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# The nature of the soft X-ray emission in obscured AGN

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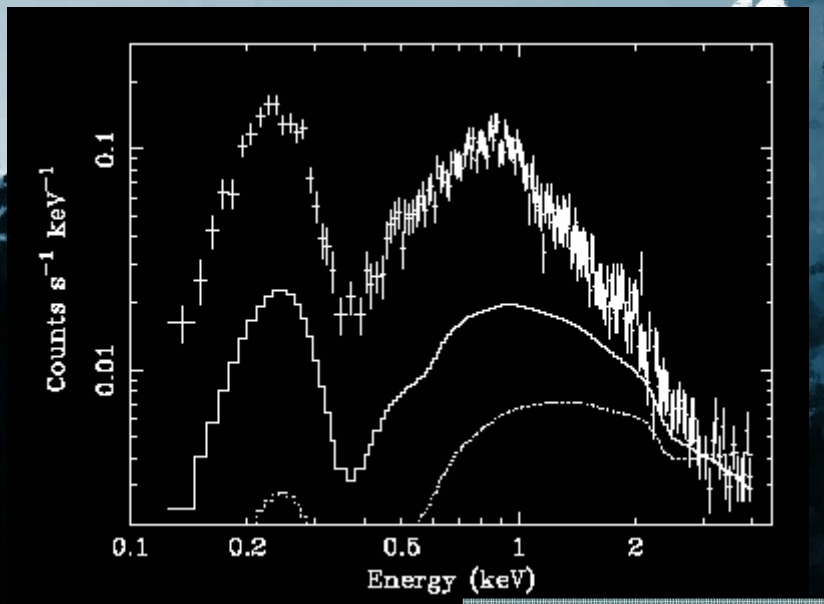
AGN7 – Montagnana - May 25th, 2006

In CCD spectra of Sy2s, a 'soft excess' appears when extrapolating the >2 keV spectrum to low energies
It's emission which is not absorbed by the large column density which blocks the nuclear continuum




Guainazzi et al. 1999

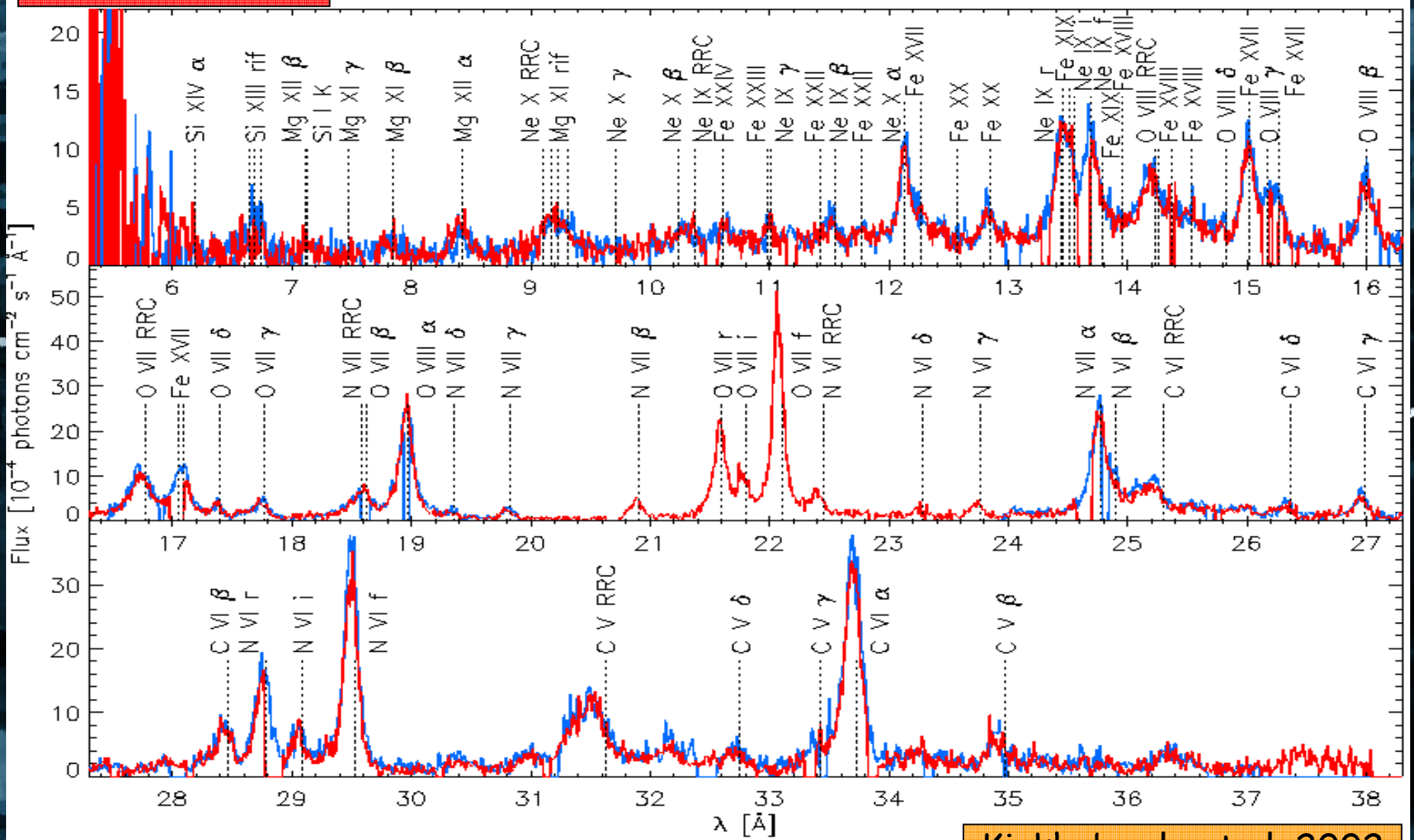
Generally, a 'scattering model', consisting of a power law with the same Γ of the incident continuum plus emission lines, gives better fits than a 'thermal model', which often results in unphysical parameters.

The key to understand its nature is
HIGH RESOLUTION SPECTRA

# NGC1068

Strong emission lines dominates!
No continuum ⇒ log(NH )<22.7

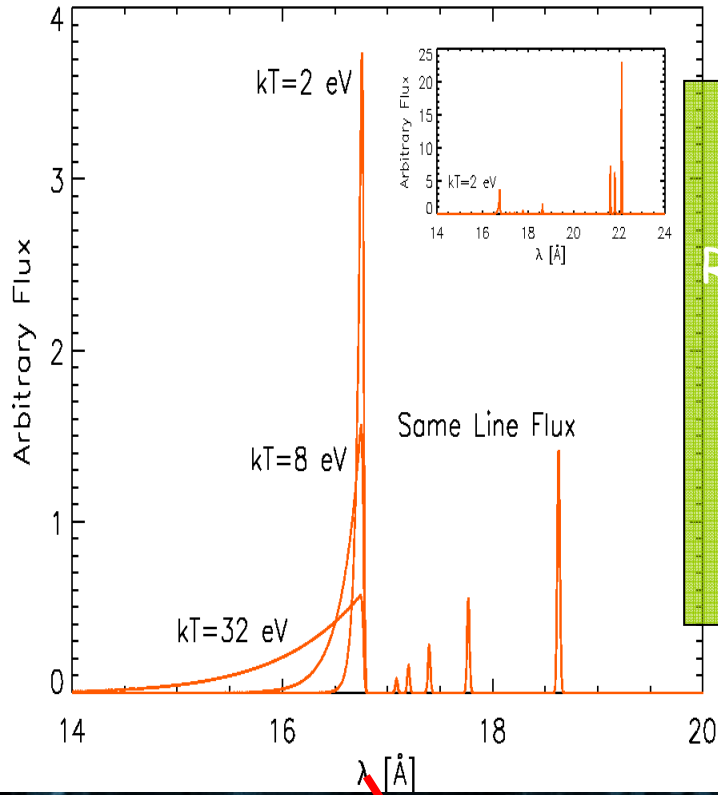
XMM RGS



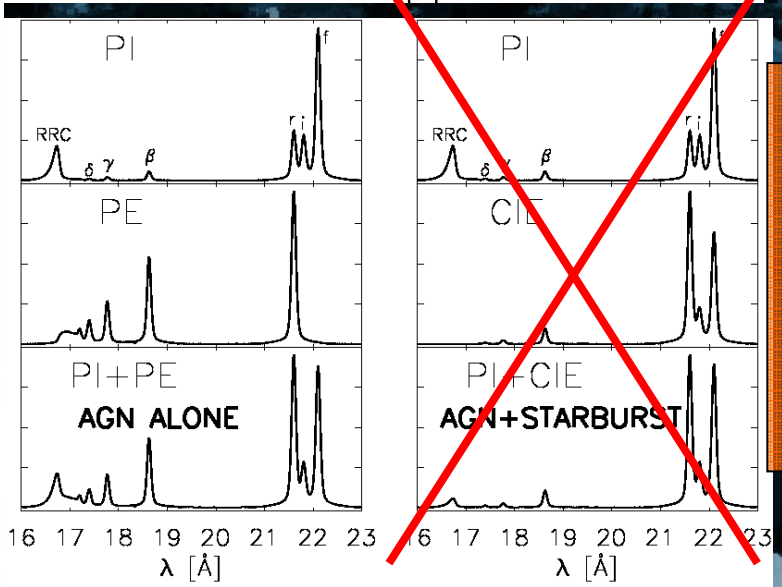

Kinkhabwala et al. 2002

# NGC1068

Kinkhabwala et al. 2002




Detection of
narrow
Radiative Recombination
Continua (RRC)
⇒
Low temperature gas
⇒
Photoionization




Diagnostic ratios on triplets AND
higher order series lines
confirm photoionization and exclude contribution
from collisional plasma
Important role of photoexcitation
(resonant scattering:
Band et al. 1990, Matt 1994, Krolik & Kriss 1995)

# Mrk3

Bianchi et al. 2006

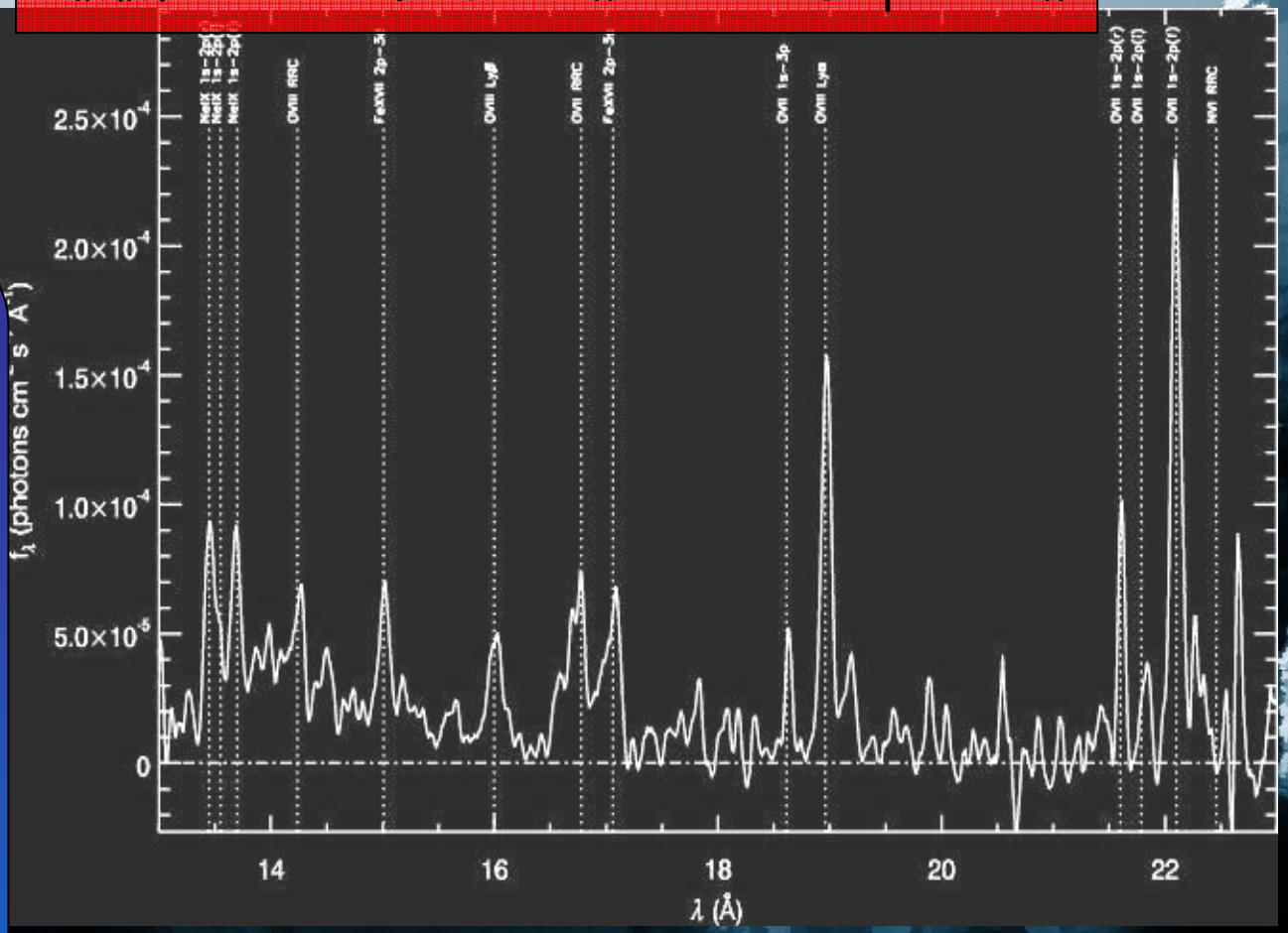
The high resolution spectrum of Mrk3 is unambiguously produced in a photoionized gas:

-K lines dominant over Fe L
-RRCs

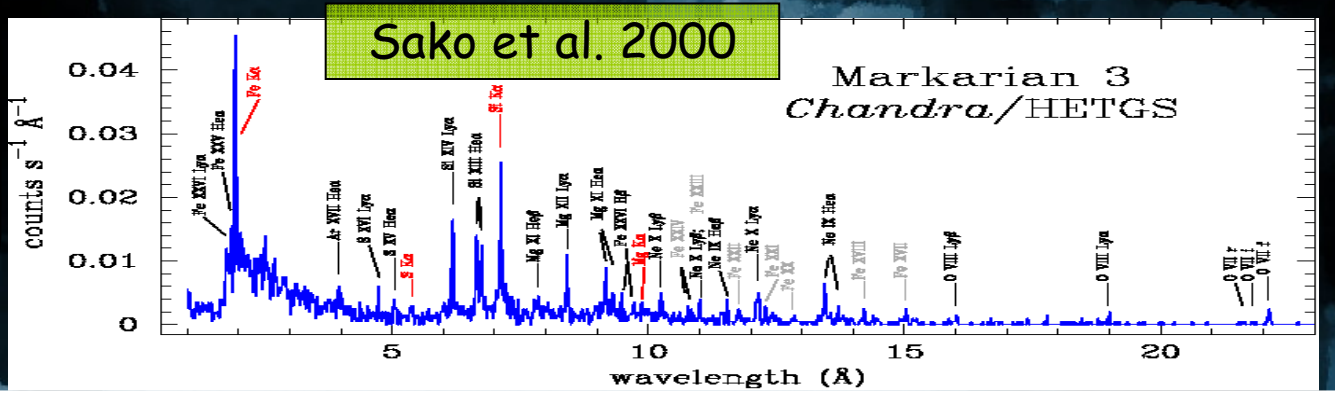
Resonant scattering is important:

-Fe L 3d-2p/3s-2p ratio
-K resonant/ forbidden ratio

XMM-*Newton* 190 ks combined RGS spectrum

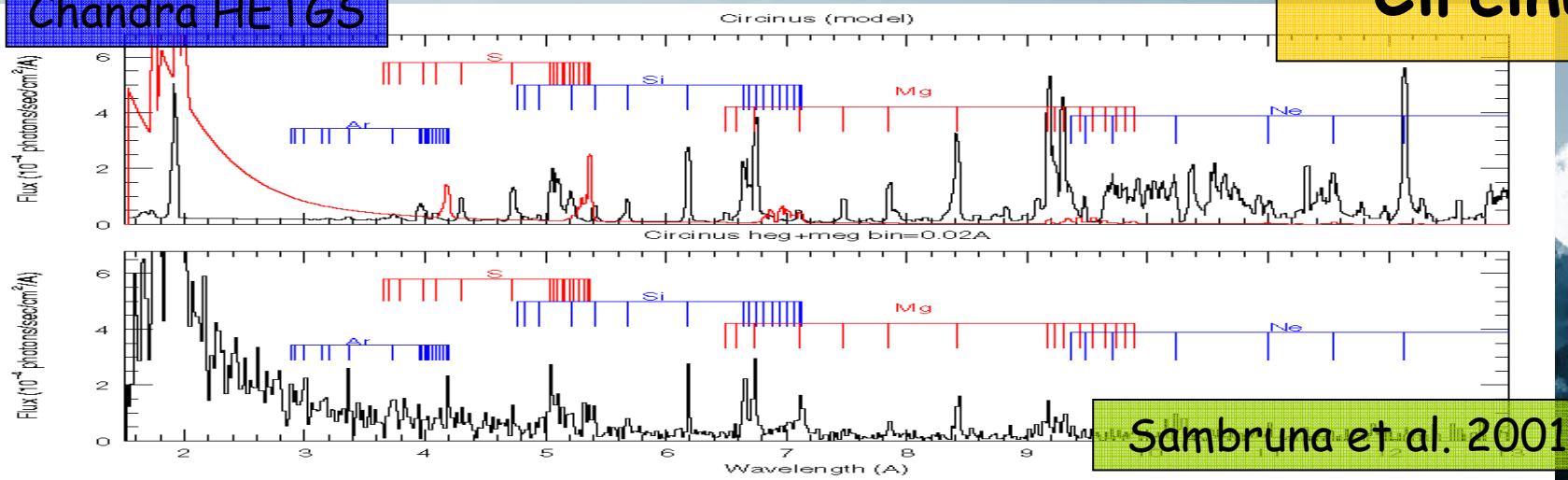



Sako et al. 2000



# Circinus

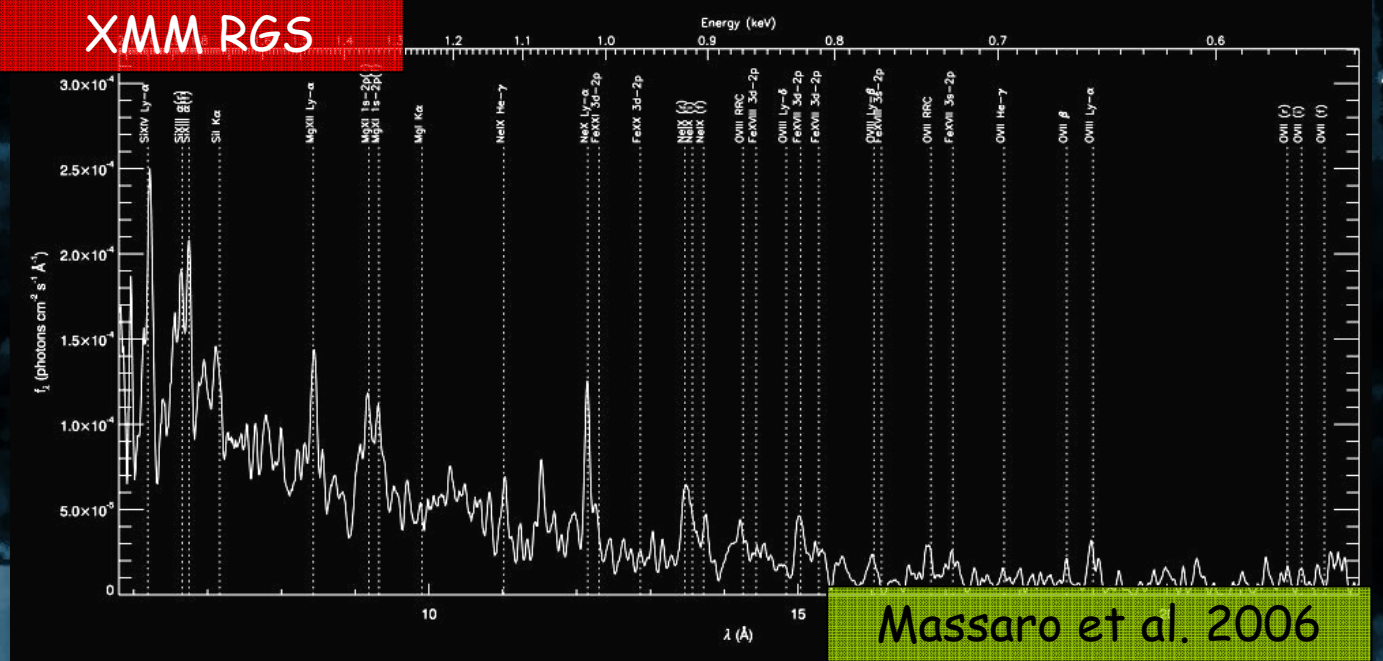
Chandra HETGS




Sambruna et al. 2001

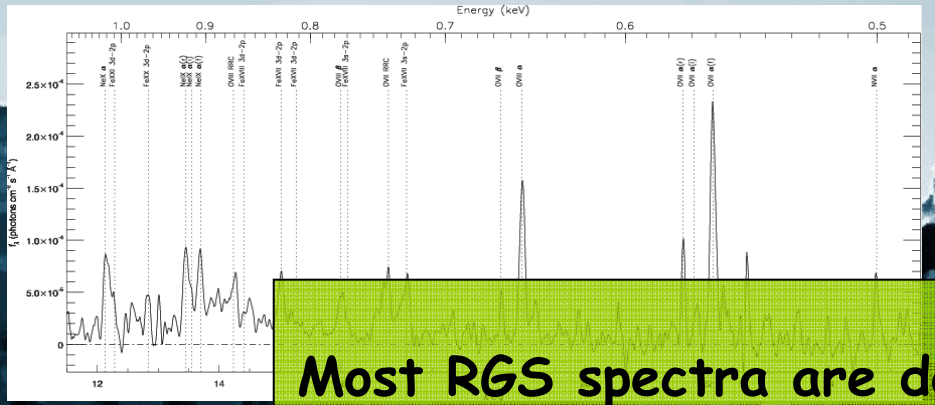
Similar results, but soft is absorbed

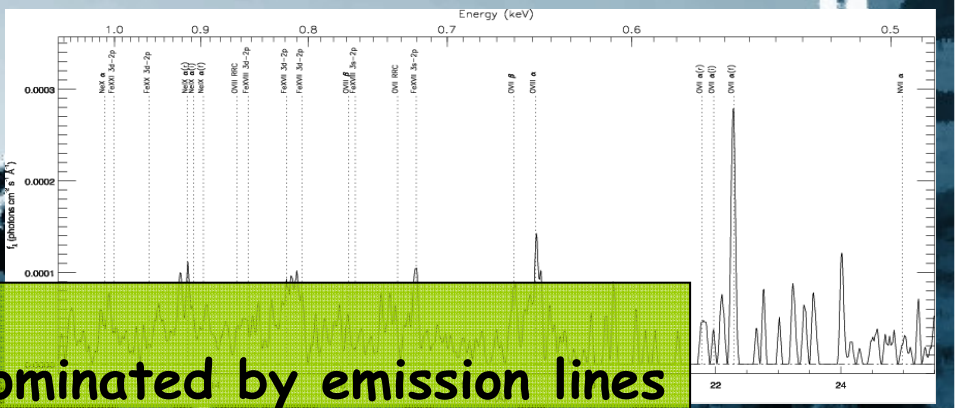
XMM RGS

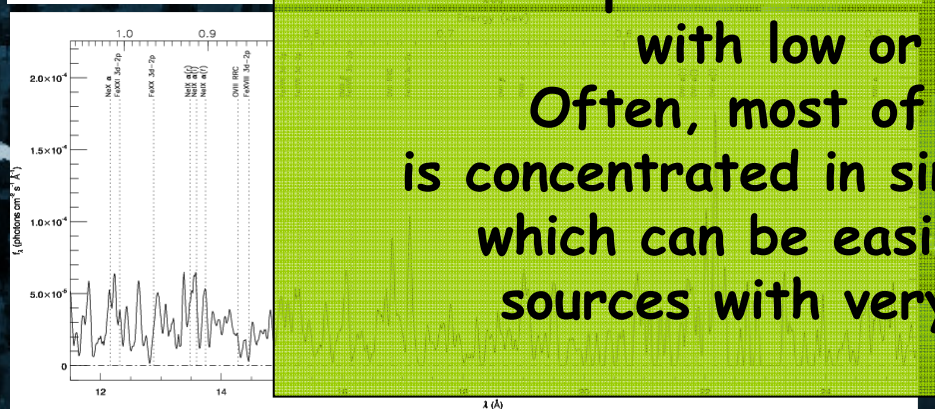


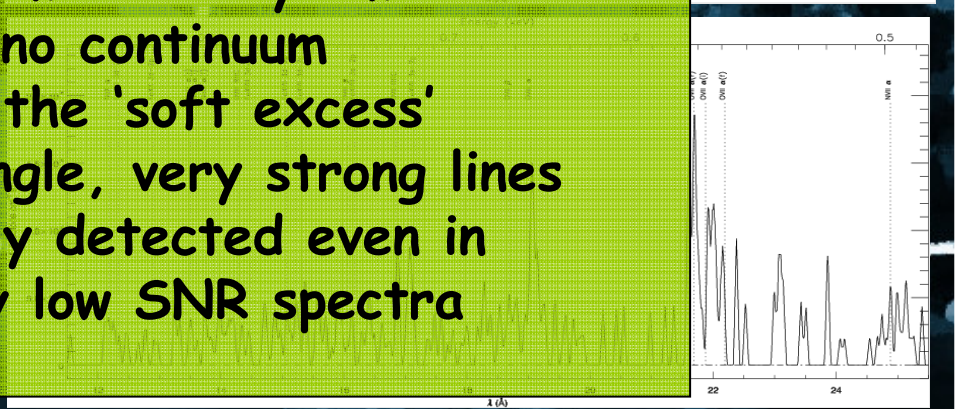

Massaro et al. 2006

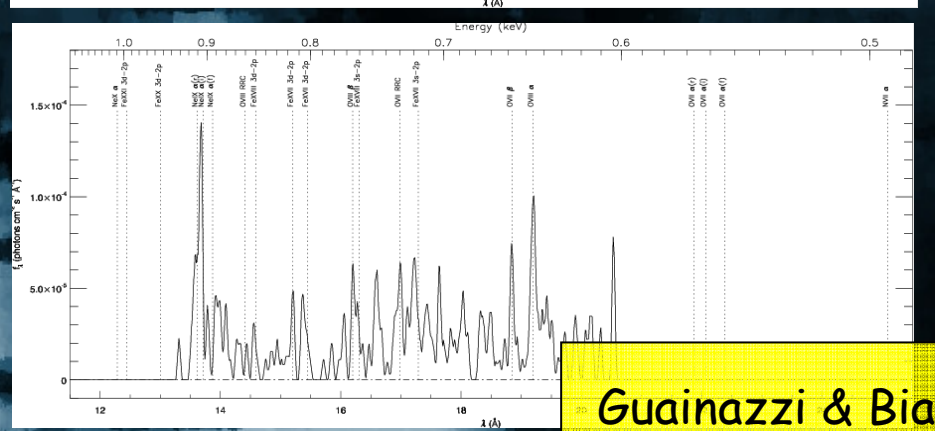
# What about the other Sy2s?

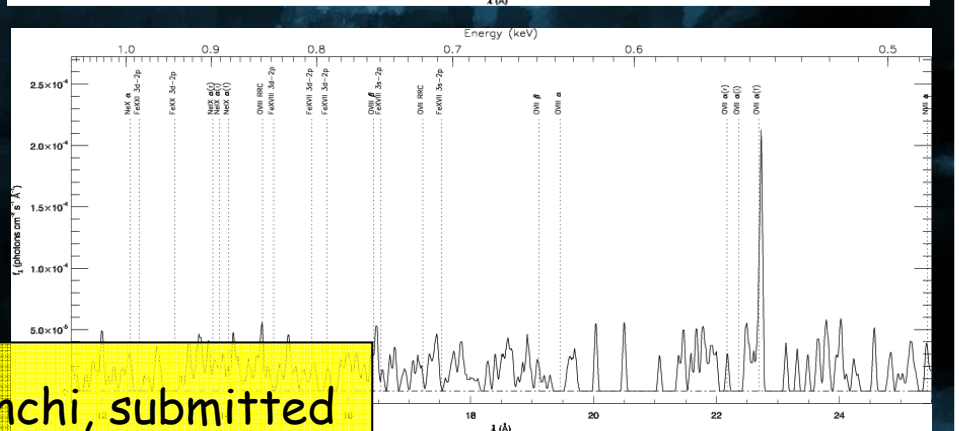


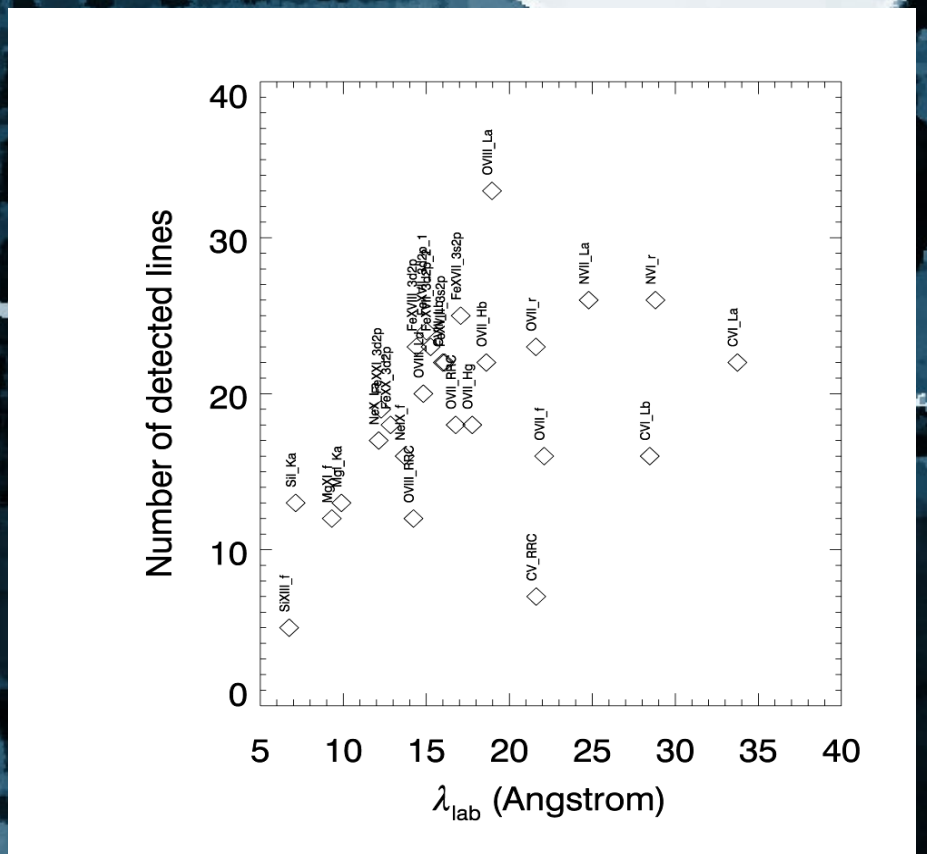

**Most RGS spectra are dominated by emission lines with low or no continuum**
**Often, most of the 'soft excess' is concentrated in single, very strong lines which can be easily detected even in sources with very low SNR spectra**

Guainazzi & Bianchi, submitted

We produced the first catalogue of soft X-ray emission lines in a sample which includes all the Sy2s observed by XMM-Newton RGS

# CIELO-AGN

## Catalogue of Ionized Emission Line Obscured AGN




70 objects

Very high detection efficiency

50% of the objects have OVIII Lya

Many other lines from O, Fe, C, Si, Mg, Ne, N

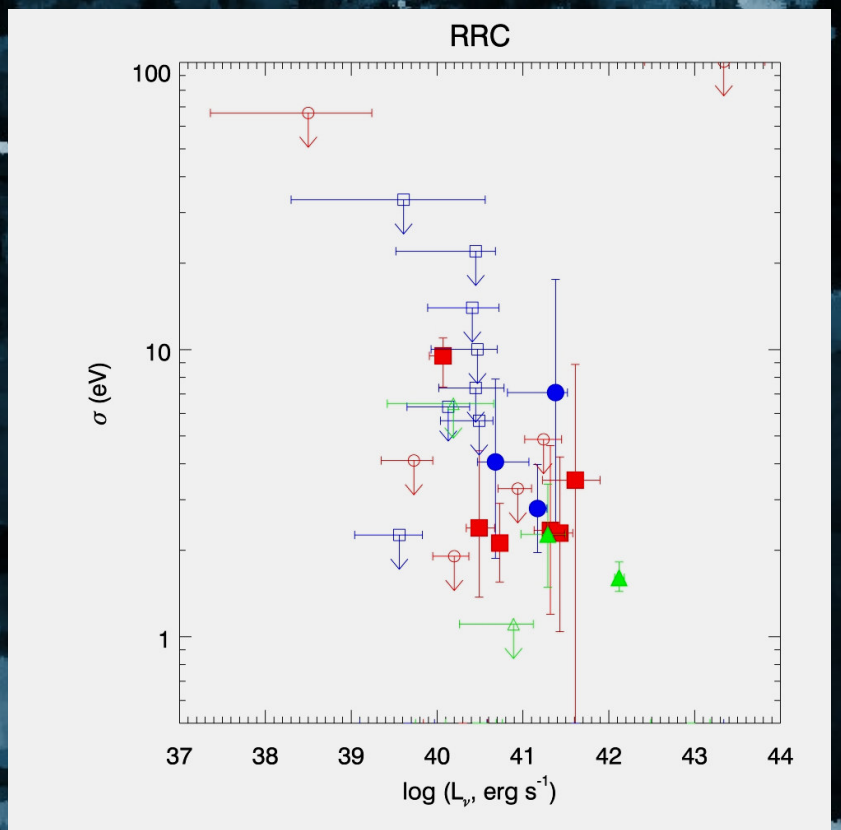
Guainazzi & Bianchi, submitted

**CIELO confirms the results derived from the analysis of the brightest sources**

RRC are common and narrow

↓

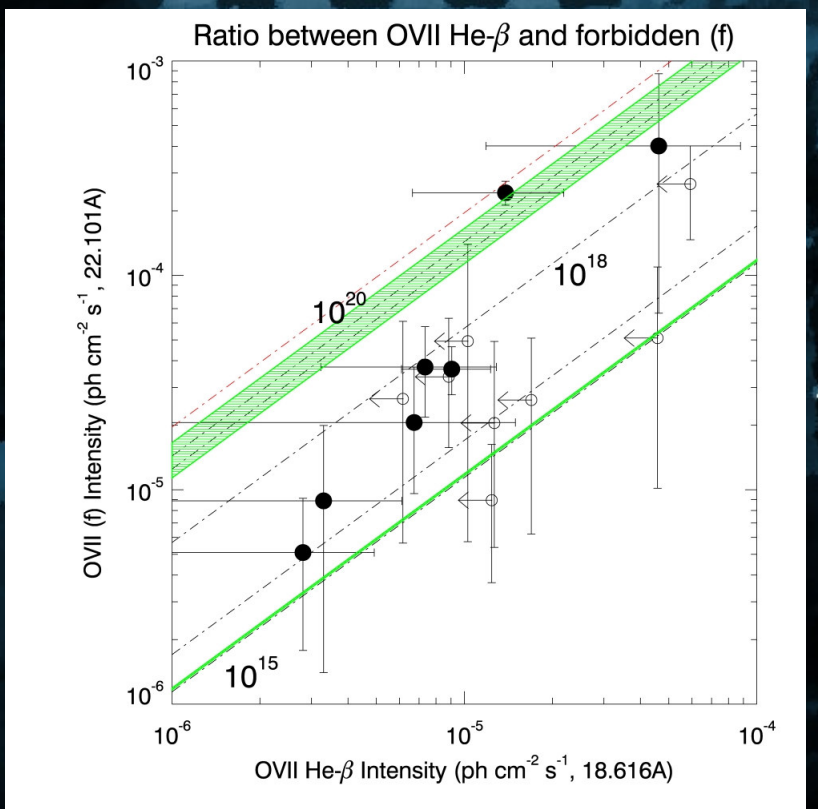
photoionization




Strong higher order lines

↓

Photoexcitation




Guainazzi & Bianchi, submitted

# Where is this gas located?

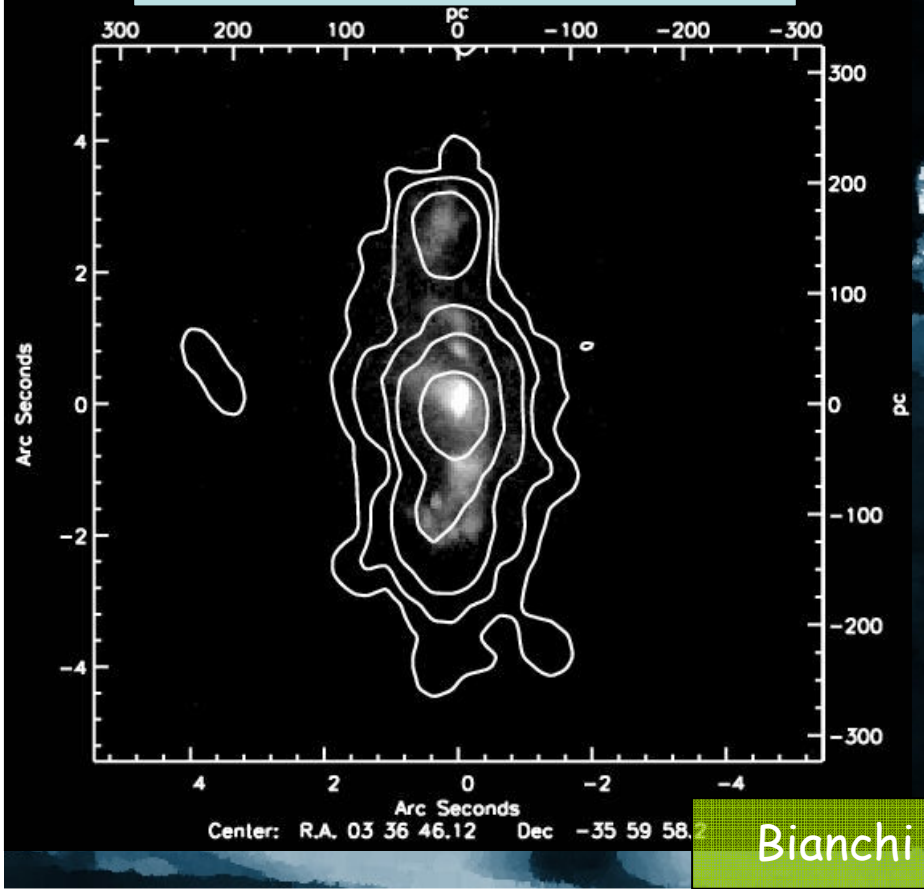
The Chandra images of NGC1068, Circinus and Mrk3 show that the soft X-ray emission coincides with the extended NLR

Both the emission lines produced in the NLR and those found in soft X-ray spectra are produced in gas photoionized by the nuclear continuum

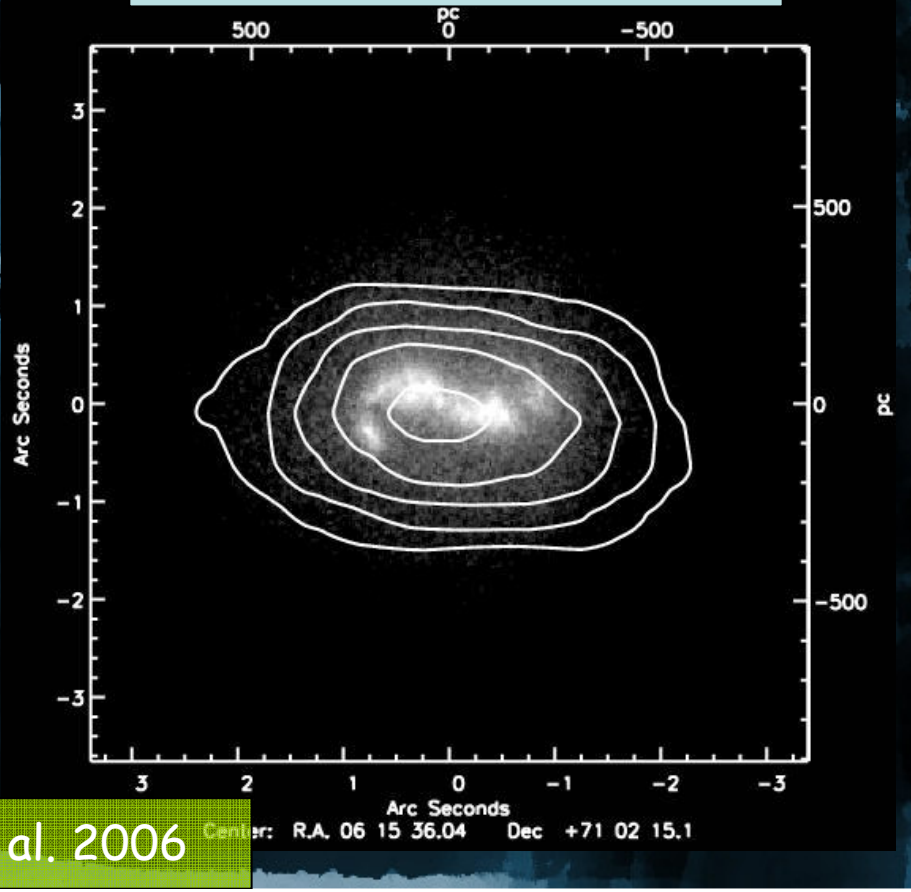
**What is the relation between the NLR and the material that produces the soft X-ray emission in Sy2?**

**To investigate the relation between the NLR and the soft X-ray emission, we selected a sample of 8 Sy2 with extended [OIII] emission in their *HST* images and observed by *Chandra*.**

NGC1386 – z=0.0029



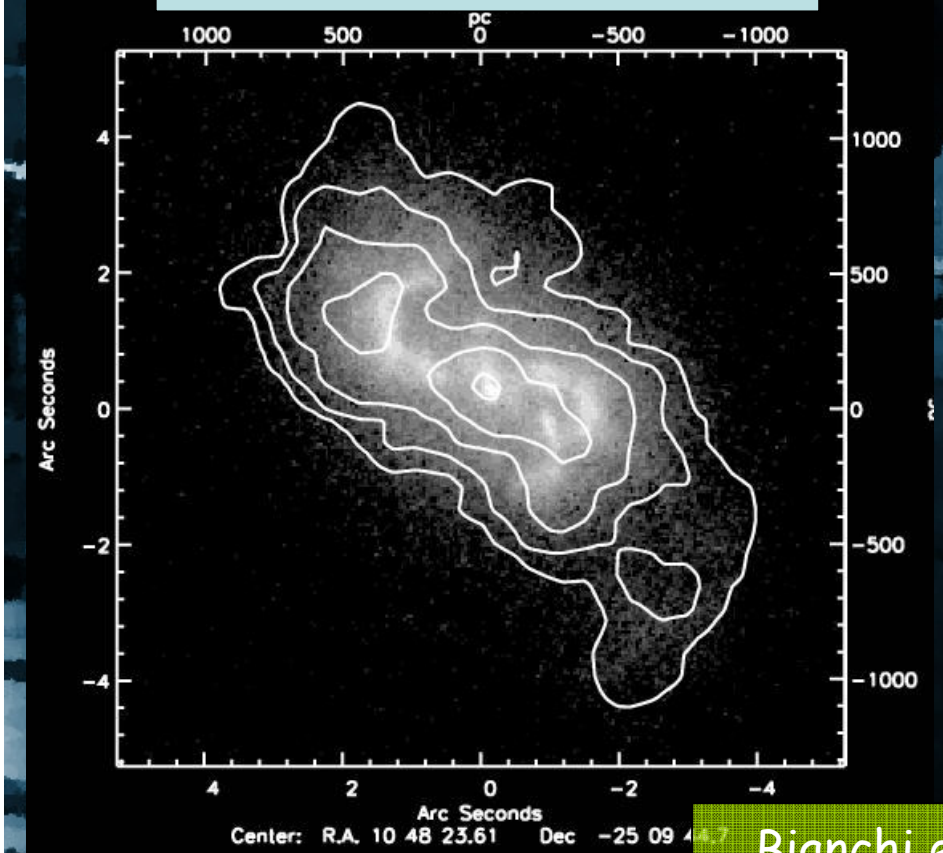

Mrk3 – z=0.0135



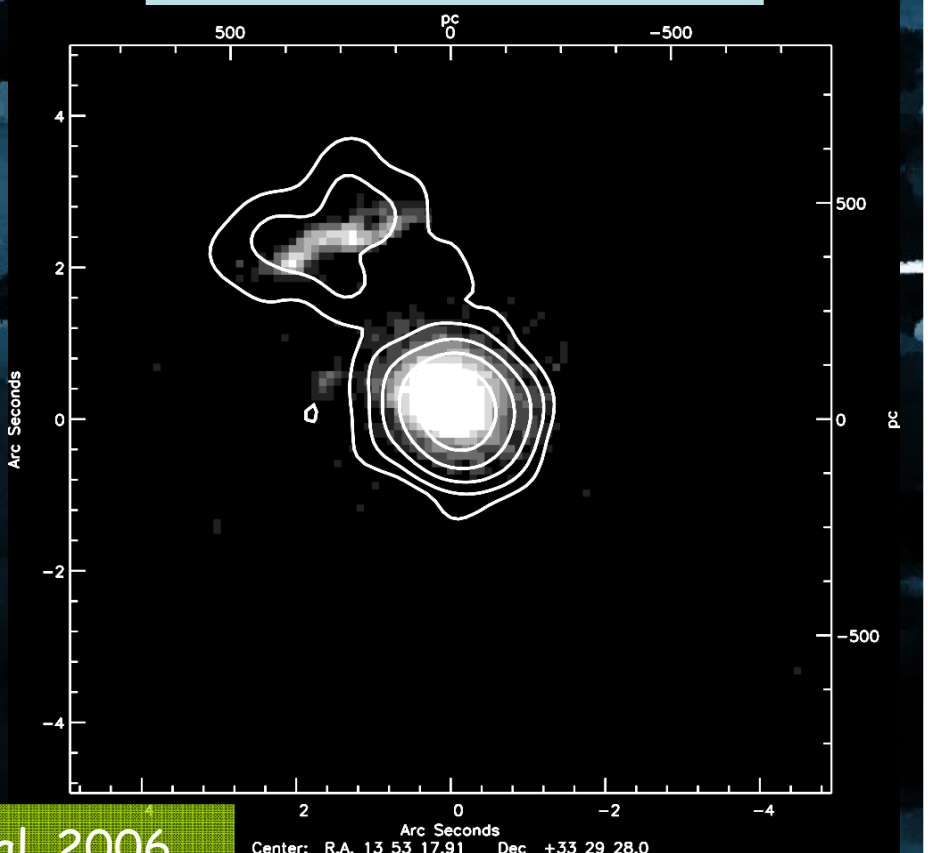

Bianchi et al. 2006

**The coincidence between the soft X-ray and [OIII] emission is striking, both in the extension and in the overall morphology.**

NGC3393 – z=0.0125



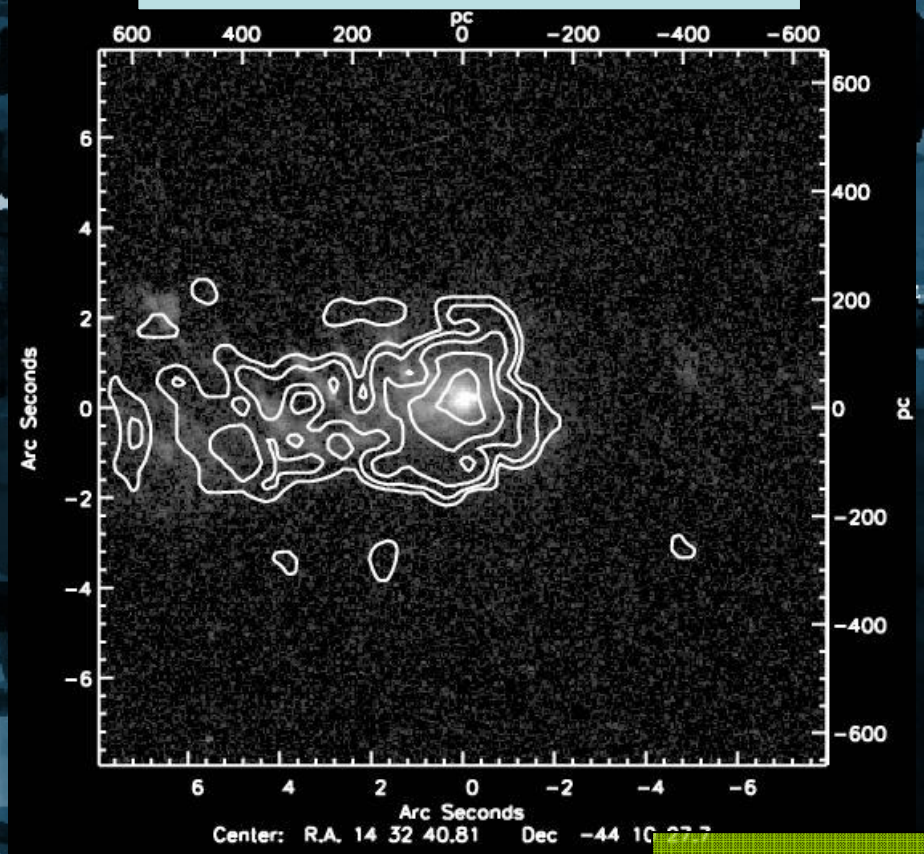

NGC5347 – z=0.0078



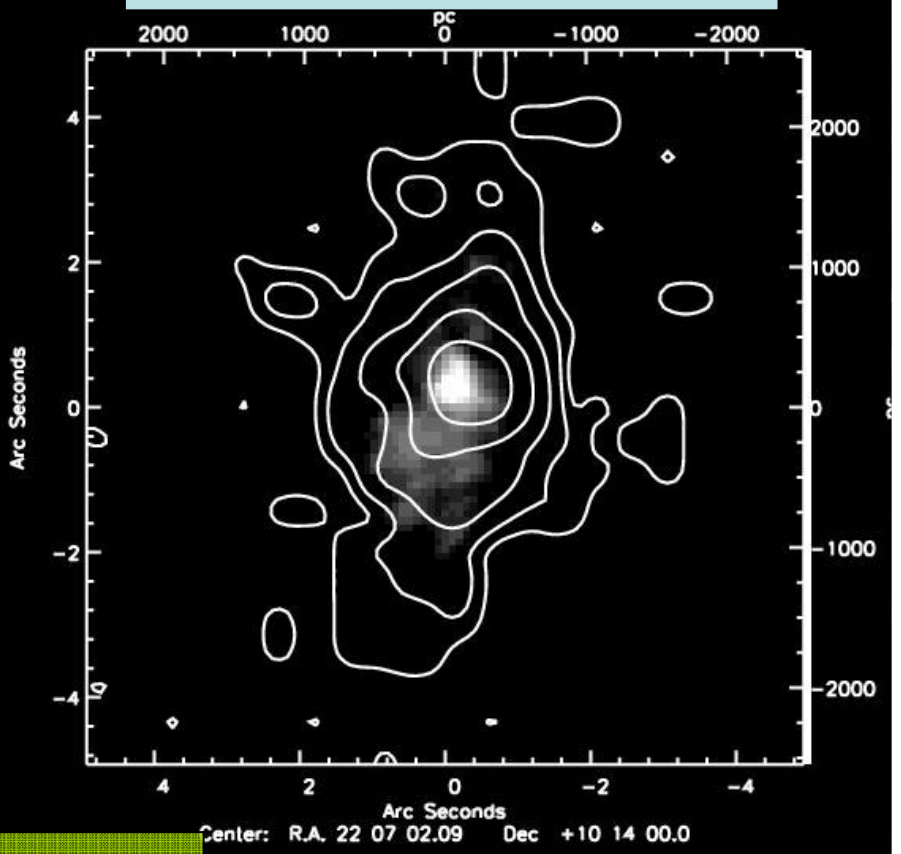

Bianchi et al. 2006

**Unfortunately, the lower spatial resolution of *Chandra* does not allow to perform a detailed comparison of the substructures apparent in *HST*.**

NGC5643 – z=0.0040

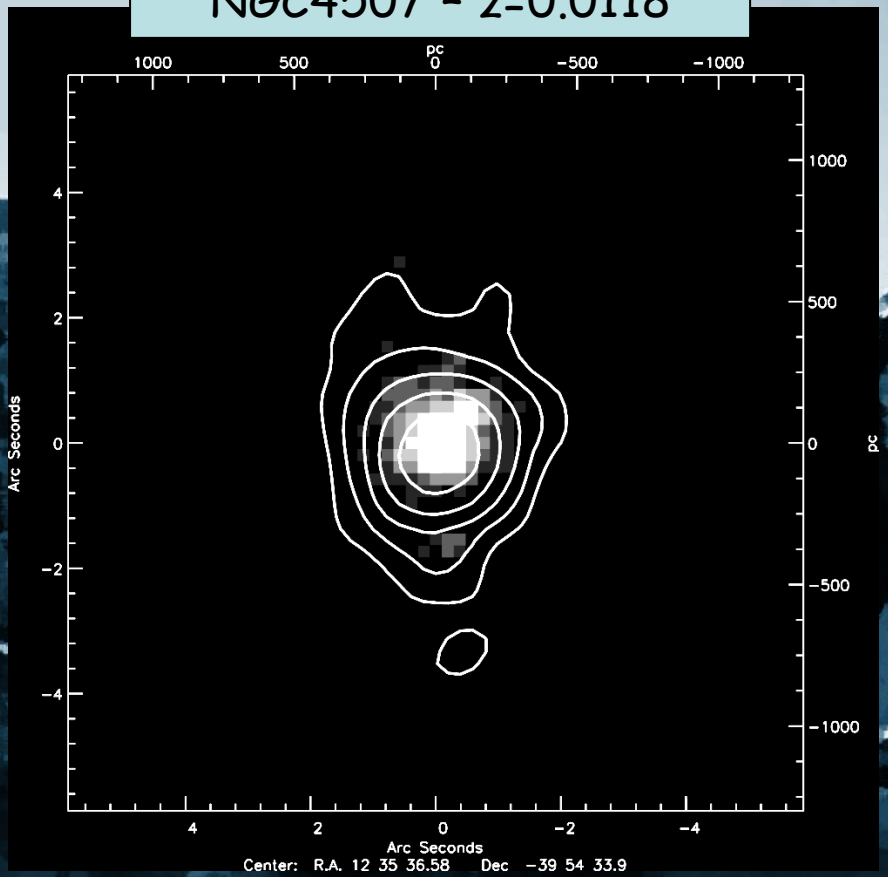



NGC7212 – z=0.0266

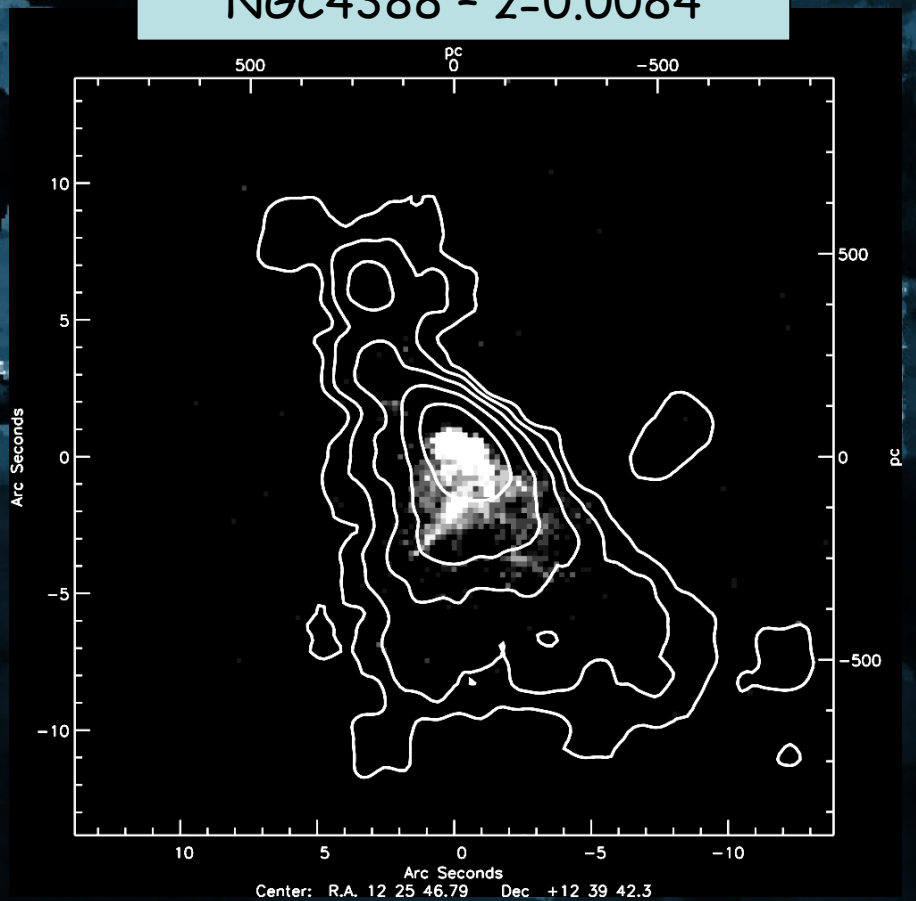



Bianchi et al. 2006

## NGC4507 - z=0.0118



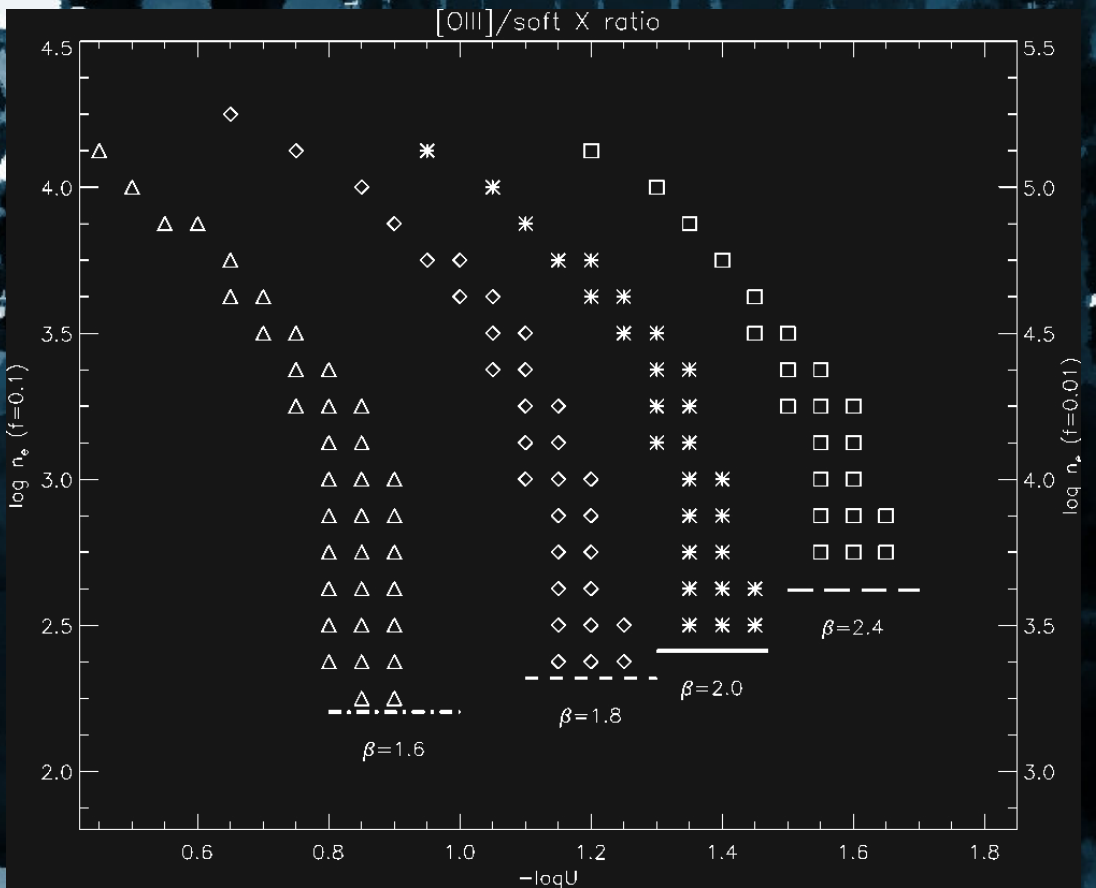

## NGC4388 - z=0.0084

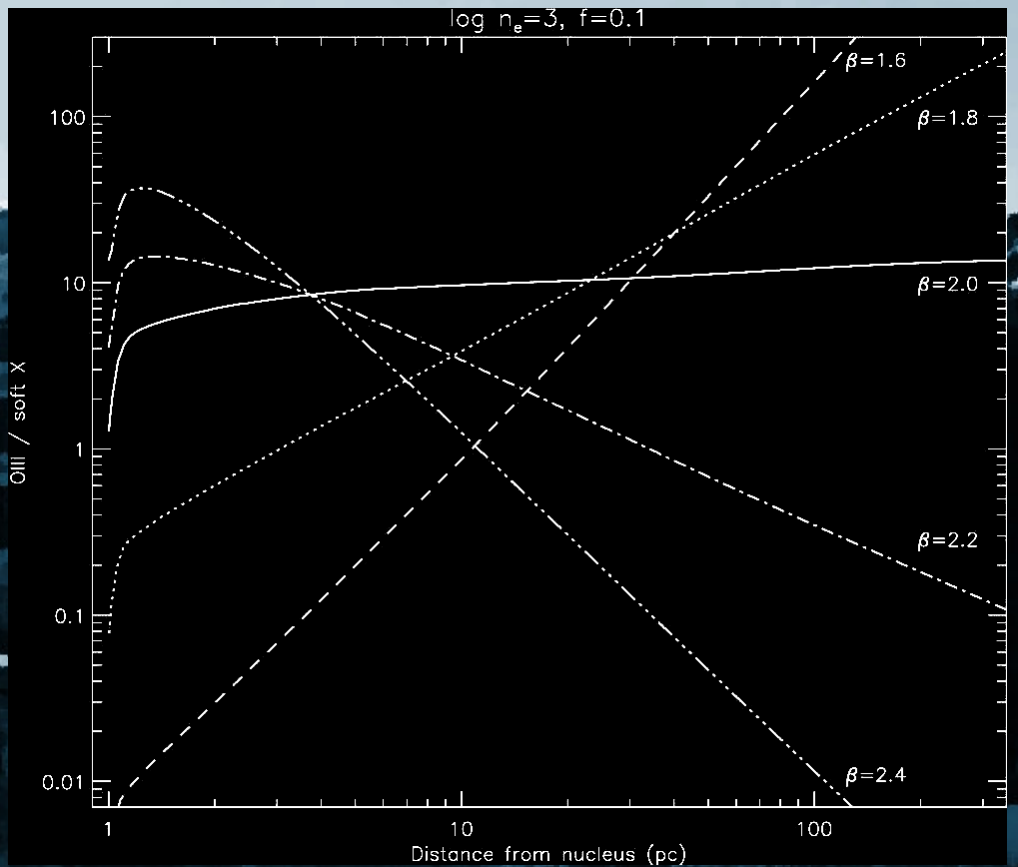



Bianchi et al. 2006

We performed a series of simulations with CLOUDY to test if it is possible that the [OIII] and the soft X-ray lines come from the same material, photoionized by the nuclear continuum.
A solution in terms of a constant density gas, extended for hundreds of pc must be rejected, as most of the X-ray emission would be produced only in a region very close to the nucleus.

On the other hand, solutions with the density falling as $r^{-\beta}$ reproduce the observed [OIII]/soft X-ray ratio, in well-defined regions of the density/ionization parameter plan.






The comparison between the *Chandra* and the *HST* images shows that the [OIII]/soft X-ray ratio is fairly constant along with the radius, up to hundreds of pc. This suggests that the value of ß is very close to 2 (→ constant U).

Interestingly, steep values of β are also found on the basis of NLR emission lines' ratios

(e.g. Kraemer et al. '00, Kraemer & Crenshaw '00, Bradley et al. '04, Collins et al. '05).

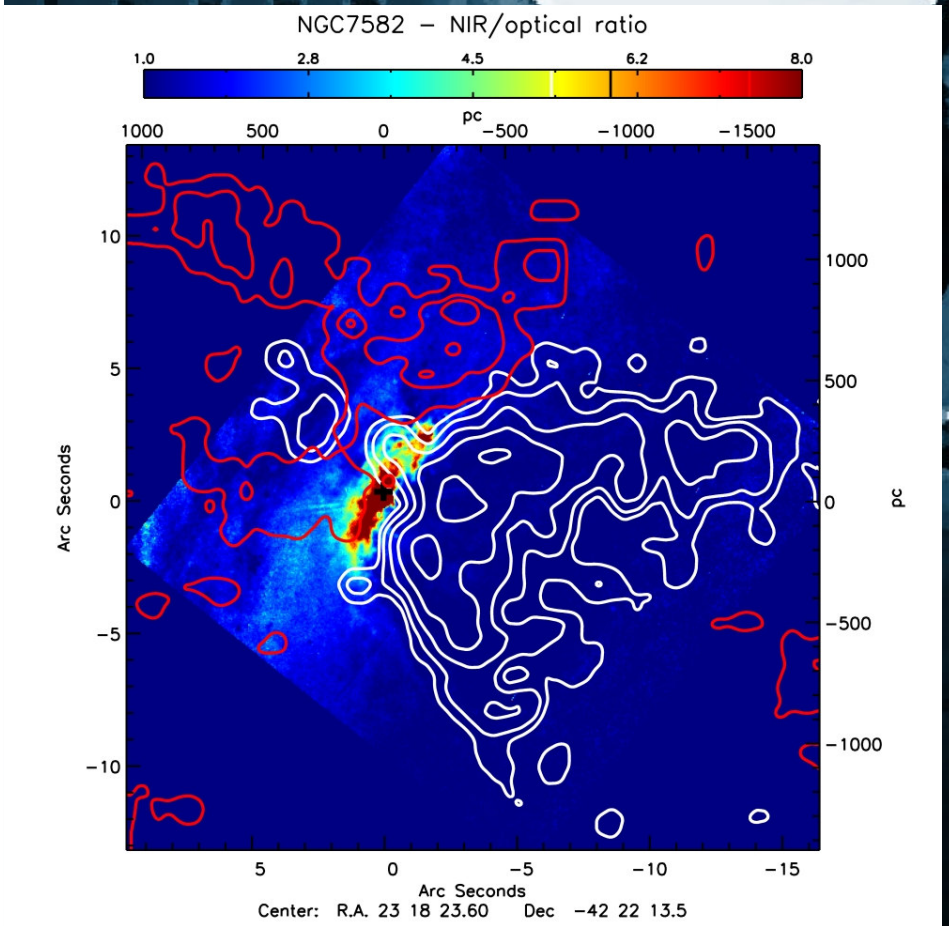
This scenario is consistent with a single material, photoionized by the AGN continuum, extended on hundreds of pc, producing both the soft X-ray emission lines and the NLR emission.

However, this model is clearly oversimplified.
It is likely that at any radius different components are present, as already suggested for the NLR itself (e.g. Kraemer et al. '00).
In the X-rays, there is also evidence of another material, with higher ionization, which produces FeXXV and FeXXVI lines (e.g. Bianchi et al. '05).

Moreover, the role of radio jets is still unclear.
There is strong evidence that they play a fundamental role in the morphology of the NLR (e.g. Nagar et al. '99, Capetti et al. '99, Cooke et al. '00), but they may also represent a further source of photoionization (e.g. Sutherland et al. '93).

# NGC7582

Bianchi et al., submitted



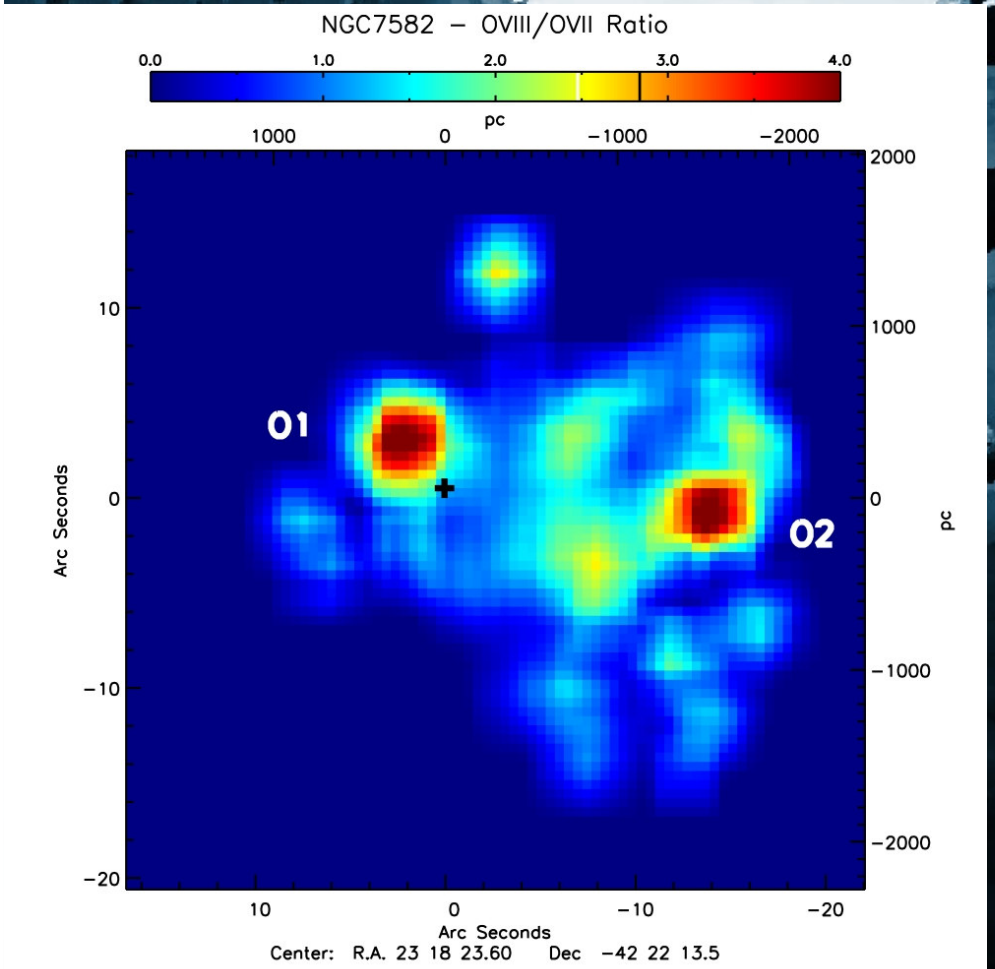

The dust lane strongly influences the soft X-ray emission:

-The lower energy part (<0.8 keV, white) is emitted only west of the nucleus and is coincident with the NLR

-On the other hand, the higher one (0.8-1.3 keV) is also emitted in the east side, but where the dust lane is thinner (in red, where the ratio between the two bands is higher)

# NGC7582

Bianchi et al., submitted




Two 'hot spots', i.e. regions where emission from OVIII is higher than OVII, are present in the soft X-ray image
They can be due to:

-Absorption (O1)

-Variation of U
->
Deviation of density law from $r^{-2}$
or
Further sources of photoionization

# Conclusions

High resolution spectroscopy of soft X-ray emission in obscured AGN reveals that it is dominated by strong emission lines, with a low level of continuum

Several diagnostic tools both on few bright sources and on a whole catalog (CIELO) agree on its origin in a photoionized gas, with photoexcitation playing an important role

The common spatial coincidence between the soft X-ray emission and the NLR suggests they can be one and the same medium, photoionized by the central AGN, as confirmed by simple models

However, the picture is complicated by the influence of the environment (dust lane, radio jets, starburst), which may contribute to make the gas heterogeneous (see NGC 7582)