The origin of the strong soft excess and puzzling iron line complex in Mkn 841

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Mkn 841

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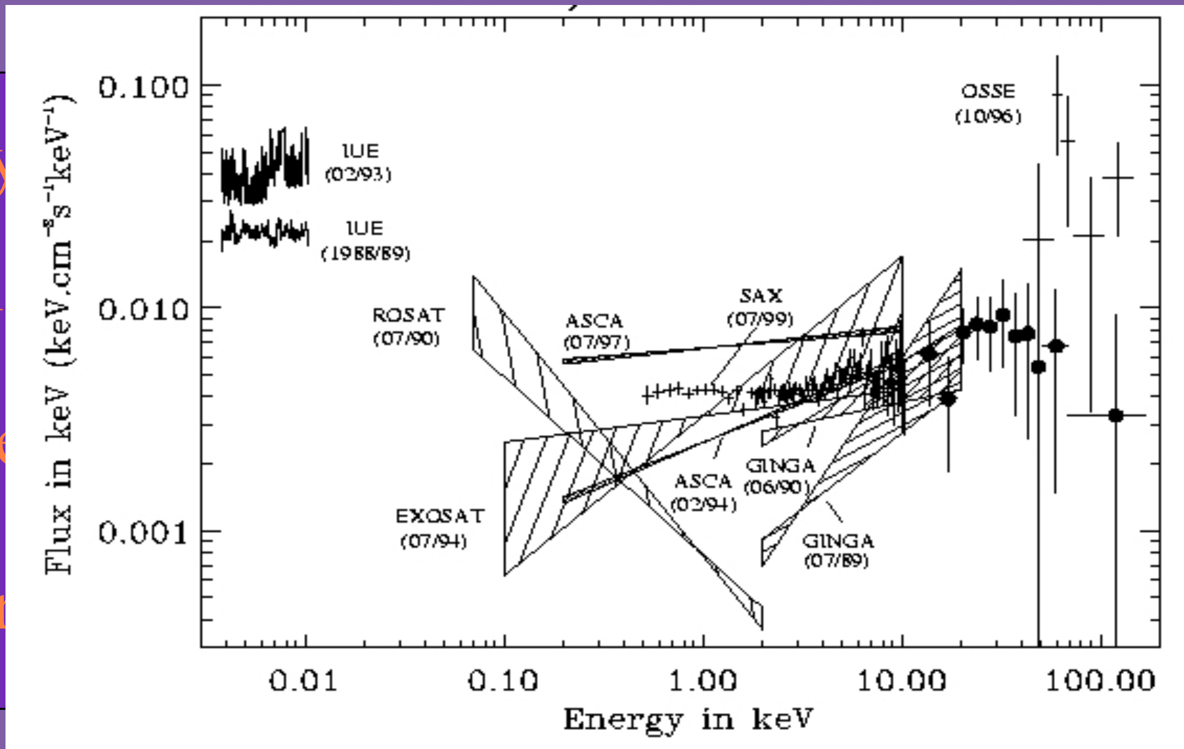

The XMM observations

15 ks | 54 ks | 1 year | 1 month

	OBS 1	OBS 2	OBS 3	OBS 4	OBS 5
Start date	2001-01-13 (05h20m55s UT)	2001-01-13 (09h33m50s UT)	2001-01-14 (00h52m28s UT)	2005-01-16 (12h38m21s UT)	2005-07-17 (06h38m03s UT)
Exposure (s)	8449	10900	13360	45982	29071
Cts.s^{-1} PN	18.0	22.2	21.8	5.6	7.2
Cts.s^{-1} MOS	5.0	5.6	5.5	1.4	1.9

100 ks simultaneous SAX data

- ✓ 5 pointings (3 in 2001 simultaneous with SAX and 2 in 2005) for a total of ~115 ks
- ✓ PN and MOS 2 in SW, MOS 1 in timing mode, UV grism

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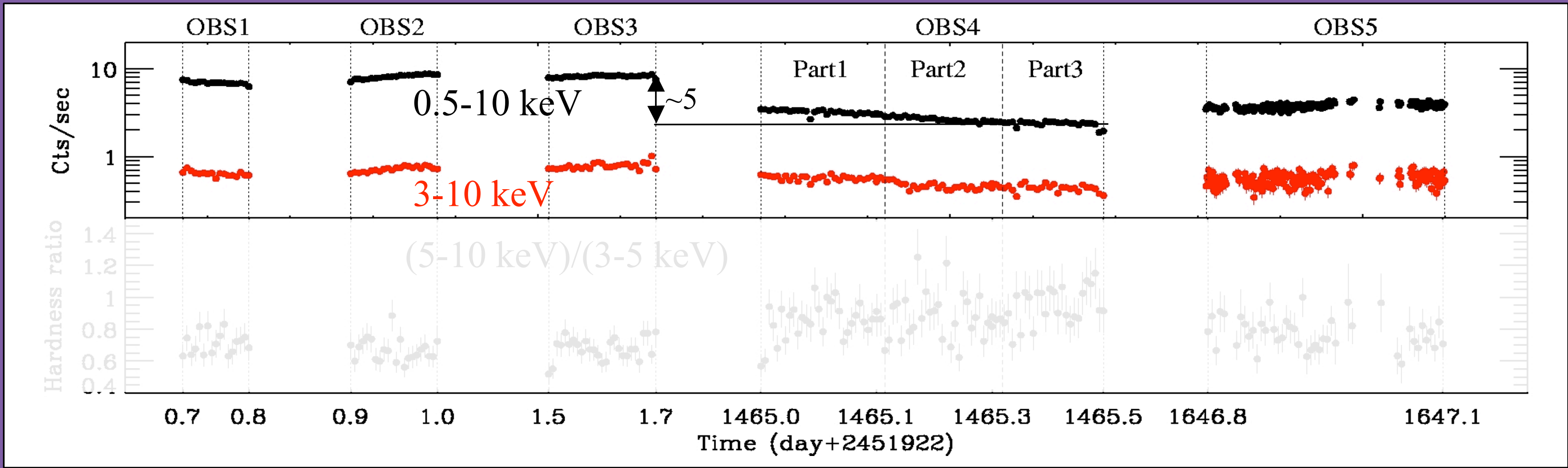
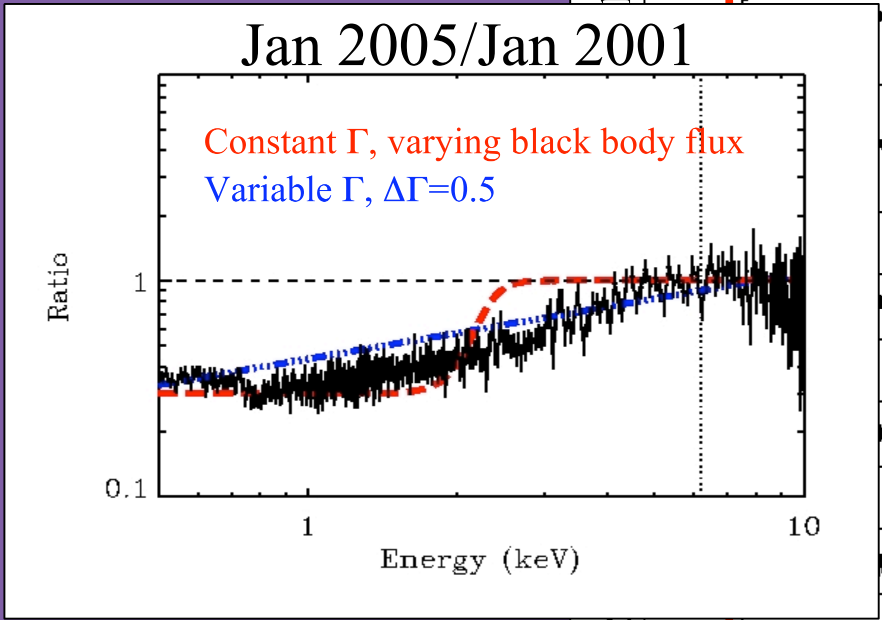
Light curves

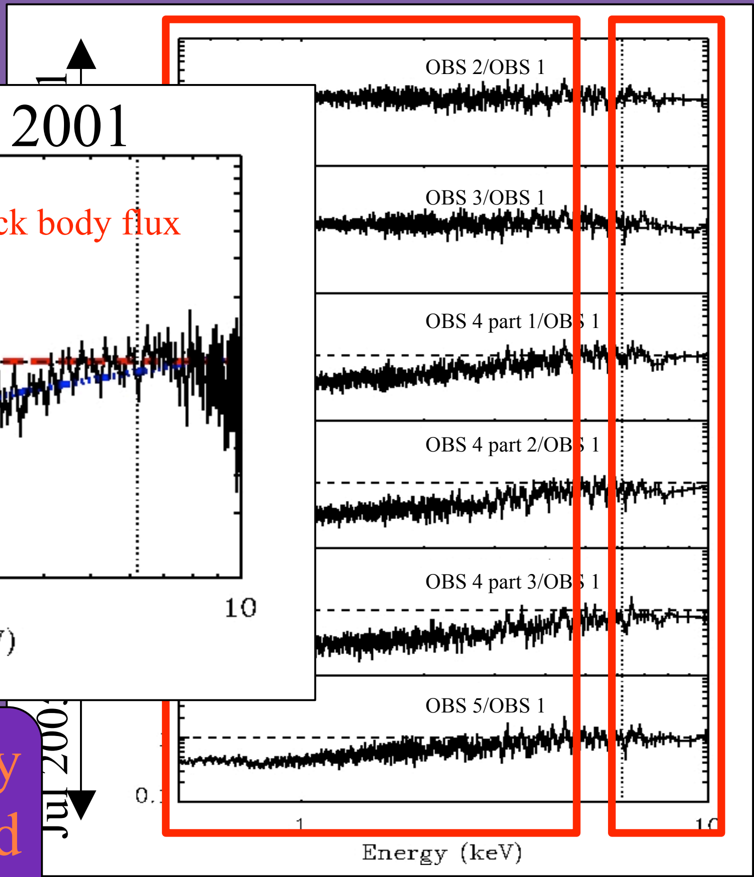


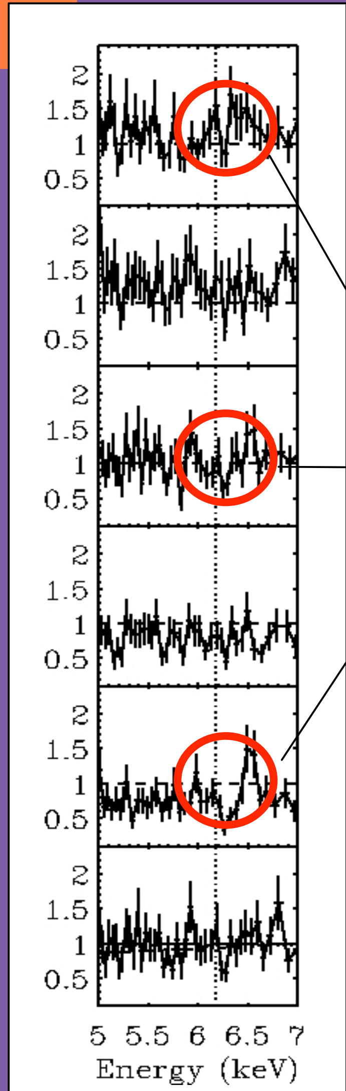
- 0.5-10 keV count rates vary by a factor ~5 in 4 years
- Long time scale variability dominated by the soft (< 3 keV) band
- Variations of ~30-50% in 10 ks
- Slight 3-10 keV hardening when the flux decreases

P.O. Petrucci

Spectral Ratios







Spectral variability due to soft and hard components

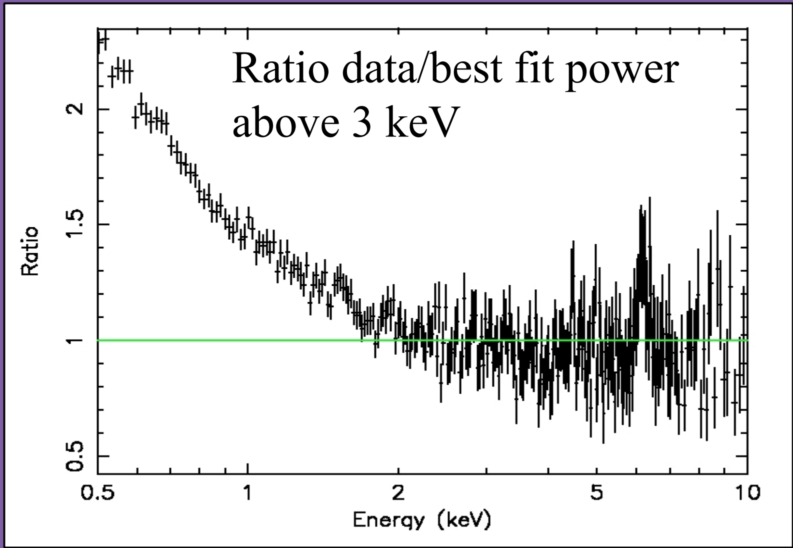
Month/year timescale

No variability

Line variability

10ks timescale

Spectral Fits

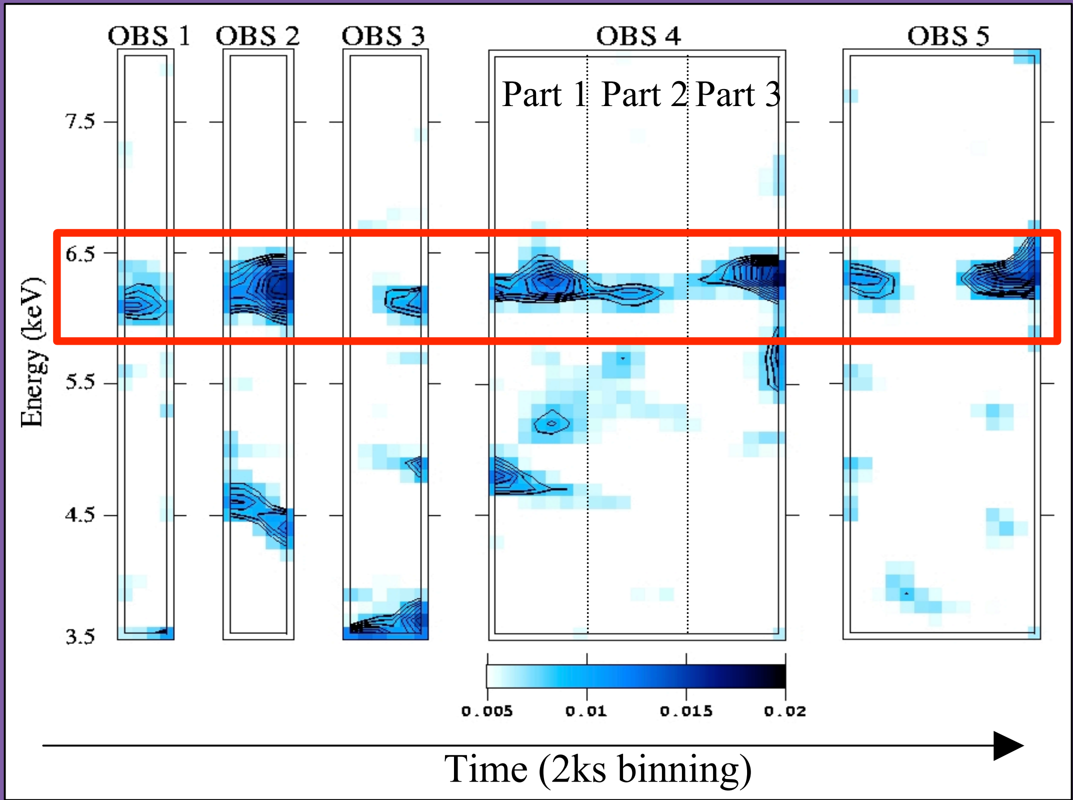


- ✓ Very simple model including a power law, a gaussian and a black body
- ✓ Bad fits especially at low energies
- ✓ Strong spectral/flux variability
- ✓ Significant line detection and apparent line variability

Obs	N_H 10^{-2}	Γ	E_{FeK_α} keV	σ_{FeK_α} 10^{-5}	F_{FeK_α} eV	EW keV	kT_{bb}	$F_{0.5-3}$ 10^{-11}	F_{3-10} 10^{-11}	$\Delta\chi^2$	χ^2/dof
1	<2.4	$1.81^{+0.07}_{-0.09}$	$6.25^{+0.15}_{-0.14}$	<2.4	$1.4^{+3.2}_{-0.6}$	90^{+210}_{-35}	$0.20^{+0.01}_{-0.01}$	1.6	1.	17	548/244
2	<2.4	$1.91^{+0.06}_{-0.08}$	$6.39^{+0.06}_{-0.05}$	<0.2	$2.7^{+1.0}_{-0.8}$	170^{+60}_{-50}	$0.18^{+0.01}_{-0.01}$	1.9	1.1	37	510/263
3	<2.4	$1.91^{+1.00}_{-0.08}$	$6.57^{+0.38}_{-0.46}$	$0.8^{+1.2}_{-0.4}$	$4.0^{+152.0}_{-1.8}$	244^{+9200}_{-110}	$0.17^{+0.01}_{-0.01}$	1.9	1.3	21	397/263
4 part 1	<3.3	$1.43^{+0.05}_{-0.07}$	$6.44^{+0.05}_{-0.04}$	<0.9	$1.3^{+2.5}_{-0.5}$	90^{+170}_{-40}	$0.13^{+0.01}_{-0.01}$	0.8	1.0	22	334/273
4 part 2	<2.6	$1.42^{+0.09}_{-0.04}$	$5.50^{+0.52}_{-0.43}$	$1.0^{+2.1}_{-0.5}$	$5.9^{+25.5}_{-4.1}$	420^{+1800}_{-290}	$0.14^{+0.01}_{-0.01}$	0.6	0.8	14	342/266
4 part 3	<2.6	$1.30^{+0.07}_{-0.06}$	$6.51^{+0.03}_{-0.03}$	<0.1	$1.6^{+2.1}_{-0.4}$	140^{+80}_{-40}	$0.14^{+0.01}_{-0.01}$	0.6	0.8	37	367/266
5	<2.6	$1.65^{+0.05}_{-0.06}$	$6.49^{+0.09}_{-0.07}$	<0.25	$1.9^{+0.5}_{-0.8}$	140^{+40}_{-60}	$0.12^{+0.01}_{-0.01}$	0.9	0.9	25	389/281

The Iron Line Complex

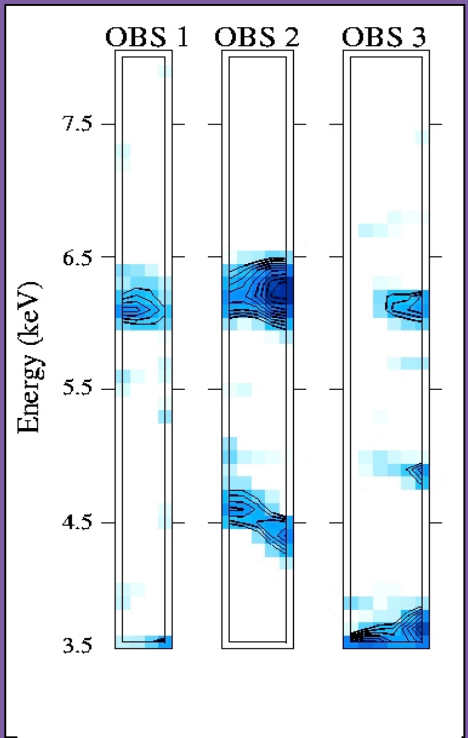
Map Excess

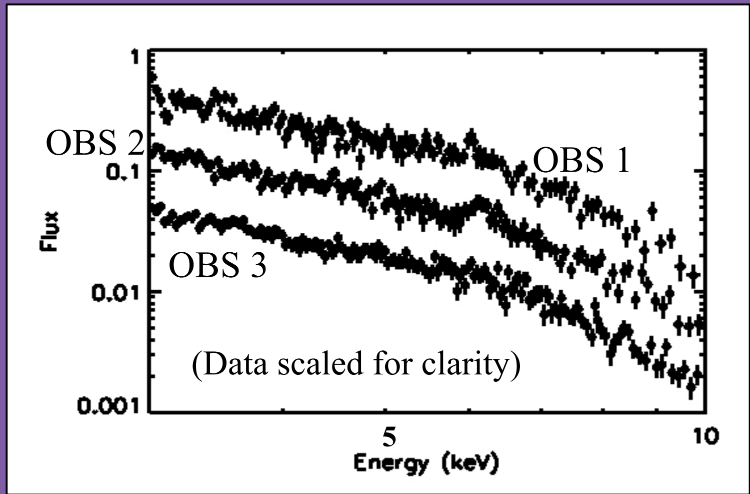


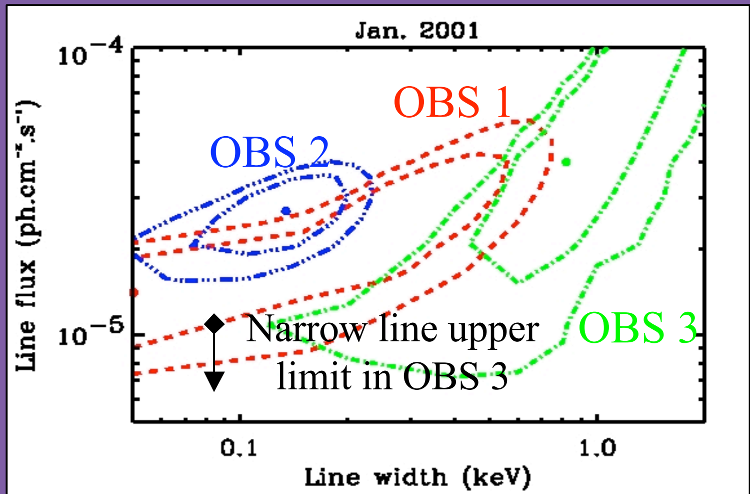
An apparently rapidly variable narrow component on ~10 ks timescale

(following Iwasawa et al. 2006)

The Iron Line Complex



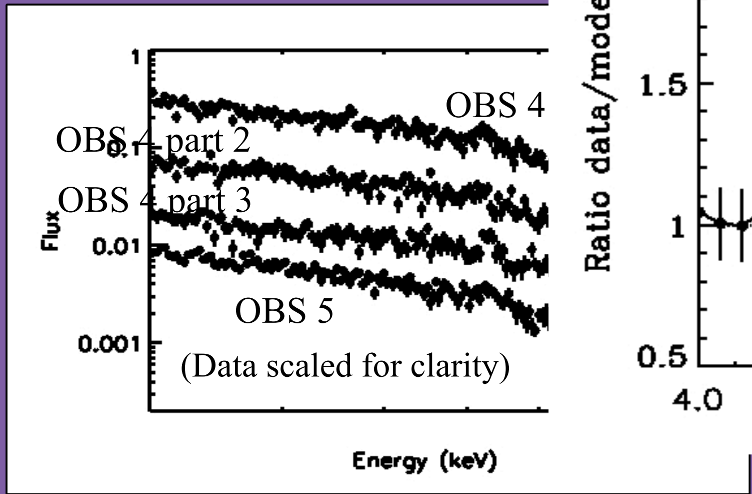


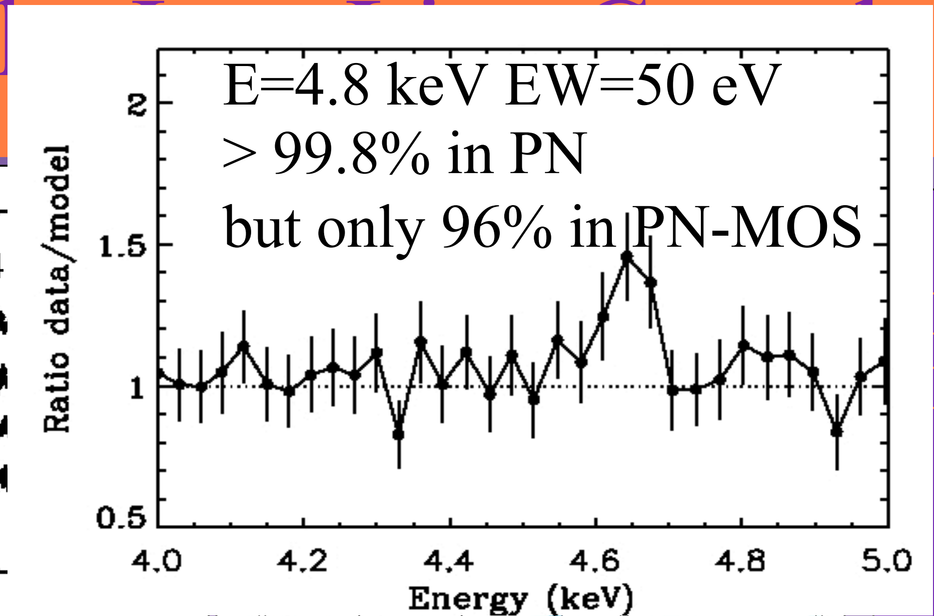


- The narrow component varies on 10 hours time scale
- Narrow and broad components could be signature of the same phenomenum:
  ➔ local illumination by a flare becoming progressively broadened as the disc rotates

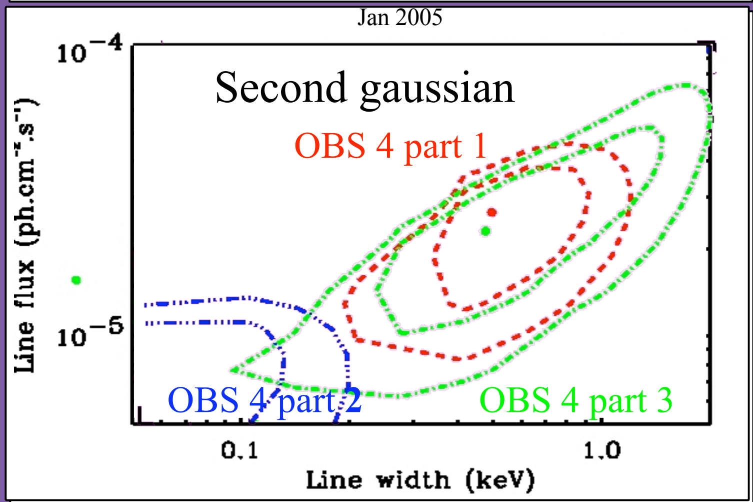
(Petrucci et al. 2002, Longinotti et al. 2004)

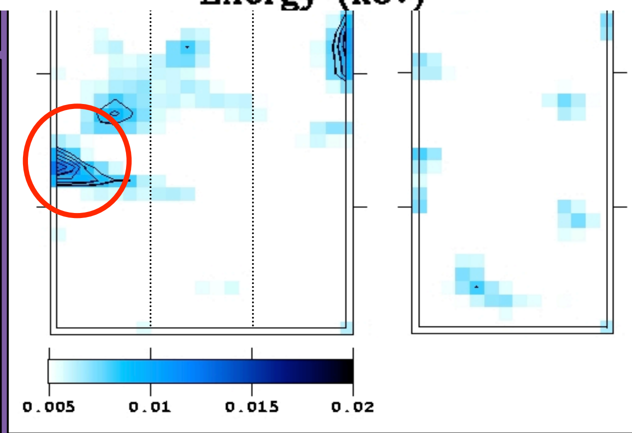
Th x





Jan 2005



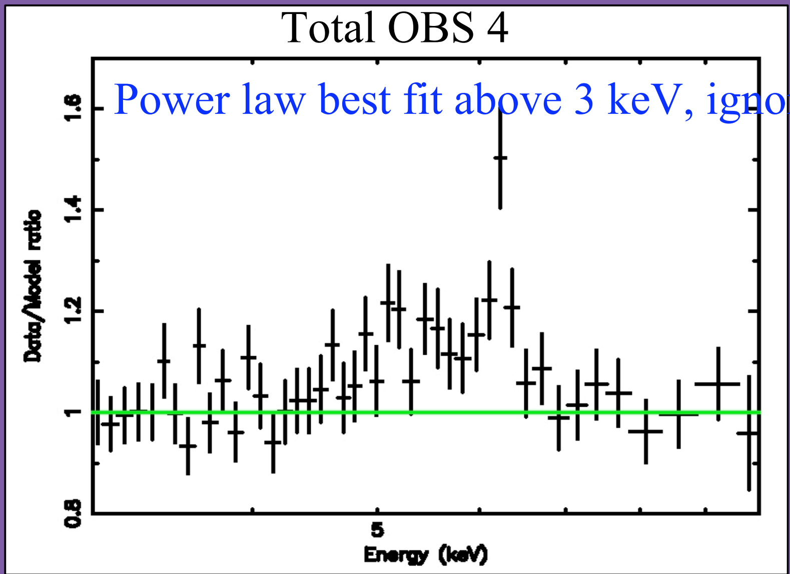


Line behavior in 005 looks similar to 001... BUT:

- Line flux variation by ~ 3-4
- Narrow and broad lines observed simultaneously in OBS 4
- The narrow component looks constant on month time scale

The Iron Line Complex

Relativistic profile



(Best fits with the DISKLINE model of XSPEC)

Obs	Γ	E_{FeK_α} keV	q (r^{-q})	r_{in} r_g	F_{FeK_α} 10^{-5}	χ^2/dof
1	$1.85^{+0.09}_{-0.08}$	$5.84^{+0.38}_{-0.15}$	$2.9^{+2.4}_{-2.2}$	<61.9	$3.6^{+1.6}_{-1.7}$	135/123
2	$1.91^{+0.07}_{-0.07}$	$5.62^{+0.11}_{-0.13}$	>3.4	$14.3^{+7.7}_{-8.1}$	$4.6^{+1.8}_{-1.7}$	131/142
3	$1.87^{+0.07}_{-0.07}$	$6.3^{+0.29}_{-0.17}$	>2.0	$58.7^{+21.9}_{-51.3}$	$2.1^{+2.0}_{-1.1}$	129/142
4 part 1	$1.44^{+0.03}_{-0.03}$	$5.63^{+0.05}_{-0.05}$	>5.1	$23.6^{+3.4}_{-7.8}$	$3.8^{+1.9}_{-1.2}$	124/154
4 part 2	$1.40^{+0.07}_{-0.05}$	$5.40^{+0.15}_{-0.11}$	>7.4	$10.6^{+1.9}_{-2.7}$	$4.6^{+1.4}_{-1.3}$	155/147
4 part 3	$1.27^{+0.06}_{-0.06}$	$5.45^{+0.14}_{-0.26}$	>5.1	<9.7	$5.5^{+1.5}_{-1.5}$	141/144
5	$1.64^{+0.06}_{-0.05}$	$5.56^{+0.17}_{-0.05}$	>4.9	<12.2	$3.8^{+1.3}_{-1.2}$	169/160

- Best fit inclination angle of 50º
- Good fits in the 3-10 keV band
- Peaked emissivity but q=4 OK!

(see e.g. Martocchia & Matt 2004)

Blurred reflection?

✓ Recent results suggest that relativistically-blurred ionized reflection could explain the soft excess in AGNs (e.g. Crummy et al. 2005)

✓ Application to Mkn 841: power law + Ross & Fabian reflection, convolved with a Laor profile (*kdblur* kernel)

✓ Good fits in 0.5-10 keV (θ~50°) except for OBS 5 (WA?)

✓ Low ionization but strong blurring effects (stronger than with DISKLINE)

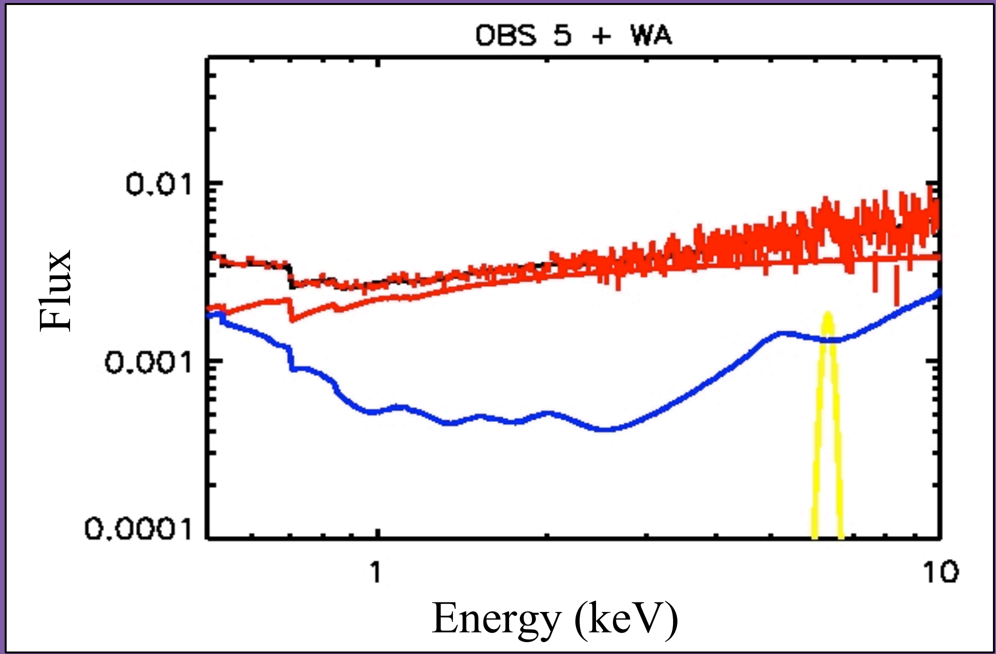
✓ Need of a narrow component

✓ q=4 OK for 2001 but not for 2005

Obs.	N_H 10^{20}	Γ	ξ	q	r_{in} r_g	E_{line} keV	σ_{line} keV	F_{line} erg.cm−2.s−1	χ^2/dof
1	<3.9	$2.21^{+0.10}_{-0.03}$	40^{+10}_{-6}	4	<10	$6.25^{+0.14}_{-0.06}$	<0.4	$1.4^{+1.8}_{-0.6}$	276/242
2	<3.6	$2.21^{+0.06}_{-0.02}$	46^{+6}_{-8}	4	$1.39^{+0.37}_{-0.16}$	$6.38^{+0.07}_{-0.06}$	110^{+80}_{-70}	$2.3^{+1.0}_{-0.8}$	253/261
3	<4.1	$2.16^{+0.10}_{-0.02}$	42^{+4}_{-5}	4	$5.4^{+0.6}_{-0.5}$				299/274
4 part 1	<5.3	$1.52^{+0.02}_{-0.02}$	135^{+75}_{-2}	4	$1.5^{+0.2}_{-0.3}$	$6.44^{+0.05}_{-0.04}$	<0.1	$1.3^{+0.5}_{-0.6}$	371/269
4 part 2	<3.4	$1.53^{+0.03}_{-0.02}$	130^{+3}_{-2}	4	$1.6^{+10.3}_{-0.3}$	$6.35^{+0.06}_{-0.07}$	<0.2	$1.1^{+0.5}_{-0.5}$	362/265
4 part 3	<3.6	$1.50^{+0.02}_{-0.02}$	130^{+10}_{-10}	4	<1.7	$6.50^{+0.03}_{-0.03}$	<0.1	$1.6^{+0.5}_{-0.5}$	381/265
5	<2.8	$1.61^{+0.01}_{-0.01}$	300^{+10}_{-35}	4	$1.6^{+0.2}_{-0.3}$	$6.50^{+0.06}_{-0.06}$	<0.2	$1.0^{+0.7}_{-0.4}$	477/279

Blurred reflection?

✓ Variability due to both blurred reflection and power law continuum



✓ Line variability

✓ WA features in OBS 5

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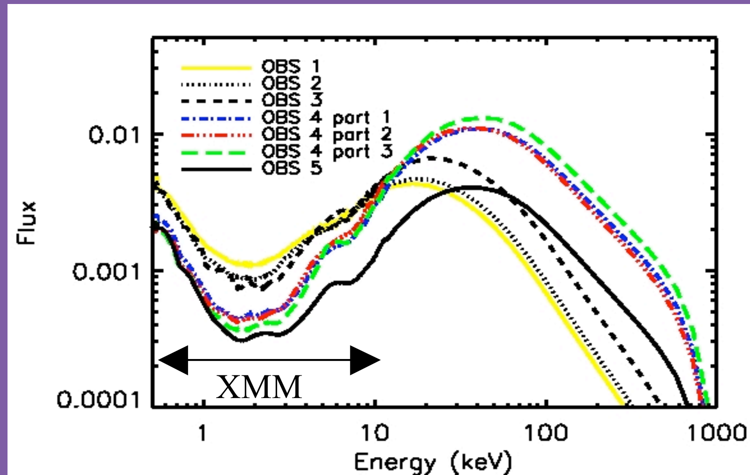
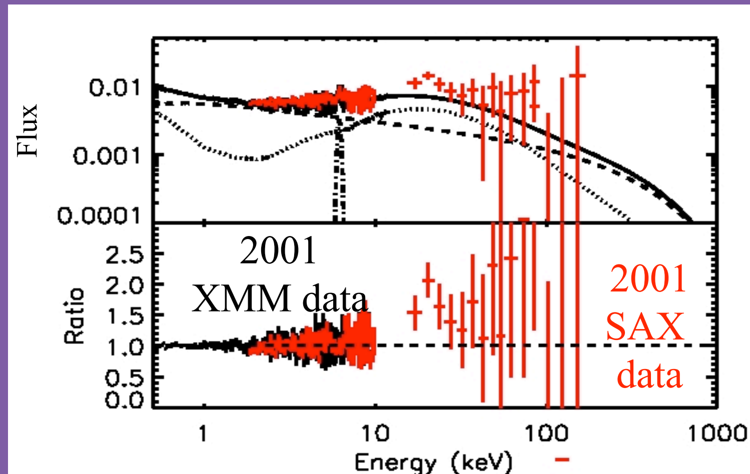
Blurred reflection?

✓ From the extrapolations of the model at high energy, we expect large reflection bumps



✓ Simultaneous (~100 ks) BeppoSAX data in 2001 show quite good agreements with the XMM best fit models obtained in 2001 ➔ encouraging results....



Conclusions

- Mkn 841 possesses a complex high energy spectrum with variable soft excess and underlying continuum on month time scale
- The iron line complex shows broad and narrow components, the broad component being variable on 10ks time scale.
- The narrow component origin is unclear and may be different between 2001 (rapidly variable) and 2005 (constant on month time scale)
- The different observations are well fitted by a relativistically-blurred reflection model with the need of a WA for OBS 5

Work in progress

- Impact of the Warm absorber on the other observations?
- MOS, RGS (but low statistics) and OM data....
- Comparison with old observations (ASCA, GINGA, SAX)

➔ 2×50 ks with Suzaku or future SIMBOL X observations will be crucial to constrain the different models

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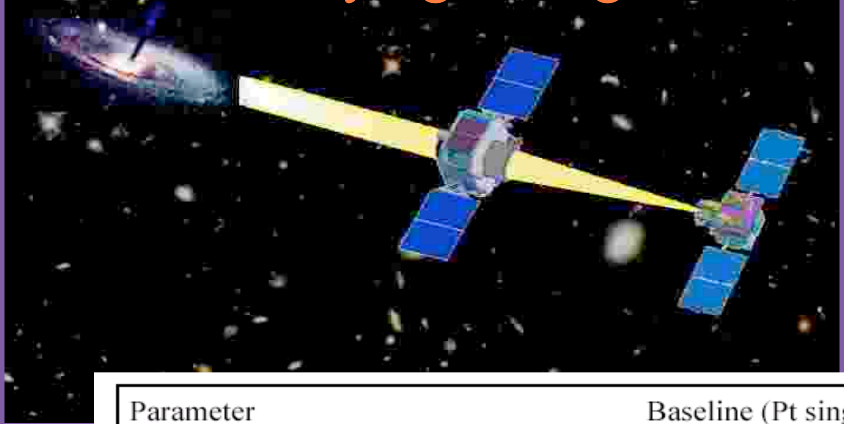
SIMBOL X

Formation flying configuration



- ✓ Consortium of european labs.
- ✓ in Phase A (CNES)
- ✓ Launch 2012

Parameter	Baseline (Pt single layer)	Changes with multi-layer
Energy range	< 1.0 keV – 70 keV	< 1.0 – 100 keV
Energy resolution	~ 130 eV @ 6 keV ~ 2 keV @ 60 keV	– 1 keV @ 60 keV
Angular resolution	< 30 arcsec HEW, goal 15 arcsec	–
Localisation	< 3 arcsec	–
Field of View (50 % vignetting)	6 arcmin	7 – 12 arcmin
Effective area	550 cm^2 below 35 keV 2 cm^2 at 70 keV	550 – 1100 cm^2 below 25 keV 200 cm^2 at 70 keV
Sensitivity (3 σ, 1 Ms, dE/E = E/2)	10^{-8} ph/cm^2/s/keV for E < 40 keV	10^{-8} ph/cm^2/s/keV up to 80 keV

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