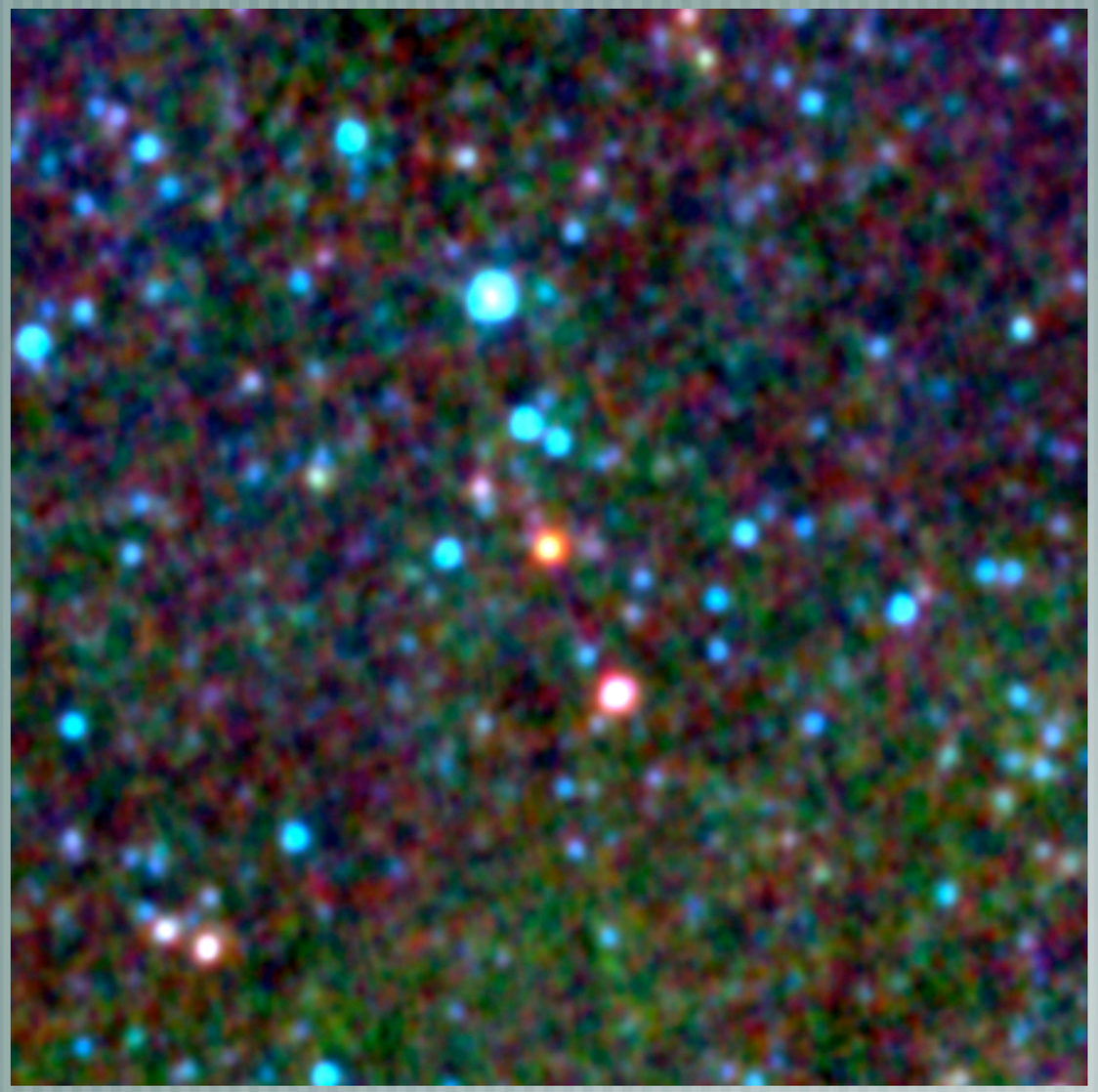
WISE quasars



Nadia Zakamska
Johns Hopkins University

WISE quasars

Toward a census of quasars

Why is this an interesting thing to do

Selection techniques

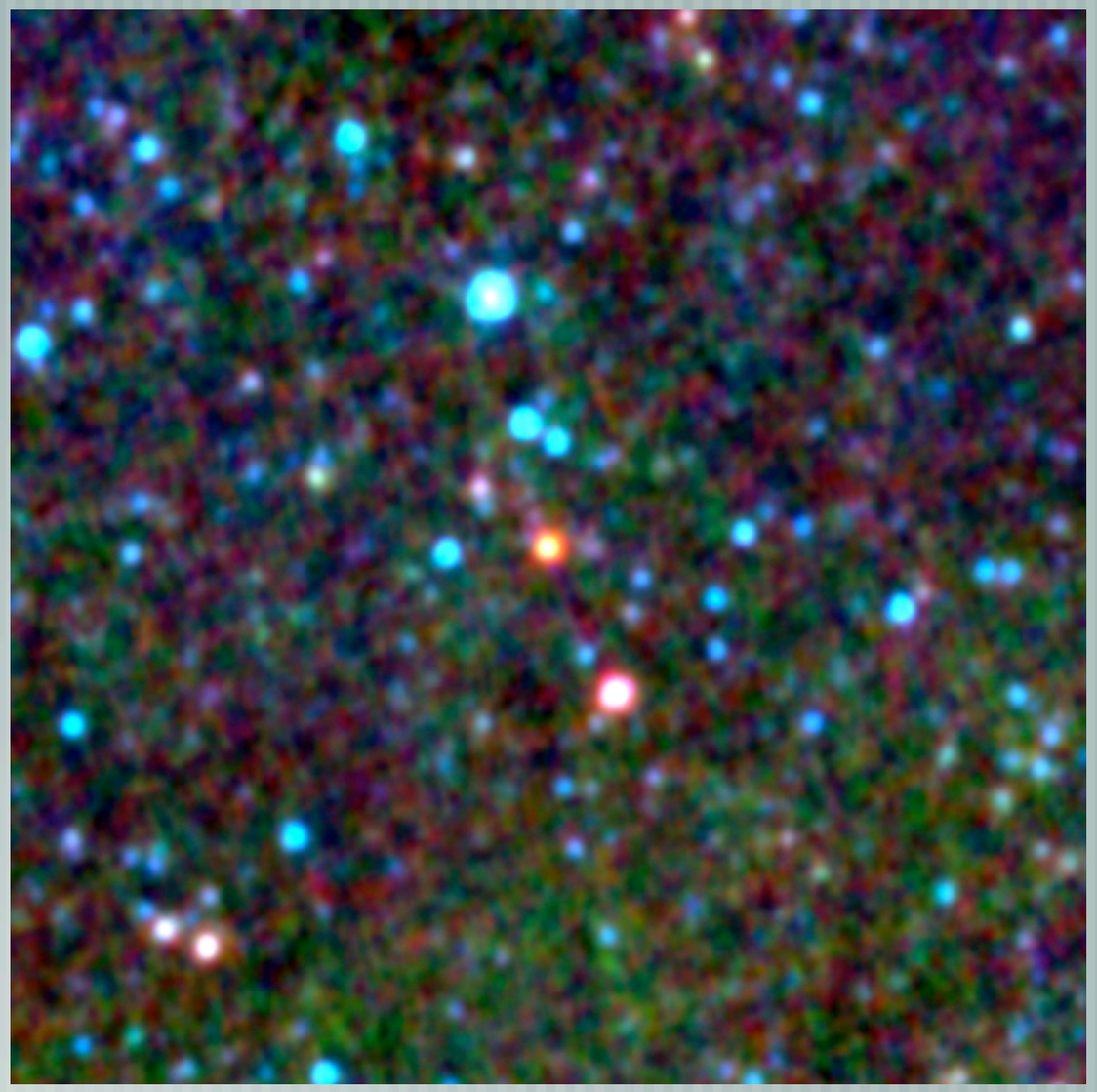
Extreme sources

Hot DOGs (Roberto Assef's talk)

Extremely red quasars (ERQs??)

Why are they extremely interesting

Quasar feedback at the peak of galaxy formation



1. Toward a complete census of quasars

- Demographics of quasars (obscured vs unobscured) is still an unsolved problem
- Especially at high luminosities, especially at z=2-3
- Quasars, quasar obscuration played key role in galaxy formation
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- Soltan argument, X-ray background, obscuration geometry / evolution

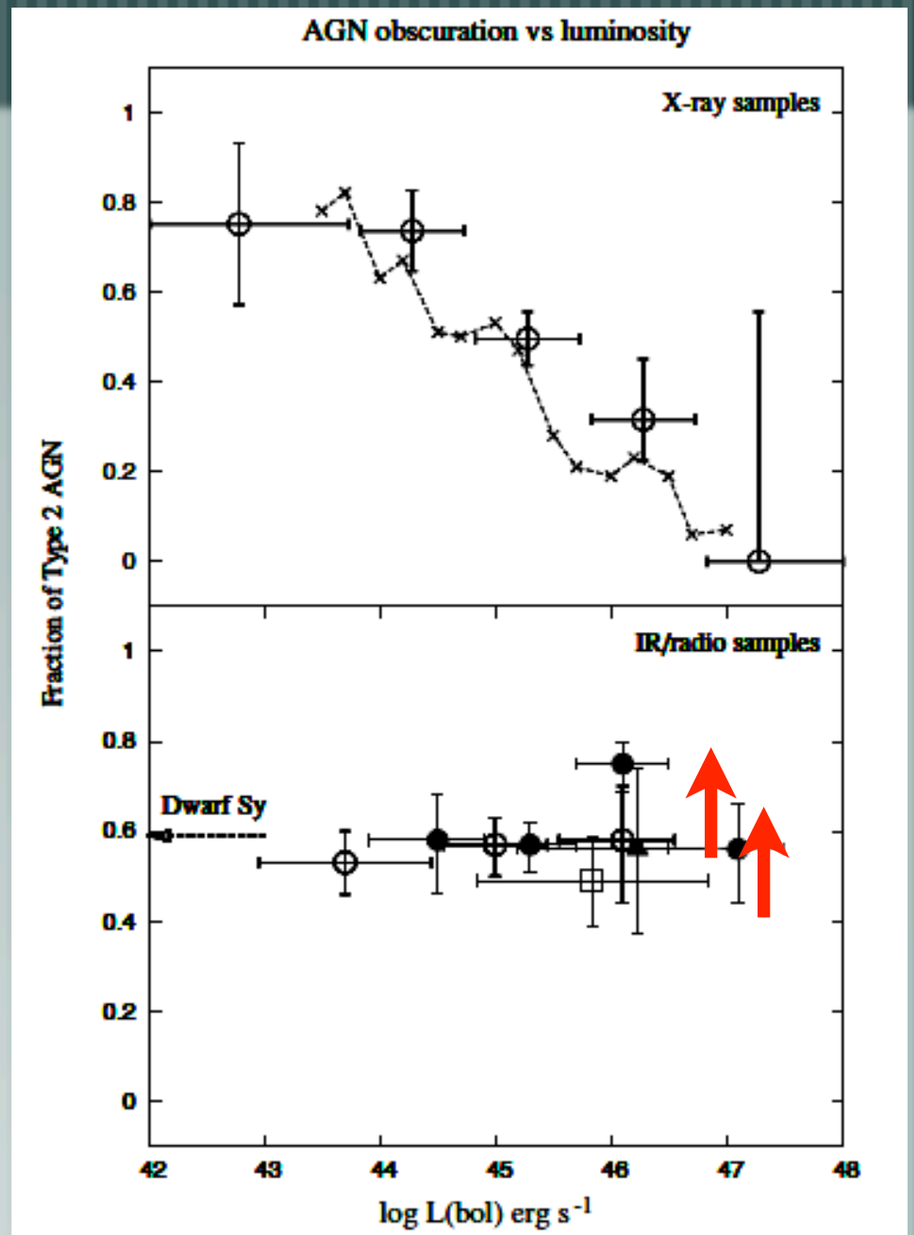

Figure 1. Behavior of f_2 with estimated bolometric luminosity. Upper panel, open symbols: data from Tueller et al. (2009); crosses: Hasinger (2008). Lower panel, filled circles: De Grijp et al. (1992); open circles: Rush et al. (1993); open squares: Lacy et al. (2007); filled triangles: Ogle et al. (2006); dashed line: Ho et al. (1997). Error bars are 68% confidence except for the lower limit at high X-ray luminosities, which shows a 90% confidence interval.

Lawrence & Elvis 2010
Reyes, Zakamska et al. 2008

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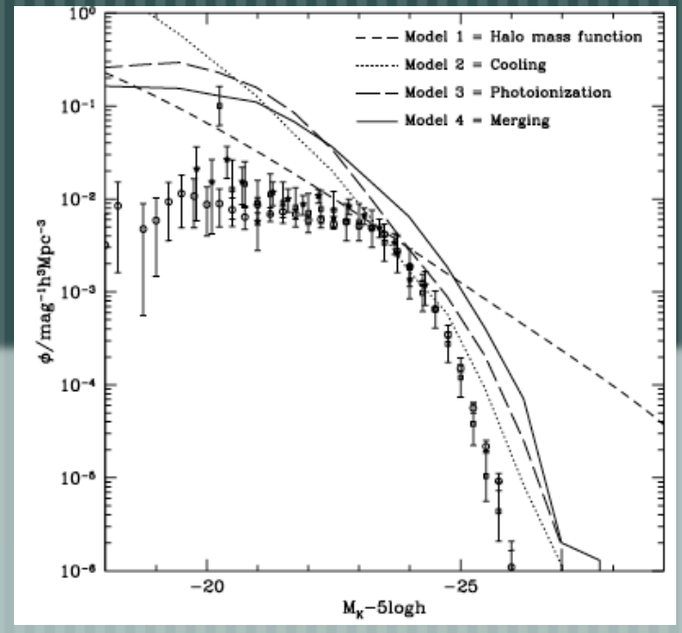
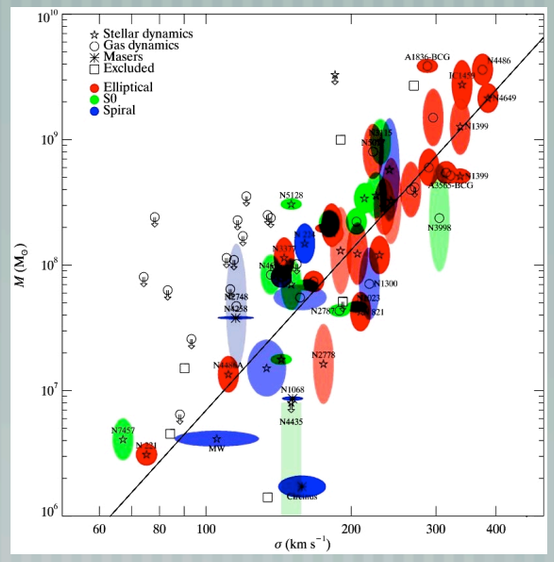
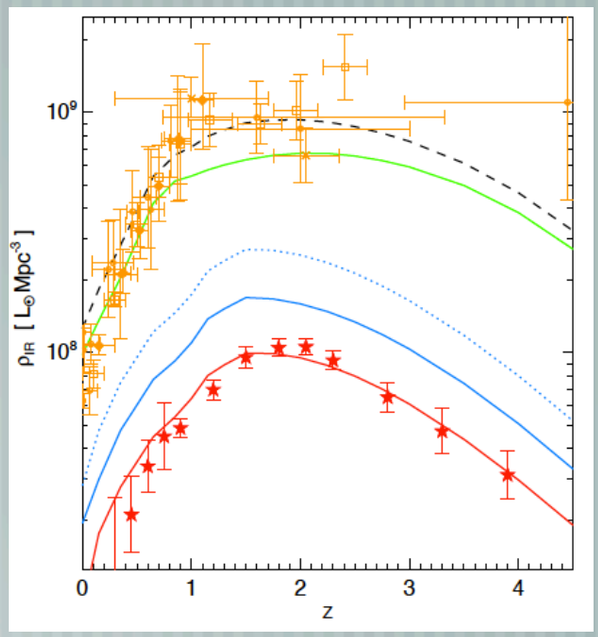


Benson et al. 2003



Gultekin et al. 2009



Hopkins et al. 2007
(Boyle & Terlevich 1998)

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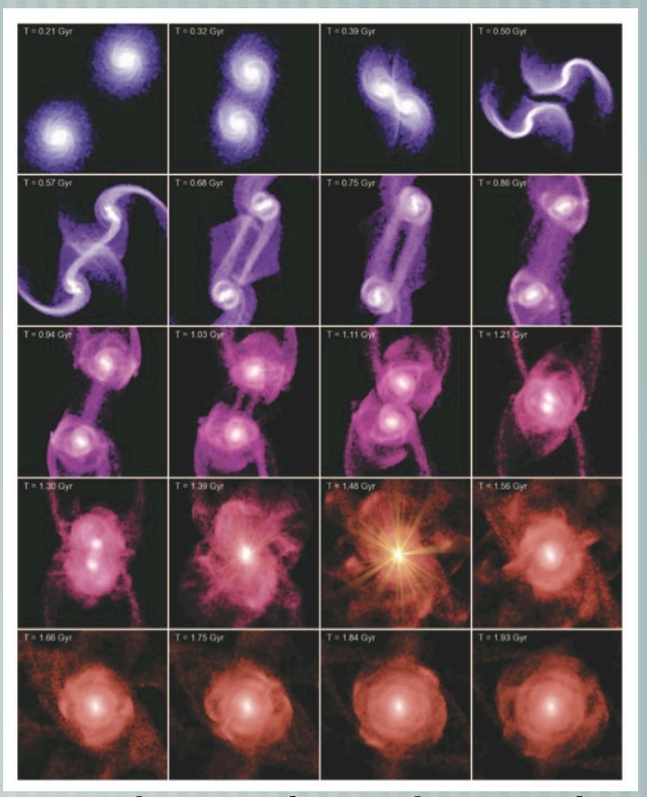
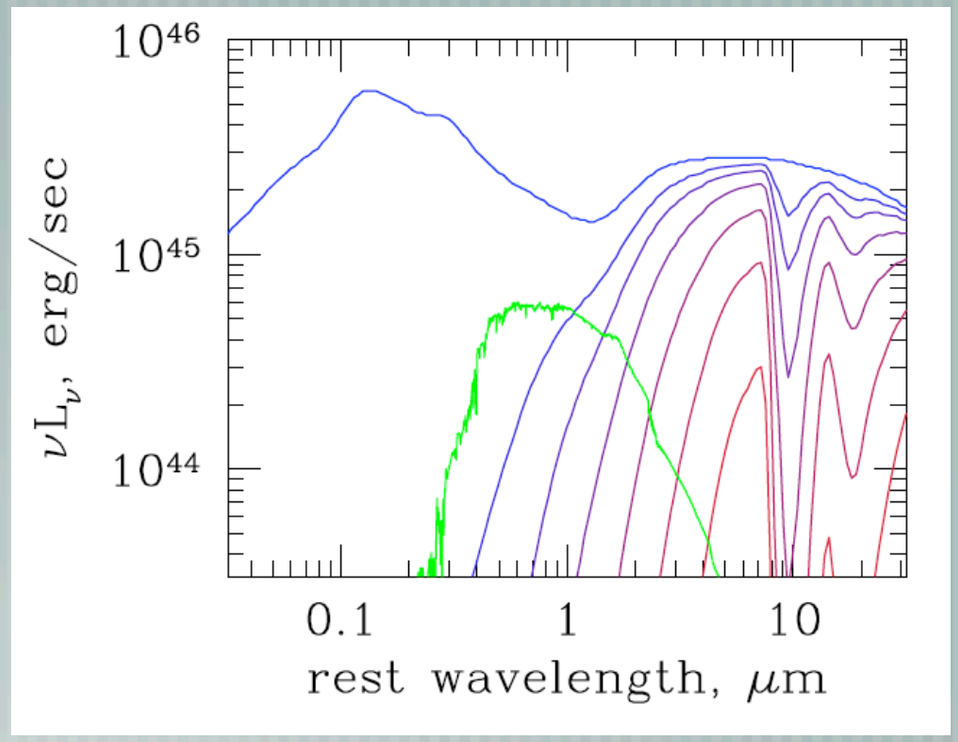
Antonucci 1993



Sanders et al., Hopkins et al.

1. Toward a complete census of quasars

- In principle, WISE is sensitive to both obscured and unobscured population
- AGN excess over the galaxy – red W1-W2 colors
- In practice, wide range of quasar SEDs
- Power-laws vs ` screen of cold dust'



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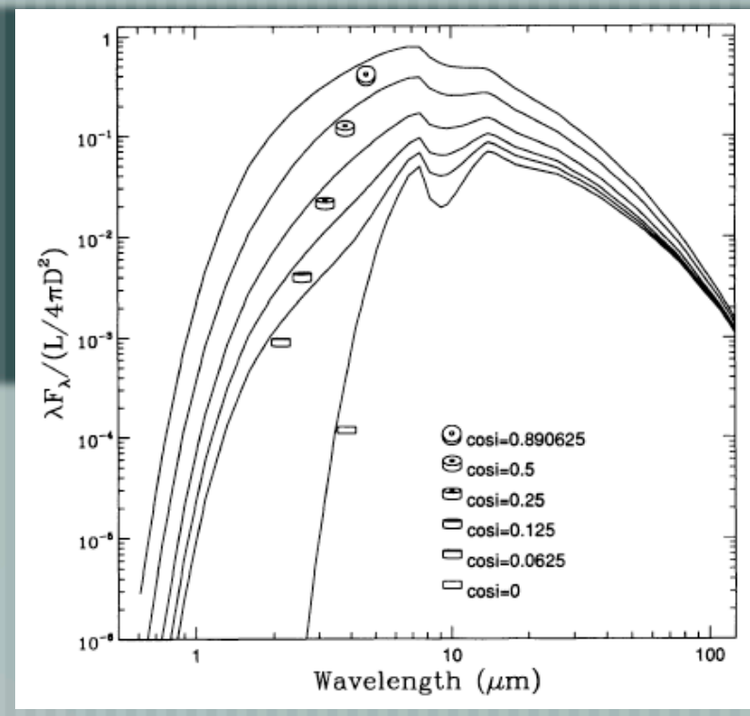
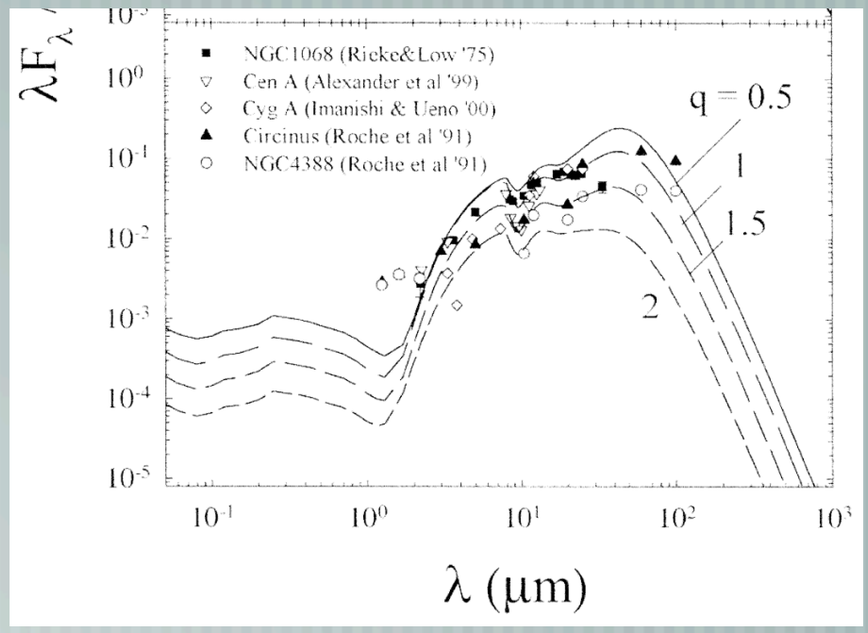


Pier & Krolik 1993



Nenkova et al. 2002 (also Nikutta's talk)

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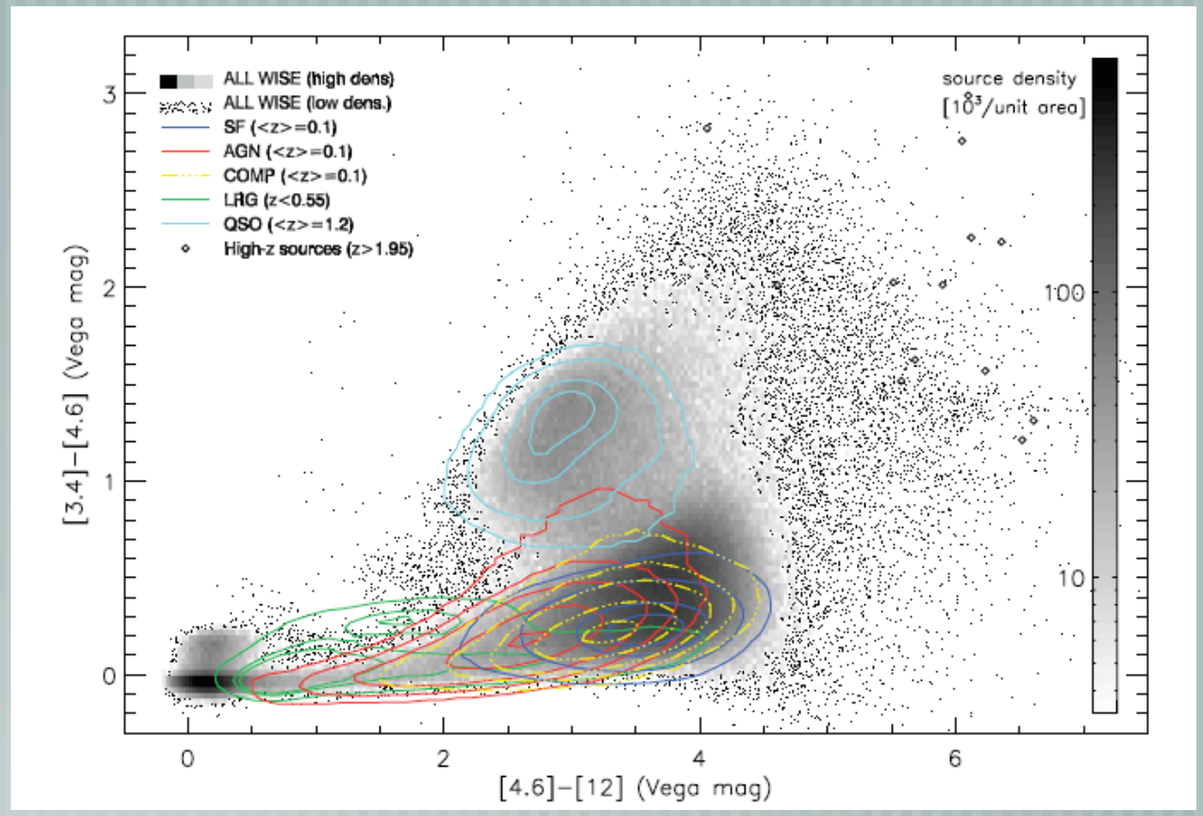

Yan et al. 2013 (also Stern et al.)

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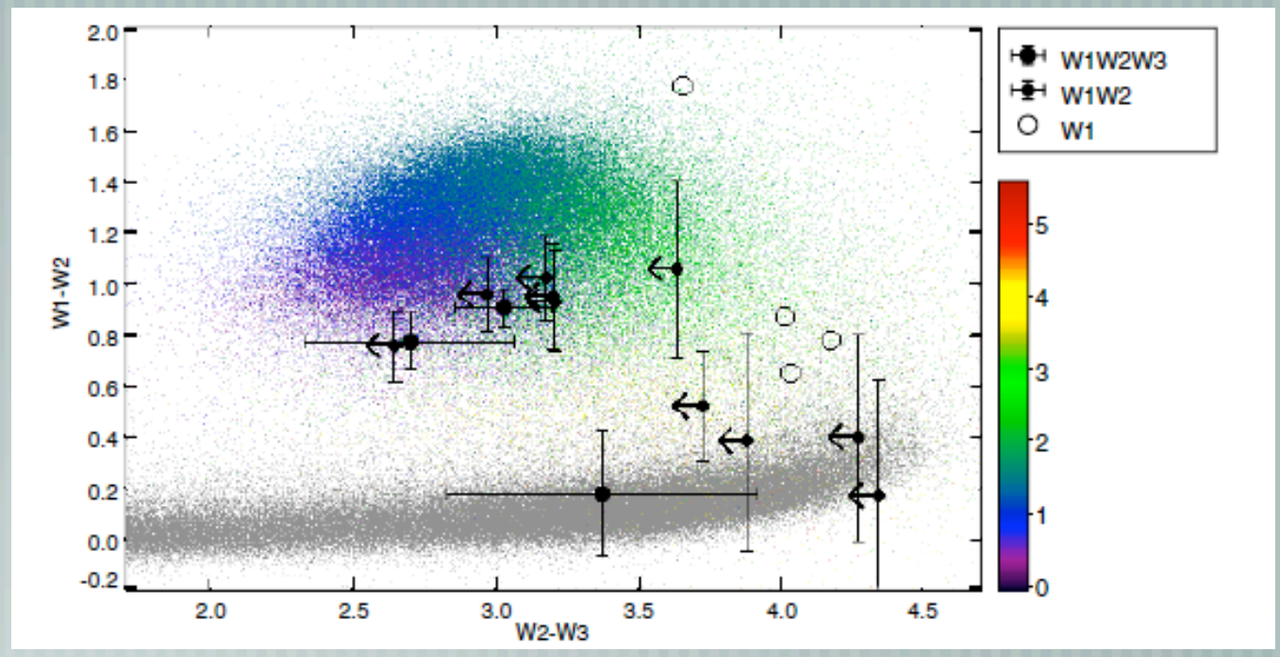
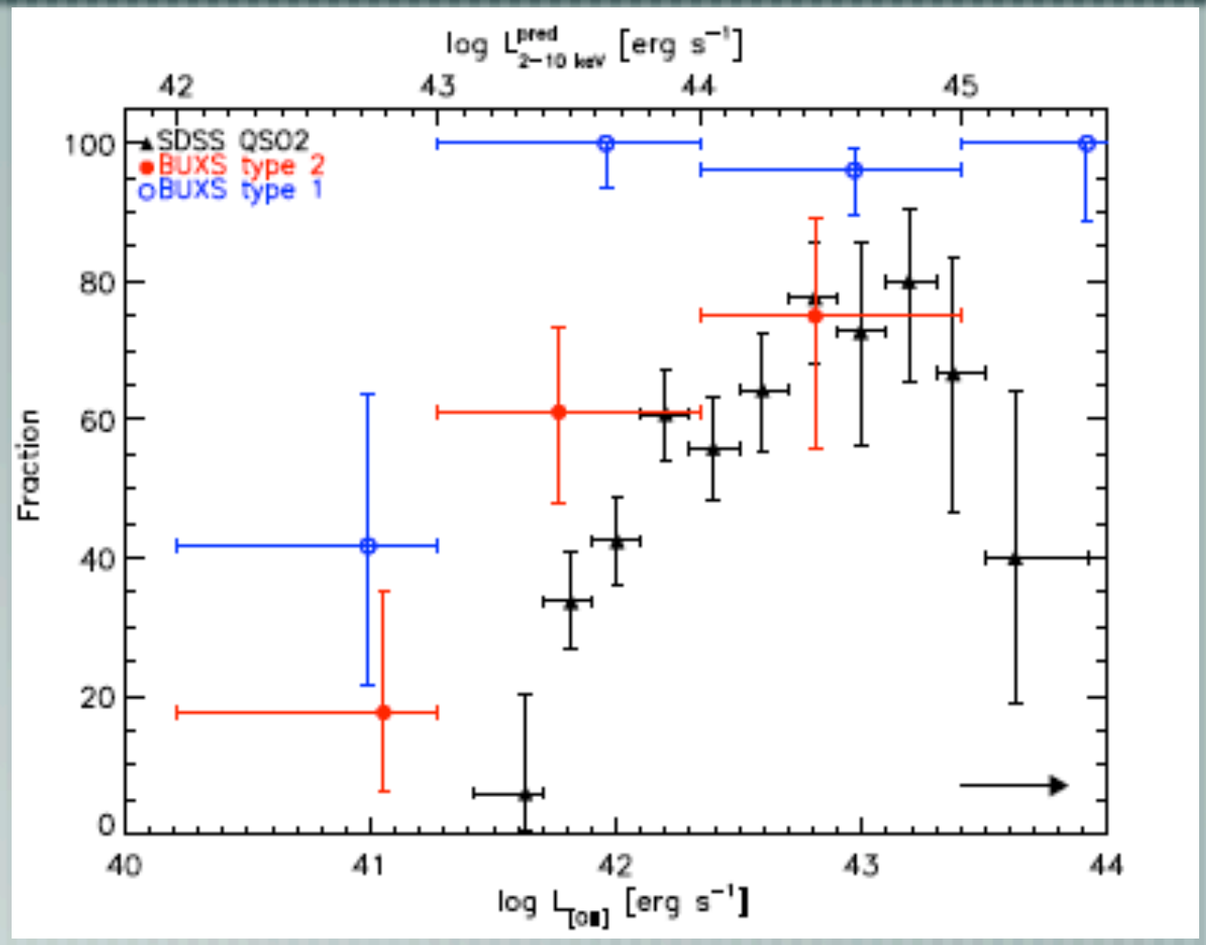


Blain et al. 2014

1. Toward a complete census of quasars

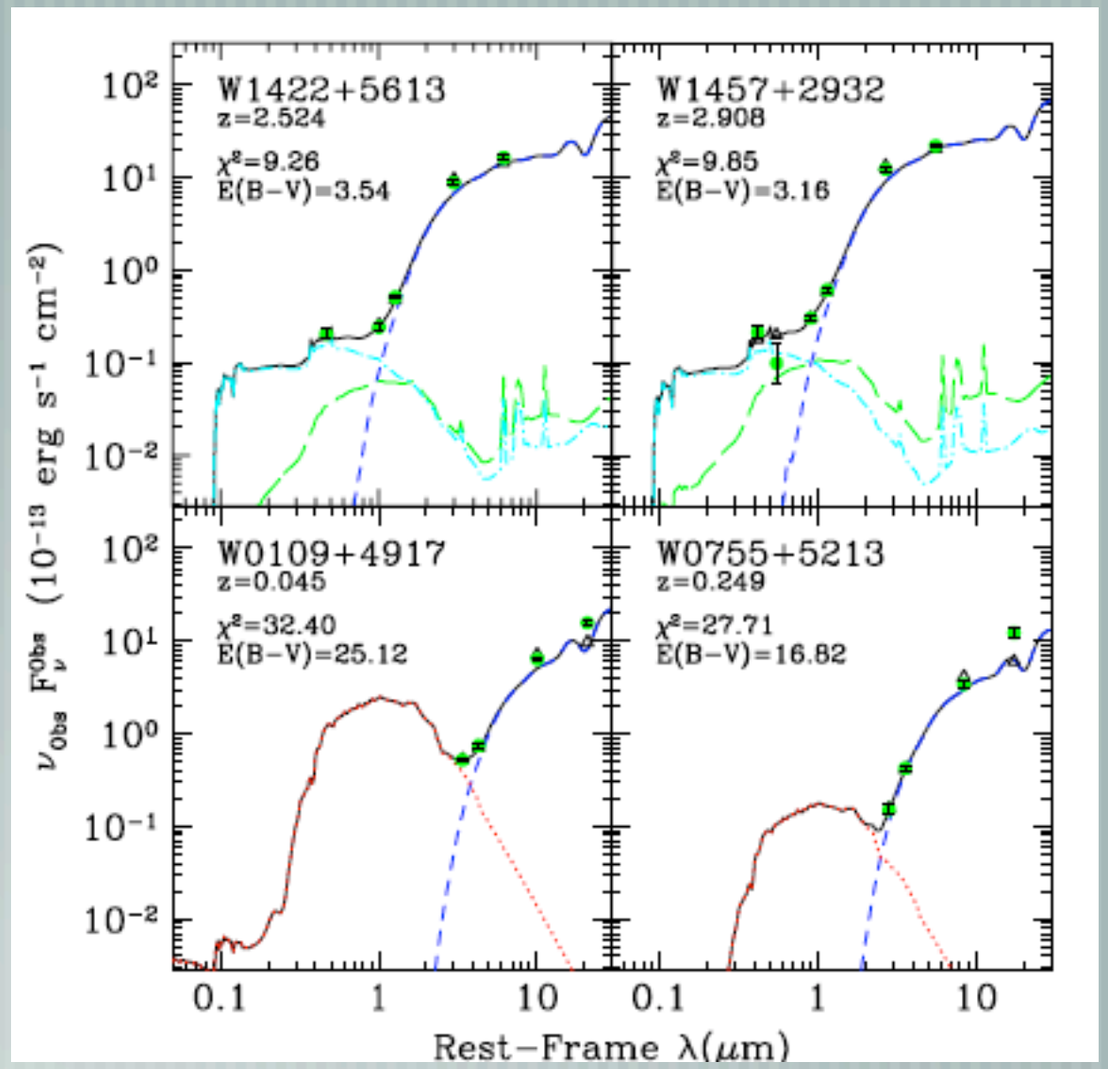
- Observationally, agreement between different selection methods at x10% level
- Something strange especially at high luminosities
- Important regime for quasar feedback
- Conclusion: existing methods are "clean" but not complete
- Solvable but unsolved problem



Mateos et al. 2013 (based on optically selected type 2s from Reyes, Zakamska, et al. 2008)
see also poster by Marvin Rose

2. Extreme sources

- Hot DOGs: Roberto's talk
- Selected as very red in WISE colors (Eisenhardt et al. 2012)
- Any redder and they would be Cold DOGs... (but typical for star-forming galaxies)
- Astonishing intrinsic luminosities: 10^{47}-10^{48} erg/sec
- X-ray follow-up: extremely luminous, extremely obscured



Assef et al. 2014

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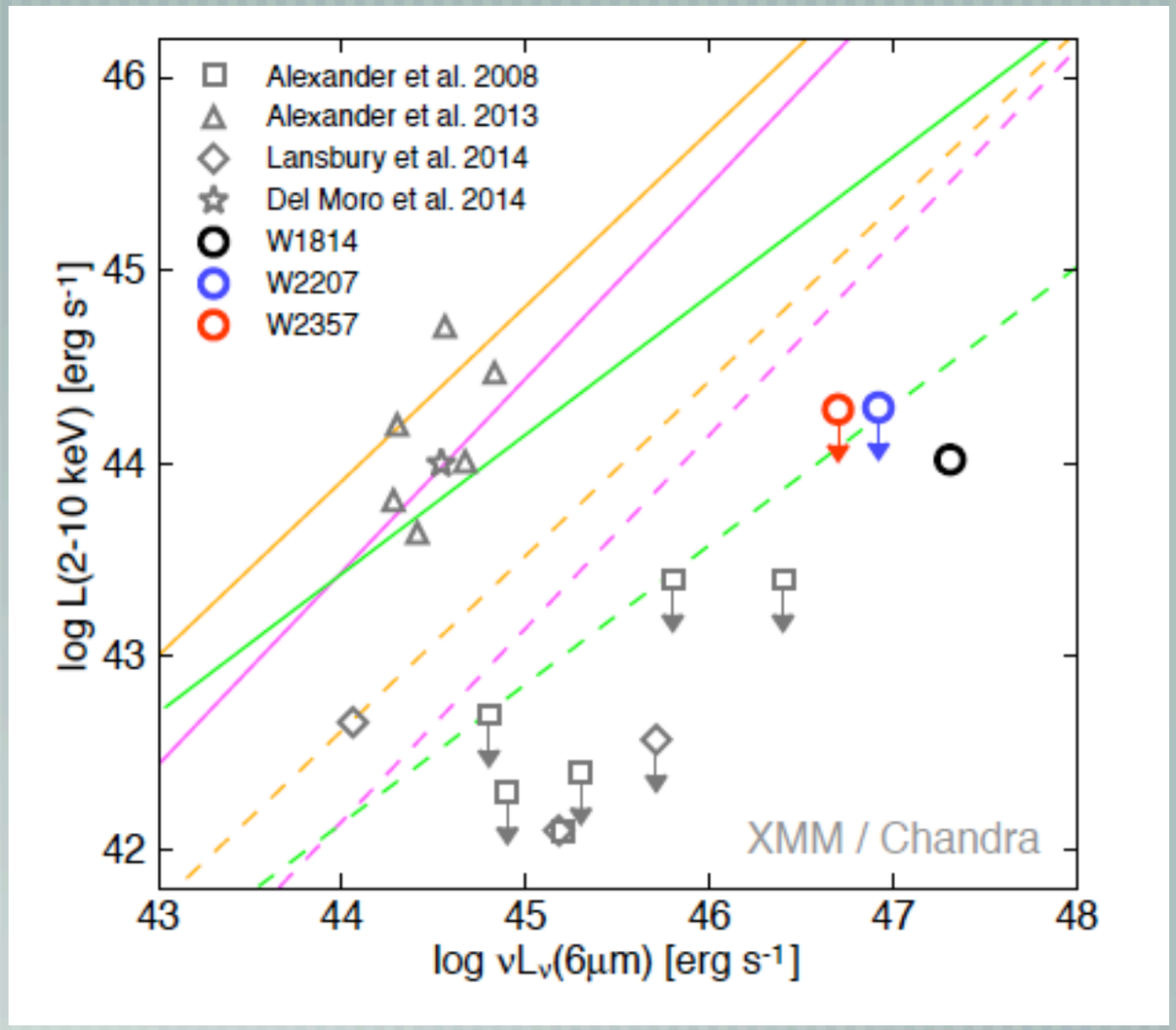

Stern et al. 2014

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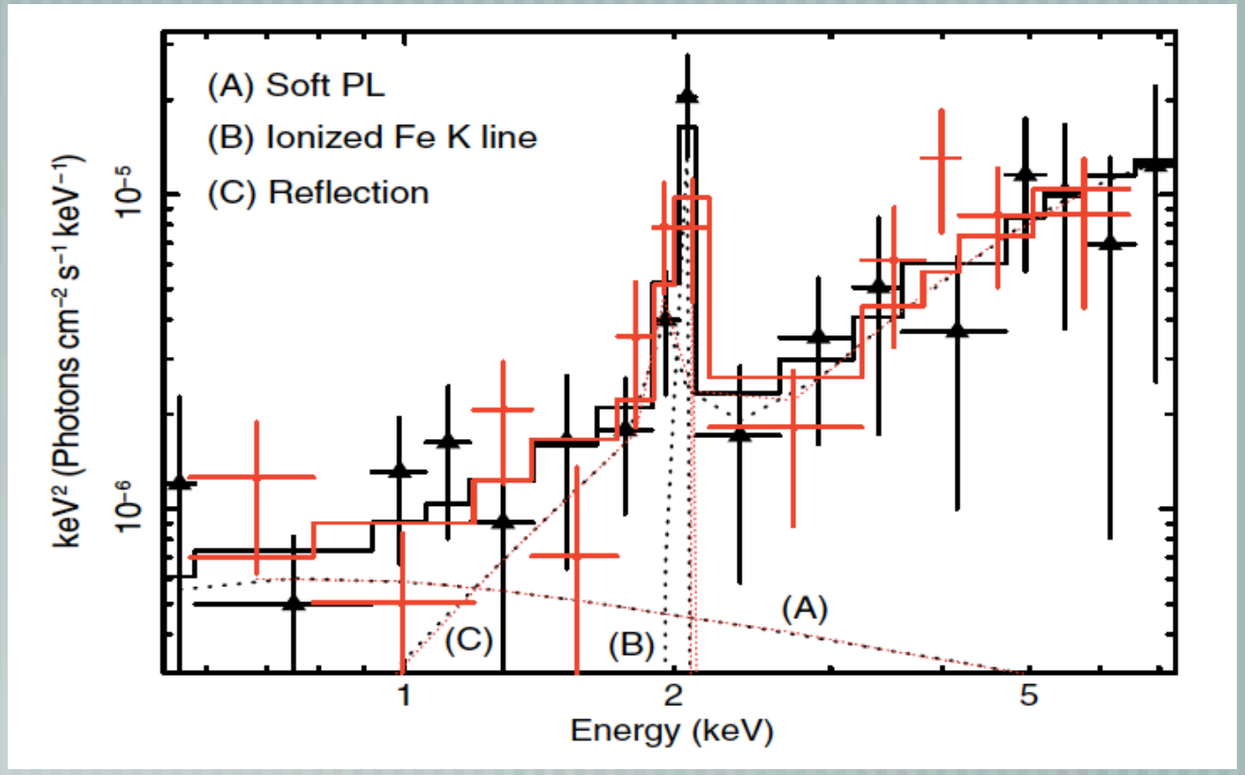

Piconcelli et al. 2015

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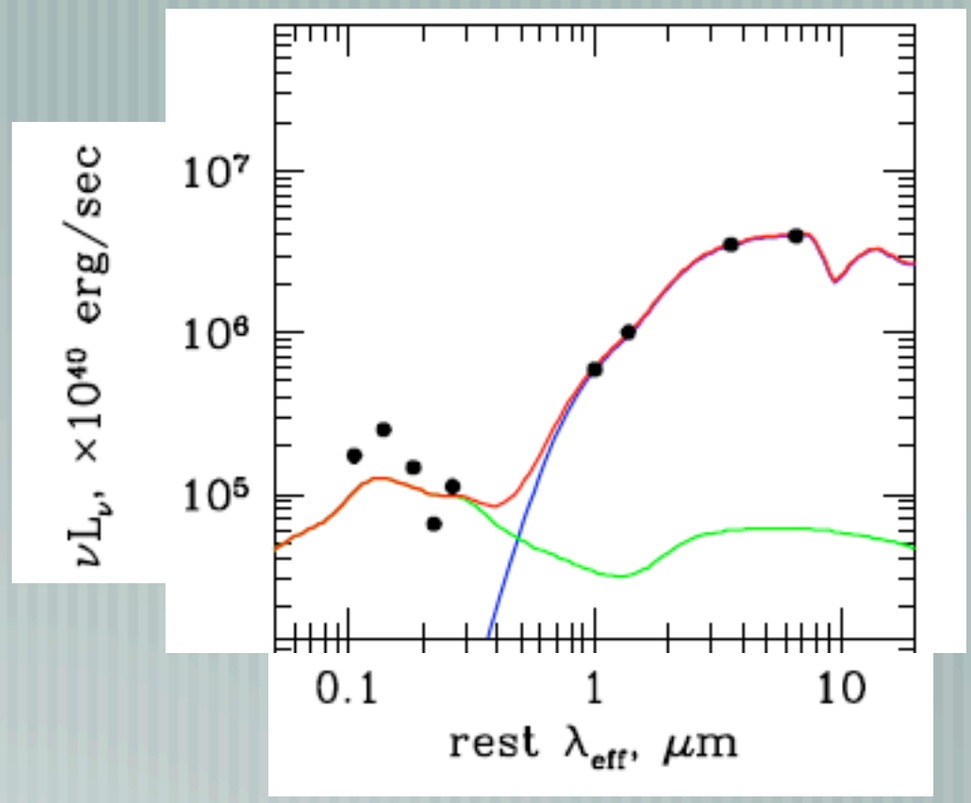
- Extremely red quasars
- Start with SDSS quasar catalog, select objects that have high W4/optical ratios
- Aim to select obscured AGN (provided they were also optically selected!)
- Bimodal redshift distribution
- Red type 1s, type 2s, BALs...
- A population with bizarre optical line properties



Ross, Hamann, Zakamska, et al. 2014

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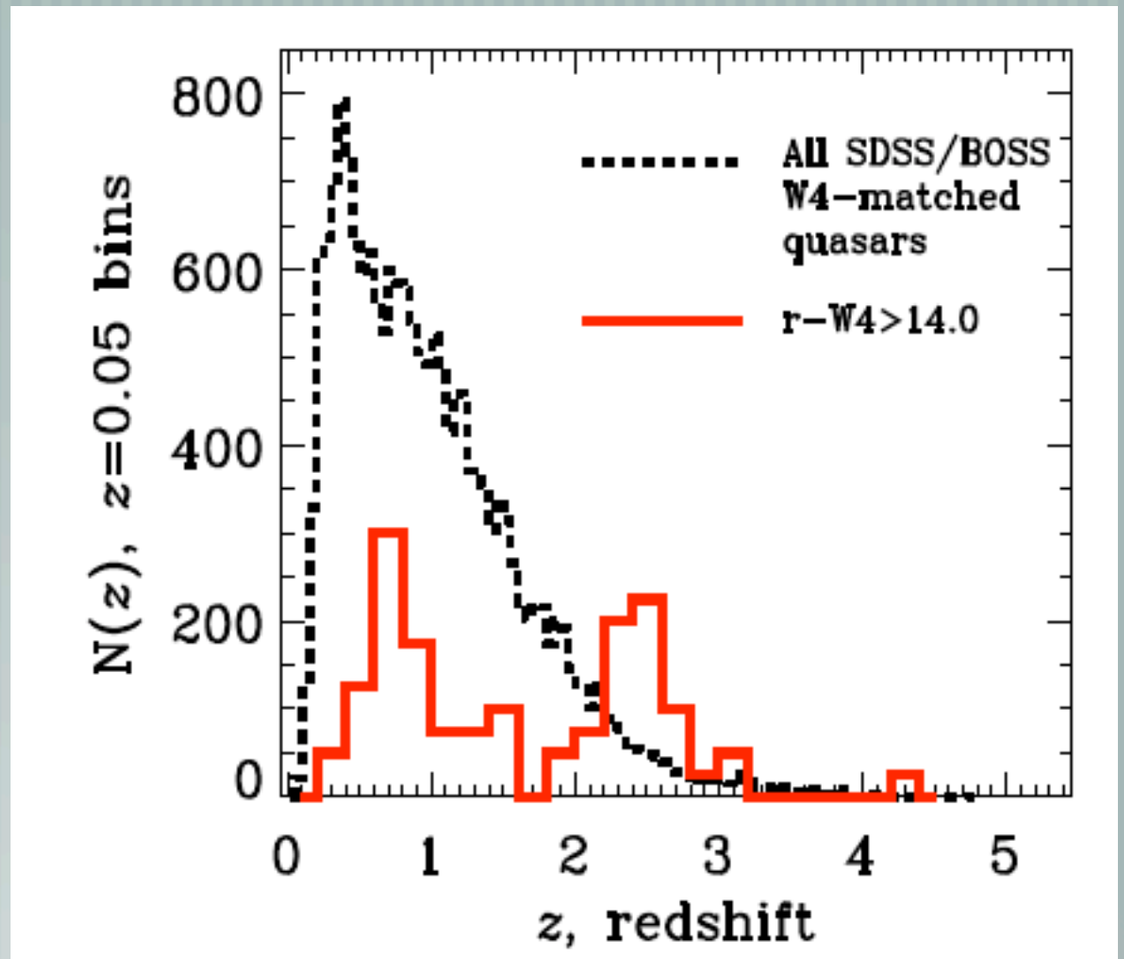

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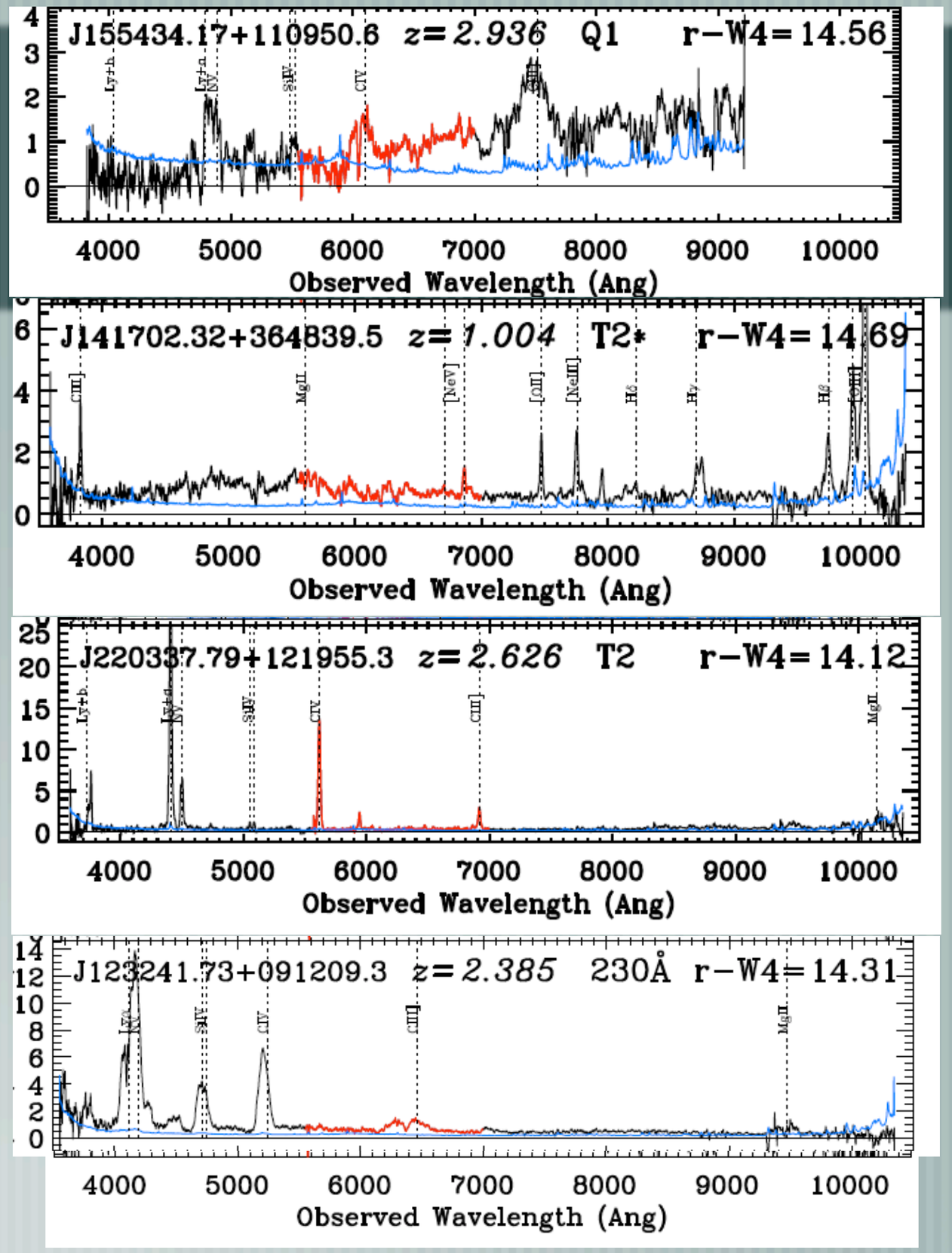
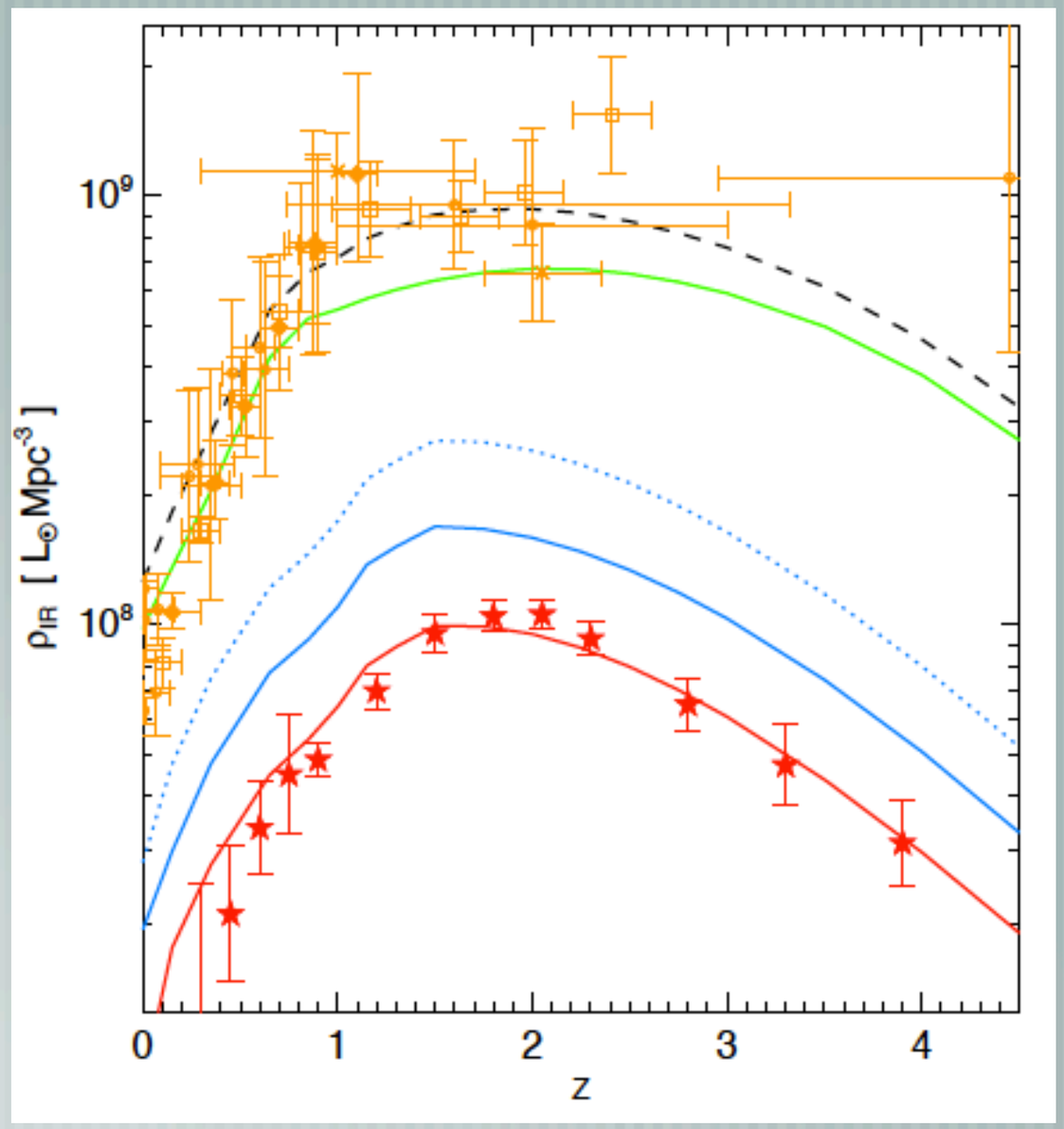


Ross, Hamann, Zakamska, et al. 2014

3. Why are these extreme sources relevant?

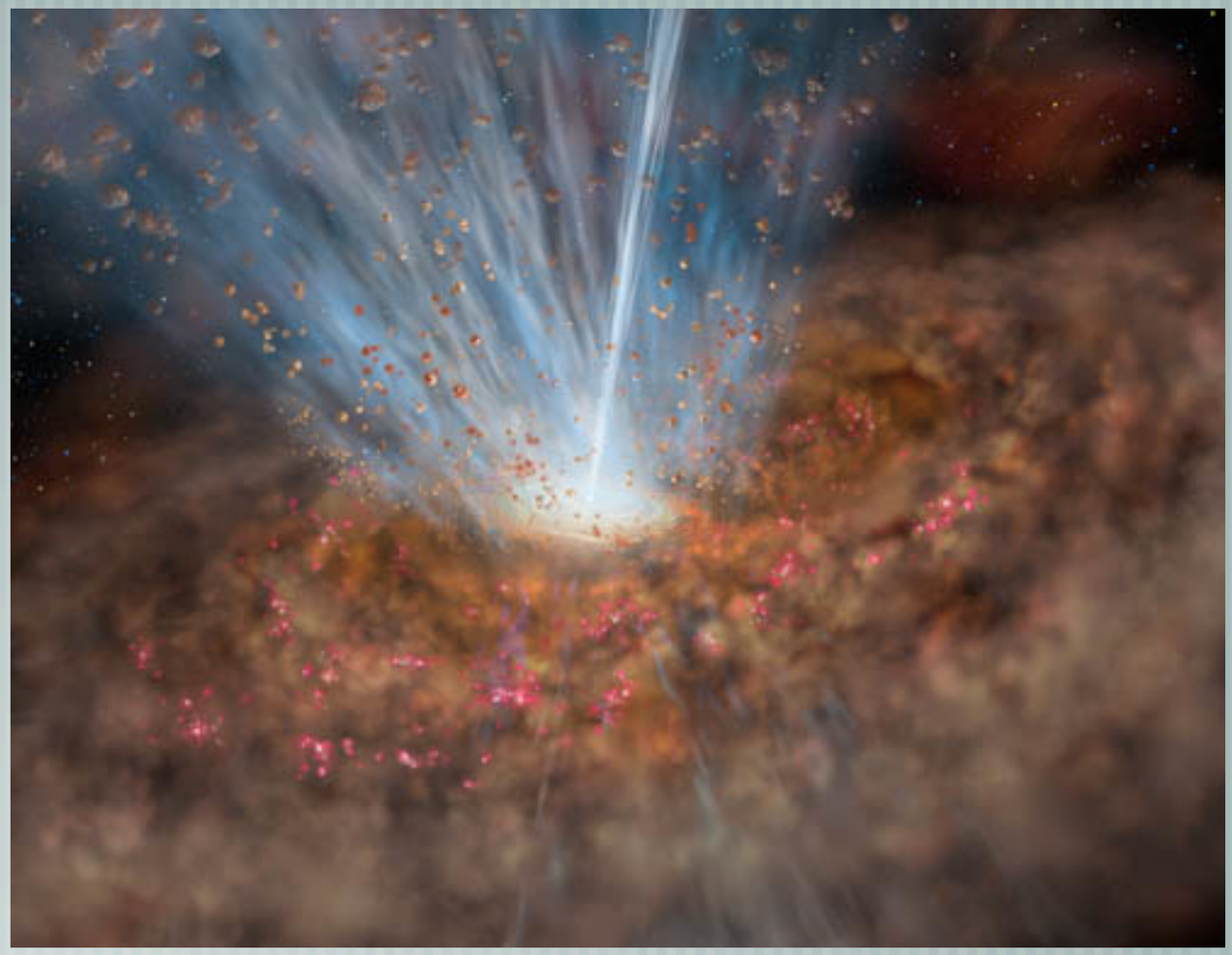
- Have a suspicion that they may be sites of "quasar feedback at peak galaxy formation"
- z=2-3 is peak of galaxy formation, quasar activity
- Likely when black hole / bulge correlations were established
- Quasar feedback limited the maximal mass of galaxies
- Major theoretical, observational effort in extragalactic astronomy, cosmology



Boyle & Terlevich 1998
Hopkins et al. 2008

3. Why are these extreme sources relevant?

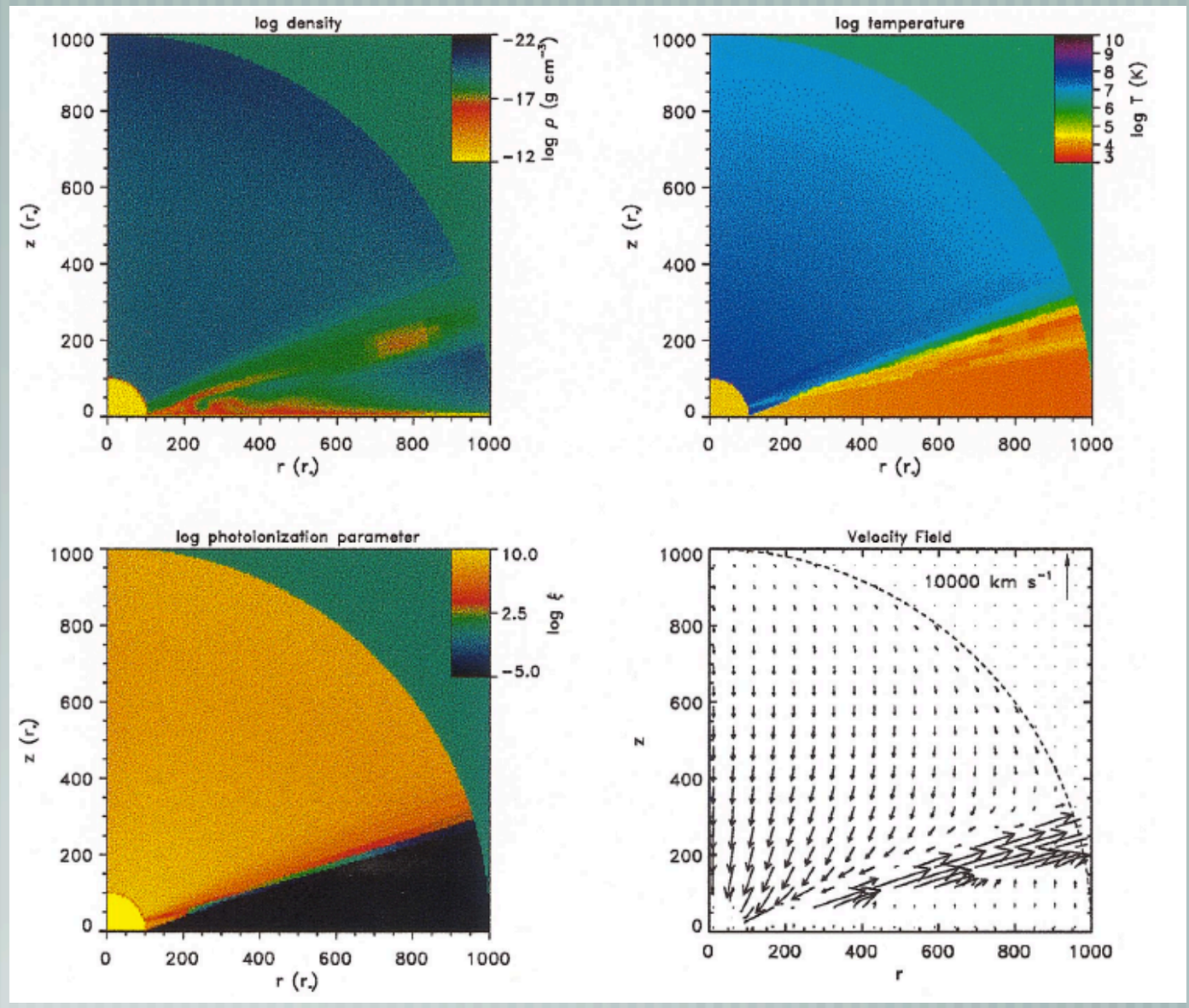
- What are observational signs of quasar feedback?
- **Feedback: strong effect of the quasar on the surrounding galaxy-wide, extragalactic environment**
- Until recently unclear. But now several different methods: molecular outflows, neutral outflows, absorption line outflows, emission line outflows
- Both radio-loud and radio-quiet quasars are capable



Artist: L. Cook / Gemini Observatory

3. Intro to quasar feedback

- For example, radio-quiet quasars (no jets)
- Close to the black hole: radiatively driven winds ("line-driving")
- up to >10% of c!
- = 10^7 year bomb in a gas-rich medium
- Density distribution, clumping of the ISM crucial



Murray et al. 1995
Proga et al 2000

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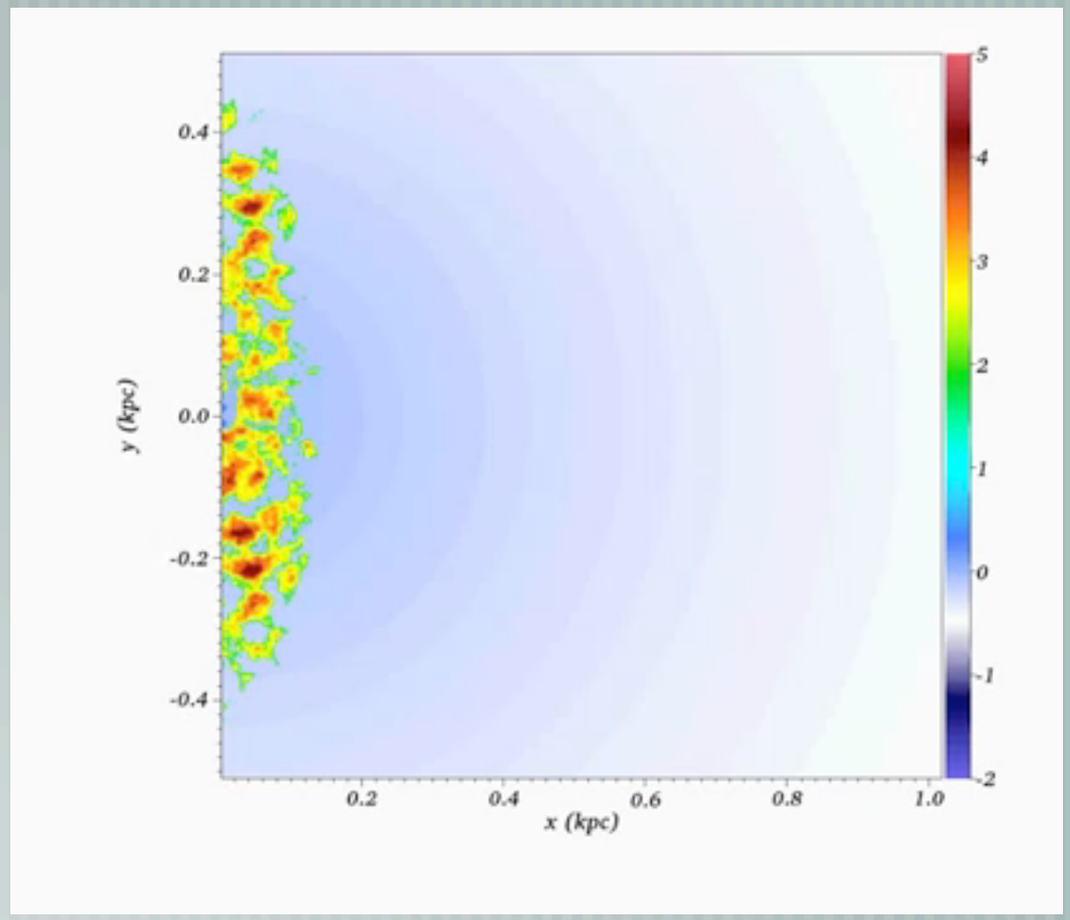


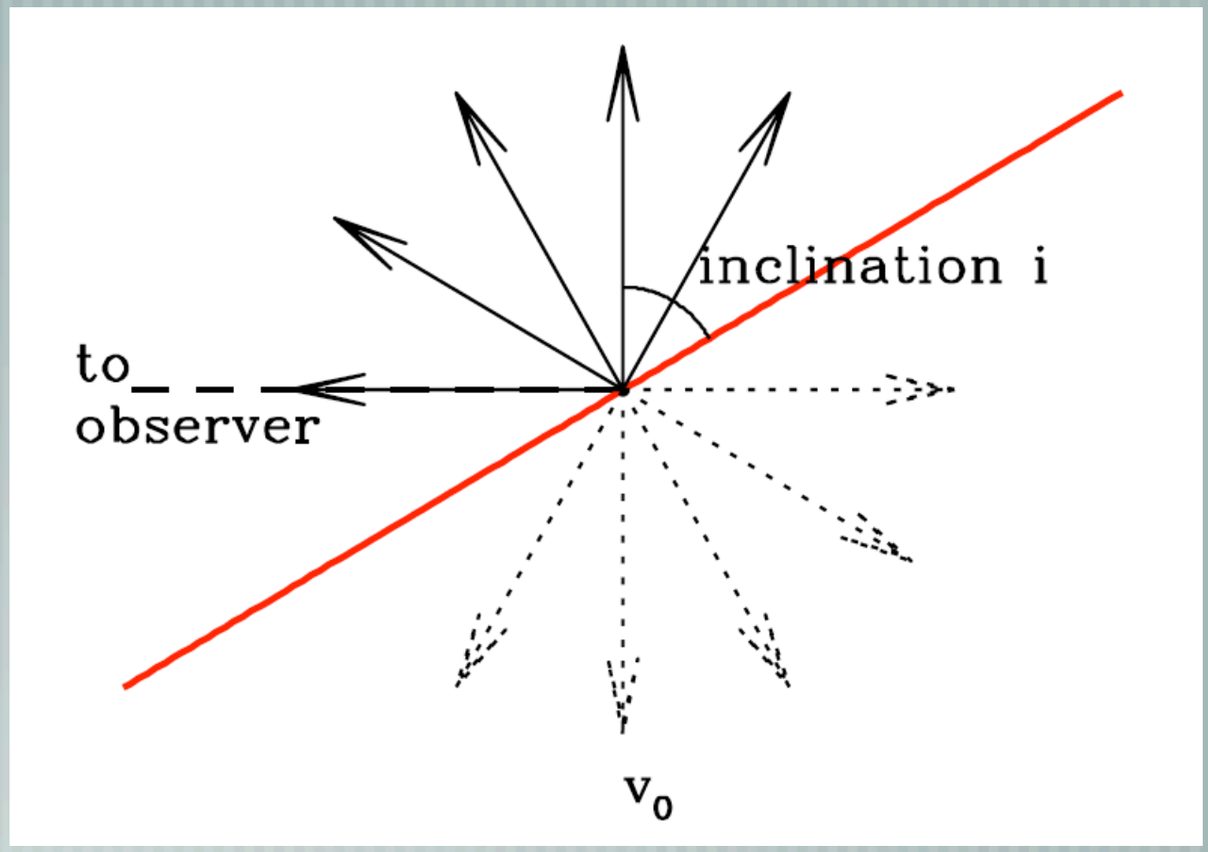
Wagner et al. 2013

Spherically symmetric models: King, Faucher-Giguere & Quataert:

typical velocities at large scales of 1000 km/sec.

3. Observations of feedback in low redshift quasars

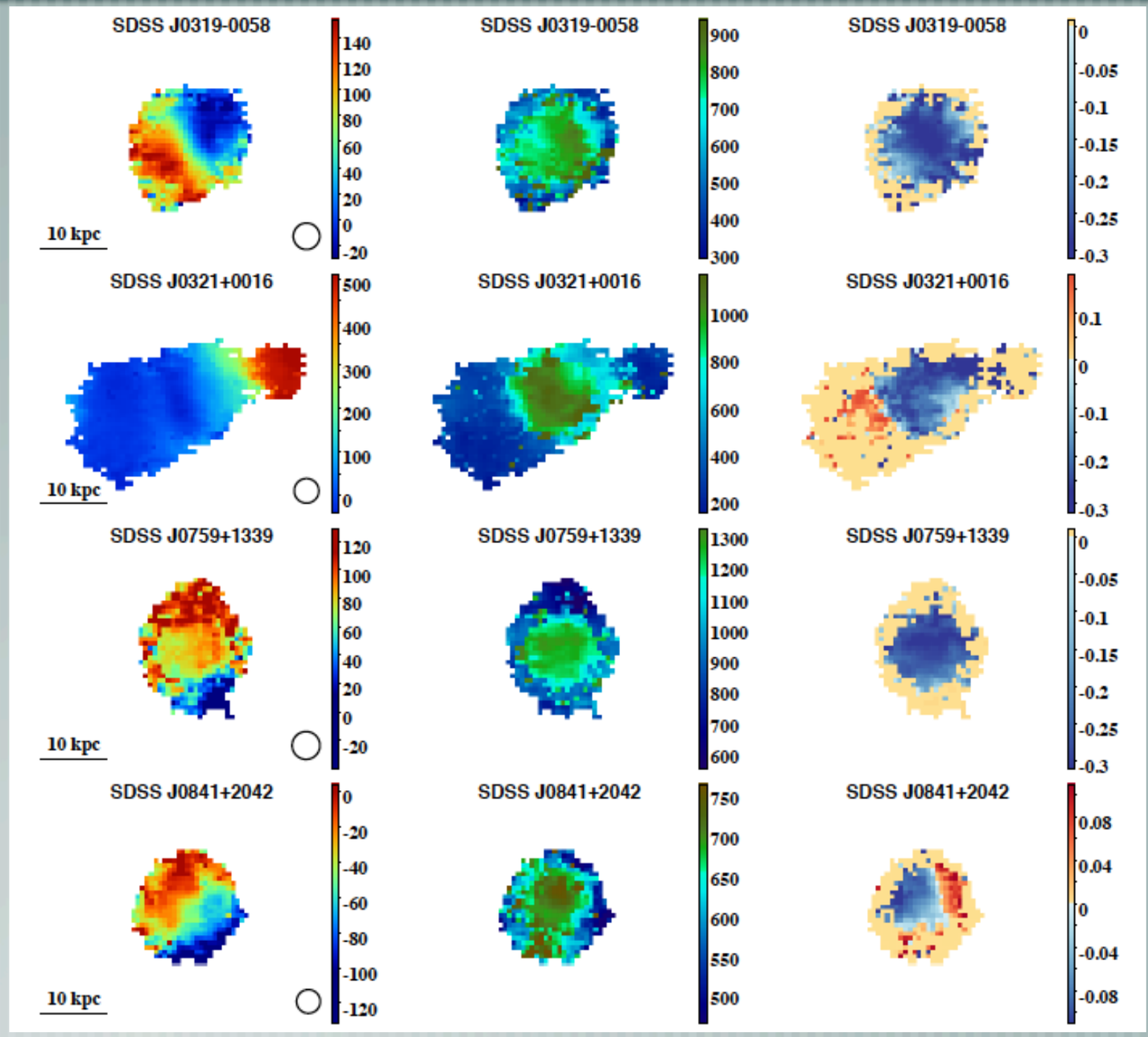
- We should see photo-ionized, shock-ionized gas in the outflow on galaxy scales
- Look at emission lines
- Spherically symmetric outflow: high physical velocity = high line-of-sight velocity dispersion
- Obscuration in the outflow or host galaxy=blueshifted asymmetries



Approximately:
v_0=FWHM/1.4

3. Observations of feedback in low redshift quasars

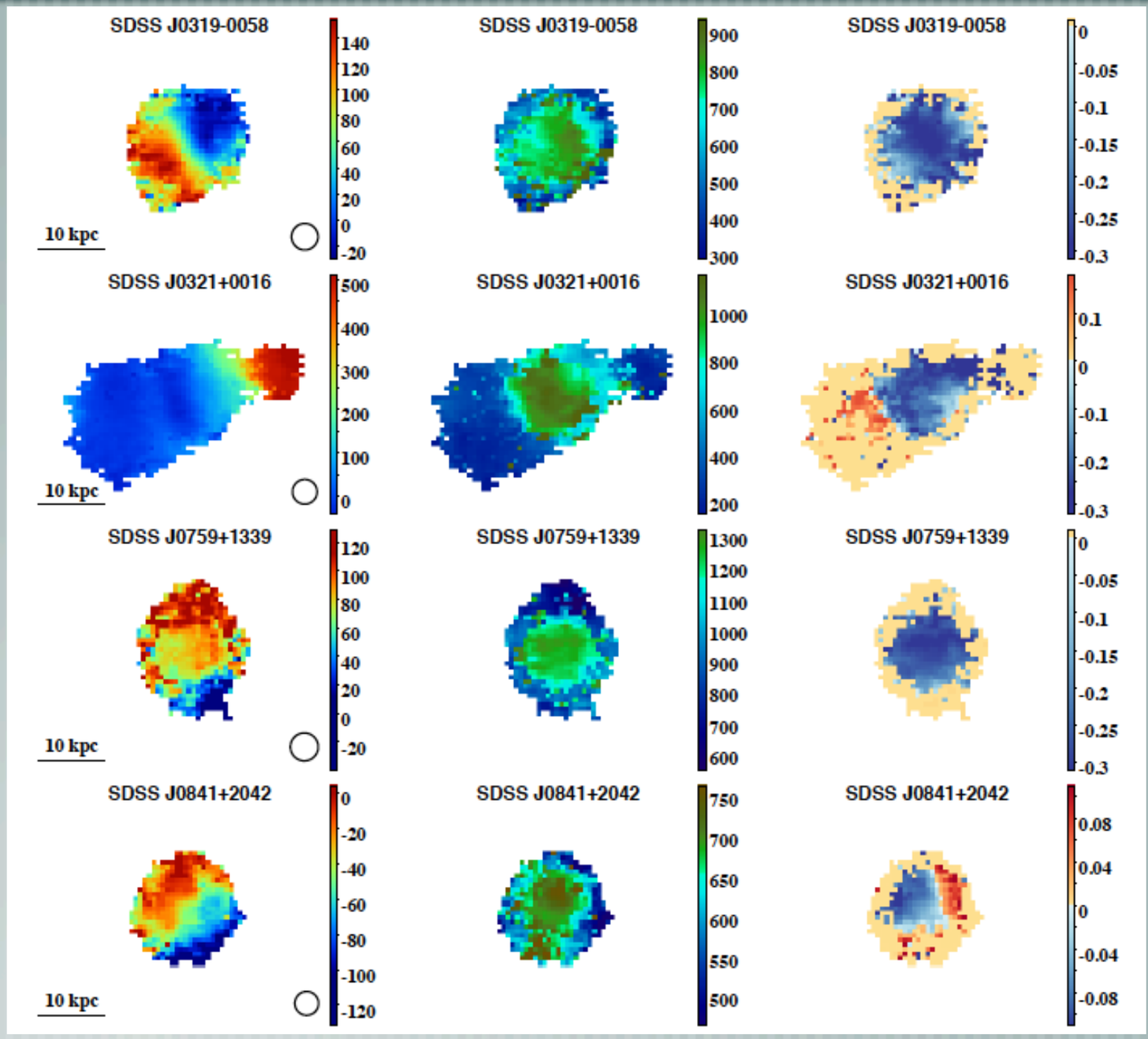
- We see this at low redshifts!
- IFU observations revolutionizing this area
- Line-of-sight velocity dispersion ⇒ typical outflow velocity=800 km/sec
- Blue-shifted asymmetries = classical outflow signatures



Liu, Zakamska, et al. 2013ab,2014

3. Observations of feedback in RQ quasars

- Now seen by several groups in type 1 and type 2 quasars (e.g., Harrison et al., Rupke & Veilleux, Husemann et al., Villar-Martin et al., Hainline et al., Alexander et al., Cano-Diaz et al., etc.)
- IFU and long-slit spectroscopy
- How to convert to masses, energies?



Liu, Zakamska, et al. 2013ab,2014

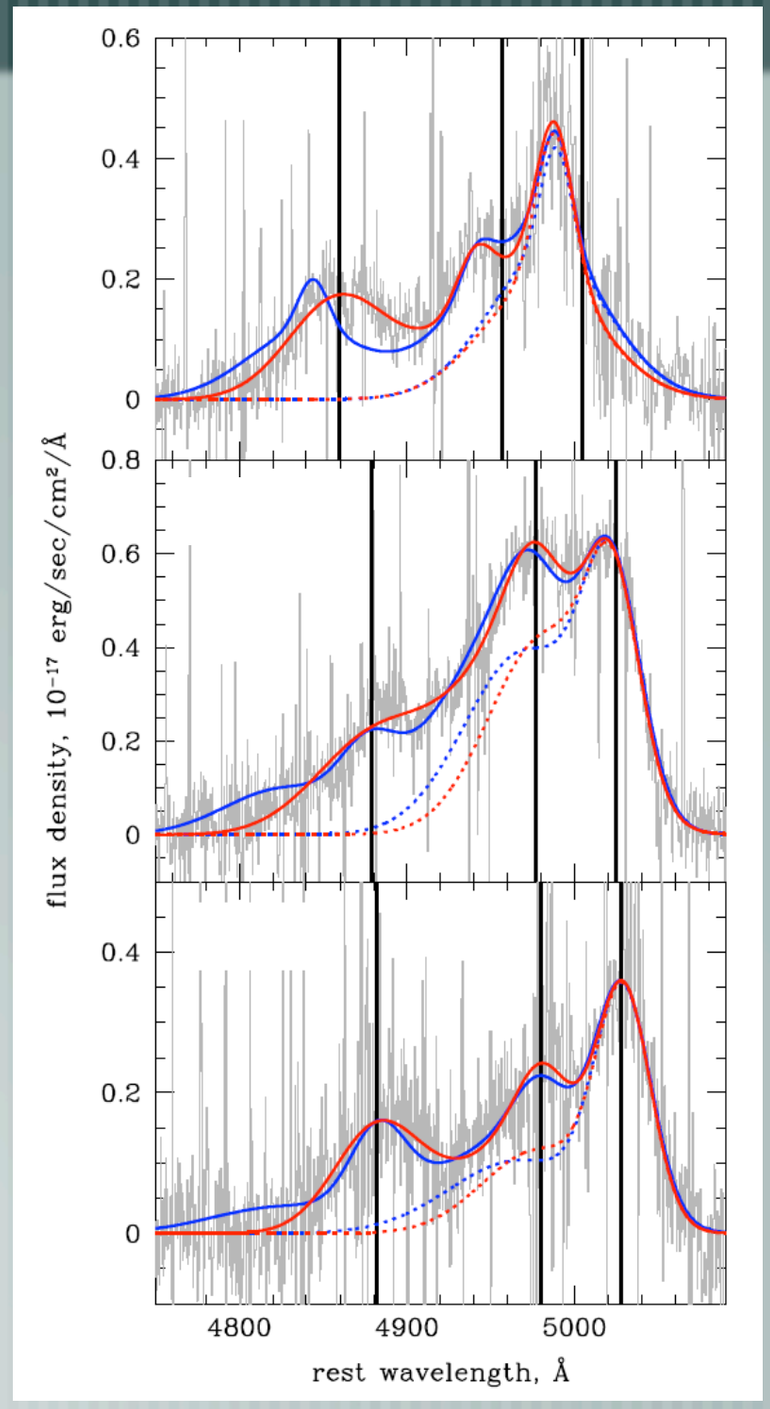
3. Extreme WISE quasars and quasar feedback

Raw results alert

Consuming raw or undercooked data may increase risk of confusion

3. Extreme WISE quasars and quasar feedback

- VLT NIR spectra, rest-frame optical
- With Fred Hamann, Isabelle Paris
- Extreme [OIII] widths, extreme blue asymmetries
- Physical velocities >3000 km/sec
- Unprecedented at low redshift
- Possibly the “smoking gun” of powerful feedback?



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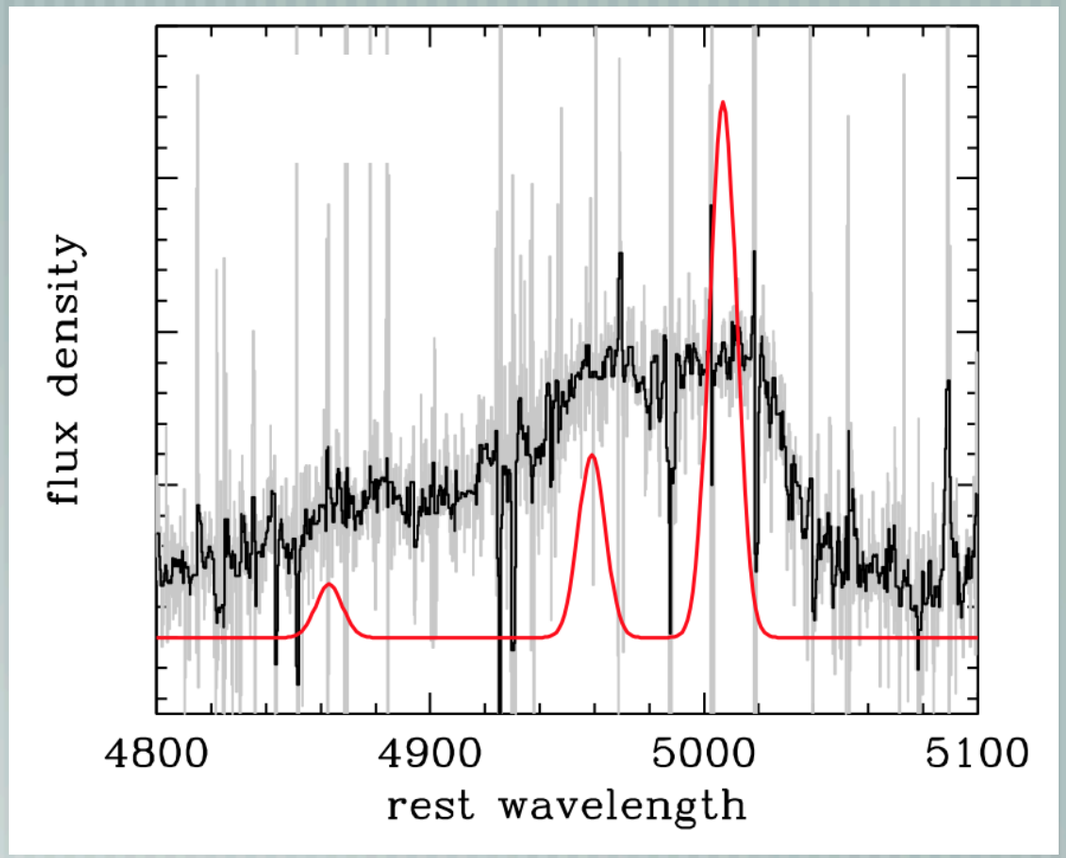

Comparison with "typical" lowz type 2 quasar, FWHM=700 km/sec

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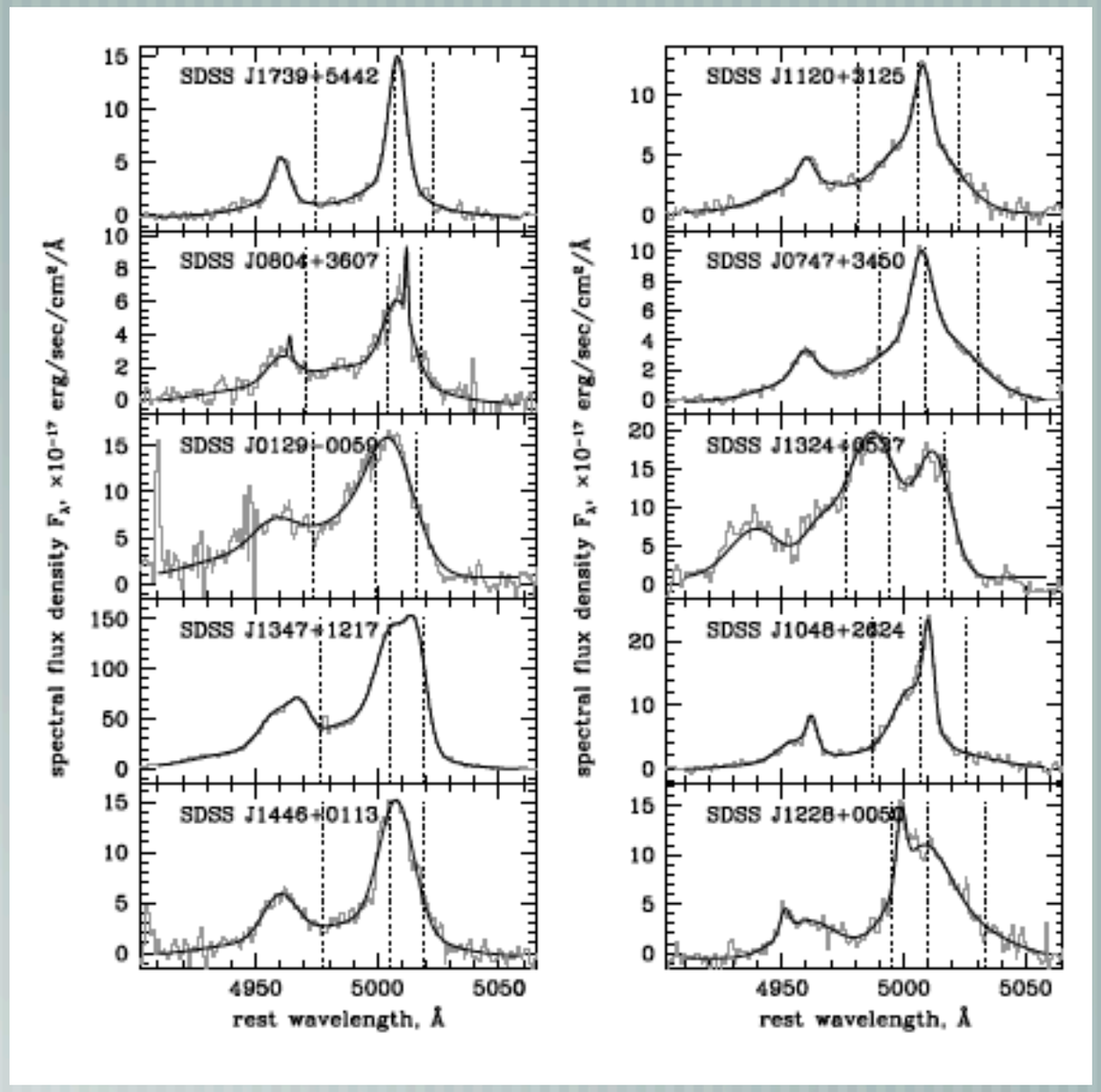

For comparison: the most extreme type 2 objects at low z, v_0=1500-2000 km/sec
Zakamska & Greene 2014

Summary

- Demographics of quasars remains an unsolved problem
- IR surveys can potentially solve this problem, especially supported by multi-wavelength observations, better models
- WISE: combination of sensitivity, wavelength coverage, sky coverage
- WISE discovery: extremely luminous obscured quasars at peak galaxy formation
- Possibly “smoking gun” of quasar feedback