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Deep X-ray view of the bare nucleus Seyfert Ark120: unveiling the core of AGN

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and the Nustar AGN team

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

Ark 120: brightest and cleanest bare AGN ($z \sim 0.033$)

- No intrinsic reddening in its IR/optical continuum.
 - No absorption signature in X-rays and UV:
no warm absorber at least 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.

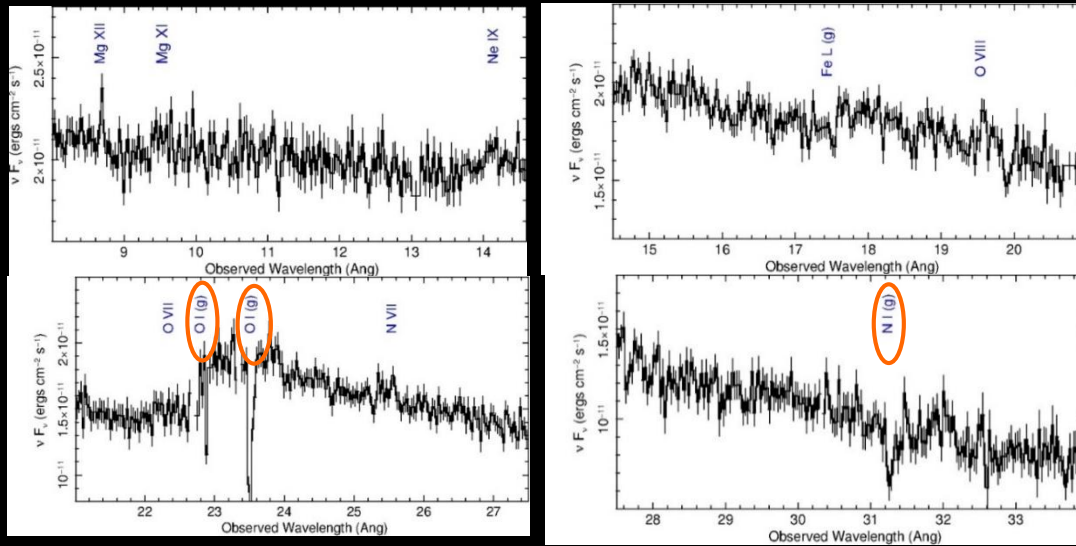
+ 120ks Chandra/HETG observation (PI: D. Porquet)

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
($\geq 6.5 \times 10^5$ counts,
S/N > 25 per bin)

- ✓ No ionized absorption line from Ark 120
 - no warm absorber on the l.o.s.
 - Confirmation of the “bare” characteristic of Ark 120

- ✓ Only neutral absorption lines from the **Galactic ISM**

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

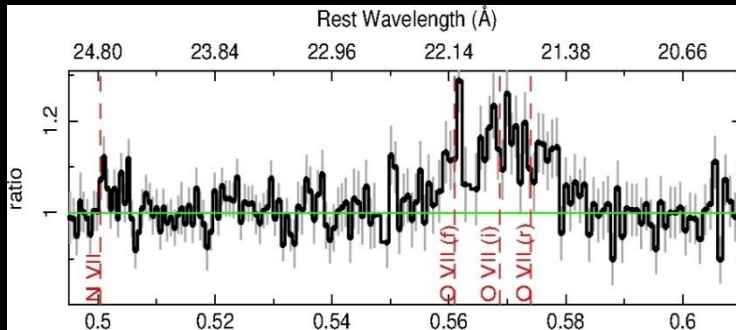
Observed for the first time for a bare AGN !

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 \rightarrow pc scale (NLR)
- He-like line profiles are velocity broadened



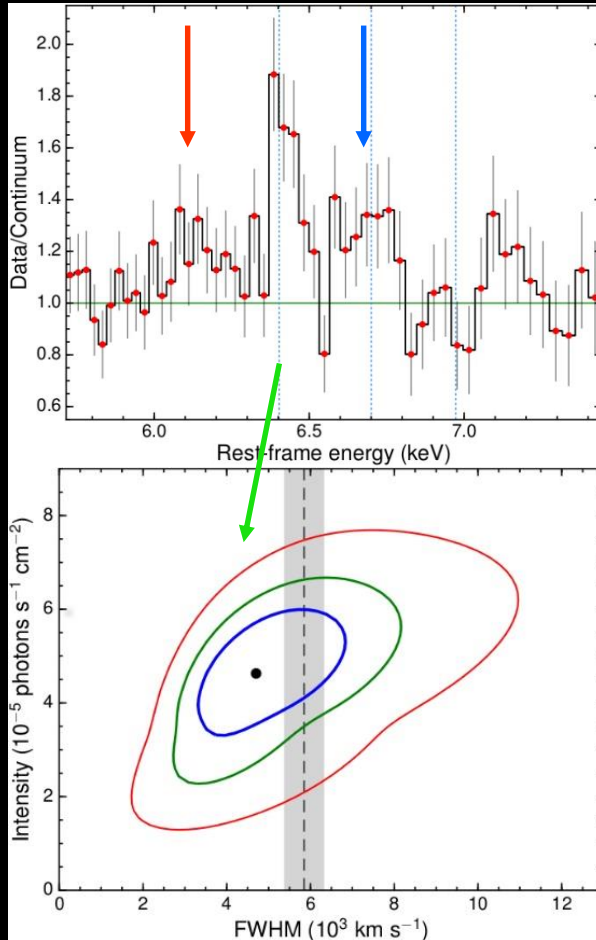
- ✓ A blend of narrow lines can be ruled out
- ✓ Can be fitted by a blend of velocity broadened lines with a common velocity of ~ 4600 km/s (BLR= 5800 km/s),
 \rightarrow sub-pc scale

- \Rightarrow Warm gas (\sim BLR and NLR) as found generally in AGN but here observed out of the line-of-sight (so only observed in emission)
- \rightarrow Ark 120 is not intrinsically bare !
- \Rightarrow 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



FeK narrow core component resolved thanks to Chandra /HETG:

$$E = 6.42 \pm 0.02 \text{ keV}$$

$$\text{Width} = 43 (+22, -15) \text{ eV}$$

$$\text{FWHM} = 4700 (+2700, -1500) \text{ km/s}$$

$$\approx \text{BLR (FWHM } \sim 5800\text{-}6100 \text{ km/s)}$$

Red and **blue** emission features :

$$\sim 6.13 \text{ keV}, \sigma \sim 83 \text{ eV}$$

$$\sim 6.68 \text{ keV}, \sigma \sim 64 \text{ eV}$$

→ broad

+ variable on short time-scale (pn energy-time map);

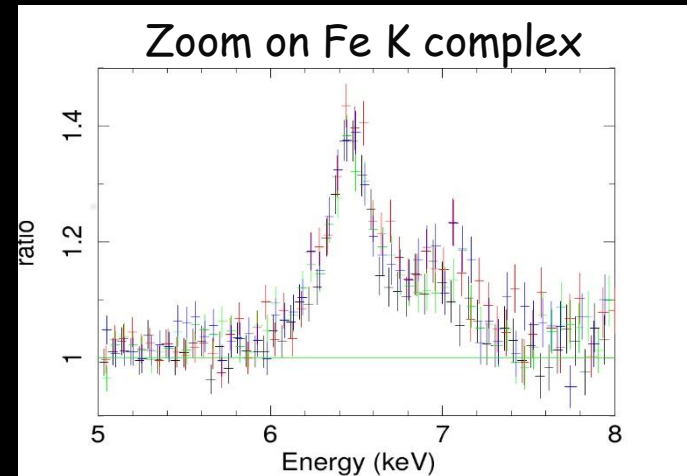
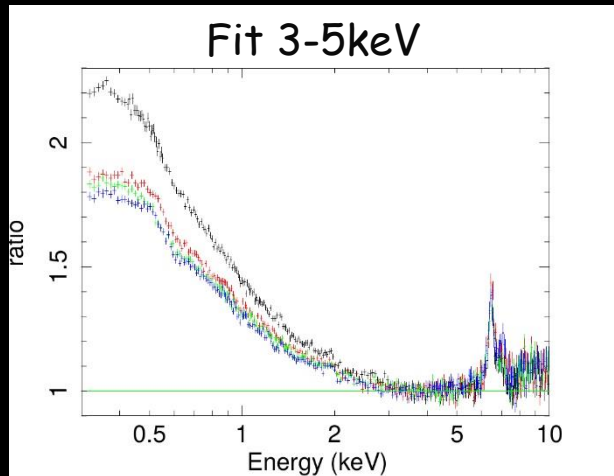
~ 30-50ks (~ 10-15 hours)

→ Located at 10s R_g from BH

+ much more results : see Emanuele's talk (Thursday)

The four consecutive pn observations Ark 120

(Porquet et al. 2017, subm. Paper IV)



$\langle \Gamma \rangle = 1.87 \pm 0.02$: 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. 2017, subm. Paper IV)

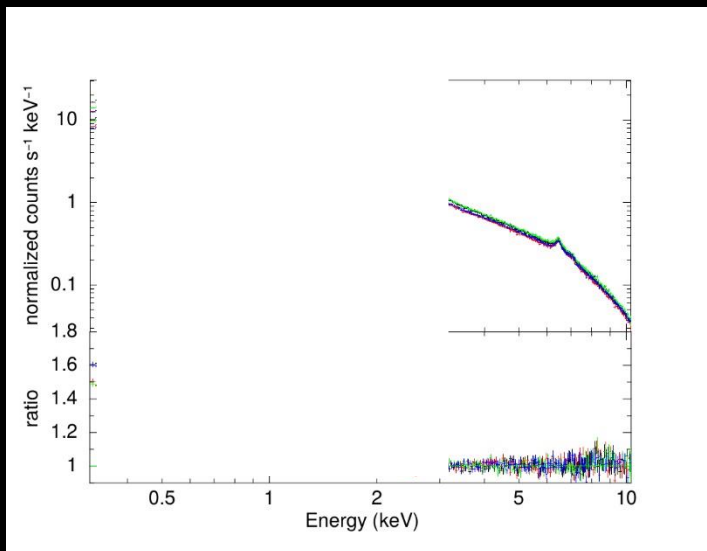
- Fit of the four pn spectra above 3 keV with a relativistic reflection model (relxill: Dauser et al. , Garcia et al.) (+ BLR FeK emissions)

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

$\Gamma \sim 1.85-1.92$, small reflection fraction $\sim 0.4-0.5$

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

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



The four consecutive pn observations Ark 120

(Porquet et al. 2017, subm. Paper IV)

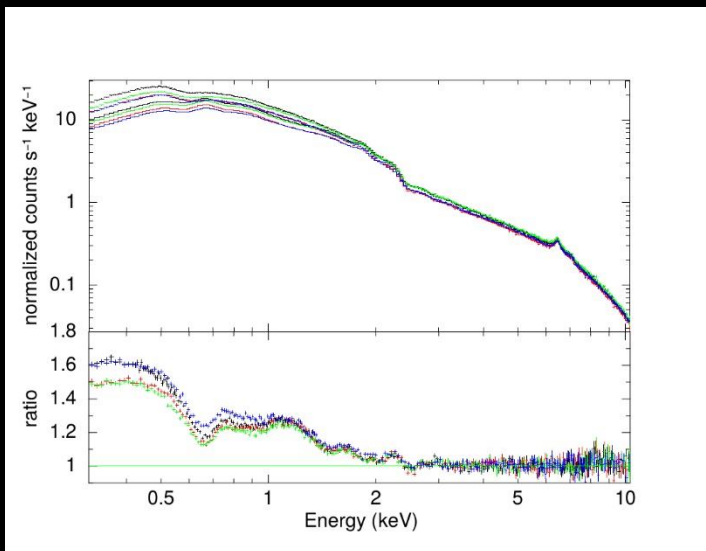
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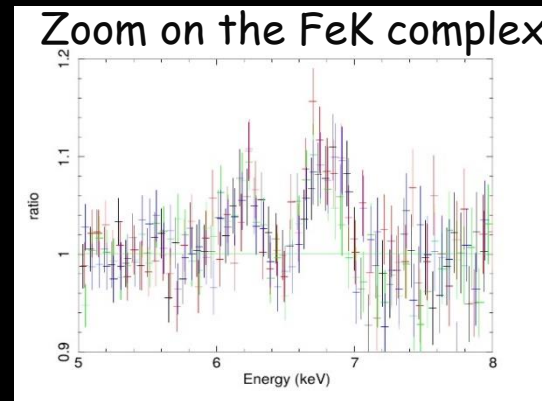
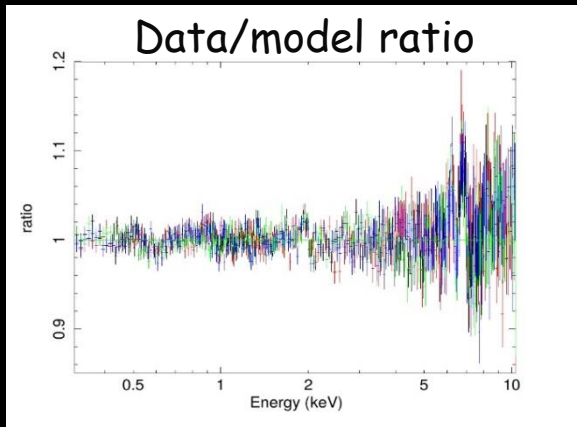


When extrapolated down to 0.3keV
the soft X-ray excess is not accounted for

The four consecutive pn observations Ark 120

(Porquet et al. 2017, *subm.*, Paper IV)

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



To fit the featureless soft excess: extrem and fine-tuned values are found: Spin ~ 0.97 reflection fraction ~ 10 , $q_1 \sim 7-8$, $\Gamma \sim 2.4-2.5$!
 \neq From fit above 3keV reflection ($R \sim 0.4-0.5$, $q \leq 1.1$, $\Gamma \sim 1.9$)

→ red and blue emission disk features still present !

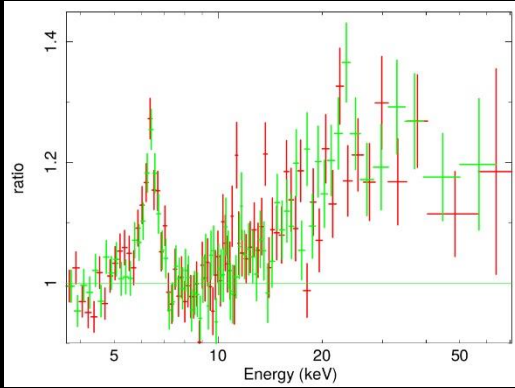
Due to a more complex disk emissivity shape (twice broken powerlaw shape), or ionization gradient, or lamppost geometry, ... ? NO

⇒ 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

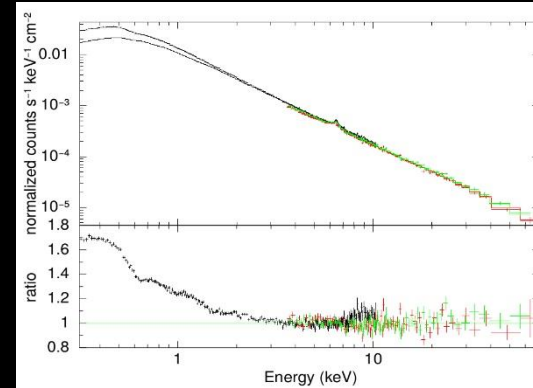
(Porquet et al. 2017, subm. Paper IV)

NuSTAR **FPMA** and **FPMB**



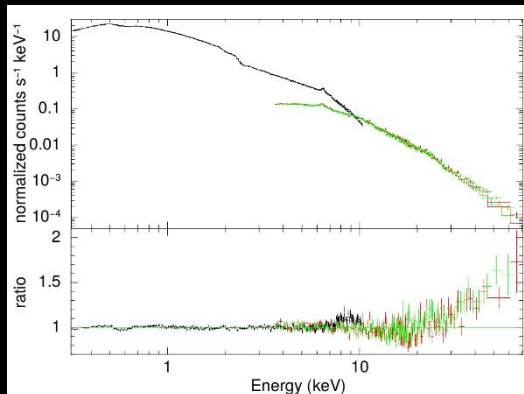
⇒ Prominent FeK complex
+ hard X-ray « hump »

Fit above 3keV and extrapolation



→ Soft excess is not accounted for

Fit over 0.3-79keV



⇒ X-ray excess above 30keV

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. 2017, subm. Paper IV)

Best fit model:

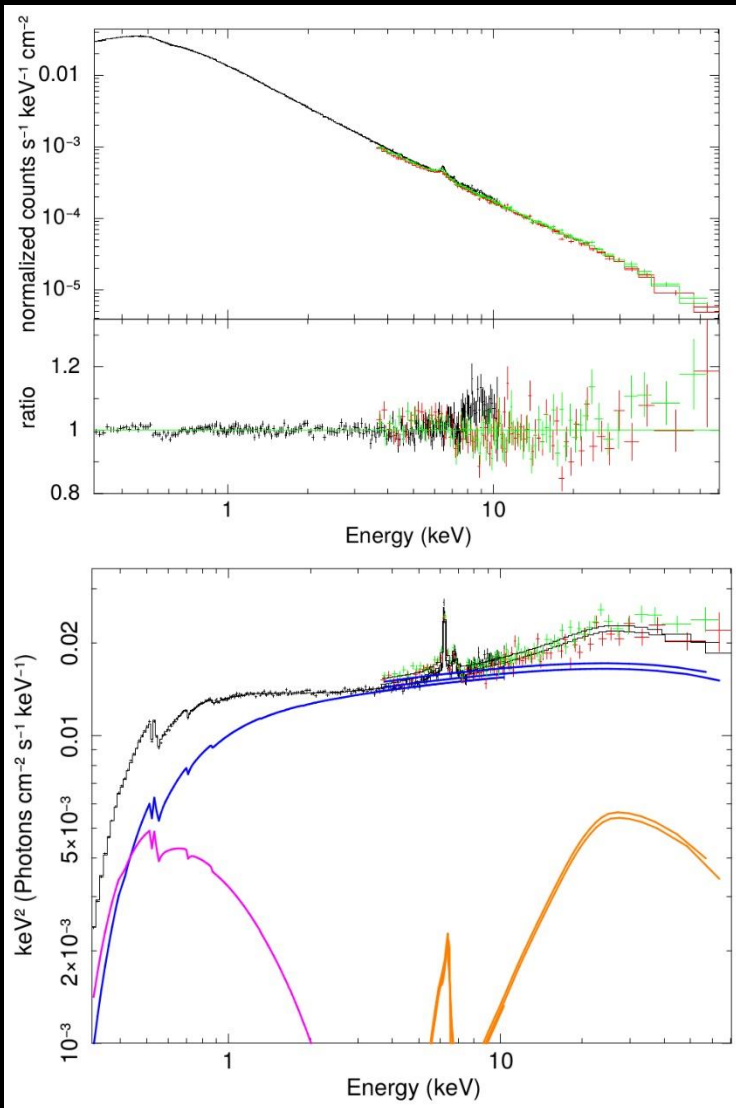
- **Soft Comptonization (comptt)**
kTe ~ 0.5 keV optical depth ~ 9
→ Warm optically thick corona
- **Hard comptonization (cutoff PL)**

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 $10s R_g$



Summary of this 2014 campaign on Ark120:

Deep RGS spectrum (Reeves et al. 2016)

- ✓ No X-ray absorption lines (i.e no warm absorber along the l.o.s.): bare !
- ✓ Detection for the first time of soft X-ray emission lines
 - warm gas out of the l.o.s (~ BLR and NLR)
 - Not intrinsically bare ! Match the Unified scheme
 - Not a peculiar type of AGN.

Chandra/HETG + deep pn (Nardini et a. 2016)

- First Chandra observation of Ark 120: The FeK narrow core resolved and its width consistent with BLR
- + discovery of red and blue transient features from the accretion disk

The broad-band X-ray spectrum: pn + NuSTAR (Porquet et al. 2017)

Soft variable and smooth X-ray excess + FeK complex + hard X-ray excess

- Relativistic reflection models unable to account simultaneously for the soft X-ray excess, the red and blue disk features and the hard X-ray excess
- X-ray broad-band spectra dominated by Comptonization with Comptonization from warm ($kT \sim 0.5 \text{ keV}$) optically thick corona ($\tau \sim 8$) + from hot optically thin corona + mildly relativistic reflection at $10s R_g$