QSO winds and galaxy evolution

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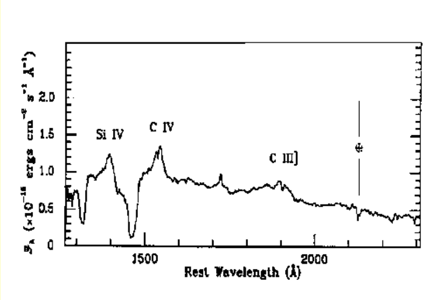
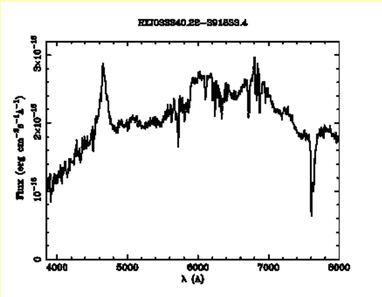
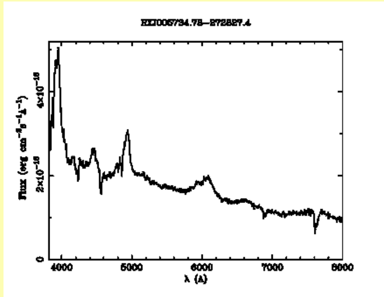
Motivation: we need to know about star formation in z~2 QSOs?

- The black hole/bulge mass relation tells us that the formation of spheroids and black holes are intimately linked.
- QSOs had their heyday at z~2.
  - Most vigorous period of black hole growth.
  - If black holes and stars grow together, QSOs should also be forming stars rapidly.
- Peak of star formation rate also at $1 < z < 3$.

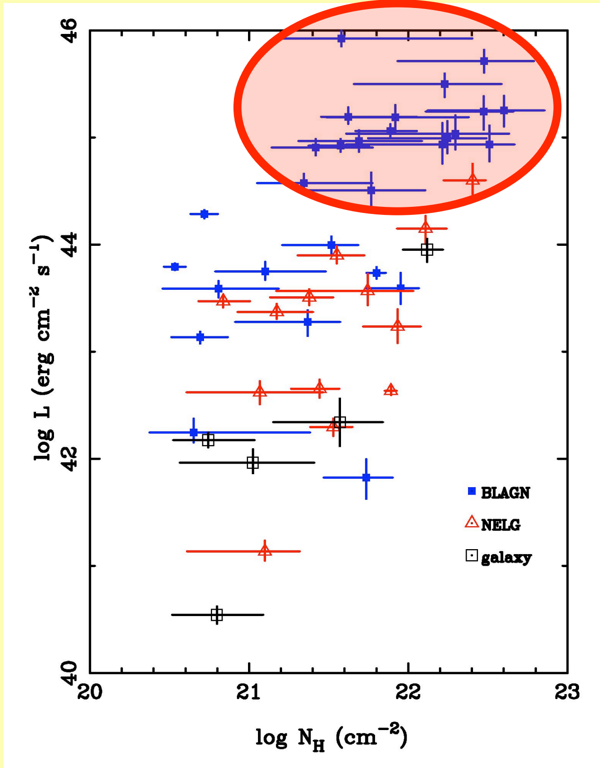
X-ray absorbed QSOs







Page, Mittaz & Carrera 2001, MNRAS 325, 575



Note the absorption lines in the restframe UV.

Two scenarios:

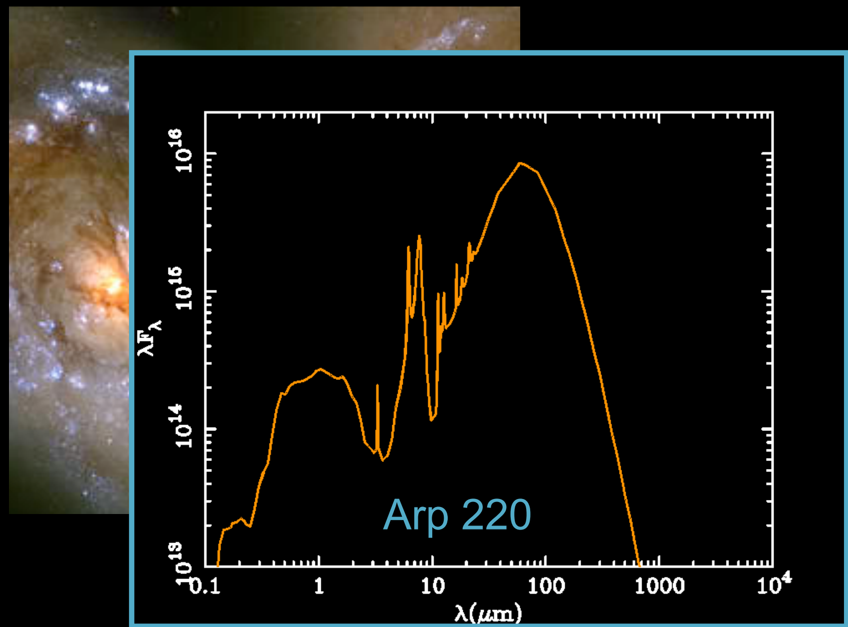
1. **According to AGN unified schemes all AGN will be absorbed when seen from some directions.**
2. **QSOs in their early growth phases may be X-ray absorbed with host galaxies still forming.**

- In scenario 1, star formation is not related to absorption.
- In scenario 2, it is.

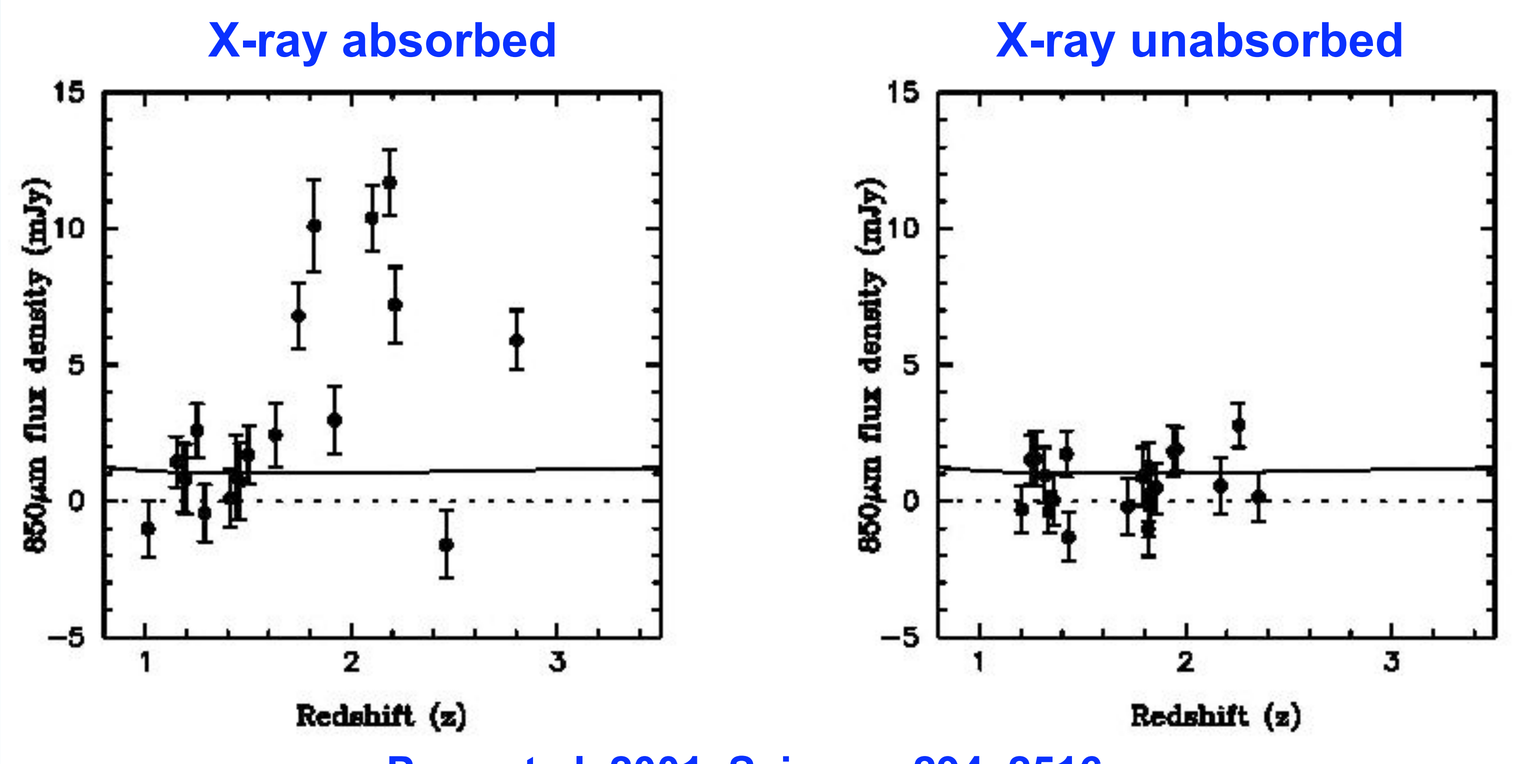
Energy release from black holes and stars

Black holes growing by accretion are best found by X-ray emission

The most rapidly star-forming galaxies are often highly obscured, emitting the bulk of their energy in the far infrared



Here's what happens when you look for submillimetre emission from QSOs



Page et al. 2001, Science, 294, 2516

Page et al. 2004, ApJ, 611, L11

Stevens et al. 2005, MNRAS, 360, 610

X-ray absorbed and X-ray unabsorbed QSOs are completely different in the submm.

What does this mean?

- X-ray absorbed QSOs are ULIRGs/hyperLIRGs
  - **The objects have L_{FIR} between 1 and 4 times L_{AGN} – must be star powered.**
  - **Can't be to do with orientation.**
- Therefore they probably form part of an evolutionary sequence.
  - **Bulge not finished yet - earlier than typical QSOs.**
  - **Black holes already large - must be later than typical submillimetre galaxies.**
  - **Only about 10% as numerous as normal QSOs.**

X-ray absorbed QSOs are a brief transition stage between the ultraluminous starburst and the unobscured QSO phase.

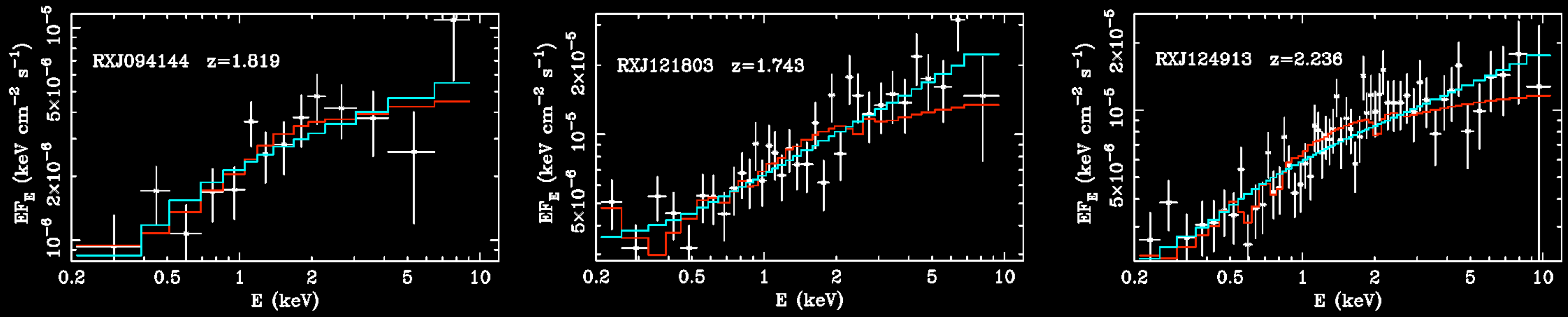
Smells fantastic, but some flies in the ointment:

1. **How come these QSOs are absorbed in X-ray but not in optical?**
   - **Low dust to gas ratio in galaxy rubbish idea since galaxy detected in FIR by its dust emission!**
2. **Why does the emergence of the QSO and the termination of the star formation happen in the same short period of time?**
   - **Winds from AGN? Attractive to theorists, but where is the evidence that there is any unusual wind coming off these QSOs?**

- **XMM-Newton spectra are the best discriminators for these questions.**

XMM-Newton spectra

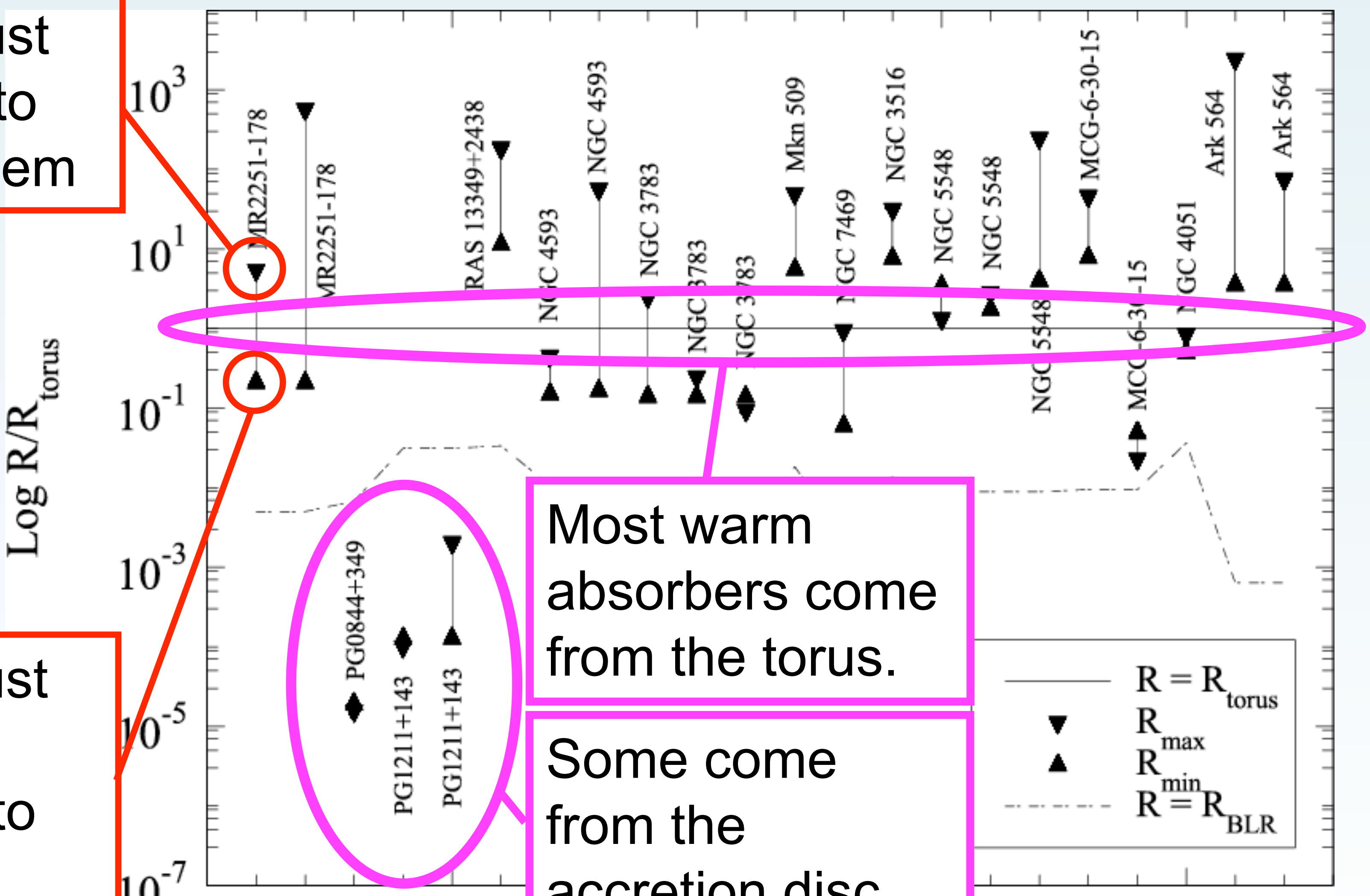
Possible models: cold absorber ionised absorber



- χ^2/υ is OK for either, but
- Cold absorber gives:
  - Abnormally low values of intrinsic X-ray / optical ratio
  - Unusually hard X-ray spectral indices
- Ionised absorber gives:
  - Sensible parameters for both
  - Absorbers have log xi ~ 2.5, log NH ~23
- An ionised absorber is required for a physically self consistent model of an absorbed QSO spectrum.

For comparison: where do ionised absorbers in Seyfert galaxies come from?

AGN must be able to ionize them



They must be fast enough to escape

Most warm absorbers come from the torus.

Some come from the accretion disc

Blustin et al 2005, A&A, 431, 111

Use some of the same tricks on these objects.

- **To keep absorbers ionized**
  - **distances of absorbers < 100pc.**
  - **Absorbers come from the AGN rather than host galaxy.**

- **Assume they are constant-velocity winds at UV-derived outflow velocities, assume filling factors ~1% similar to Seyfert winds.**
  - **Distances compatible to torus (except RXJ124913).**
  - **Outflow rates about 10 times accretion rates.**

- **Over lifetime of X-ray absorbed phase**
  - **Energy expelled in wind ~ 4% of bolometric luminosity of QSO.**

Physical implications

- **The reason that these QSOs are bright in the UV but absorbed in the X-rays is that the absorber is a highly ionised wind from the QSO, and contains little dust.**
  - **(Ionised absorbers in nearby Seyferts are well known to contain little dust)**
  - **The absorbers are not related to the gas forming stars in the host galaxy.**
- **These QSOs inject kinetic energy into their surrounding host galaxy close to the 5% level anticipated by theorists to terminate star formation by feedback.**
- **The outflow is ejecting mass from the torus (i.e. the food reservoir) at 10 times the accretion rate during the X-ray absorbed phase.**
  - **The outflow can terminate accretion as well as star formation.**
  - **Hence the relatively short lifetime of this phase.**
- **Loose ends look to be more or less tied up.**

Big issues remaining.

- **Outflow rates have big uncertainties both statistically and from assumptions.**
  - **Far too simplistic model for absorber properties:**
  - **unknown filling factor**
  - **unknown distribution of ionization parameter**
  - **impossible to measure the outflow velocities directly for the X-ray absorber.**
- **<u>Only</u> solution is a high resolution spectrometer >100 times more sensitive than XMM-Newton RGS**
  - **i.e. IXO cryogenic spectrometer.** SPICA

Conclusions

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- **X-ray absorbed QSOs at z=2 are hyperluminous galaxies with huge star formation rates.**
- **Normal z=2 QSOs are not. They are mature objects.**
- **The absorbed QSOs appear to represent a transitional phase between submillimetre galaxies and QSOs.**
- **Absorbed QSOs could be key to understanding how accretion onto massive black holes, galaxy formation and the formation of clusters of galaxies relate to each other.**
- **They have ionised winds coming from the QSO.**
- **These winds <u>could be</u> the terminators of star formation <u>and</u> accretion.**