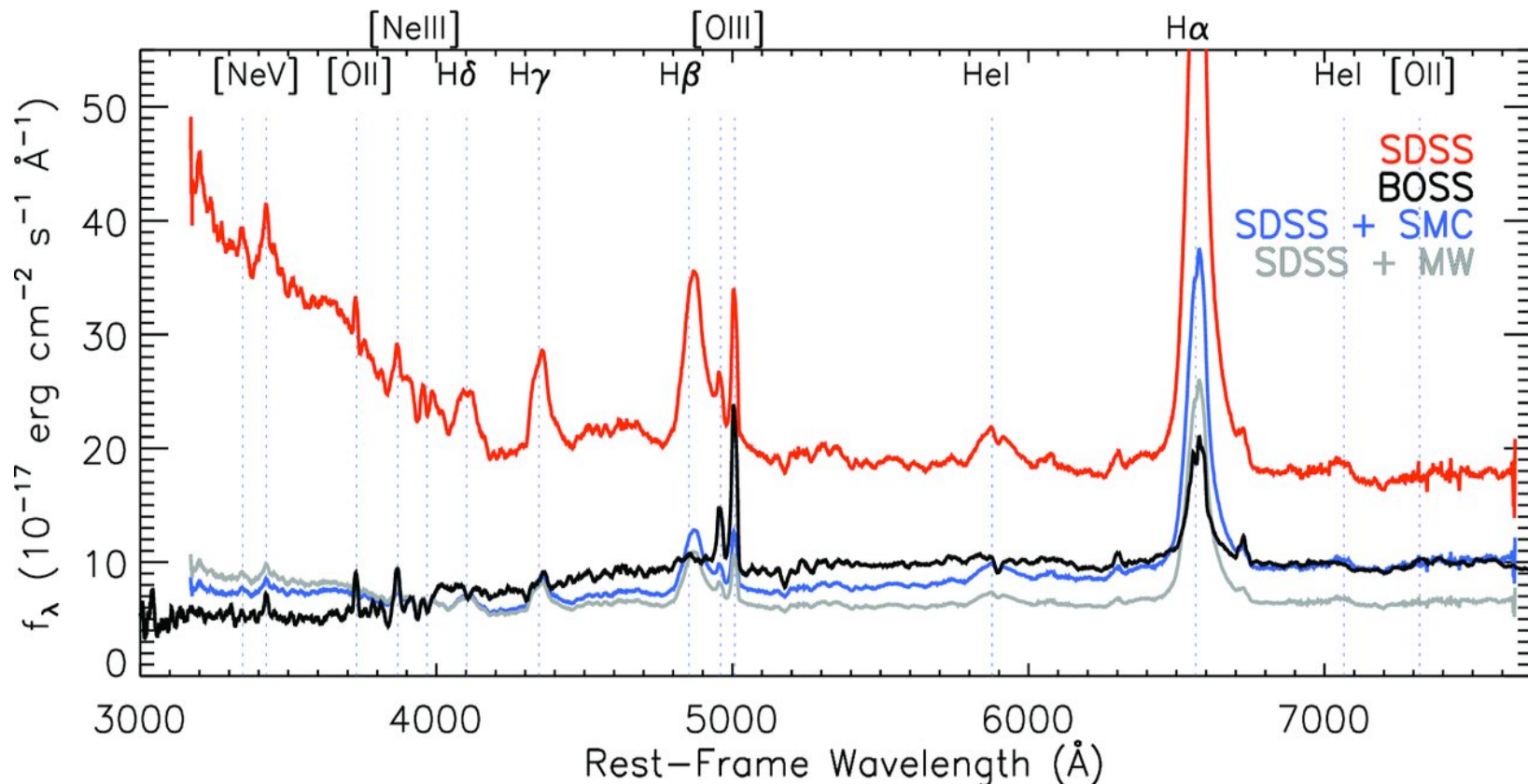
Results (3/5)

- 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



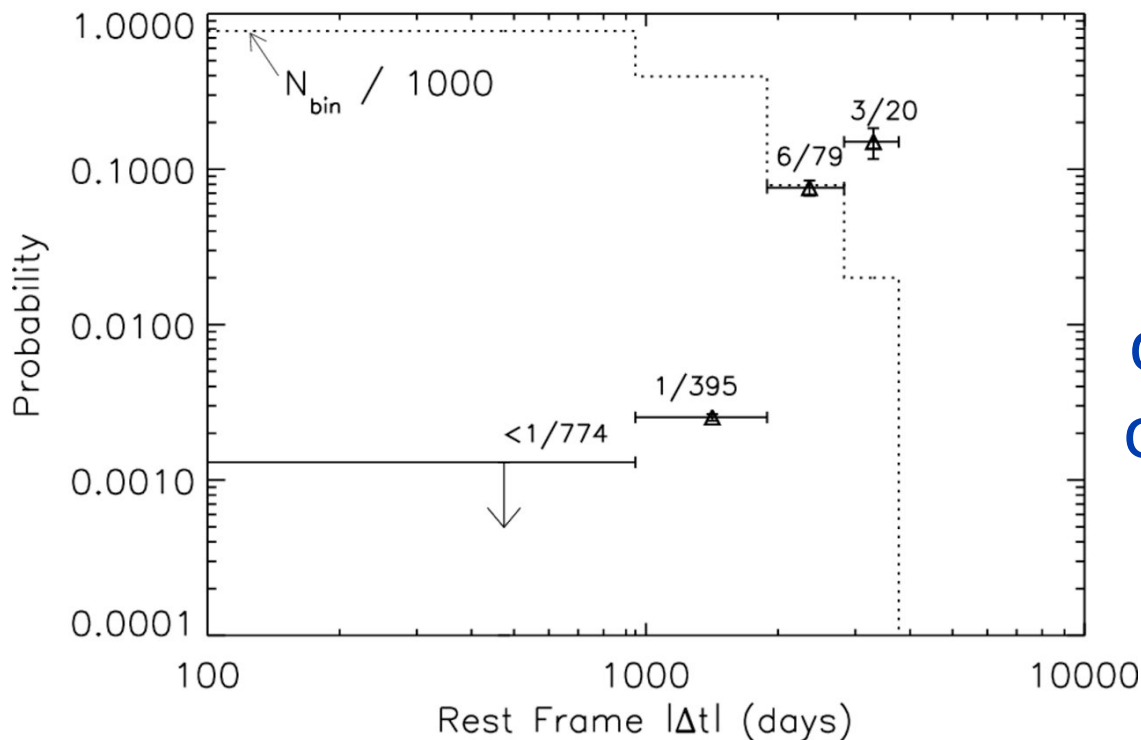
Results (4/5)

- 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 ($t_{\text{cross, dust}}$ 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... ;-)

