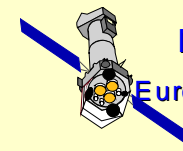


Open EPIC-CAL action items

Marcus G. F. Kirsch

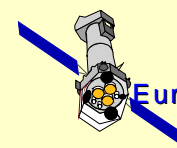
ESAC, 03.10.2005



Selected actions

Meeting/Action	Status	Description	Actionee	Open	Due	Closed
EPIC Ca 23b -0012.4	Open	EPIC-CAL-12-4: JB to provide VILSPA with a tool to check MOS data for '3 missing raws' feature	Jean Ballet	2003-09-25		closed
EPIC Ca 23b -0014.1	Open	EPIC-CAL-14-1: Additional time column with other 0 point for ODF (rd, mk, jkl)	Marcus Kirsch	2005-02-23		open
EPIC Ca 23b -0014.2	Open	EPIC-CAL-14-2: MK to update frame times according to analysis presented in 1.1	Marcus Kirsch	2005-02-23		open
EPIC Ca 23b -0014.3	Open	EPIC-CAL-14-3: MK to implement time jump in a Q-check type procedure in the long term.	Marcus Kirsch	2005-02-23		open
EPIC Ca 23b -0014.4	Open	EPIC-CAL-14-4: KD to provide new gain values for refinement of the colour dep. pn gain correction	Konrad Dennerl	2005-02-23		closed
EPIC Ca 23b -0014.5	Open	EPIC-CAL-14-5: MS to implement KDs values into CCF	Martin Stuhlinger	2005-02-23		open
EPIC Ca 23b -0014.6	Open	EPIC-CAL-14-6: MK to put warning on energy accuracy in for doubles with input from KD.	Marcus Kirsch	2005-02-23		closed
EPIC Ca 23b -0014.7	Open	EPIC-CAL-14-7: MK open new NRCO for pn LW CTI determination with N132D, request low BG time	Marcus Kirsch	2005-02-23		closed
EPIC Ca 23b -0014.8	Open	EPIC-CAL-14-8: SS to provide RS with newest RMF parameters to be implemented in CCF (SS, RS)	Steve Sembay	2005-02-23		closed
EPIC Ca 23b -0014.9	Open	EPIC-CAL-14-9: AA to provide diagnostics proposal	Marcus Kirsch	2005-02-23		closed?

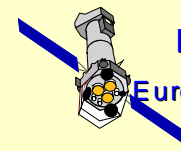
Selected: 10 entries

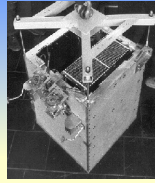


Crab: the standard X-ray candle with all (modern) X-ray satellites

**M.G.F. Kirsch^a,
U.G. Briel^b, D. Burrows^c, S. Campana^d, G. Cusumano^e, K. Ebisawa^f,
M.J. Freyberg^b, M. Guainazzi^a, F. Haberl, K. Jahoda^g, J. Kaastraⁿ, P.
Kretschmar^a, S. Larsson^h, P. Lubinskiⁱ, K. Mori^j, P. Plucinsky^k, A.M.T.
Pollock^a, R. Rothschild^l, S. Sembay^m, J. Wilms^o, M. Yamamoto^j**

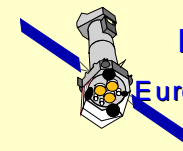
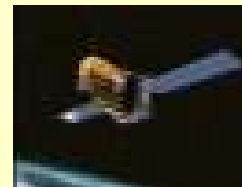
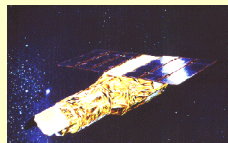
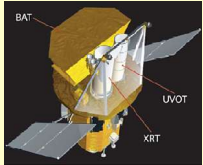
^aEuropean Space Agency, ^bMPE, ^cPenn State University, ^dOsservatorio Astronomico di Brera, ^eIFCAI/CNR ^fAstro-E2 Guest Observer Facility, ^gNASA's GSFC, ^hStockholm Observatory, ⁱCAMK, Warsaw; INTEGRAL Science Data Center, ^jUniversity of Miyazaki ^kHarvard-Smithsonian Center for Astrophysics, Cambridge, ^lCenter for Astrophysics & Space Sciences, University of California, ^mLeicester University, ⁿSRON, ^oUniversity of Warwick





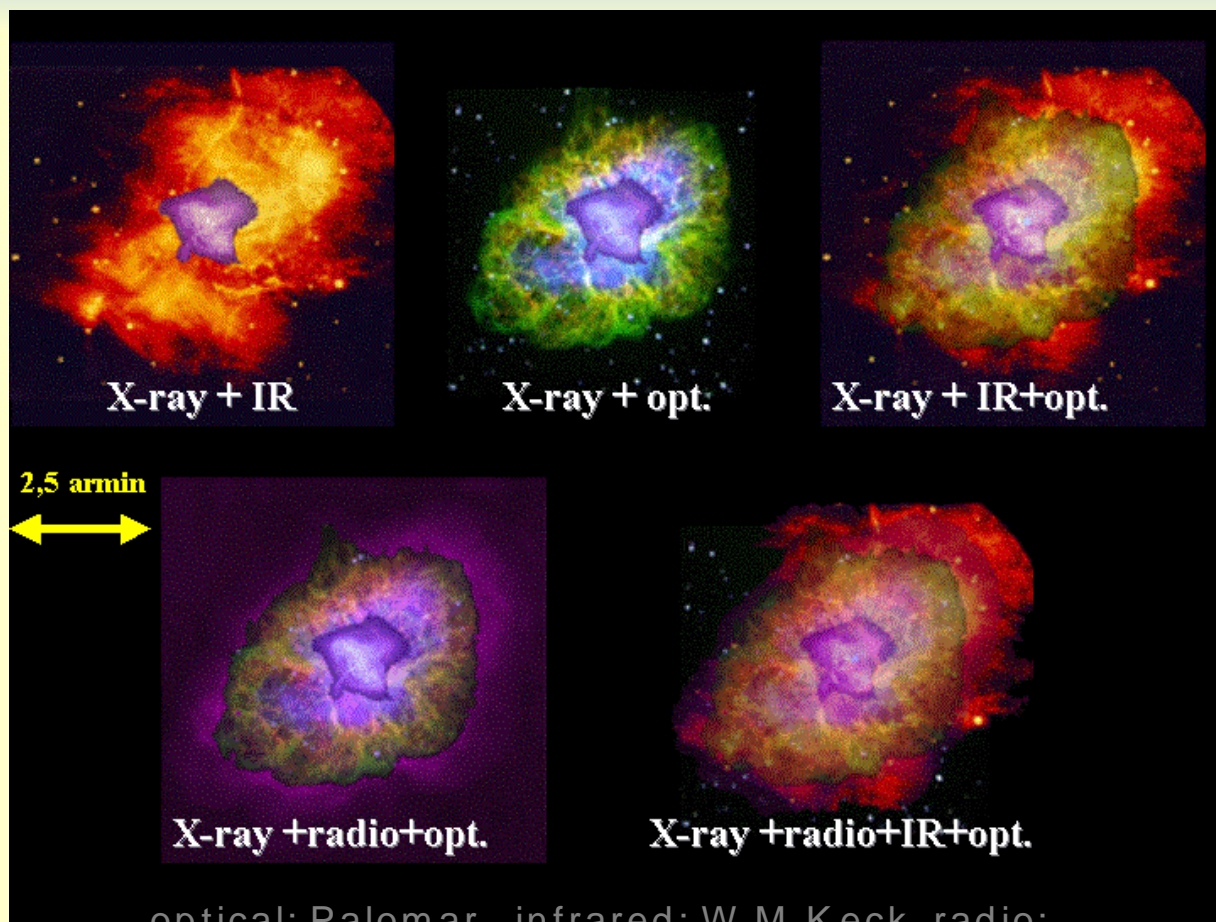
- The Crab
- XMM-observations of the Crab
- Comparison with other observatories

- The need for X-ray standards

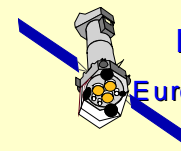


the Crab

- Age: 900 years
- Distance: 2200 pc
- RA: 05 34 31.97
- DEC: +22 00 52.1
- L: $5 \cdot 10^{38}$ erg/sec
- Lx: $4.9 \cdot 10^{37}$ erg/sec
- P: 33.1 ms
- Pdot: 36 ns/d

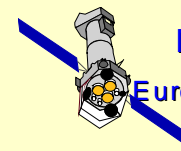
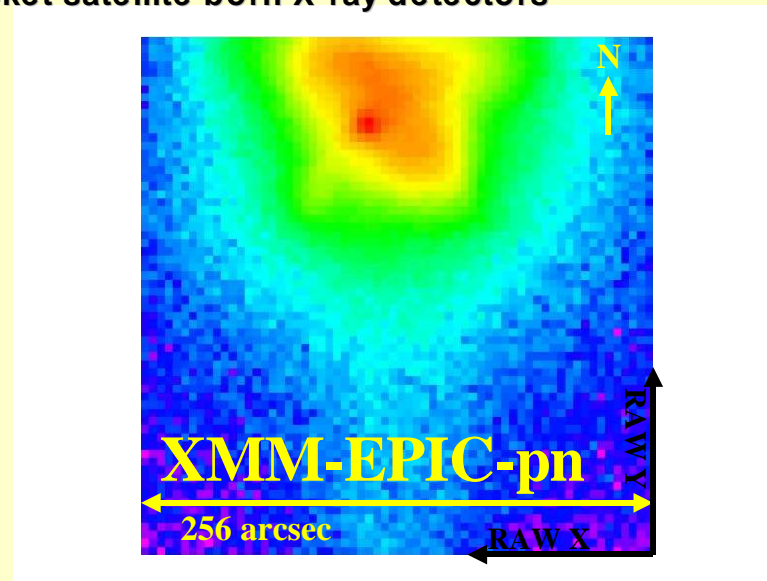
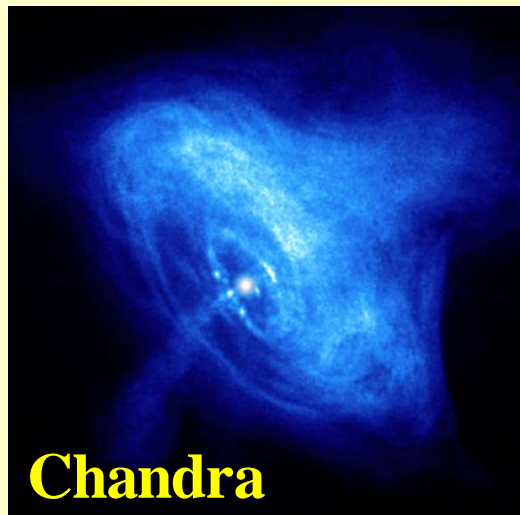


optical: Palomar, infrared: W M Keck, radio:
VLA/NRAO:



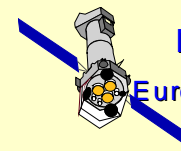
the Crab in X-ray

- 1963 Gurskey discovered x-ray source in Taurus region
- 1964 Bowyer located that source in the Crab region with an error box of $2^\circ \times 2^\circ$
- High energy Crab is smaller than low energy Crab (Staubert 75)
- Lx: $4.9 \cdot 10^{37}$ erg/sec
- P: 33.1 ms
- Pdot: 36 ns/d
- Used as calibration source for balloon, rocket satellite born X-ray detectors



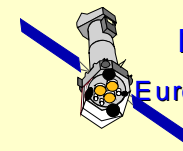
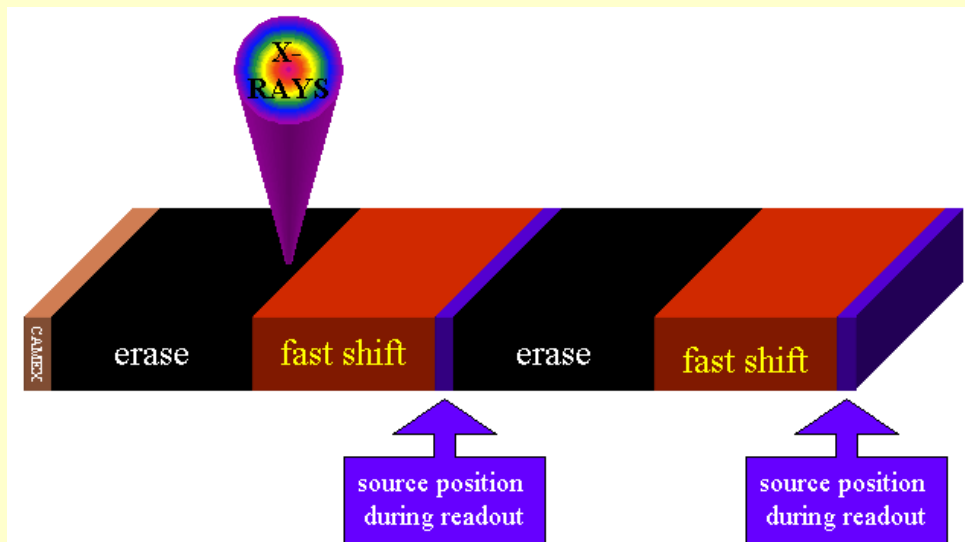
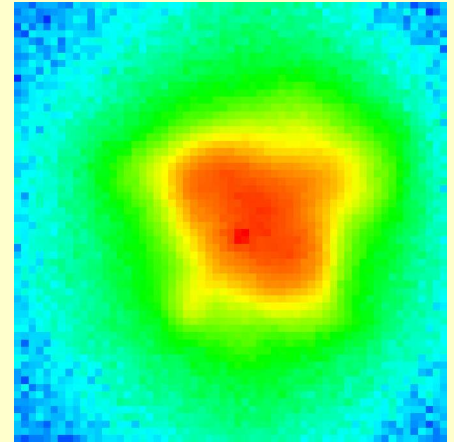
Toor and Seward 1974

- Crab can be interpreted as a constant intensity source
- simple power law spectrum
- Used various observations with balloon, rocket and satellite born proportional Geiger and scintillation counters in energy ranges from 0.2-500 keV
- joint fit to past data: power law
 $\alpha=1.08\pm0.05$ and $N=9.5$ photons/keVcm²s at 1 keV
- best spectral shape between 2-50 keV measured from their own experiment: a power law $\alpha=1.1\pm0.03$ and $N=9.7\pm1.0$ photons/keVcm²s at 1 keV
- Note: modern XSPEC notation: $\Gamma = \alpha + 1$



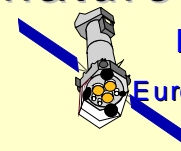
EPI C-pn observation

- Re-pointed such that the full nebula fell on the active CCD areas (checked in SW-mode)
- Observe in Burst mode:
 - fast transfer of pixels under PSF
 - time resolution: **7 μ s**
 - life time only 3 %
 - Max. count rate (flux) point source [s^{-1}] ([mCrab]) : **60000 (6300)**



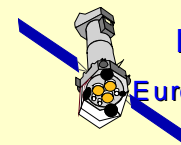
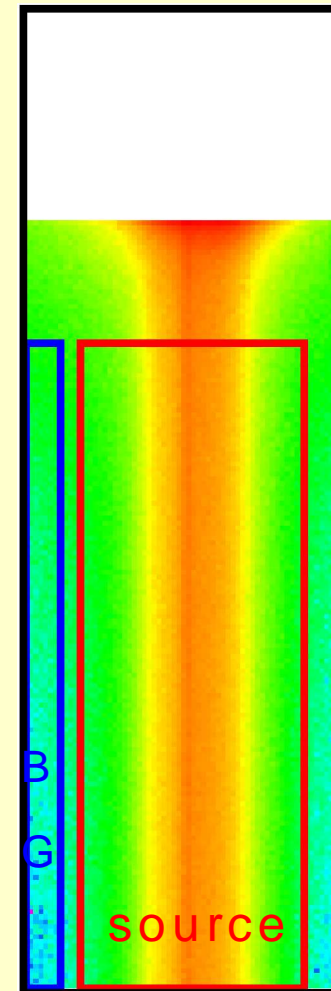
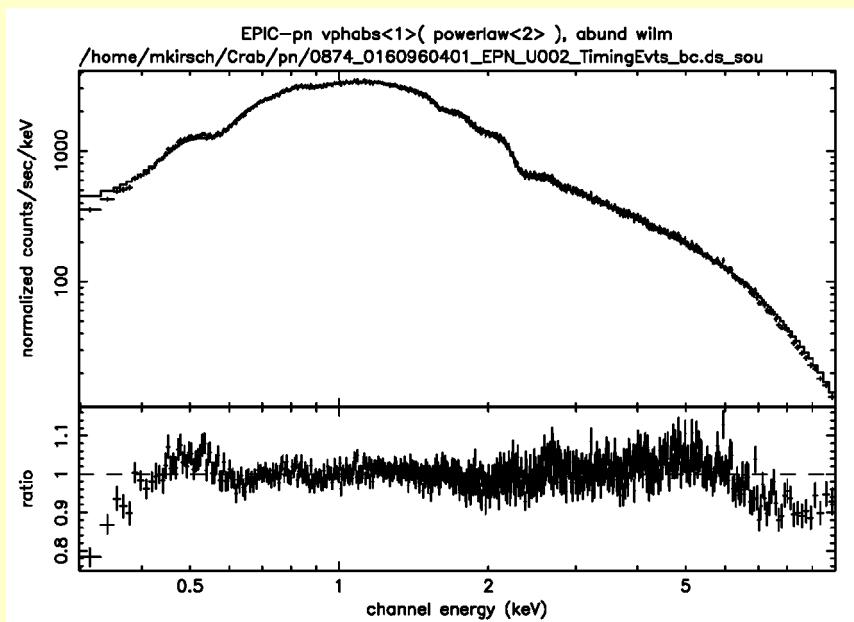
Best fit model

- simple absorbed power law
- question on the correct absorption model
- Based on an updated compilation of UV and optically derived abundances, *Wilms et al.* proposed new abundances with regards to the default XSPEC abundances of Anders and Grevesse
- For the Crab direction under-abundances in oxygen, neon and iron has been claimed by Willingale and Weisskopf .
- *(v)phabs*powerlaw* using abundances of Wilms et al. and cross-sections of Balucinska-Church & McCammon or Verner et al.
- Observations in the gamma-ray range typically indicate a steeper spectral shape but there is no general agreement on the best overall spectral model or the nature of the steepening



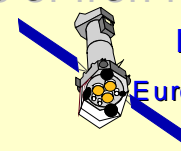
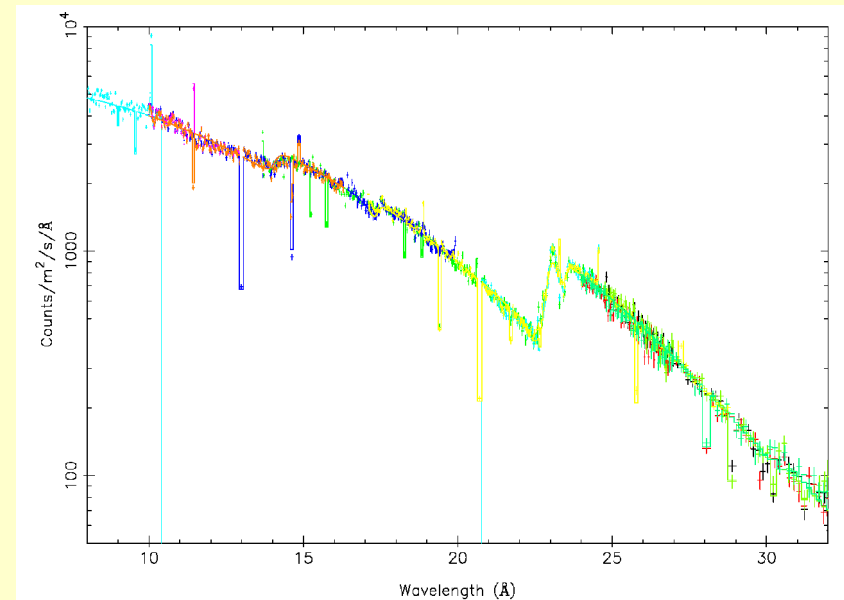
Spectral EPIC-pn results

- $\Gamma=2.118\pm0.005$ $N=8.56\pm0.05$ $N_H = (4.04\pm0.03)\cdot 10^{21} \text{ cm}^{-2}$
- variable abundances
 - O: 0.93 ± 0.02 ,
 - Ne: 0.86 ± 0.09
 - Fe: 0.76 ± 0.08



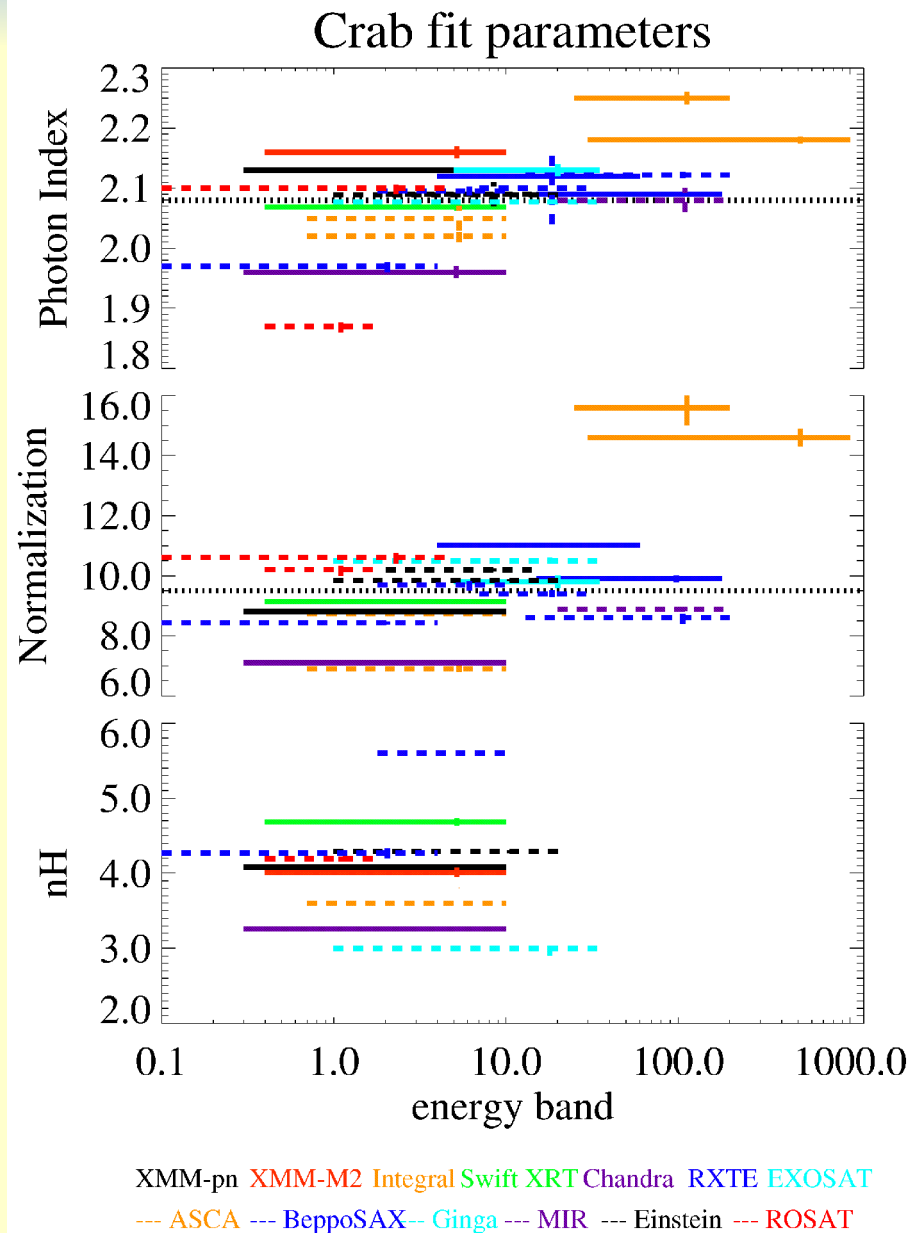
Spectral RGS results

- high spectral resolution depths of the absorption edges due to interstellar gas can be measured much better with the RGS than with any other instruments
- accurate column densities of individual elements
- Caution: nebula has a significant dust-scattering halo which may scatter a wavelength-dependent fraction outside the RGS aperture serious at the longest wavelengths
- spectrum was extracted from data in which only 3 CCDs were used in order to avoid pile-up
- Solar Abundances:
 - H: 1 ($=37.7 \pm 0.04 \cdot 10^{21} \text{cm}^{-2}$)
 - C: 0
 - N: 1.04 ± 0.13
 - O: 0.93 ± 0.007 ,
 - Ne: 2.51 ± 0.04
 - Fe: 0.456 ± 0.019
- C not real but probably a consequence of dust scattering
- strong over-abundance of Ne and the under-abundance of iron may be signatures that line of sight contains significant amounts of dust



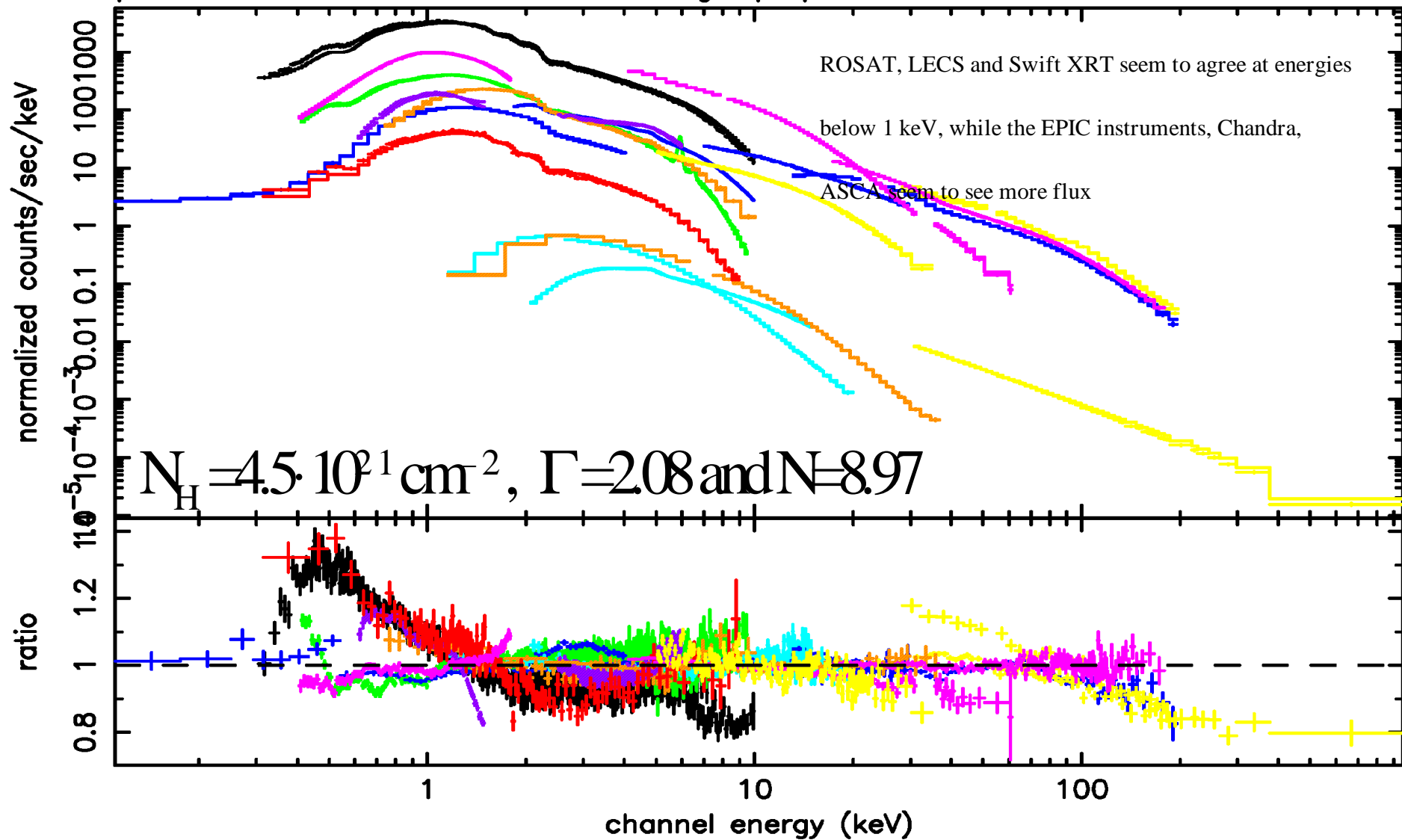
Individual fits

- Model: $phabs * powerlaw$
(abundances of Wilms et al. and cross-sections of Verner et al.)
- No systematic errors
- parameters for N_H differ in absolute terms from previous values since we use a different absorption model and not the obsolete *wabs* model
- comparison of the 1 keV flux can be misleading for the high energy instruments since tiny differences in the power-law index are hugely magnified
- work is underway to determine the "best-fit flux" in several bands and to compare the flux for each instrument in the appropriate band to the "best-fit flux" in that band
- EPIC suggests a lower N_H than BeppoSAX, Swift, EXOSAT, however those have been calibrated to the Crab
- ASCA, Ginga, Chandra N_H is lower than EPIC (Chandra has pile-up problems)
- EPIC with their immense throughput can refine possibly the N_H value of the Crab.



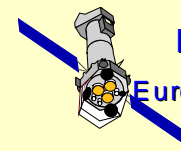
Joint fit

black: pn, red: MOS, green: Swift, blue: Sax, lblue: EXOSAT, yellow: INTEGRAL
 pink: RXTE+ ROSAT, brown: ASCA + Ginga, purple: Chandra



Conclusion

- Most of the instruments that have their main sensitivity range above 2 keV cannot be used efficiently to constrain the absorption towards the Crab and have been calibrated to fit canonical Crab parameters.
- **XMM-Newton may revise the X-ray absorption of the Crab**, given EPIC' s very high effective area in the low-energy regime.
- **Photon index and normalization provided by EPIC agree within the errors of the Toor and Seward values** taking also into account the systematic errors of EPIC on the photon index (0.05).
- Further work needs to be carried out to combine the RGS results of the under-abundances with the EPIC results.
- XMM-Newton may soon provide the best calibrated spectrum of the Crab. The current discrepancy between EPIC-pn and MOS in photon index is comparable to the scatter among all instruments.
- Resolving the pn-MOS discrepancy will provide a precise and accurate (and modern!) spectrum of the Crab with no assumptions about the spectrum built into the calibration. The modern spectrum will contain high-quality measurements of the absorption, in contrast to previous efforts.
- For energies above 30 keV the Crab is definitely difficult to use as calibration source. Since its spectrum is no longer a single power law no consensus obtains on the proper model of the spectrum which should be used for calibration tests. Different results may well be caused by the more complex character of these instruments which are generally difficult to calibrate and have a large intrinsic background that increases with energy
- **Crab will be possibly too bright and too extended for future X-ray missions one may think about establishing a set of standard calibration sources for the X-ray regime**



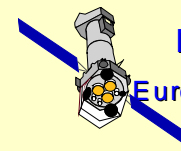
The need for X-ray standards

- As much need in the X-ray domain for a set of objects to serve as photometric or spectrometric standards as at longer wavelengths
- The X-ray equivalents are much harder to define, not least because variability is a very common property of X-ray sources.
- Crab nebula has served as a reference which in common with other fainter SNRs is confidently expected to be constant, but may be too bright for future missions
- XMM-Newton has repeatedly observed a small set of objects that have been judged to serve as X-ray standards with the intention of both monitoring the evolution of instrument performance and providing straightforward comparisons with other instruments.
see also talk M. Kirsch Tuesday 11:30
- strong need for a set of standard calibration sources for the X-ray regime luxury situation of having 6 satellites (**XMM-Newton, Chandra, RXTE, Swift, Integral, Astro-E2**) in orbit that are having X-ray instruments as their payload for the coming years we strongly recommend to **found an international calibration group that may steer the cross calibration efforts**



Splinter meeting for interested calibration people

Tuesday 2 August lunch break



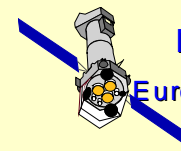
Marcus Kirsch, XMM-Newton

European Space Astronomy Center

EPIC long term calibration



Marcus G. F. Kirsch



main plans for the future

- MOS:
 - Redistribution for line rich sources not yet perfect in lines
 - High energy flux higher than pn
 - CTI update
 - CTI for special column areas
 - column dependent CTI correction (NO)
 - Spatial dependence of very low energy response of MOS (lab testing at LUX in 2006)
- pn:
 - Redistribution for line rich sources not yet perfect in lines
 - High energy flux lower than MOS, mirror measurements soon at PANTER (Feb 2006)
 - pn energy refinement for fast modes mode (CTI(energy, rate)), possibly NRCO needed
 - Fast modes drm
 - Random jumps in pn energy scale of <20 eV
 - Special CTI due to vent hole (can only be checked after implementation of column gain refinement)
 - usage of the FIFO-reset-counter for improving the integration time (lab measurements at IAAT, possible check also at PANTER in 2006)
 - Check of the rel timing accuracy with NRCOs in 2006
 - Investigation of double event behaviour (within 2 years)
 - Column gain refinement
 - Time jumps + timing document
- general:
 - Cross Cal document

