The Properties of Extremely Red Quasars Observed During the Epoch of Peak Galaxy Formation

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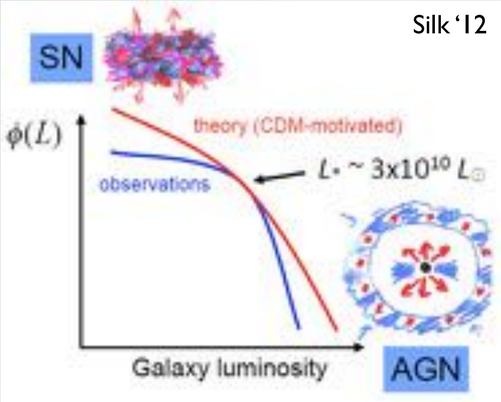
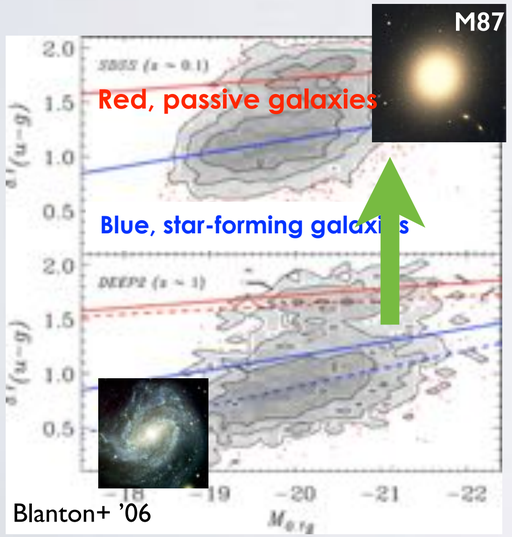
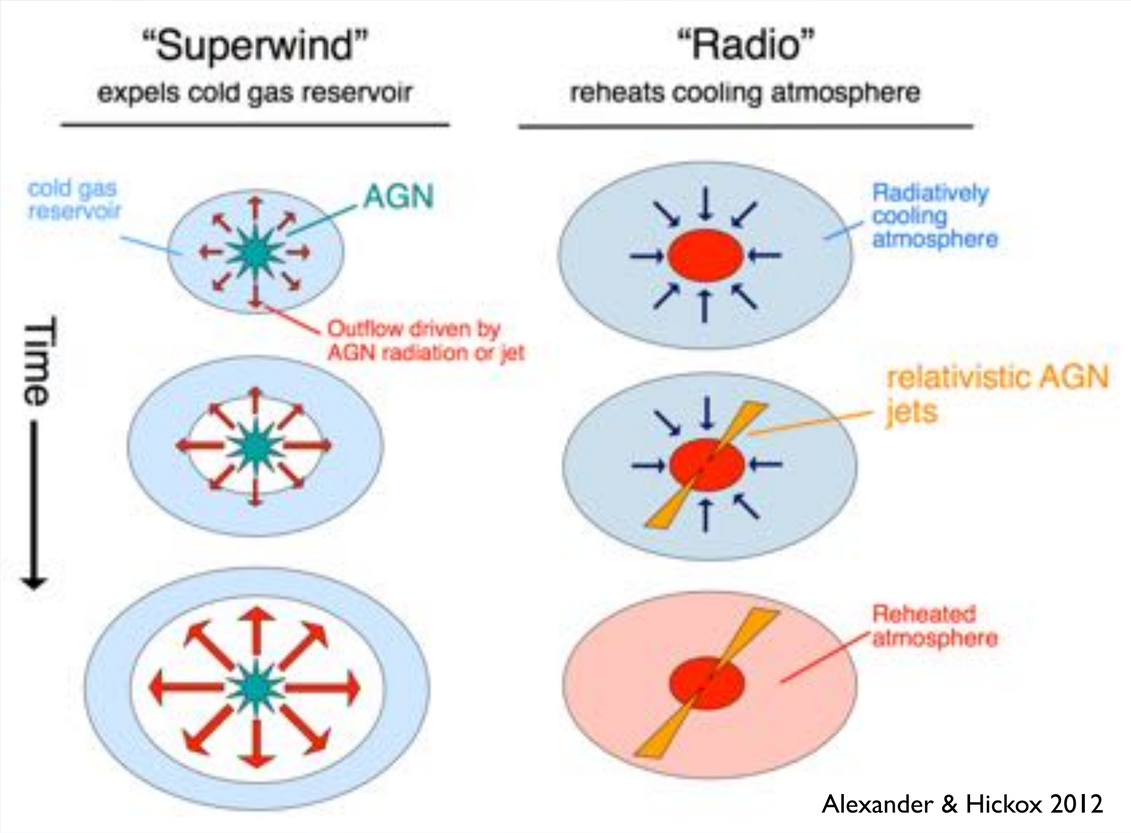
PRINCETON UNIVERSITY | Department of Astrophysical Sciences

A KEY GOAL OF X-RAY ASTRONOMY : UNVEILING RADIATIVE/ MECHANICAL FEEDBACK — THE SUPPRESSION OF STAR FORMATION

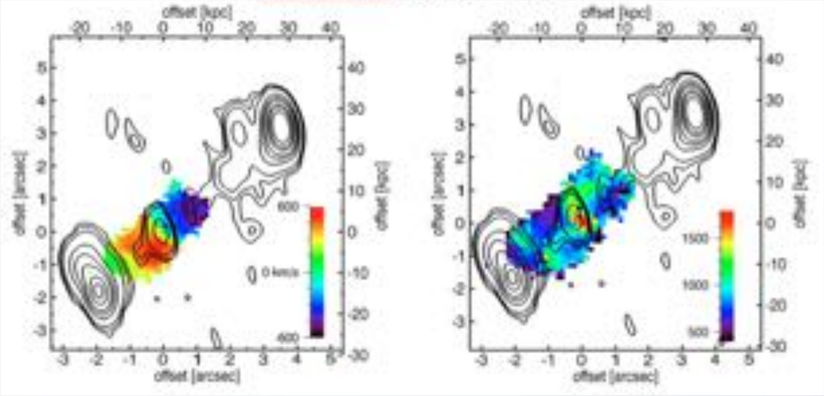






Radio mode case is clear!

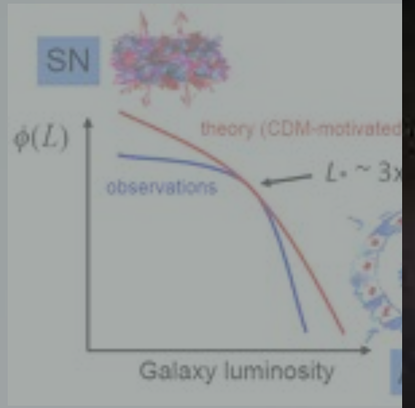
Bubbles in clusters

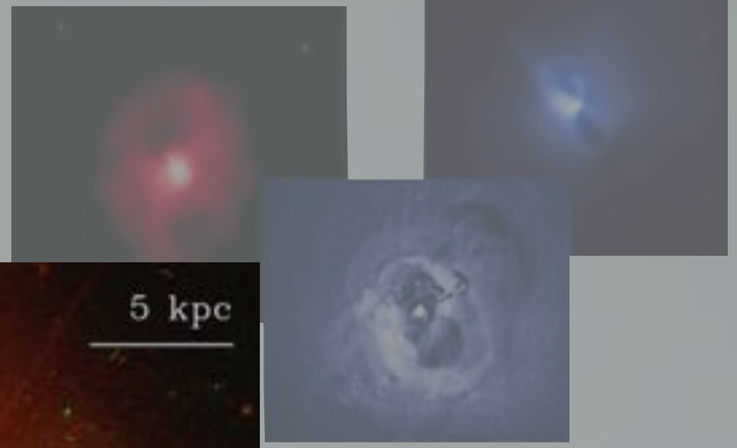


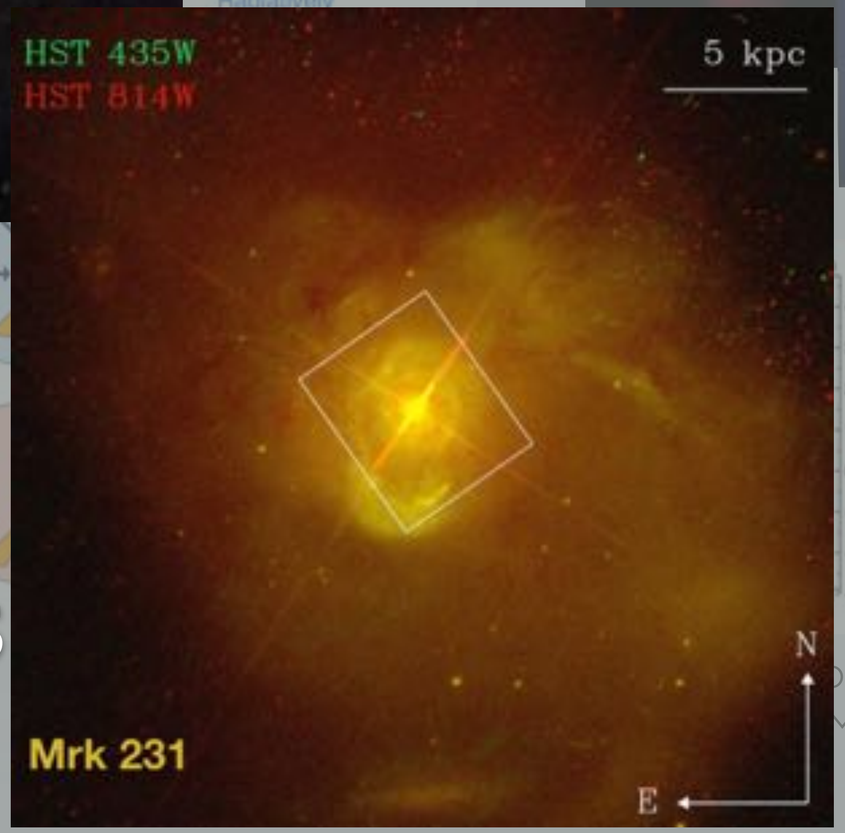
Powerful radio jets entrain & remove galaxy ISM (Nesvadba+08)

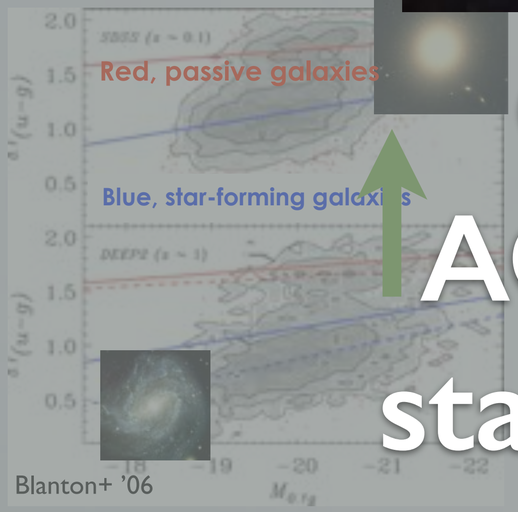
A KEY GOA VEILING RADIATIVE/
MECHANIC ION OF STAR FORMATION

Radio mode case is clear!



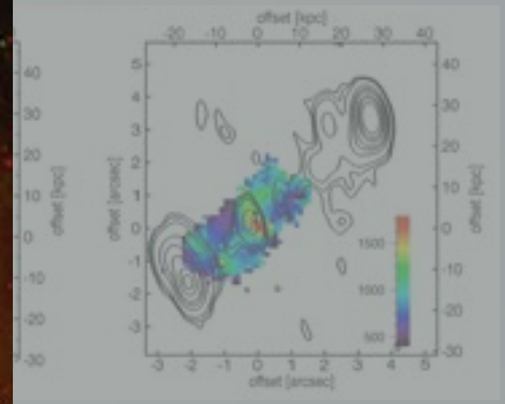






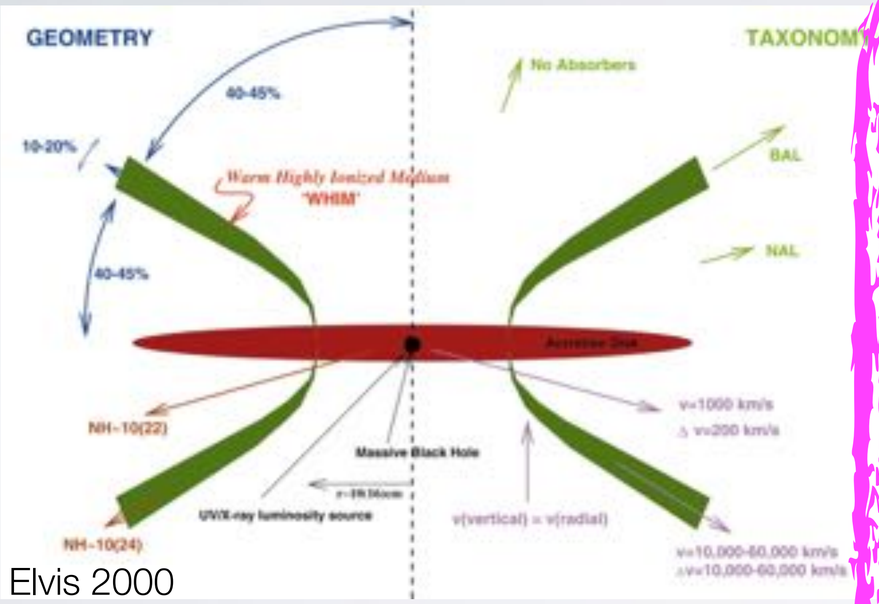
Blanton+ '06

Challenge: AGN-winds & starburst winds

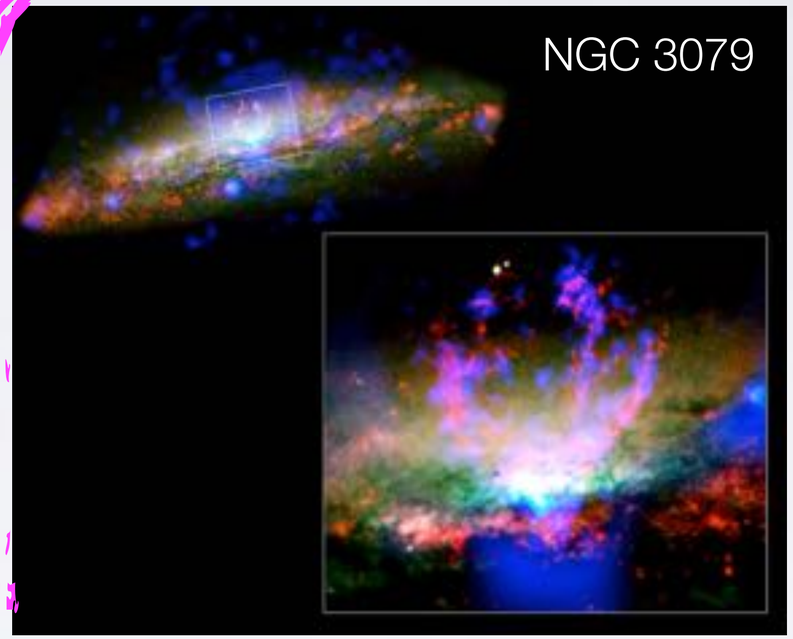


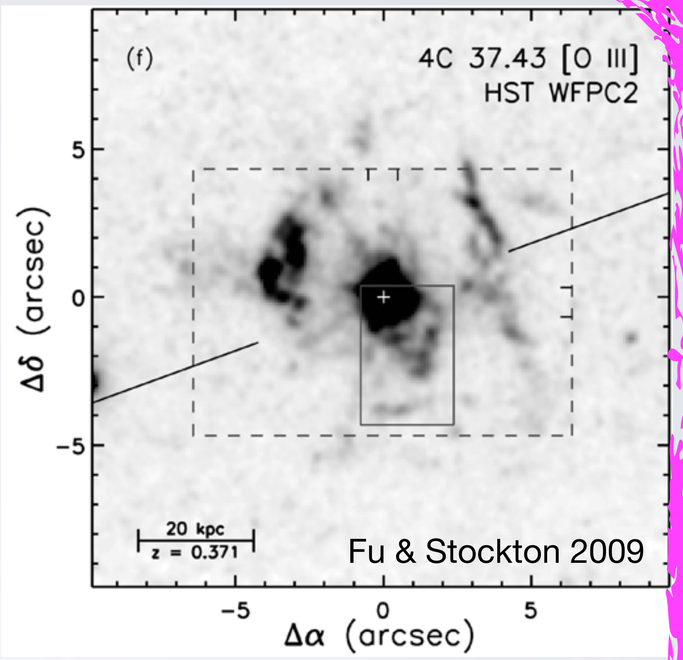
o jets entrain & remove
M (Nesvadba+08)

OUTFLOWS ARE A COMPLEX, MULTI-SCALE, MULTI-PHASE PHENOMENA



Elvis 2000





Broad-line region scales

Narrow-line region scales

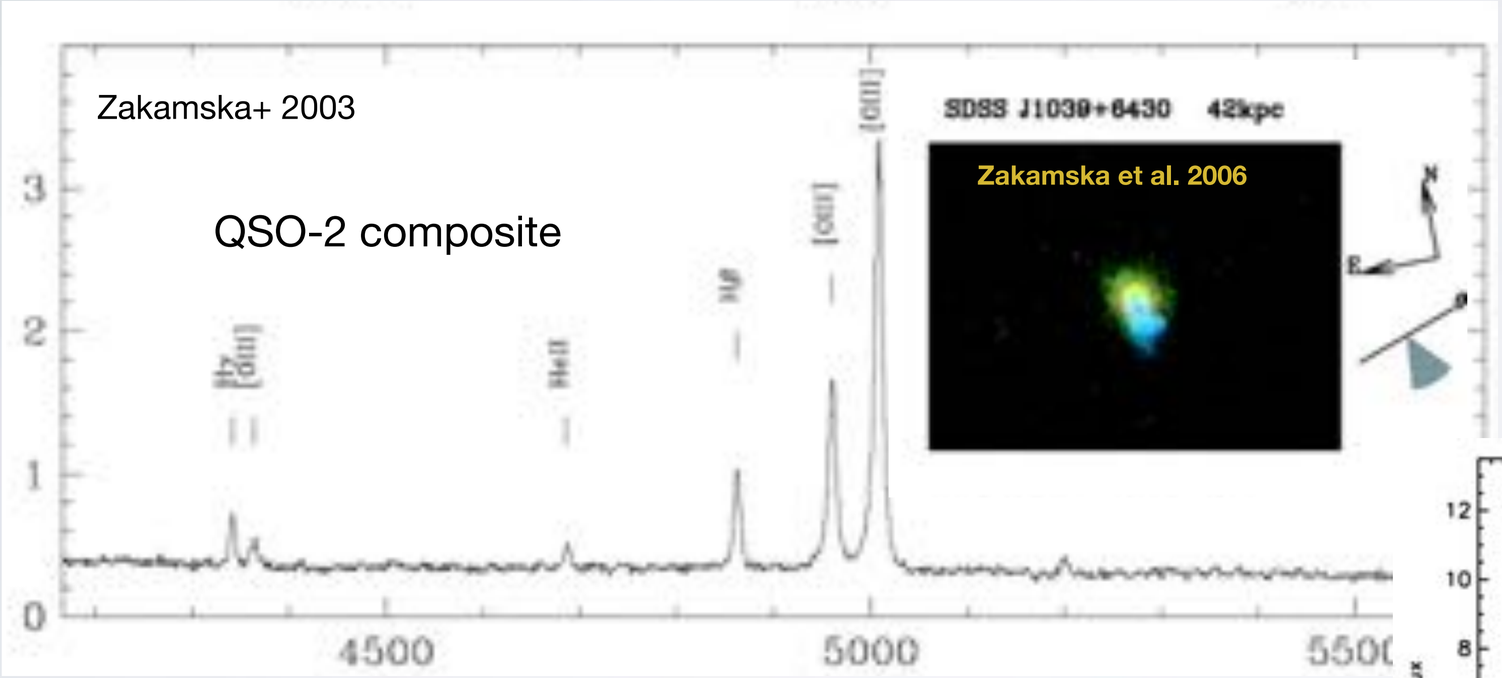
Extended narrow-line region scal

0.1 pc

0.1 kpc

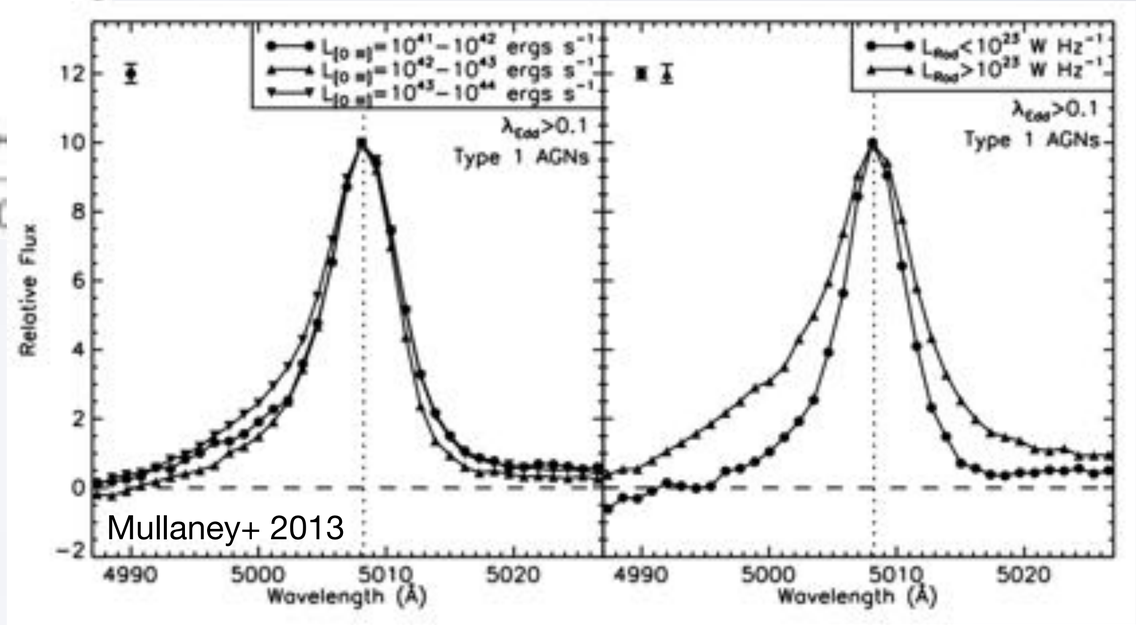
0.1 Mpc

LUMINOUS OBSCURED QUASARS IN SDSS

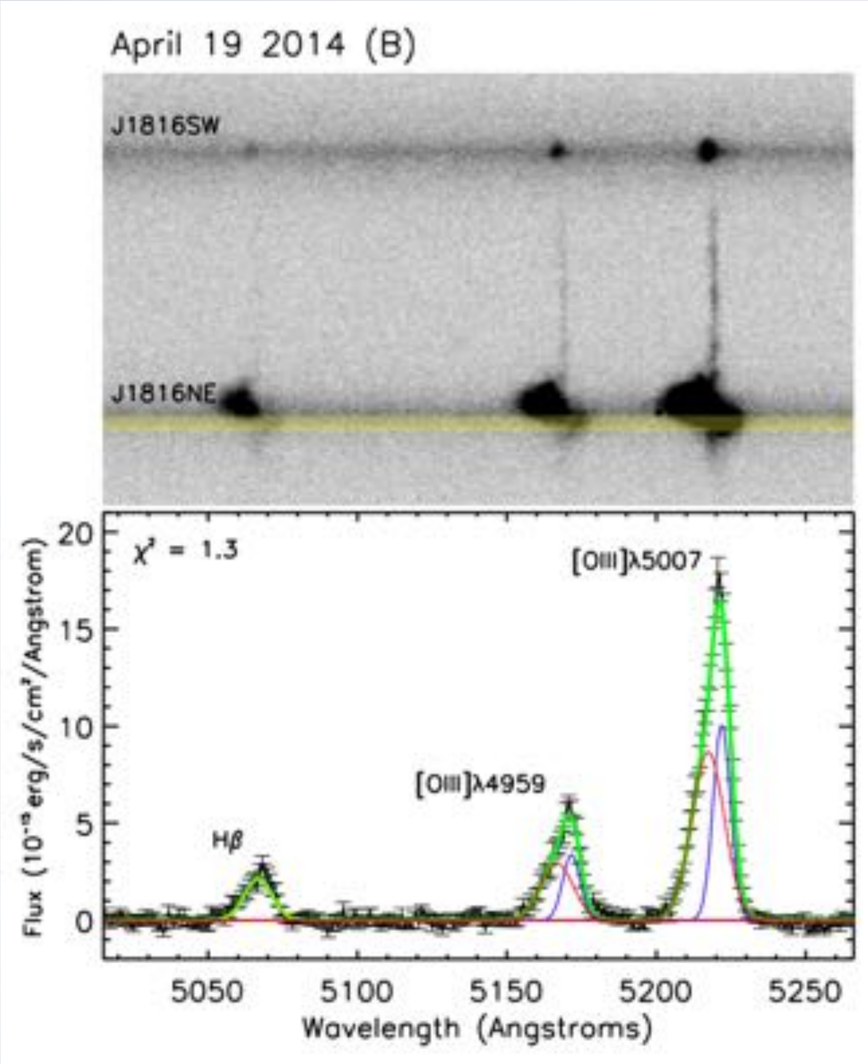


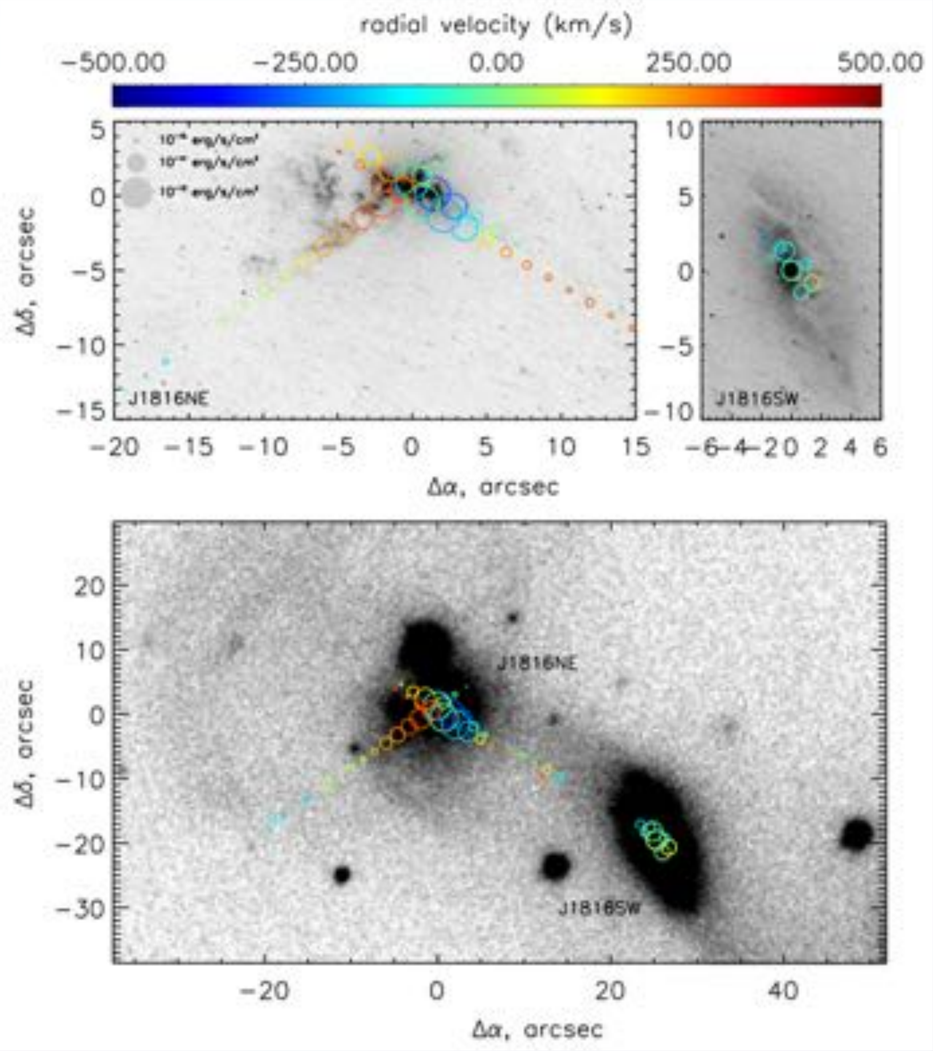
Can use the strong and ubiquitous [OIII] λ5007 to select targets and estimate AGN luminosities

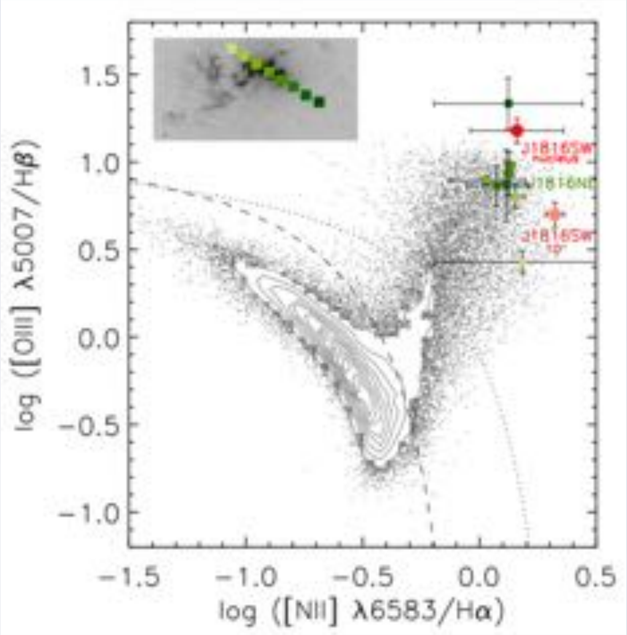
Asymmetric [OIII] profiles from SDSS spectra are often associated with outflows



SPATIALLY RESOLVED [OIII] OUTFLOWS

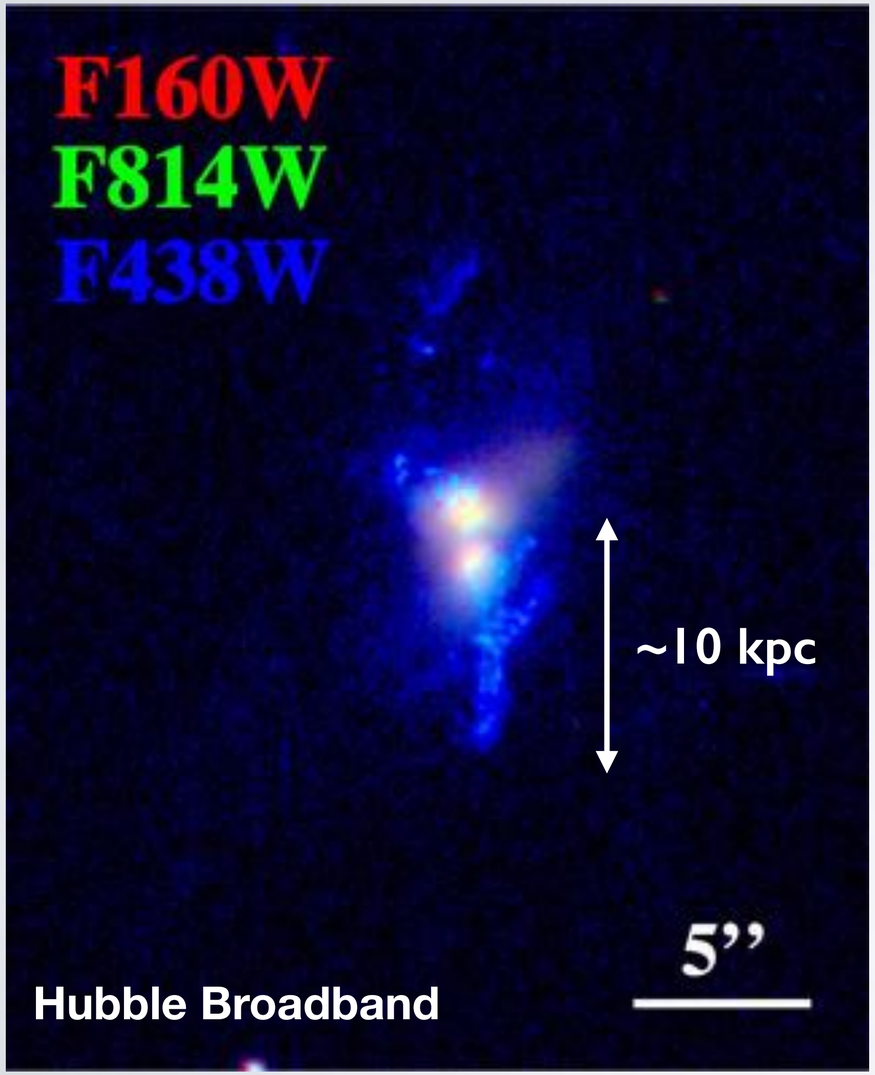


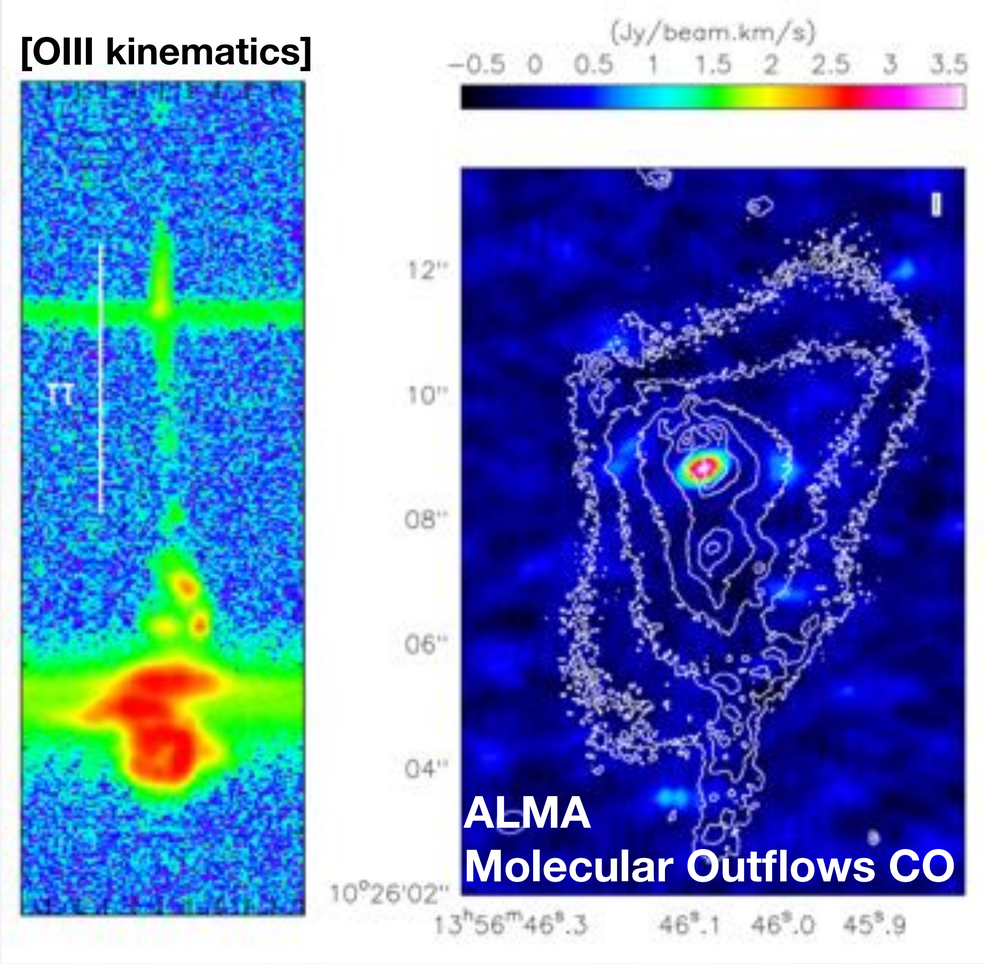




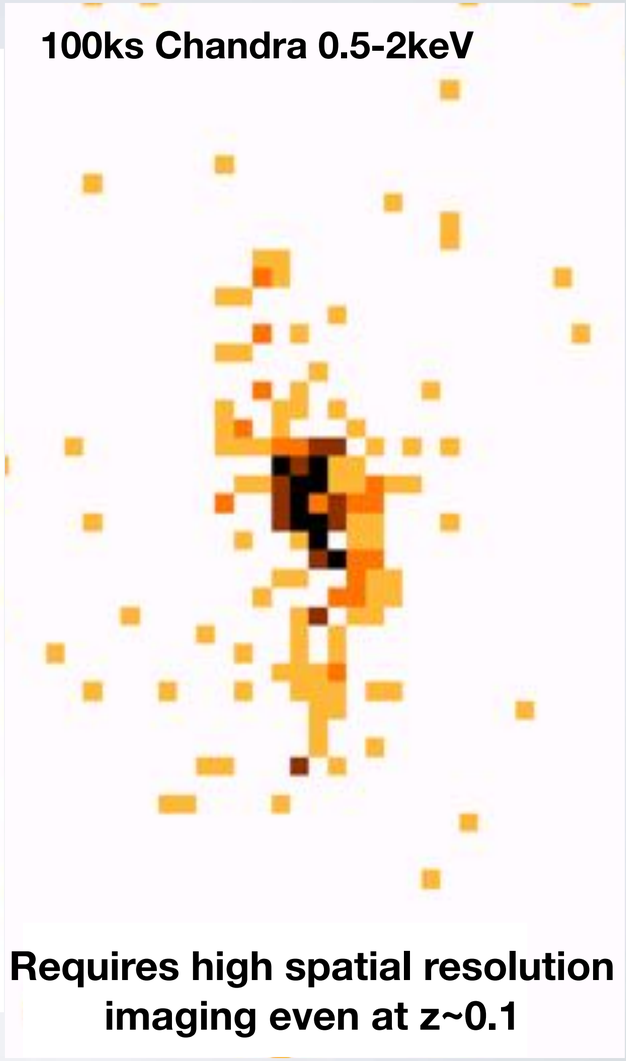
Spatially resolved ionized outflows and their kinematics in SDSS AGN (Hainline+'16)

MULTI WAVELENGTH FOLLOW-UP OF KPC-SCALE OUTFLOWS



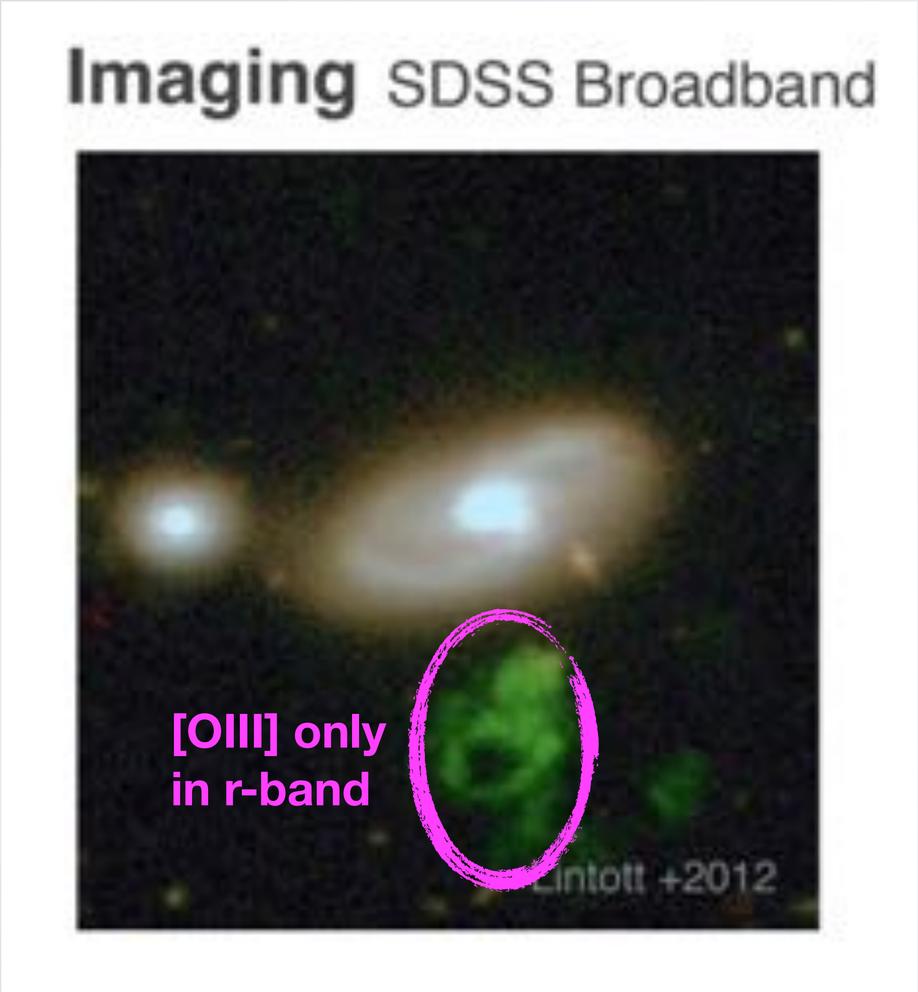


Greene+ 2013; Greene+2014; Sun+16; Broome+in-prep

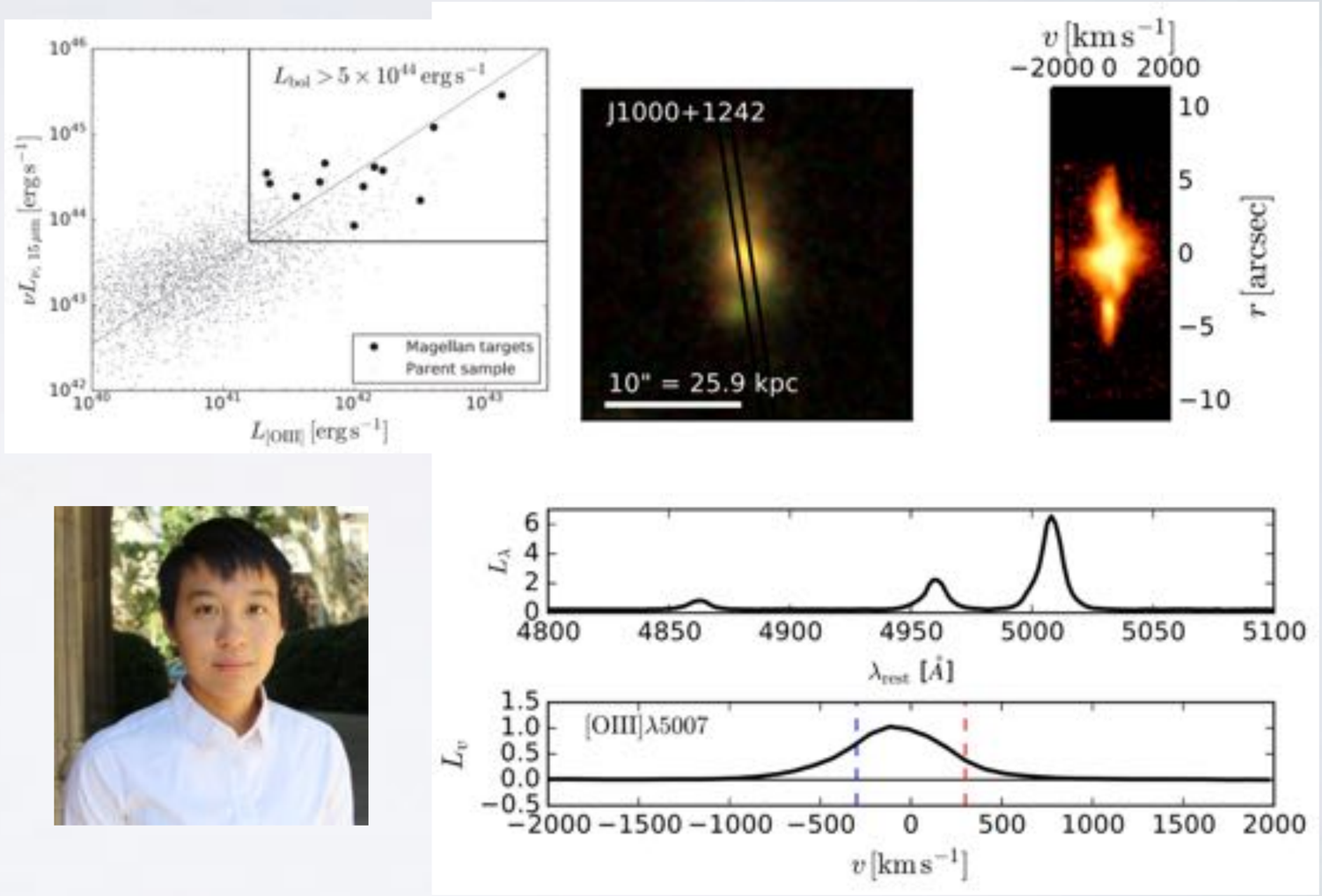


Requires high spatial resolution imaging even at z~0.1

SEARCHING FOR EXTENDED NARROW LINE REGIONS

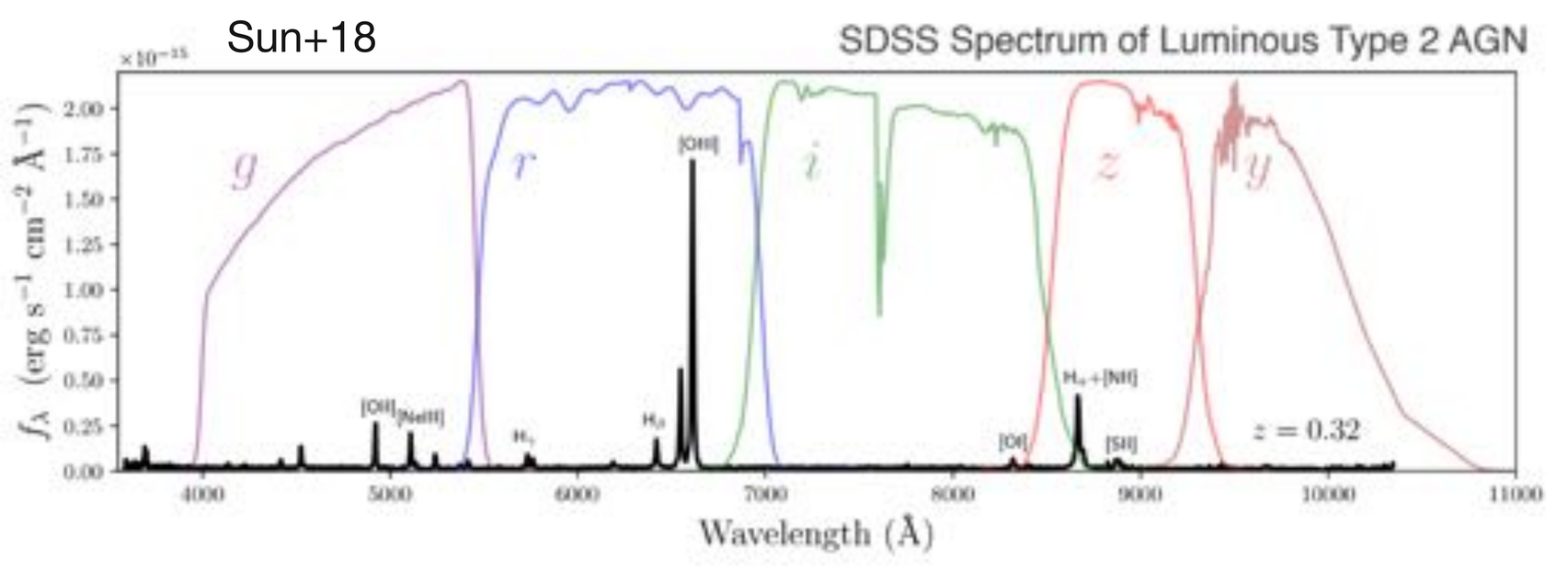


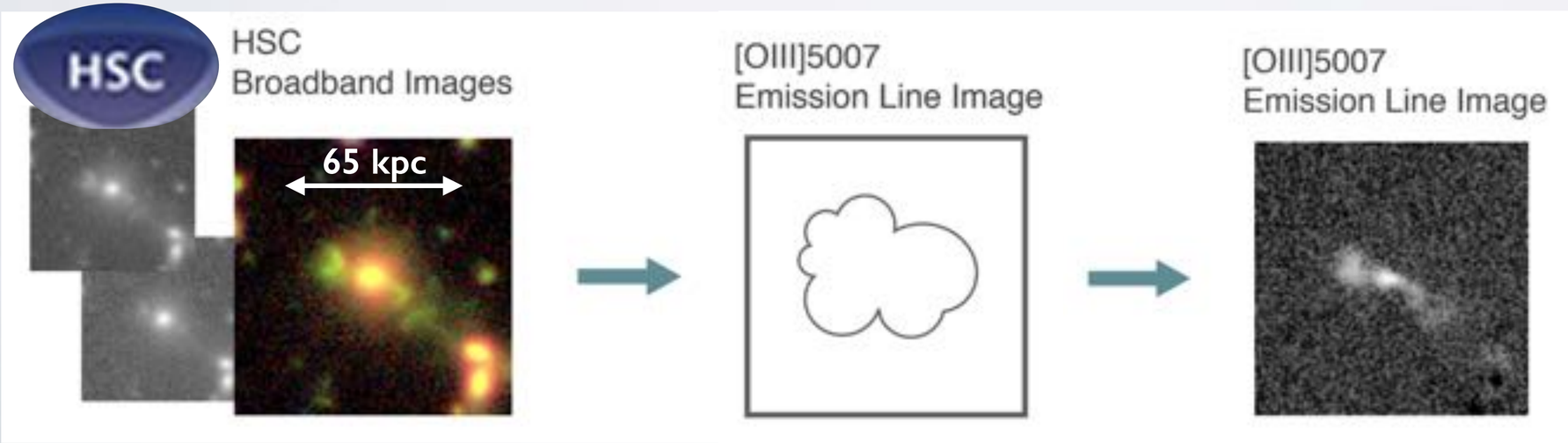
Hanny's Voorwerp

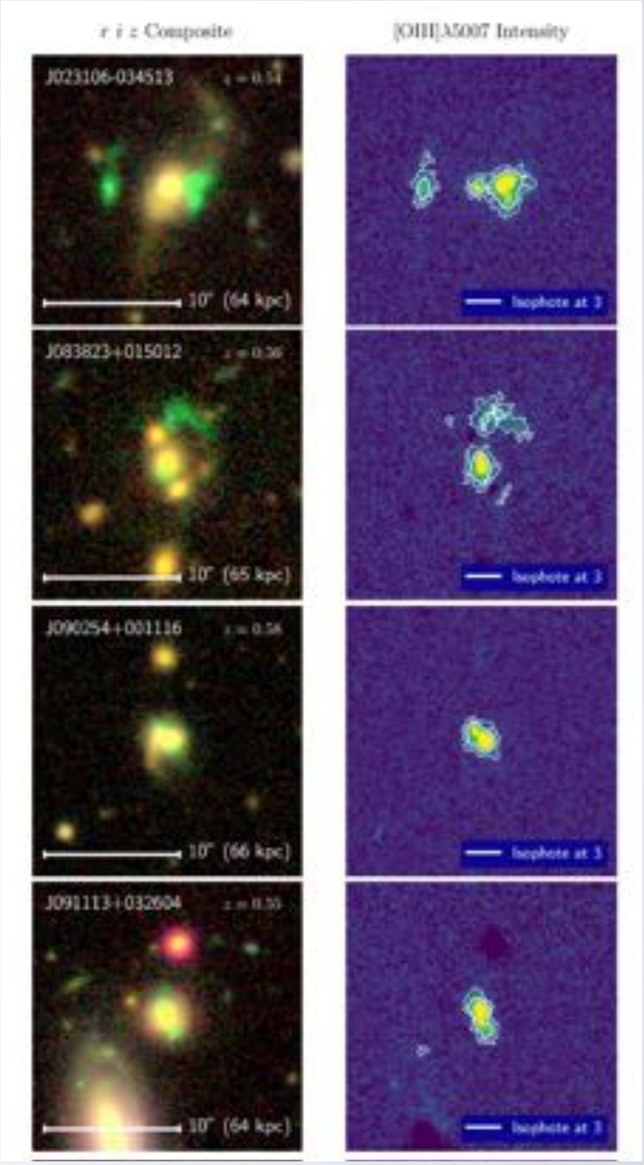


Sun+17

IDENTIFYING EXTREMELY EXTENDED NL-REGIONS AT Z~0.5-1.5







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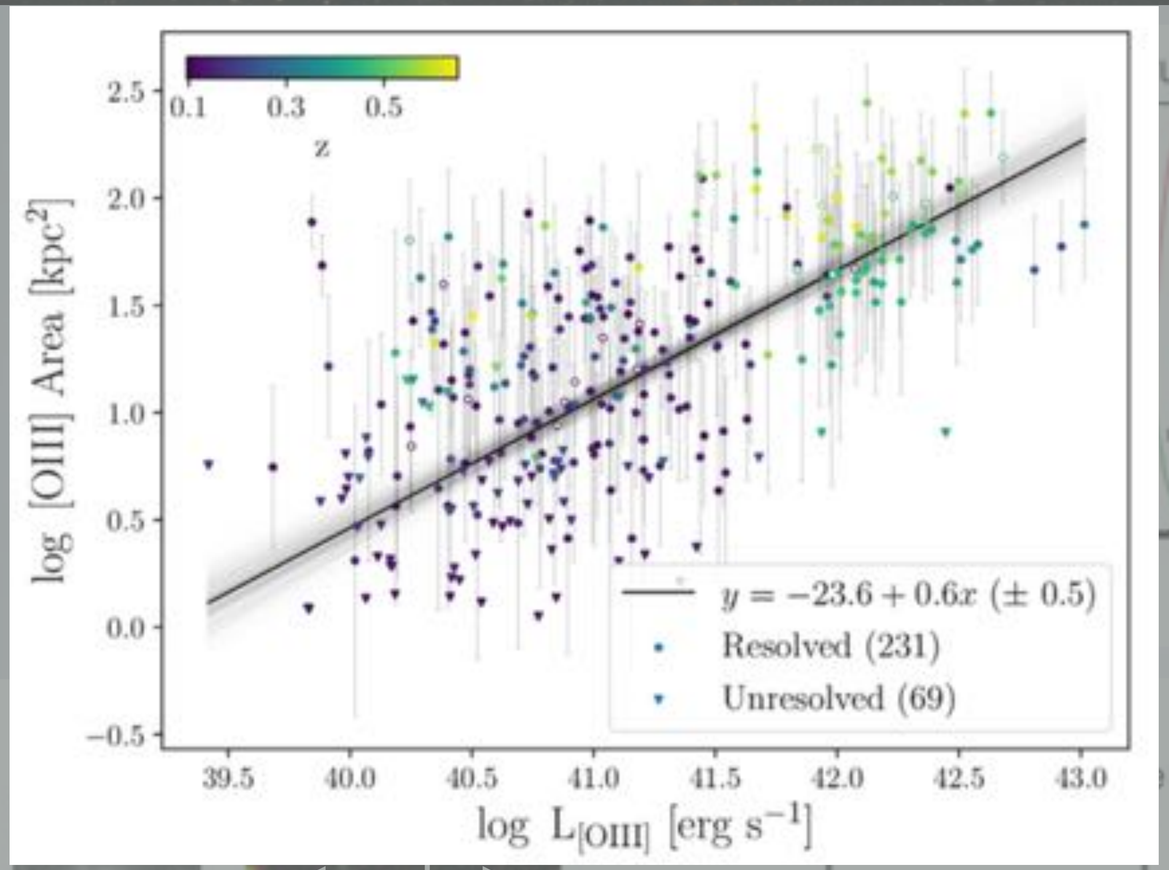
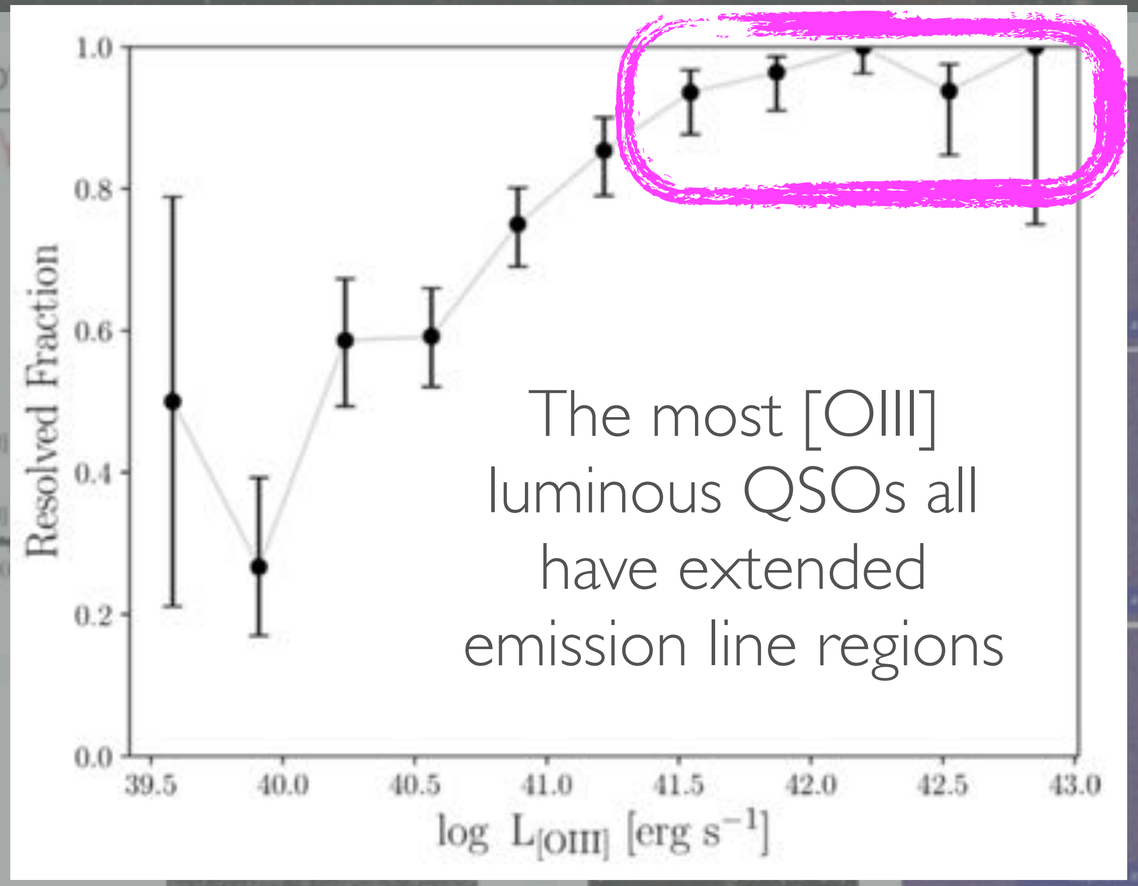
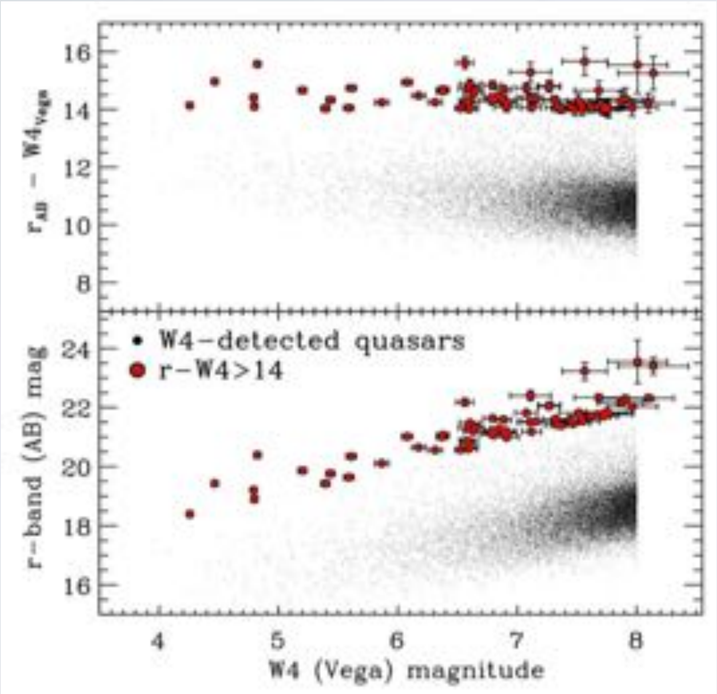
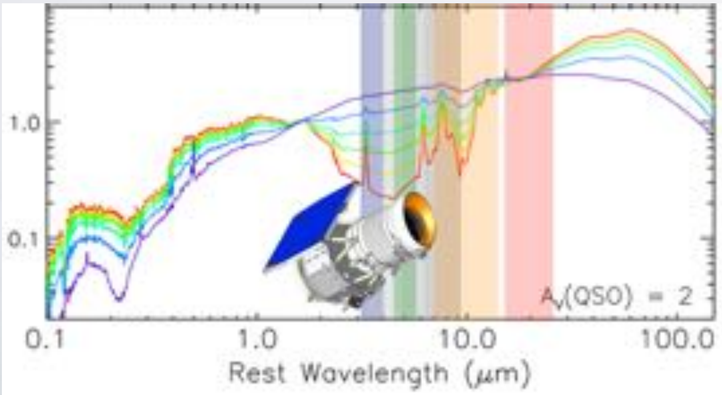


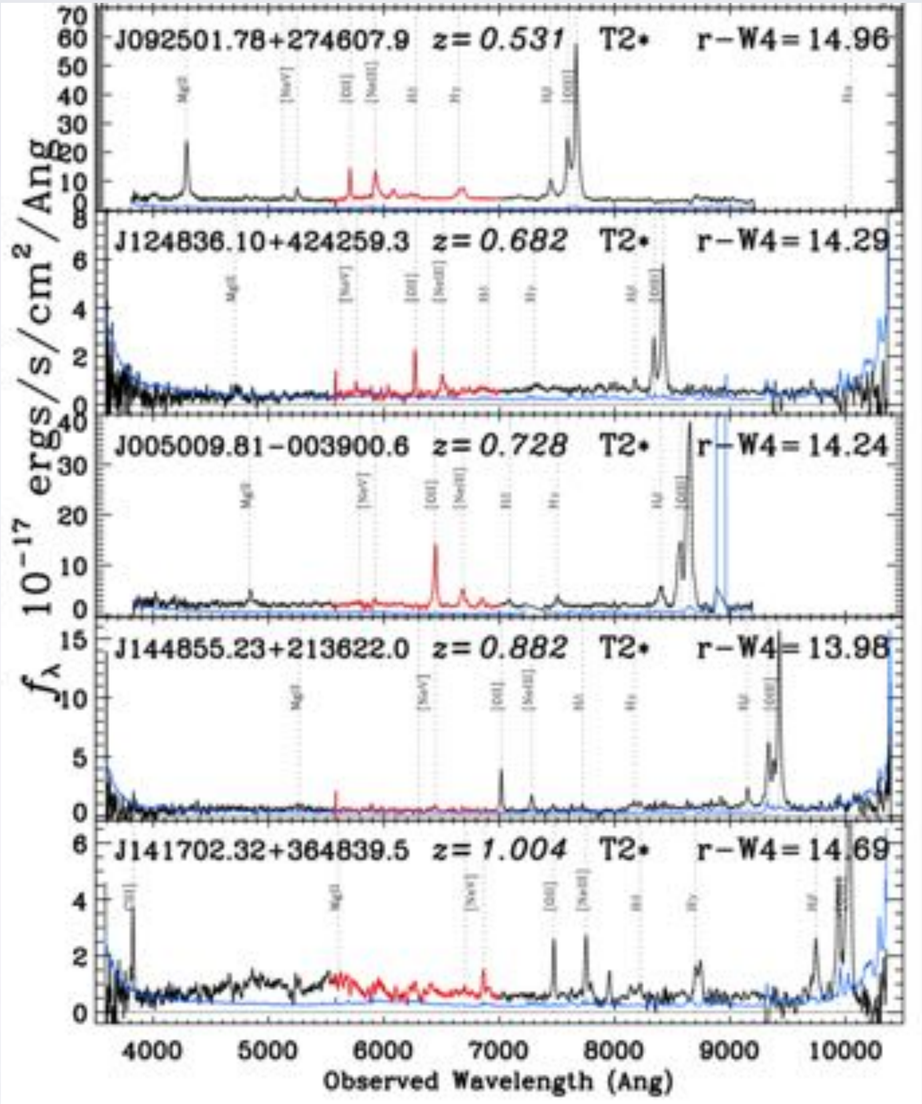


The most [OIII] luminous QSOs all have extended emission line regions

CRANKING UP THE POWER AT HIGH-REDSHIFT…







<u>Extremely Red Quasars (Ross+15; Hamann+17')</u>

At z>2 unusual line properties:

1) very large EWs
2) wingless profiles
3) strange line ratios

Analogs to…

2MASS AGN (Wilkes+)

…& F2M Quasars (Glikman+)

…& DOGs (Dey+)

…& HotDOGs (Stern+)

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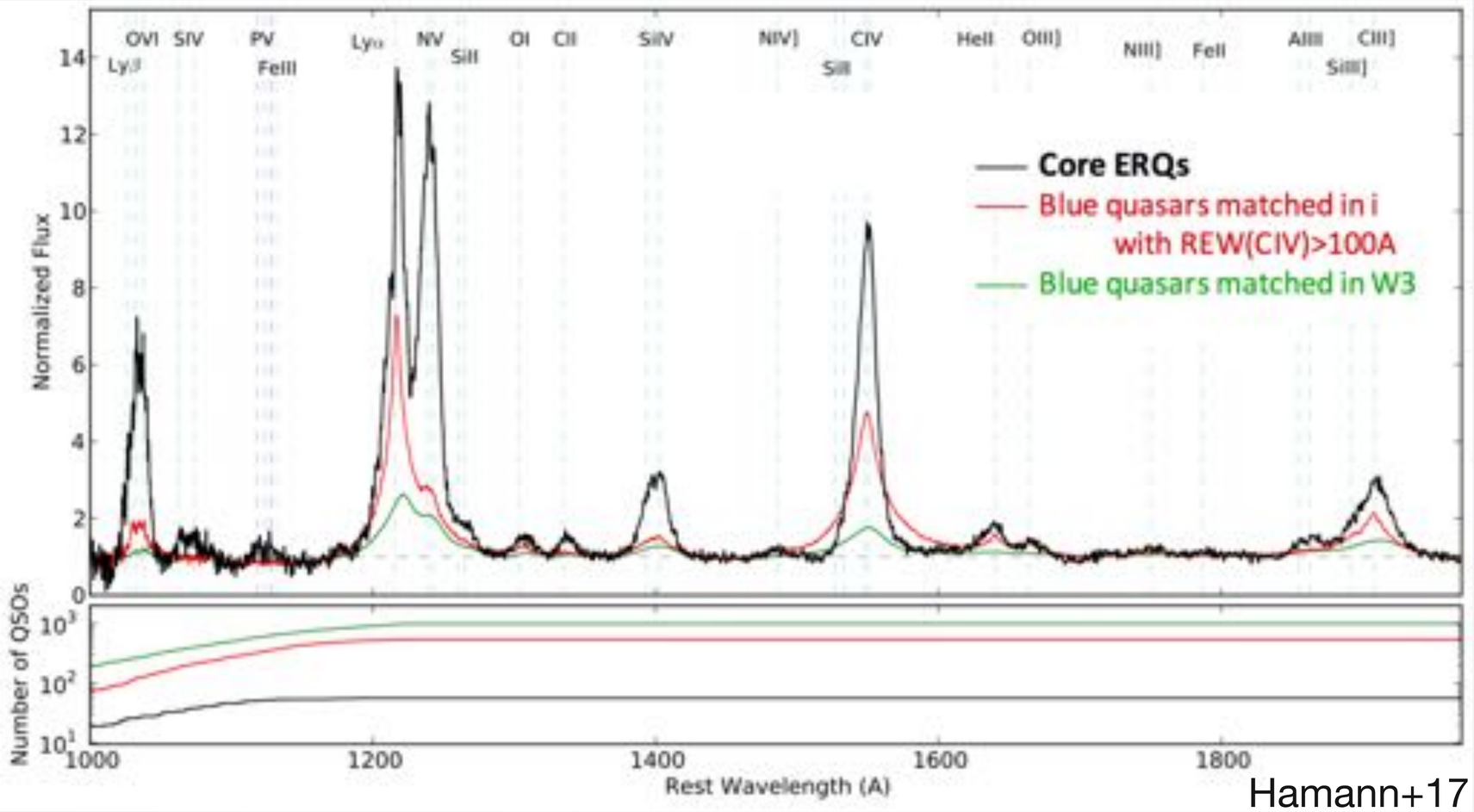

Hamann+17

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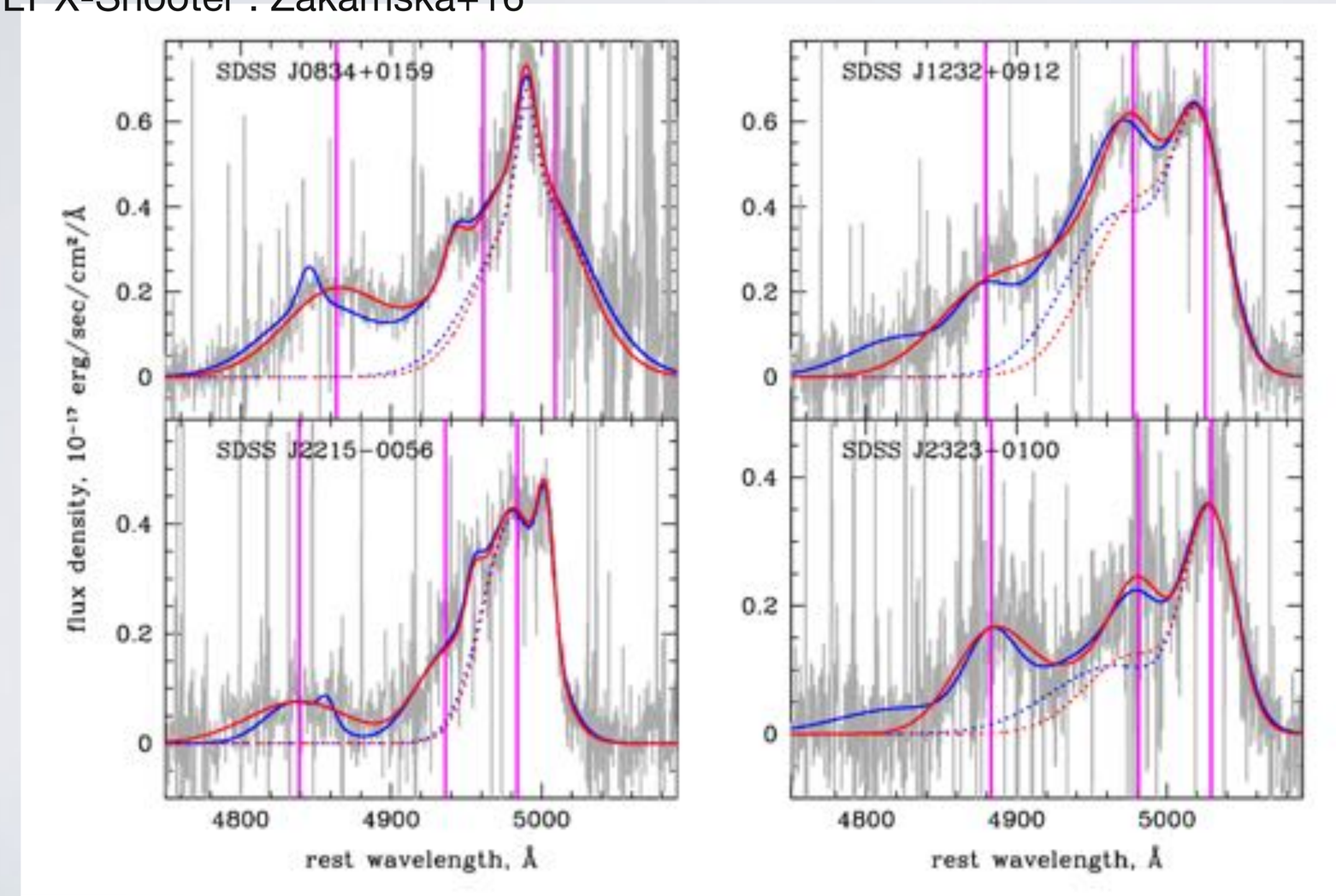
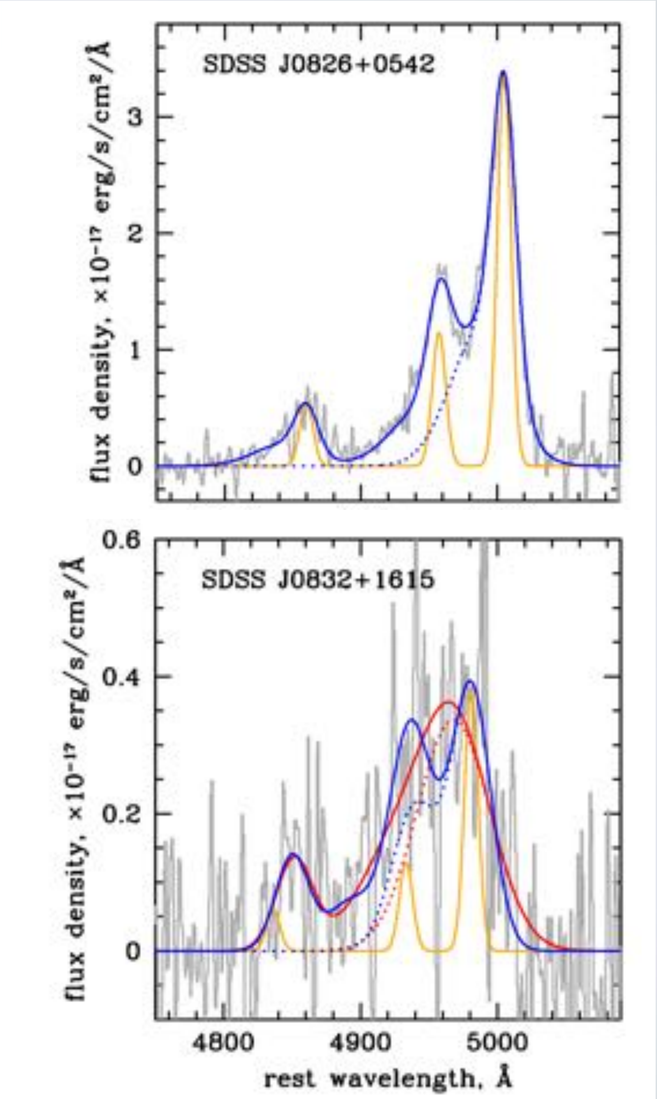
CRANKING UP THE POWER AT HIGH-REDSHIFT…

VLT X-Shooter : Zakamska+16

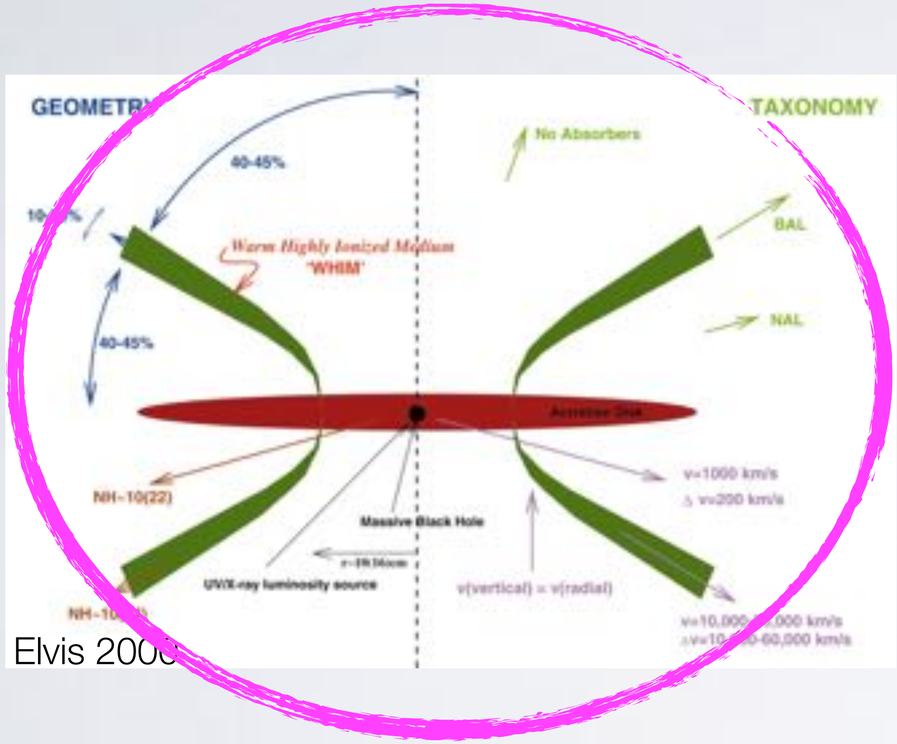




[OIII] velocities ~ 2000—5000 km/s !!

Gemini GNIRS: Goulding+18; Alexandroff+18

OUTFLOW SCALES



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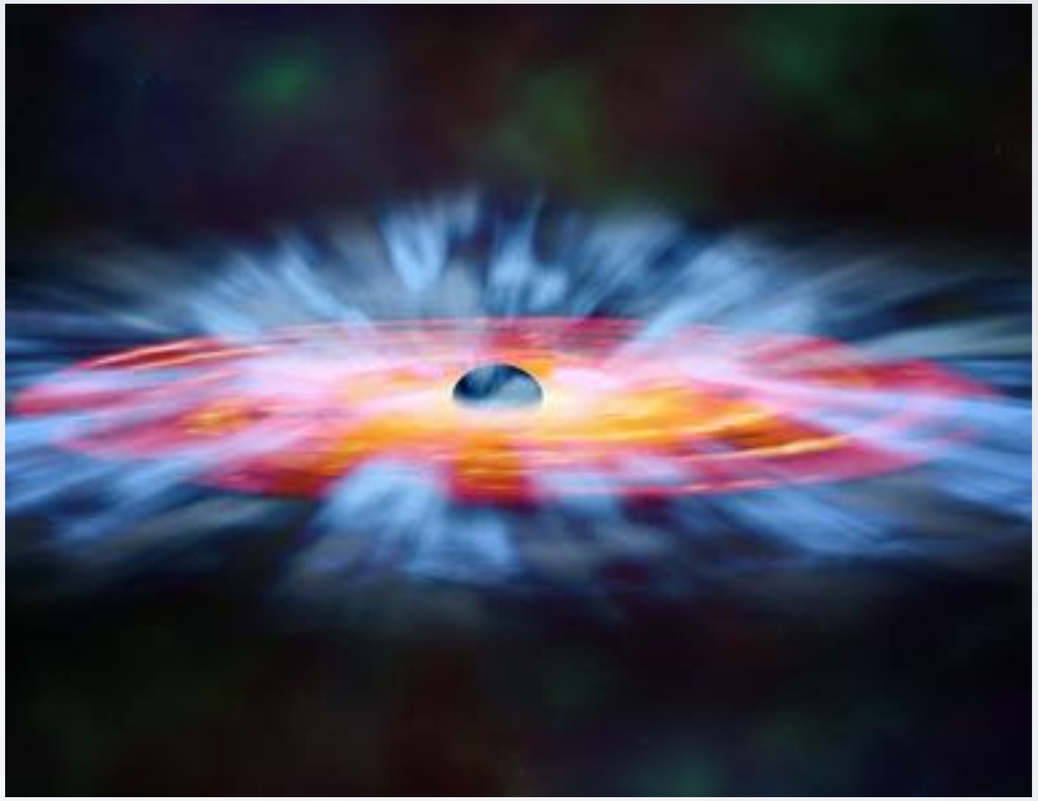

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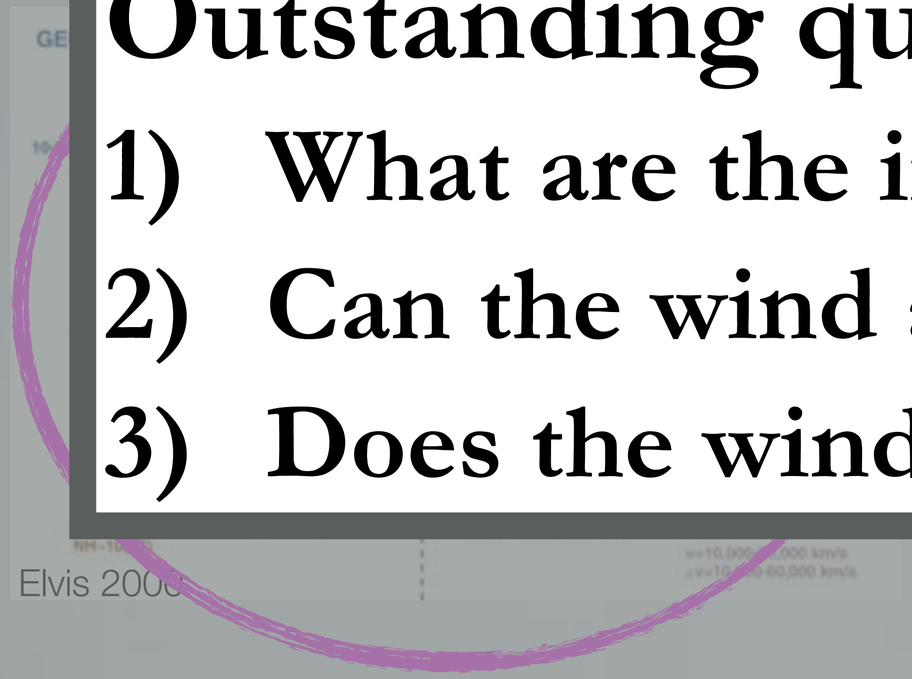
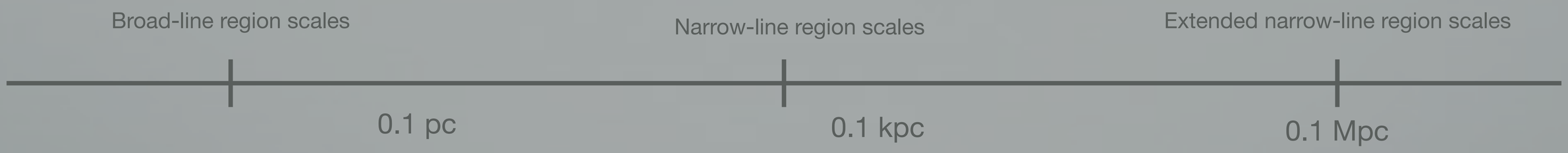
OUTFLOW SCALES



Outstanding questions::

1) **What are the intrinsic luminosities of ERQs?**
2) **Can the wind affect the X-ray emitting corona?**
3) **Does the wind obscure the central BH?**

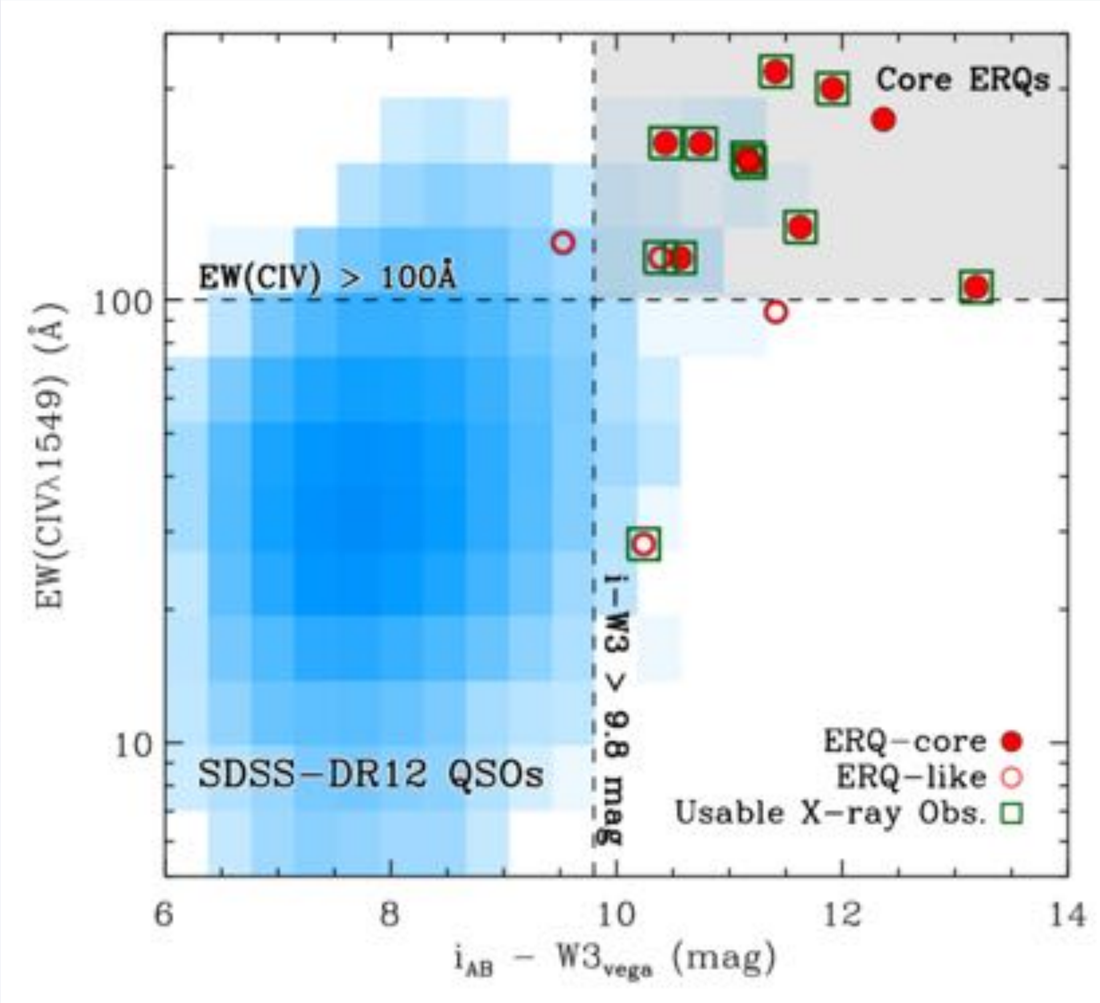


FOLLOW-UP X-RAY OBSERVATIONS OF A PILOT SAMPLE OF ERQS

Pilot Sample of ERQs (Goulding+18b)

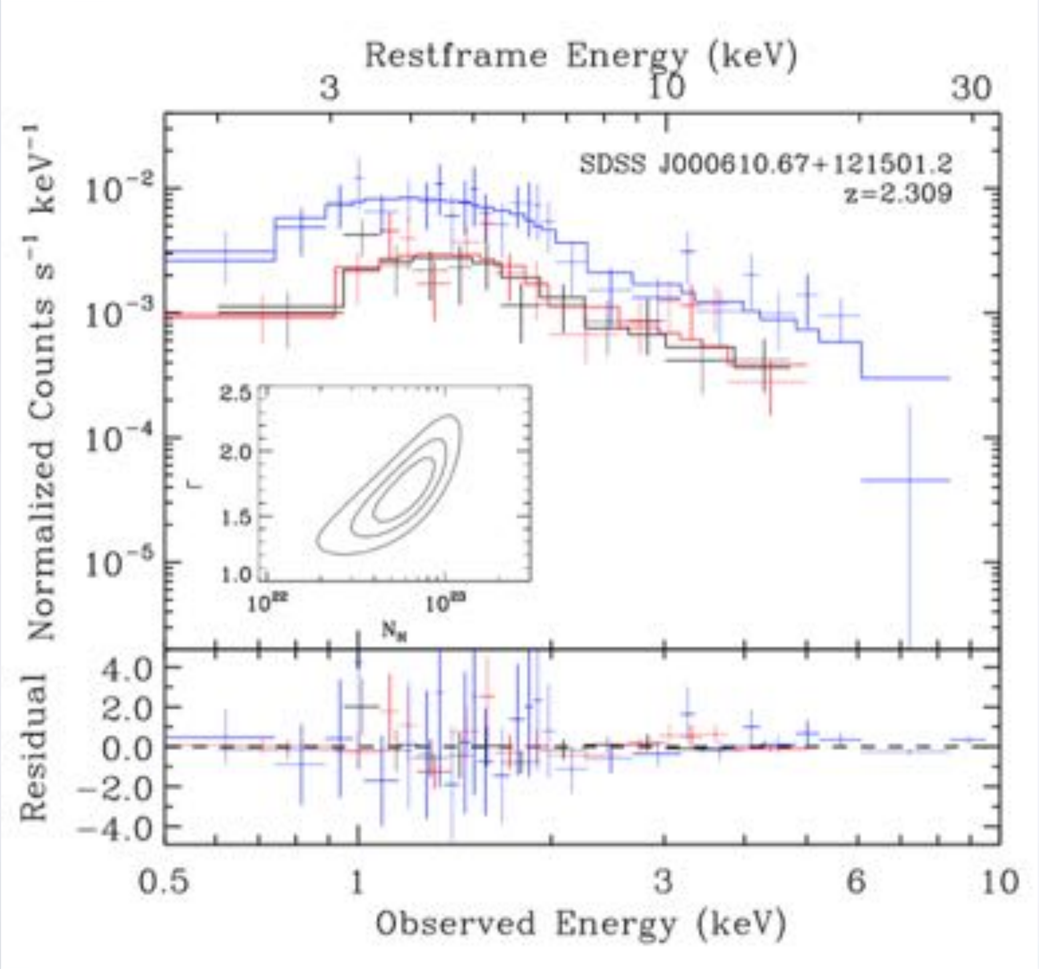
Sample of 14 (16) ERQs at z~3:

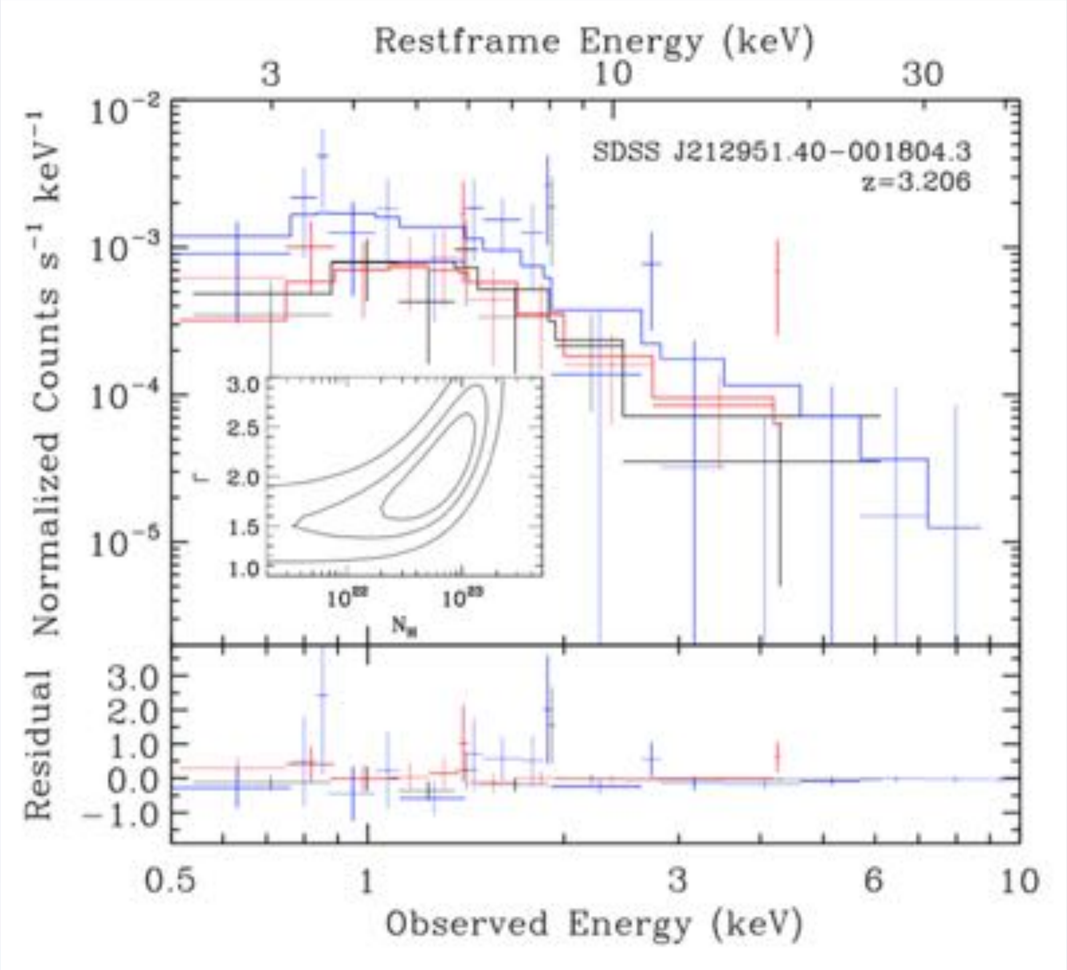
- mixture of CXO/XMM
- 8 we were PI for (15ks)
- 8 archival + serendipitous (5-70ks)
- 6/7 have follow-up NIR spectra
- All 6 show powerful [OIII] outflows (>2000km/s)
- Mid-IR 6um luminosities ~10^{47} erg/s



A DIFFICULT POPULATION TO OBSERVE…

Majority were only weakly detected with 10-50 counts





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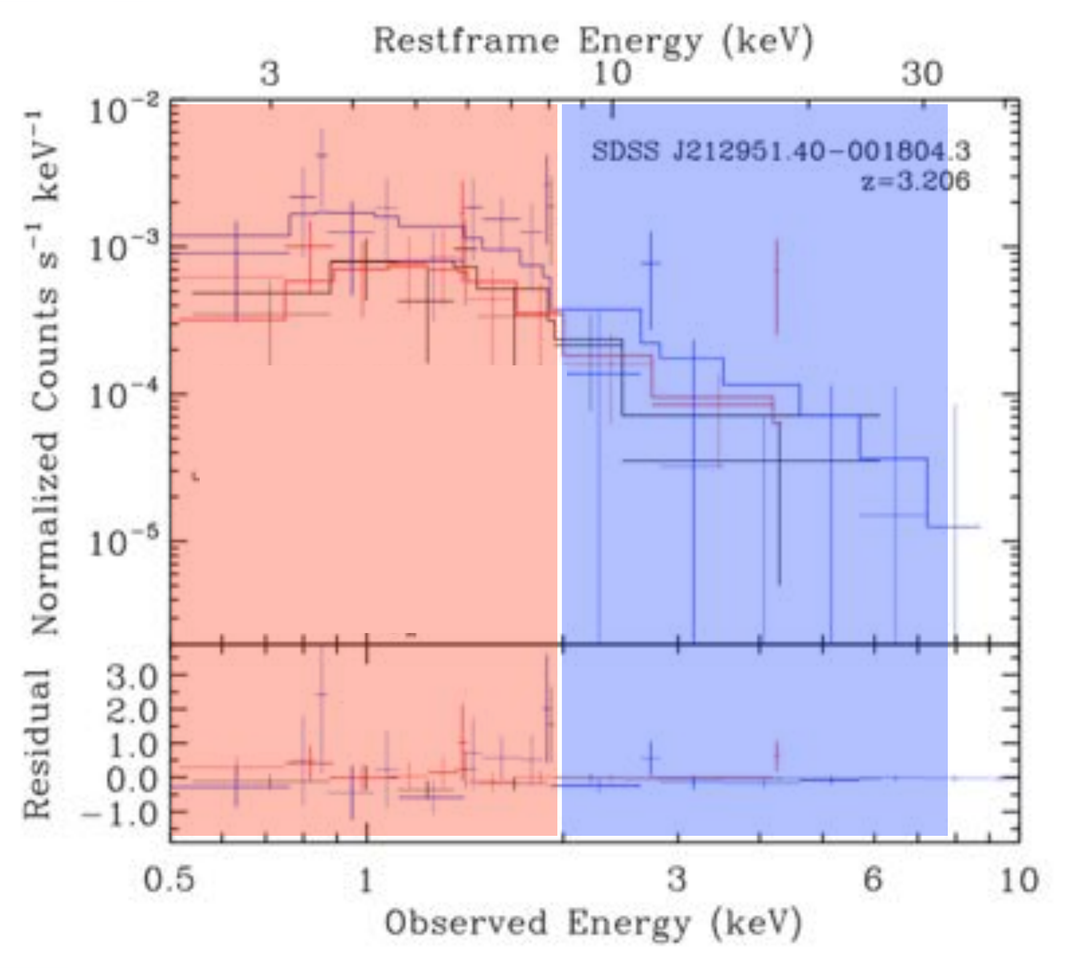
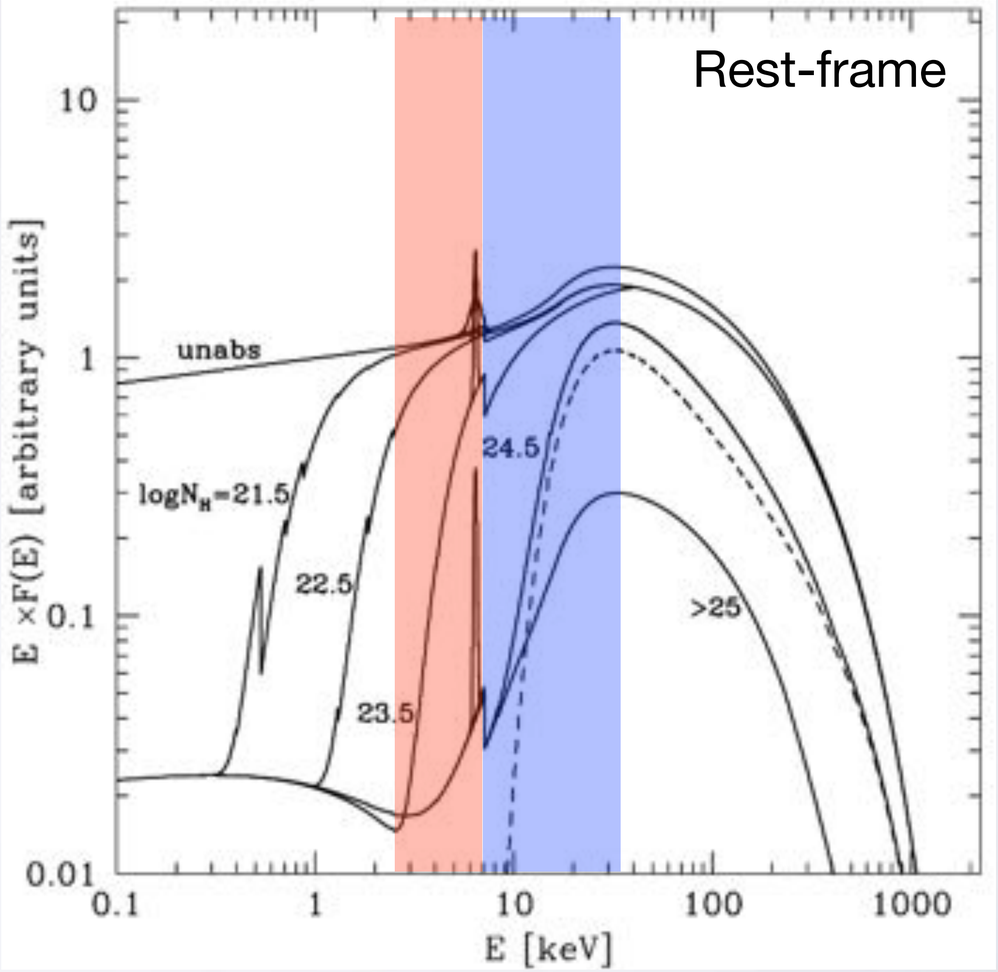
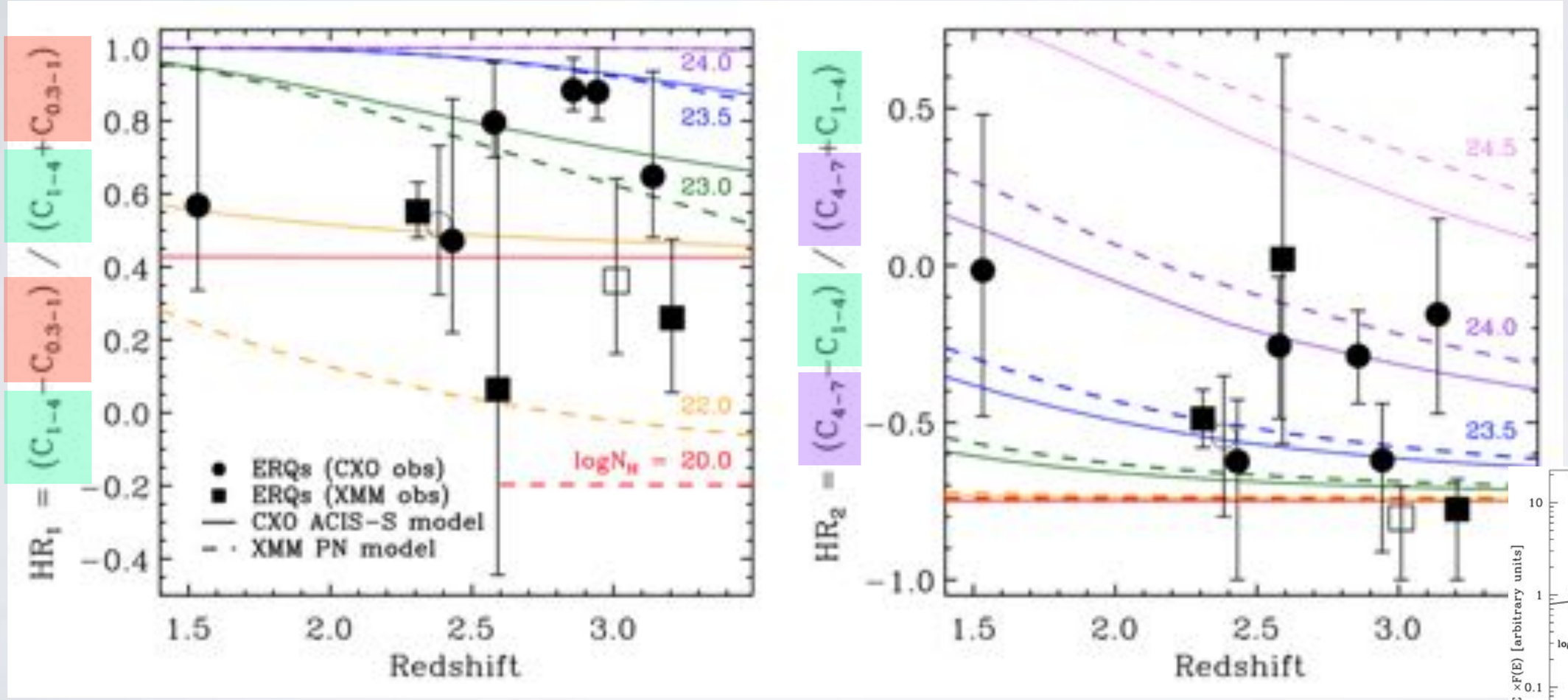
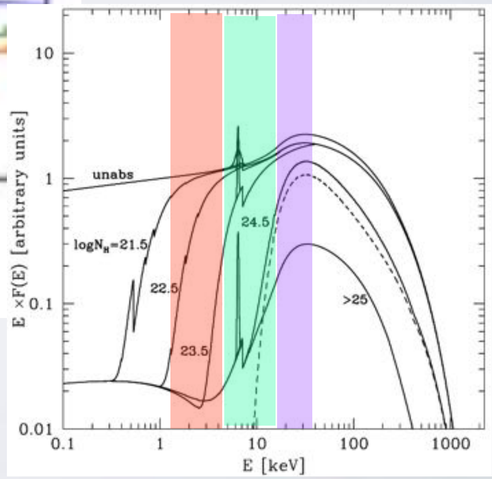




INFORMATION GLEANED FROM HARDNESS RATIOS





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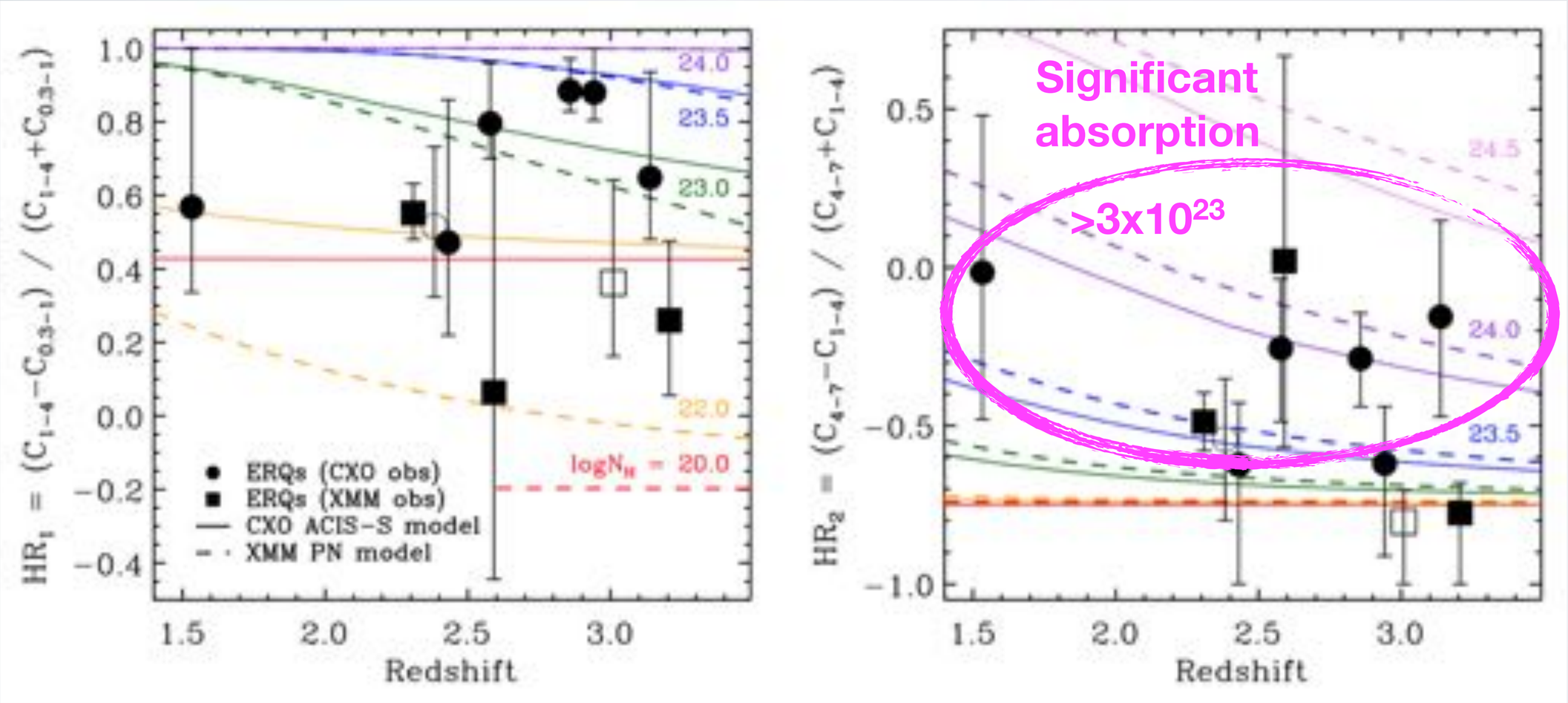

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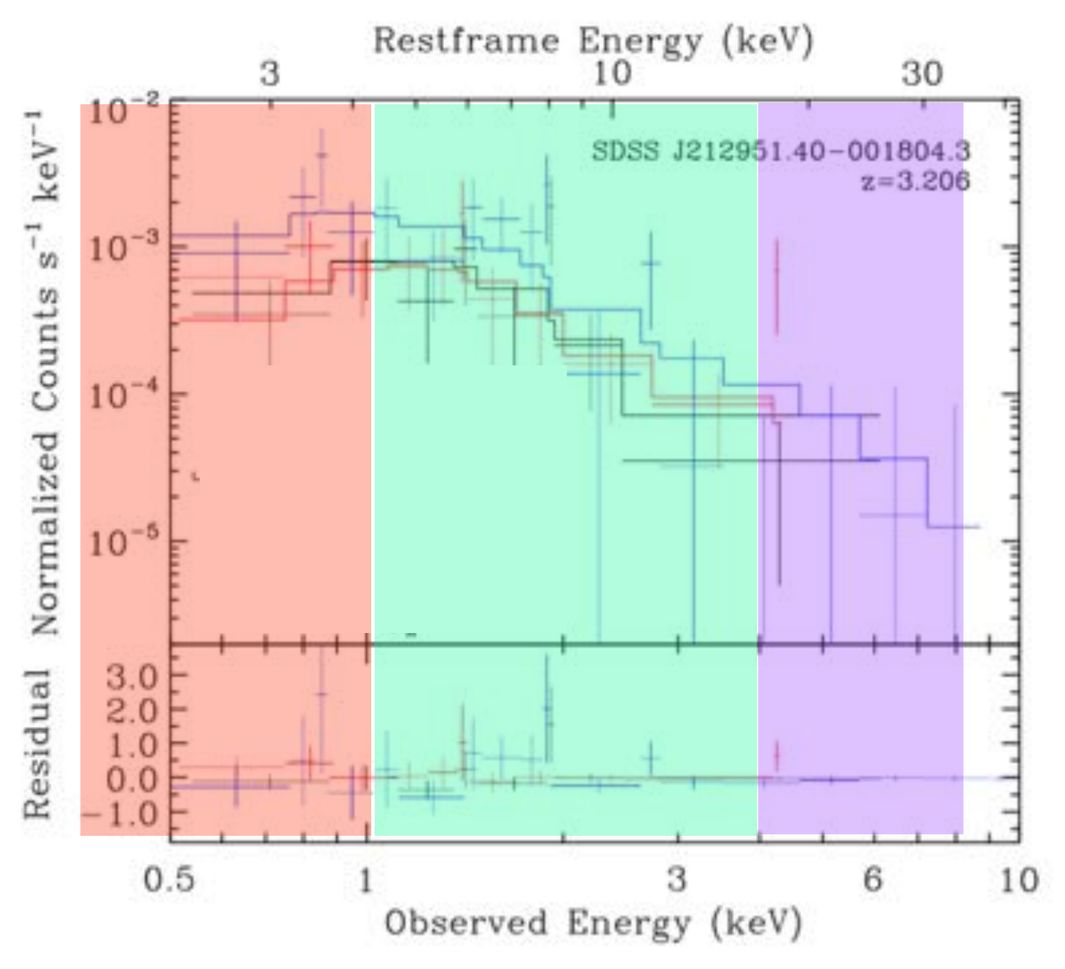
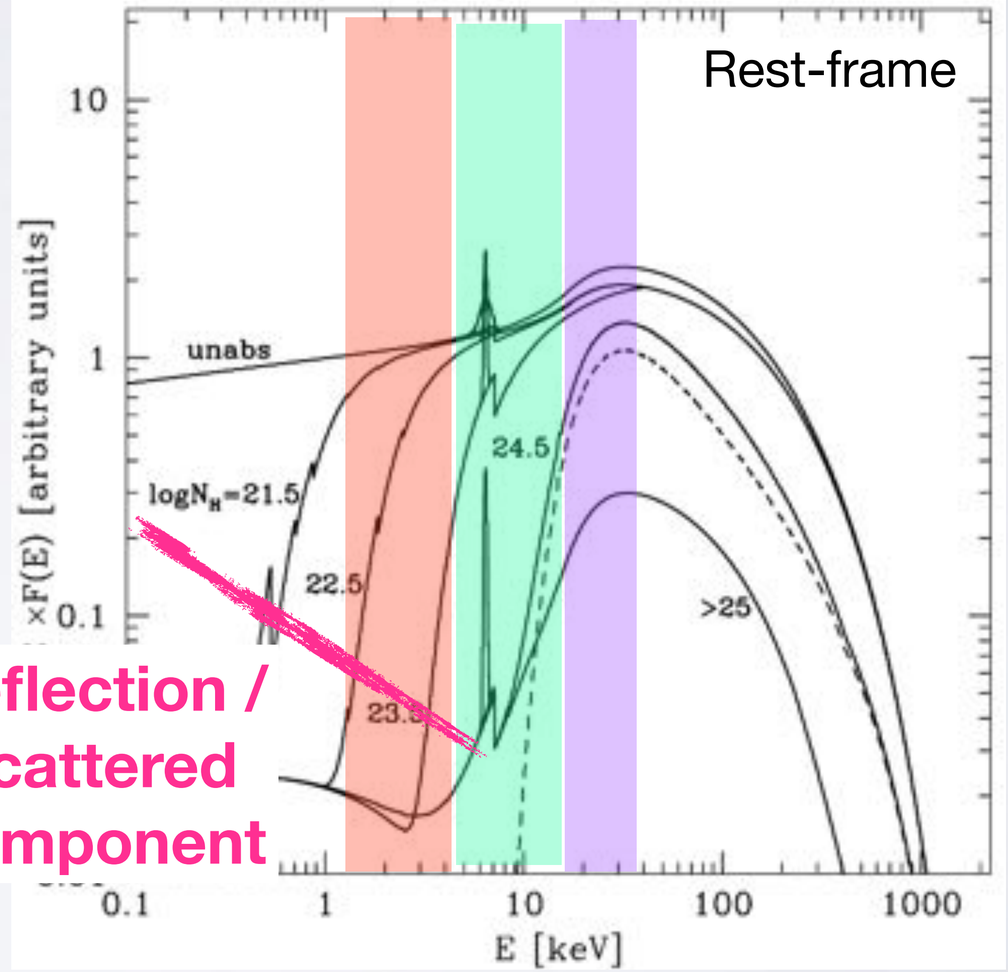
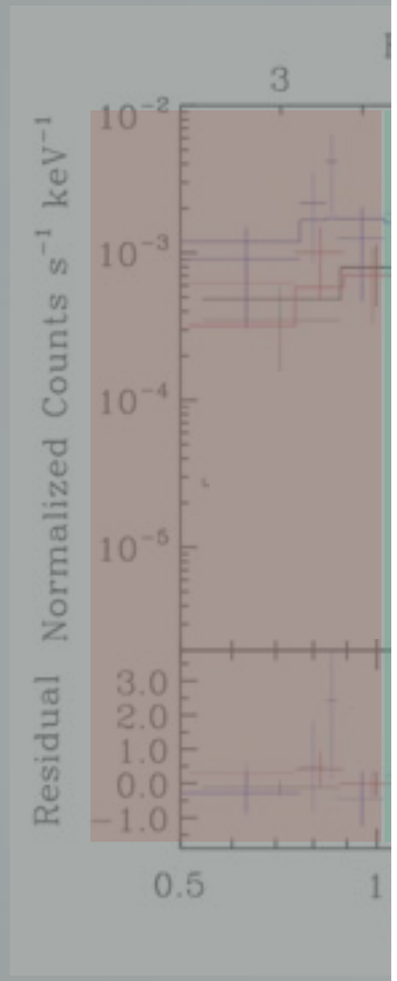


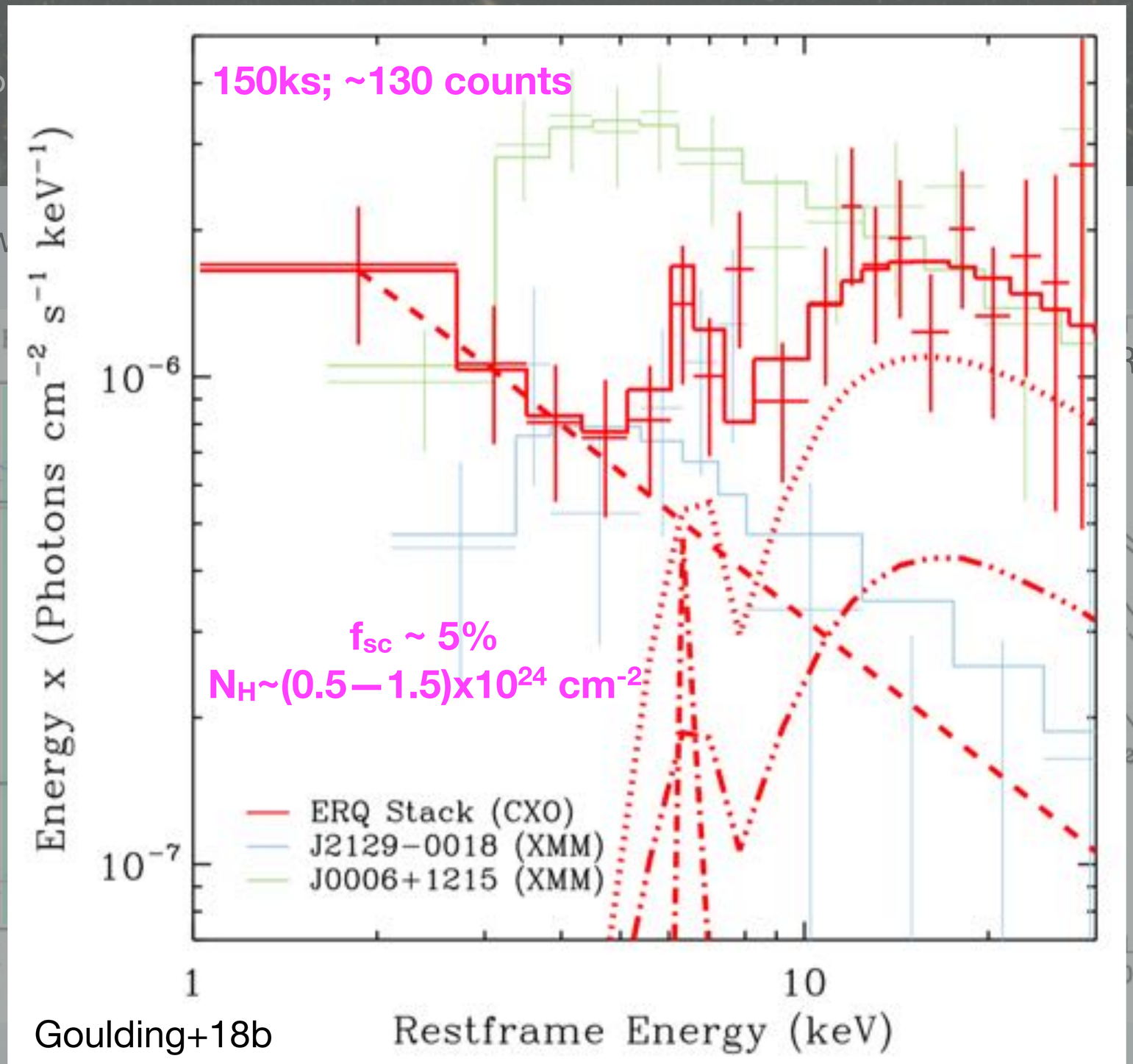


Reflection / scattered component

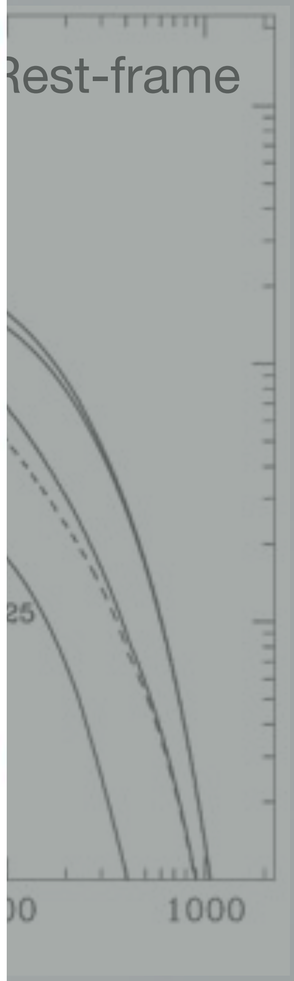
A DIFFICULT P

Majority were only w





Goulding+18b



A DIFFICULT PO

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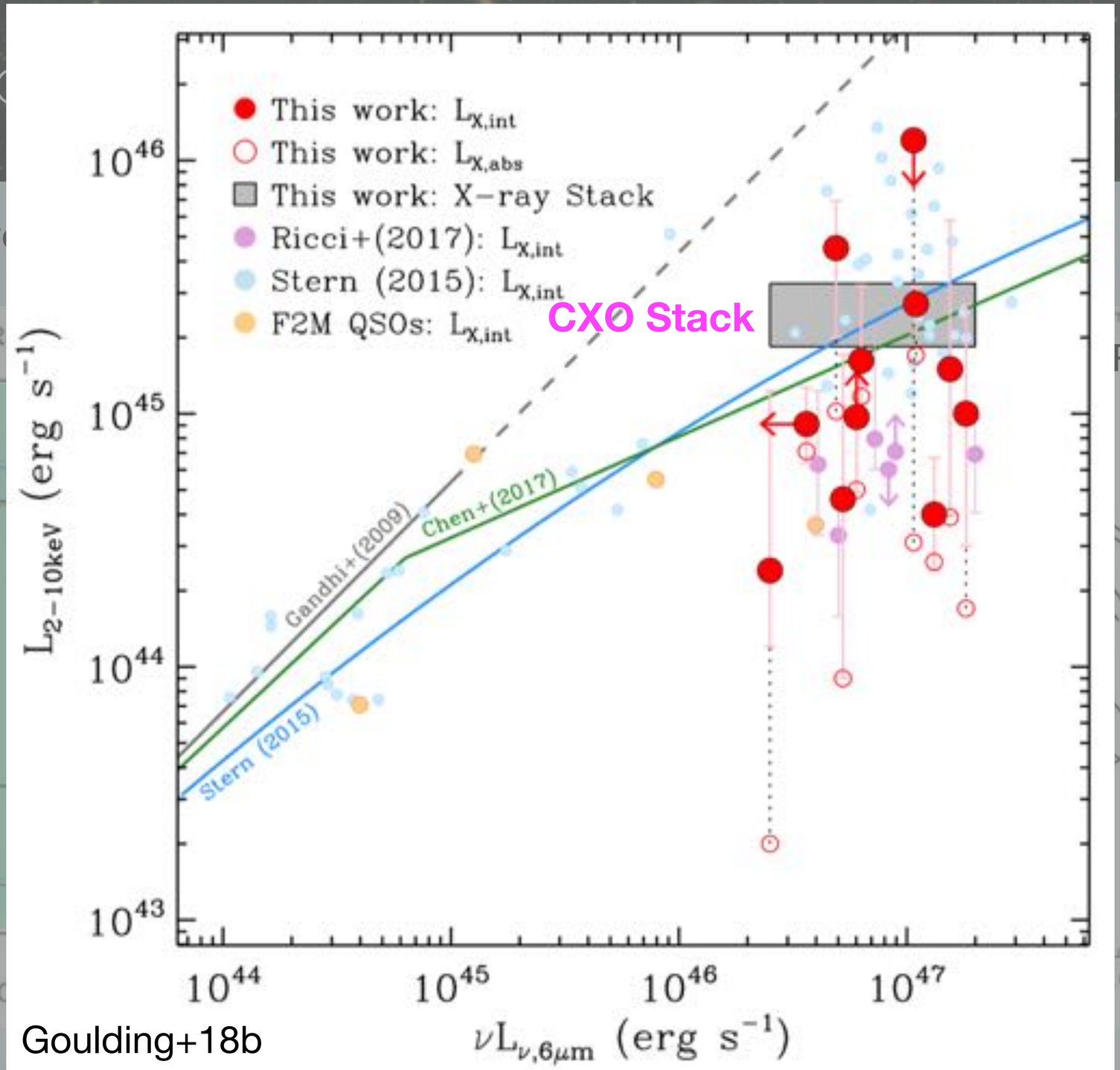
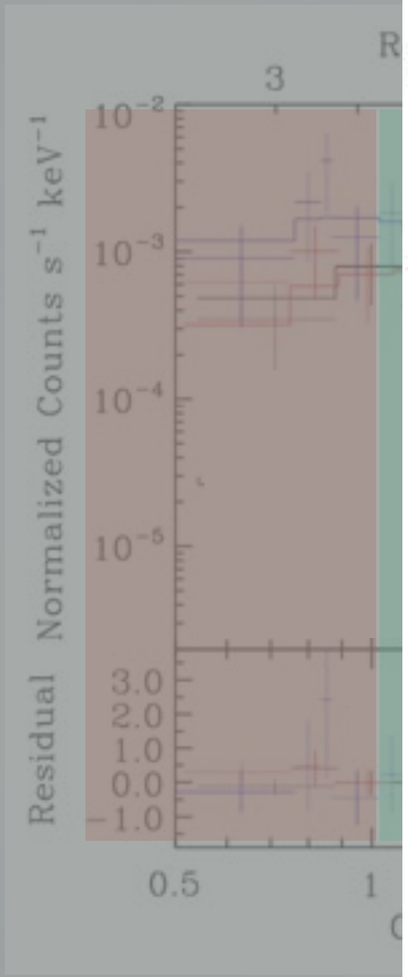
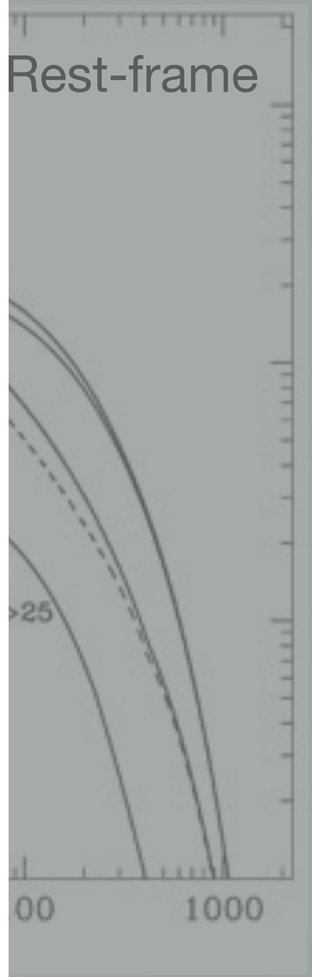
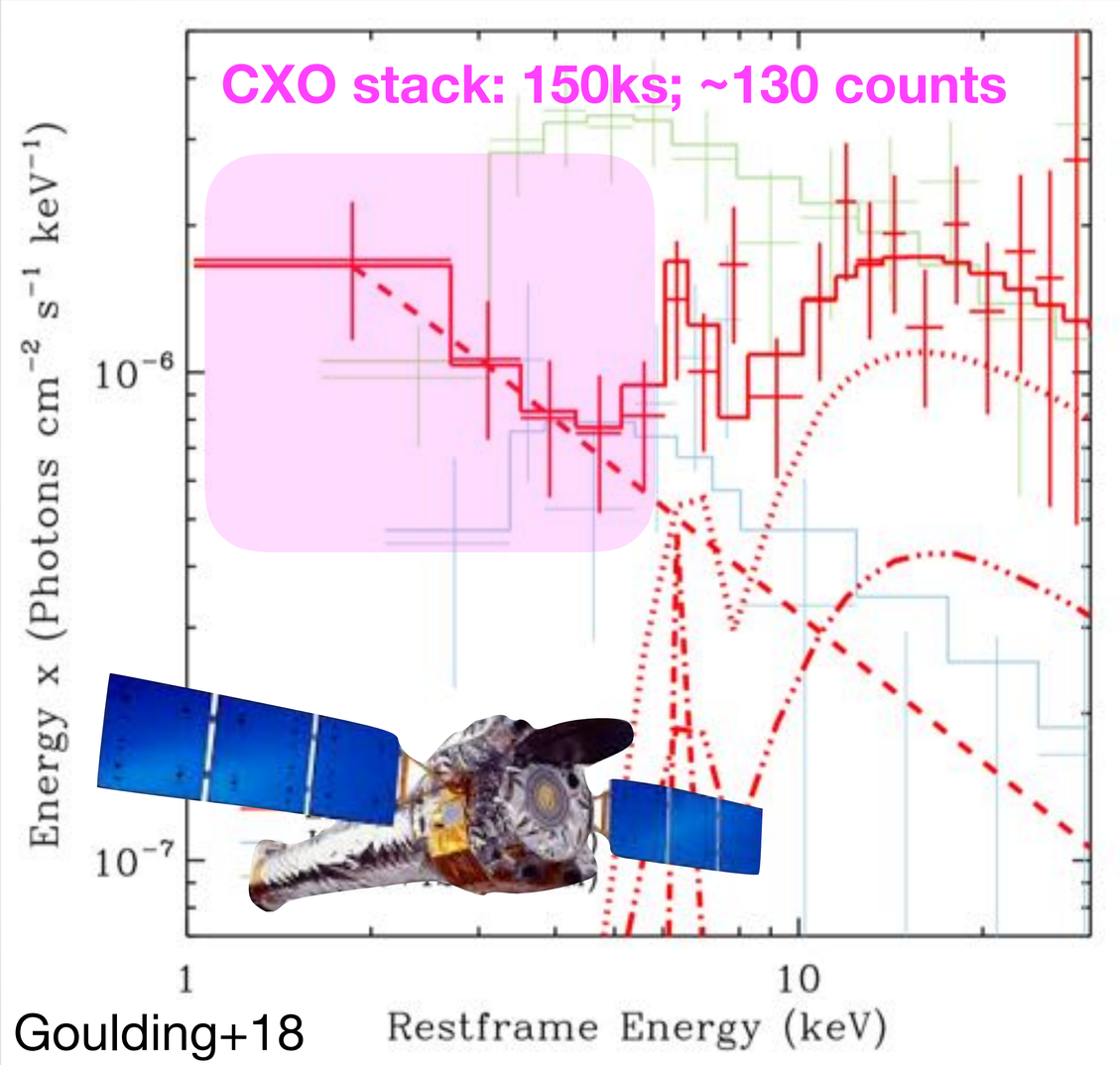


Goulding+18b





FOLLOW-UP X-RAY OBSERVATIONS OF A PILOT SAMPLE OF ERQS



Goulding+18

Scattered X-ray fraction ~ 5%

N_H~(0.5—1.5)x10^{24} cm^{-2}

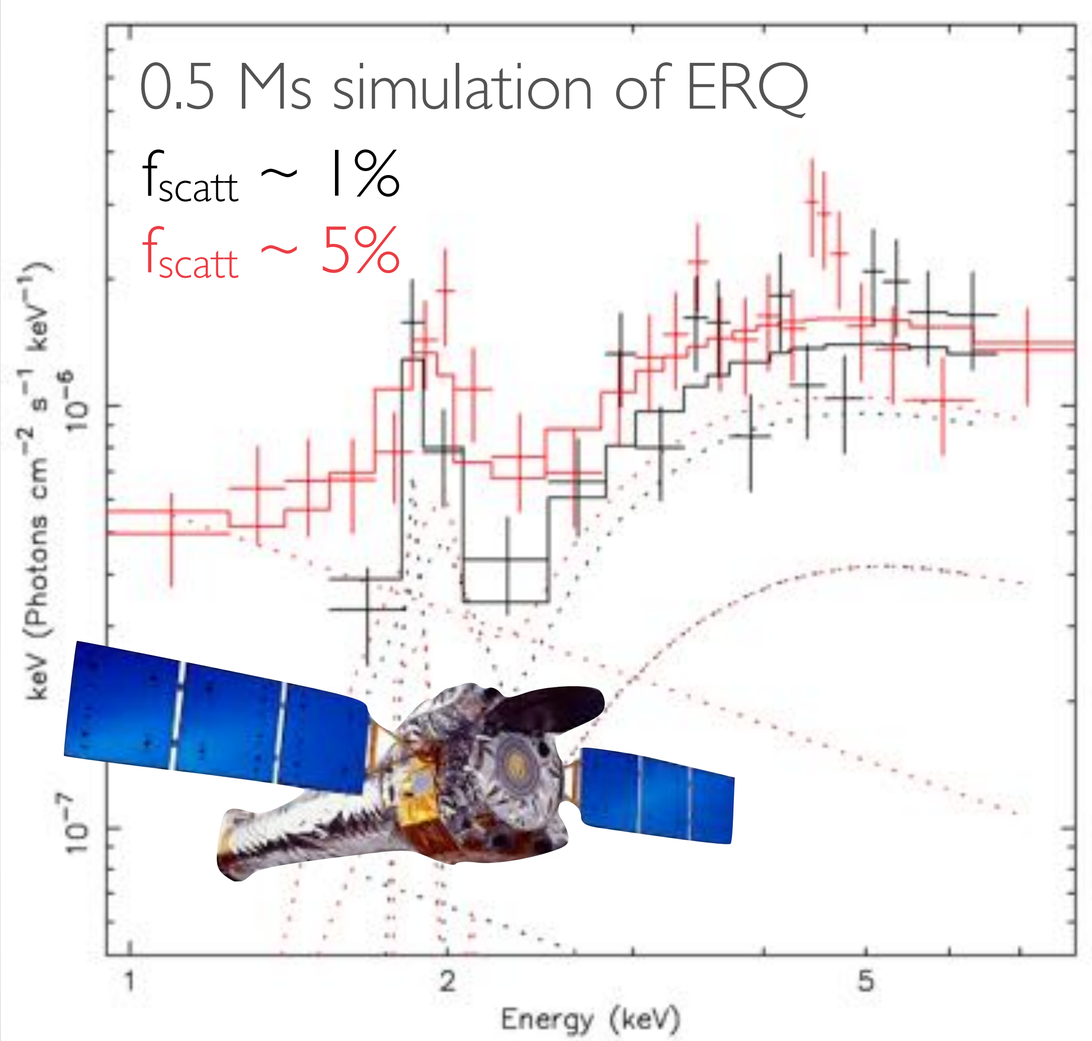
Mass outflow rate in the wind:

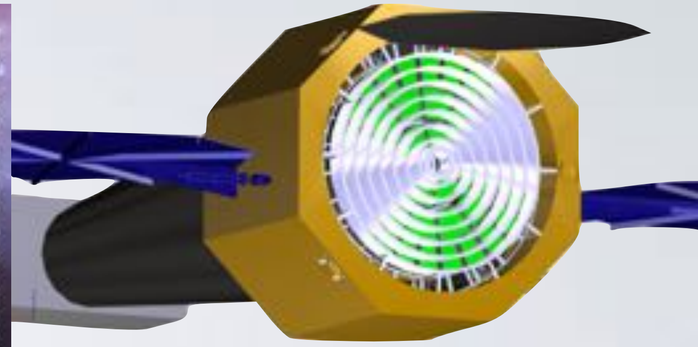
$$\dot{M} = 58 M_\odot/\mathrm{year} \times \left(\frac{r_{\rm in}}{1\mathrm{pc}}\right)\left(\frac{N_{\rm H}}{10^{24}\mathrm{cm}^{-2}}\right)\left(\frac{v}{2000\mathrm{km\,s}^{-1}}\right)\left(\frac{\Omega}{0.2}\right)$$

Resulting kinetic power of the wind:

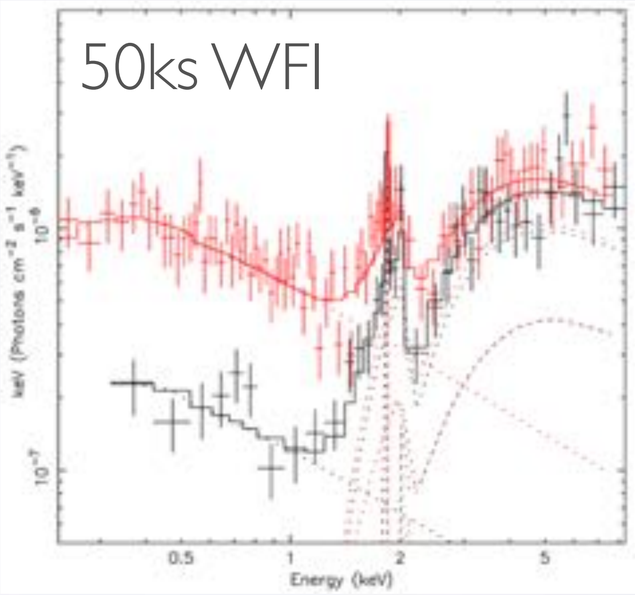
$$\dot{E}_{\rm kin} = \frac{\dot{M}v^2}{2} = 7\times10^{43}\mathrm{erg\,s}^{-1}$$

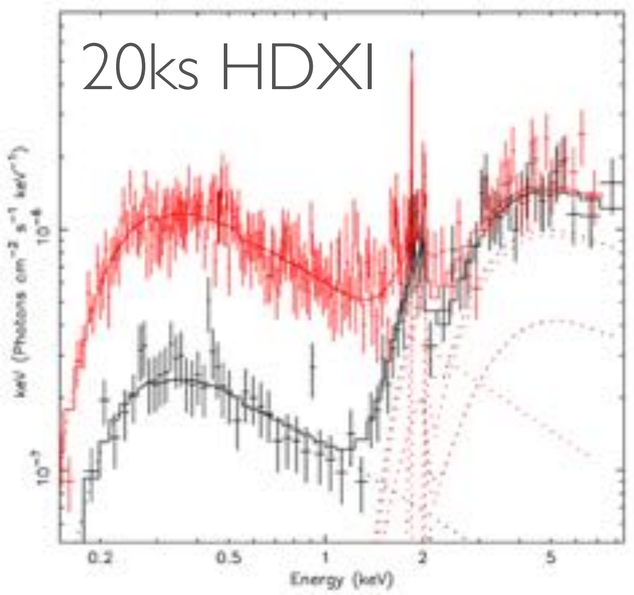
FUTURE X-RAY OBSERVATIONS OF THE MOST POWERFUL KPC-SCALE OUTFLOWS AT REDSHIFT~2-3



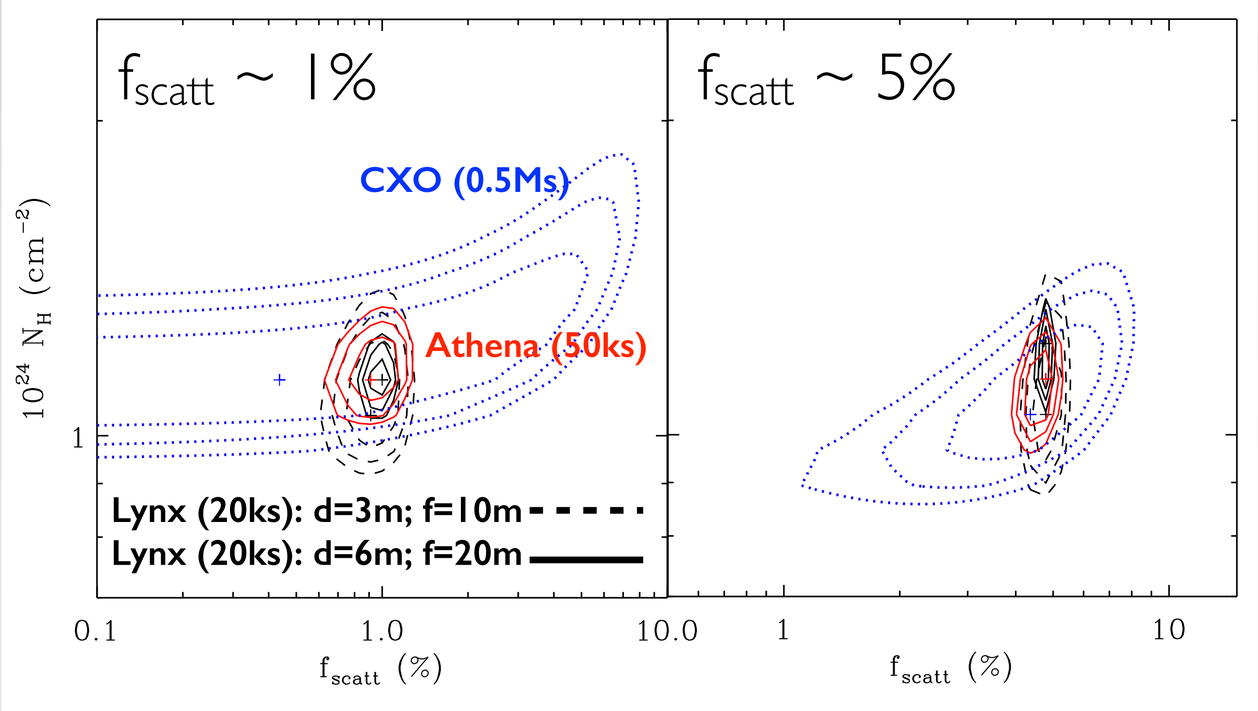


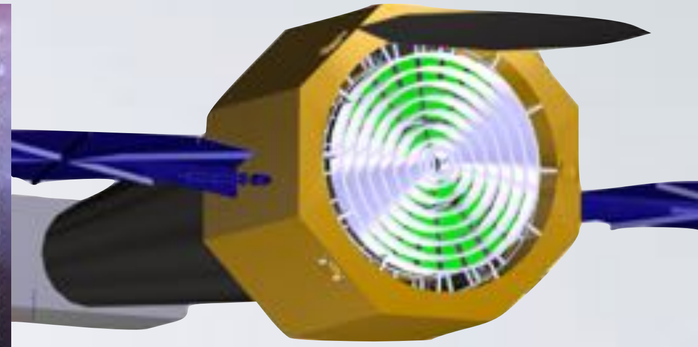
Lynx X-ray Surveyor



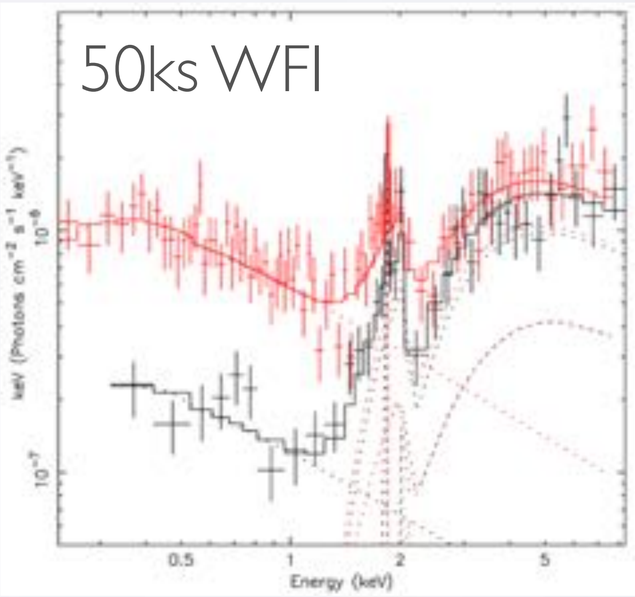


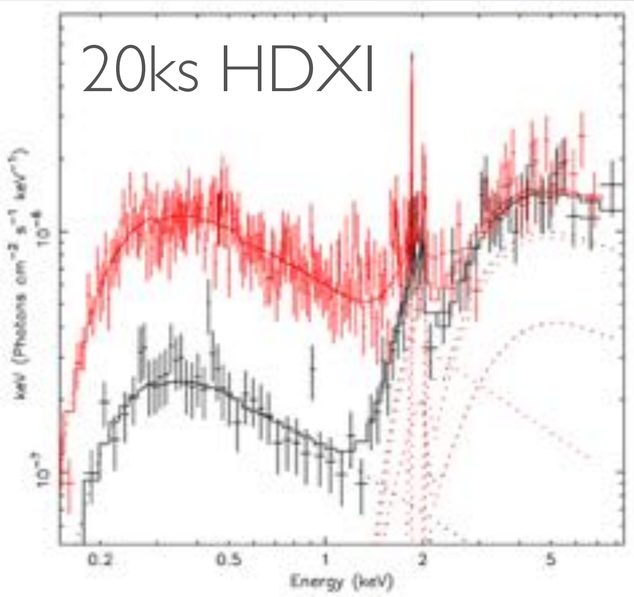
FUTURE X-RAY OBSERVATIONS OF THE MOST POWERFUL KPC-SCALE OUTFLOWS AT REDSHIFT~2-3





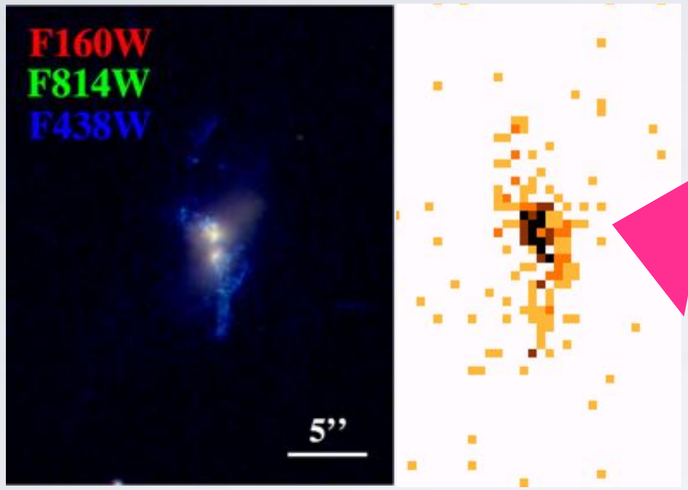
Lynx X-ray Surveyor



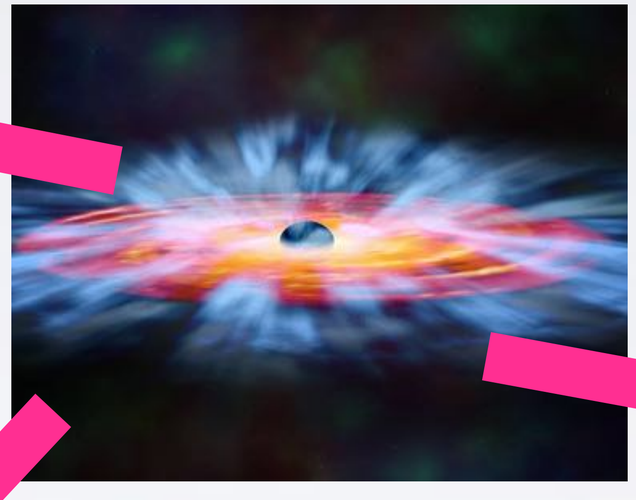


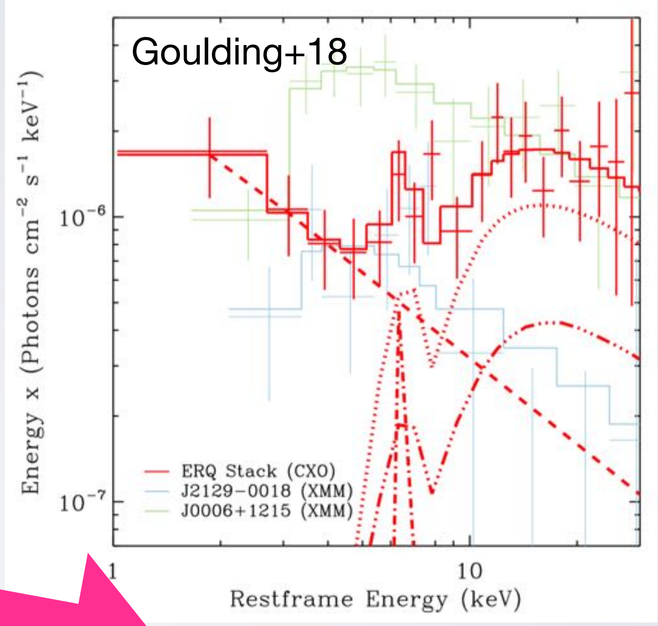
The next generation of X-ray telescopes will explore the obscured quasar population at z~3 with similar observations & exposure times to those that are required for nearby AGN with today's generation

SUMMARY

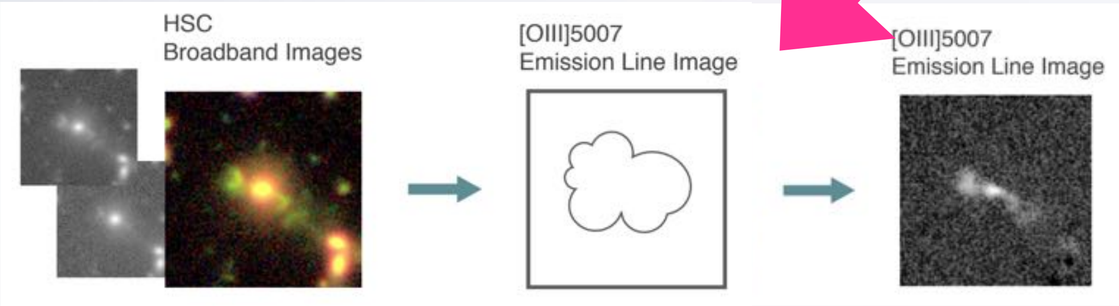


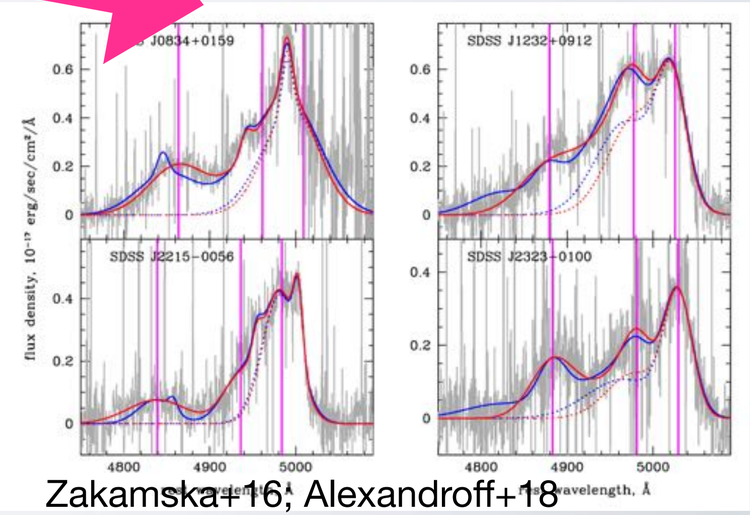
Broome+in-prep





Sun+18





Zakamska+16; Alexandroff+18