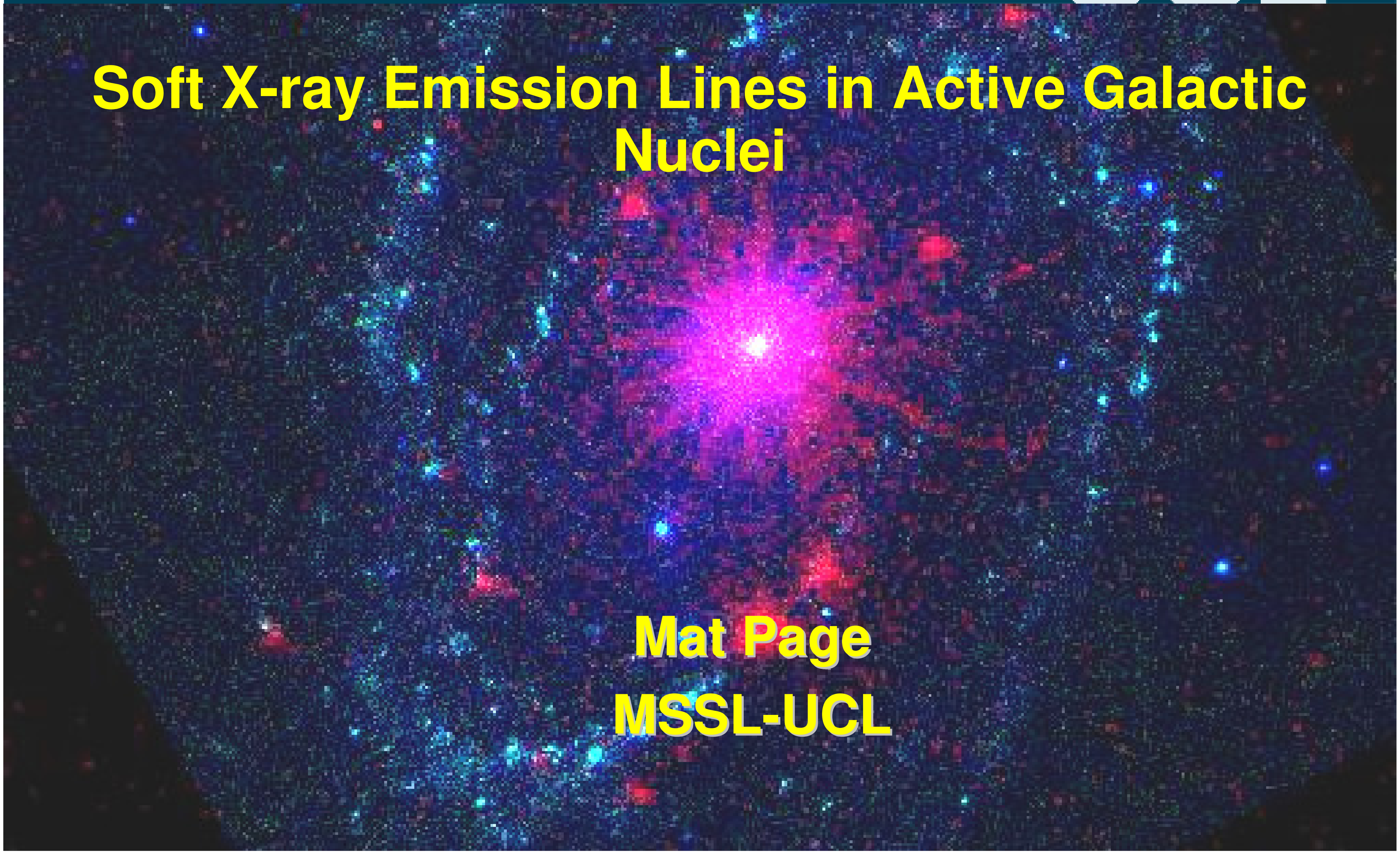
Soft X-ray Emission Lines in Active Galactic Nuclei



Mat Page

MSSL-UCL

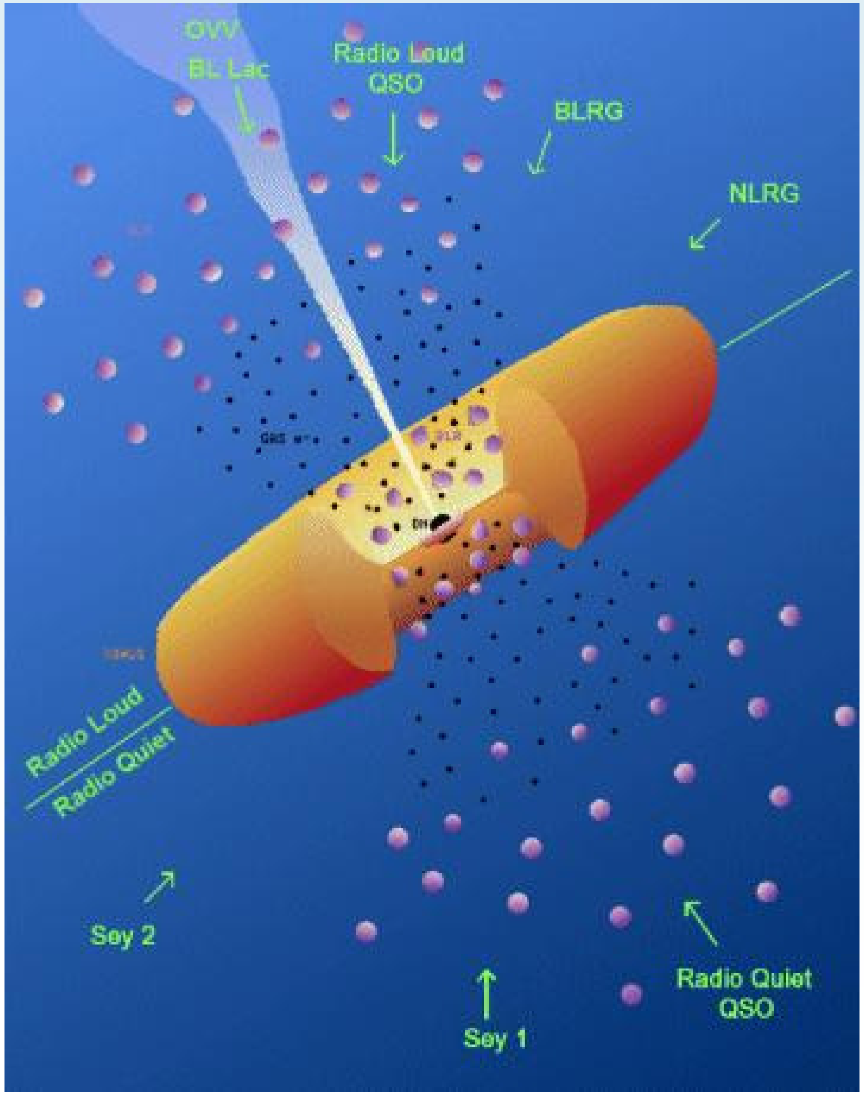
- **Observations of soft X-ray line emission allow us to investigate highly ionized plasmas in galaxies and AGN.**

- I'll start with the most powerful sources and work down in power:
- **Quasars.**
- **Seyfert** galaxies
  - **Broad lines and narrow lines, absorption and emission.**
- Low luminosity AGN optically classified as **Low Ionization Nuclear Emission Regions**
  - **(LINERs; includes 1/5 - 1/3 of all galaxies)**
  - **middle ground between normal galaxies and AGN**
  - **In particular: M 81 and NGC 7213**
- How does the soft X-ray line emission from LINERs compare with that from more active Seyferts?
- What is powering the lines?

Quasars: the most powerful sources

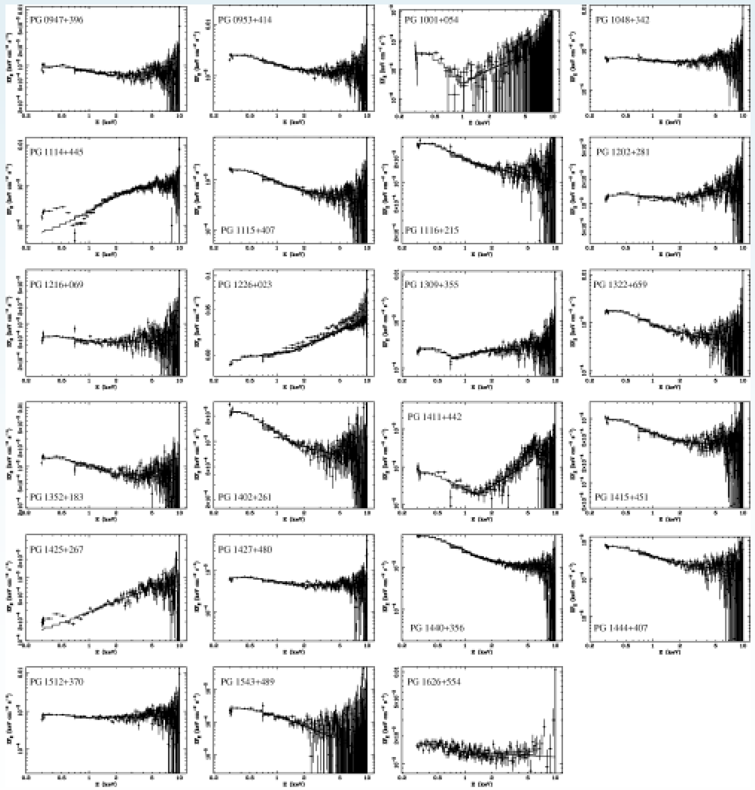
- First, reminder of the AGN 'unified' model:

- In quasars and Seyfert 1 galaxies, we are looking through the open part of the torus to the central engine and broad line region.
- In Seyfert 2s, our view of the central regions is obscured by the torus.



Quasars: the most powerful sources

- 'Traditional' picture of quasar X-ray spectra:



- Power law continuum
- Mysterious Soft excess could be:
  - **Thermal (Gierlinski & Done 2004)**
  - **Non-thermal (Brocksopp et al 2006)**
- Maybe an Fe line at 6.4 keV
- Maybe some absorption.
- But otherwise **very** smooth.

Brocksopp et al. 2006, MNRAS 366, 953

The archetypal example is 3C273

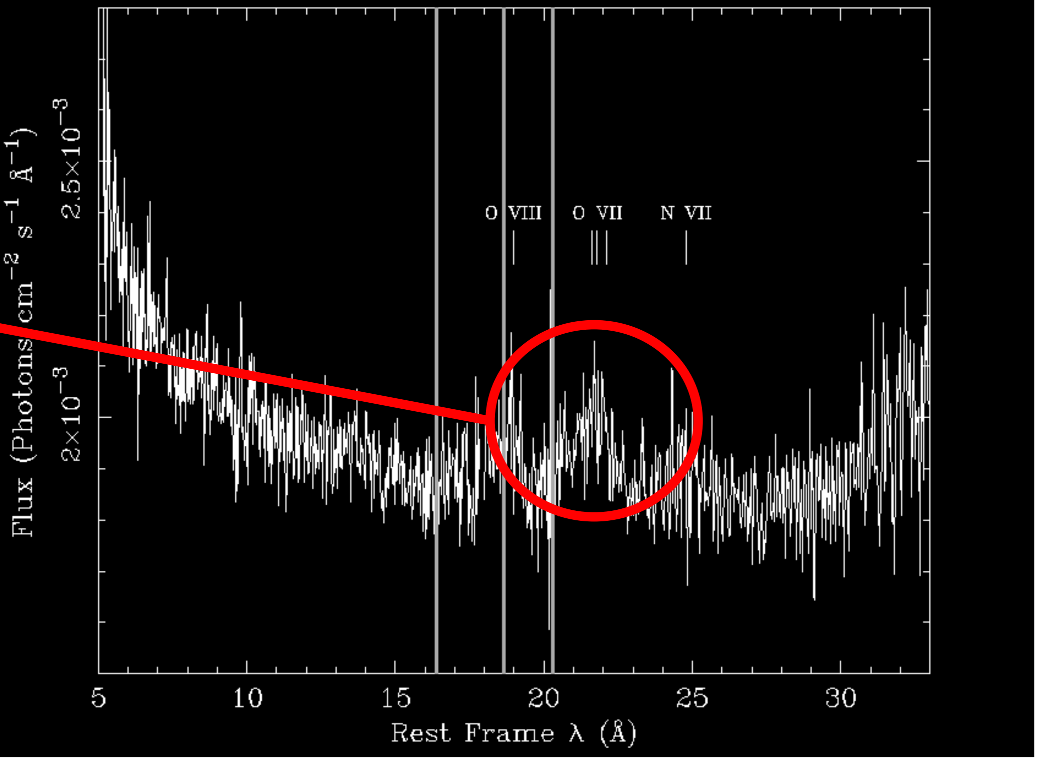
- So smooth in EPIC it is used as a 'pure continuum' comparison source by many authors.
- Here's what it looks like with RGS:

Broad emission lines

Velocity similar to the inner BLR

Most prominent lines are Oxygen VII

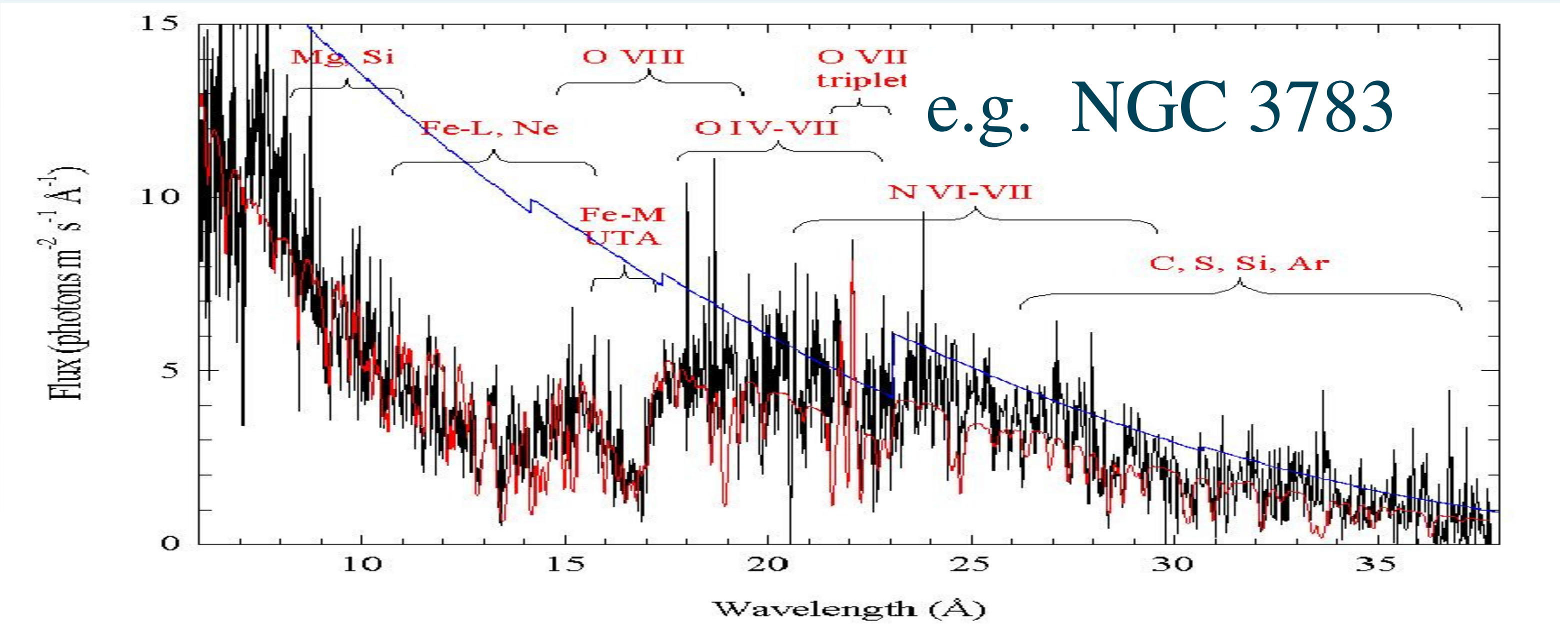
Page & Blustin 2006



Moving down to Seyferts...

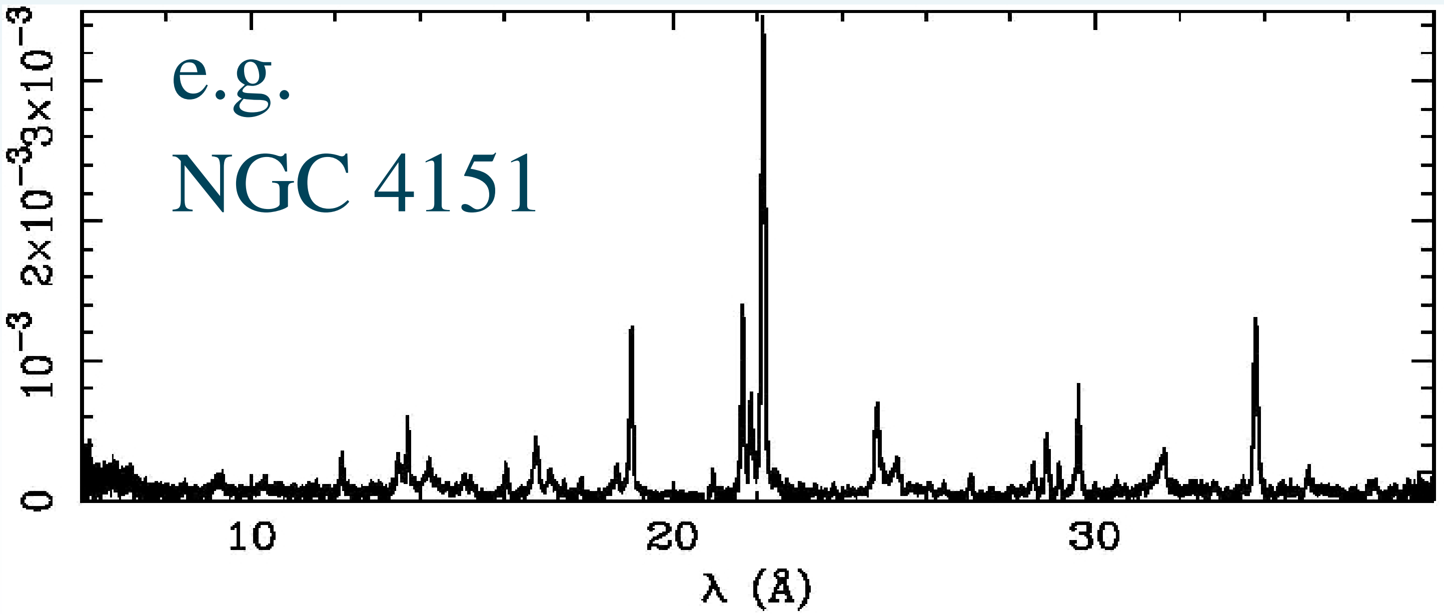
- What do luminous Seyfert galaxies look like?
- **Basically 2 flavours:**

1) nucleus visible in soft X-ray



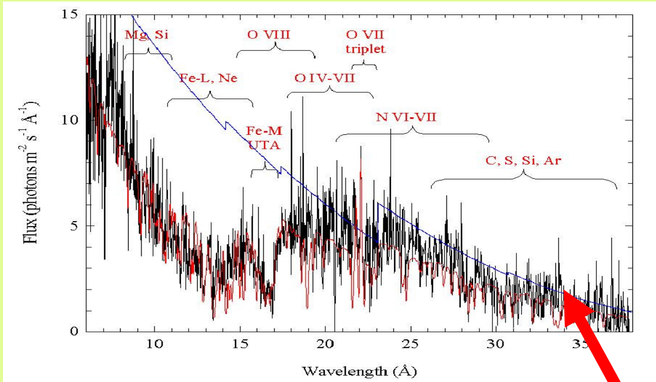
- What do luminous Seyfert galaxies look like?
- **Basically 2 flavours:**

2) nucleus hidden in soft X-ray

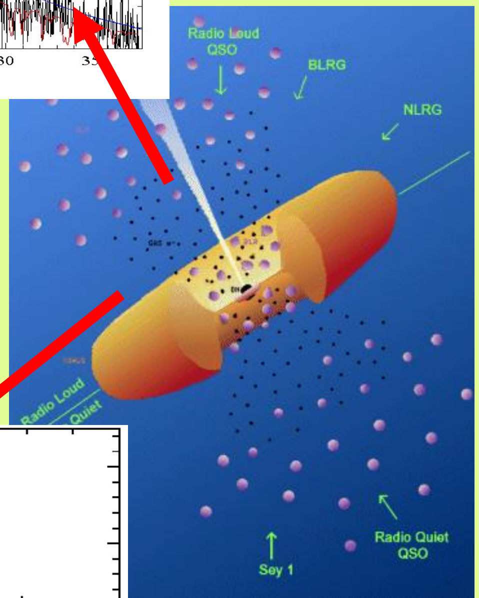


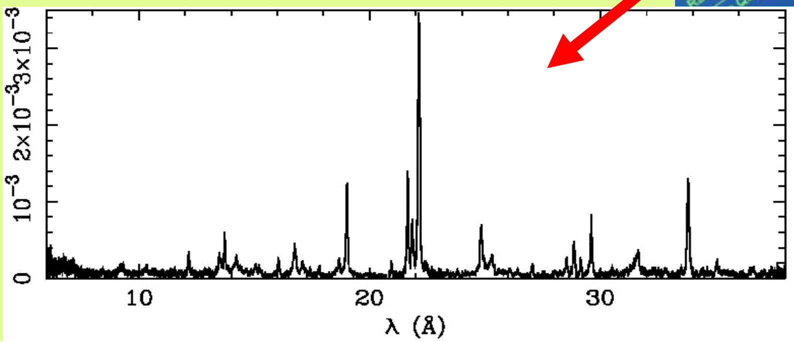
Seyfert type 1 and 2 galaxies

- More or less corresponds to optical classification



- Except that the emission lines are in the edge on Seyferts.
- Absorption lines are in the face on Seyferts.

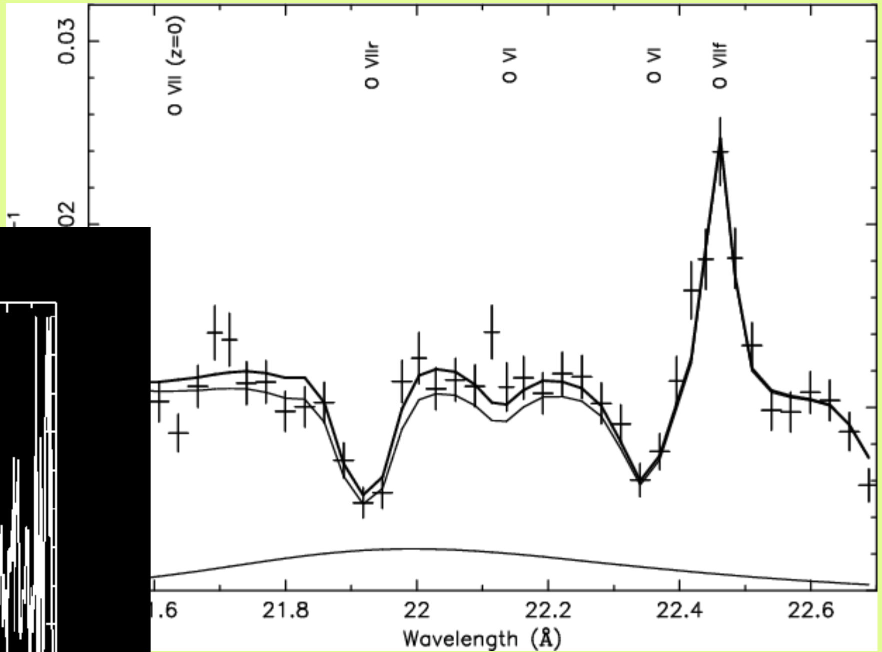


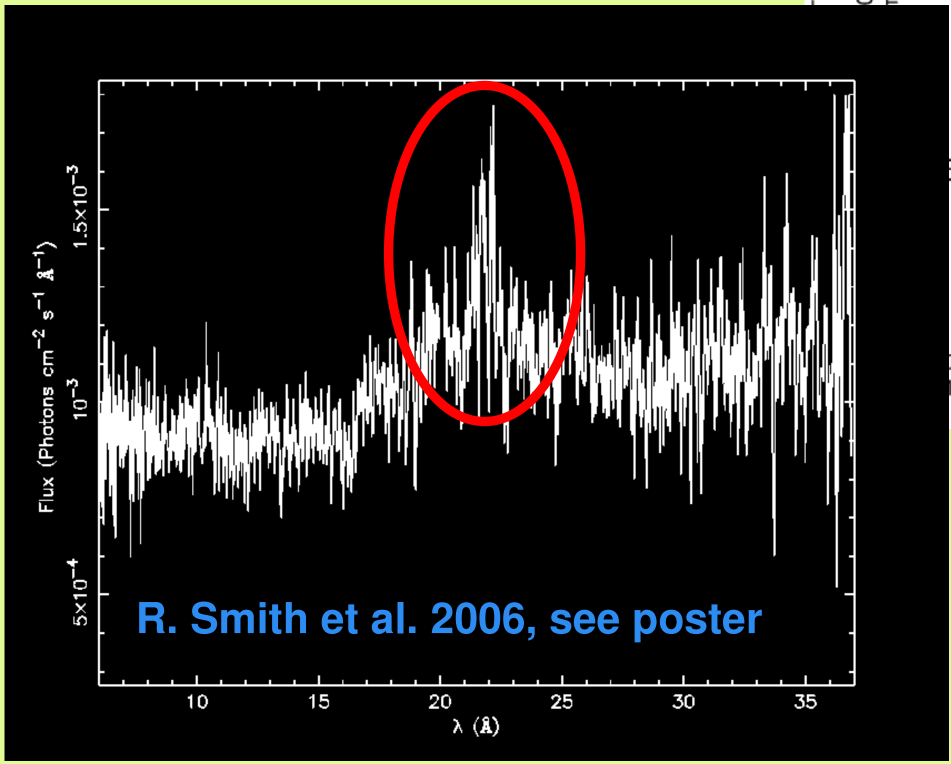


Starting with Seyfert 1s

- Broad lines?
  - yes

Steenbrugge et al. 2005, A&A, 434, 569



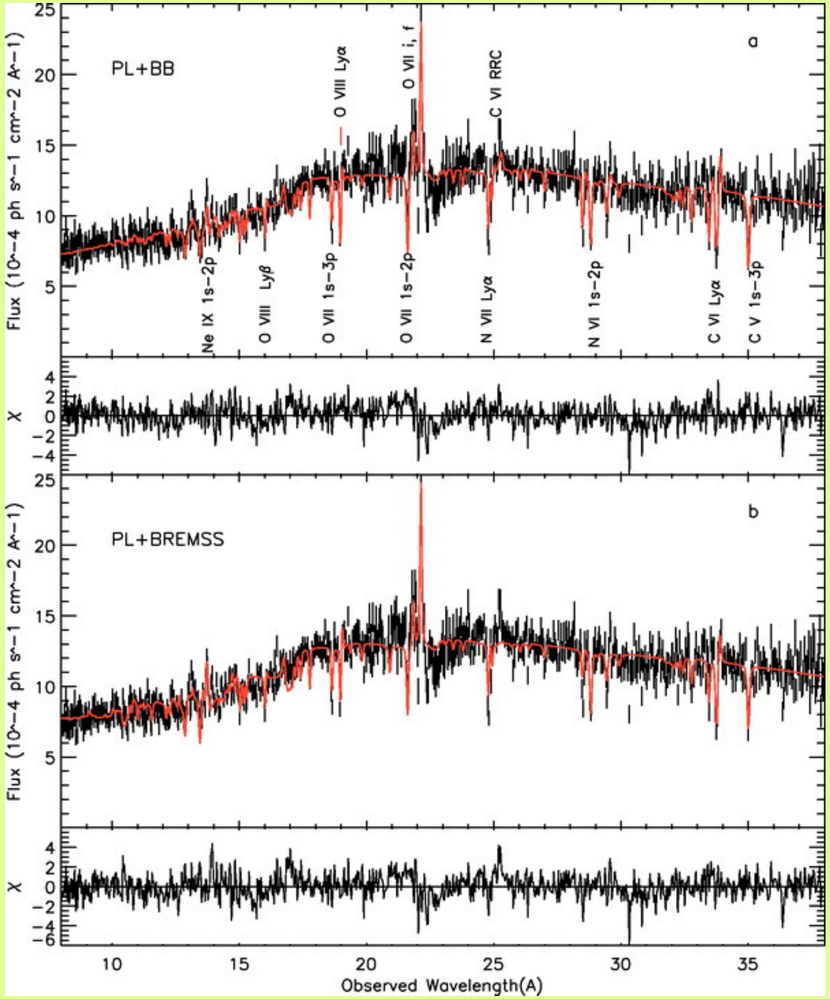


Quite difficult to see though!

Starting with Seyfert 1s

- Broad lines?
  - yes
- Narrow lines?
  - yes

Also difficult to see!

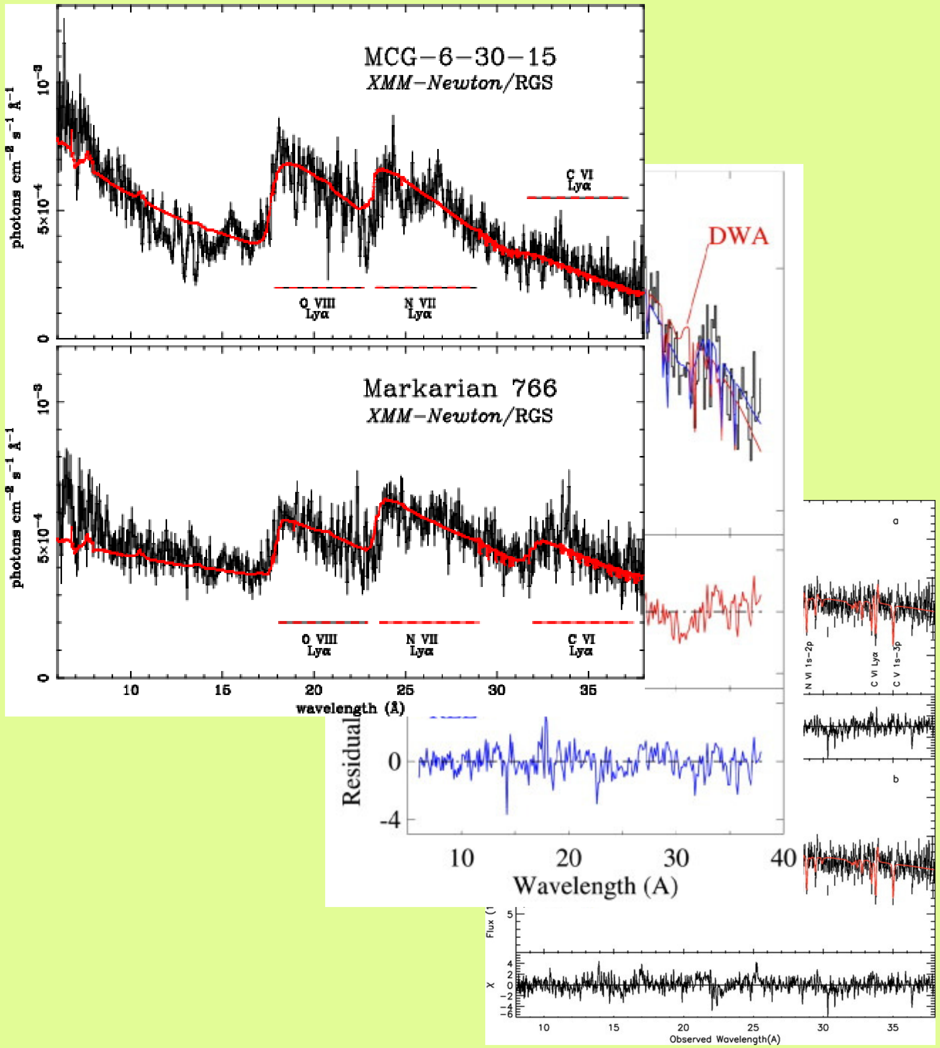


Ogle et al. 2004, ApJ, 606, 151

Starting with Seyfert 1s

- Broad lines?
  - yes
- Narrow lines?
  - yes
- Relativistic lines?
  - yes?

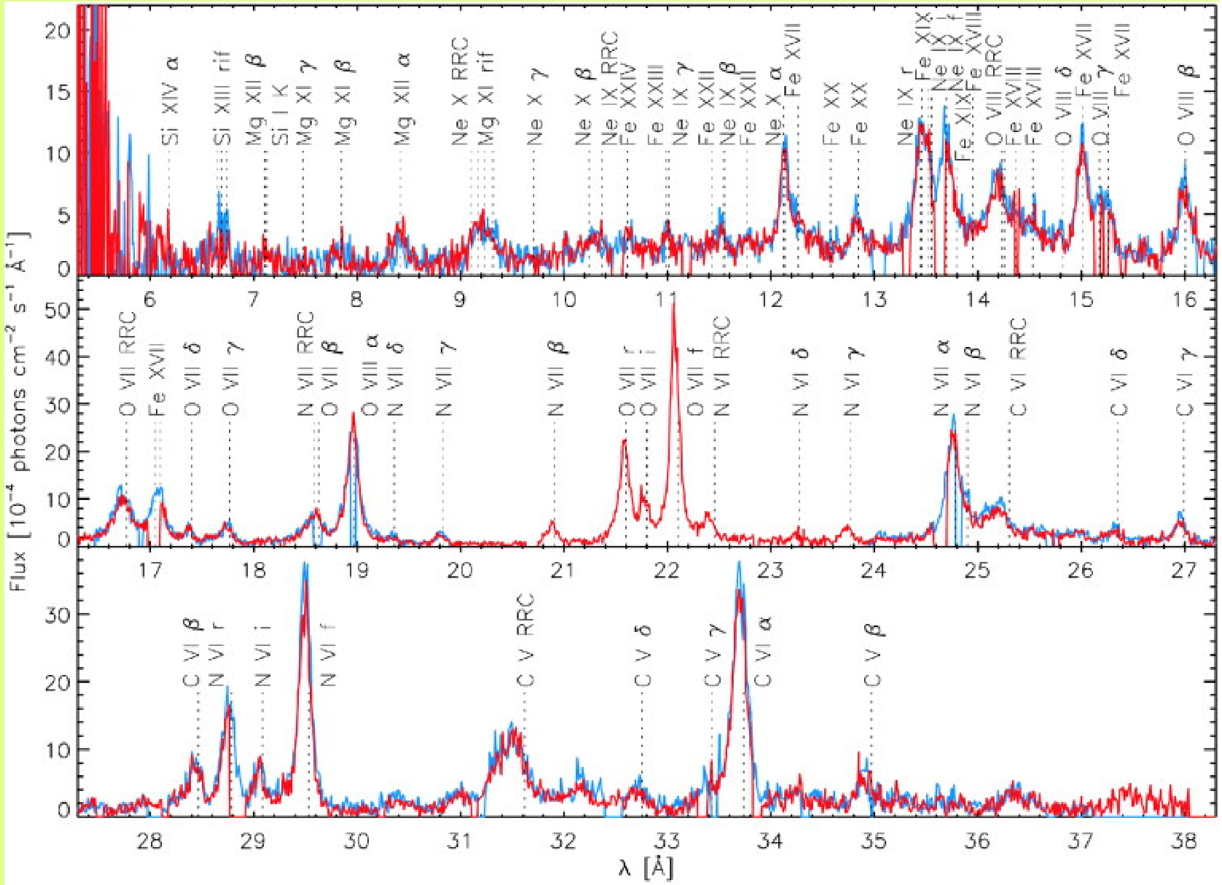
But still very controversial!



Ogle et al. 2004, ApJ, 606, 151
Mason et al. 2003, ApJ, 582, 95
Sako et al. 2003, ApJ, 596,114
Branduardi-Raymont et al 2001, A&A, 365, L140

Moving to Seyfert 2s

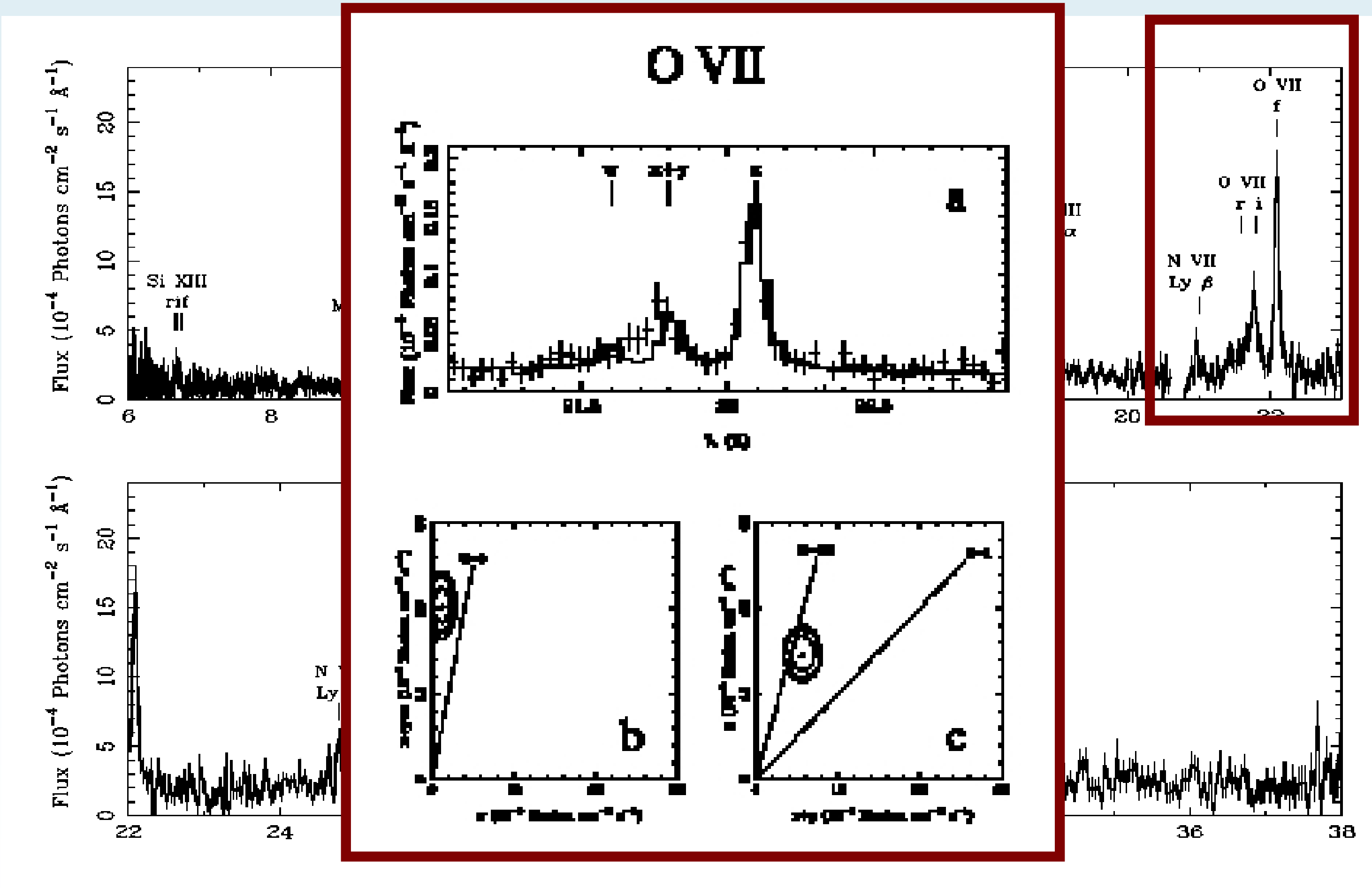
- Broad lines?
  - no
- Narrow lines?
  - yes
- Relativistic lines?
  - no
- Photoionisation/ photoexcitation model reproduces the emission lines



Kinkhabwala et al. 2002, ApJ, 575, 732

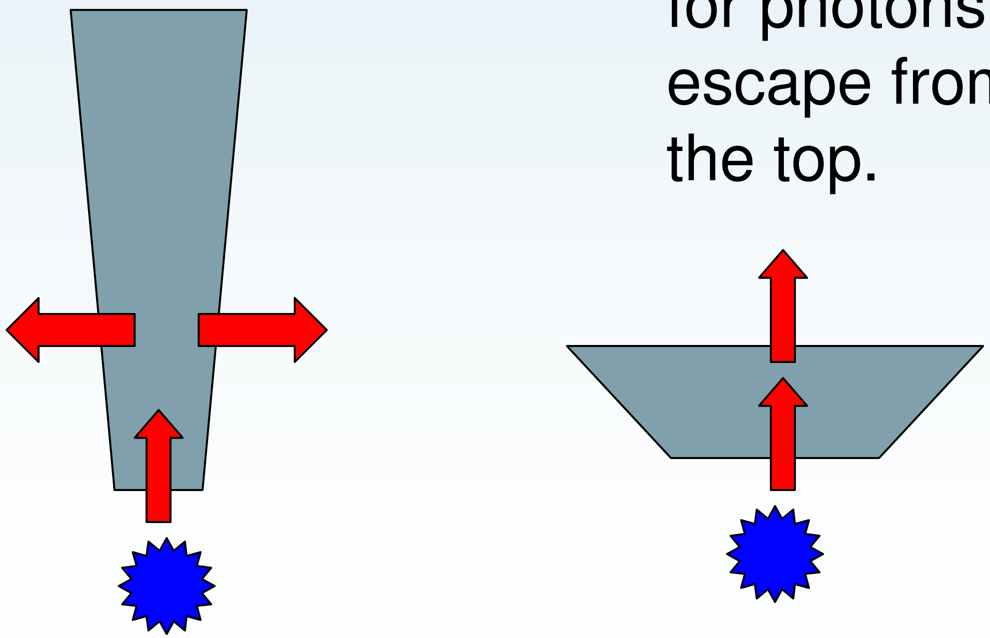
What if you took the continuum away from a Seyfert 1?

No resonance line - photoionised



Resonance scattering tells us the geometry of the warm absorber:

In deep cone, easier for photons to escape from the sides



In shallow cone, easier for photons to escape from the top.

Moving to lower luminosity objects

- Low luminosity AGN optically classified as **Low Ionization Nuclear Emission Regions**
- LINERs (includes 1/5 - 1/3 of all galaxies)
  - **middle ground between normal galaxies and AGN**

2 LINERs observed with XMM

M81:

- Nearest **L**ow **I**onization **N**uclear **E**mission **R**egion
- Nearest early type spiral outside the local group.
- Contains a low-L AGN, ~10^7 M_o

NGC7213:

- More luminous Seyfert/LINER
- Contains a larger black hole, ~10^8 M_o

Luminosities re low w.r.t. Eddington:

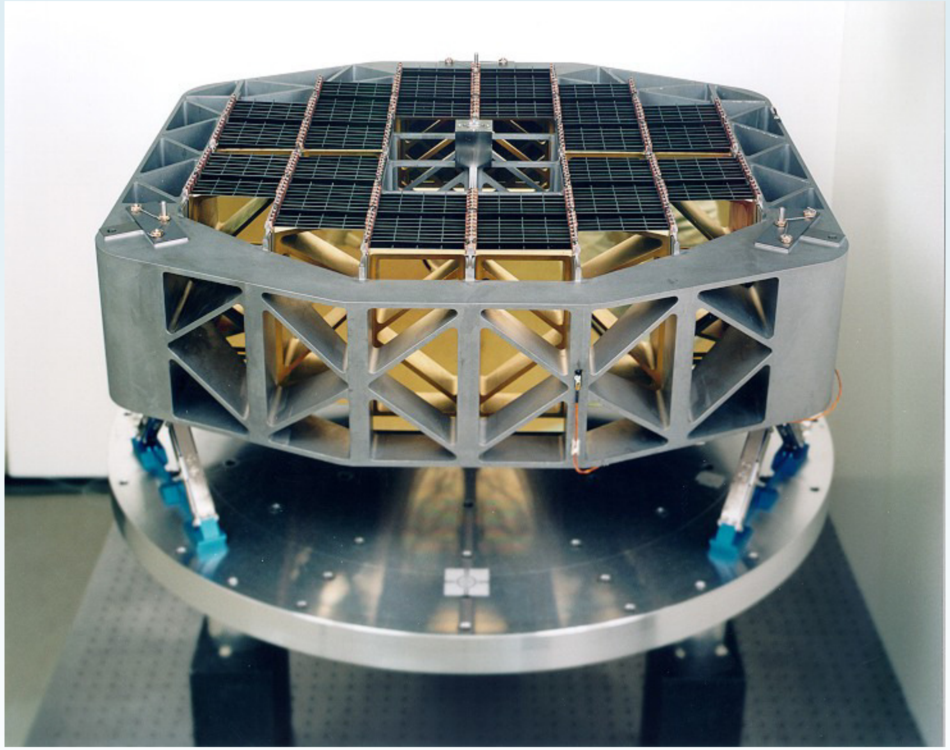
~10^{-4} (M 81) ~10^{-3} (NGC 7213)

M81 in X-rays

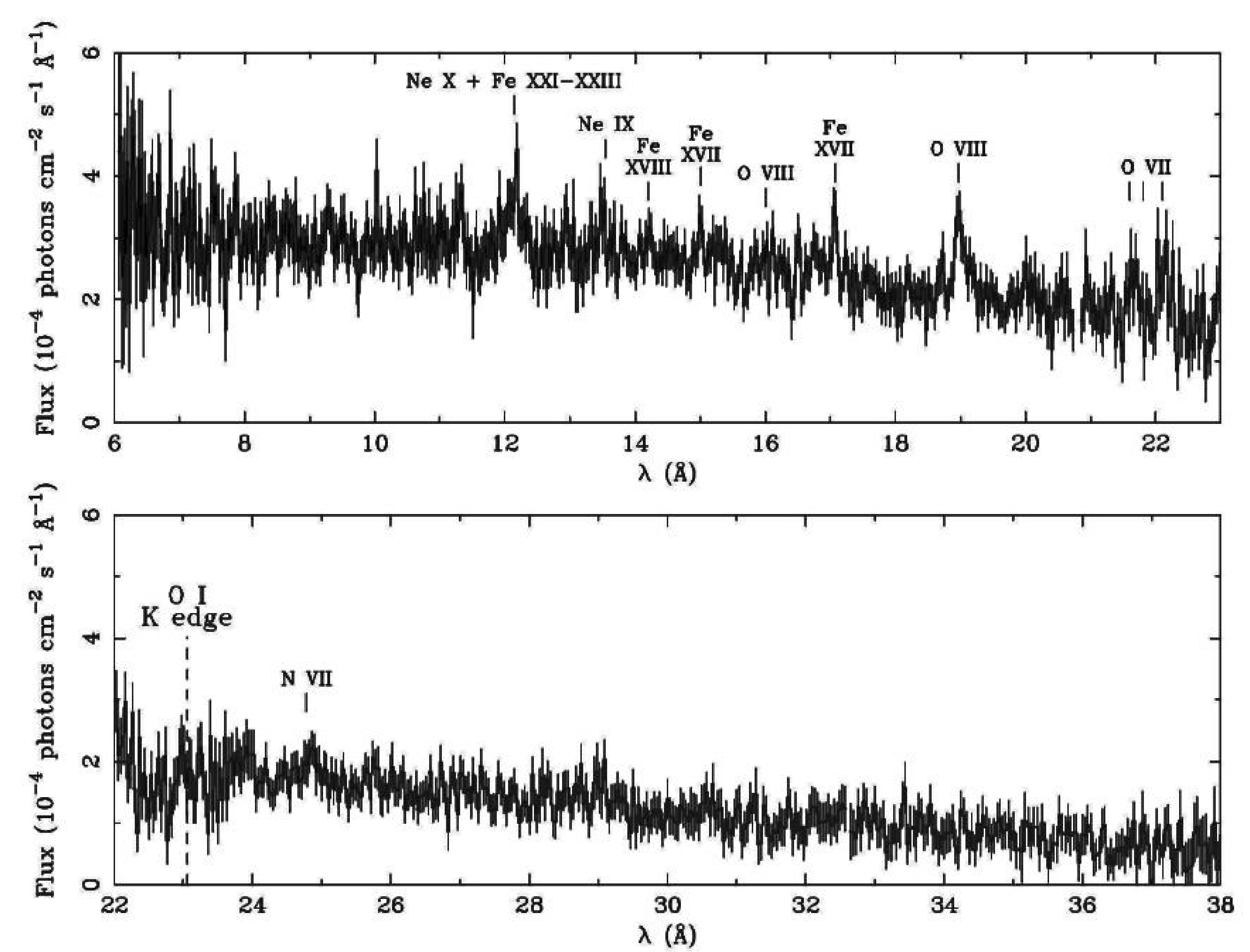
- First images from Einstein.
  - Several point sources, brightest associated with the nucleus (Fabbiano 1988, ApJ, 325, 544)
- Rosat:
  - Point sources and an apparently diffuse component (Immler and Wang 2001, ApJ, 554, 202)
- Chandra:
  - Many point sources, but about 35% of the bulge emission is diffuse (Tennant et al 2001, ApJ, 549, L43)

Long XMM-Newton observation of M 81

- RGS guaranteed time
- 22-23 April 2001
- Complete orbit
- 138ks total RGS exposure



RGS spectrum of M 81

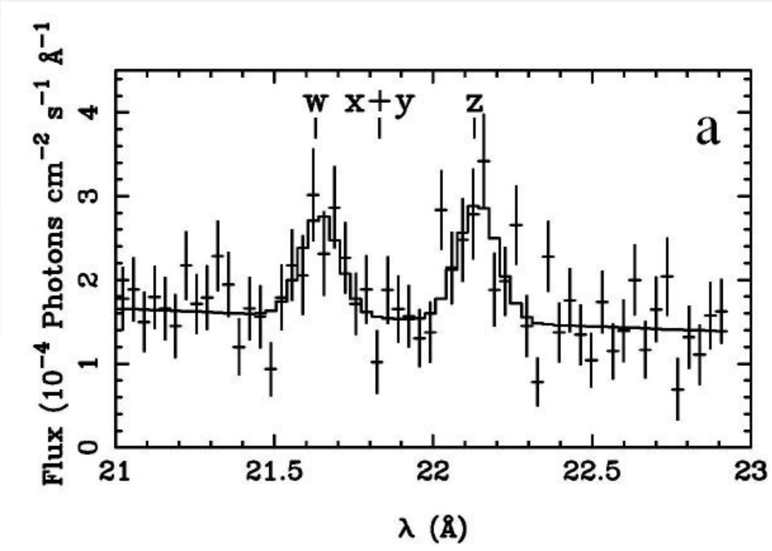


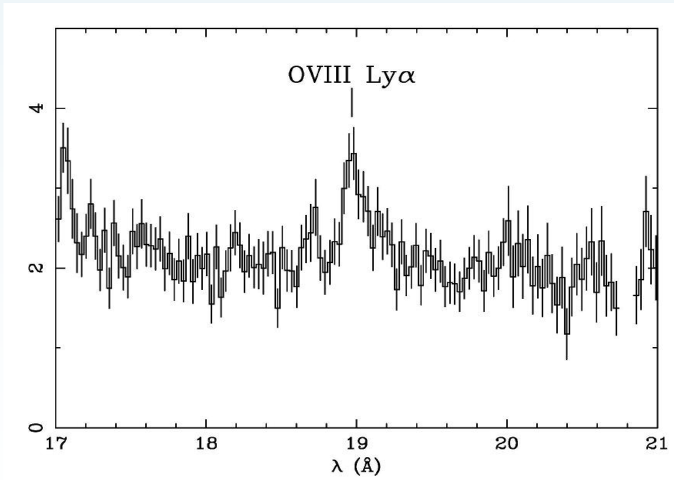
Important features

- Continuum spectrum with emission lines
  - -Most of the emission coming from the AGN

Note: He-like OVII triplet

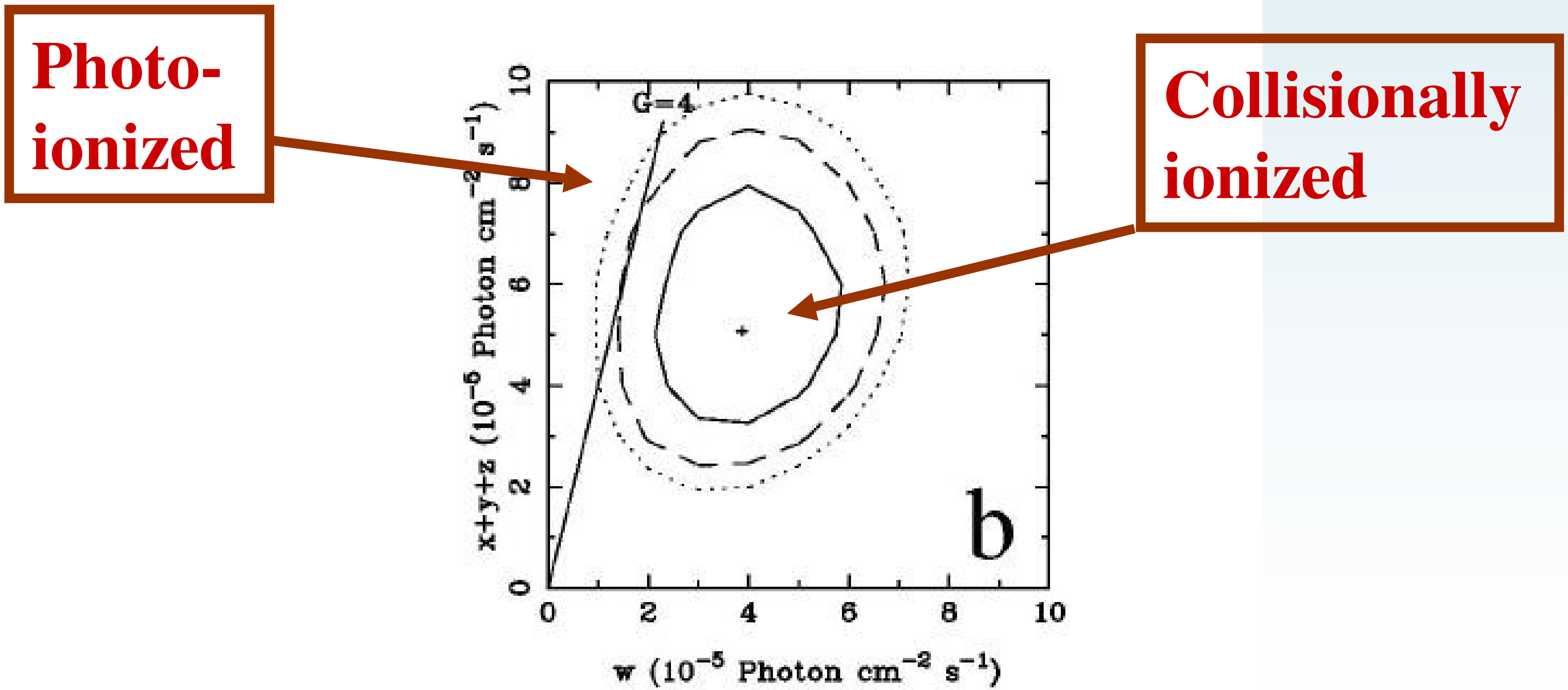
Lines are broad





What does the He-like triplet tell us?

Diagnostics from Porquet & Dubau (2000, A&AS, 143, 495)



What about the broad lines in M81?

Either

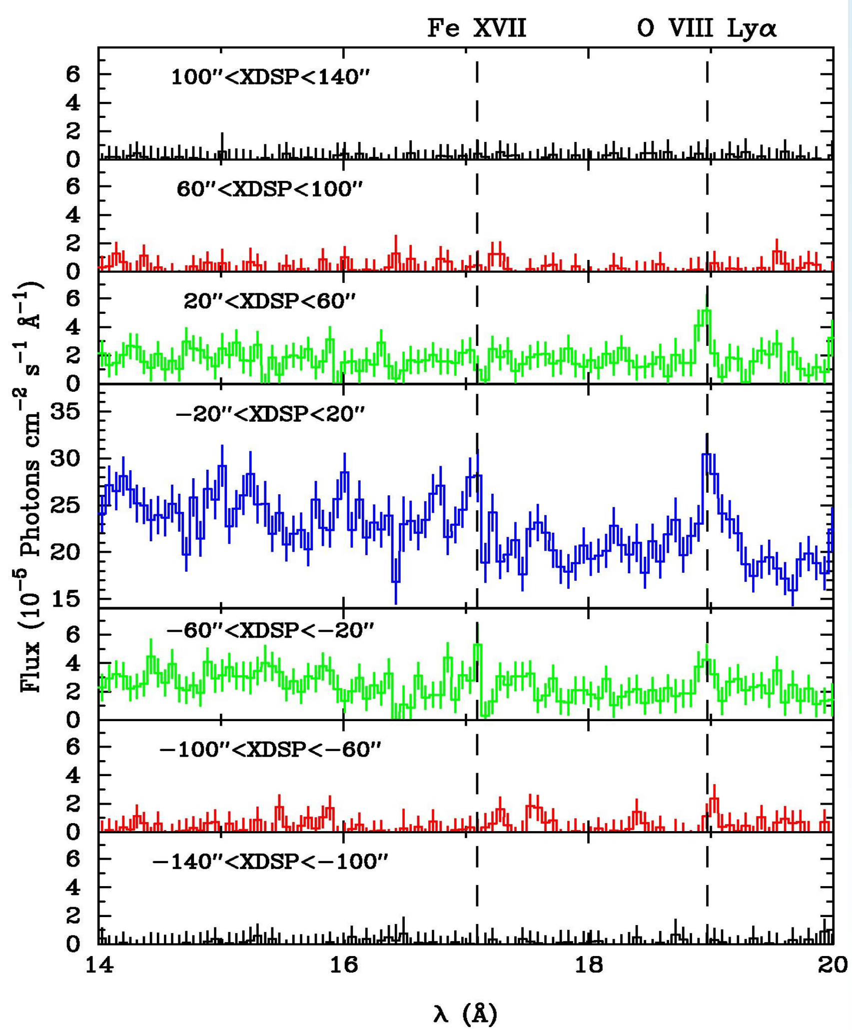
- emission line source extended over arcminute (kpc) scales

OR

- High velocities from gas close to the AGN

Discriminate by seeing if the emission lines are extended in the cross dispersion direction

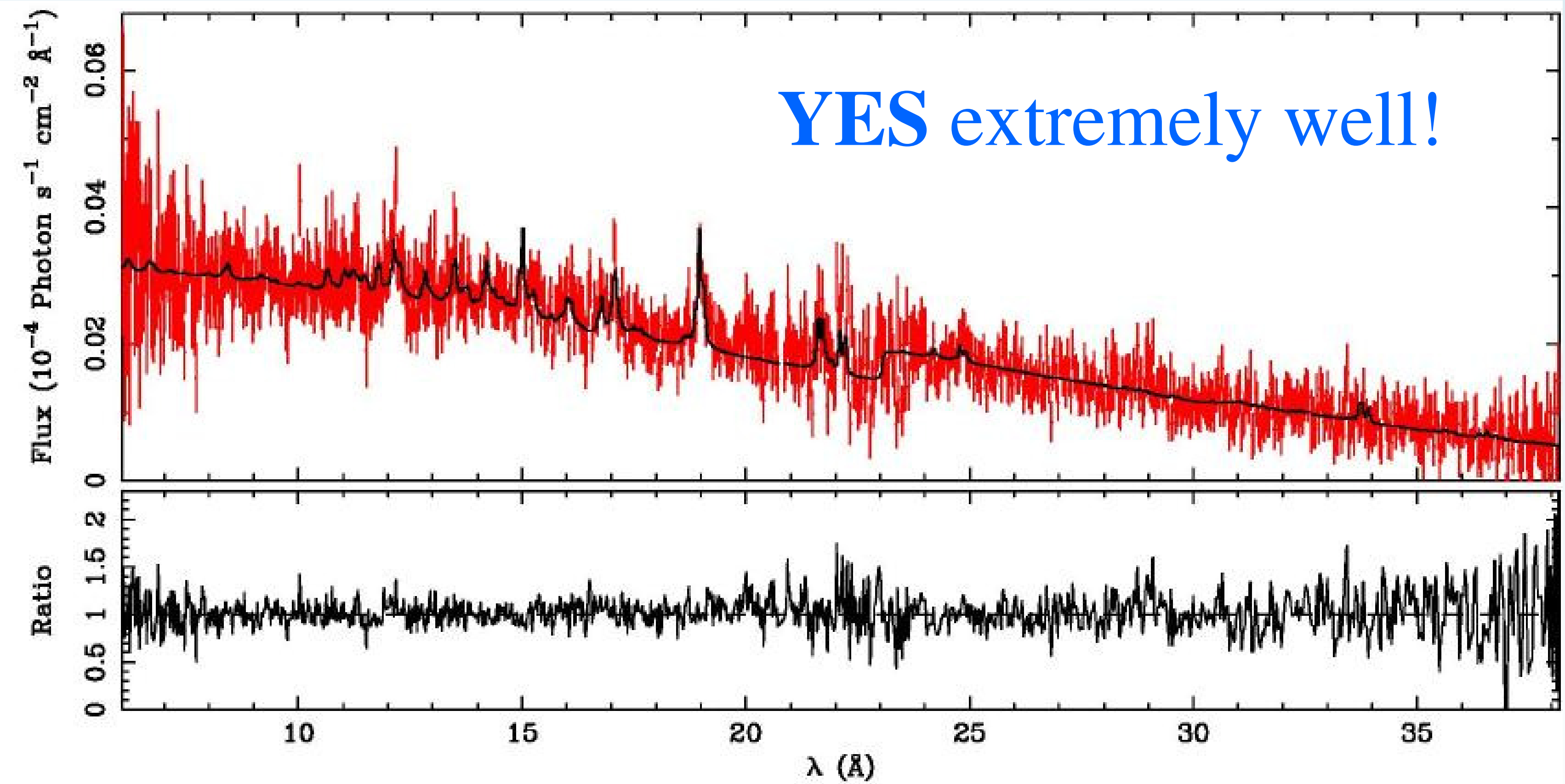
What about the line width?



Emission lines detected > 1 arcminute from the nucleus.

Emission lines are from collisionally ionized gas over kpc scales

Can the lines be modelled as a thermal plasma?



$$\chi^2/\nu=803/980$$

(c.f. $\chi^2/\nu=1085/992$ for absorbed power law)

How does it compare with Chandra?

- Three temperatures:

0.18 keV,	Fx= 1.1+/-0.5	$\times 10^{-13}$ erg cm^{-2} s^{-1}
0.64 keV,	Fx= 4.2+/-0.9	$\times 10^{-13}$ erg cm^{-2} s^{-1}
~1.7 keV,	Fx= 3.4+7.6/-2.2	$\times 10^{-13}$ erg cm^{-2} s^{-1}

Chandra unresolved bulge emission: ~3×10^{-13} erg cm^{-2} s^{-1}

The 0.2 and 0.6 keV components easily account for the Chandra unresolved emission.

Hotter component probably from X-ray binaries.

Where does the diffuse emission come from?

- Temperatures of 0.2 – 0.6 keV characteristic of hot ISM resulting from **supernovae**.
- Observed luminosity can be sustained by supernova rates of $4x10^{-3}$ – $2x10^{-2}$ $year^{-1}$ *
- Reasonable?
- No hot young stars in the bulge of M81** -> SNIa
- Canonical `expected' rate for M81 ~6 10^{-3} ***

It works (just), but it may not be the right story as we will see…

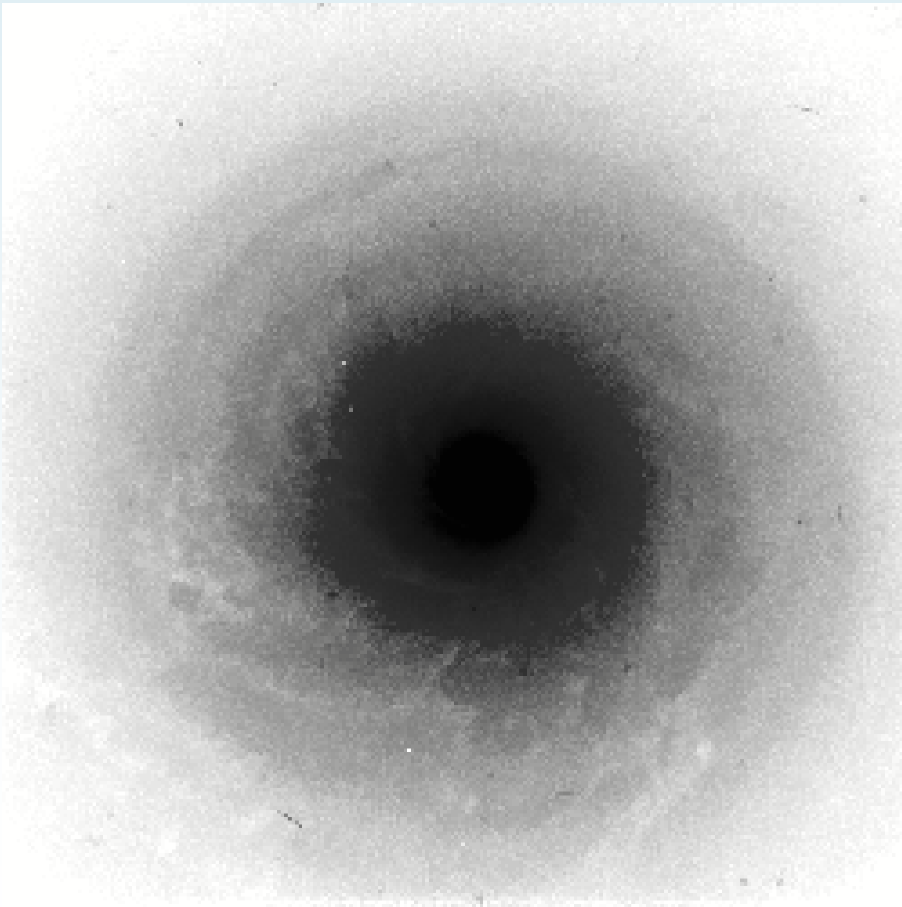
* Based on Shelton (1998, ApJ, 504, 785)

** Devereux et al (1997, ApJ, 481, L71)

***Based on VdB & T (1991, ARAA 29,363)

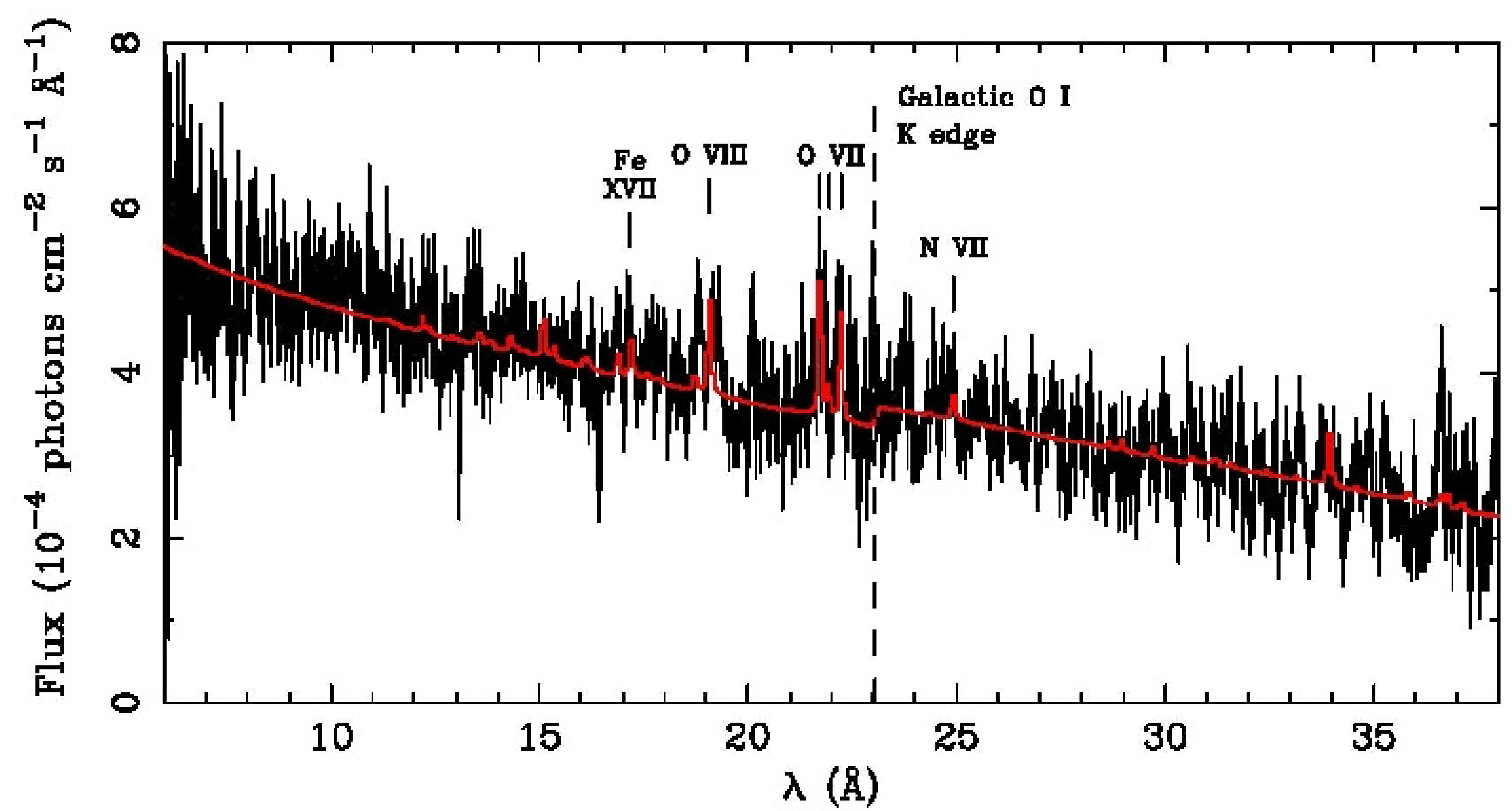
What about NGC7213?

- Bigger galaxy than M81
- Larger black hole
- Larger L/L_{edd}
- 47ks RGS



What about NGC7213?

- Somewhat similar spectrum.



Starling et al, MNRAS, 356, 727

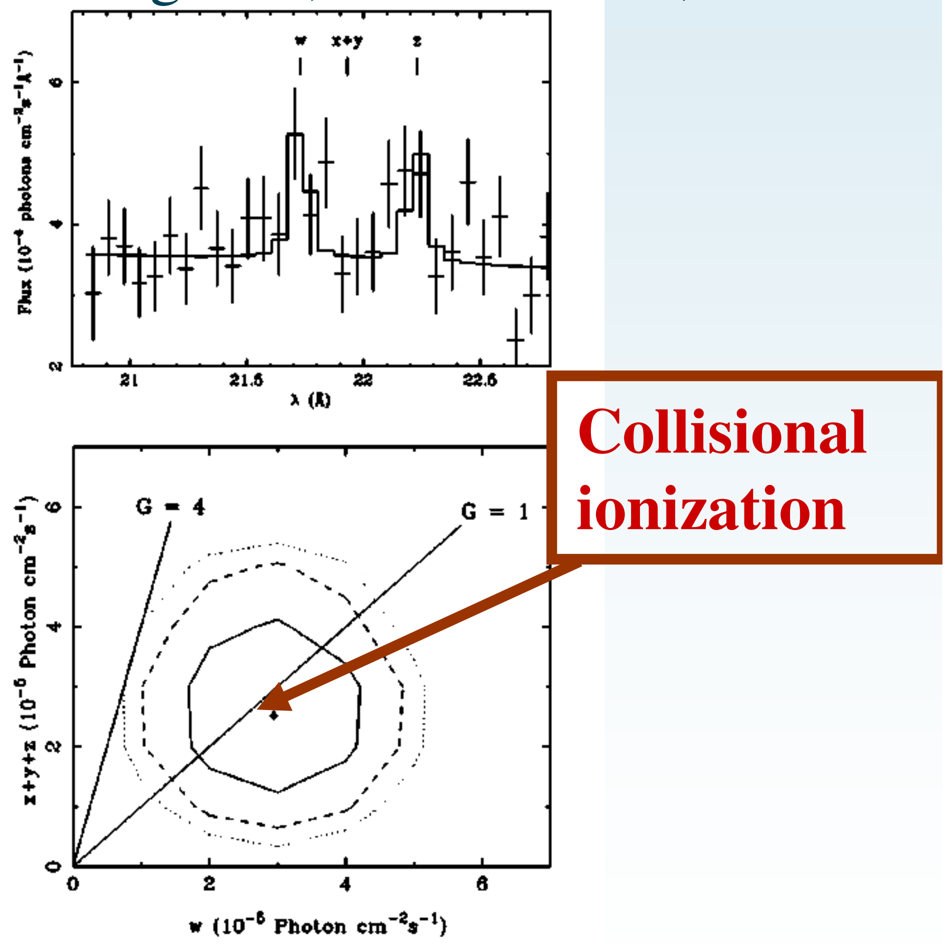
Where does the diffuse emission come from?

- With just a power law the χ^2/υ=586/498
- with 2 temp plasma added χ^2/υ=546/494
- kT of 0.2 and 0.6 keV similar to M81
  - **but emission lines contribute much smaller fraction of the soft X-rays than in M81**
  - **(1% in NGC 7213 rather than 10% in M81).**
  - **NGC 7213 X-ray spectrum more 'Seyfert-like'**

What about the OVII triplet?

- As in M81, photoionization is ruled out.
- The plasma is collisionally ionized.
- Mechanically heated soft X-ray plasma appears to distinguish LINERs from more active Seyferts.

Starling et al, MNRAS 356, 727



So what does this tell us about LINERS?

Long debate about whether LINERs powered by photoionization or by fast shocks (eg Heckman 1980, A&A 87, 152).

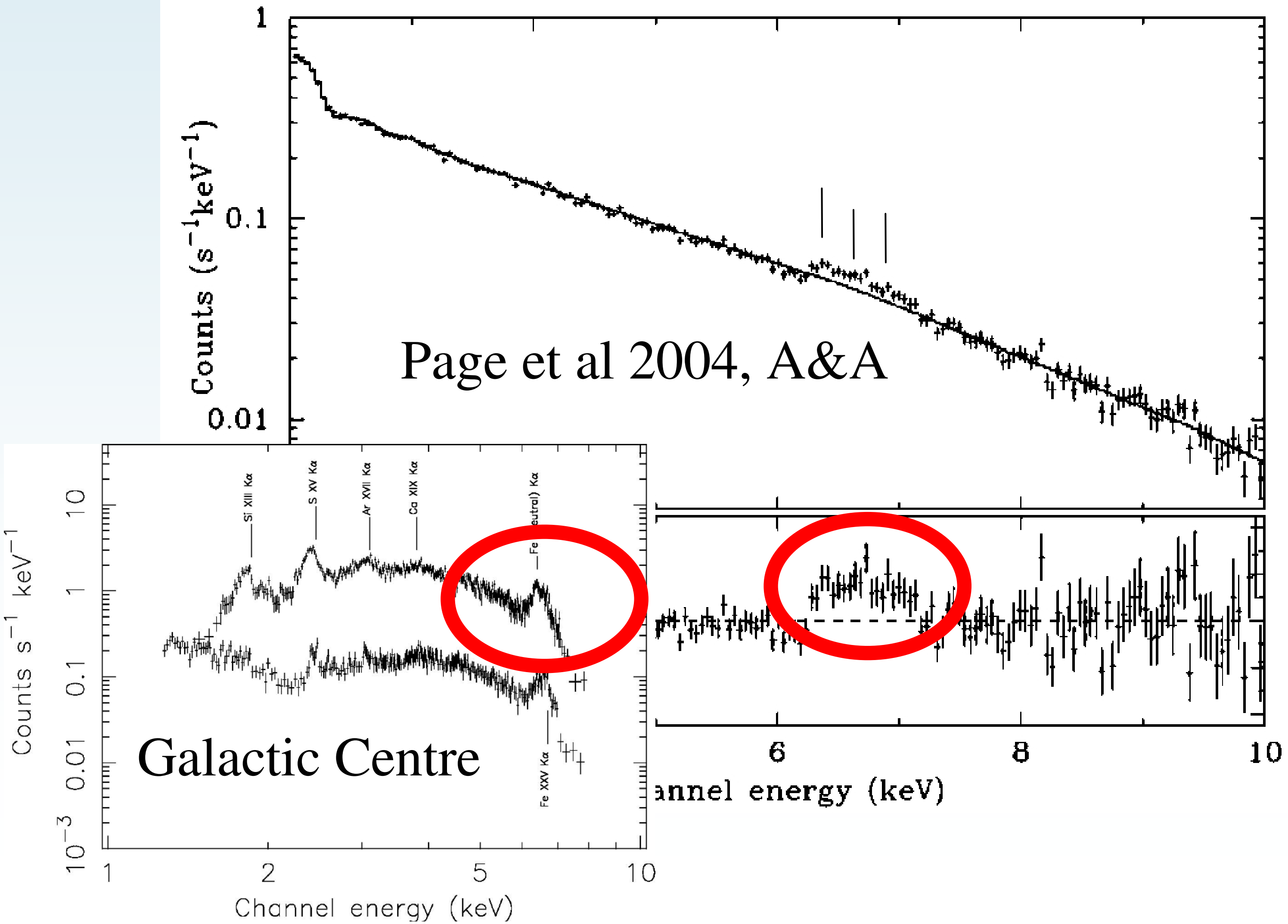
If the hot ISM seen in M 81 and NGC 7213 is maintained by supernovae **or by the AGN**, then fast shocks **are** propagating through the bulge.

Optical line emission in M81 and NGC7213 could well be shock powered

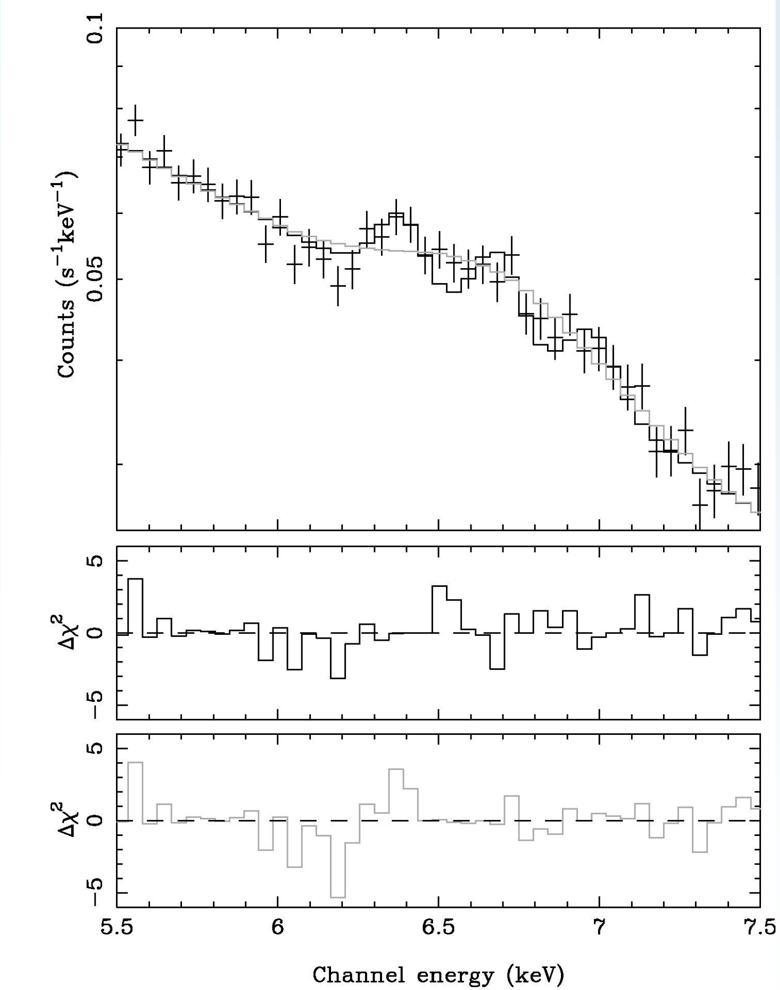
What about above 2 keV?

M81 in 2-10 keV

- Fe I, Fe XXV, FeXXVI emission lines



Complex of lines or broad line?



- Impossible to discriminate statistically
- We favour the line complex (Page et al., A&A, 2005, 422, 77)
- Dewangan et al favour broad line (2004, ApJ, 607, 788)

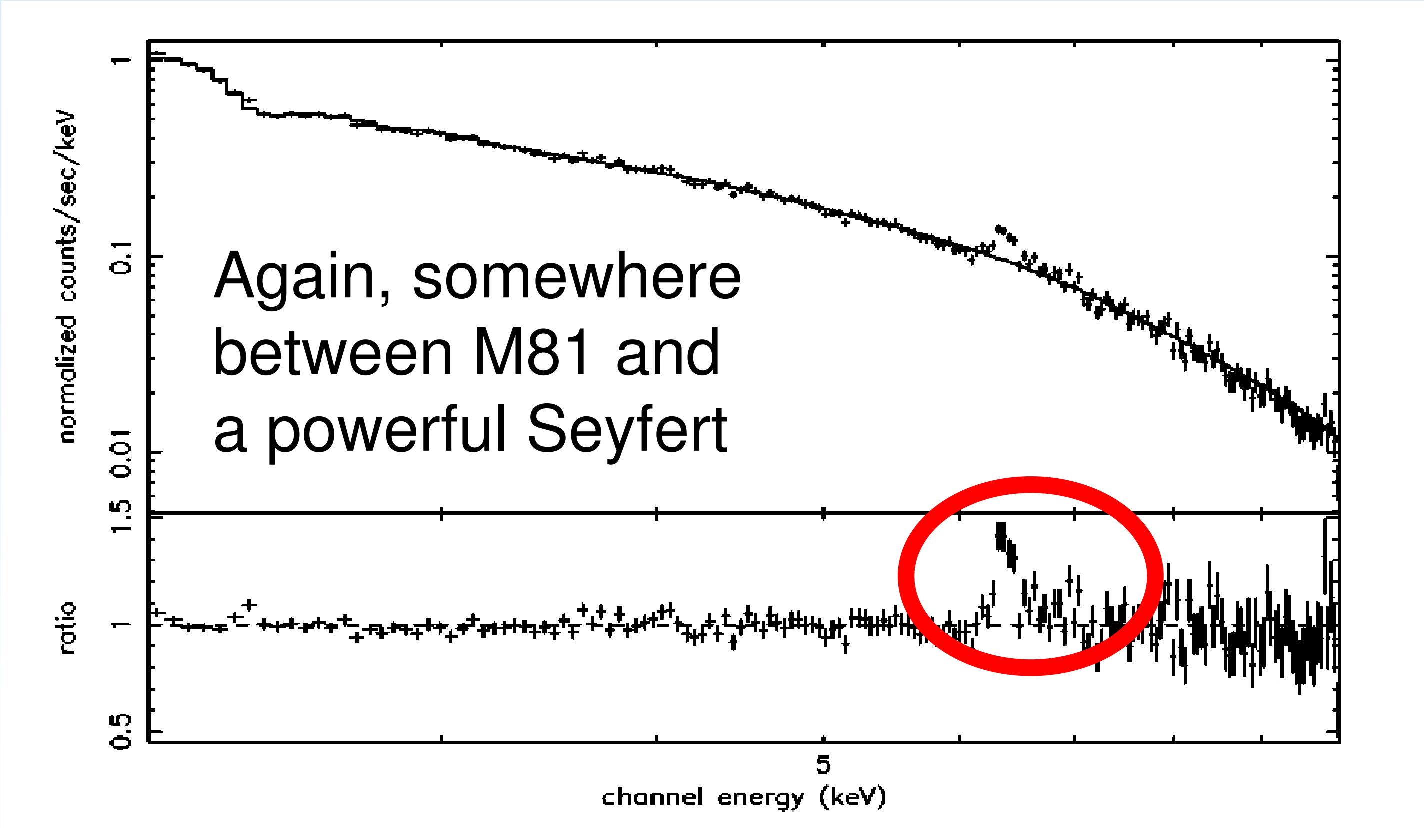
Big shame we don't have sensitive enough high-res spectroscopy at 7 keV!

Broad line or complex of lines?

- Origin of Galactic centre Fe lines could be faint binaries.
  - Untenable for M81, 150 times more line emission, but galaxy is similar to Milky way.
- Thermal plasma + low energy cosmic rays more likely.
  - M81* 10,000 times more powerful than Sgr A*

NGC7213 in 2-10 keV

- Fe I, Fe XXV, FeXXVI emission lines



Starling et al 2005, MNRAS, 356, 727

What could this mean?

In Galactic binaries, in the low accretion state more of the energy goes into driving outflows than into photons.

The collisionally ionised plasmas and highly ionised Fe lines in LINERs indicates a larger fraction of their power could be released in mechanical form.

Could be a universal characteristic of accreting black hole systems.

Summary - I. Powerful AGN

Rich phenomonology of soft X-ray emission lines in AGN.

In quasars and Seyferts, the lines are photoionised, just like the optical emission lines.

In Seyfert 1s we see broad and narrow lines

In Seyfert 2s we see only the narrow lines

The difference between the narrow emission lines in Seyfert 1s and Seyfert 2s will allow us to probe the geometry of the outflow.

Summary - II. Weak AGN

Much stronger soft X-ray emission lines.

The lines are collisionally ionised, not photoionised.

X-ray line properties form a sequence from the weakest AGN (e.g. our Galactic centre) to the most powerful.

Suggests that low luminosity AGN may output a larger fraction of their power as mechanical energy.

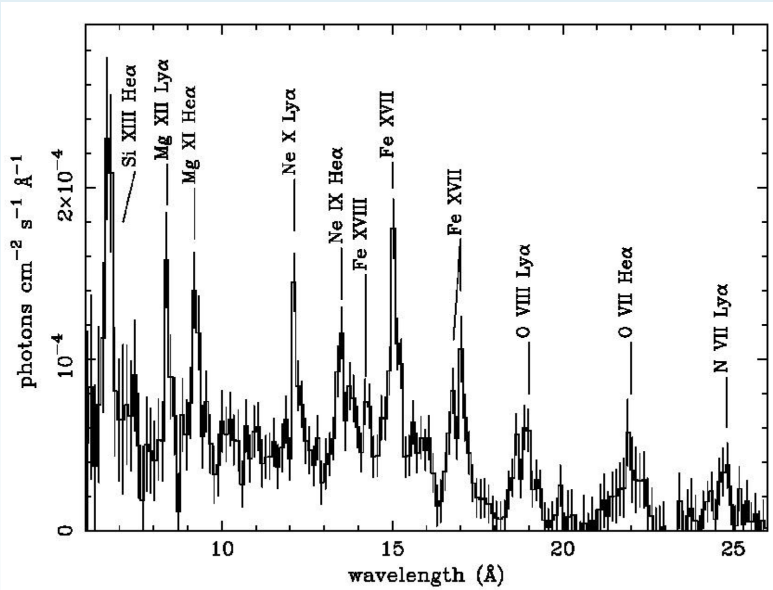
UCL

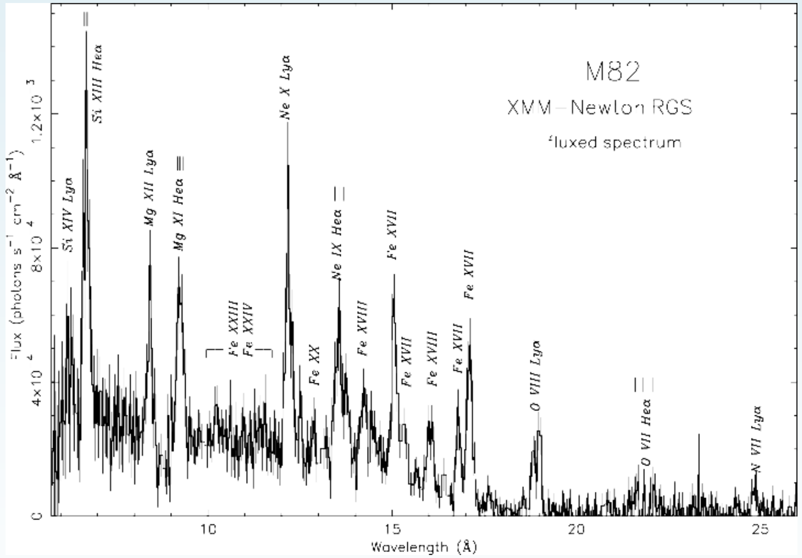
Back pocket slides…

Origin of soft X-ray lines in AGN and starburst galaxies

- Soft X-ray lines in AGN, whether in absorption or emission, come from photoionized gas.
- Soft X-ray lines in Starburst galaxies are seen in emission, and come from collisionally ionized gas.

- What about starbursts?





NGC253

Pietsch et al

2001, A&A 365 L174

M82

Read & Stevens

2002, MNRAS 335 L36