Signposts of Co-evolution at high z: properties of Submm-bright QSOs z ~2

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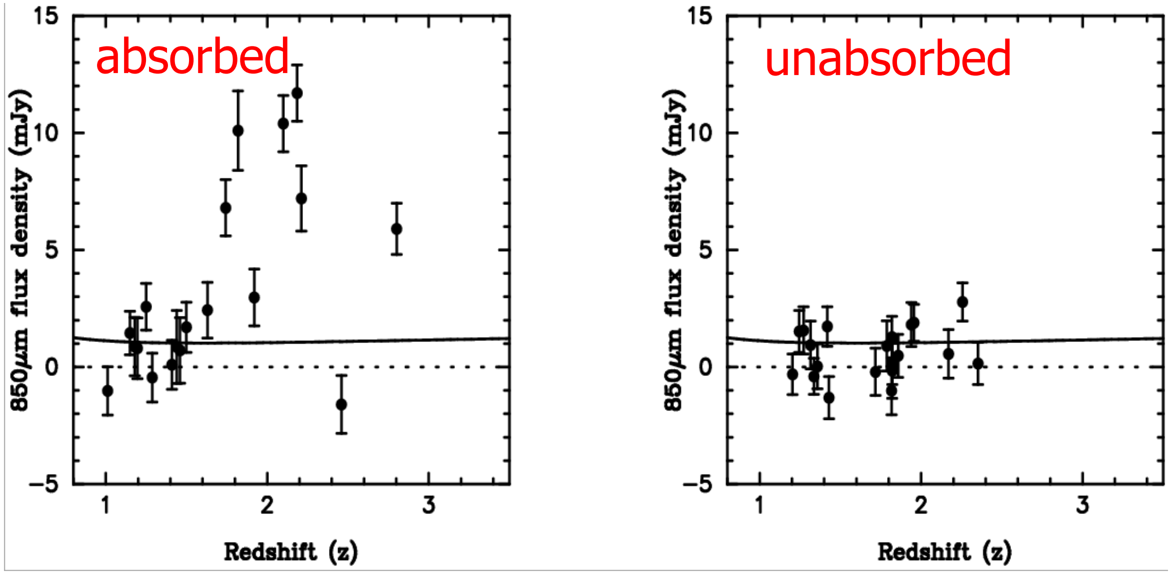
Introduction: our hard QSO sample

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

- Sample of (Broad Line) QSO1 with X-ray absorbed spectra
  - Matched sample of similar (L_X,z) unabsorbed QSO control sample
- 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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5 objects:

• Simultaneous strong growth of BH and star formation.

• Stronger SF in the past.

• Transitory phase ~10-15% QSO life.

Our data

- SCUBA 450 and 800μm.
- Herschel: PACS (100, 160μm) and SPIRE (250, 350, 500μm).
- **Spitzer:** IRAC 4.5, 8μm and MIPS 24μm.
- Own optical/NIR (R, I Z, **J, H, K** filters).
- X-ray and UV spectra.
- Public data: **WISE**, 2MASS, SuperCosmos, Sloan.

(Khan-Alí et al. 2015)

QSO SEDs: Aim: contribution of diff. components to SED

- Really strong star formation (SF)?
- Apparent covering factor CF ~ $L_{\mathrm{Torus}}/L_{\mathrm{BOL}}$
- M_{BH}, acc. rate...

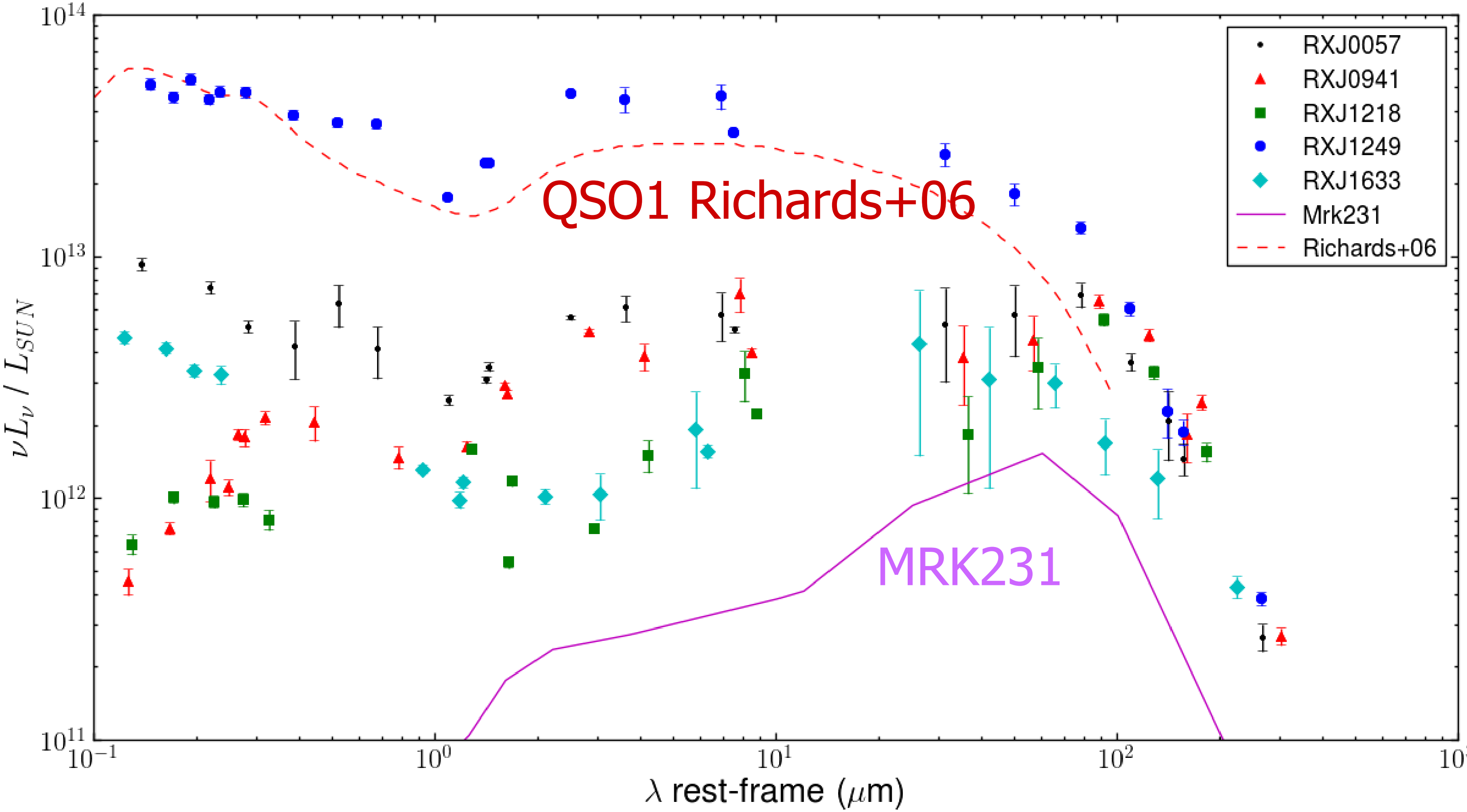
(Khan-Alí et al. in prep)

SMG SEDs: Association with the central QSO?

- Photometric redshifts
- Star formation ?

QSO SEDs

(Khan-Alíet al. 2015)

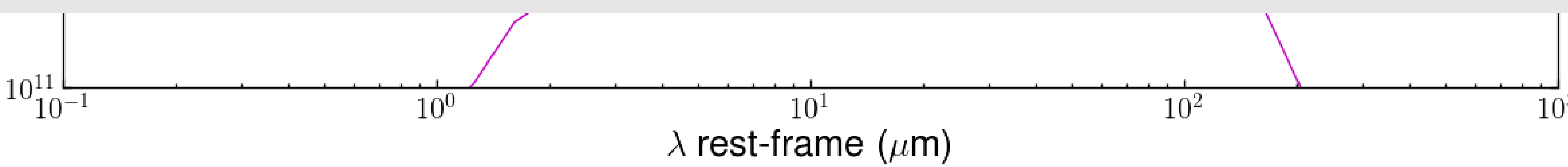


QSO SEDs

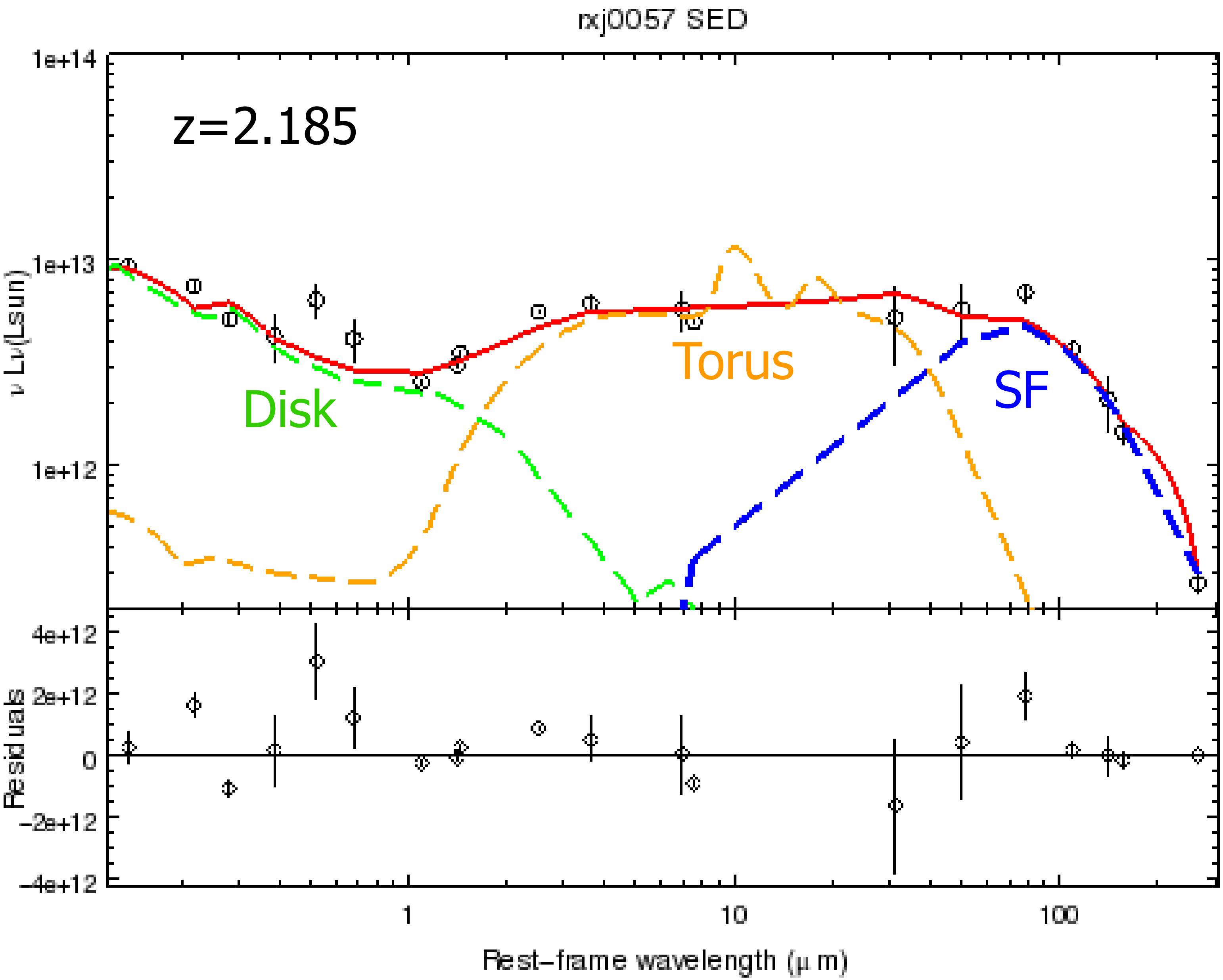
(Khan-Alíet al. 2015)

Fit to 0.1215-330μm rest-frame νL_ν using:

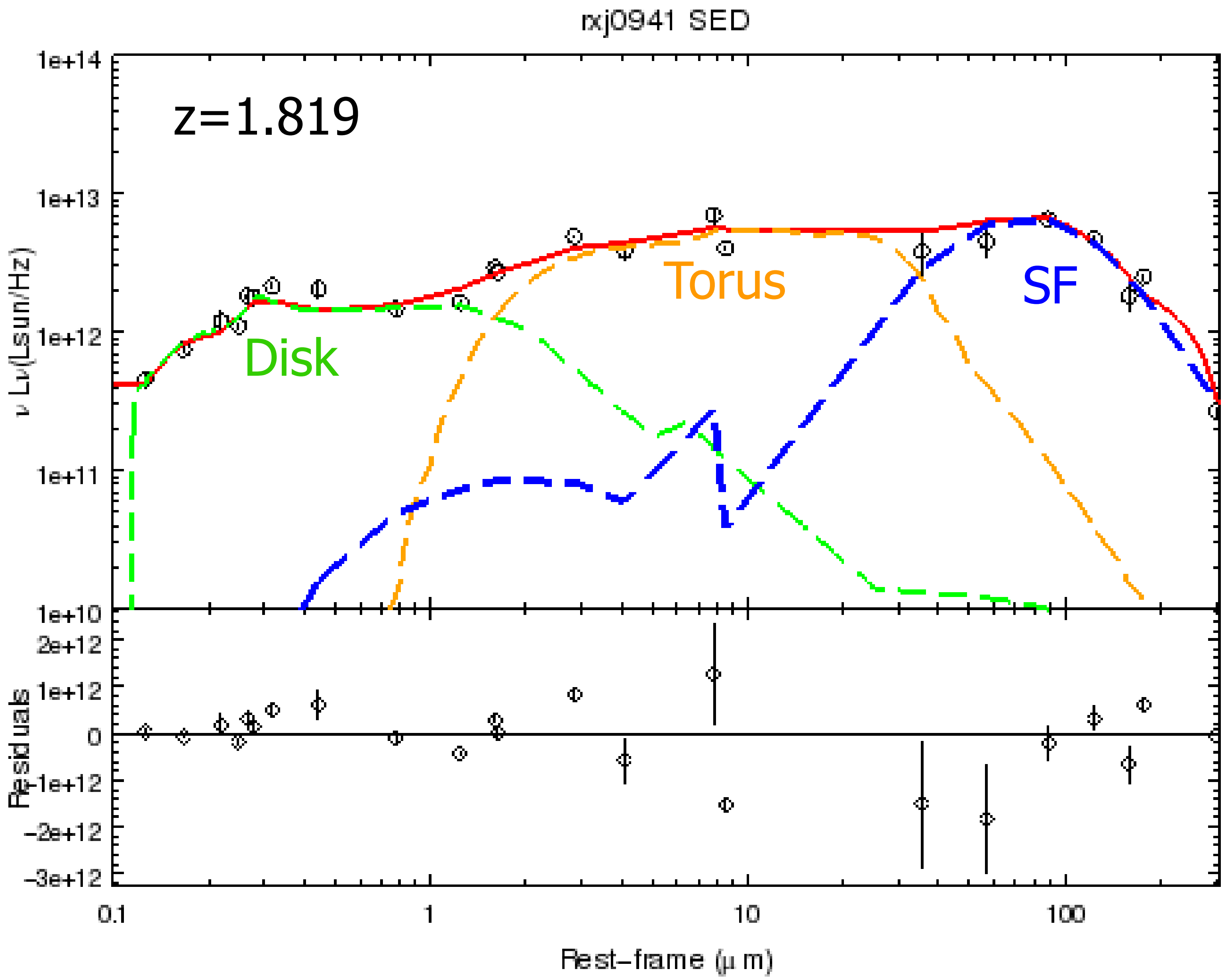
- Disk component: Rowan-Robinson+08 SWIRE newagn4
- Torus component: Rowan-Robinson+08 SWIRE dusttor, Roseboom+12 (sub-sample of 3 clumply Torus from Nenkova+08):
- SF component: Siebermorgen & Krügel 2007 (Starburst templates)



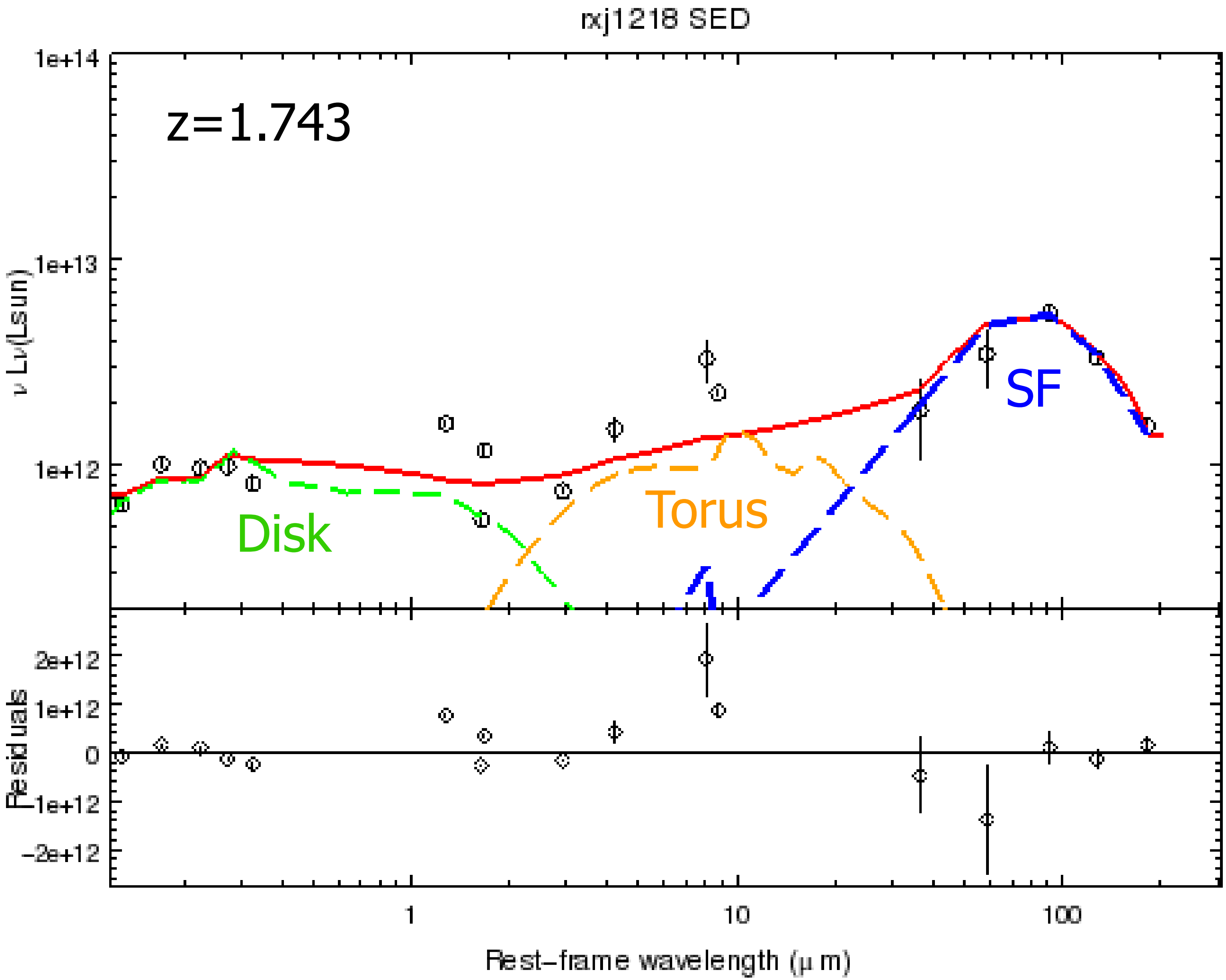
RXJ0057: L_{Disk}=1.25 × $10^{13} L_{sun}$ L_{Torus}=1.90 × $10^{13} L_{sun}$ L_{FIR}=4.9 × $10^{12} L_{sun}$



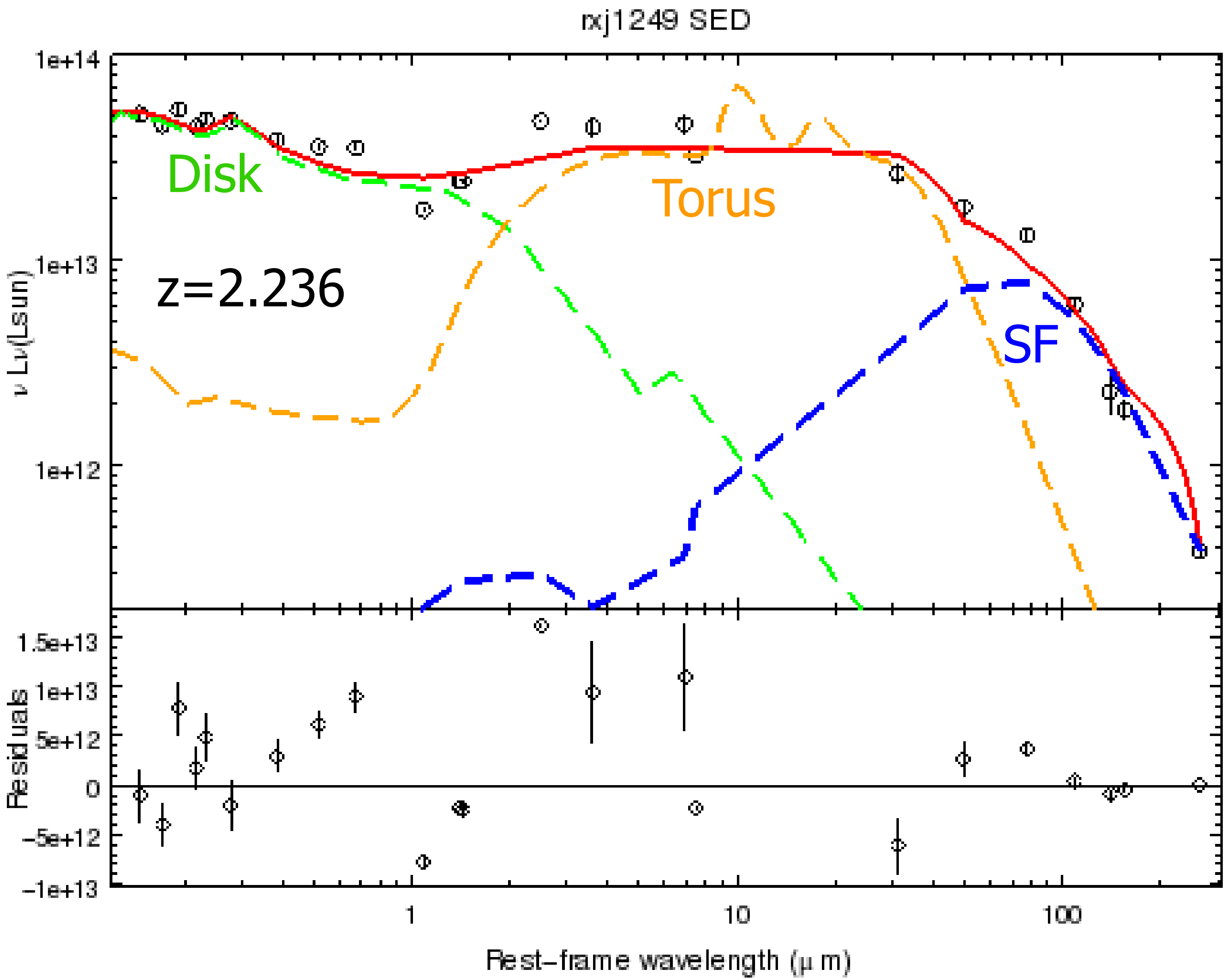
RXJ0941: $L_{\rm Disk}=1.00\times10^{13}L_{\rm sun}$ $L_{\rm Torus}=1.50\times10^{13}L_{\rm sun}$ $L_{\rm FIR}=7.8\times10^{12}L_{\rm sun}$



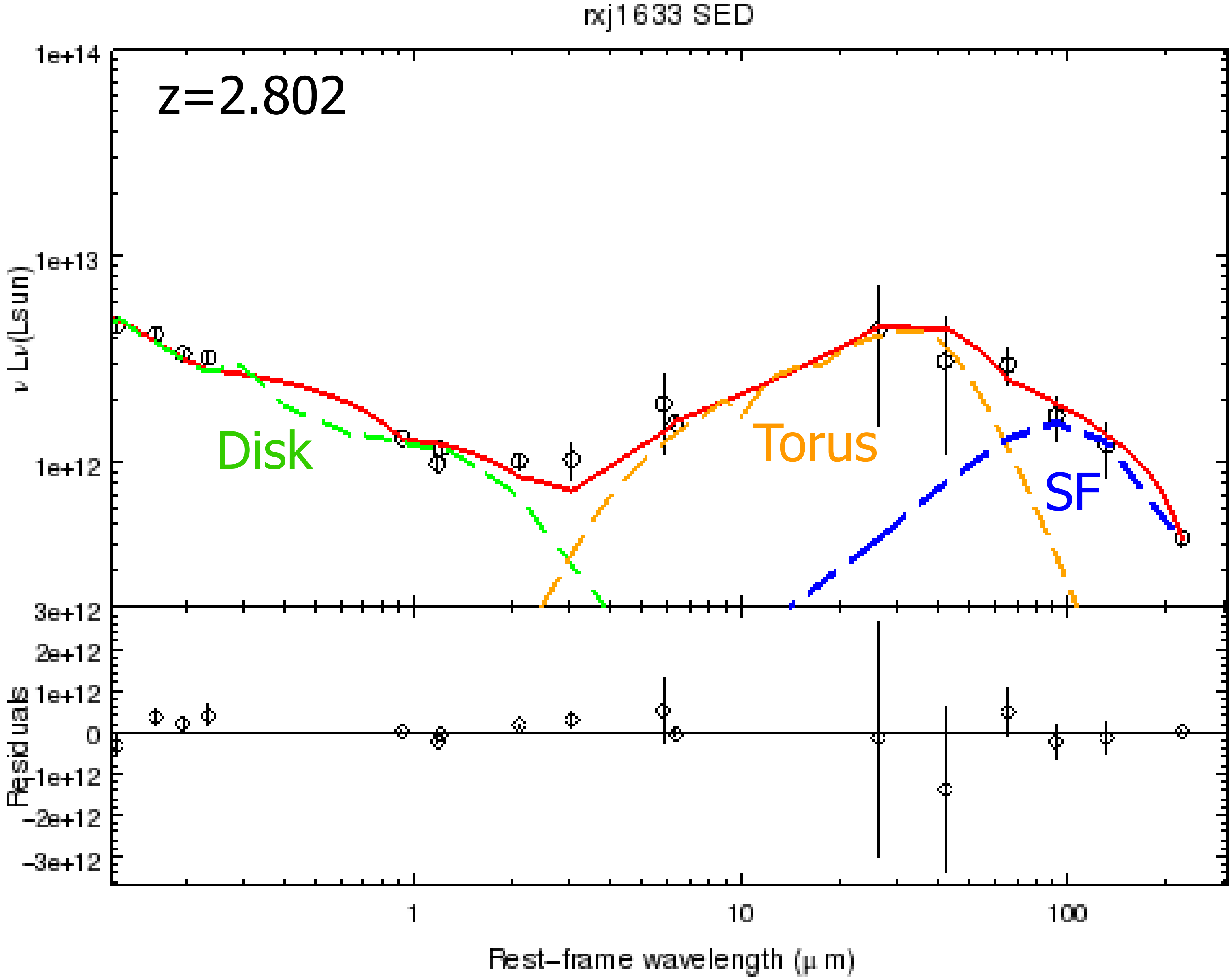
RXJ1218: $L_{\rm Disk}=4.2\times10^{12}L_{\rm sun}$ $L_{\rm Torus}=2.5\times10^{12}L_{\rm sun}$ $L_{\rm FIR}=6.3\times10^{12}L_{\rm sun}$



RXJ1249: $L_{\rm Disk}=1.23\times10^{14}L_{\rm sun}$ $L_{\rm Torus}=1.16\times10^{14}L_{\rm sun}$ $L_{\rm FIR}=7.0\times10^{12}L_{\rm sun}$



RXJ1633: $L_{Disk}=6.50\times10^{12}L_{sun}$ $L_{Torus}=7.00\times10^{12}L_{sun}$ $L_{FIR}=2.2\times10^{12}L_{sun}$



Results from the fits

(Khan-Alíet al. 2015)

- **L_{BOL}** is calculated **using L_x and L_{Disk}** (100 Kev – 100 μm).
- Apparent covering factors L_{Torus}/L_{BOL} ~ (0.32-0.87).

Field	$L_{X,2-10}$ (10^{11} L_{SUN})	SFR (M_{SUN} Years^{-1})	L_{BOL} (10^{11} L_{SUN})	L_{IR} (10^{11} L_{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-Alíet al. 2015)

- **L_{BOL}** is calculated **using L_x and L_{Disk}** (100 Kev – 100 μm).
- Apparent covering factors L_{T} /L_{BOL} ~ (0.32-0.87)

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

RXJ0941	0.93	1350±190	169±13	180±30
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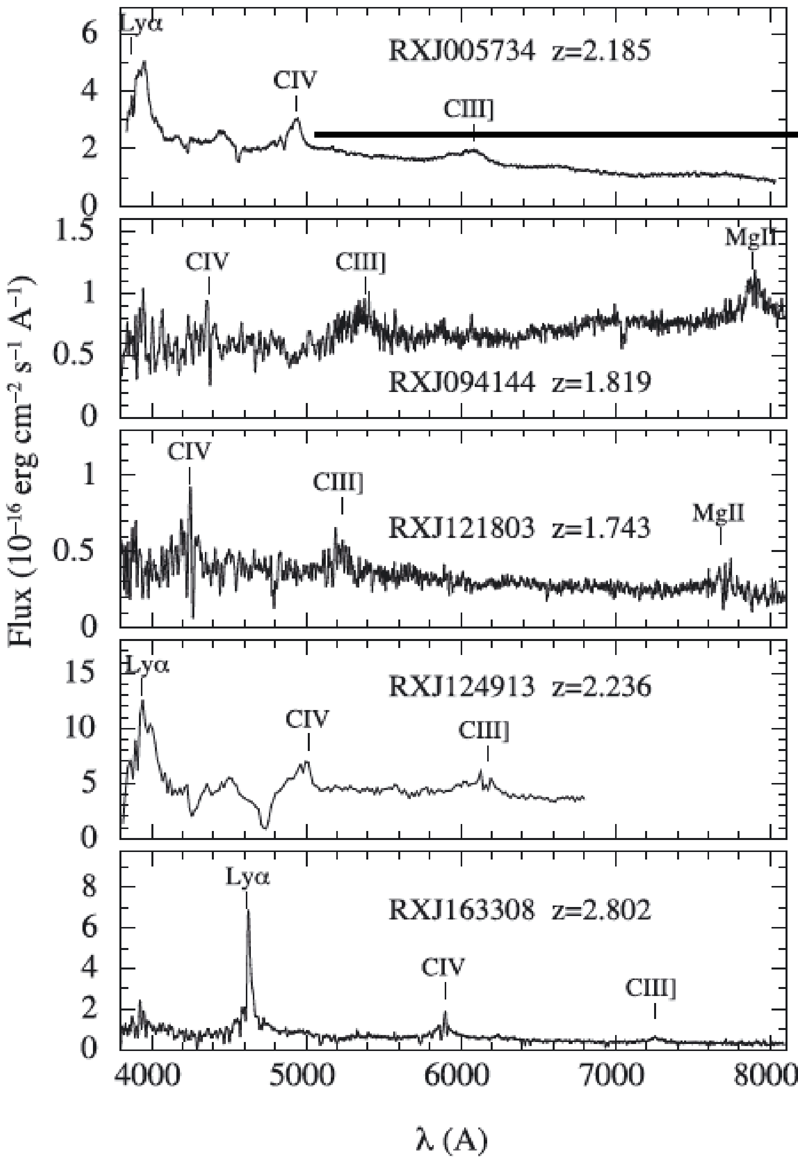
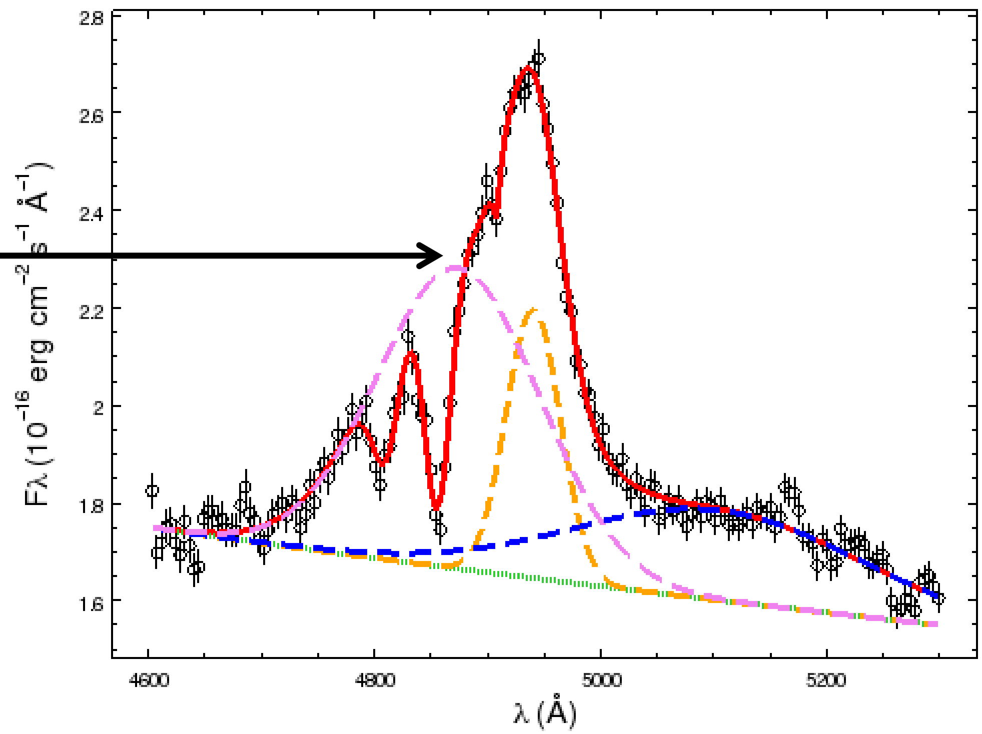
Black hole Masses





RXJ 0057 → log(M_{BH}) = 9.90 log(M_{SUN})

RXJ 0941 → log(M_{BH}) = 9.77 log(M_{SUN})

RXJ 1218 → log(M_{BH}) = 9.28 log(M_{SUN})

RXJ 1249 → log(M_{BH}) = 9.99 log(M_{SUN})

RXJ 1633 → log(M_{BH}) = 8.73 log(M_{SUN})

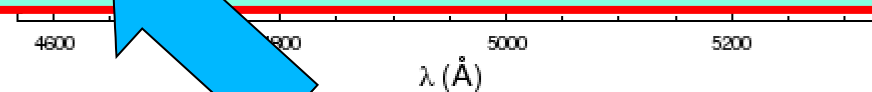
Black hole Masses

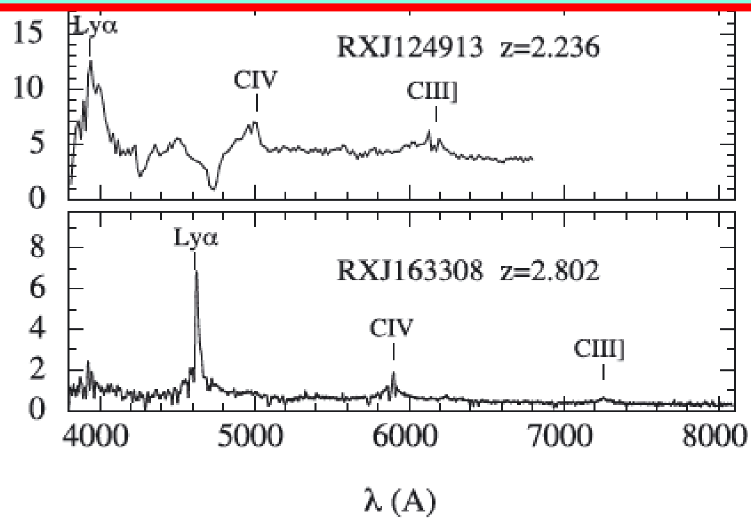
Super Massive Black Holes: 10^9 -10^{10} M_{SUN}

close to

Black Hole maximum mass known:

$M_{BH,max}$ = $2x10^{10}$ M_{SUN}





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AGN: co-evolution

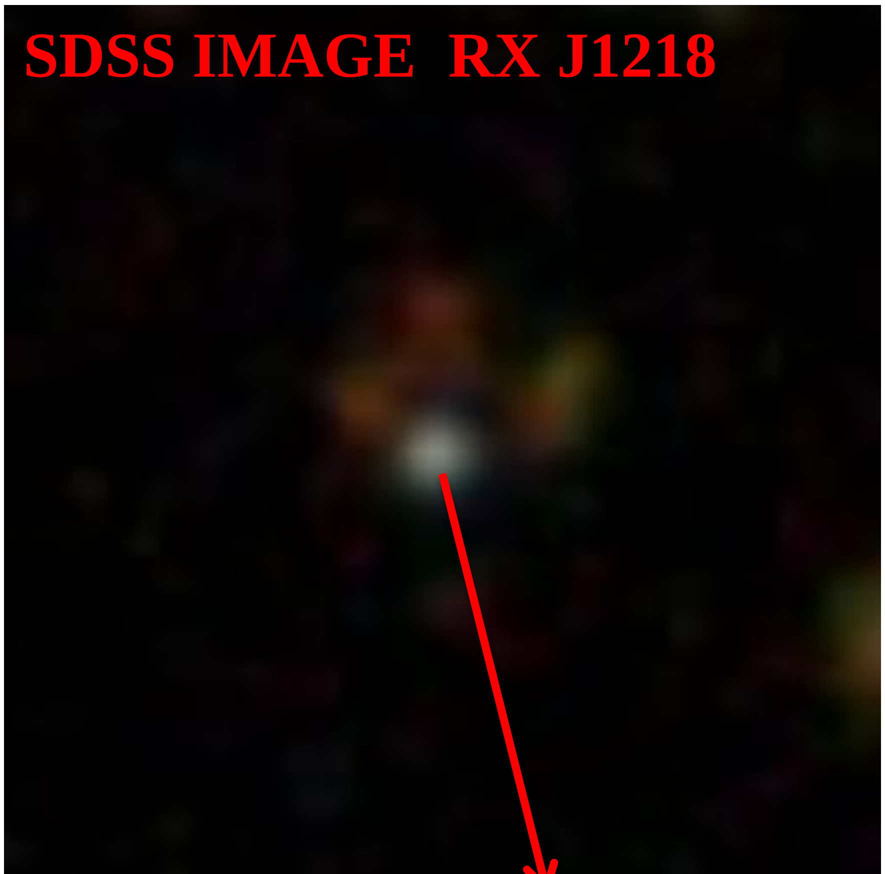
- SMBH (close to the maximum) and high SFR.
- Marconi & Hunt (2003) local relation: $M_{BULGE} = 10^{2.63}\ M_{BH}$
- Their growth is a transitory phase (peak of activity z ~2).
- Look-back time ~ 10-11 Gy.
- Starburst time required to reach $M_{BULGE,max}$ ~ 6-22 Gy

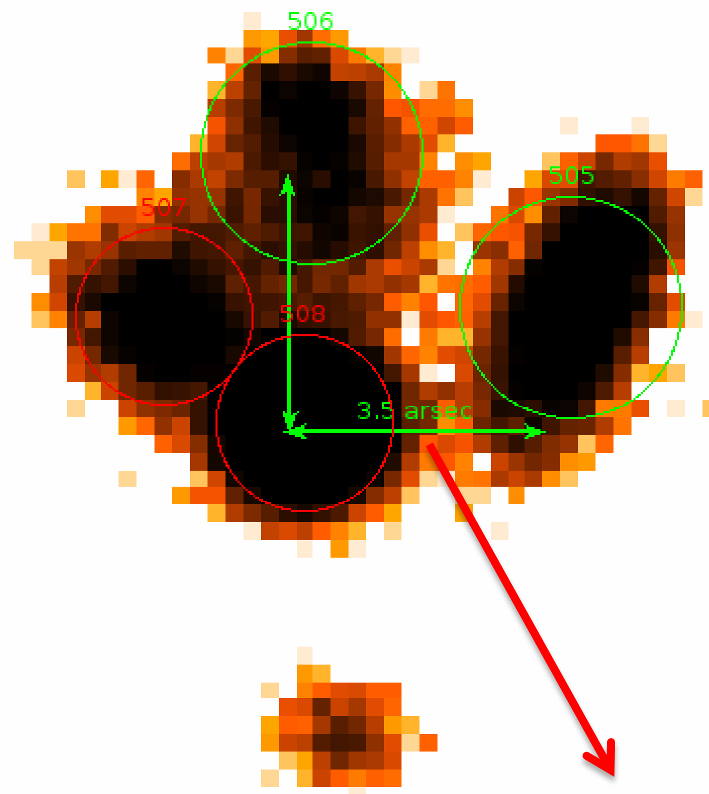
The galaxies have to be already formed and they have to be very massive.

Present and future work

(Khan-Alí et al. in prep)

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

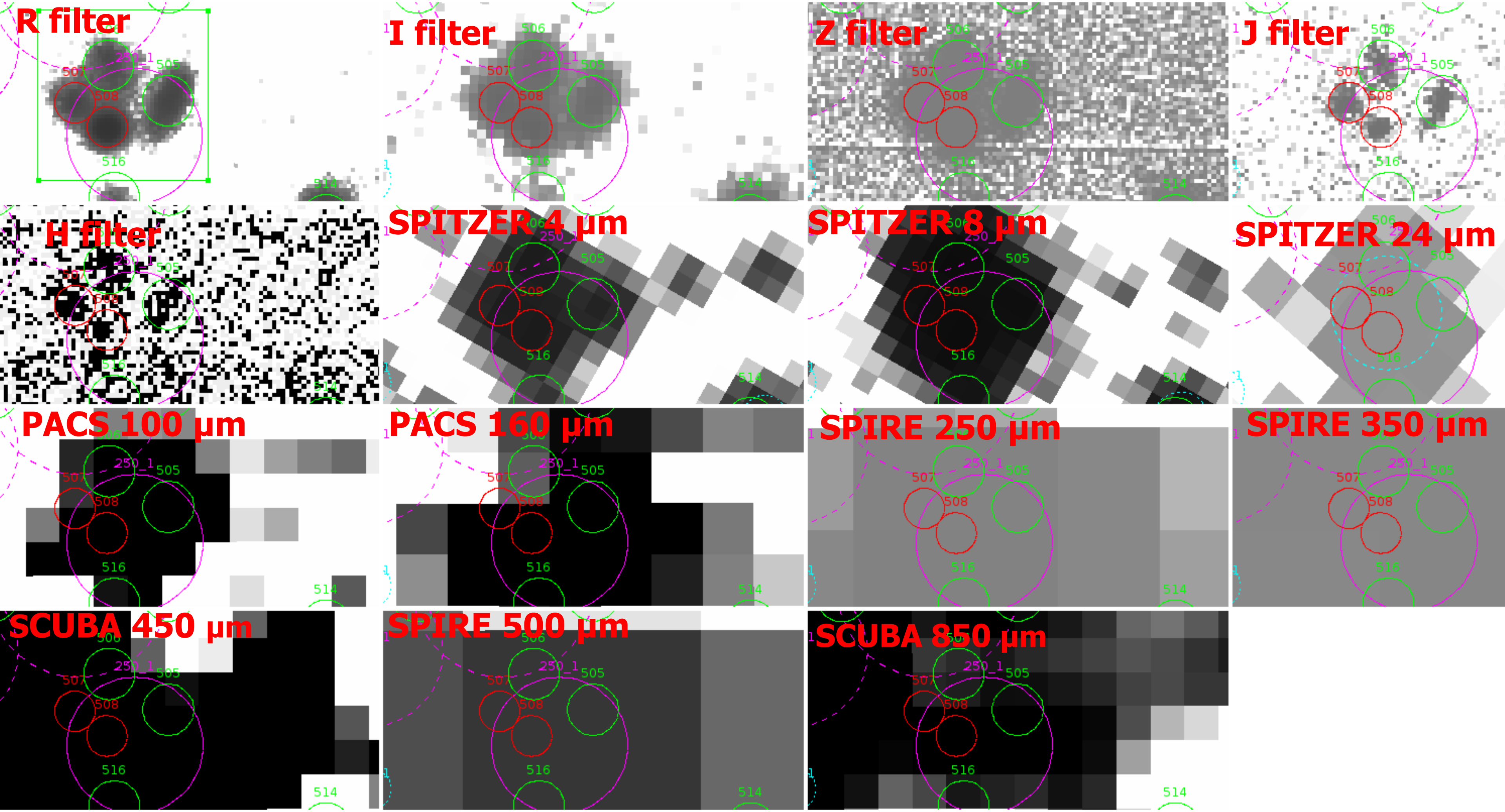


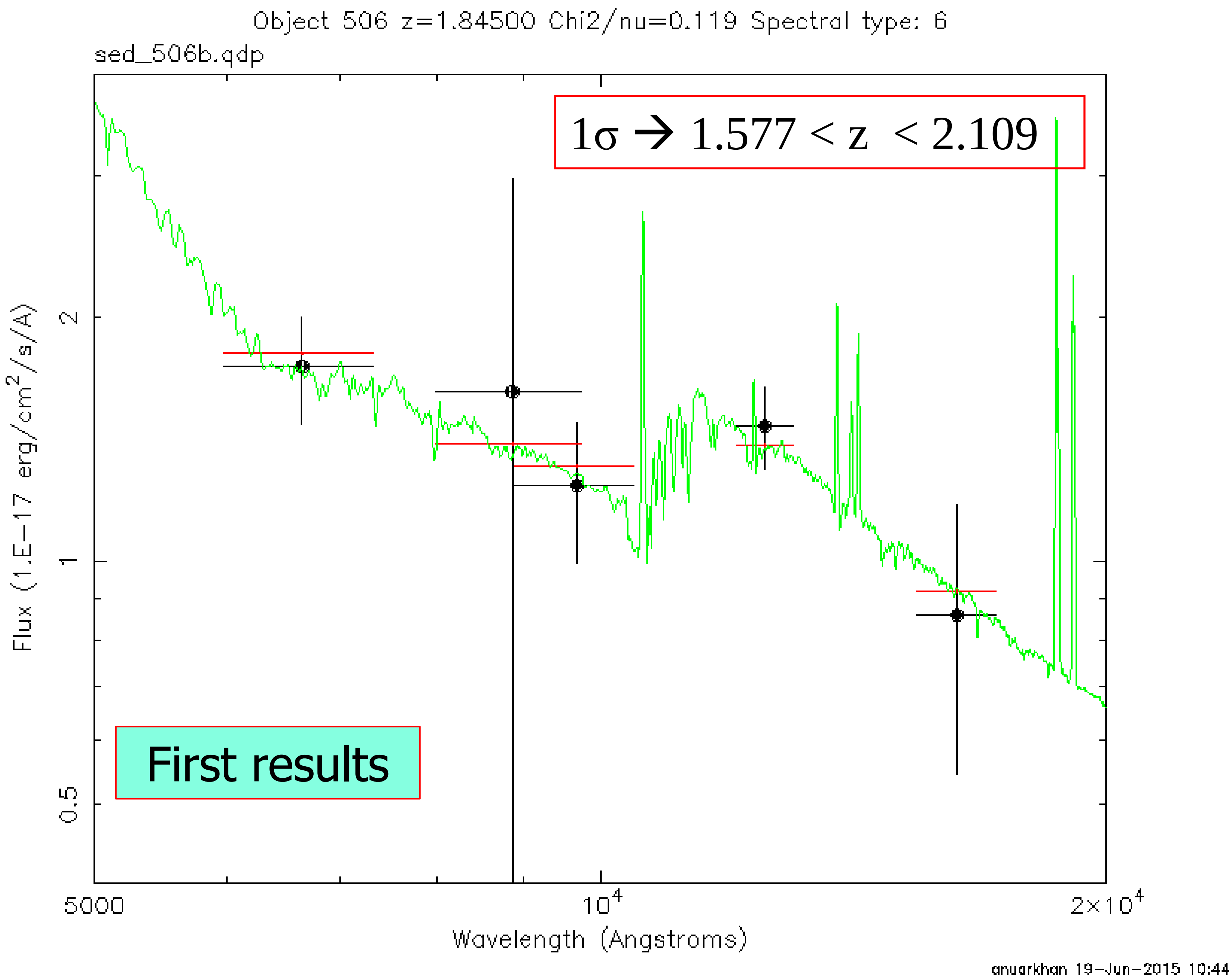


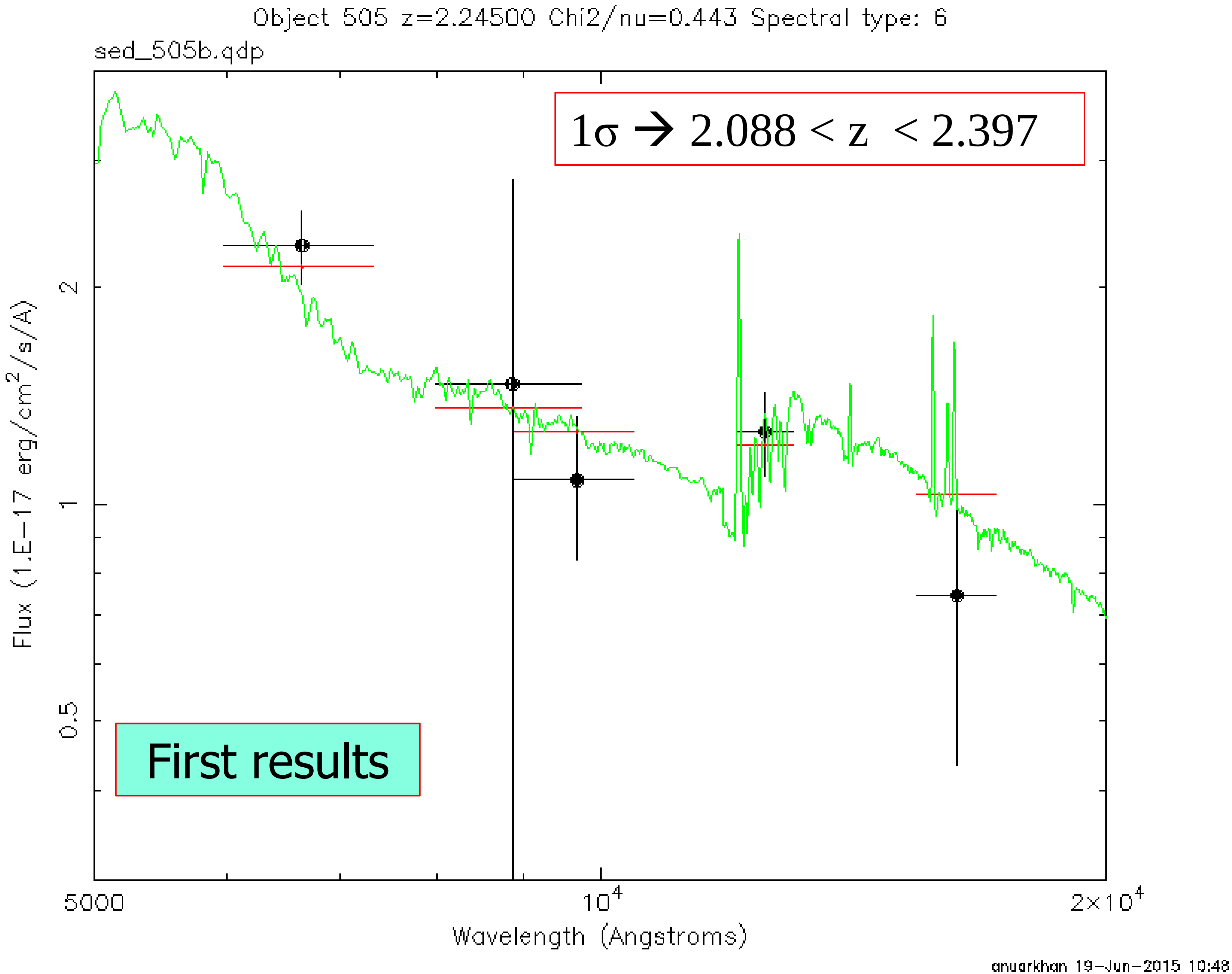
Central QSO z = 1.74

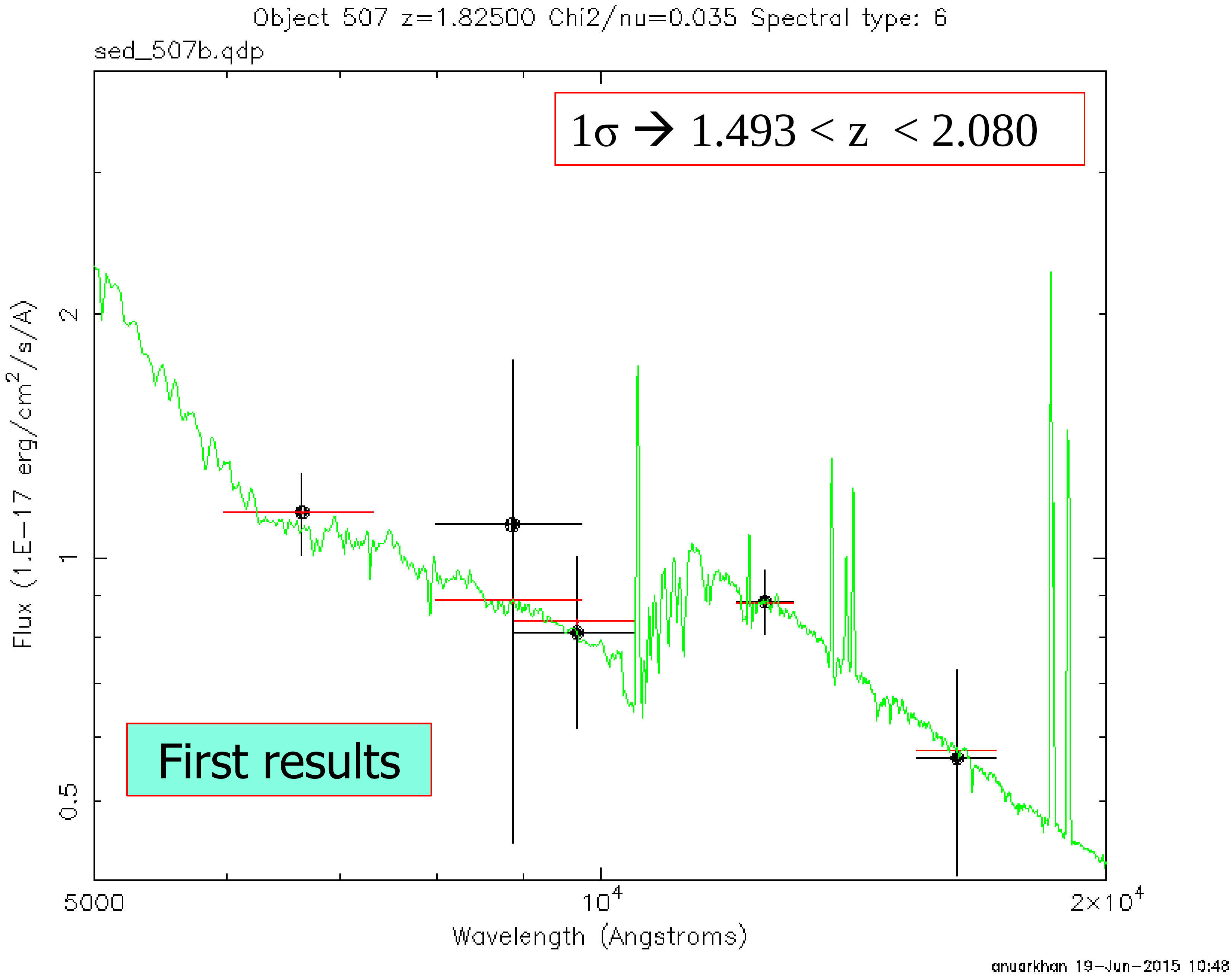
3.5 arcsec

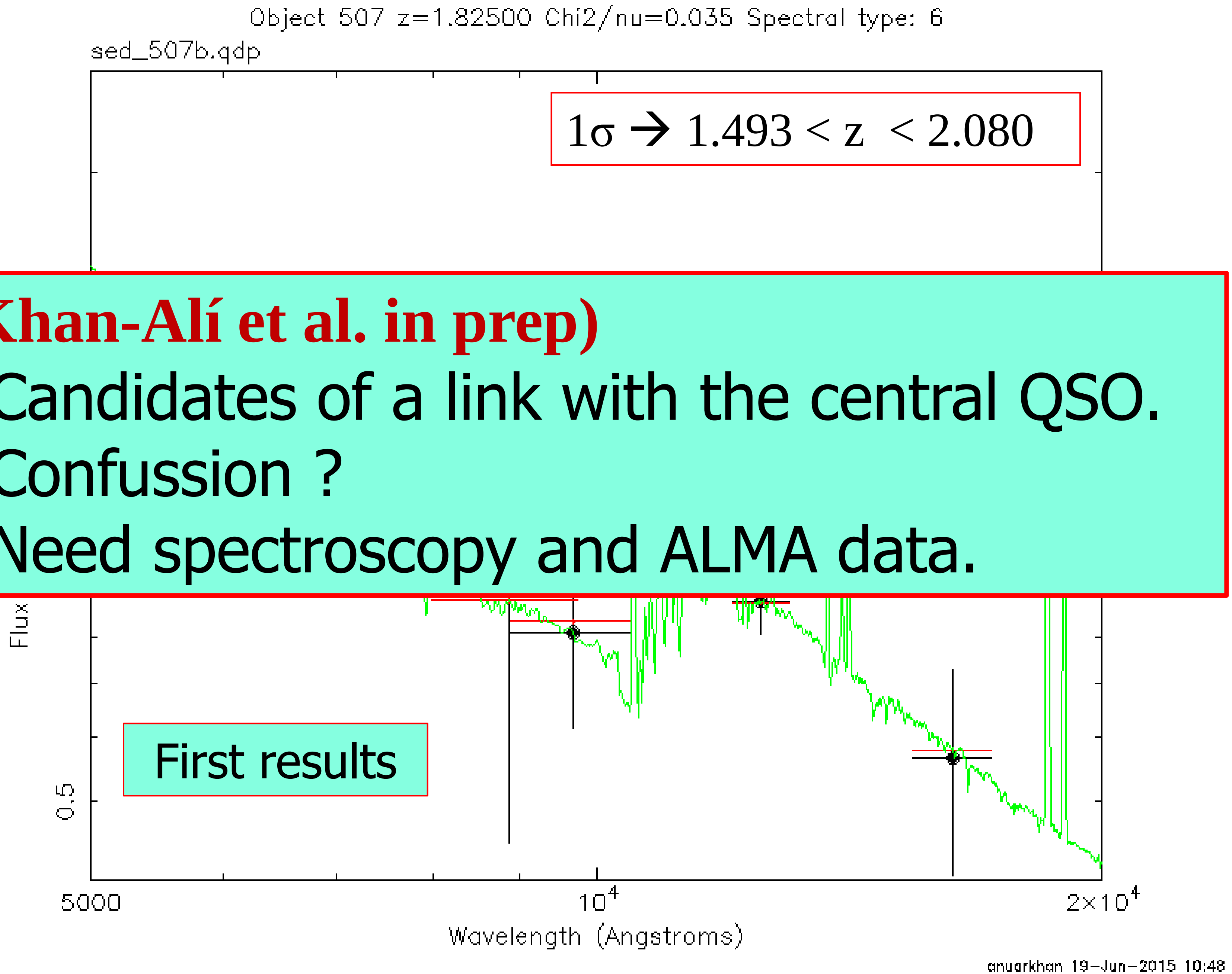
Present and future work




Object 506 z=1.84500 Chi2/nu=0.119 Spectral type: 6
sed_506b.qdp
1σ → 1.577 < z < 2.109
First results
Flux (1.E−17 erg/cm2/s/A)
2
1
0.5
5000
10^4
2×10^4
Wavelength (Angstroms)
anuarkhan 19−Jun−2015 10:44


Object 505 z=2.24500 Chi2/nu=0.443 Spectral type: 6
sed_505b.qdp
1σ → 2.088 < z < 2.397
First results
Flux (1.E−17 erg/cm^2/s/A)
2
1
0.5
5000
10^4
2×10^4
Wavelength (Angstroms)
anuarkhan 19−Jun−2015 10:48


Object 507 z=1.82500 Chi2/nu=0.035 Spectral type: 6
sed_507b.qdp
1σ → 1.493 < z < 2.080
First results
Flux (1.E−17 erg/cm2/s/A)
2
1
0.5
5000
10^4
2×10^4
Wavelength (Angstroms)
anuarkhan 19−Jun−2015 10:48



(Khan-Alí et al. in prep)

- Candidates of a link with the central QSO.
- Confussion ?
- Need spectroscopy and ALMA data.

Summary

- 5 **X-ray-obscured QSOs** at z~2.
- Rest-frame UV-FIR QSO **SED** and their **best-fits**.

- We do **not know the masses of their host galaxies**, but their **BH masses** and their **high SFR lead us to conclude** that they are already **very massive**.

- We are working to get SMG with **an association** with the **central QSOs**.

- We have found some **good candidates** with **a photo z compatible** with the central **QSO**.

- We **need spectroscopy** and/or **ALMA** data for these candidates.

Thank you