

Star-forming outflowing QSOs at $z \sim 2$: their status, future and environments

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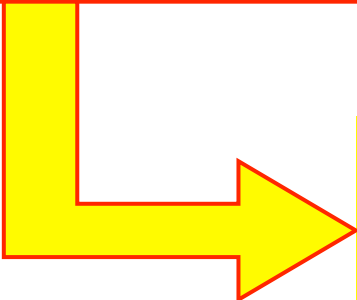


Outline

- Why bother?
- Our hard QSO sample
- Central QSOs:
 - Outflows
 - SEDs: correlations
- Environments:
 - Overdensities
 - Association: 1 proved, 3 coming, 1 to go
- Summary

Why bother?

- BH in centers of most local gals (Kormendy & Gebhardt, 2001)
- Correlation between mass of central BH and spheroid (Magorrian et al. 1998, McLure & Dunlop 2002)
- Similar evolution of X-ray AGN and optical galaxies (Silvermann et al. 2004)
- Most energy emitted by accretion in the Universe obscured (Fabian & Iwasawa 1999)
- Star formation in obscured environments

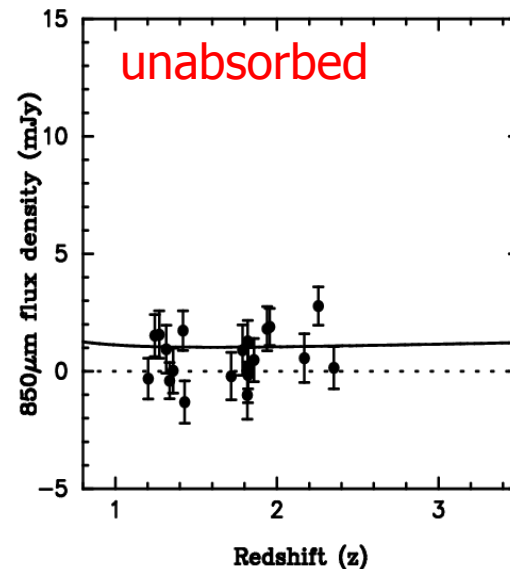
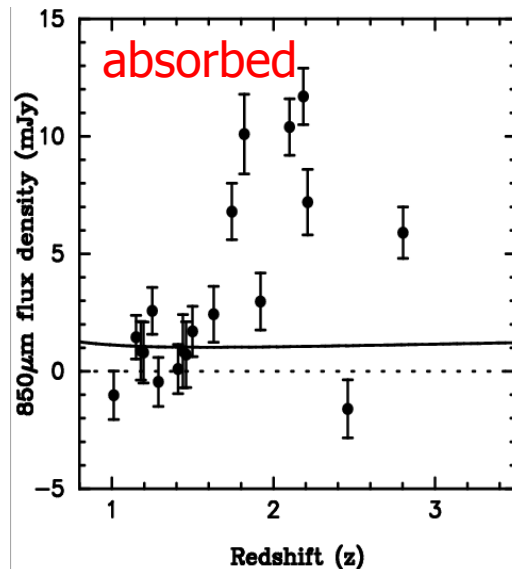


Connected growth of central BH through accretion, and spheroid through star formation. Obscuration is relevant

Our hard QSO sample

(Page+01,04, Stevens+04,05)

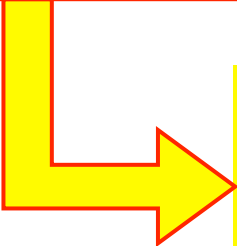
- Sample of (Broad Line) QSO1 with X-ray absorbed spectra
 - At z and L_X where most contribution to X-ray background
 - Matched sample of similar (L_X, z) unabsorbed QSO
- X-ray-absorbed QSO1 are ~ 10 -15% of QSO1 population
- Strong difference in submm fluxes:
 - Absorbed mostly bright, unabsorbed mostly faint
 - All submm detected are at $z > 1.5$
 - Submm much too bright to come from RQ AGN: strong star formation



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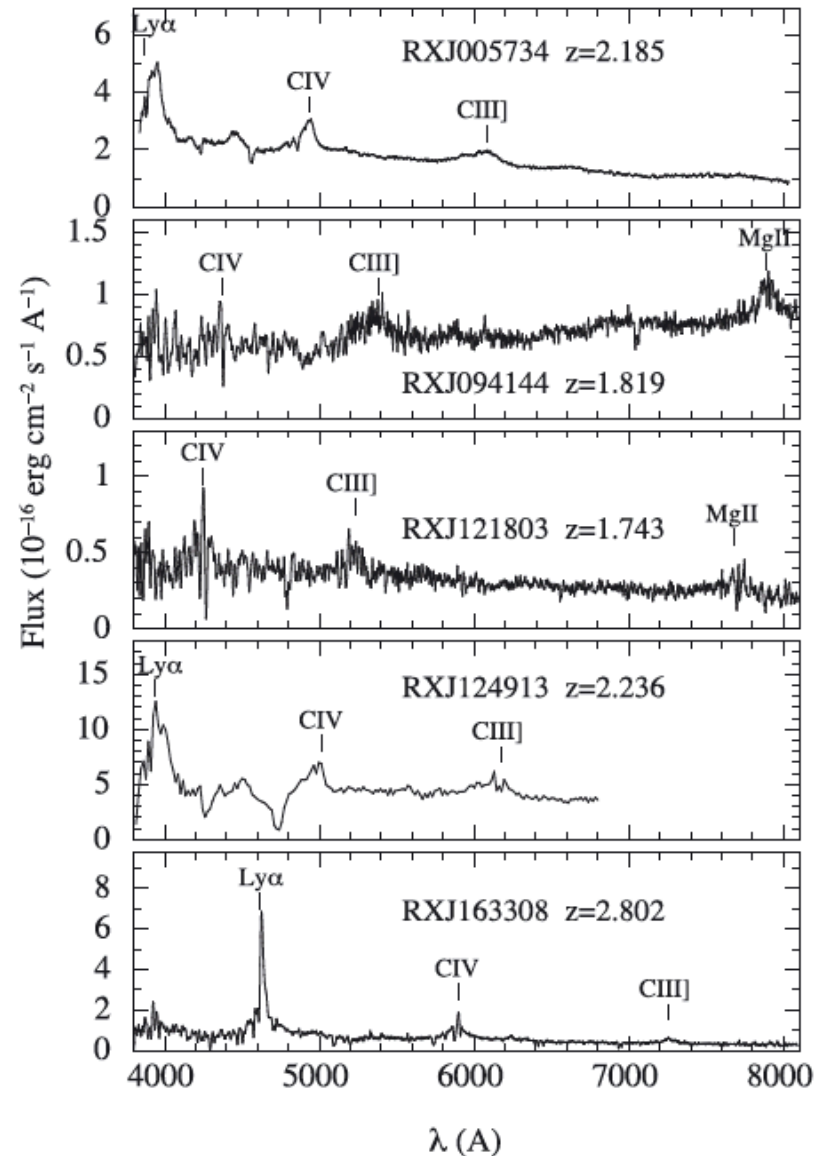


Simultaneous strong growth of BH and star formation
Stronger SF in the past
Transitory phase $\sim 10-15\%$ QSO life

Outflows

(Page+11)

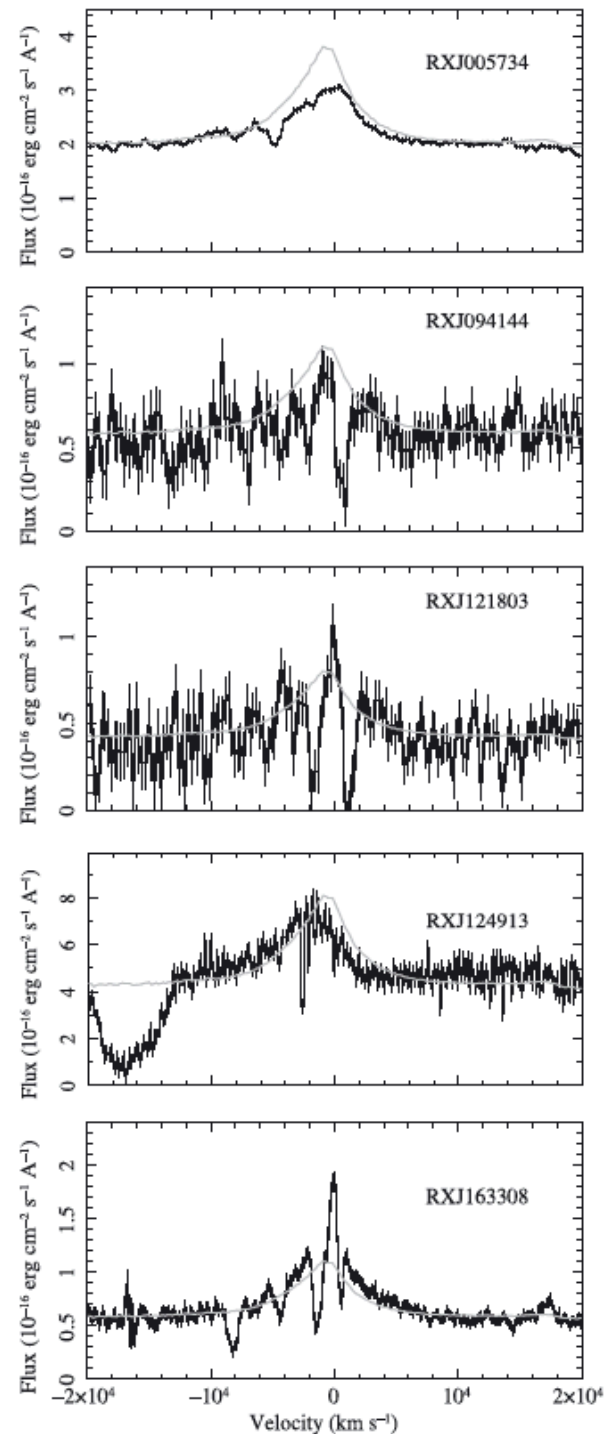
- One RL QSO dropped from submm-bright sample: 5 remaining
- Broad band XMM spectra: confirmed X-ray absorption
- Only physical explanation for their absorbed X-ray spectra but opt. QSO 1 nature is **ionized absorption** (no dust in gas)
- All QSO show $EW > 5\text{\AA}$ abs. in their rest-frame UV spectra
- $\sim 4\%$ of radiative power into kinetic luminosity of outflows
 - \sim kinetic feedback to produce $M-\sigma$



Outflows

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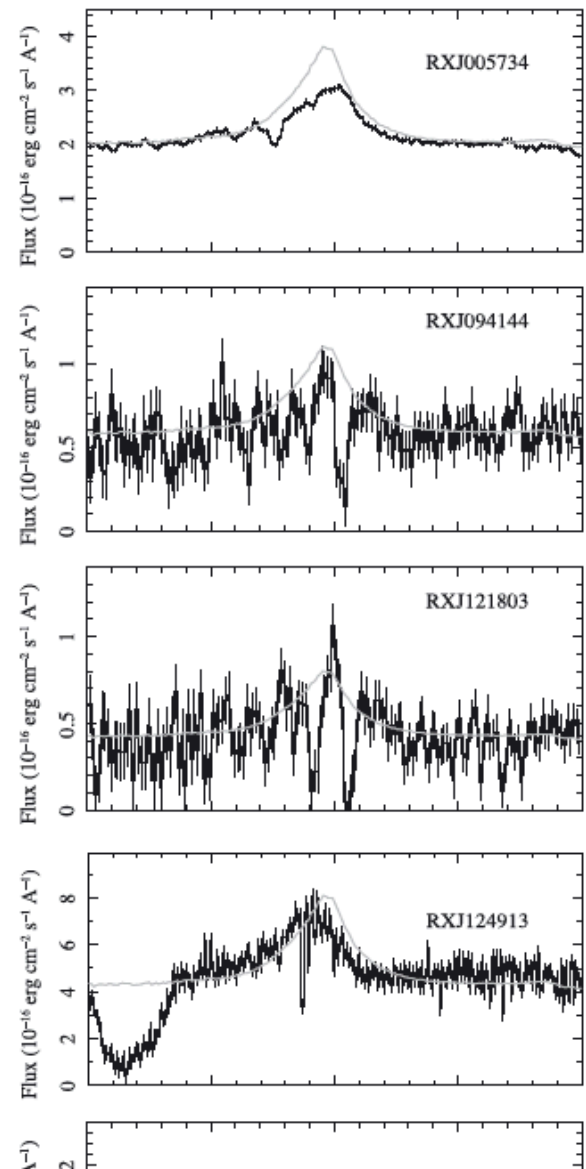
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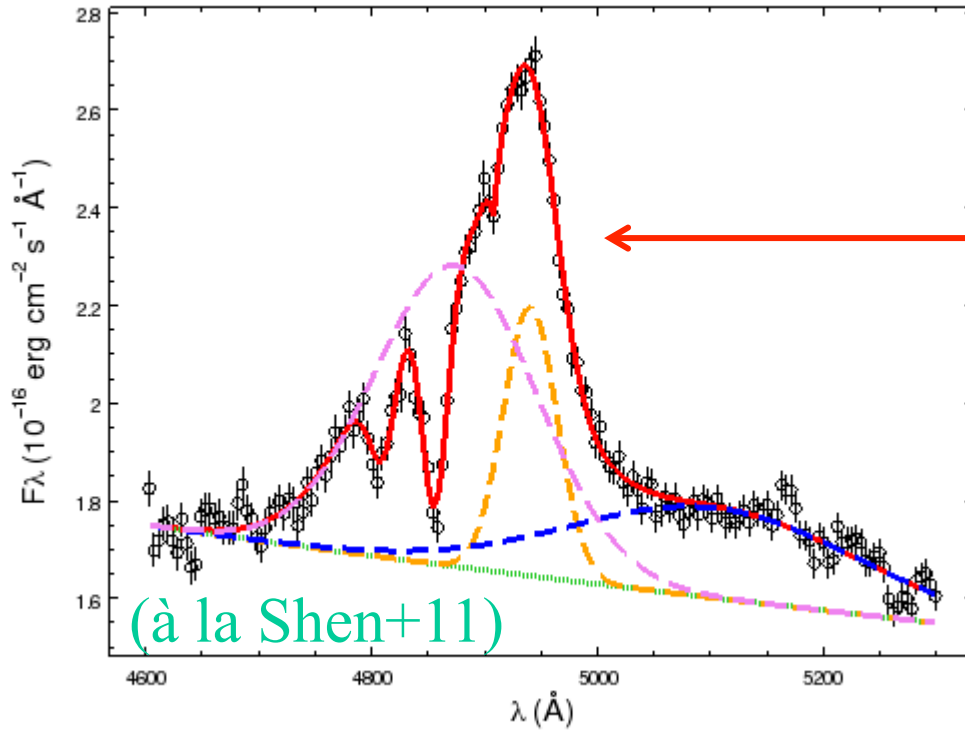
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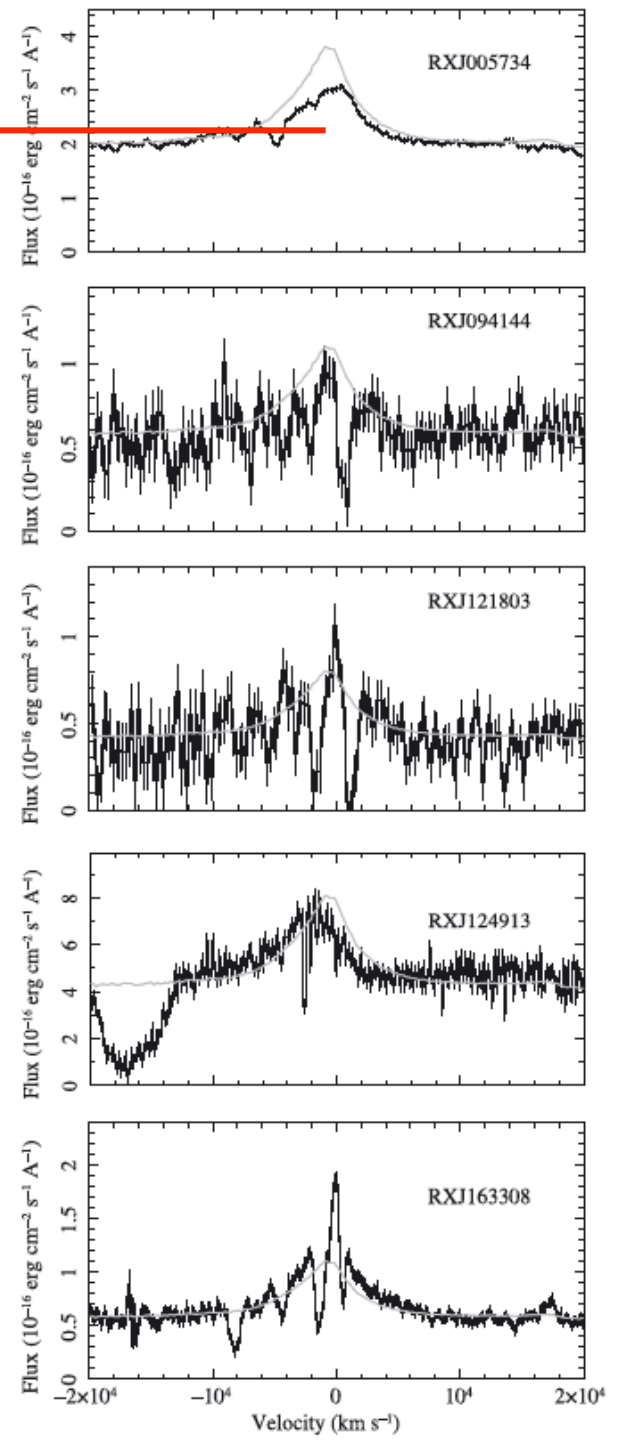


Consistent with hypothesis that X-ray absorbed QSOs represent transition phase between obscured accretion and luminous QSO phase

BH masses (Khan-Ali+15)



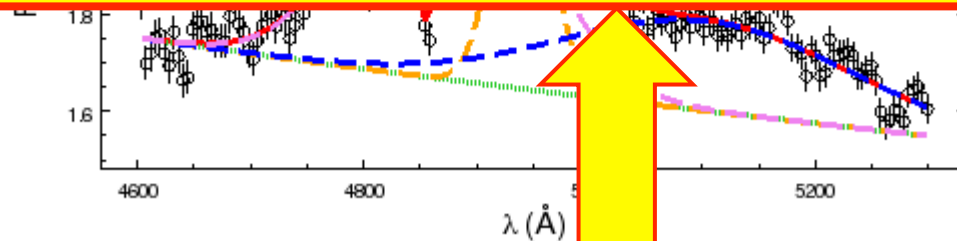
- RXJ 0057 $\rightarrow \log(M_{\text{BH}}) = 9.90 \log(M_{\text{SUN}})$
- RXJ 0941 $\rightarrow \log(M_{\text{BH}}) = 9.77 \log(M_{\text{SUN}})$
- RXJ 1218 $\rightarrow \log(M_{\text{BH}}) = 9.28 \log(M_{\text{SUN}})$
- RXJ 1249 $\rightarrow \log(M_{\text{BH}}) = 9.99 \log(M_{\text{SUN}})$
- RXJ 1633 $\rightarrow \log(M_{\text{BH}}) = 8.73 \log(M_{\text{SUN}})$



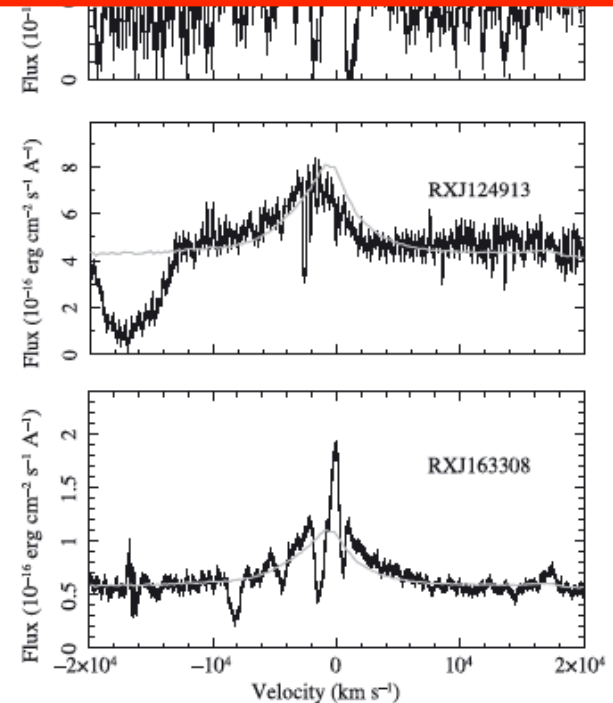
Super Massive Black Holes: $10^9 - 10^{10} M_{\odot}$

close to
Black Hole maximum mass known:

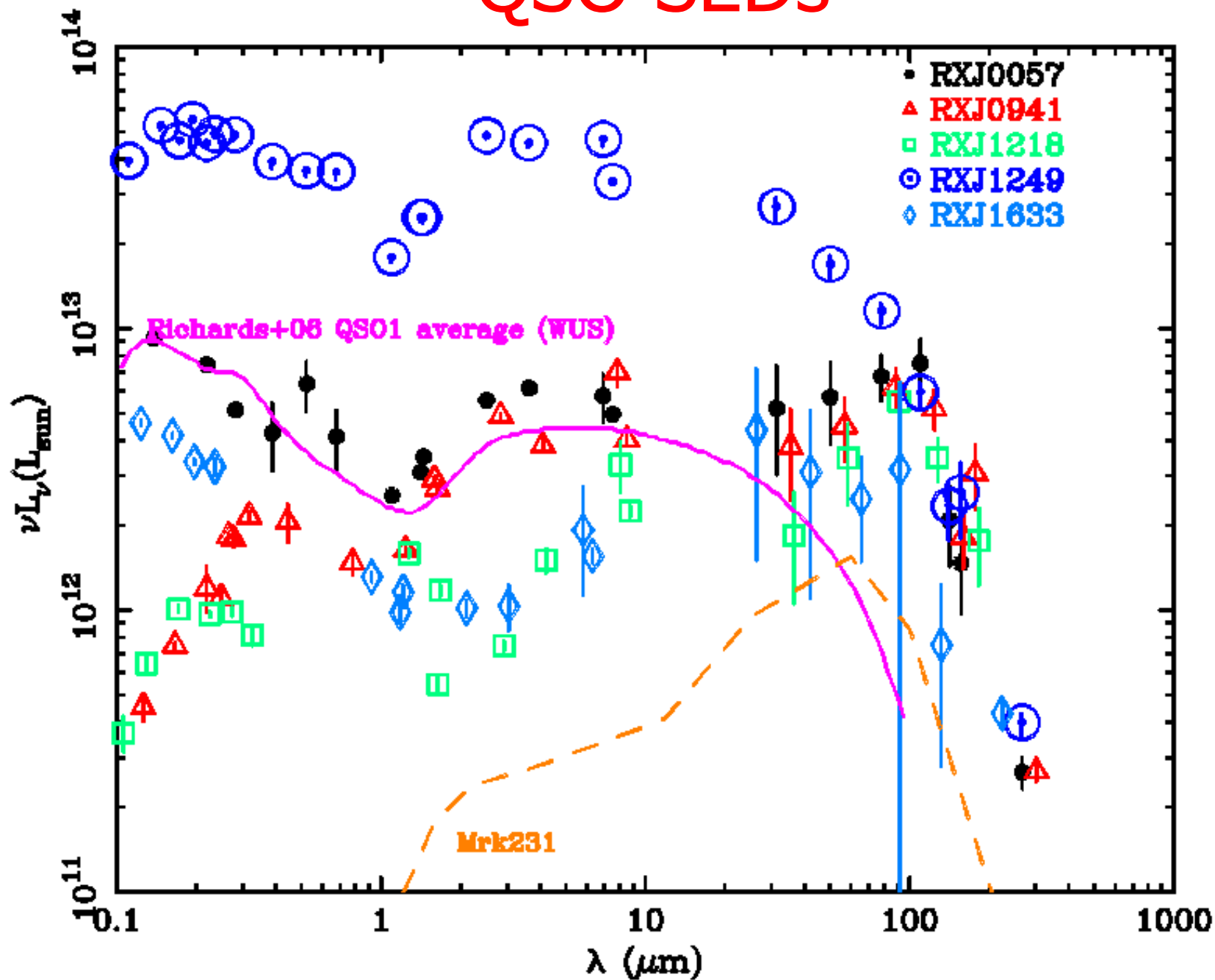
$$M_{\text{BH,max}} = 2 \times 10^{10} M_{\odot}$$



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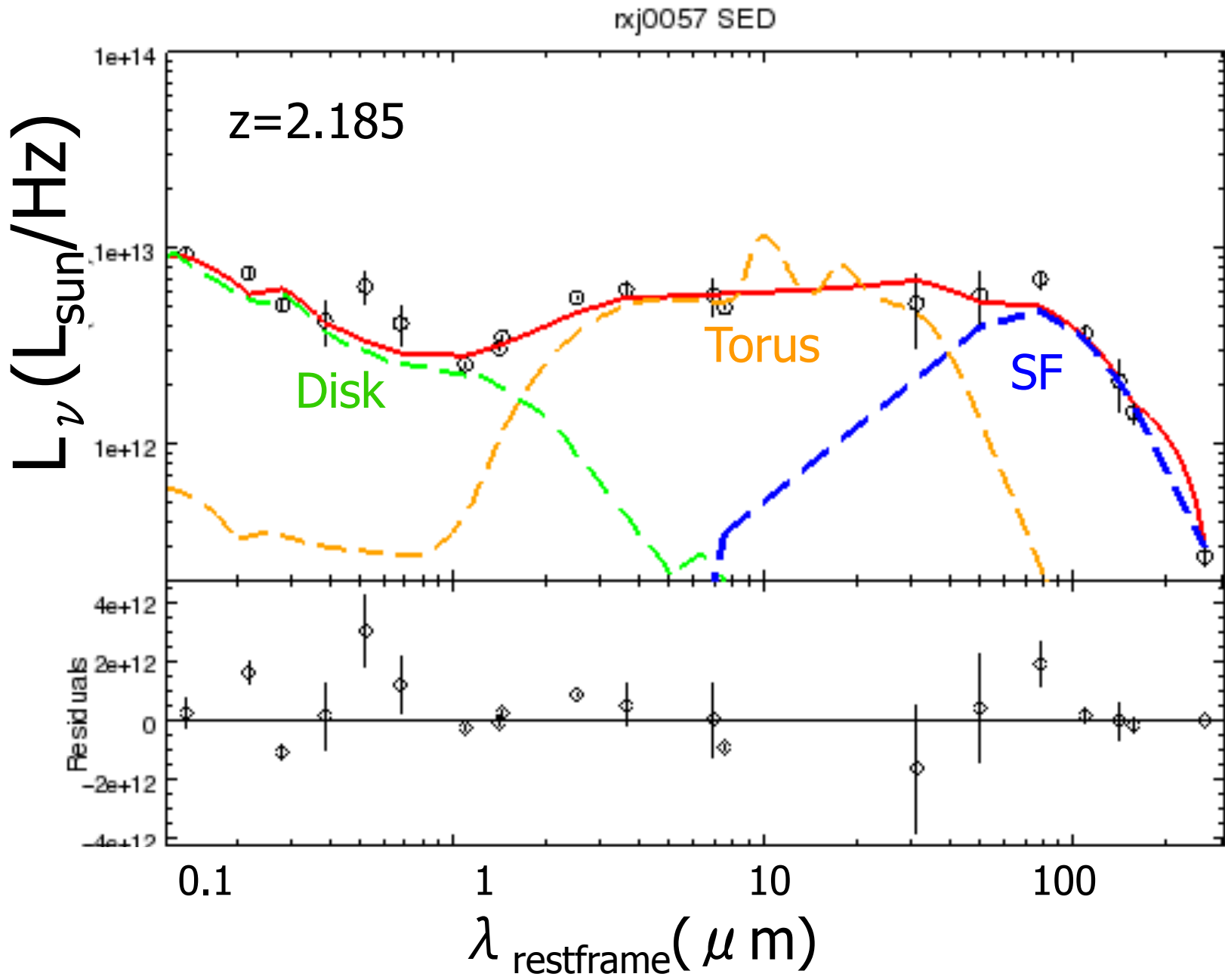
QSO SEDs



QSO SEDs

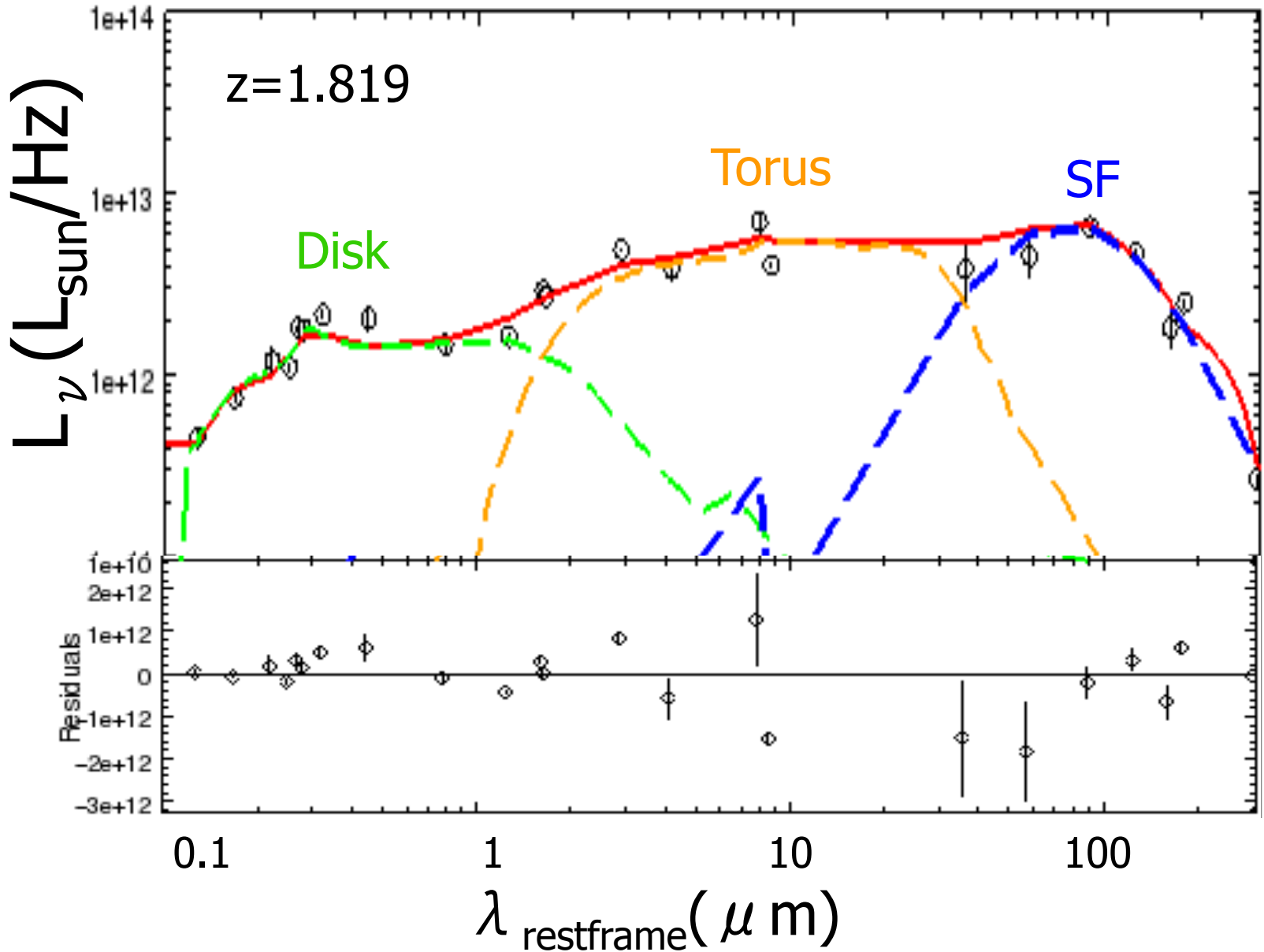
- Fit to 0.1215-330 μm rest-frame L_{ν}
 - Spitzer/WISE photometry in MIR and PACS/SPIRE in FIR
 - Disk component: Rowan-Robinson+08 SWIRE newagn4
 - Absorbed by intervening material (host galaxy)
 - Two parameters: A_{Vr} , integrated 0.5-250 μm luminosity L_{disk}
 - Torus component: Roseboom+12, Nenkova+08:
 - $\tau_V=20$, $\sigma=45$, $q=2$, $Y=10$, $N_0=3$, $i=20^\circ$
 - Single parameter: integrated 1-300 μm luminosity L_{tor}
 - Also tried Rowan-Robinson+08 SWIRE dusttor
 - SF component: Siebenmorgen & Krügel'07
 - Single parameter: L_{FIR} (\Rightarrow SFR)

RXJ0057: $L_{\text{Disk}} = 1.25 \times 10^{13} L_{\text{sun}}$ $L_{\text{Torus}} = 1.90 \times 10^{13} L_{\text{sun}}$ $L_{\text{FIR}} = 4.9 \times 10^{12} L_{\text{sun}}$



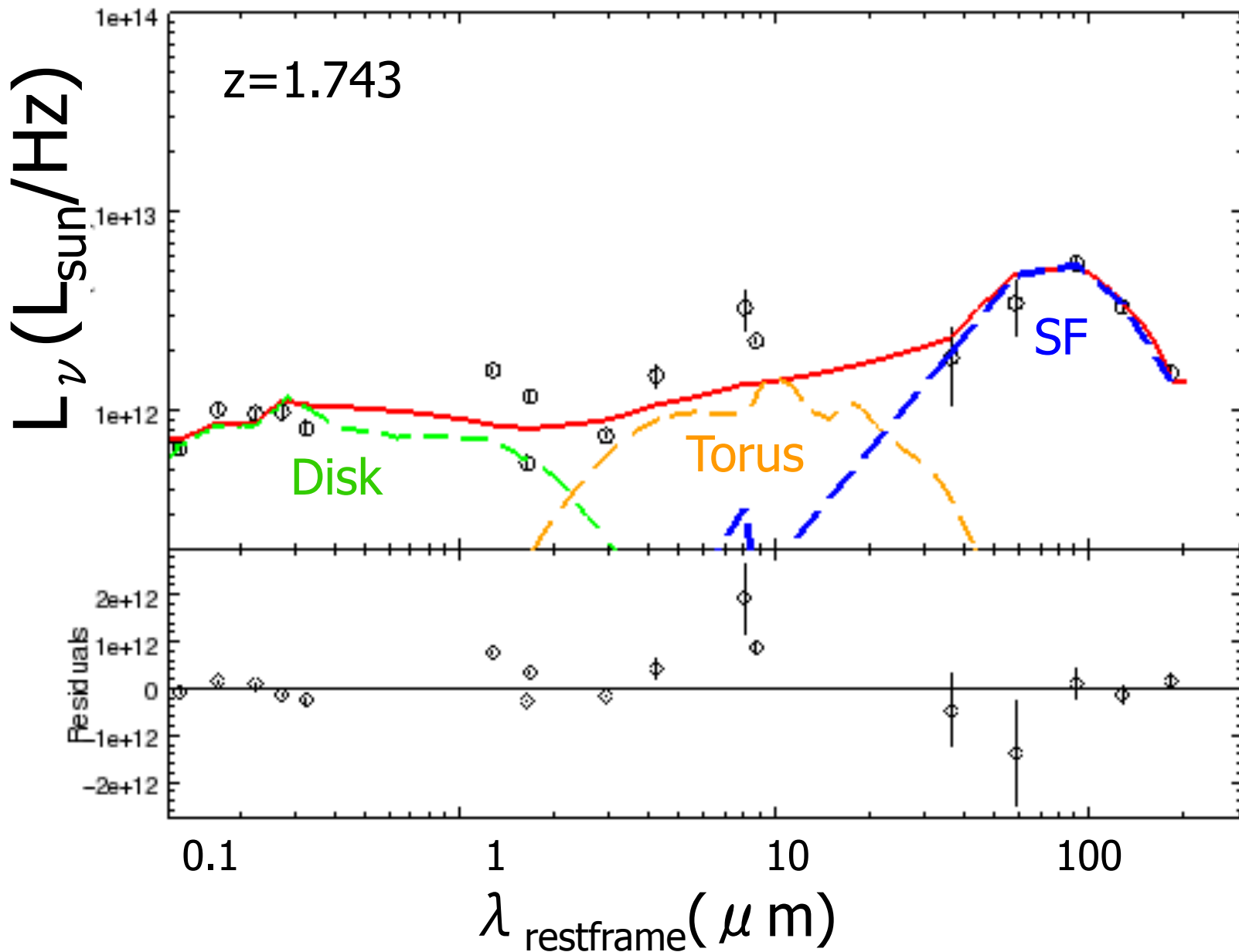
RXJ0941: $L_{\text{Disk}}=1.00\times 10^{13}L_{\text{sun}}$ $L_{\text{Torus}}=1.50\times 10^{13}L_{\text{sun}}$ $L_{\text{FIR}}=7.8\times 10^{12}L_{\text{sun}}$

rxj0941 SED

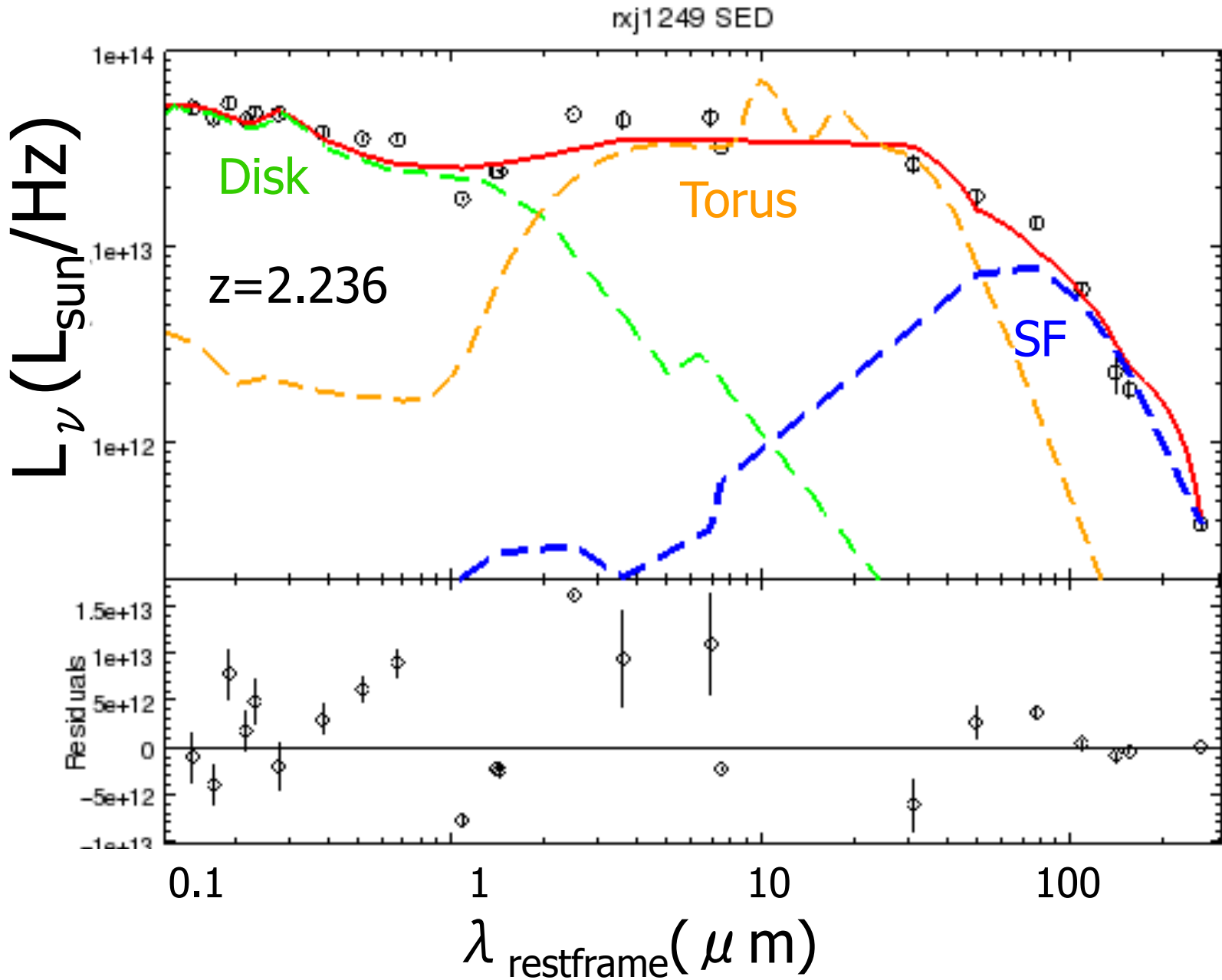


RXJ1218: $L_{\text{Disk}}=4.2\times 10^{12}L_{\text{sun}}$ $L_{\text{Torus}}=2.5\times 10^{12}L_{\text{sun}}$ $L_{\text{FIR}}=6.3\times 10^{12}L_{\text{sun}}$

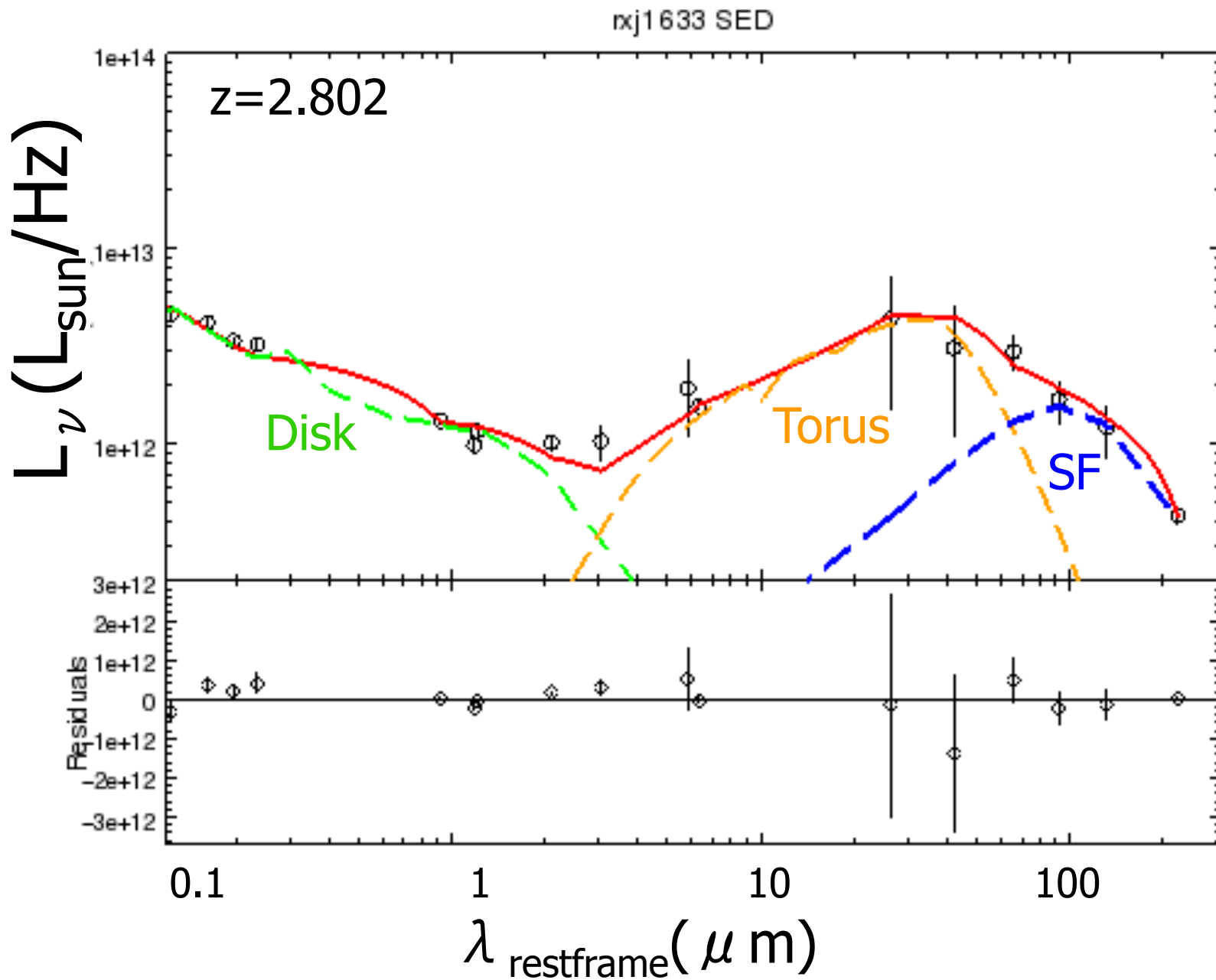
rxj1218 SED



RXJ1249: $L_{\text{Disk}}=1.23\times 10^{14}L_{\text{sun}}$ $L_{\text{Torus}}=1.16\times 10^{14}L_{\text{sun}}$ $L_{\text{FIR}}=7.0\times 10^{12}L_{\text{sun}}$



RXJ1633: $L_{\text{Disk}}=6.50\times 10^{12}L_{\text{sun}}$ $L_{\text{Torus}}=7.00\times 10^{12}L_{\text{sun}}$ $L_{\text{FIR}}=2.2\times 10^{12}L_{\text{sun}}$



Results from the fits

(Khan-Alí+15)

- L_{BOL} is calculated **using L_x and L_{Disk}** (100 keV – 100 μm).
 - Apparent covering factors $L_{\text{Torus}}/L_{\text{BOL}} \sim (0.32-0.87)$.

Field	$L_{x,2-10}$ ($10^{11} L_{\text{SUN}}$)	SFR ($M_{\text{SUN}} \text{ Years}^{-1}$)	L_{BOL} ($10^{11} L_{\text{SUN}}$)	L_{IR} ($10^{11} L_{\text{SUN}}$)
RXJ0057	2.93	840 ± 170	250 ± 30	170 ± 40
RXJ0941	0.93	1350 ± 190	169 ± 13	180 ± 30
RXJ1218	2.33	1090 ± 100	78 ± 7	90 ± 19
RXJ1249	3.69	1200 ± 300	1890 ± 90	780 ± 90
RXJ1633	5.85	380 ± 90	186 ± 15	90 ± 30

Results from the fits

(Khan-Alí+15)

- Strong star formation
- ULIRG / HLIRG level (L_{IR})
- Very High L_{BOL} (RX J1249)

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Properties of the host galaxies?

- No direct measurement: emission dominated by AGN
 - Need (sub)mm obs. of CO lines to measure host gal. mass
- Clues:
 - Mature and massive SMBH
 - High SFR, not likely kept for long
- If not mature galaxy as well:
 - Galaxy growth without substantial SMBH growth (SMBH-less mergers, or $SFR \gg$ but $\dot{M} \ll$)
 - Or bulk gas in host gal. form stars, but today's ellipticals formed $z \gtrsim 3$

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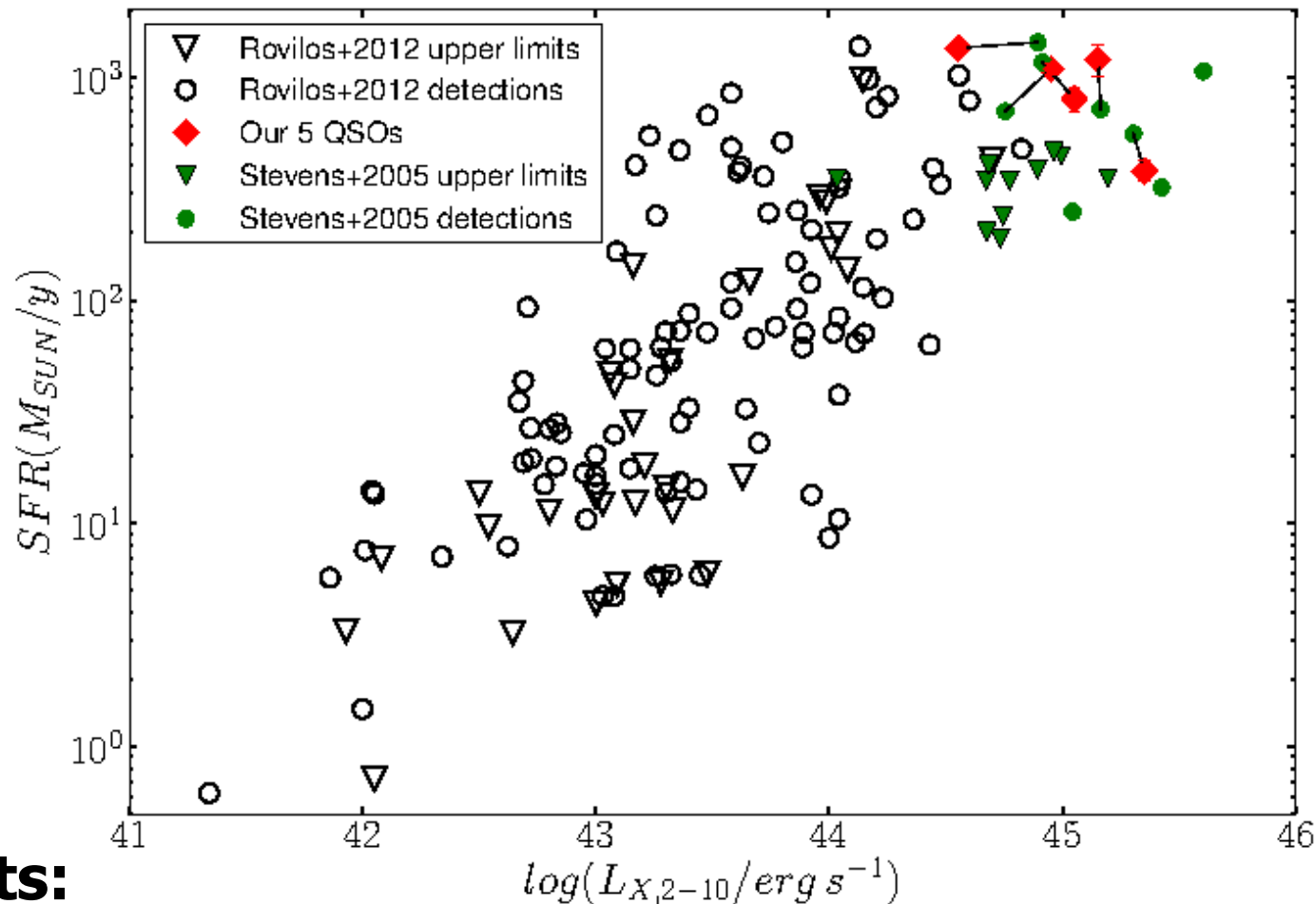


The galaxies have to be already formed

AGN-SF relationship

- Is there an influence of the central AGN on the evolution of its host galaxy?
- Controversial context:
 - + Lutz+08, Rosario+12, Rovilos+12, etc.
 - Mullaney+12, Page+12, etc.
- We have revised the $\log(\text{SFR})$ vs $\log(L_{x_{2-10}})$ correlation using the Rovilos+12 sample and our sources, including data from Stevens+05 with his upper limits.
- We have tested for a “hidden” correlation with redshift (specifically with luminosity distance: Akritas & Siebert’96).

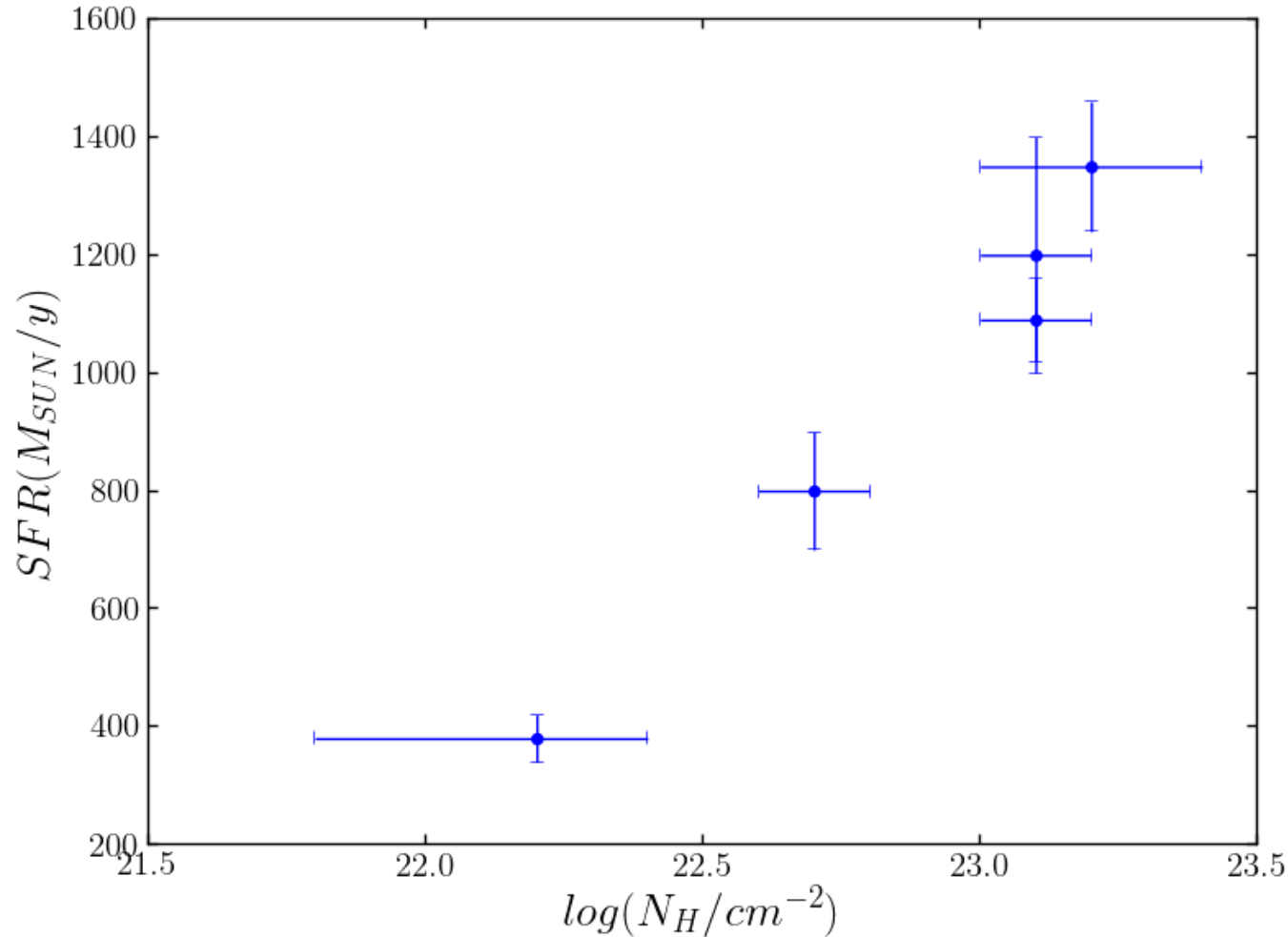
It appears that there is a significant correlation between the growth of the galaxies and their SMBH in the joint sample.



Caveats:

- The very different selection functions of the samples (wavelength and size)
 - Each covers different FIR rest-frame range
- ⇒ Large samples of objects at the relevant redshifts with well-controlled selection functions are needed

AGN: co-evolution?

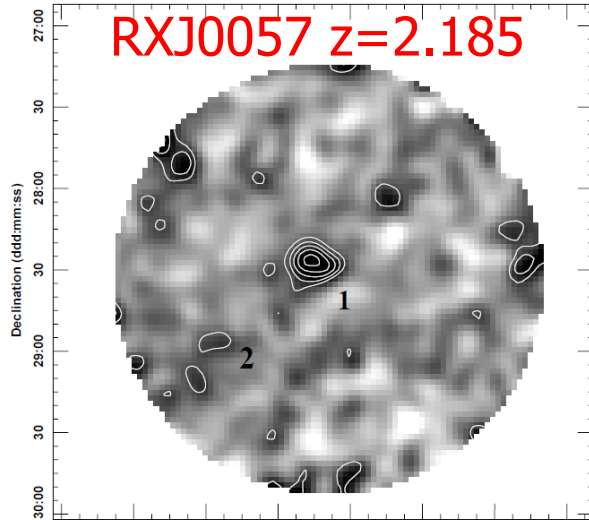


- Tentative positive correlation between $N_{H_{ion}}$ and SFR
- It would imply a coupling of the ionized gas absorbing the X-rays (AD or BLR scale) with the gas forming stars (host galaxy bulge).
- **Only 5 objects** (larger samples??)

Environment in submm: SCUBA 850 μ m

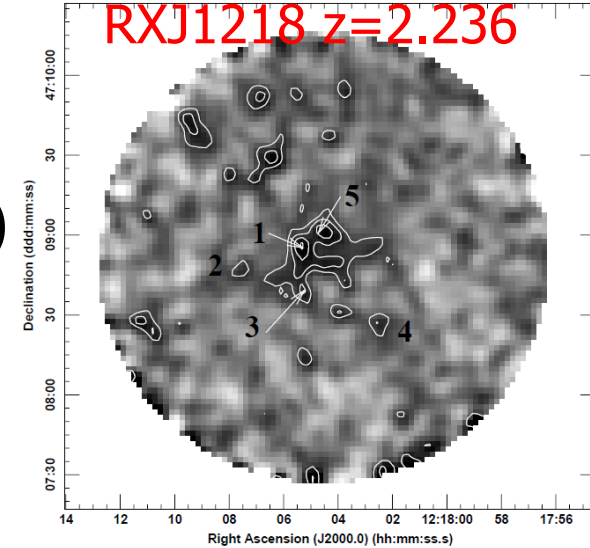
(Stevens+05,+10)

RXJ0057 $z=2.185$

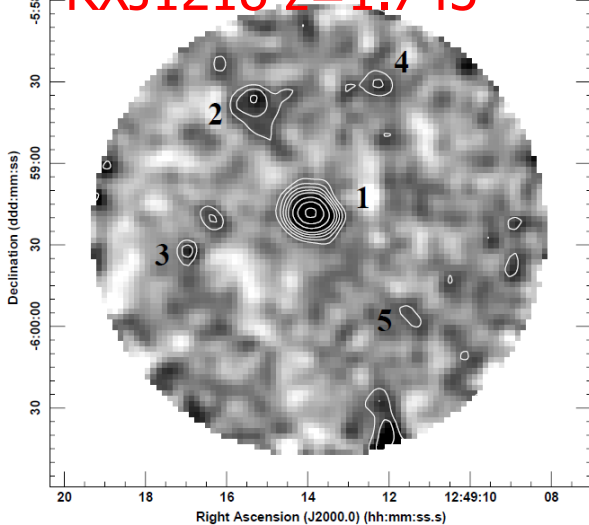


- 2-4 \times overdensities
- Structure in 100skpc
- Each an ULIRG (if @z)
- Some: disturbed morphol.
 - Major galaxy merger

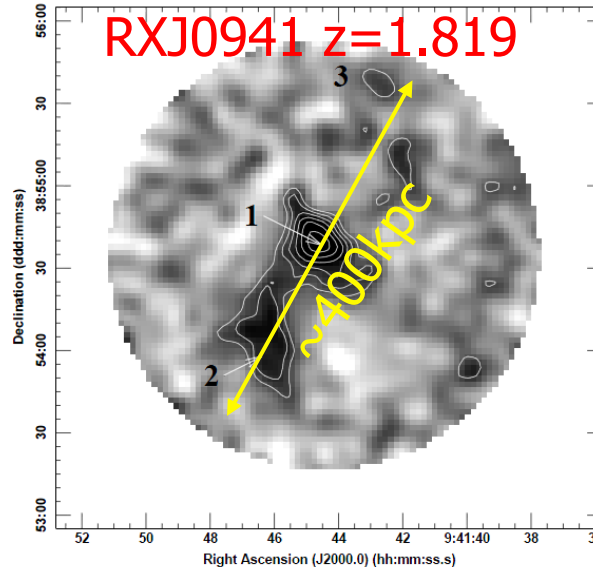
RXJ1218 $z=2.236$



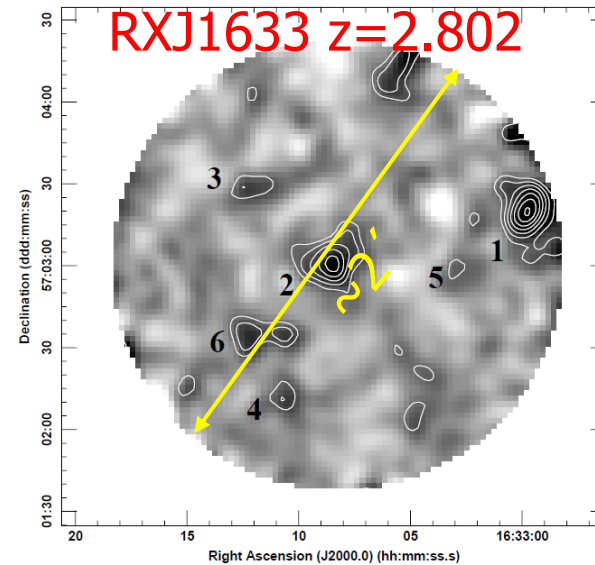
RXJ1218 $z=1.743$



RXJ0941 $z=1.819$



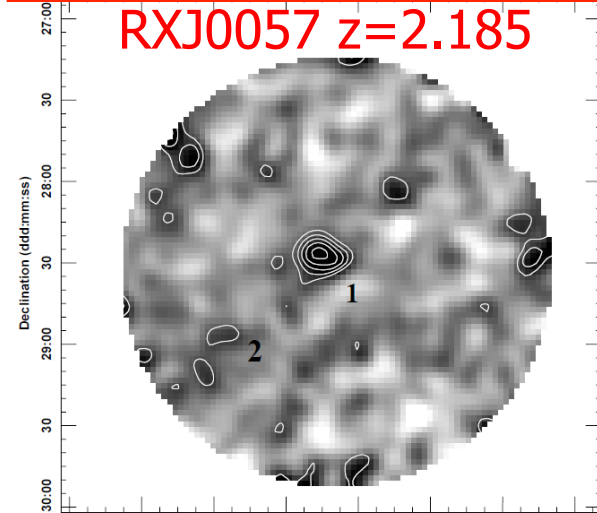
RXJ1633 $z=2.802$



Environment in submm: SCUBA 850 μ m

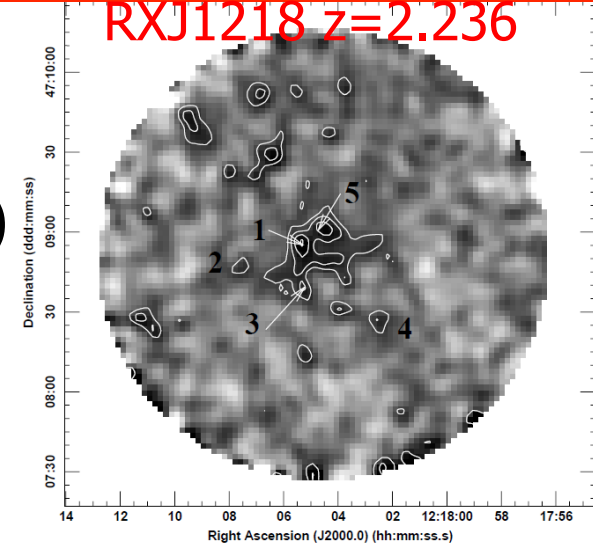
These QSOs are sitting in overdensities in the Universe
Submm luminosity from starburst (triggered by fusion/interaction?)

RXJ0057 $z=2.185$

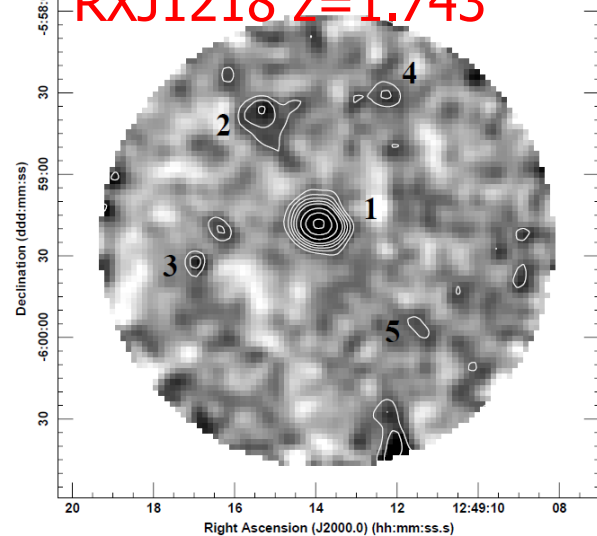


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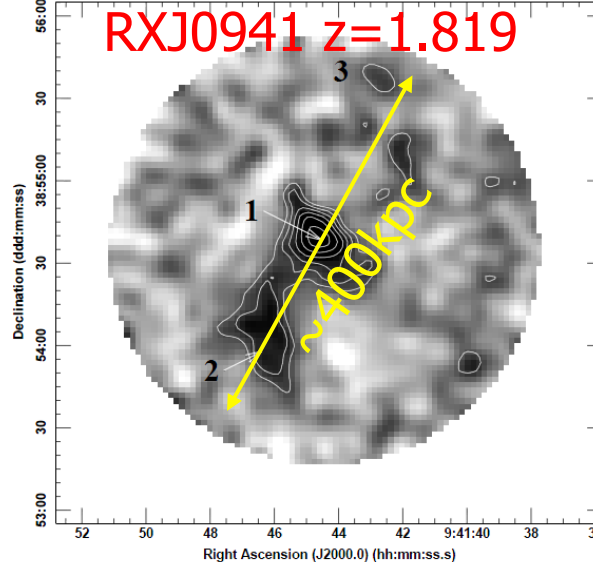
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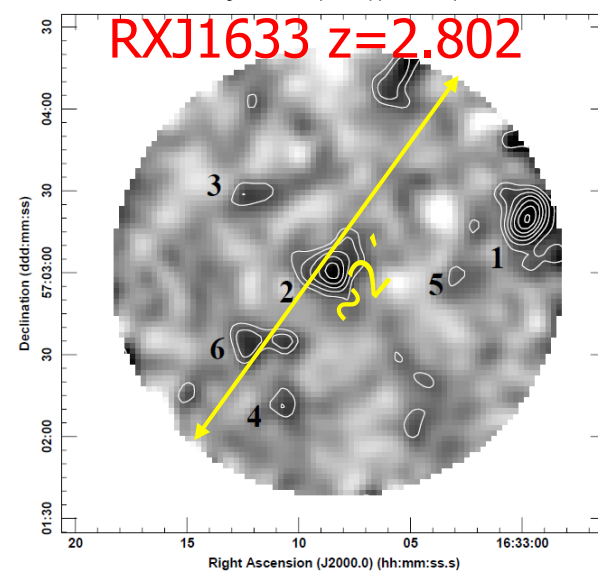
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RXJ1633 $z=2.802$



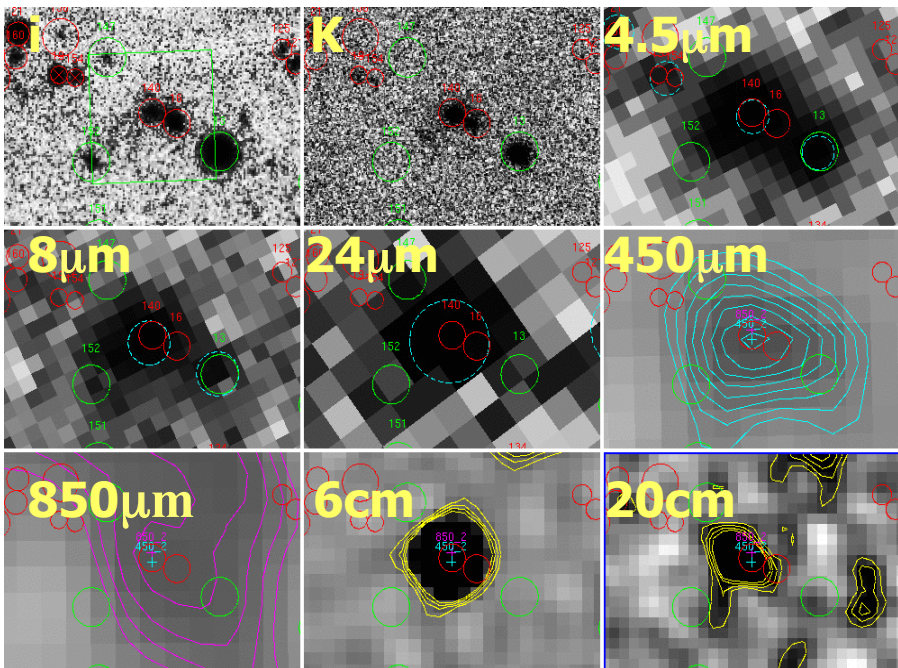
Confirmation of association: RXJ0941

(Carrera+11)

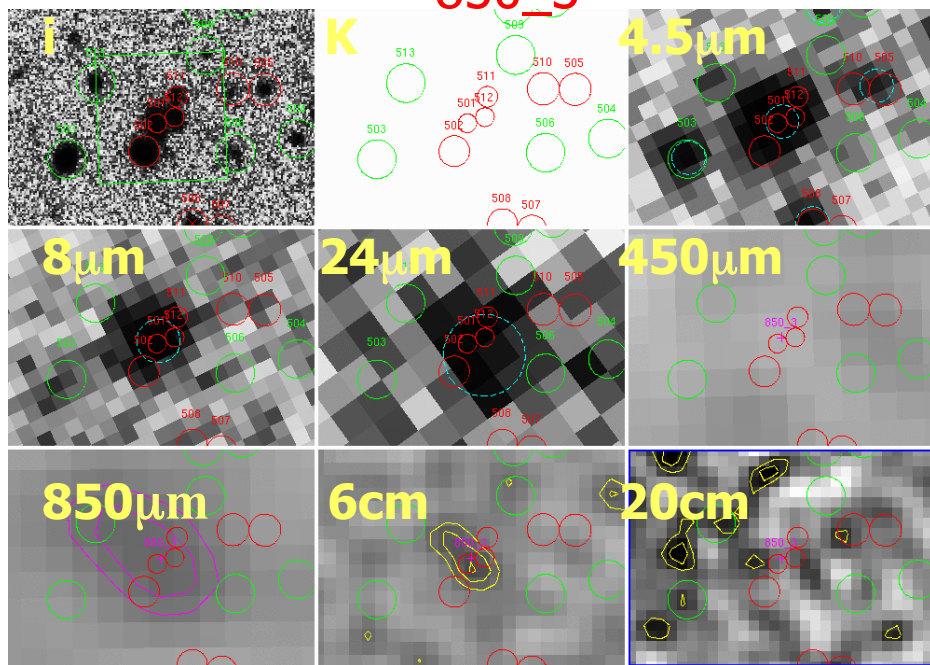
- 4 in 450 μ m, 3 in 850 μ m (2 common): 5 total (inc. QSO)
- Faint \Rightarrow Photo-z (robust) in rest-frame optical-NIR:
 - QSO +3 SMG $z\sim 1.82$
 - 1 background obj.: One spurious expected from logN-logS (Coppin+06)
- SMG: from opt-NIR fit and Chary & Elbaz'01 SED:
 - Massive galaxies $\log(M_*/M_\odot)\sim 11.5\pm 0.2$
 - Strong star formation $L_{\text{IR}}\sim 10^{13}L_\odot$ U/HLIRG \Rightarrow SFR $\sim 2000 M_\odot/\text{y}$
 - Additional material $M_{\text{dust}}\sim 10^9 M_\odot \Rightarrow M_{\text{gas}}\sim 5\times 10^{10} M_\odot$
- SMG: from X-ray uplims and 24 μ m
 - Only uplim on SMBH mass $\log(M_{\text{BH}}/M_\odot) < 8.1$
 - Below local relation $(M_{\text{BH}}/M_*)/(M_{\text{BH}}/M_*)_{\text{local}} < 6$

Galaxies mature and not much further growth
Growth of BH lags growth of galaxy: plenty of fuel left (1.5% gas)

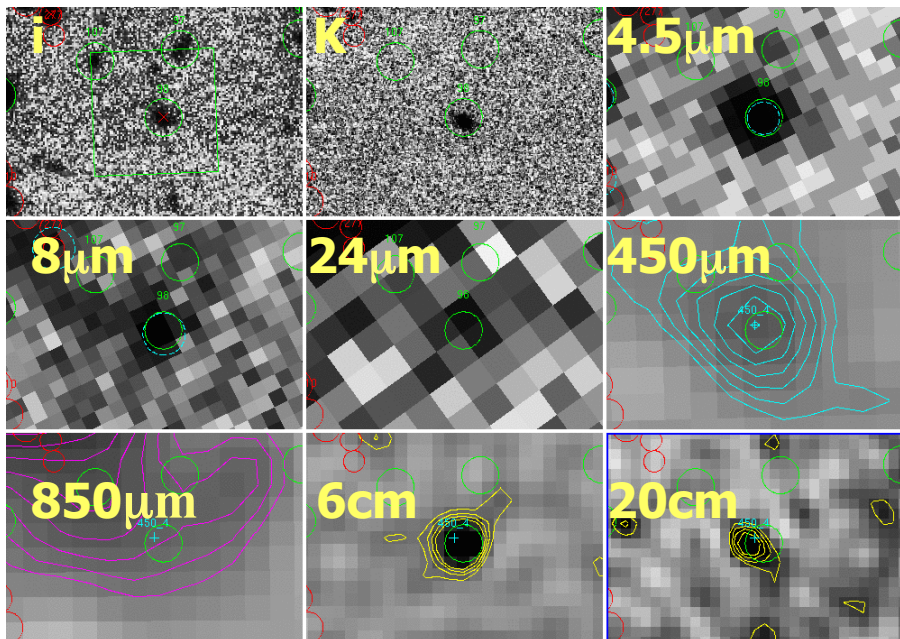
850_2/450_2

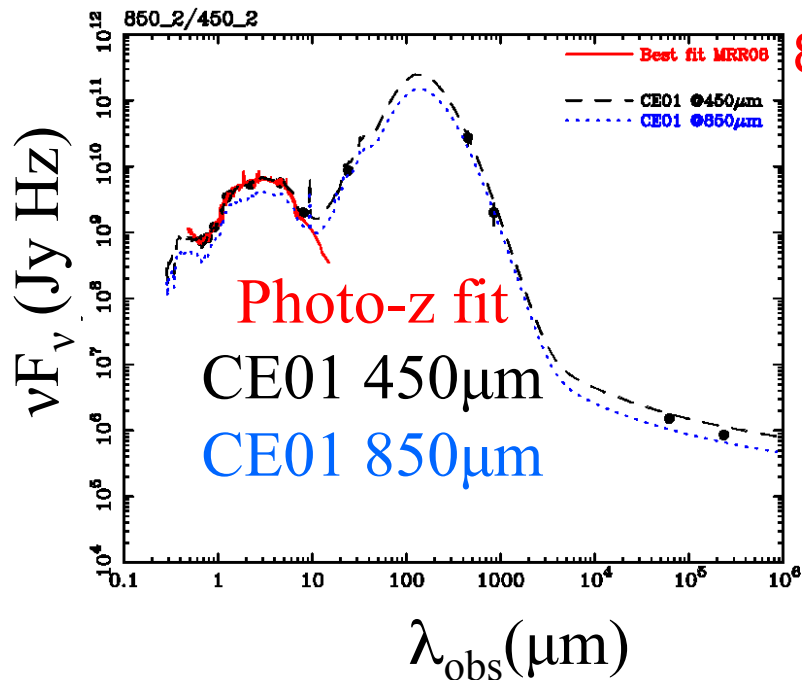


850_3

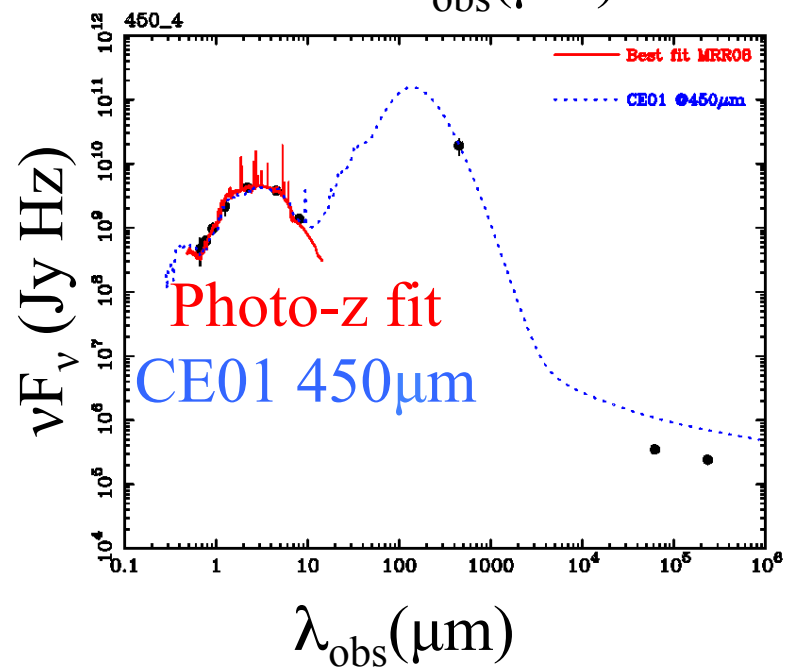


450_4

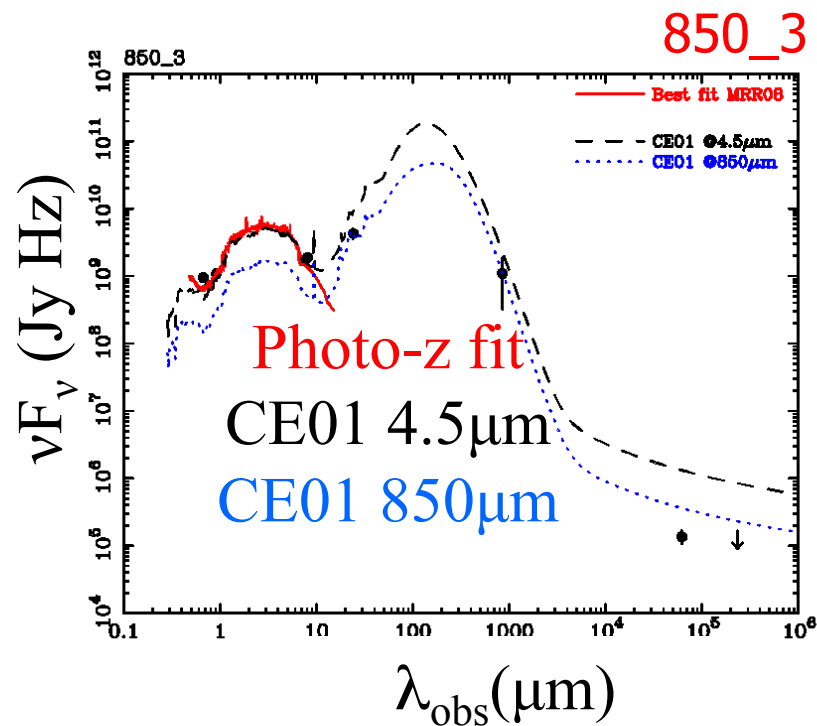




850_2/450_2



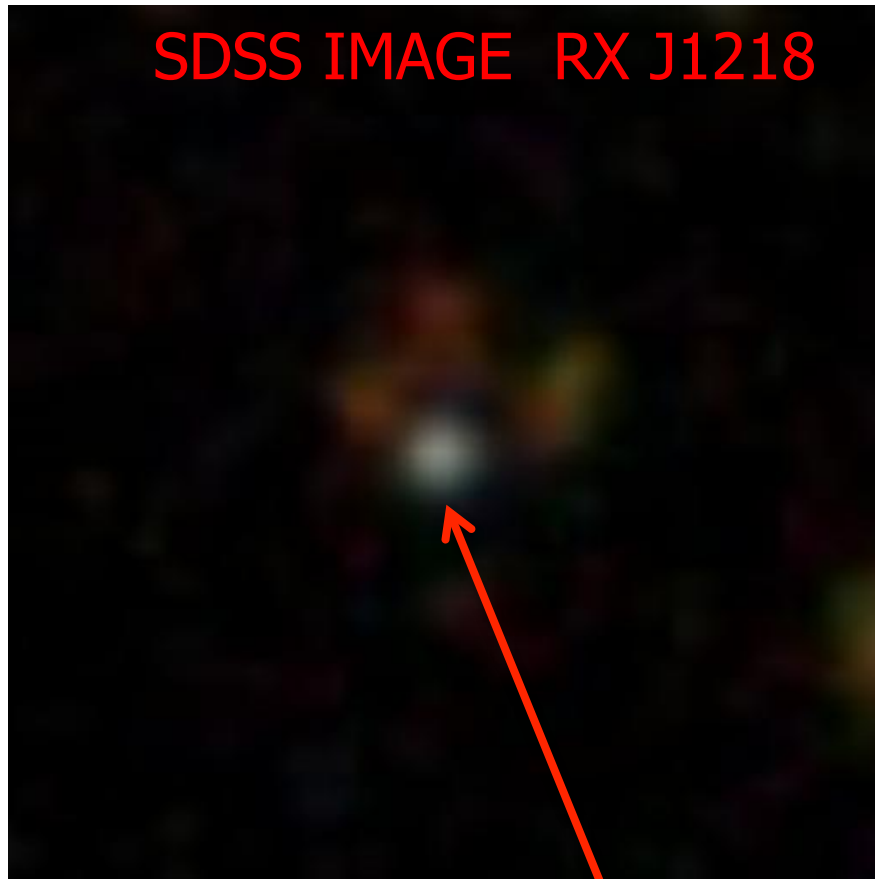
450_4



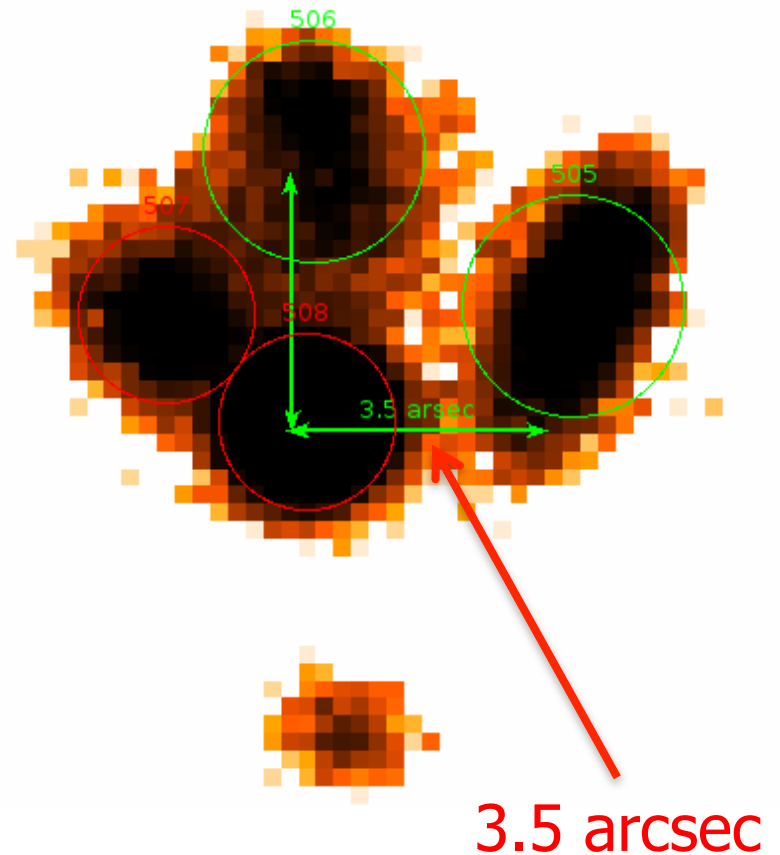
Present and future work

(Khan-Ali+15, in prep)

- We are studying the fields around the central QSO to find an association between these objects and the QSO.

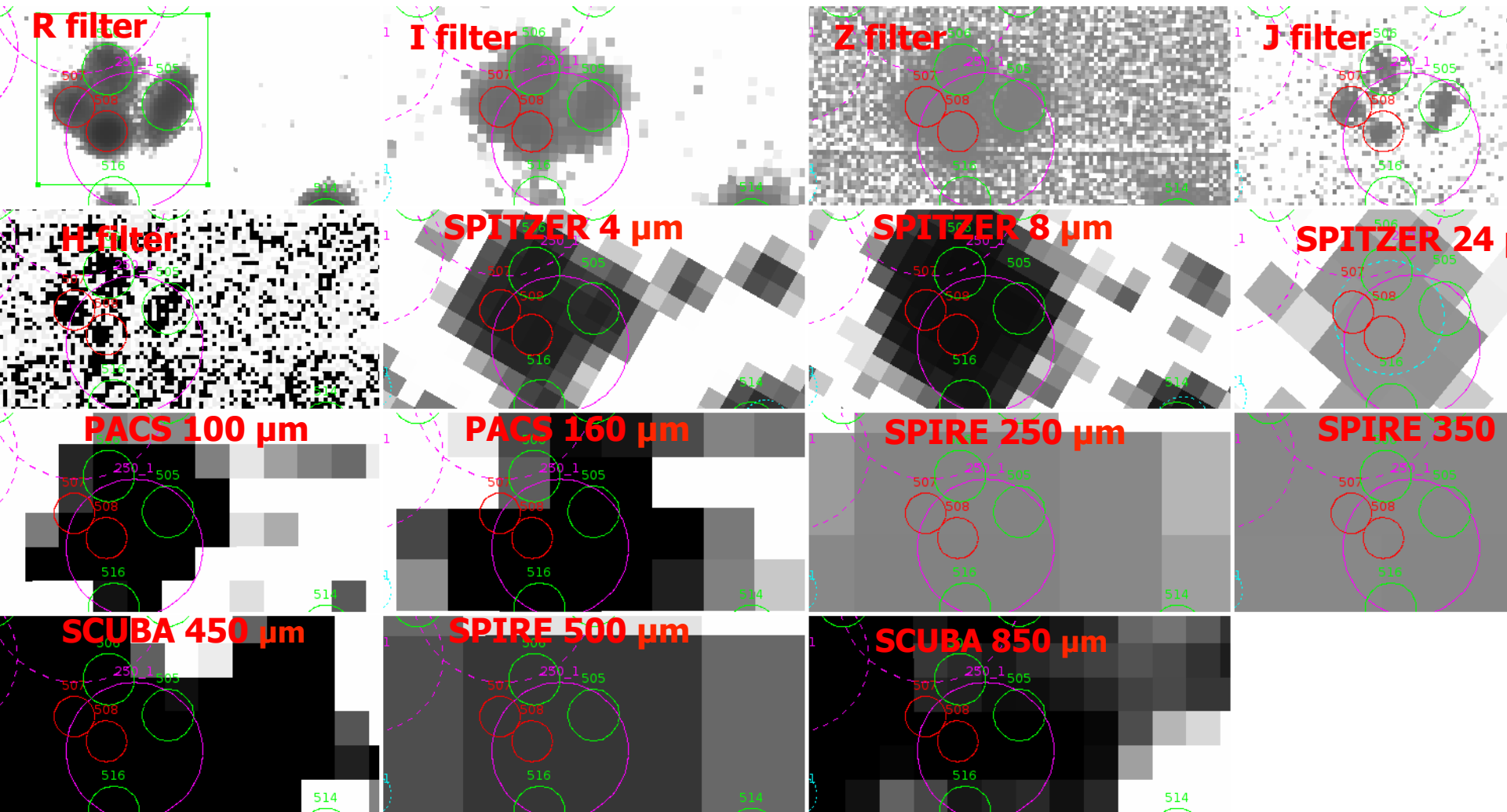


Central QSO $z = 1.74$

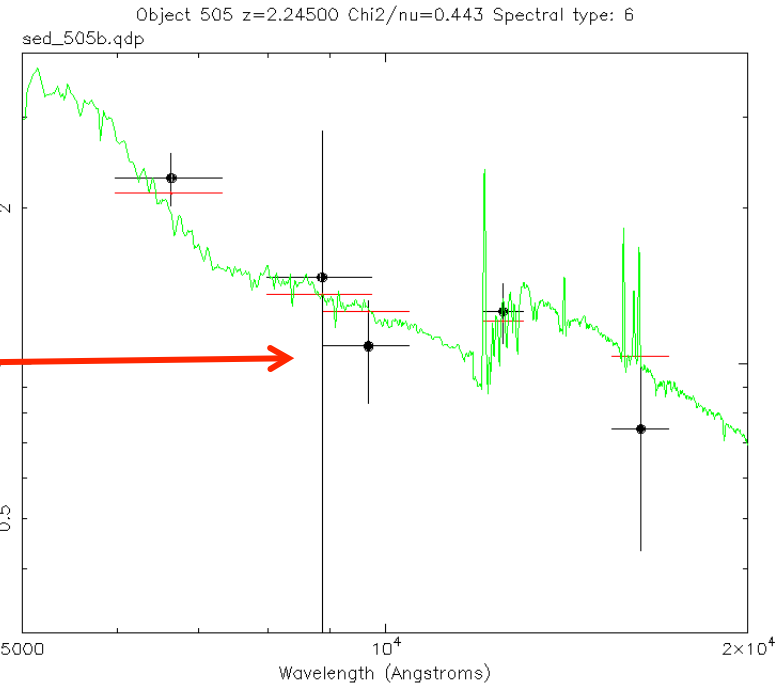
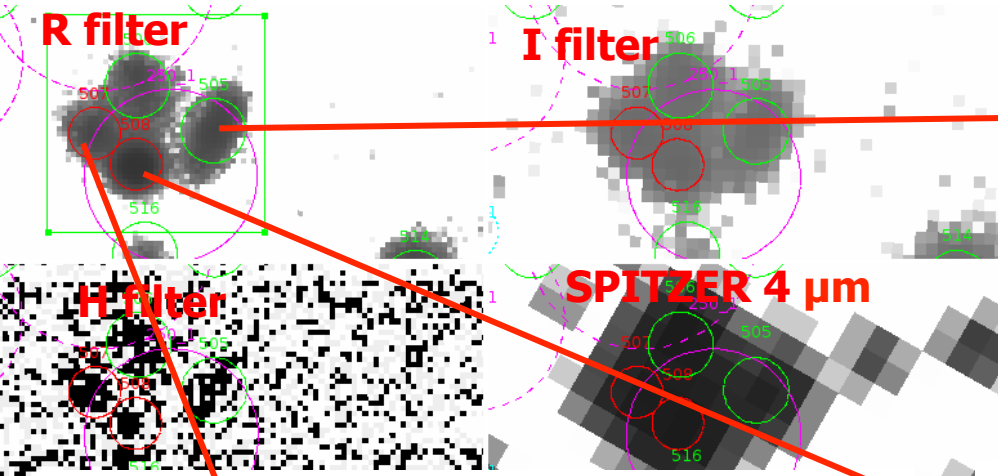


Present and future work

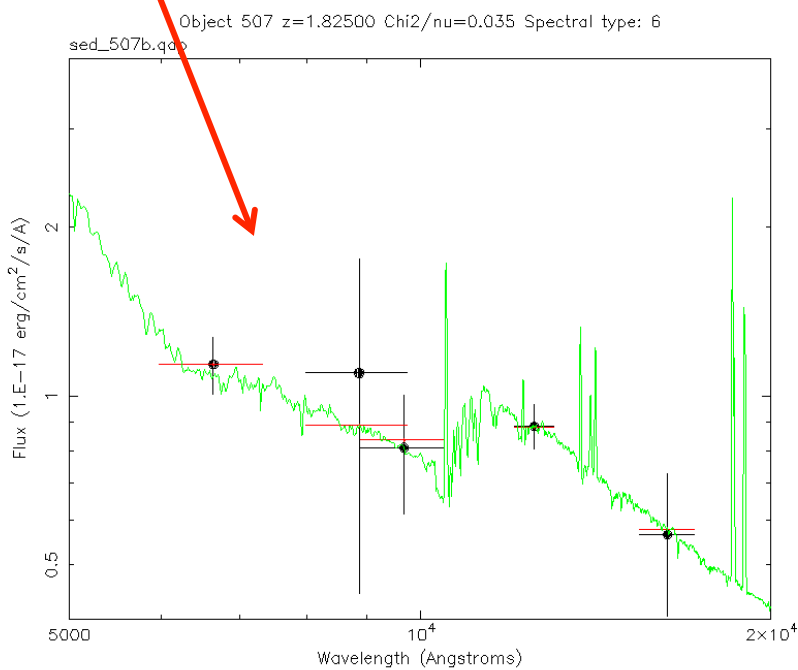
(Khan-*Alí*+15, in prep)



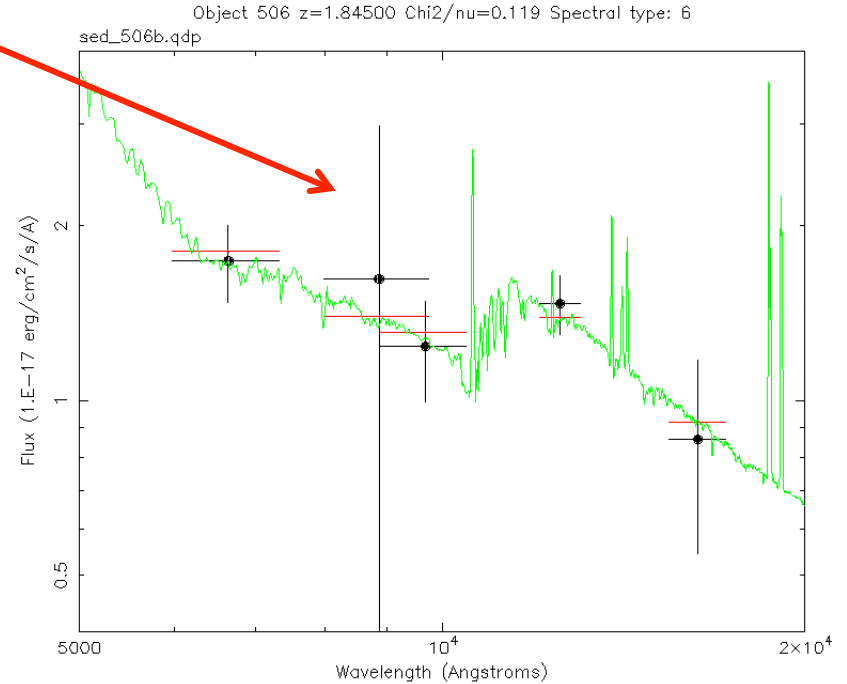
Present and (Khan-Ali+15)



anuarkhan 19-Jun-2015 10:48

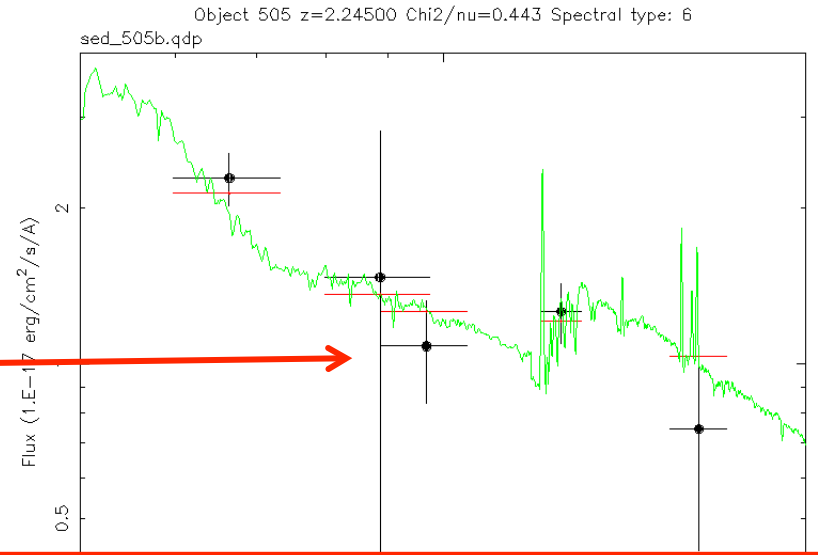
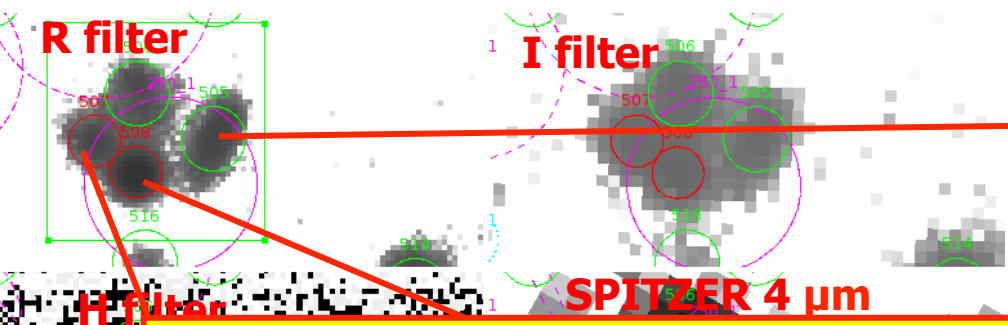


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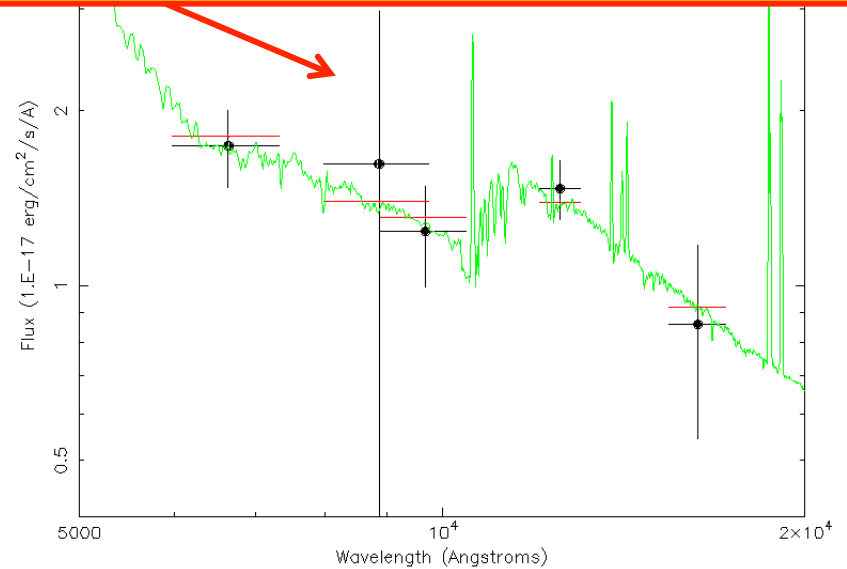
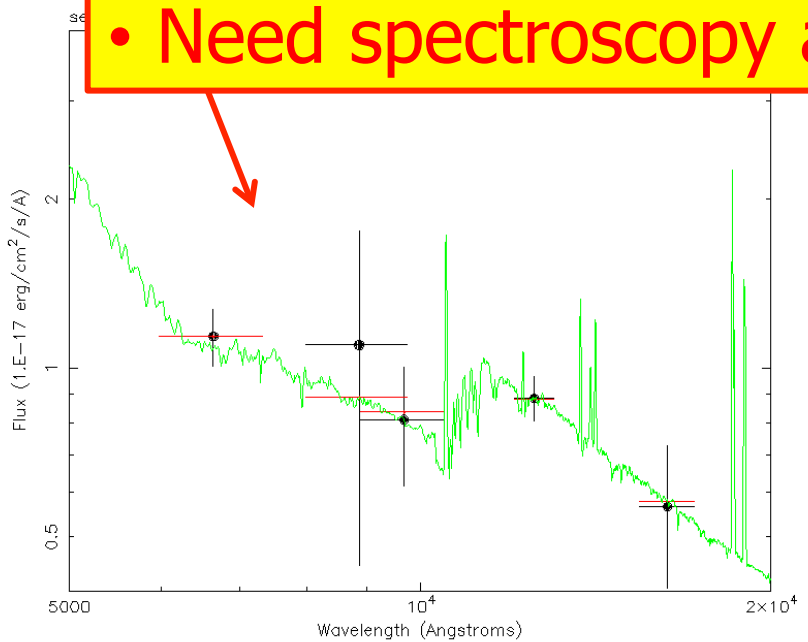


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Present and (Khan-Ali+15)



- More candidates to links with the central QSO.
- Confusion?
- Need spectroscopy and hi-res submm data



Summary

- 5 fast BH-growing X-ray absorbed QSO1:
 - @z,Lx most contribution XRB
- X-ray absorption from ionized material, and UV outflows: sufficient feedback for M- σ
- Strong star formation, massive BH: SMBH already mature, host galaxies too?
 - Correlation between ionised column density and SFR !?
- In centres of overdensities of SMG
 - In at least one case confirmed association: SMG mature but undergrown SMBH (if any)
 - Working on rest
- Future:
 - Properties of the QSO host galaxies (submm)
 - Confirming the associations (submm, opt/NIR spcpy)
 - Enlarging the sample (X-ray and/or submm photometry)