Deep X-ray view of the bare nucleus Seyfert Ark 120: unveiling the core of AGN

Delphine Porquet

Laboratoire d'Astrophysique de Marseille, CNRS, CNES, France

J. Reeves, A. Lobban, V. Braito, E. Nardini, C. Done, …
G. Matt, A. Marinucci, the Nustar AGN team, …

Deepest X-ray observations of a « bare » AGN: Ark 120

Ark 120: brightest and cleanest bare AGN (z~0.033)

- No intrinsic reddening in its IR/optical continuum.
- No absorption signature in X-rays and UV:
  no warm absorber on the line of sight

⇒ *direct view of the inner part of the accretion disc*

- A prominent soft X-ray excess and a possible relativistic FeK line…

An extensive simultaneous observation campaign in March 2014:

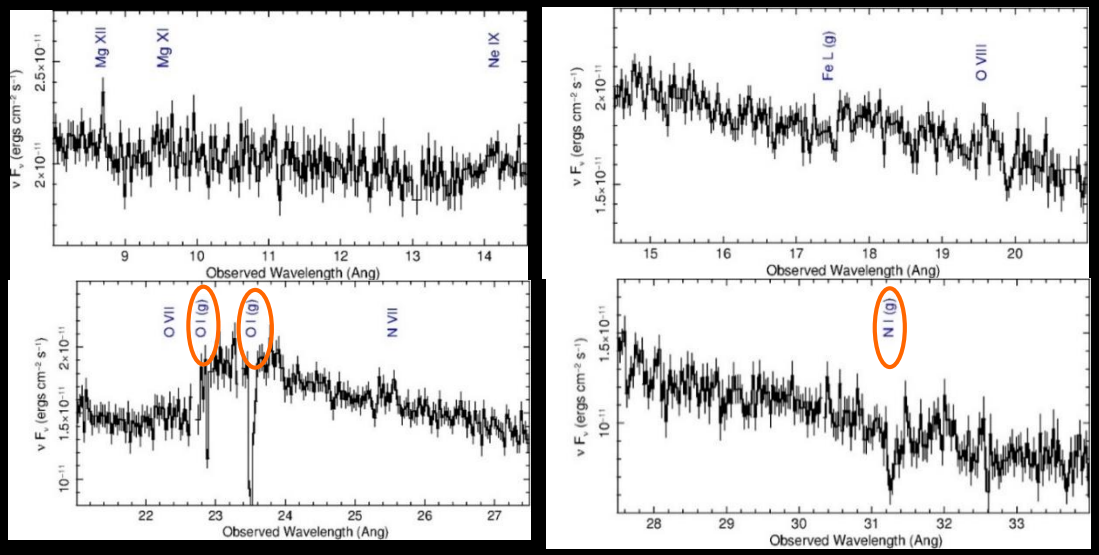
Large XMM-Newton Program of 480 ks (OM, RGS, EPIC)
(PI: D. Porquet; ~5.5 days) over 4 consecutive orbits March 18-24.
Highest S/N data and longest elapsed time observation for a bare AGN.

+ 120ks Chandra/HETG observation (PI: D. Porquet)
First Chandra observation of Ark 120.

+ 65ks Nustar observation performed during the 3rd XMM-Newton observation (PI: Nustar AGN team; 65ks)

A very deep RGS observation Ark 120

(Reeves et al. 2016, Paper I)



480 ks of RGS data
($\geq$ 6.5 x 10^5 counts,
S/N > 25 per bin)

- ✓ Only neutral absorption lines from the Galactic ISM
- ✓ No ionized absorption line from Ark 120
  - → No warm absorber on the line of sight
  - → Confirmation of the "bare" characteristic of Ark 120

BUT several ionized emission lines from H-like and He-like ions (N, O, Ne, Mg) from Ark 120

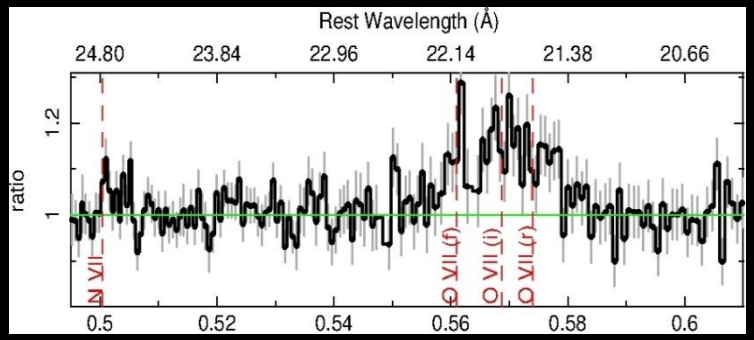
Observed for the first time for a bare AGN at high S/N !

A very deep RGS observation Ark 120

Reeves et al. (2016, Paper I)

The emission ionized lines from Ark 120 :

- H-like line profiles are narrow and unresolved → pc scale (NLR)
- He-like line profiles are velocity broadened



- ✓ A blend of narrow lines can be ruled out
- ✓ Can be fitted by a blend of velocity broadened lines with a common velocity of ~ 4600 km/s (BLR= 5800 km/s),

→ sub-pc scale

⇒ Warm gas (~ BLR and NLR) observed out of the line-of-sight (so only observed in emission)

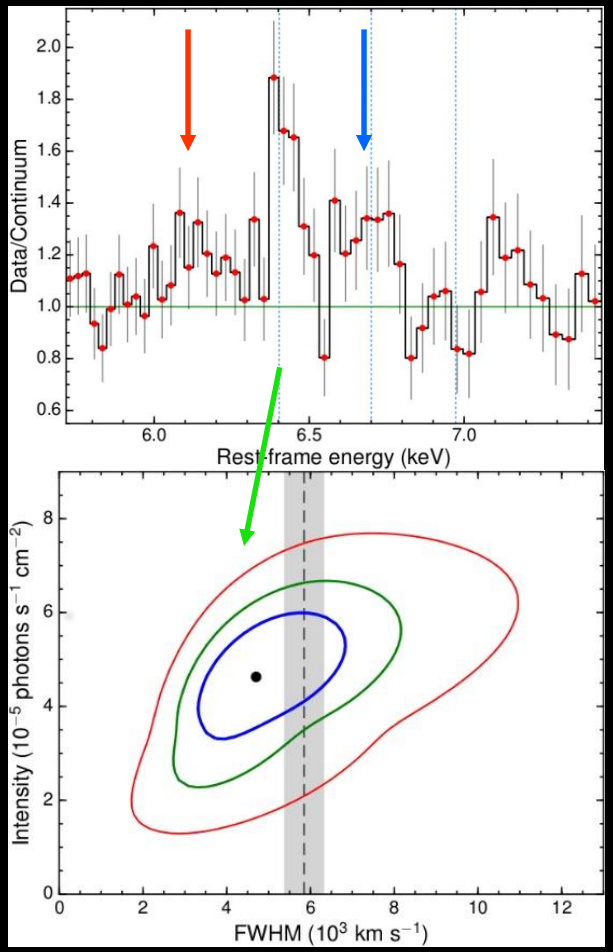
→ Ark 120 is not intrinsically bare !

⇒ Ark 120 is not a peculiar AGN type but an AGN for which the l.os. does not intercept the warm absorber.

The deep view of the FeK complex: HETG + pn

Nardini et al. (2016, Paper II)

Chandra/HETG



Chandra/HETG :
FeK narrow core component resolved thanks to Chandra /HETG:

E = 6.42 ± 0.02 keV

Width = 43 (+22,-15) eV
FWHM = 4700 (+2700, -1500) km/s
≈ BLR (FWHM ~ 5800-6100 km/s)

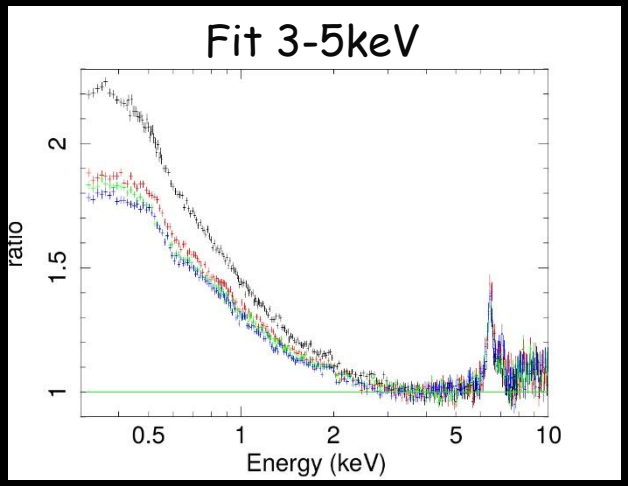
+ Red and blue emission features :

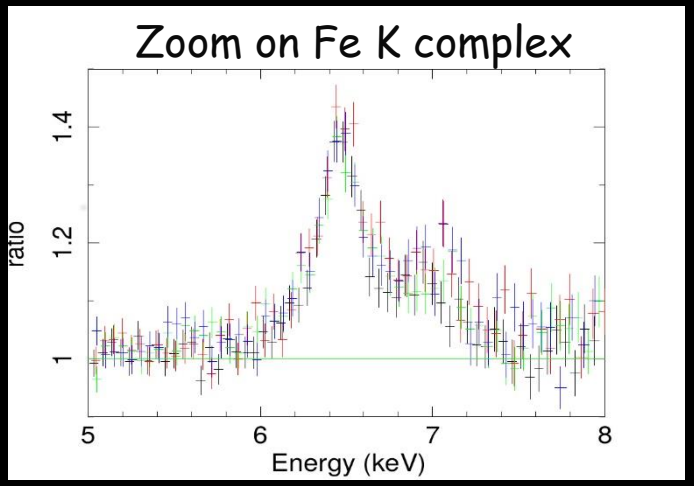
~ 6.13 keV, σ ~ 83 eV
~ 6.68 keV, σ ~ 64 eV
→ broad

+ variable on short time-scale (pn energy-time map);
~ 30-50 ks (~ 10-15 hours)
→ Located at 10s R_g from BH

The four consecutive pn observations Ark 120

(Porquet et al. 2018a, Paper IV)





$\langle\Gamma\rangle$ =1.87 ± 0.02 : typical for a radio-quiet quasar.

A prominent variable smooth soft excess, and a significant FeK complex

→ Confirmation of previous XMM-Newton and Suzaku observations (e.g., Vaughan et al. 2004, Patrick et al. 2011, Nardini et al. 2011, Walton et al. 2013, *Matt et al. 2014*)

The four consecutive pn observations Ark 120

(Porquet et al. 2018a, Paper IV)

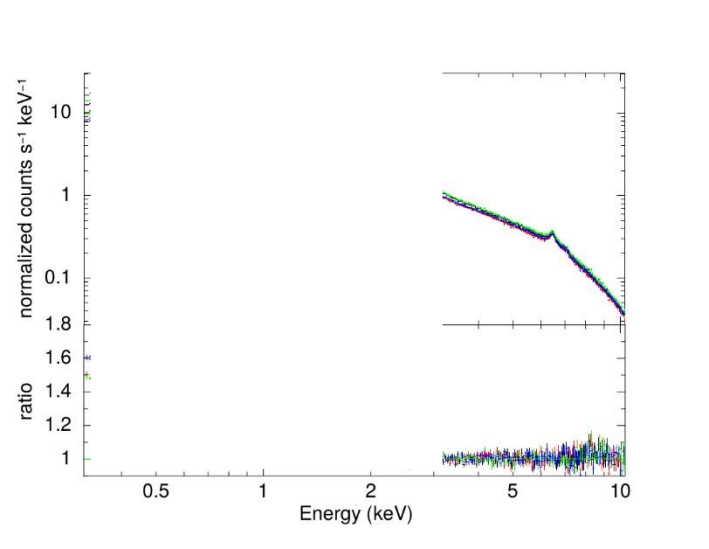
- Fit of the four pn spectra above 3 keV with a relativistic reflection model (relxill: Dauser et al. , Garcia et al.) (+ BLR FeK emissions)

→ Very good statistical fit ($\chi^2_{(reduced)} \sim 1$) :

$\Gamma \sim 1.9$, small reflection fraction ~ 0.5

BUT either very flat disk emissivity index $q \leq 1.1$ for R_{in} = ISCO

or $R_{in} \geq 56\ R_g$ ($R_g = GM/c^2$) assuming a standard $q = 3$



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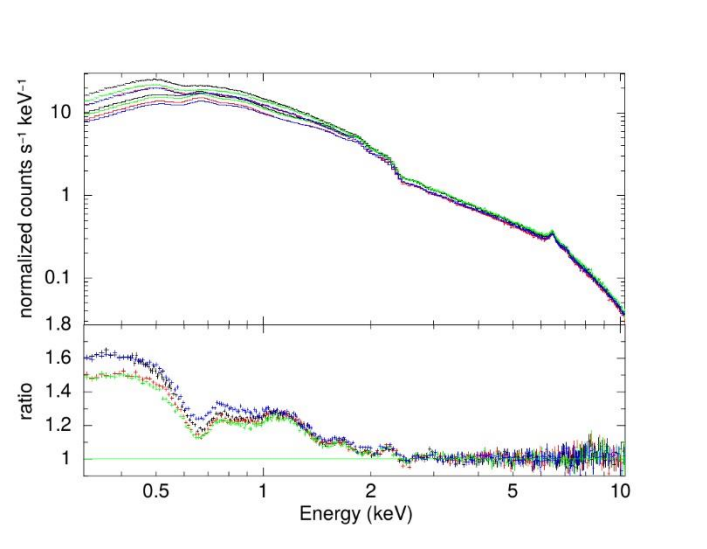
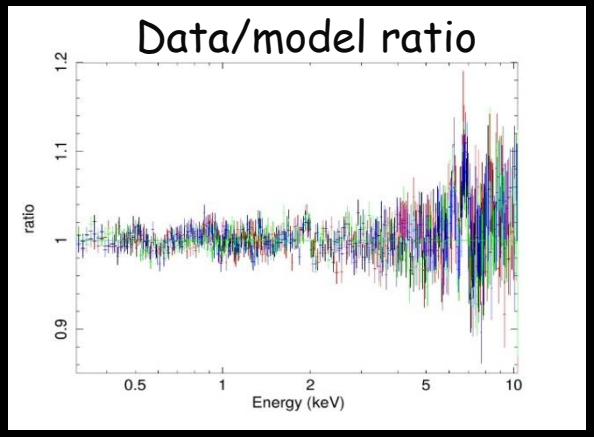


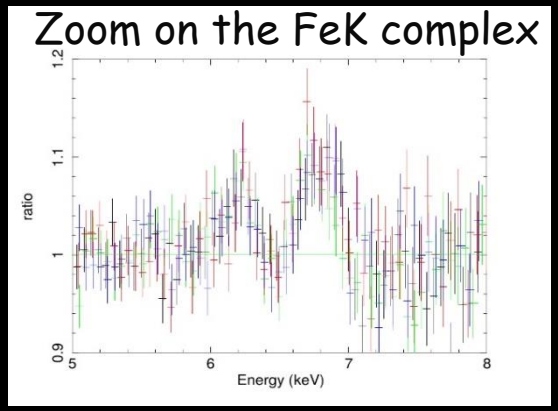
When extrapolated down to 0.3 keV
the soft X-ray excess is not accounted for

The four consecutive pn observations Ark 120

(Porquet et al. 2018a, Paper IV)

Fit with relxill over the 0.3-10 keV energy range:





To fit the featureless soft excess: extreme and fine-tuned values are required:

Spin ~ 0.97 reflection fraction ~ 10, q_1 ~ 7-8, Γ ~ 2.4-2.5

$\neq$ From fit above 3 keV : R ~ 0.4-0.5, $q \lesssim 1.1$, Γ ~ 1.9

$\rightarrow$ red and blue emission disk features still present !

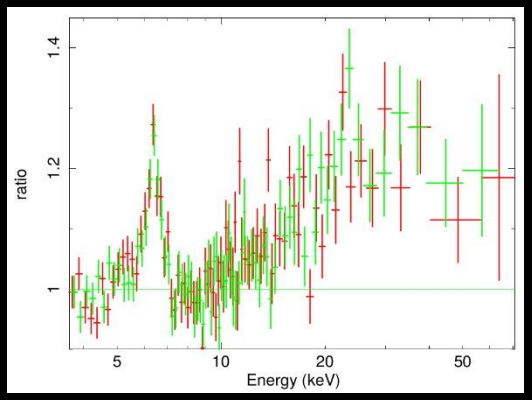
Due to a more complex disk emissivity shape (twice broken powerlaw shape), or ionization gradient, or lamppost geometry, … ? NO

$\Rightarrow$ Relativistic reflection models cannot simultaneously account for both the soft X-ray excess and the FeK red and blue disk features.

Broad-band X-ray view on 2014 March 22: pn + Nustar

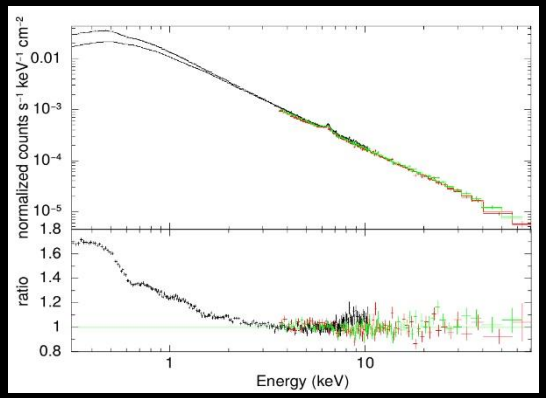
(Porquet et al. 2018a, Paper IV)

NuSTAR FPMA and FPMB



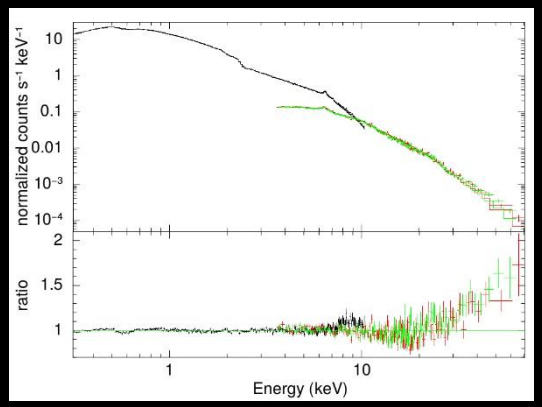
⇒ Prominent FeK complex
+ hard X-ray « hump »

Fit above 3keV and extrapolation



→ Soft X-ray excess is not accounted for

Fit over 0.3-79 keV



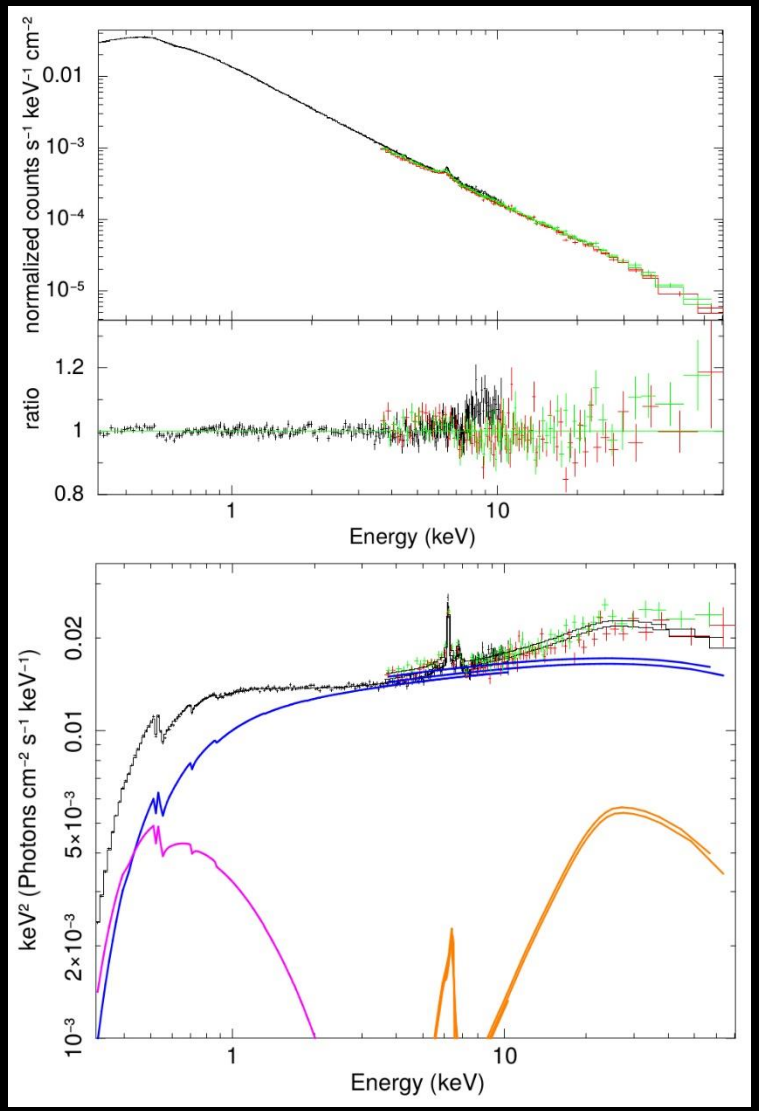
⇒ X-ray excess above 30 keV

Relativistic reflection emission not able to account for both the soft and hard X-ray excesses

whatever models used (emissivity shape, ionization gradient, geometry, density, ….) .

Broad-band X-ray view on 2014 March 22: pn + Nustar

(Porquet et al. 2018a, Paper IV)



Best fit model:

- « Soft » Comptonization (comptt)

kTe ~ 0.5 keV optical depth ~ 9

→ Warm optically thick corona

- « Hard » Comptonization (cutoff PL)

Hot optically thin corona
$\Gamma \sim 1.9$

- Relativistic reflection (relxill)

$R_{in} \sim 26\ R_g$

⇒ 2014 X-ray spectra dominated by warm and hot Comptonization + relativistic reflection at 10s R_g