Lead-up from ROSAT to XMM-Newton

Joachim Trümper

XMM-Newton 20th anniversary at ESAC Madrid

December 2019

XMM-NEWTON 20th ANNIVERSARY

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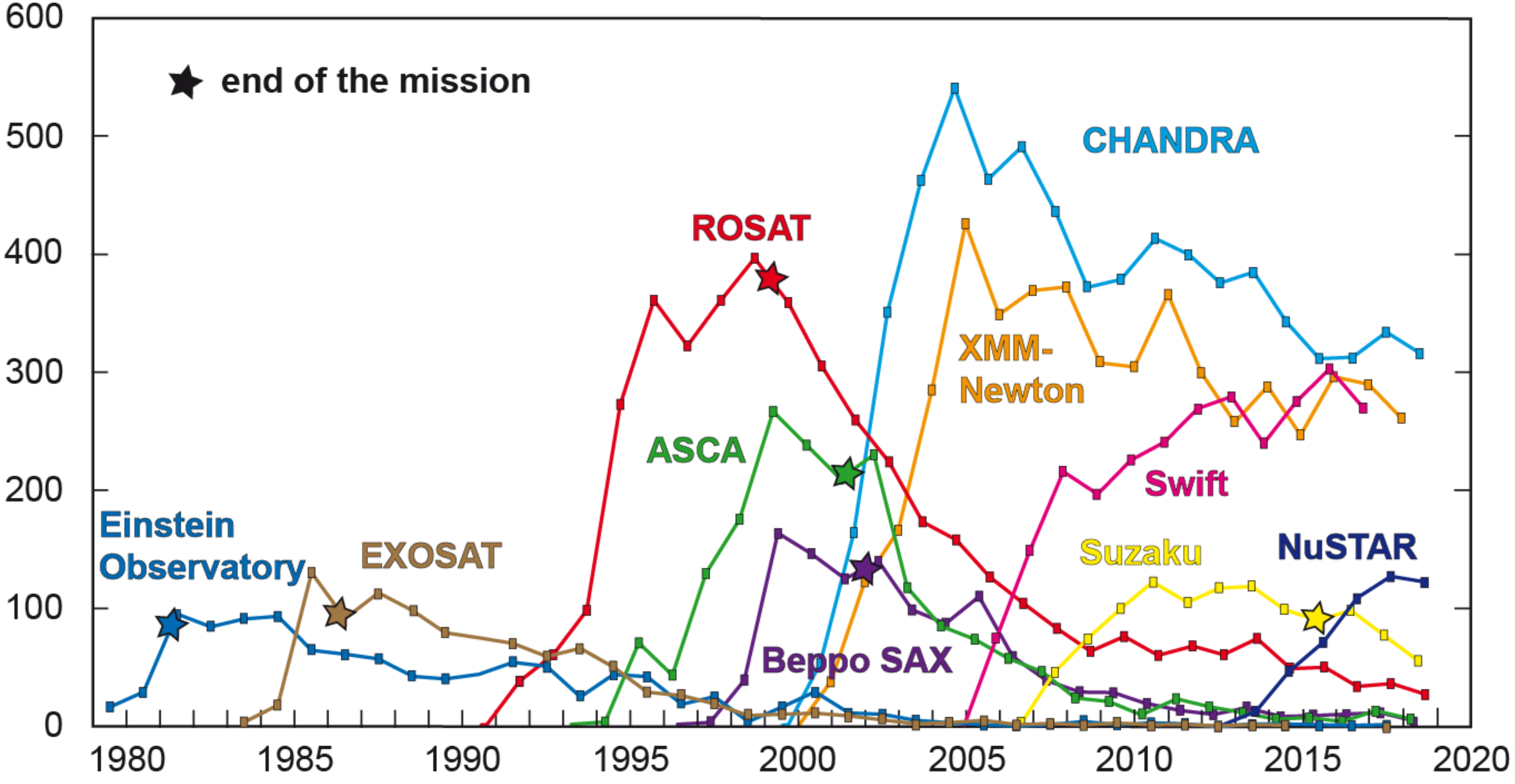
The ROSAT sky over Munich in December

1990/91 ROSAT performed the first all sky survey with an imaging X-ray telescope in half a year - boosting the number sources from 841 (HEAO-1) to about 100.000. In the following 8 years it performed ten thousands of pointed observations for a wide astrophysical community

Number of refereed publications of X-ray telescope missions (ADS)



Note that the numbers for some of the missions include publications from collimated instruments, e.g. in the case of EXOSAT from the ME-experiment

In the following I will discuss five scientific topics illustrating the synergy between ROSATand XMM-Newton

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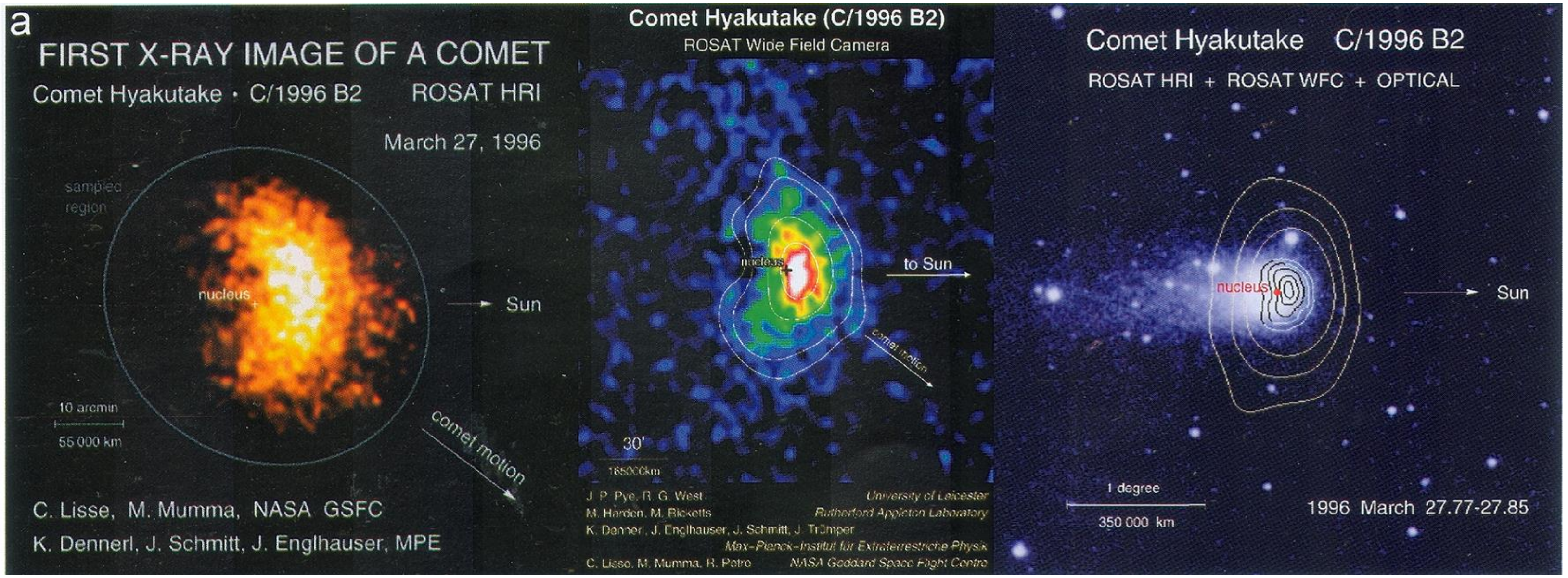
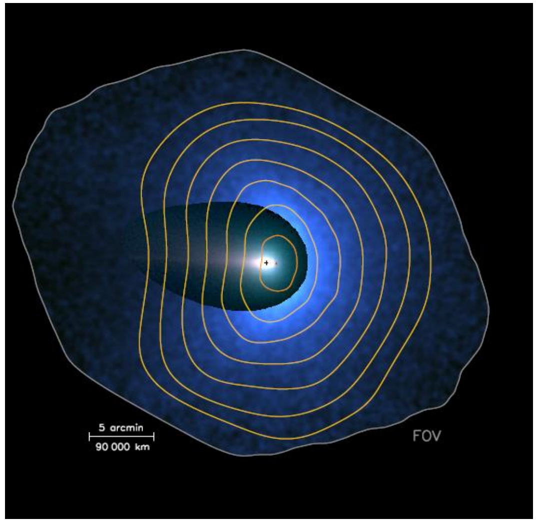
1. ROSAT 1996: A great surprise: Comets emit X-Rays!



Electron exchange between solar wind ions neutral gas atoms of the coma (Cravens, 1997).

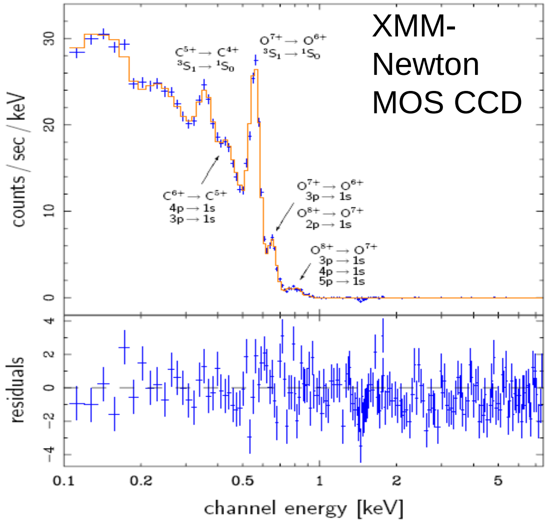
Until now more than 30 comets have been detected by ROSAT, EUVE, XMM-Newton & Chandra)



Comet C/2000 WM1 observed with XMM-Newton

(K. Dennerl 2000)

The first XMM-Newton spectrum of a comet
(K. Dennerl 2003)



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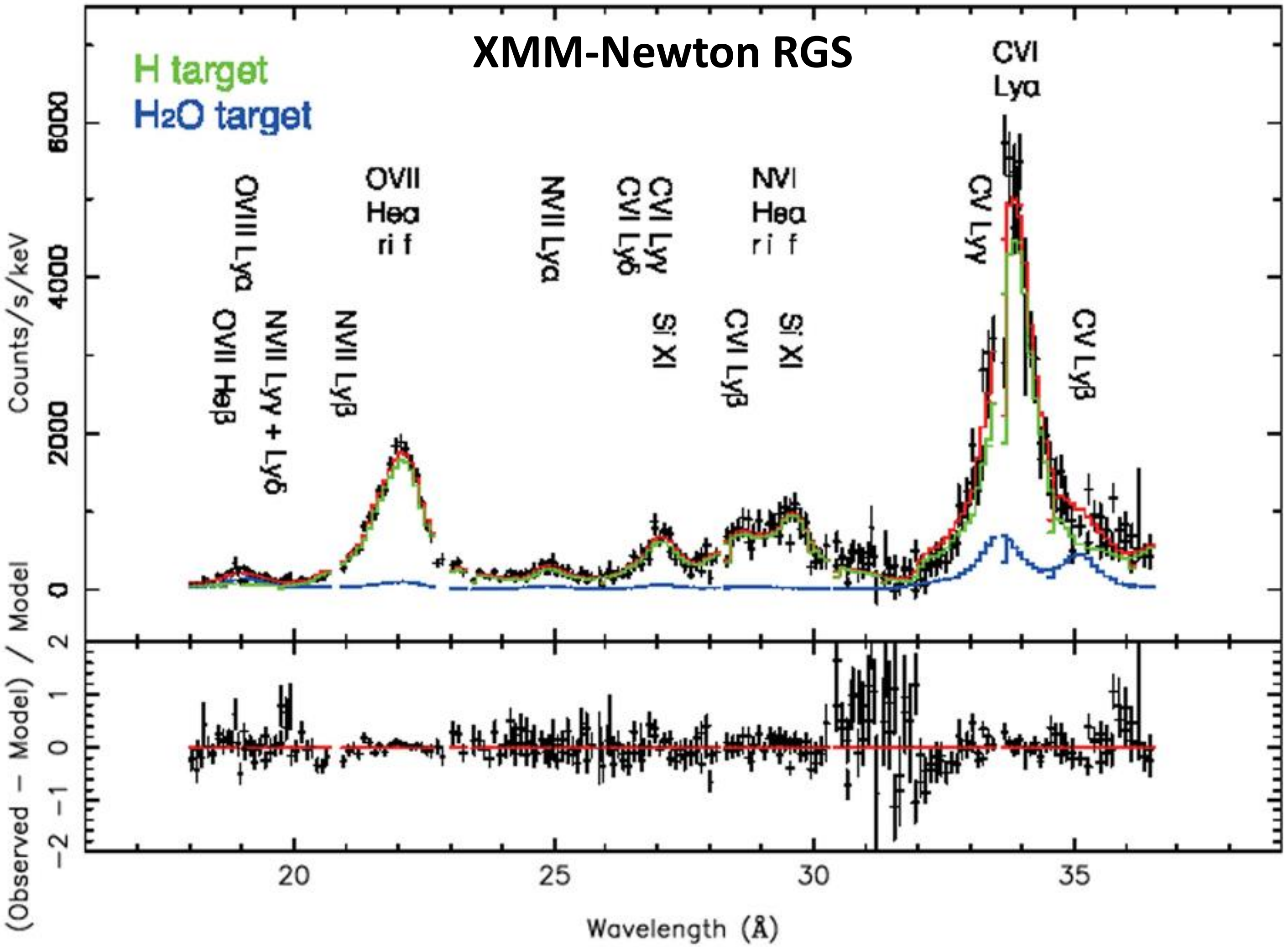
Line Ratios for Solar Wind Charge Exchange with Comets

P.D. Mullen, R.S. Cumbee, D. Lyons et al. 2017

Comet C/2000 WM1 (linear)



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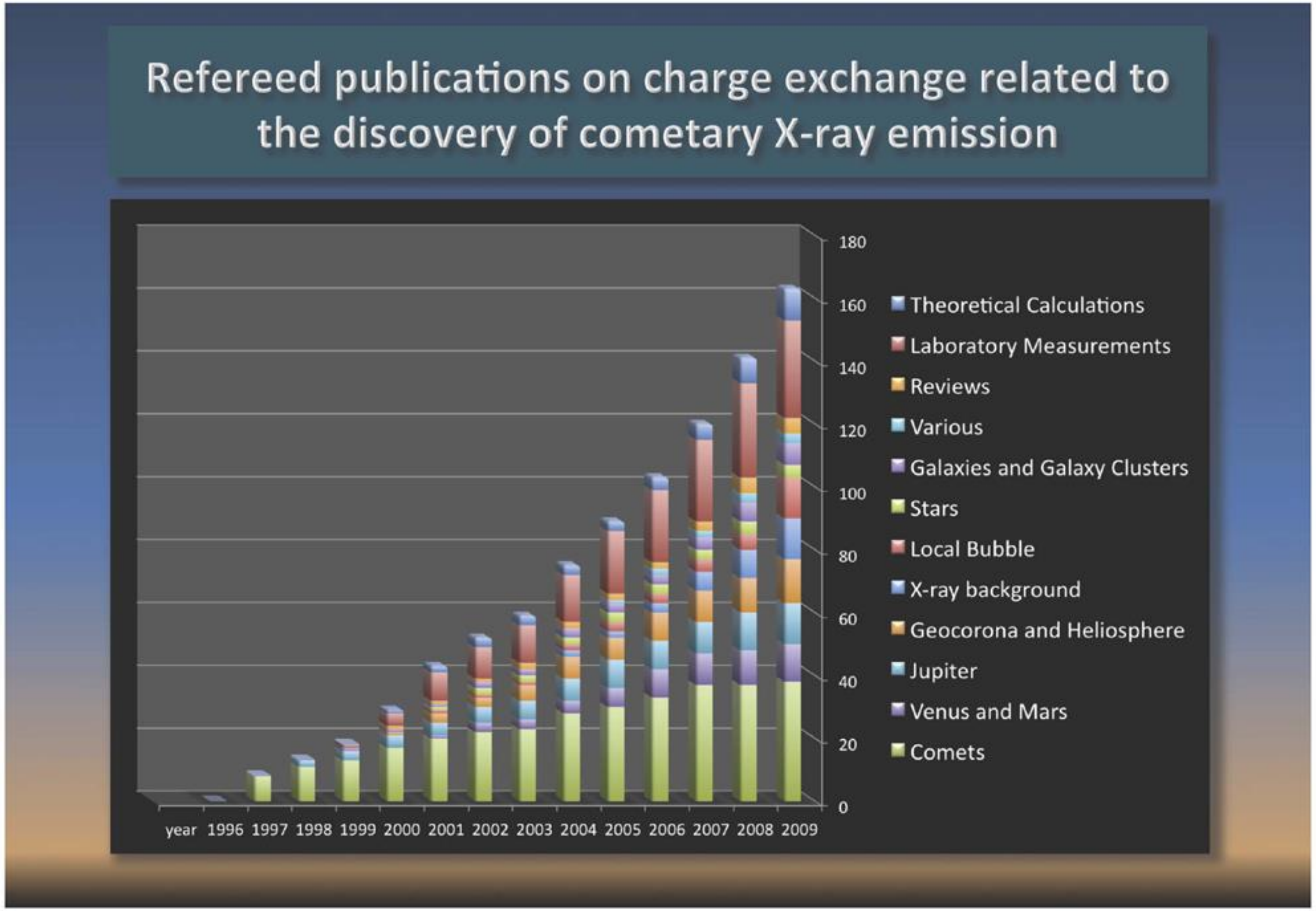
Charge exchange happens at any interface between hot plasma and cool gas

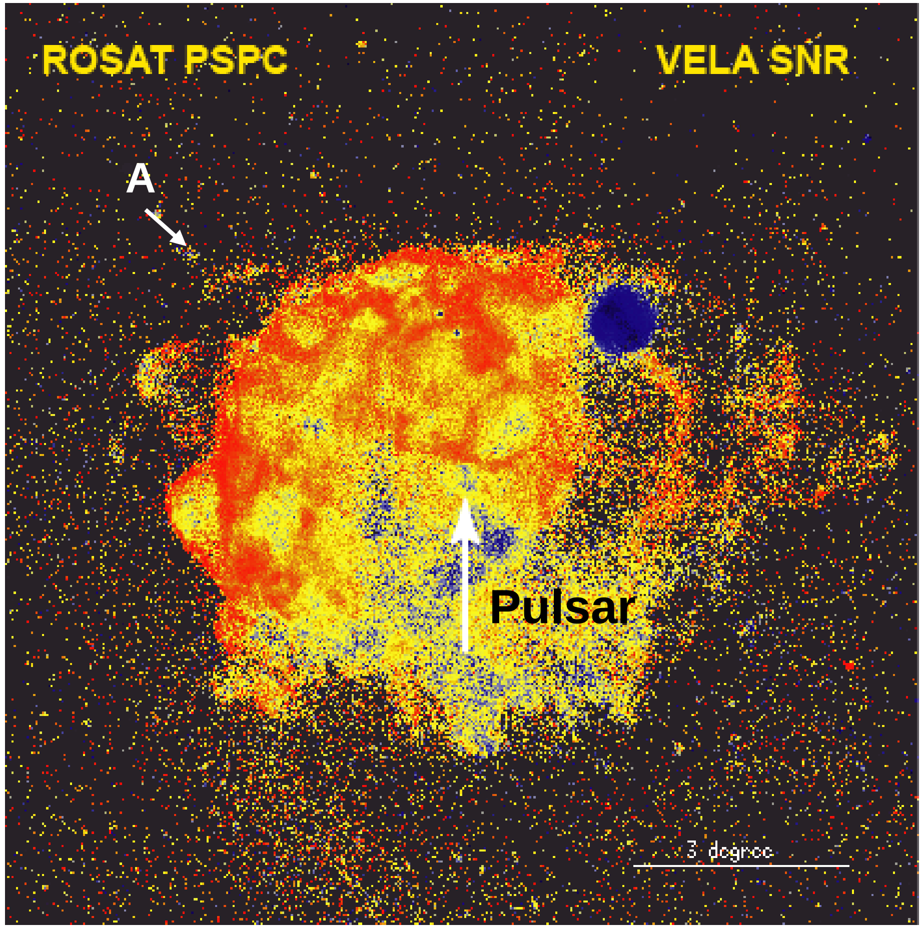


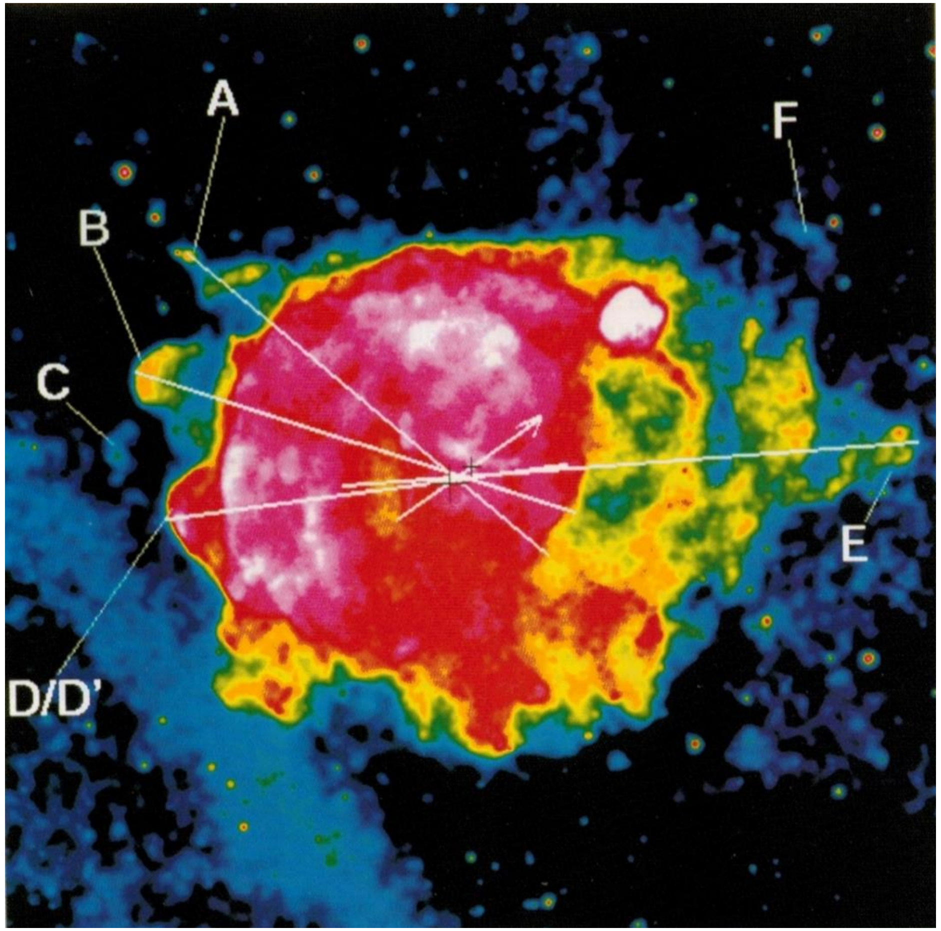
K. Dennerl 2010 : Total 160 papers

December 4, 2019 : 390 papers

2. ROSAT Discovery of Shrapnels in the Vela Supernova Remnant

B. Aschenbach, R. Egger & J. Trümper 1995

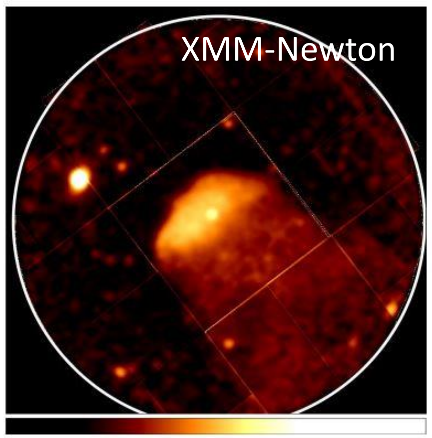




The shrapnells show Mach cones indicating supersonic velocities (Mach numbers 2.4 … 4) in the surrounding hot ISM (T ~ 10^6 K). Obviously they represent compact fragments which are moving with higher velocity than the shock front

X-ray Spectroscopy of Vela Shrapnel A with XMM-Newton

S. Katsuda & H. Tsunemi 2006



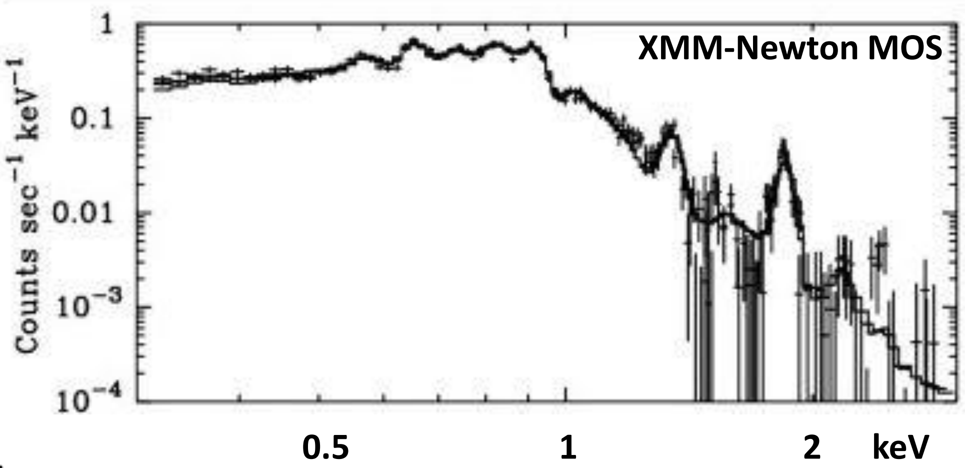


Table 1. Spectral-fit parameters.

Parameter	Head region in figure 1	Tail region in figure 1
$N_{\rm H}[10^{20}\ {\rm cm}^{-2}]$	$3.2^{+1.4}_{-0.4}$	$1.4^{+0.02}_{-0.01}$
$kT_{\rm e}$[keV]	0.52±0.01	0.37±0.01
C	2.5±0.2	$2.6^{+0.5}_{-0.6}$
N	$0.55^{+0.06}_{-0.08}$	$0.5^{+0.2}_{-0.1}$
O	0.34±0.01	$0.4^{+0.01}_{-0.02}$
Ne	1.07±0.04	$1.28^{+0.09}_{-0.07}$
Mg	0.87±0.08	$0.96^{+0.4}_{-0.3}$
Si	3.3±0.3	$3.7^{+0.7}_{-1.0}$
Fe	0.96±0.03	$1.10^{+0.08}_{-0.07}$
$\log(\tau)$ [s cm^{-3}]	10.75±0.02	$10.97^{+0.04}_{-0.03}$
EM[cm^{-5}][a]....	$(2.35^{+0.1}_{-0.03})\times10^{17}$	$(0.53^{+0.04}_{-0.02})\times10^{17}$
χ^2/d.o.f.	705/465	698/544

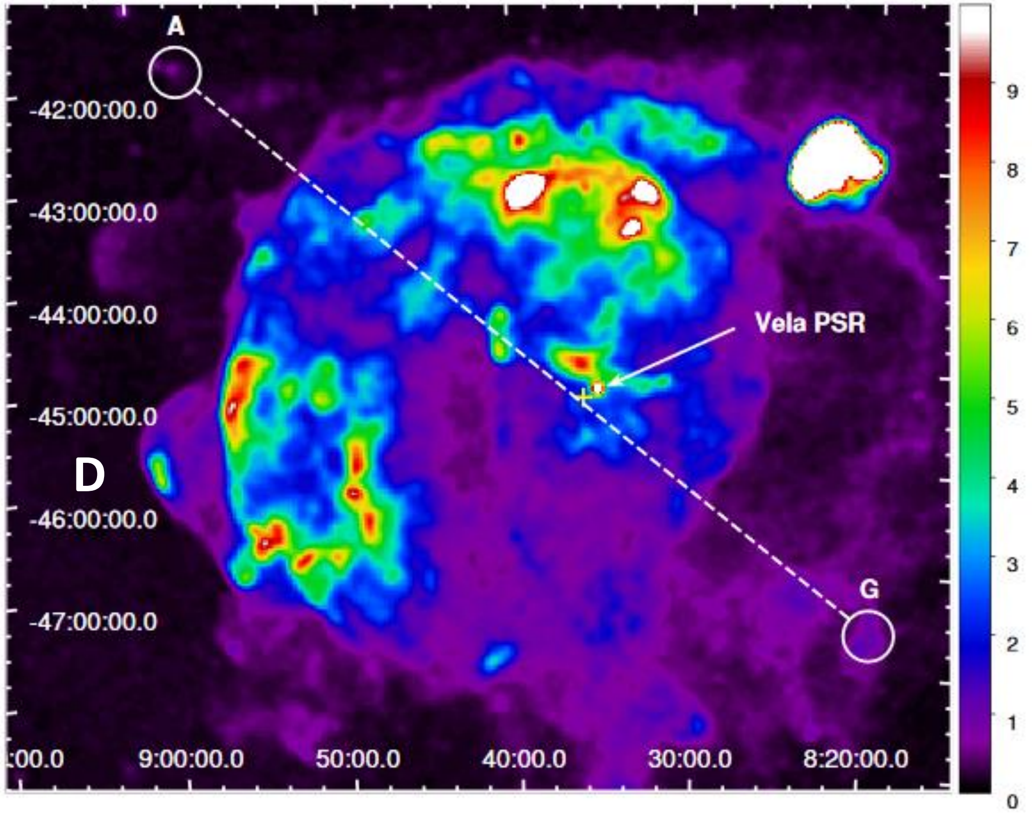
Note. — Other elements are fixed to those of solar values. The values of abundances are multiples of solar value. The errors are in the range $\Delta\chi^2 < 2.7$ on one parameter.

Silicon 3.3 x solar →

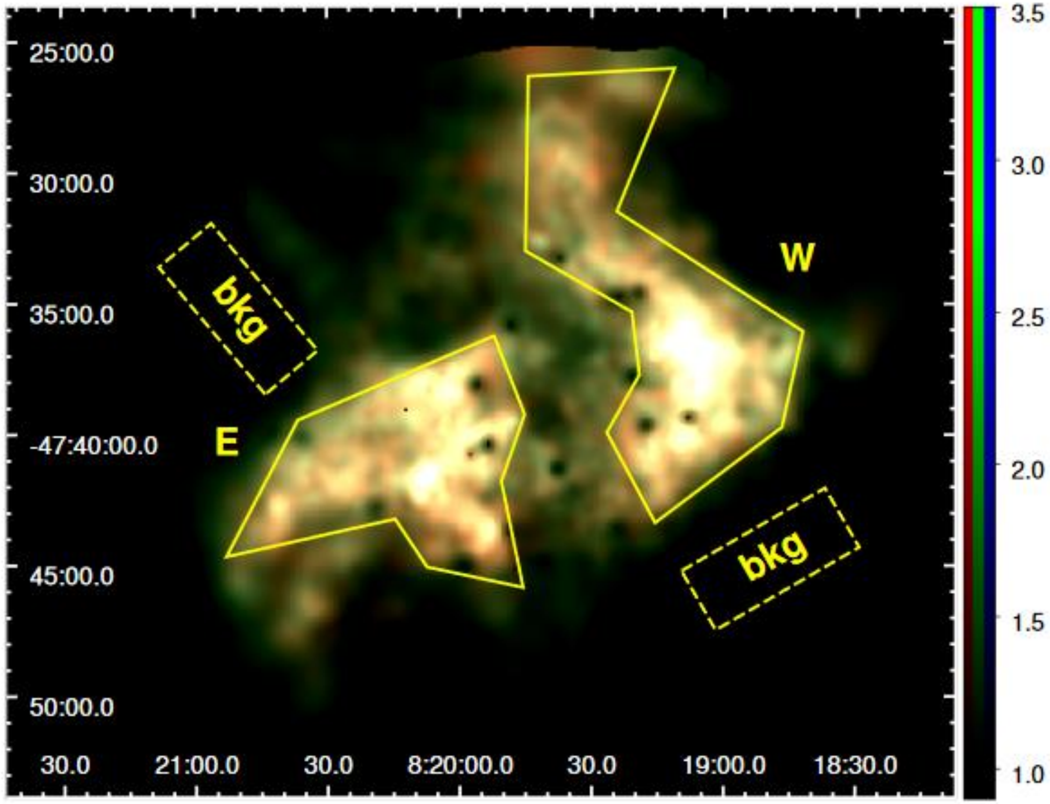
← **Silicon is overabundant in this and other shrapnels (e.g. G) indicating that they originate in deeper layers of the exploding star**

Mere accident? Indication of a Si-reach bilateral jet of ejecta in the Vela SNR observed with XMM-Newton (Garcia et al 2017)

ROSAT map of the Vela SNR



XMM-Newton image of shrapnel G



Summary of over-abundances in shrapnels of the Vela SNR:

A: Carbon, Silicon

G: Neon, Magnesium, Silicon

D: Oxygen, Neon, Magnesium,

That tells us about the depths the shrapnels are coming from

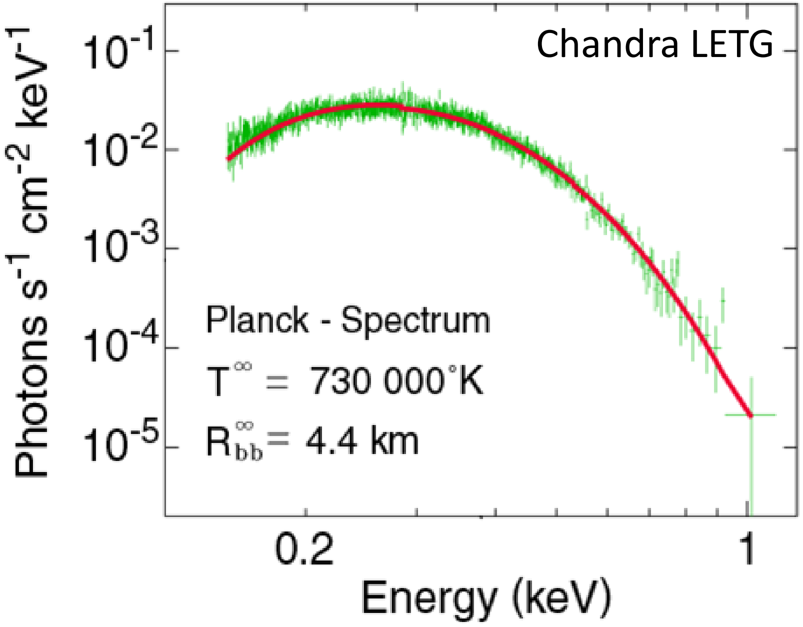
J. Trümper, Madrid 2019

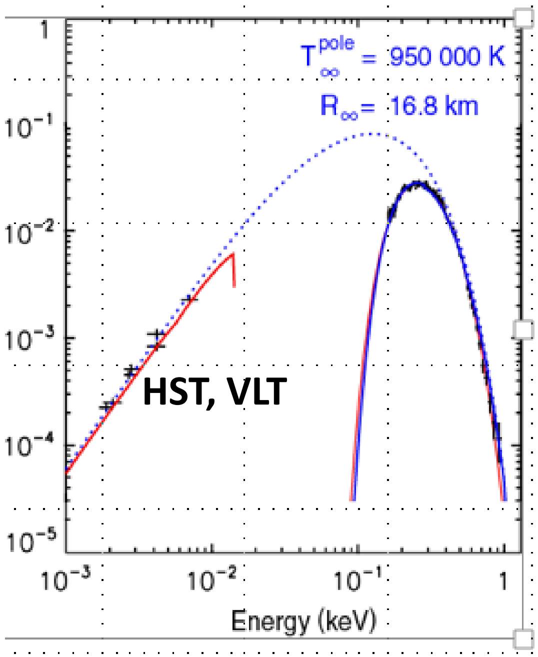
3. The thermally emitting isolated neutron stars (XTINS alias Magnificent Seven) discovered by ROSAT

Compilation by F. Haberl 2018

Object	kT_∞ (eV)	P (s)	p.f.[a] (%)	$\dot{P}$ ($\mathrm{s\,s^{-1}}$)	B_{dip} (10^{13} G)	τ (Myr)	t_{kin} (Myr)	m_B[b] (mag)	d[c] (pc)
RX J0420.0−5022	48	3.45	17	-2.8×10^{-14}	1.0	1.95	?	26.6	$\sim$345
RX J0720.4−3125	84–94	16.78	8–15	-1.40×10^{-13}	5.0	1.91	0.85	26.6	286^{+27}_{-23}
RX J0806.4−4123	95	11.37	6	-5.50×10^{-14}	2.5	3.24	?	>24	$\sim$250
RX J1308.6+2127	100	10.31	18	-1.12×10^{-13}	3.5	1.45	0.55/0.90/1.38	28.4	?
RX J1605.3+3249	100	?	<2	?	?	?	0.45	27.2	$\sim$390
RX J1856.5−3754	61	7.06	1	-2.97×10^{-14}	1.5	3.80	0.42–0.46	25.2	120^{+11}_{-15}
RX J2143.0+0654	104	9.43	4	-4.00×10^{-14}	1.9	3.72	?	>26	$\sim$430

For the brightest source RX J856-3754 the distance is known well by HST measurements





Trümper, Burwitz, Haberl, Zavlin 2004:

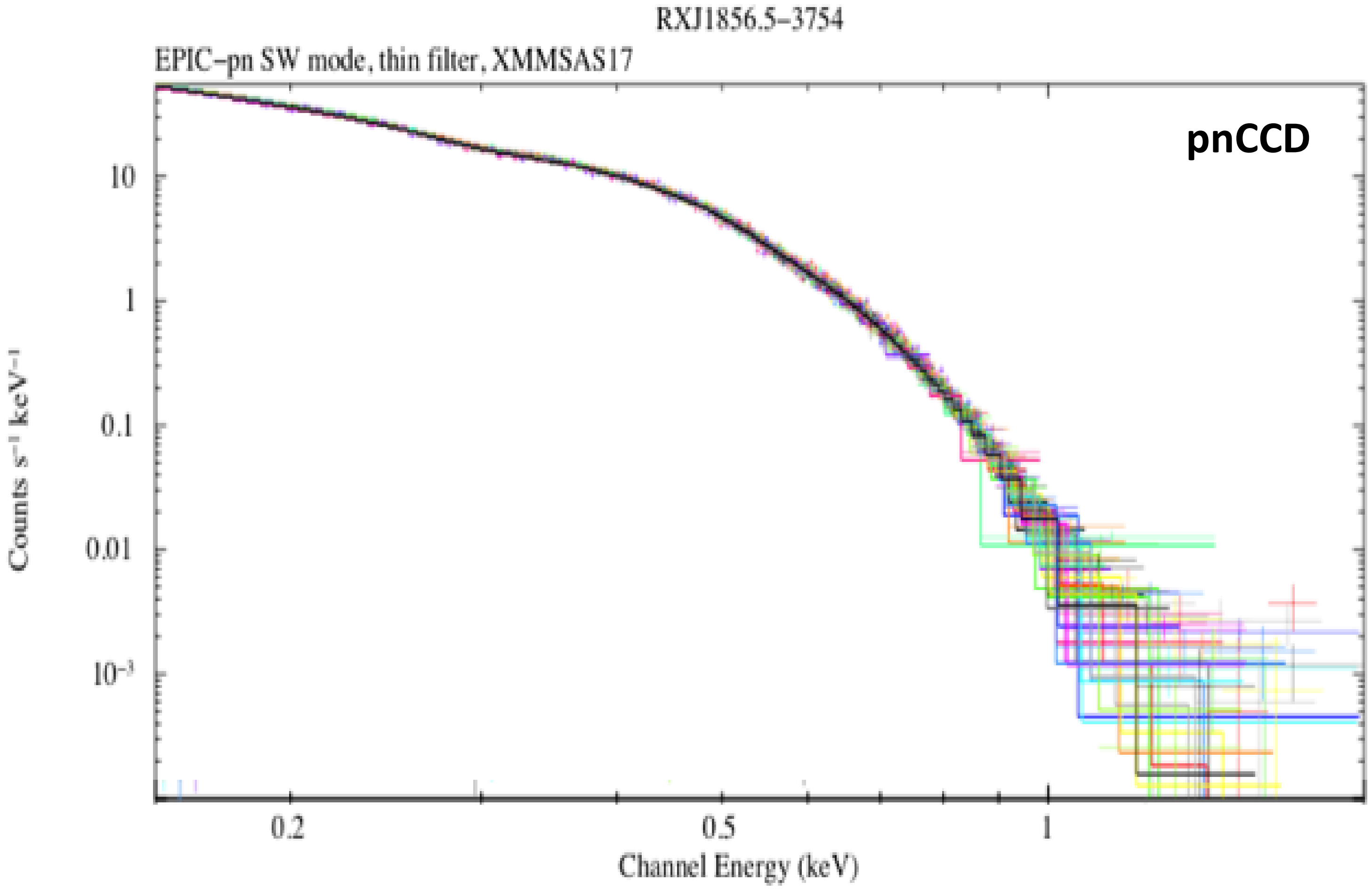
The neutron star has a small hot polar cap seen in X-rays and a radius $R_{infinity}$ = 16.8 km, corresponding to R ~ 13 km for M = 1.4 M_0

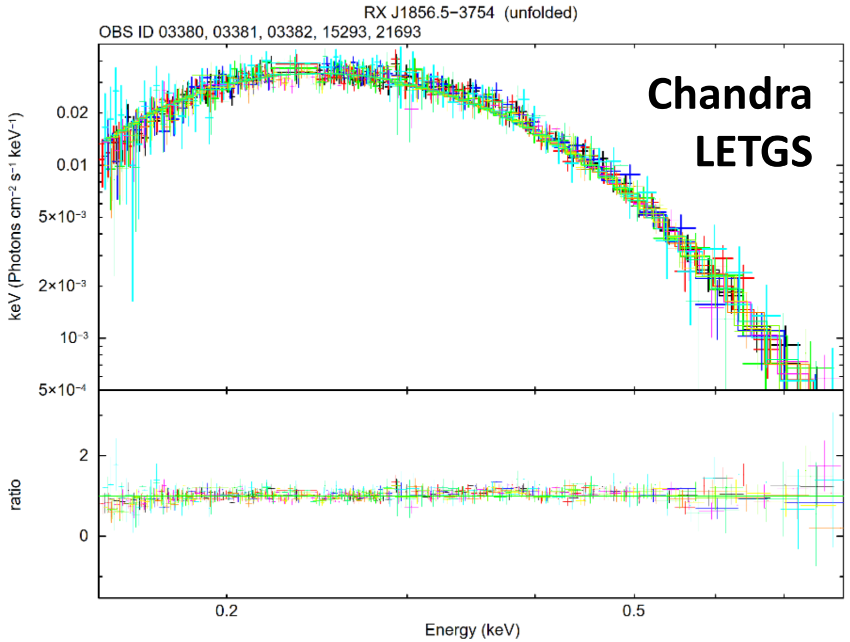
This result requires a stiff equation of state of the high density nuclear matter

RX J1856-3754 is one of the calibration sources of XMM-Newton and Chandra

The diagram shows the stability of the pnCCD over a period of 17 years

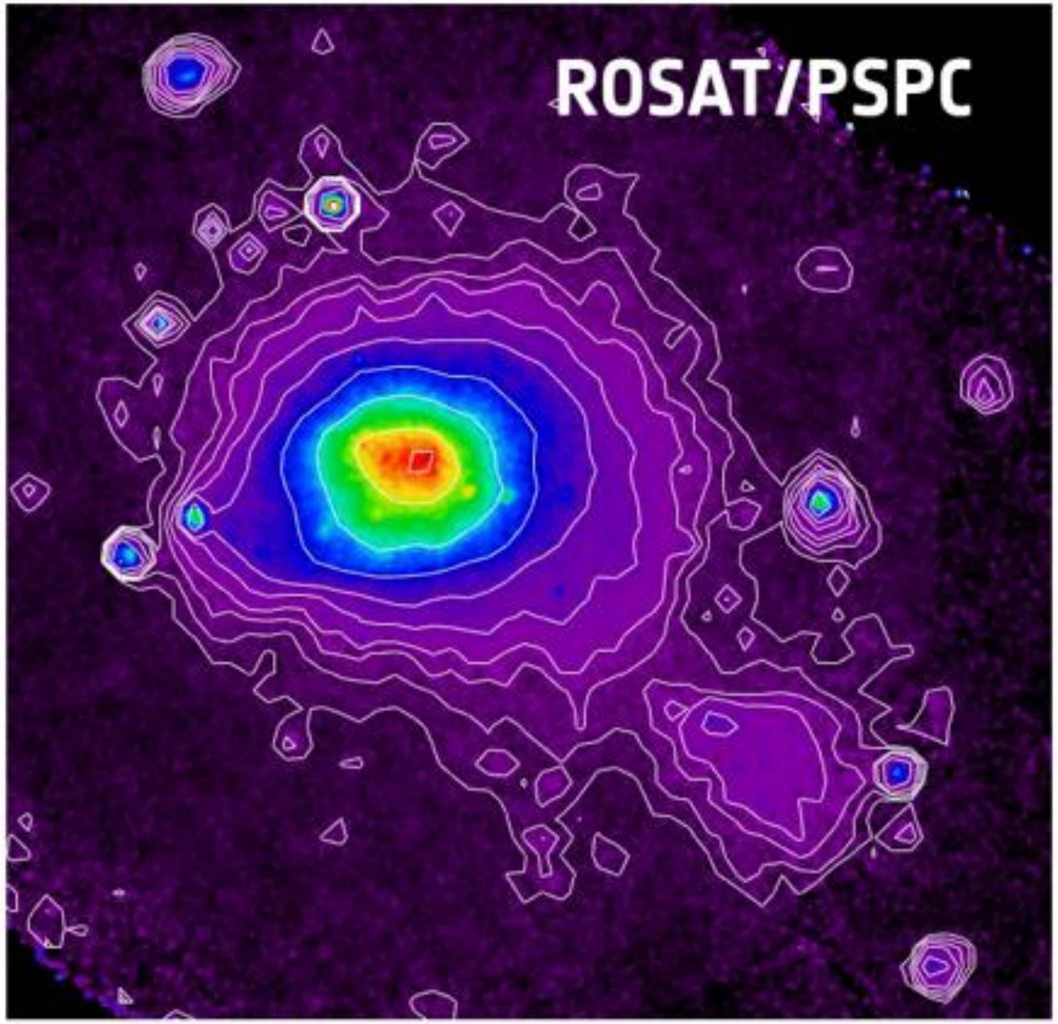
K. Dennerl, V. Burwitz, private communication 2019





4. X-ray Archeology of the Coma Cluster

White, Briel & Henry 1993

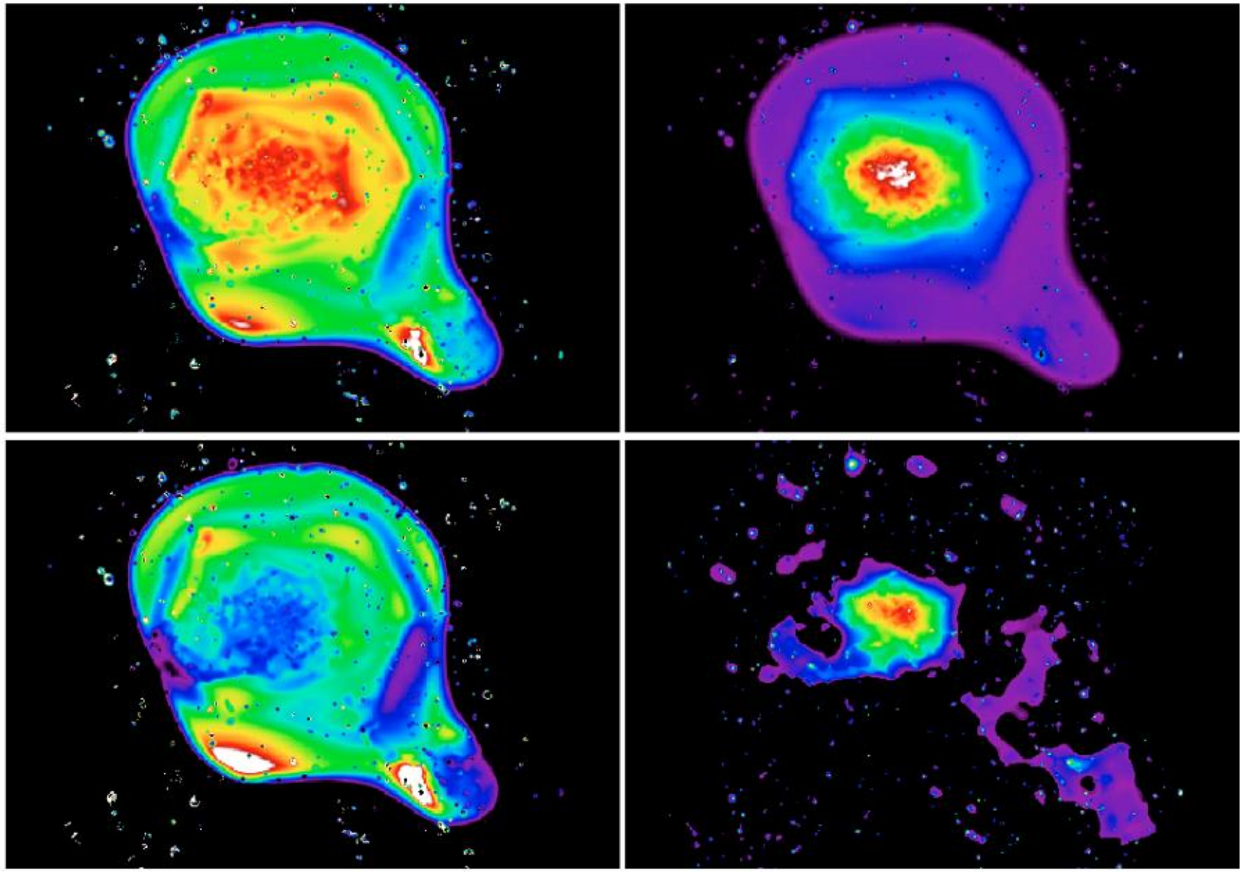


A smaller cluster falling into the Coma cluster
Intensity fluctuations at the center are due to previous mergers

XMM-Newton: Turbulence in the Coma galaxy cluster resulting from previous mergers

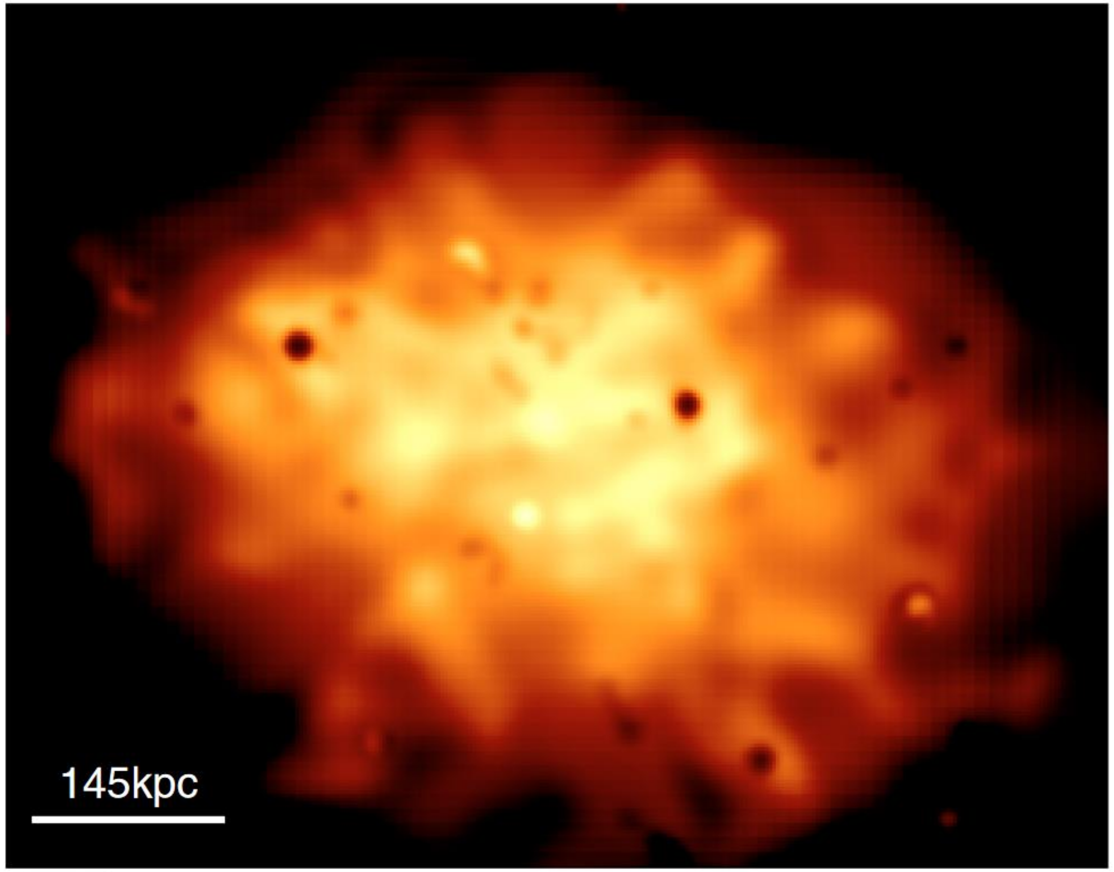
P. Schuecker, A. Finoguenov, F. Miniati, H. Böhringer & U.Briel 2004

Temperature | Pressure



Entropy | Residual substructure

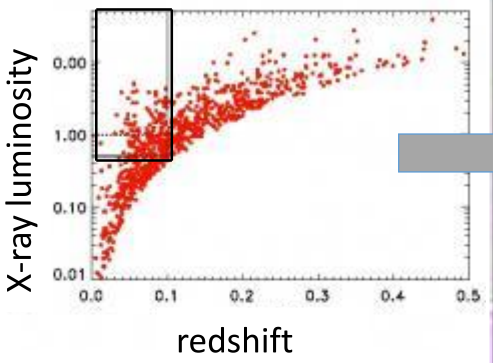
Pressure map of the inner region



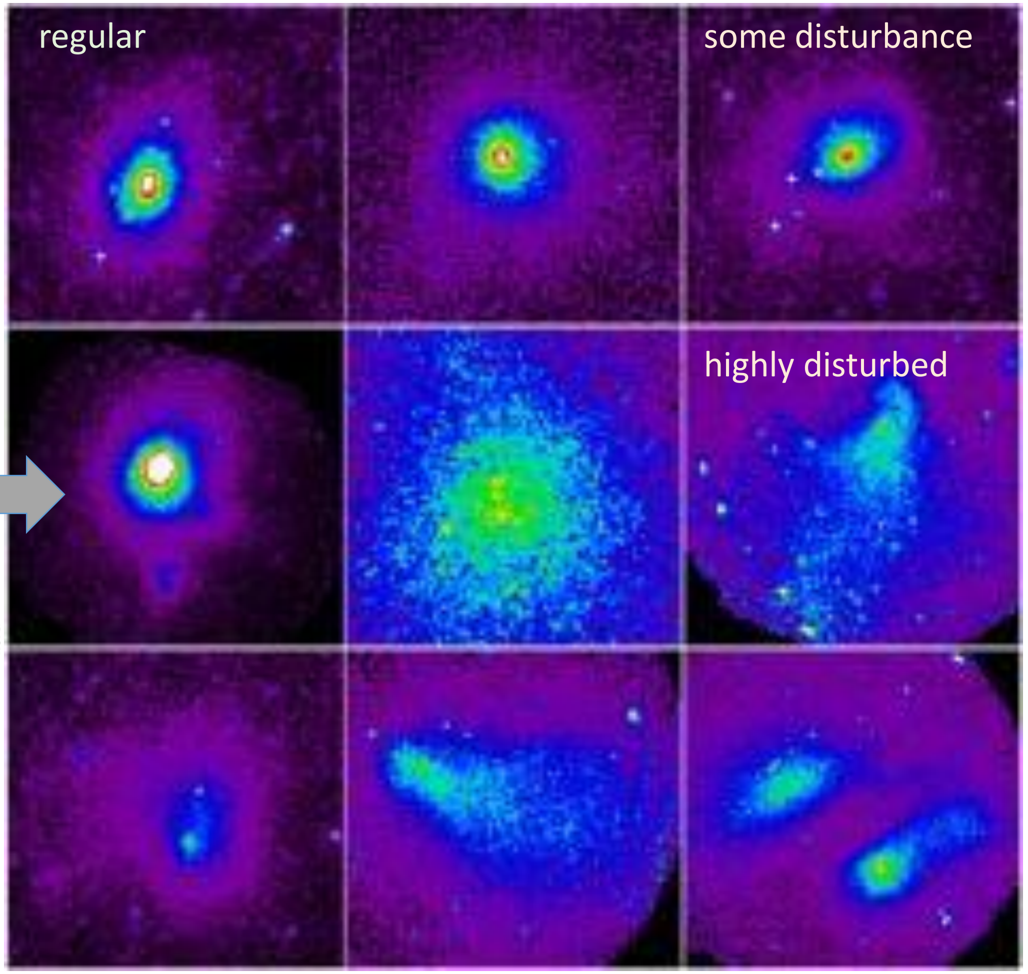
XMM-Newton Study of the Morphology Distribution of a Representative ROSAT Cluster Sample G.

G. Chon & H. Böhringer 2017

Selection of a representative, volume-limited sample of 93 systems from the clusters found in the ROSAT Survey ($z < 0.1$)



Detailed, deep study of a cluster sample with XMM-Newton and structural analysis



Statistics of Morphologies

volume –lim. sample:
30% regular
60% disturbed 10% intermed.

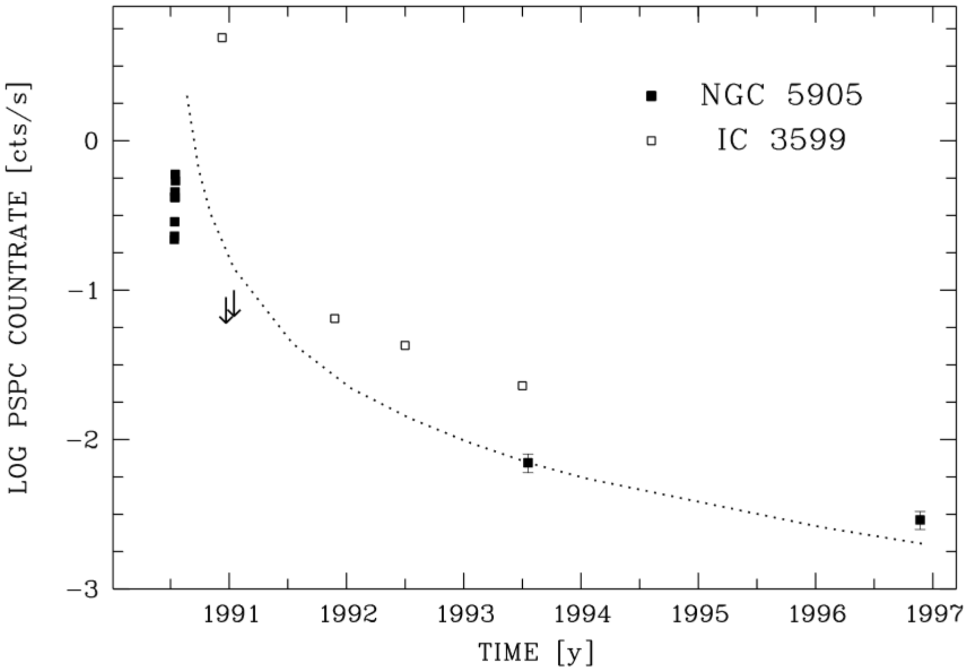
Compared to flux-limited (traditional):
41% regular
45% disturbed
(rest intermed.)

Cool-Core-Statistic
vol.-lim.: 39%
flux-lim.: 53 -60%
Planck: 29%

ROSAT and Planck are not so different if compared using similar selection !

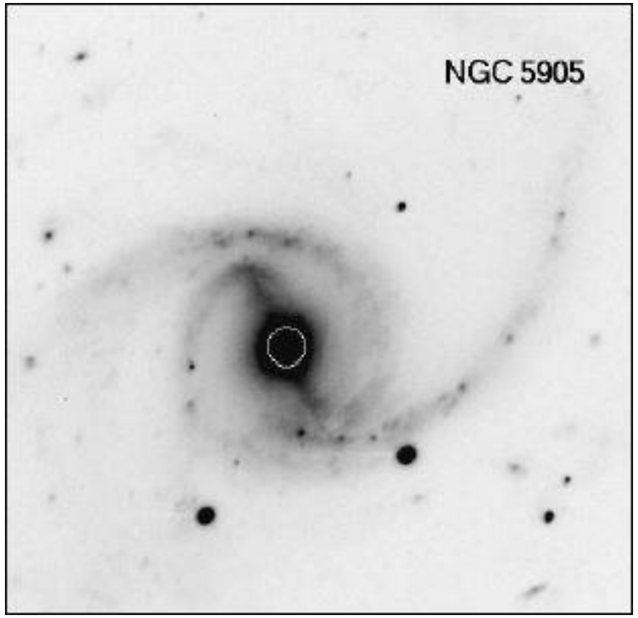
5. ROSAT discovery of tidal disruptions by massive black holes

S. Komossa & N. Bade 1999



The X-ray light curves

N. Bade, S. Komossa, M. Dahlem 1996



TDE host galaxy NGC 5905;
a very nearby giant barred
spiral galaxy.
Circle: ROSAT HRI X-ray error box.

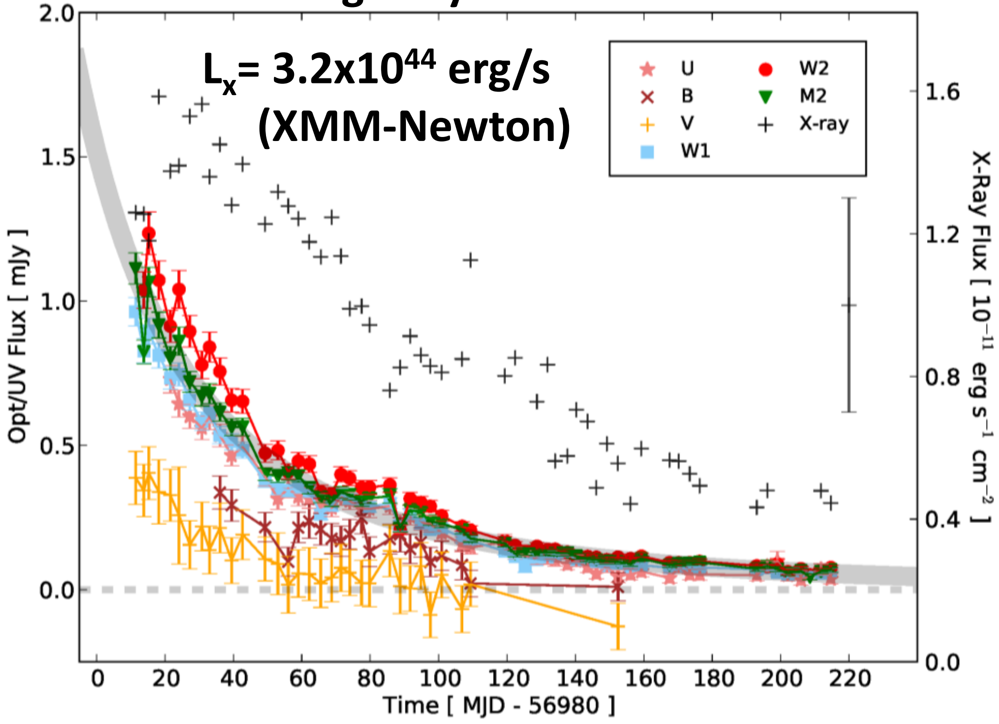
M.J. Rees 1988, 1989

Theoretical prediction

Flows of X-ray gas reveal the disruption of a star by a massive black hole

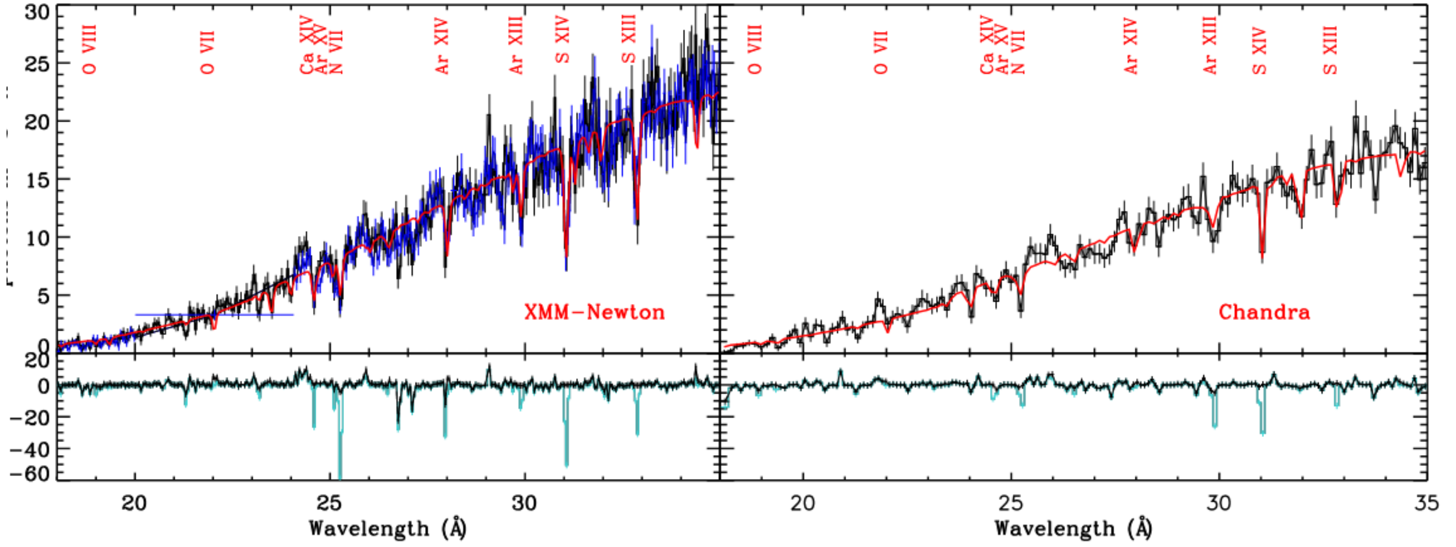
J.M. Miller, J.S. Kaastra, M.C. Miller and 18 co-authors

In the galaxy PGC 043234



XMM RGS

Chandra



PGC 043234 was not detected in the ROSAT All Sky Survey:
$L_x < 4.8 \times 10^{40}$ erg s^{-1}

The gray band depicts the $t^{-5/3}$ flux decay predicted by fundamental theory
M.J. Rees 1988

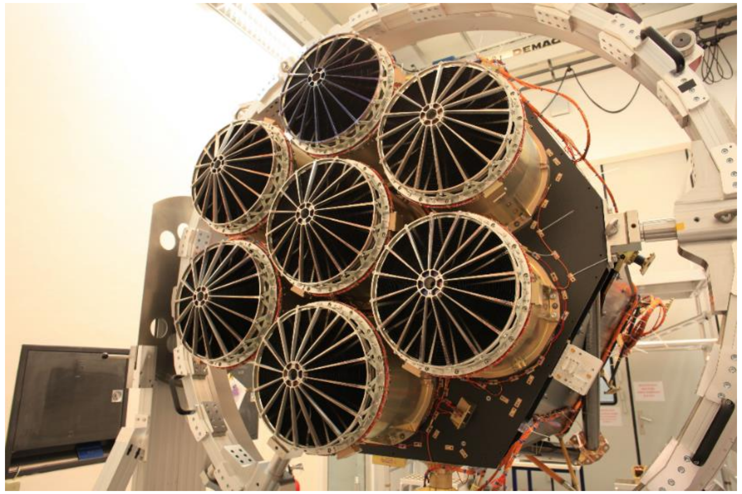
The best-fit photoionized absorption model for the outflowing gas detected in each spectrum is shown in red

Modest outflow speeds of few × 100 km s^{-1} are observed

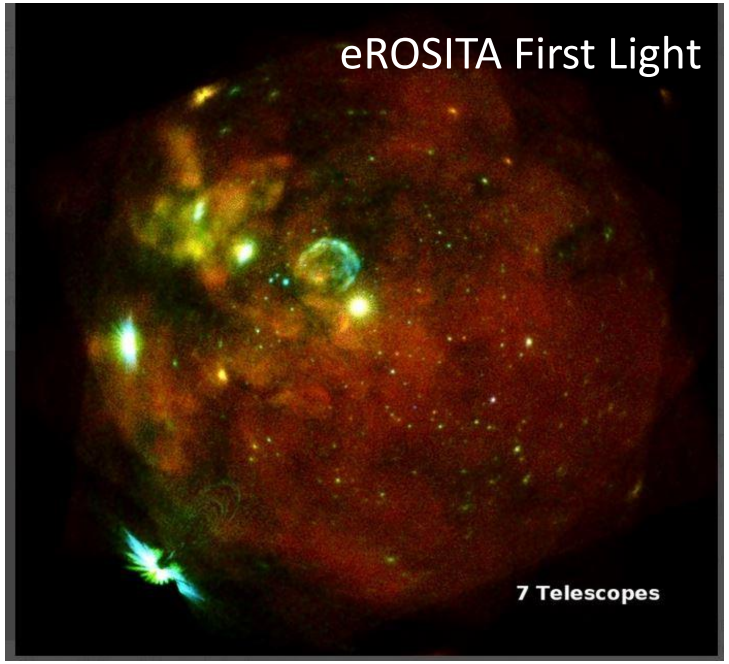
J. Trümper, Madrid 2019

The Future: Lead-up to the third decade of XMM-Newton and to ATHENA

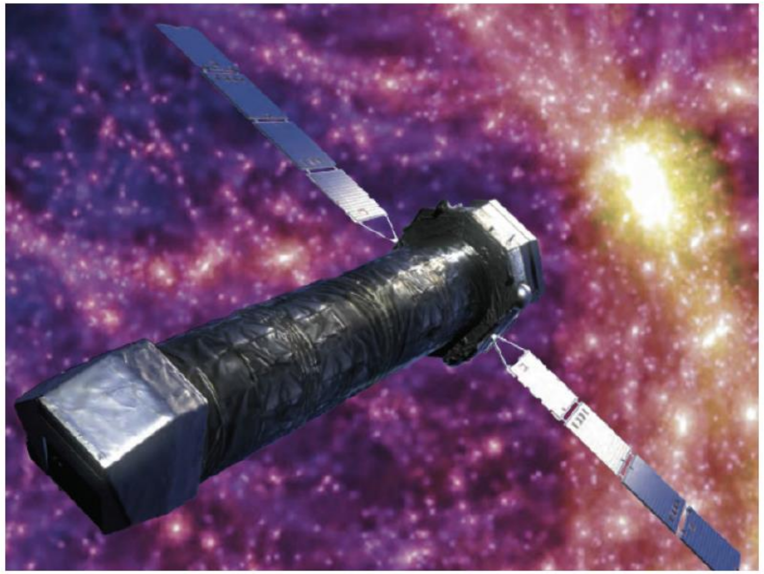
eROSITA on SRG:



Launched in July 2019 on the Russian SRG
- 4 years all-sky survey, sensitivity ~ 20 x ROSAT all sky survey
> 3 years pointed observations



Athena



eROSITA with will discover many new sources, which can be studied with the advanced instruments of Athena
- cryogenic X-ray spectrometer X-IFU and
- wide field imager WFI

THANK YOU !