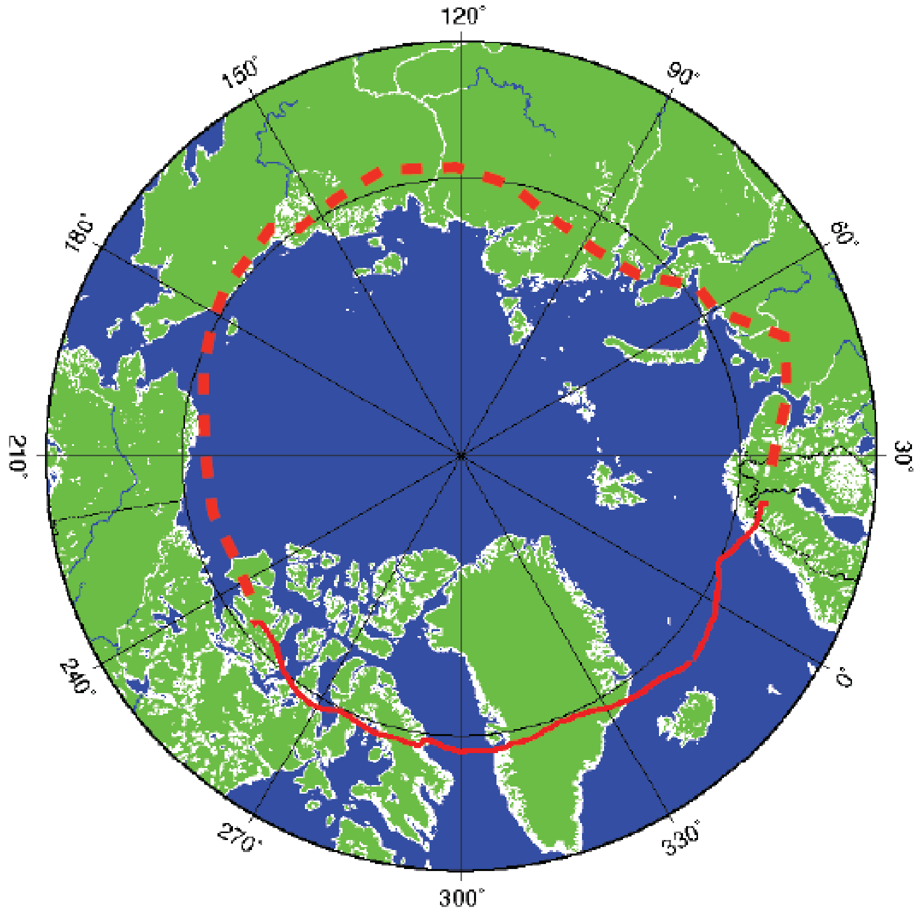
PoGOLite Update

- Flight plan in 2011 -

May 6 2011 KIPAC Tea Talk
Tune Kamae



Collaboration and Funding

- Swedish consortium (KTH and Stockholm U):
  Mark Pearce (Current PI), Per Carlsson, Stefan Larsson, Felix Ryde, et al.
  PhD students: Mozsi Kiss, Cecilia Marini Bettolo, Magnus Axelsson, Olle Engdegard et al.
  Doiploma students: Nick Barkas, Pau Mallou, Daniel Walldin, Erik Brandrup, Kristoffer Myrsten, Jaroslav Kazejev, Tomi Ylinen, et al.
- Japanese consortium (Hiroshima U, Tokyo Inst Tech, Waseda U, Yamagata U)
  Tsunefumi Mizuno, Hirotaka Takahashi, Jun Kataoka, Masaru Ueno, et al.
  Graduate students: Yoshikazu Kanai, Makoto Arimoto, Takuya Tanaka, et al.
- US consortium (SLAC, U. of Hawaii)
  Tune Kamae (First PI), Hiro Tajima, Greg Madejski, Gary Varner, Tim Thurston, Johnny Ng, and Reggie Rogers

- Swedish National Space Board (funding and technical supports)
- Knut and Alice Wallenberg Foundation (funding)
- SLAC National Accel. Lab. (funding and technical supports)
- KIPAC ,Stanford University (funding and technical supports)
- Japan Soc. for Promotion of Science (funding)
- Inst Space and Astro. Sciences, JAXA (funding)
- NASA (funding in early R/D phase)

Pol. measurement in the X/γ bands

- Unexplored area in high energy astro -

- What will we learn?
  - **Emission mech**: synchrotron, inverse Compton scattering
- Why not much explored until now?
  - **Typical pol. expected is small** (5-10%)
  - Pol. expected **only in non-thermal emission** (E>>a few keV)
  - Eff. area of X-ray mirrors drops sharply beyond ~20keV
  - **Need very long observation time**, typically a few 100ks
  - Only one exploratory mission launched into orbit in 1970s
  - Integral measured polarization in Crab and Cygnus X-1
- Future polarization experiments
  - **PoGOLite61** (2011) will cover 80>E>20keV
  - **GEM mission** (2013?) will cover E<8 keV
  - **Astro-H SGD** (2015?) will cover 200>E>40 keV

Crab Nebula Polarization Measurements

Instrument	Energy	Pol. degree	Pol. angle	Ref.
OPTIMA	450–950 nm, ∼1–3 eV (Optical)	Peaks: low polarization, ∼5–10%	Peaks: rapidly changing, ∼70–170°	[34]
OSO-8	2.6 keV (X-rays) 5.2 keV (X-rays)	$(19.2 \pm 1.0)\%$ $(19.5 \pm 2.8)\%$	$(156.4 \pm 1.4)^\circ$ $(152.6 \pm 4.0)^\circ$	[32, 33]
INTEGRAL (IBIS)	0.2–0.8 MeV (Gamma-rays)	Peaks: little or no polarization Off-pulse: >88% pol.	Peaks: N/A Off-pulse: $(122 \pm 7.7)^\circ$	[38]
INTEGRAL (SPI)	0.1–1 MeV (Gamma-rays)	Off-pulse: $(46 \pm 10)\%$	Off pulse: $(123 \pm 11)^\circ$	[40]

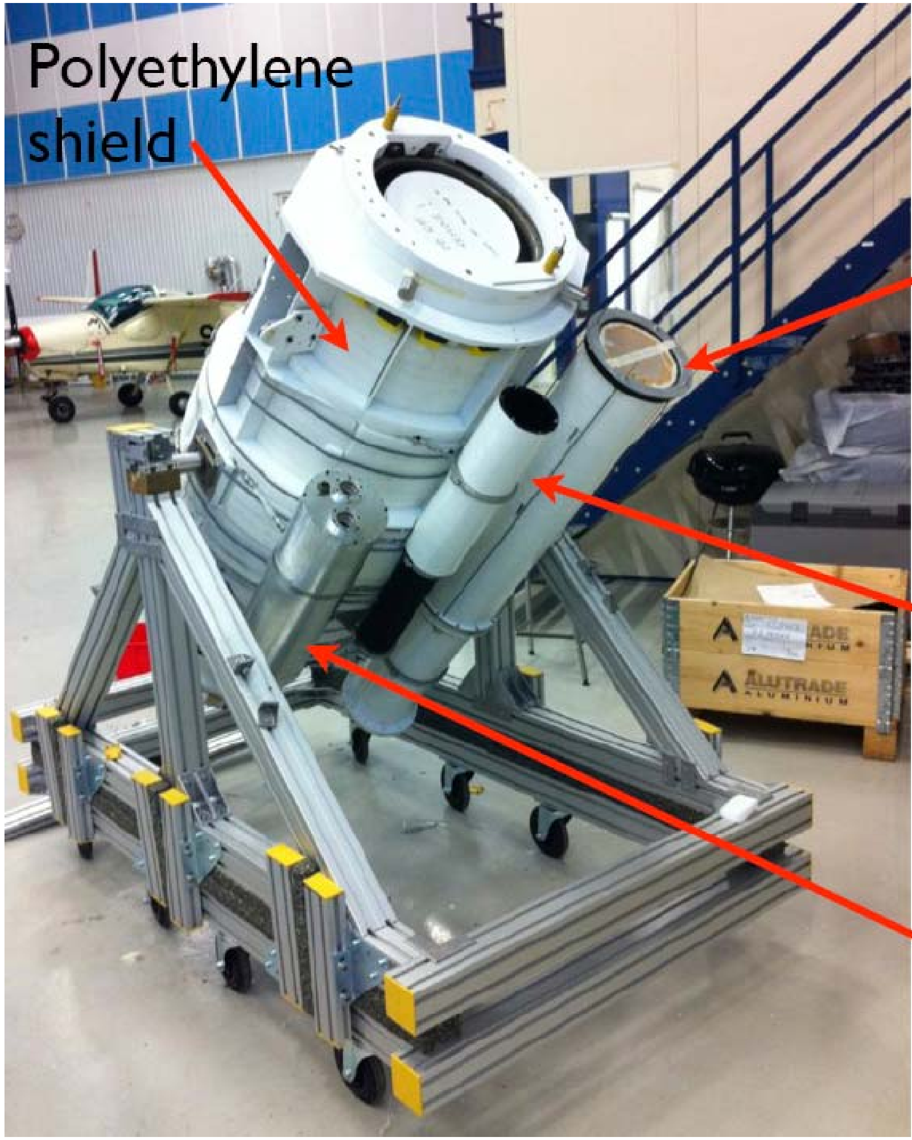
PoGOLite61	20-80keV	+/–3% (1 day)	+/–2 deg (1 day)	
		+/–1% (10 days)	+/–1 deg (10 day)	

Cygnus X-1 Polarization Measurement

Instrument	Energy	Pol. degree	Pol. angle	**Ref**
Integral (IBIS)	250-400keV	<20%	?	Laurent 2011
	400-2000keV	67+/–30%	?	Laurent 2011
PoGOLite61	20-80keV	+/–3% (1 day)	+/–2 deg (1 day)	
		+/–1% (10 days)	+/–1 deg (10 day)	

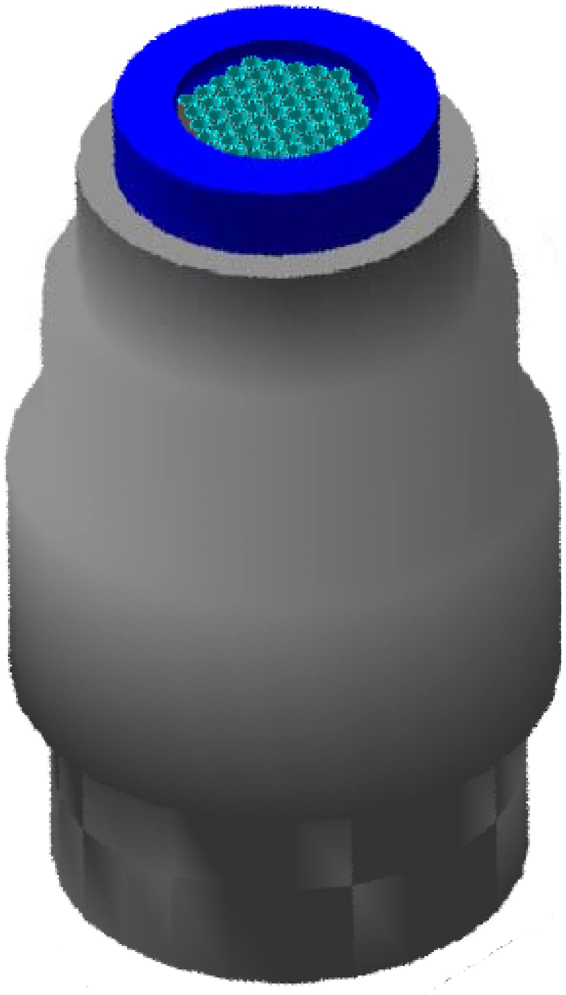
PoGOLite Instrument

Polarimeter, and Star Trackers

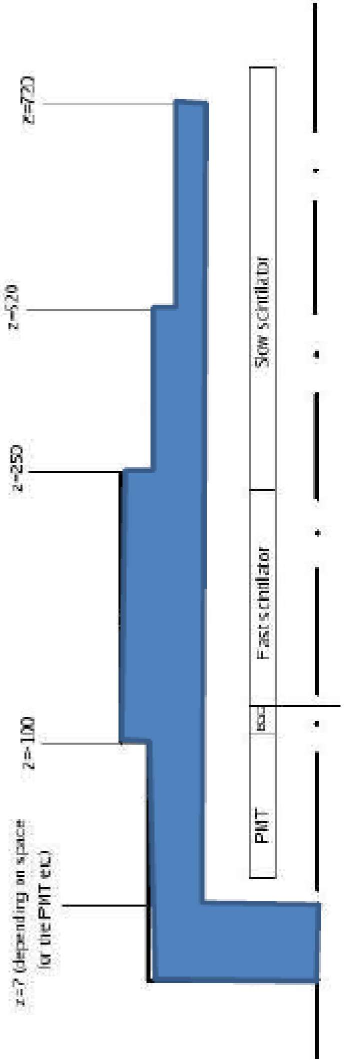


Polarimeter

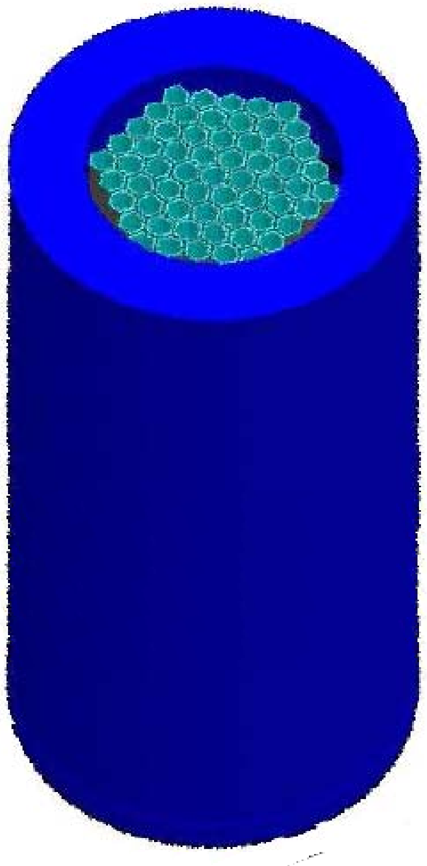
Entire assembly



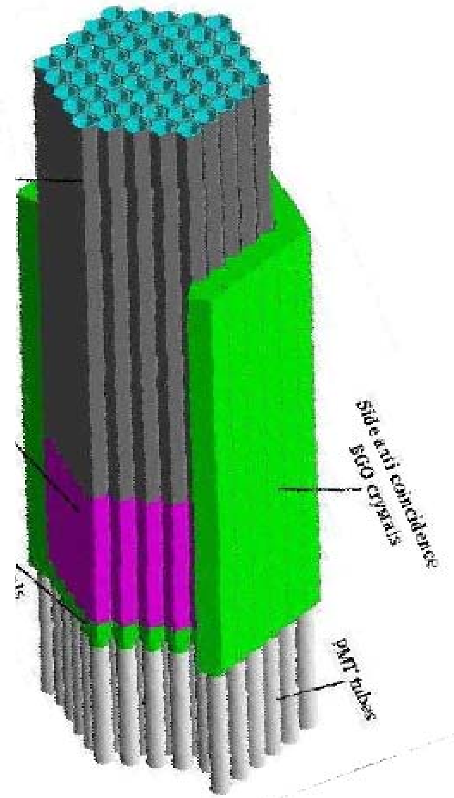
Neutron shield
(5-15cm thick)



Pressure vessel
rotatable around axis



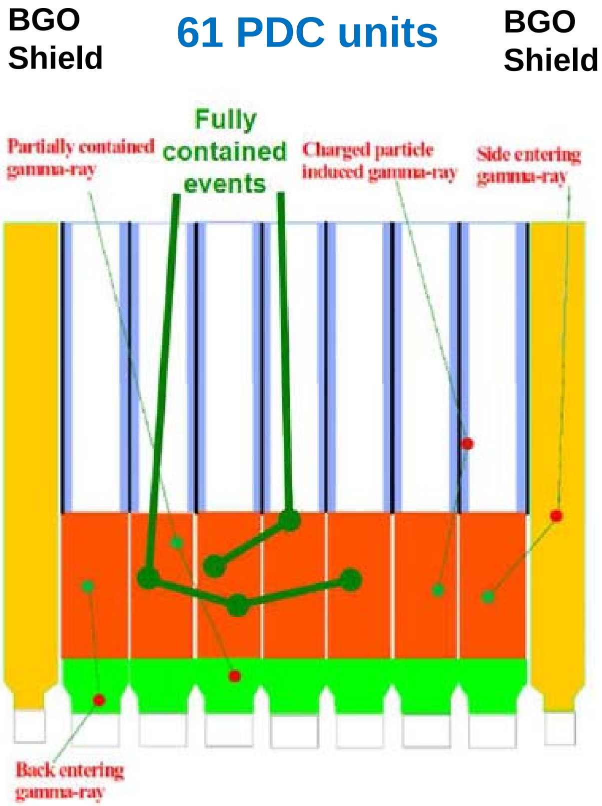
Detector + electr
assembly



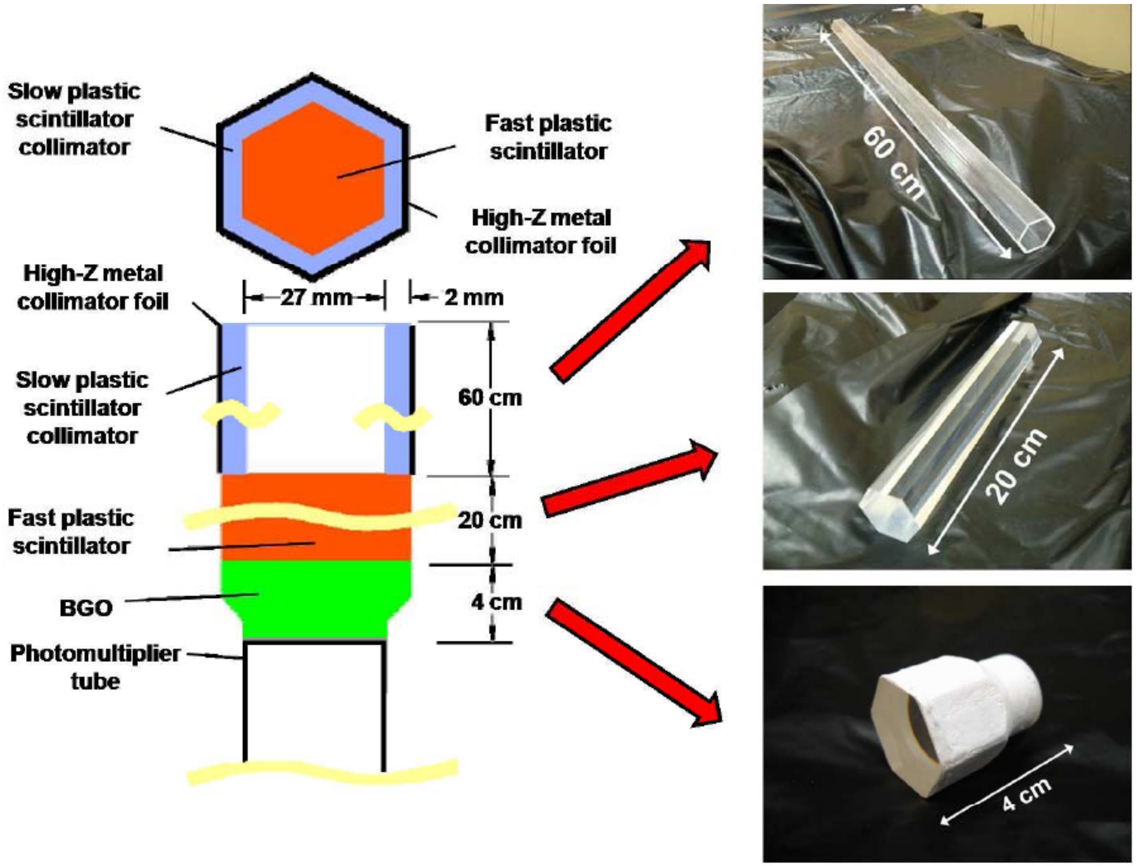
Mozsi Kiss, PhD thesis (2011 KTH)

Polarimeter developed at SLAC/KIPAC

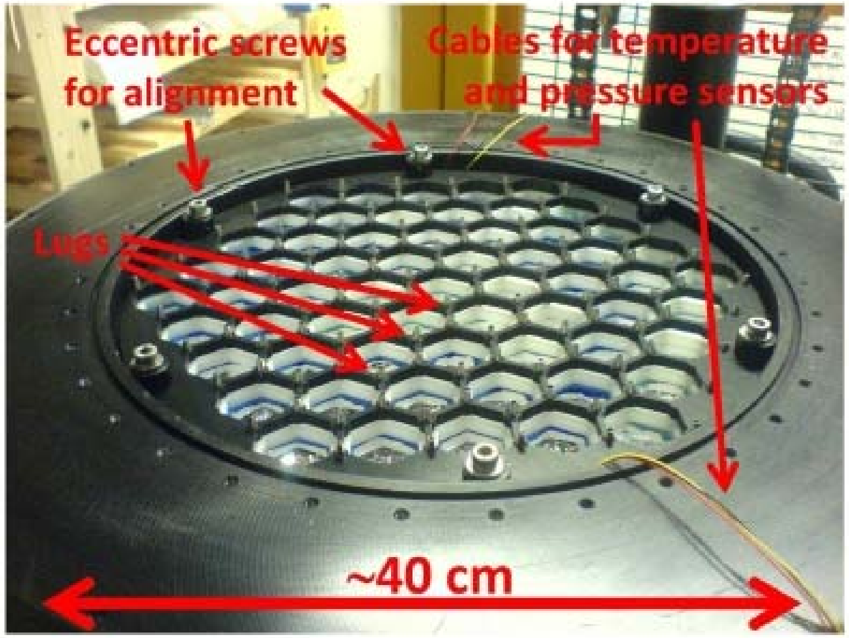
Cross section

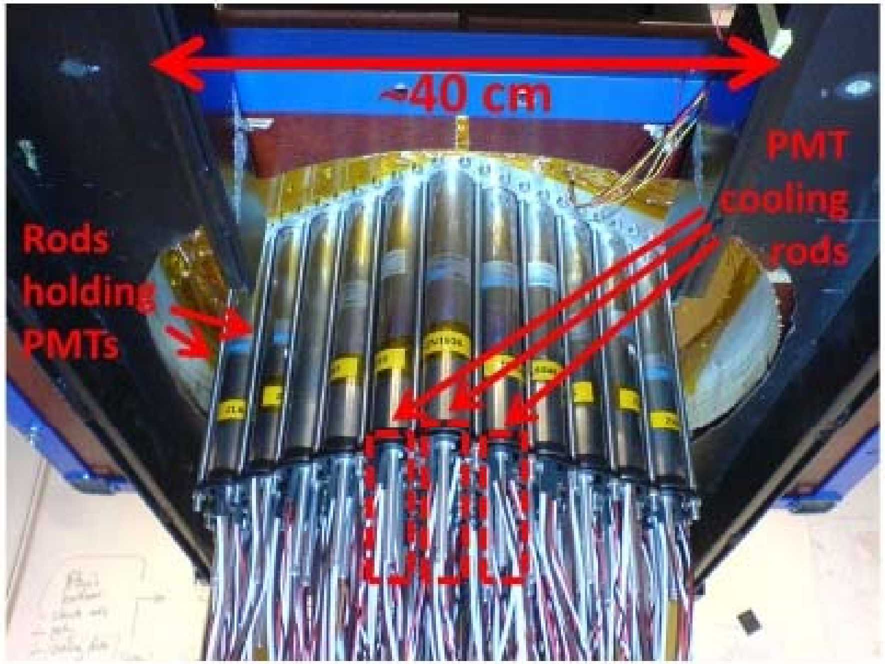


Phoswich Detector Cell (PDC)



Most other works done at KTH and Stockholm U

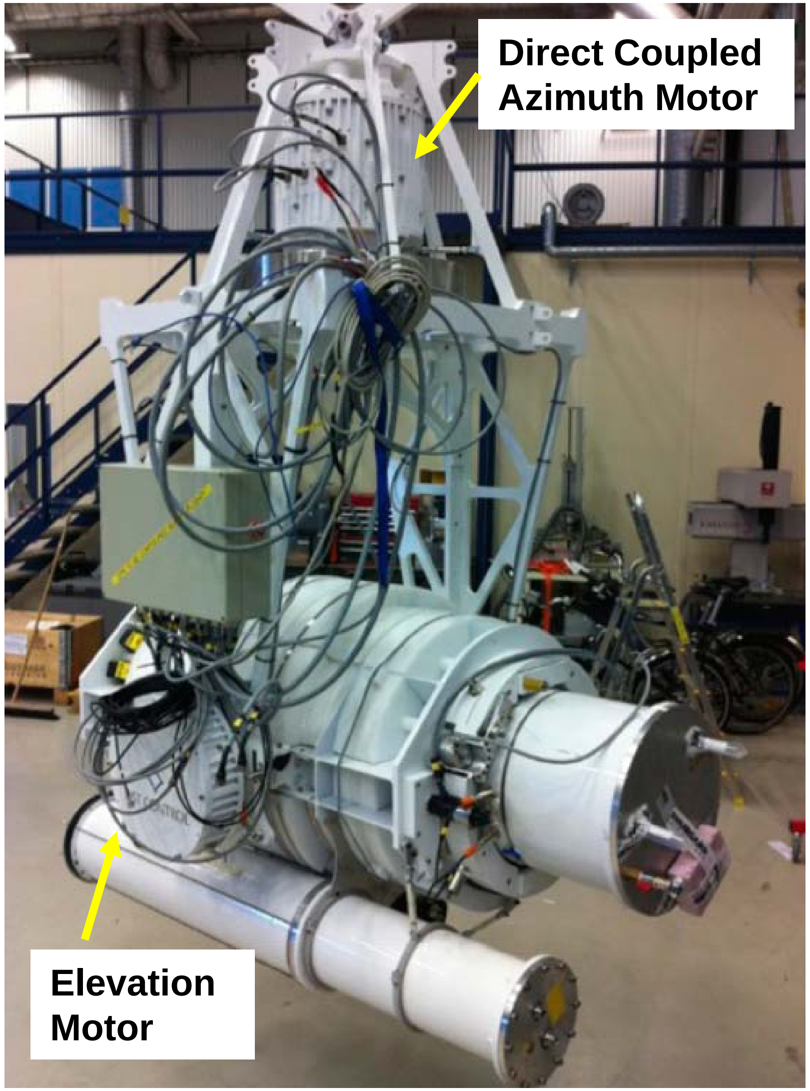




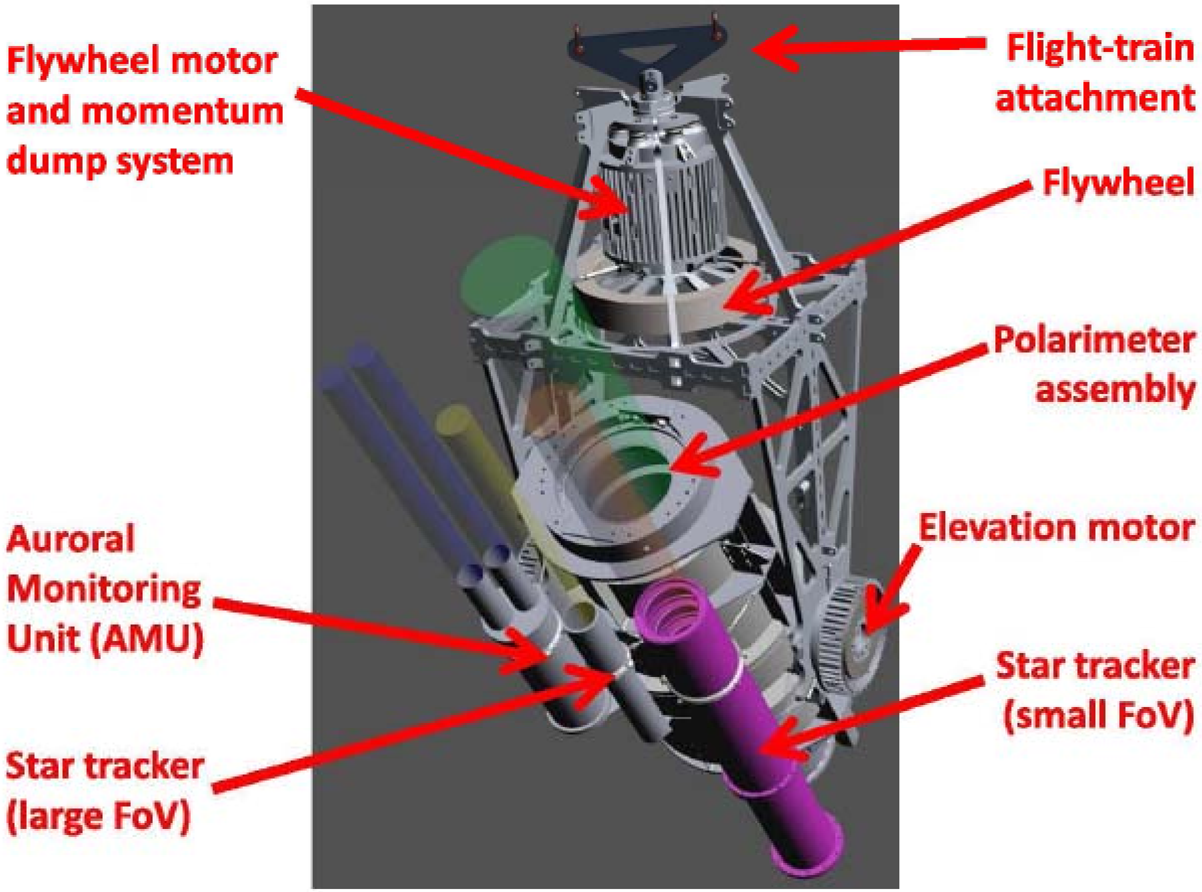
Mozsi Kiss, PhD thesis (2011 KTH)

Mechanical structure and attitude control

Mozsi Kiss, PhD thesis (2011 KTH)



PoGOLite61 Payload



Mozsi Kiss, PhD thesis (2011 KTH)

Gondola assembly

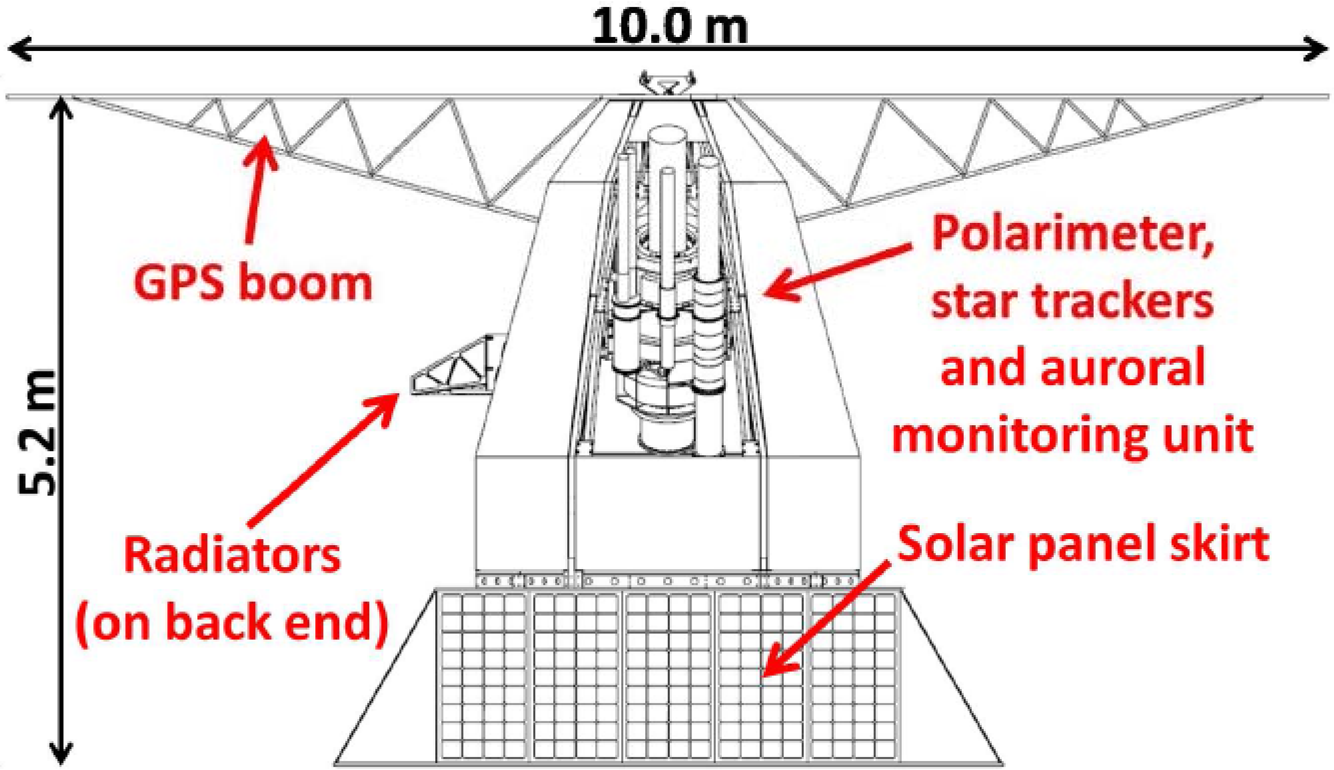
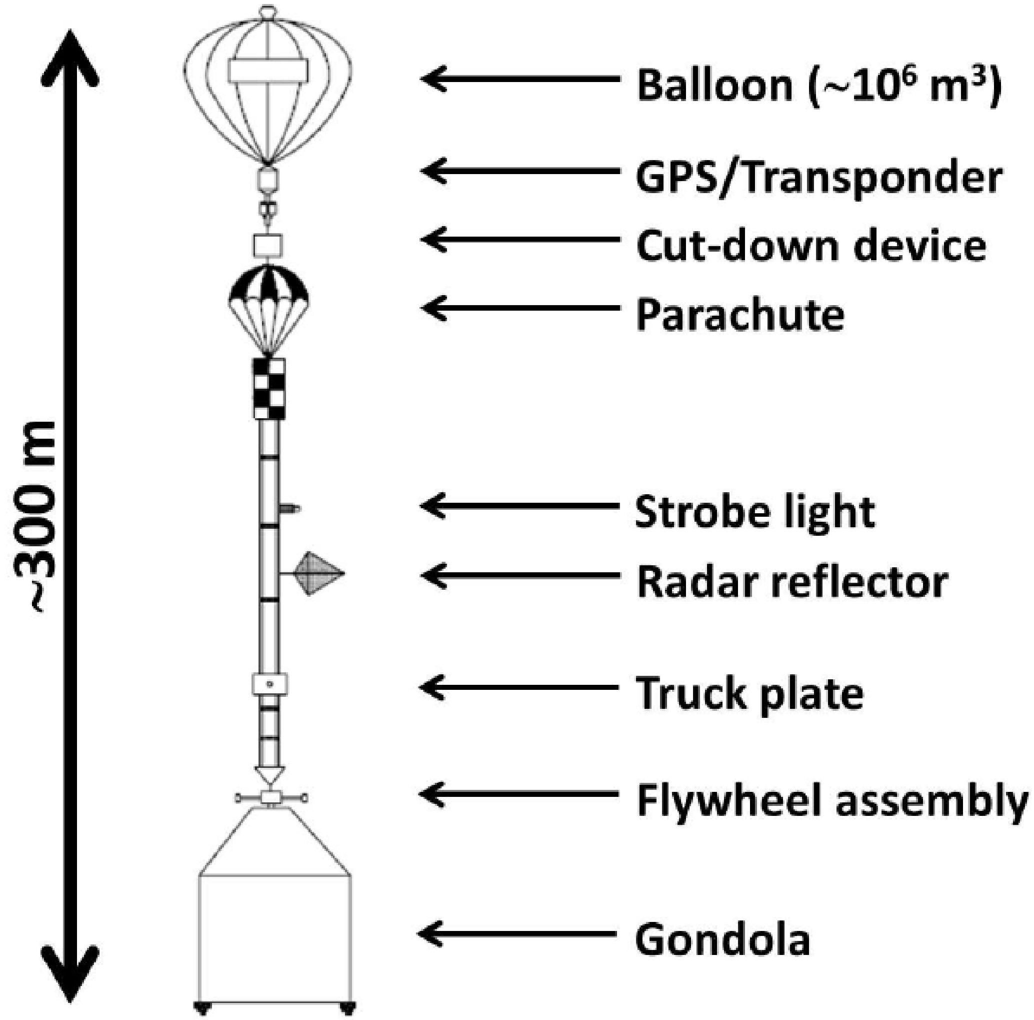


Figure 2.27. Foreseen flight-configuration of the PoGOLite Pathfinder gondola.

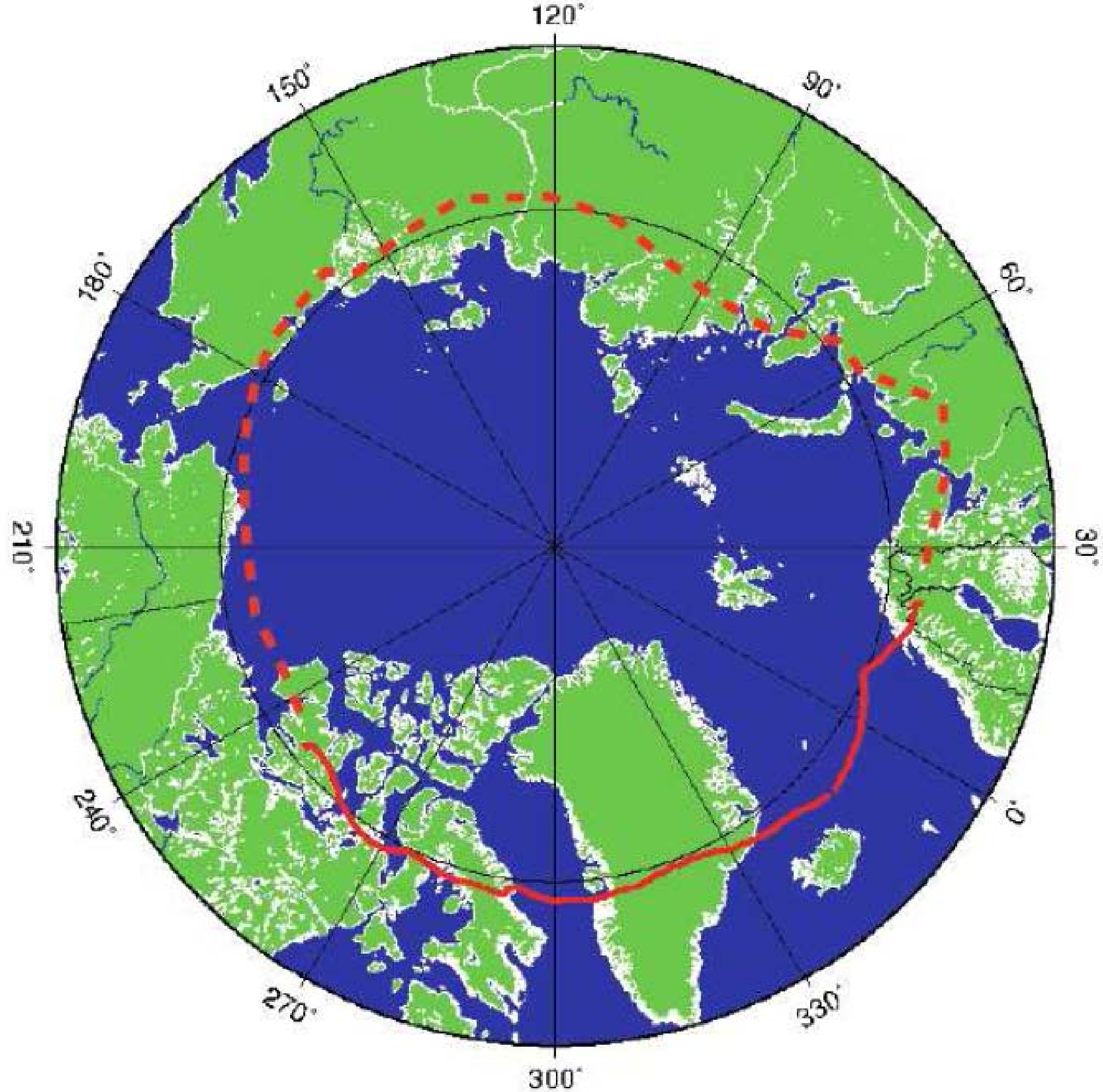
Mozsi Kiss, PhD thesis (2011 KTH)

Gondola in Oct 2010

Balloon, parachute, ladder, and gondola



North Pole circumnavigation



Elevation angle: atmospheric attenuation

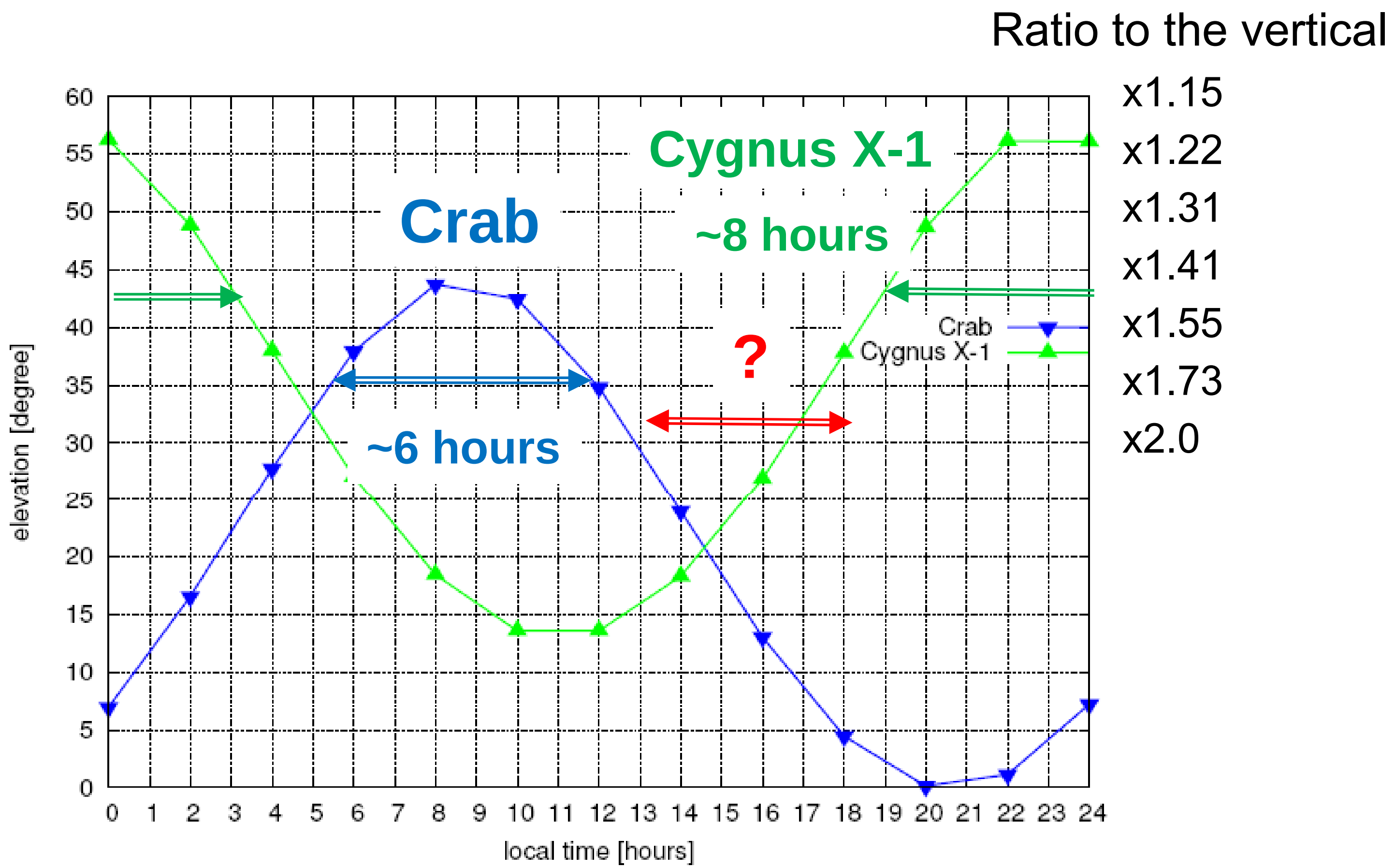


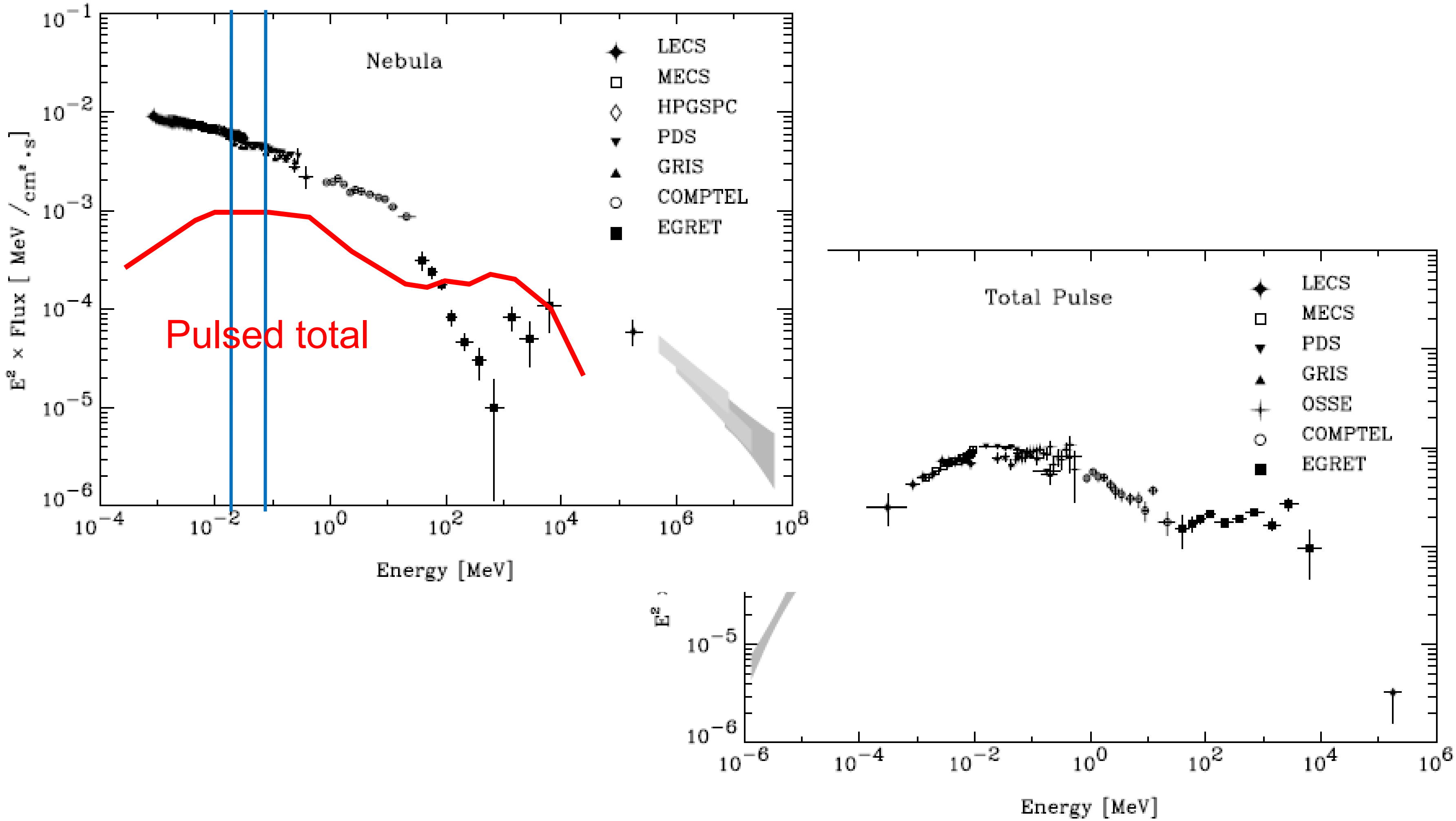
Figure 3.5: Elevation angle of targets during PoGOLite pathfinder flight (inclination angle is 90° - elevation). Observations of the Crab will begin upon reaching observation altitude at approximately four hours with an elevation angle of 28°, or inclination of 62°, and continue at least until hour ten. The smallest inclination angle during this time will be 46° at eight hours. From [2].

Science with PoGOLite

Possible targets in the northern sky

Target	ra, dec	mCrab in Swift/BAT	
Crab (nebula+pulsar)	84, 22	1000	PWN and pulsar
Cygnus X-1	300, 35	56-743	HM XB (BH)
Cygnus X-3	308, 41	97-209	HMXB (BH or NS)
Hercules X-1	254, 35	32-81	LMXB (NS cyclotron)
Mkn 421	166, 38	6-72	Blazar
GRS 1915	289, 11	147-274	LMXB (BH)

Crab nebula and pulsar



Crab Total Spectral Model

- Total Pulsed, Off-Pulse, Nebula -

Eckert, D.; Savchenko, V.; Produit, N.; Ferrigno, C., 2010, A&A, 509, 33
"INTEGRAL probes the morphology of the Crab nebula in hard X-rays/soft γ-rays"

Pulsed component = Count(0.95-0.45) – (0.5/0.3)*Count(0.6-0.9)
Crab nebula total = Count(0.95-0.45) + (0.5/0.3)*Count(0.6-0.9)

For PoGO (monitoring) we will simplify by
Pulsed = Count(0.95-0.45) – Count(0.45-0.95)
Total = Count(0.95-0.45) + Count(0.45-0.95)

Pulsed Fraction
= 0.13 + 0.055 log(E/20) [keV]

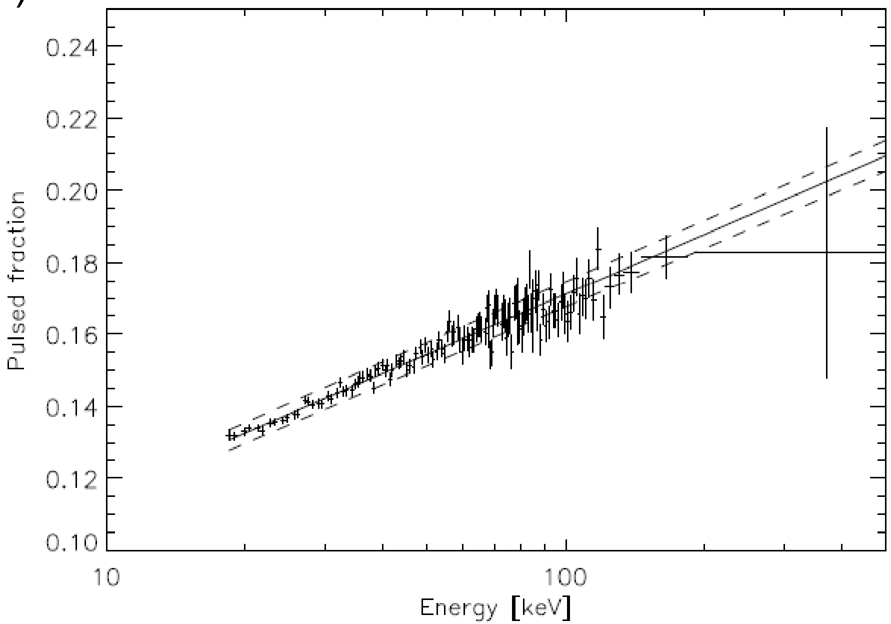
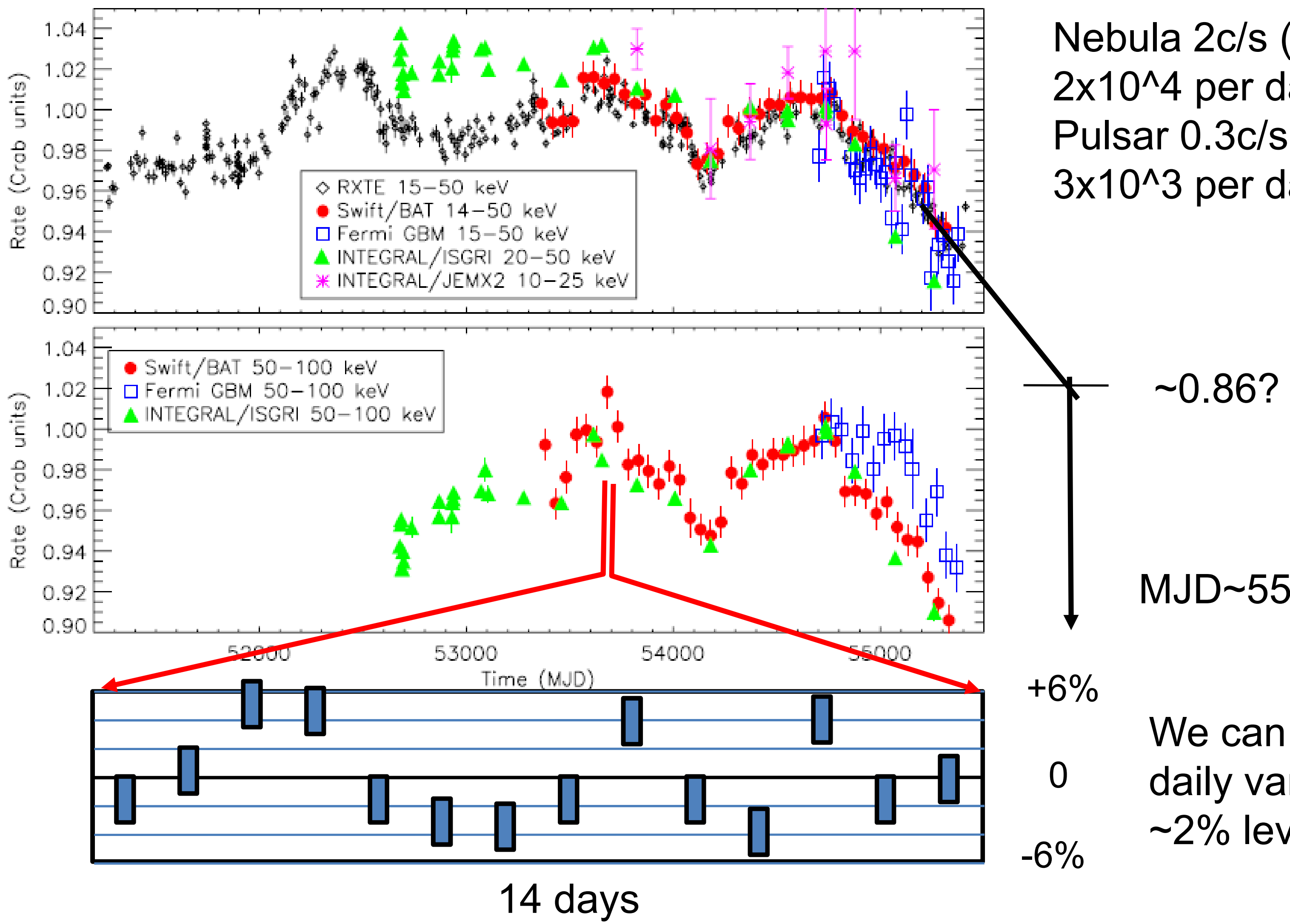


Fig. 6. Pulsed fraction of the Crab pulsar/nebula complex as a function of energy. The solid line shows a linear fit to the data, with 1σ error given by the dashed lines.

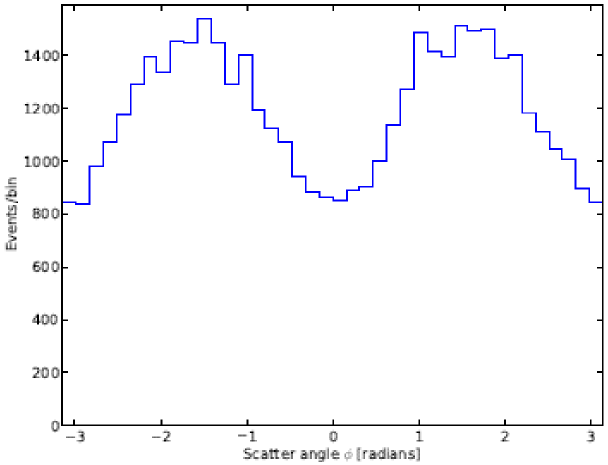
The nebula flux normalized by the pulsar



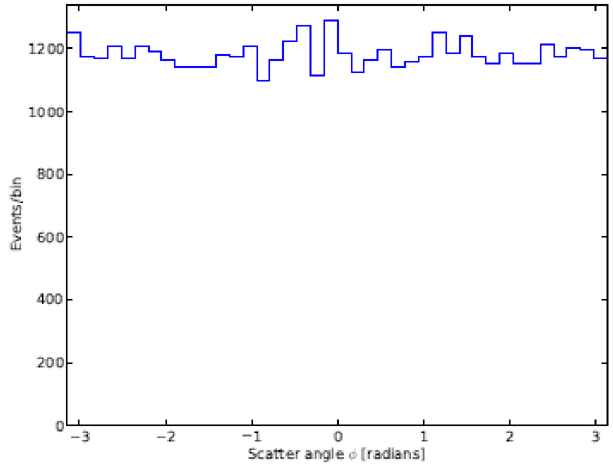
Nebula 2c/s (20-80keV)
2x10^4 per day (6 hrs)
Pulsar 0.3c/s (20-80keV)
3x10^3 per day

We can measure daily variability to ~2% level.

Polarization Measurement on Crab

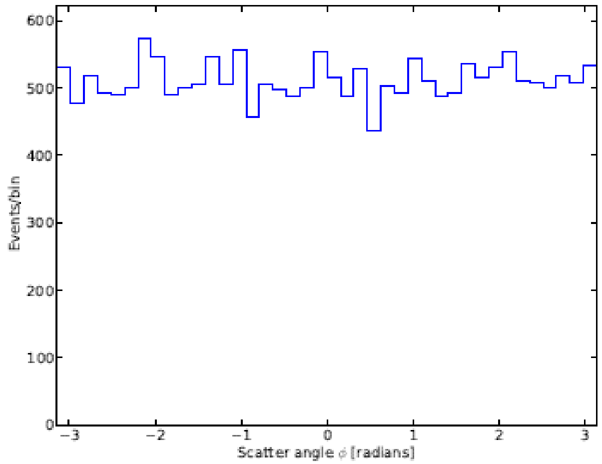


(a) Crab 100% polarized at 0°

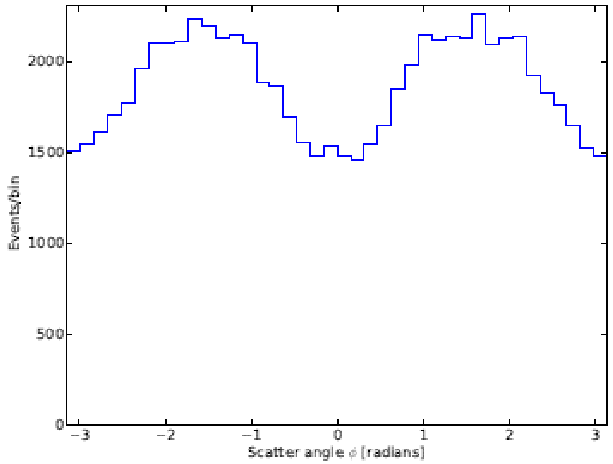


(b) Unpolarized Crab

Crab nebula
6 hrs obs



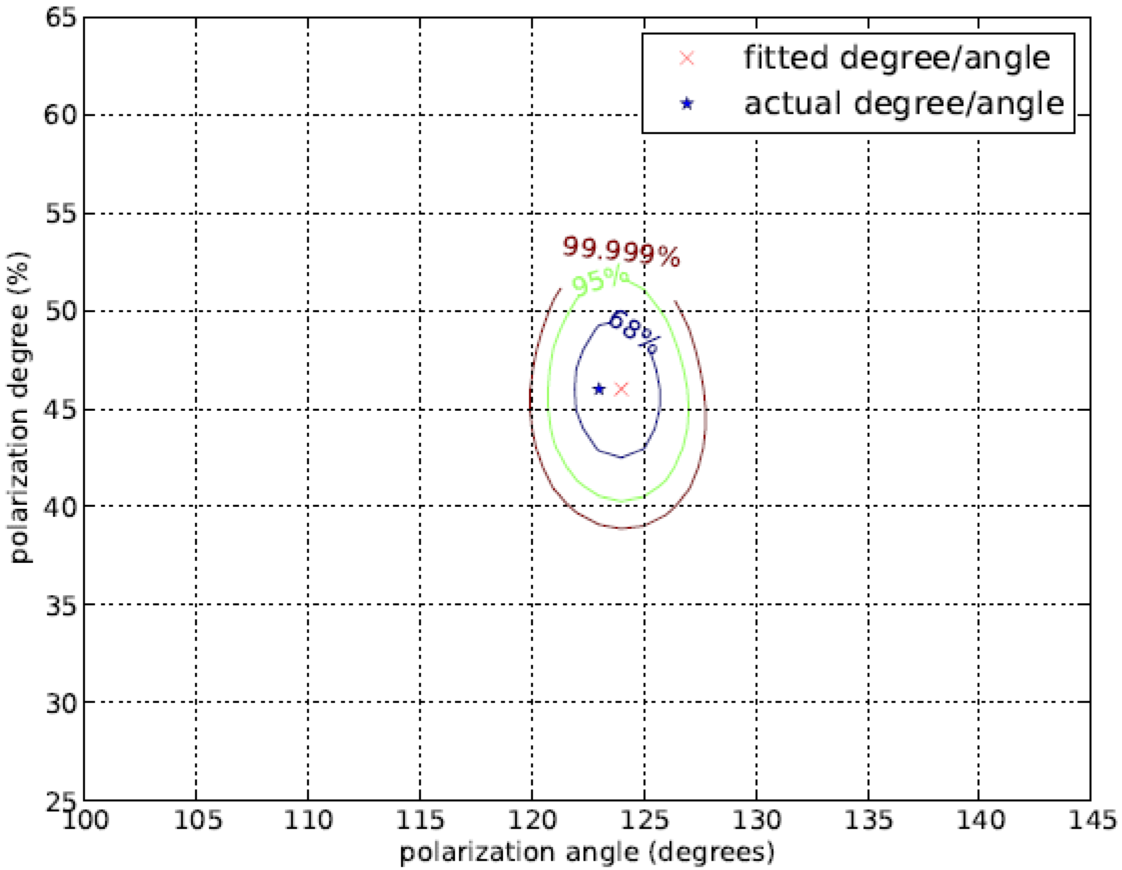
(c) Neutron background



(d) Polarized Crab + neutron

S. N. Bakas: Master thesis

Expected Polarization Measurement



Crab nebula
6 hrs obs
ΔP(rms) = 3%
Δangle = 2deg

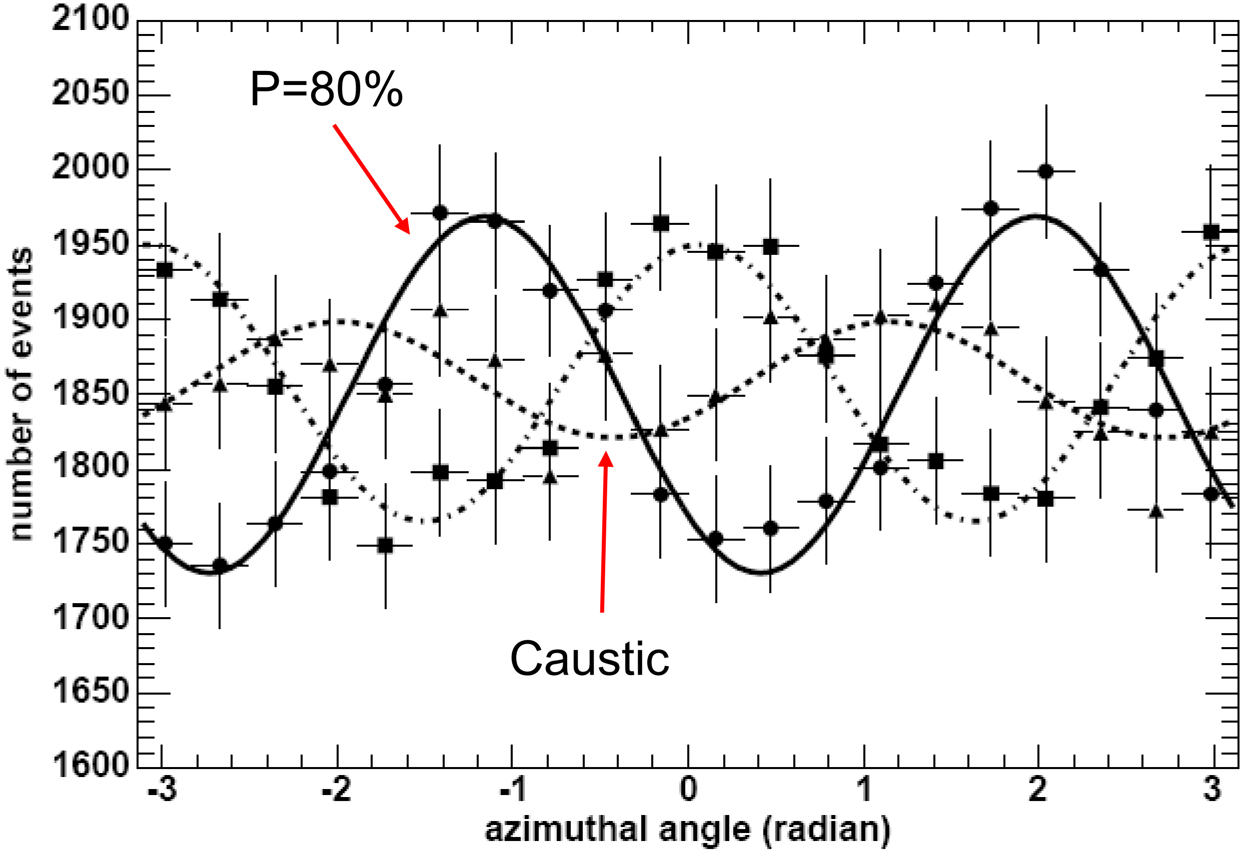
We can detect daily variability in P and angle.

Figure 3.12: Finding the best fit of a simulated observation of a signal polarized 46% at 123° in the polarization dataset. Confidence levels around the fitted value are also shown, and the real degree and angle are within the 68% level.

S. N. Bakas: Master thesis

Crab pulsar (P1)

Expected polarization at **P1 (Δphase=0.1)** in **4 days (24 hours)**
for Polar cap model (P=80%) and Caustic model (P changes sign)

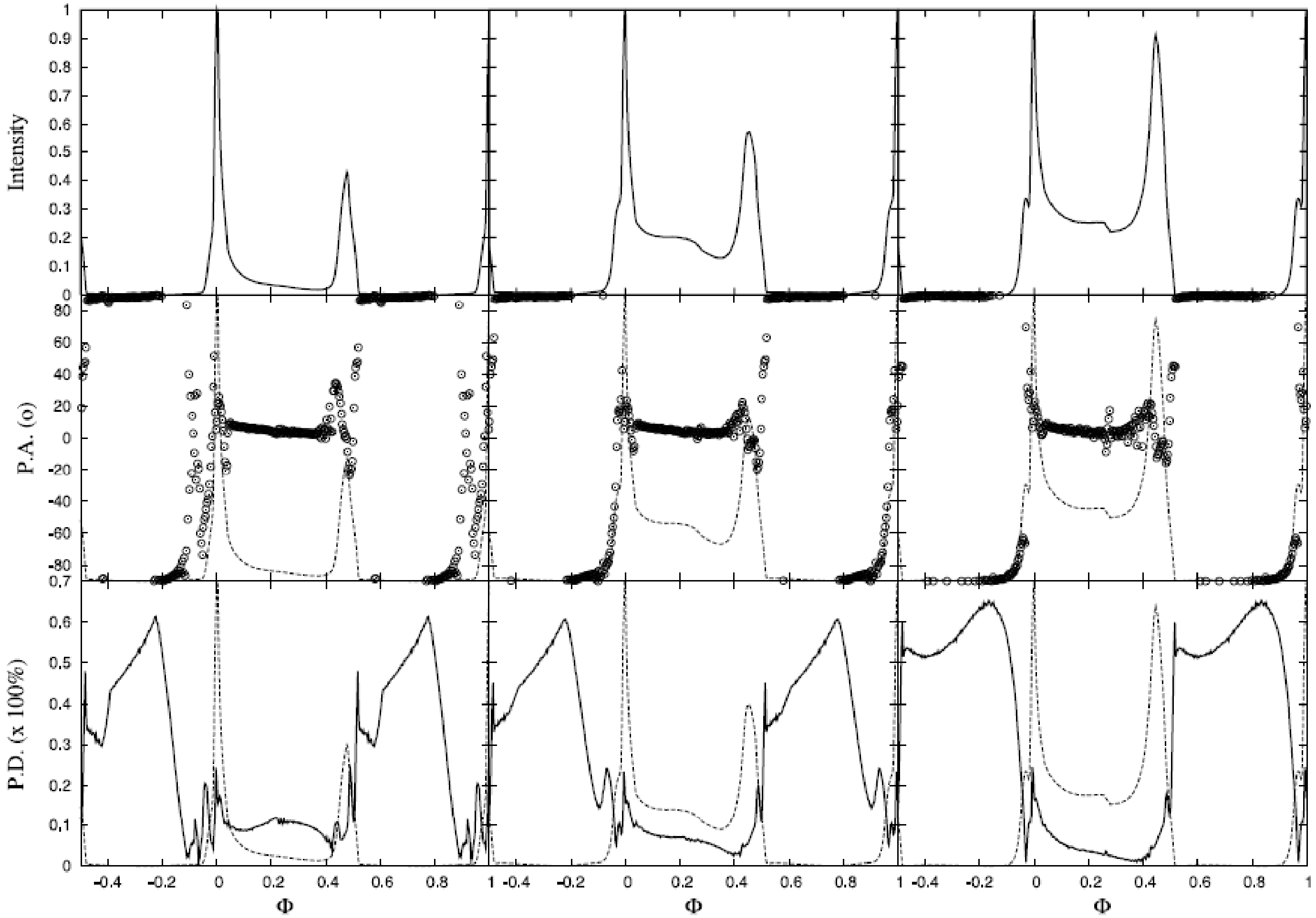


Crab pulsar polarization

- No reliable prediction -

J. TAKATA H.-K. CHANG K. S. CHENG THE ASTROPHYSICAL JOURNAL, 656:1044–1055, 2007 February 20

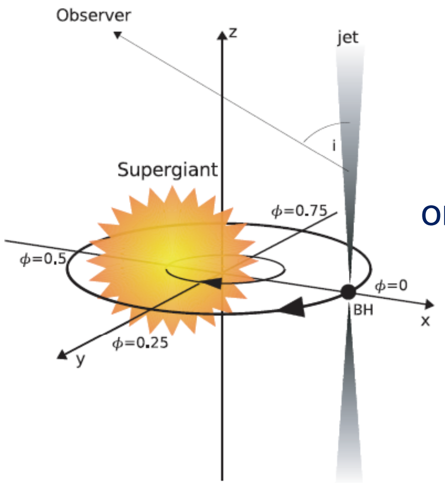
TAKATA, CHANG, & CHENG



Cygnus X-1

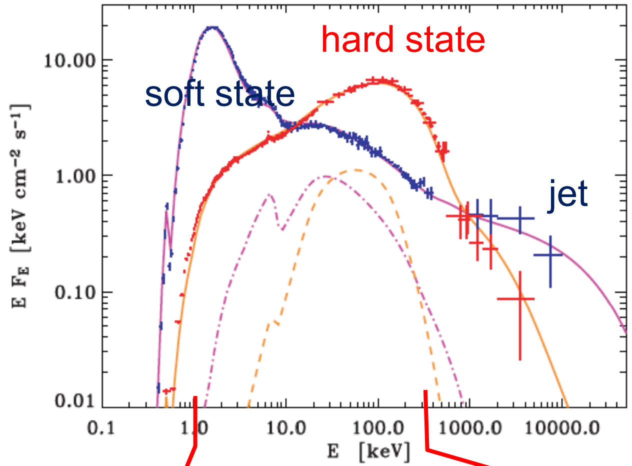
- Most studied Black Hole X-ray binary -

Anna Szostek★ and Andrzej A. Zdziarski★
Mon. Not. R. Astron. Soc. **375**, 793–804 (2007)

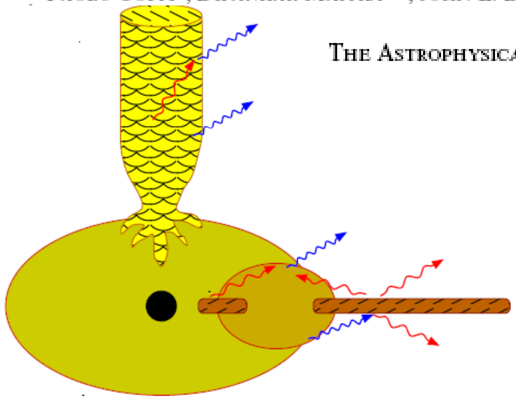


orbit 5.6d

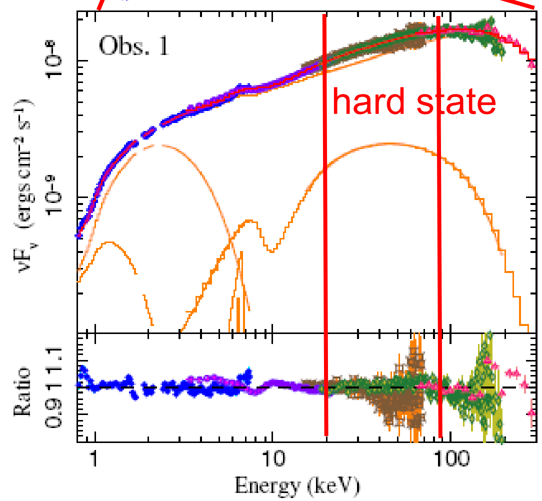
JULIEN MALZAC* and RENAUD BELMONT
International Journal of Modern Physics D
Vol. 19, No. 6 (2010) 769–776



Michael A. Nowak[1], Manfred Hanke[2], Sarah N. Trowbridge[1], Sera B. Markoff[3], Jörn Wilms[2], Katja P
Paolo Coppi[5], Dipankar Maitra[3,6], John E. Davis[1], and Frank Tramper[3]



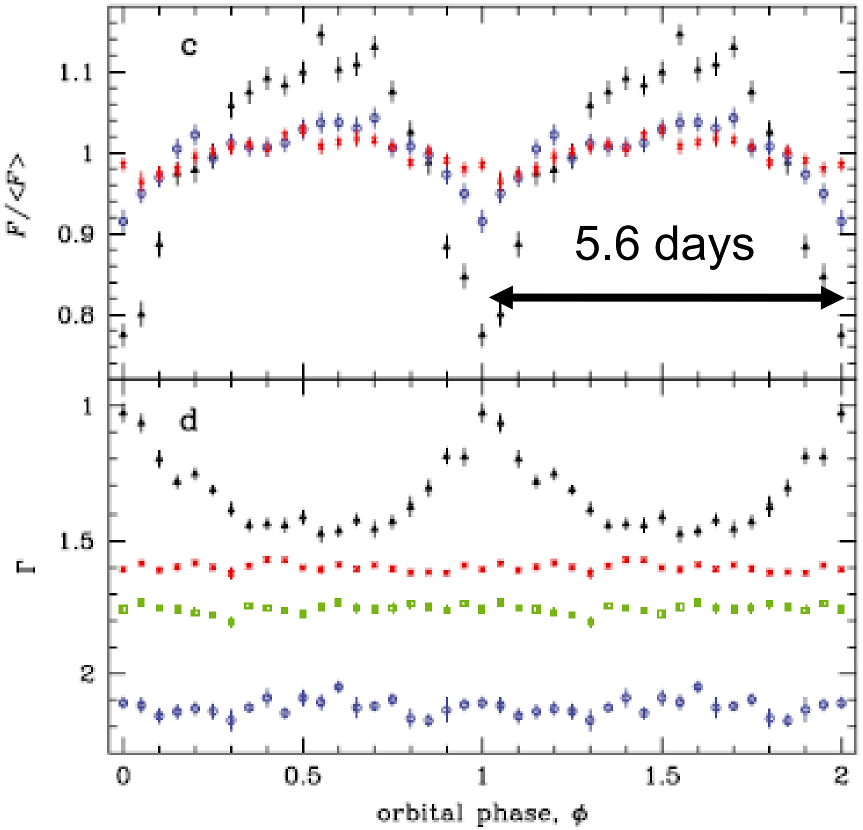
The Astrophysical Journal, 728:13 (21pp), 2011



Cygnus X-1: orbital motion

Andrzej A. Zdziarski,[1★] Guy G. Pooley[2] and Gerald K. Skinner[3,4]

Mon. Not. R. Astron. Soc. 412, 1985–1992 (2011)



Cygnus X-1: may flare

Boris E. Stern,[1,2] Andrei M. Beloborodov,[1] and Juri Poutanen   The Astrophysical Journal, 555:829–833, 2001

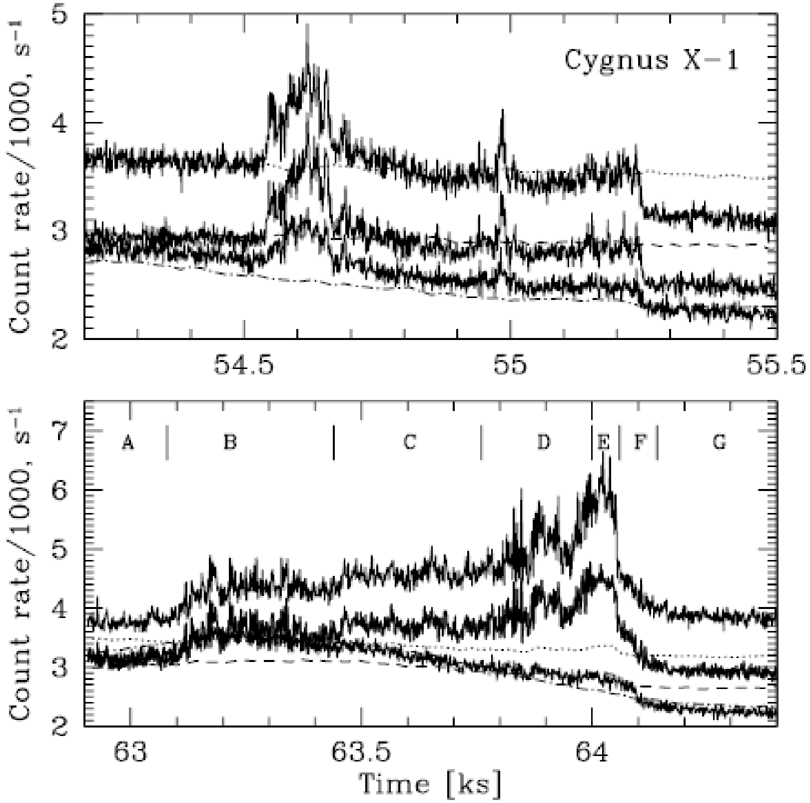


Fig. 1.—Count rate during the two outbursts of Cyg X-1 on 1999 April 21 (TJD 11,289) in LAD energy channels 1–3. The count rate is summed over two detectors closest to the line of sight to Cyg X-1. Count rates are higher in softer channels. Dotted, dashed, and dot-dashed curves show the background in channels 1, 2, and 3, respectively, as seen by two detectors looking away from Cyg X-1.

BATSE (50-300keV) detected 2 bursts
In April 1999.

Pol. meas. of Cygnus X-1 by Integral

Soft state

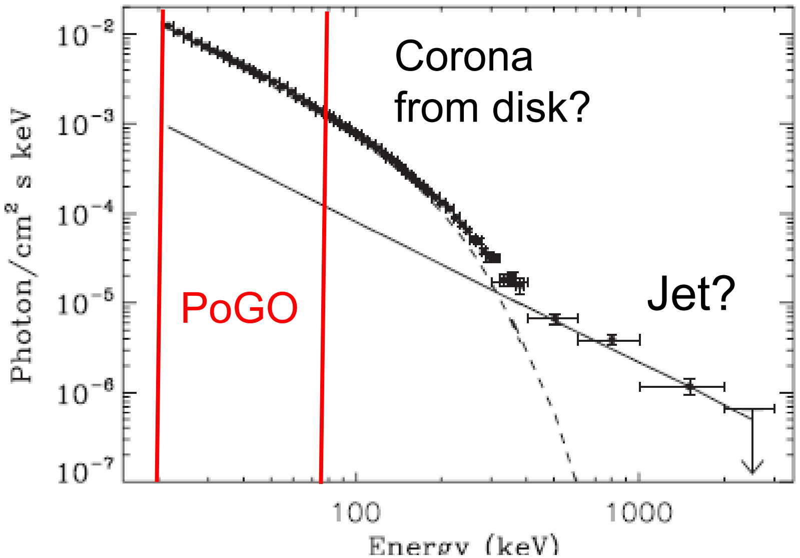
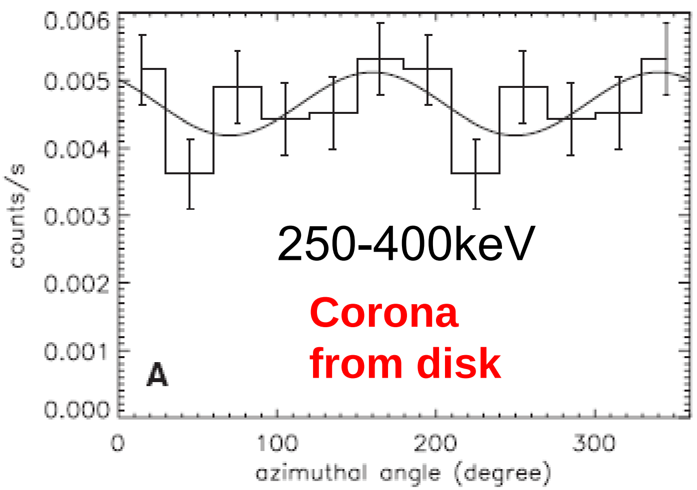
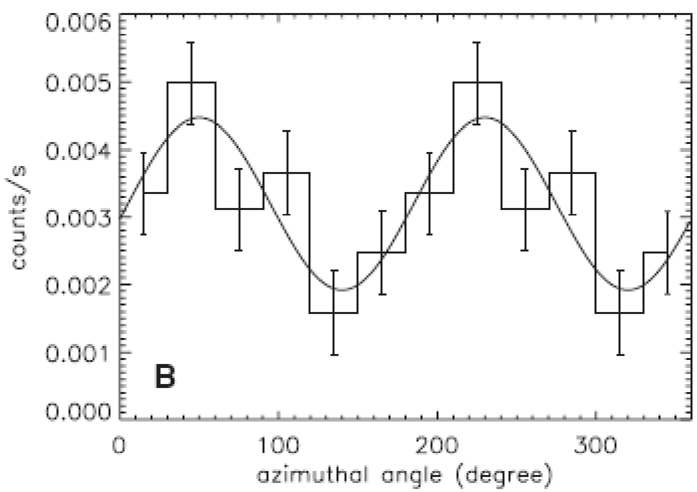


Fig. 1. Cygnus X-1 energy spectrum as measured by the INTEGRAL/IBIS telescope and obtained with the standard IBIS spectral analysis pipeline. Two components are clearly seen: a "Comptonization" spectrum caused by photons upscattered by Compton scattering off thermally distributed electrons in a hot plasma (dashed line), and a higher-energy component (solid line) whose origin is not known.



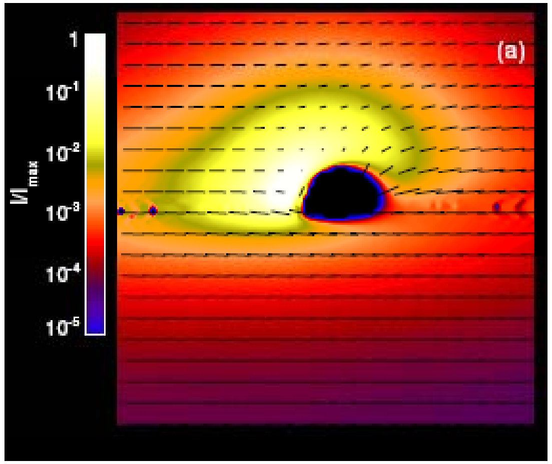
400-2000keV **Jet**



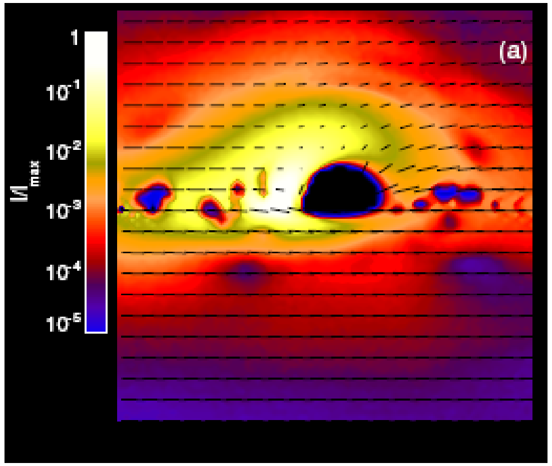
Cyg X-1 in hard state

- Physical model -

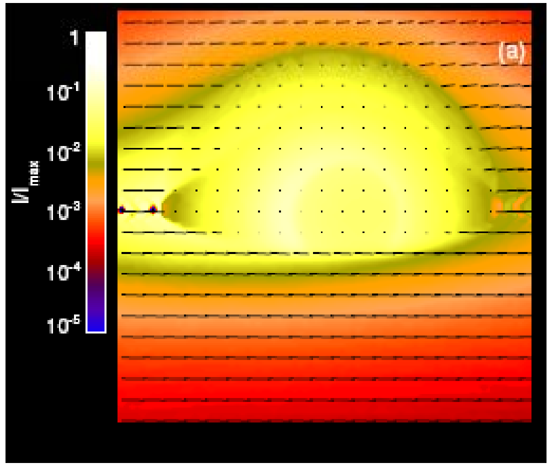
JEREMY D. SCHNITTMAN AND JULIAN H. KROLIK
THE ASTROPHYSICAL JOURNAL, 712:908–924, 2010



Thin disc ("sandwich")

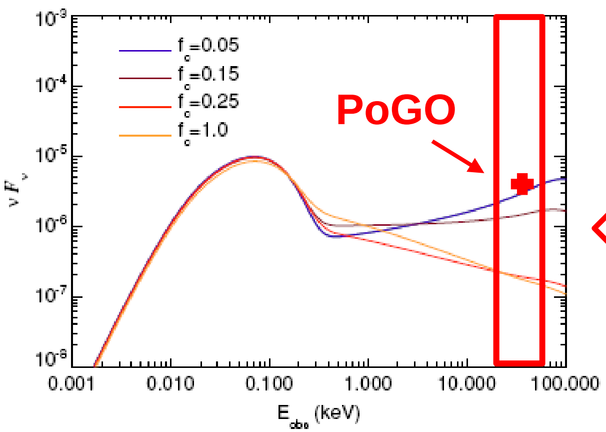


Hot spots

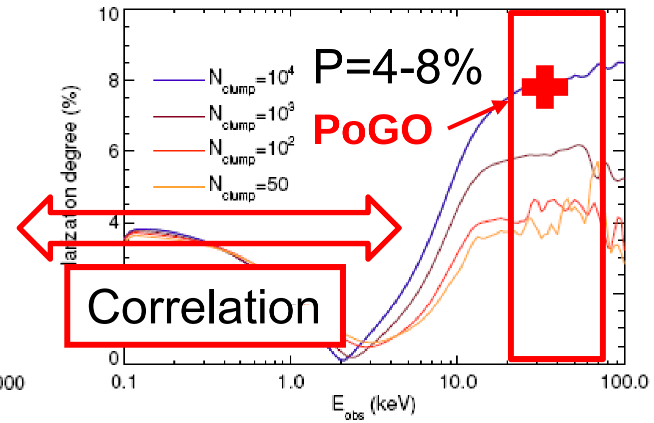


Spherical corona

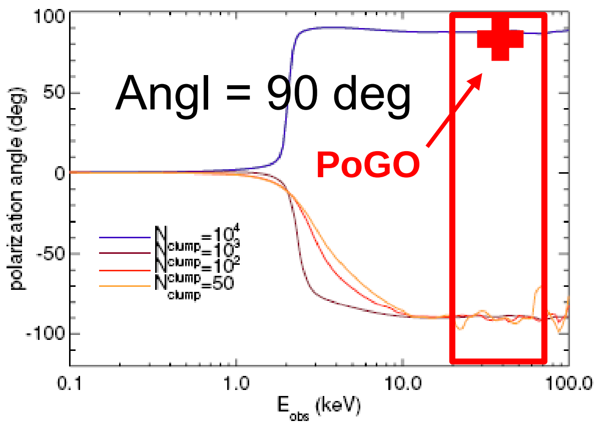
Flux vs model param



Pol degree vs param

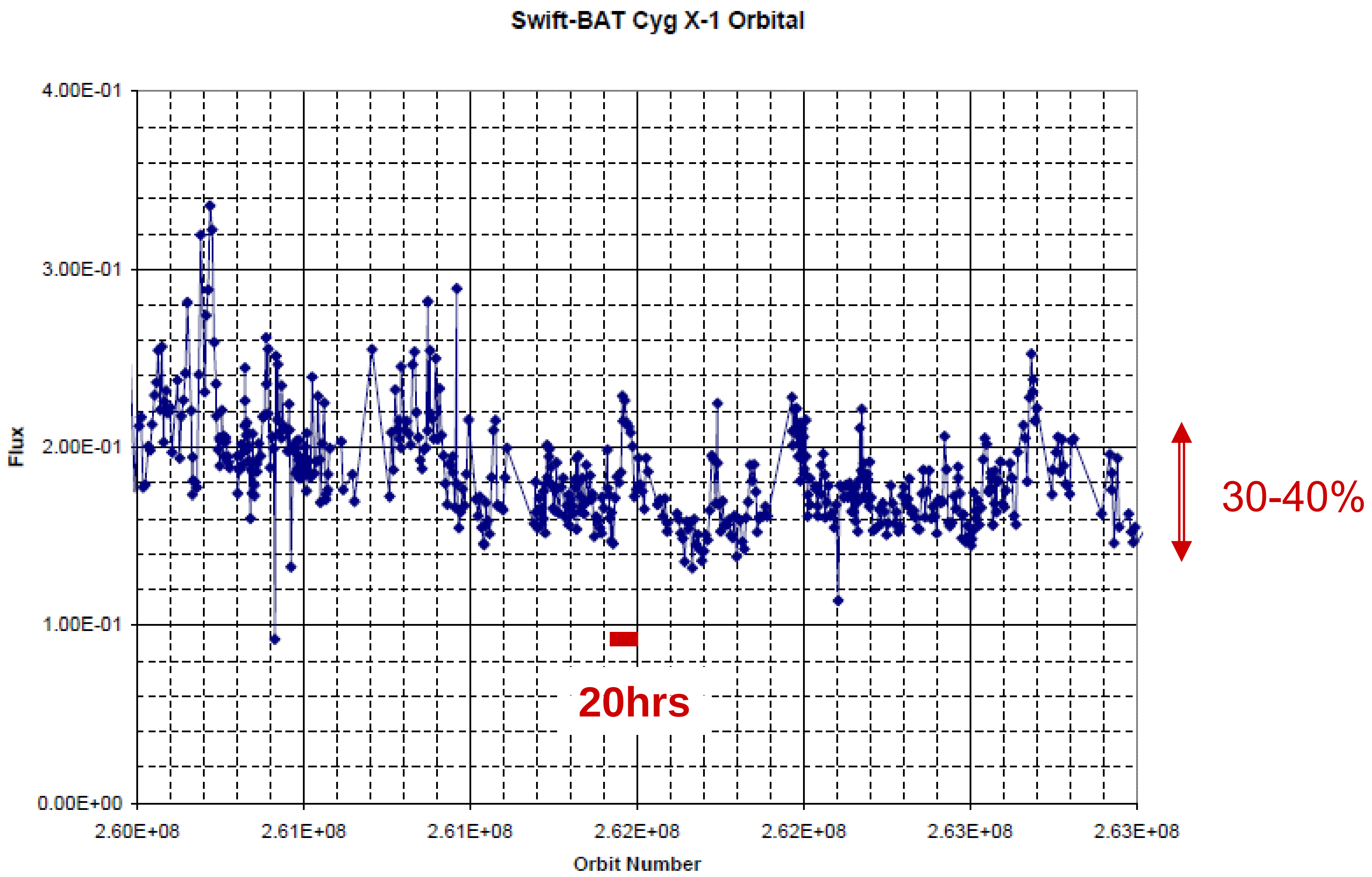


Pol angle vs param



Cygnus X-1

- Orbit-by-orbit Variability -



Cygnus X-1

- Sorting out Low and High Count-Rate Time-Bins -

Makishima, K., Takahashi, H. et al. 2008, PASJ, 60, 585
"Suzaku Results on Cygnus X-1 in the Low/Hard State "

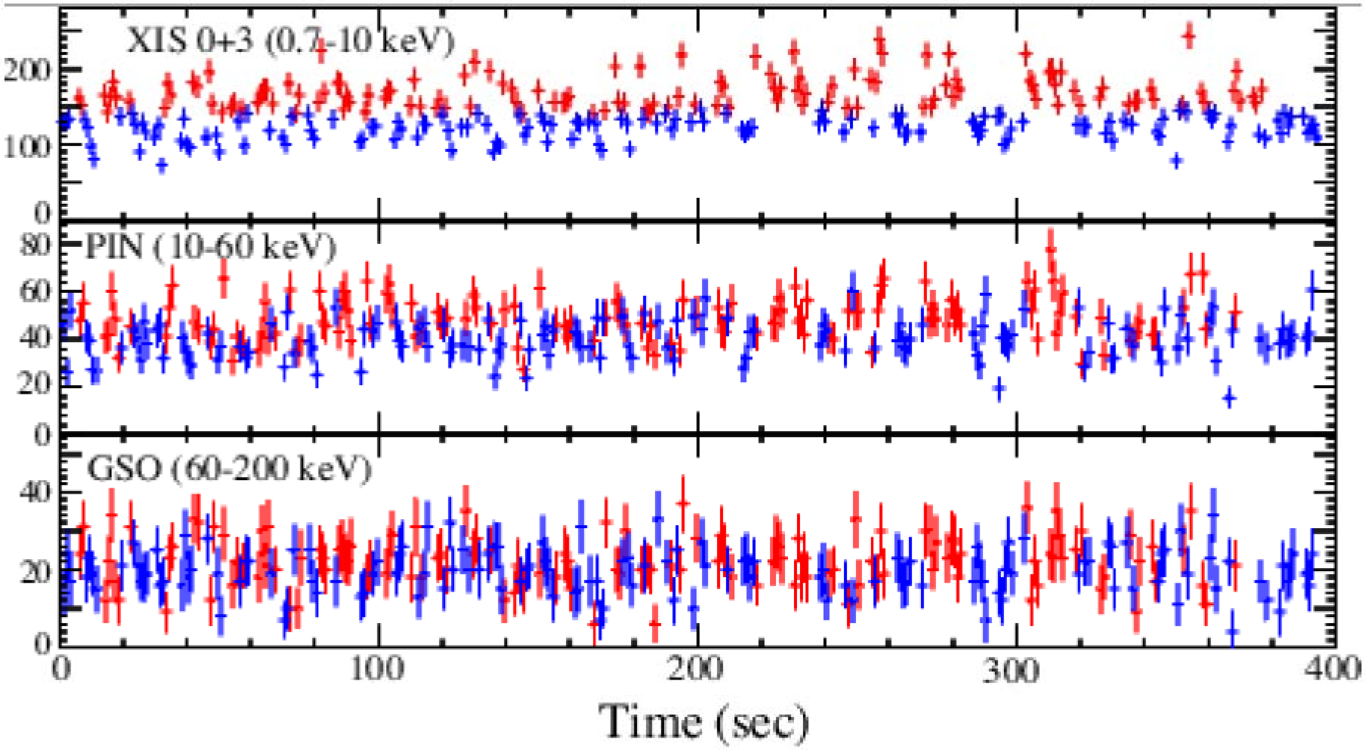


Fig. 7. Background-inclusive XIS (top: 0.7–10 keV), HXD-PIN (middle: 10–60 keV), and HXD-GSO (bottm: 60–200 keV) light curves of Cyg X-1 with 1-s binning, sorted according to the instantaneous XIS0+XIS3 counts. Red and blue data bins represent those when the XIS0+XIS3 counts, C_i, are higher and lower than the local 200 s average, $\bar{C}$, respectively. No correction is made for the instrumental dead times.

Cyg X-1 flip-flops btwn 2 states at hour scale

Makishima, K., Takahashi, H. et al. 2008, PASJ, 60, 585
"Suzaku Results on Cygnus X-1 in the Low/Hard State "

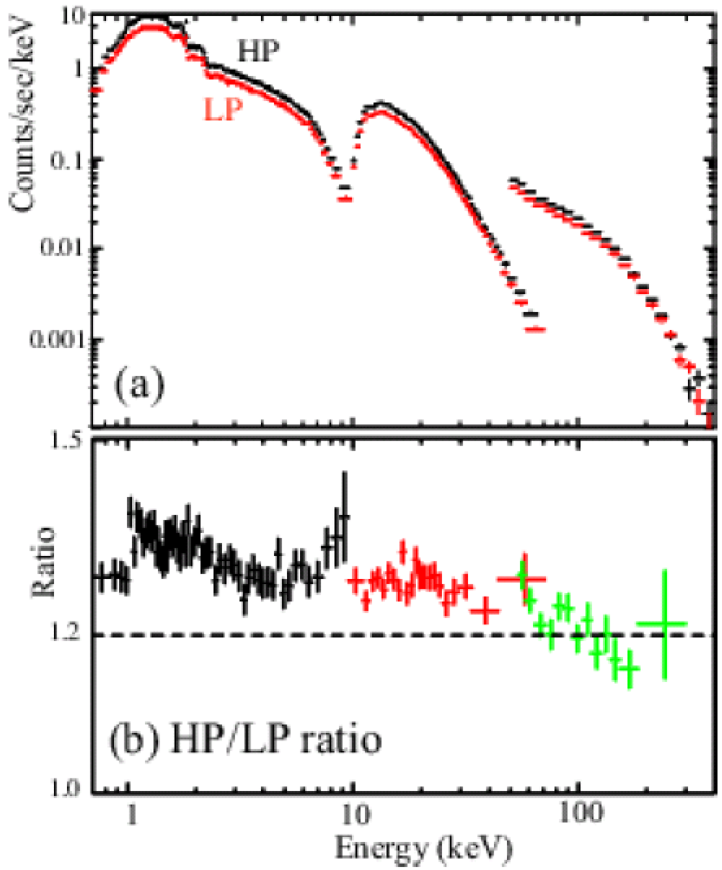
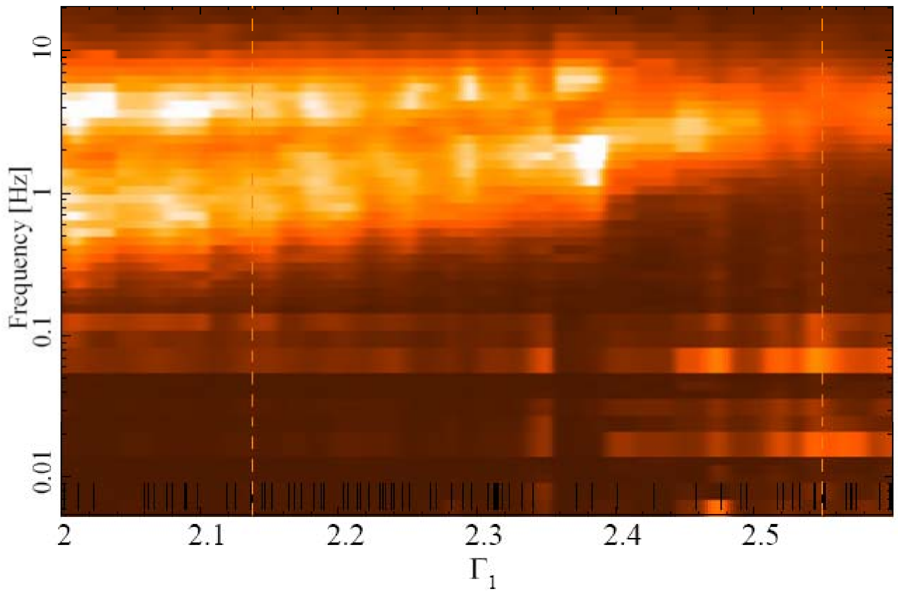
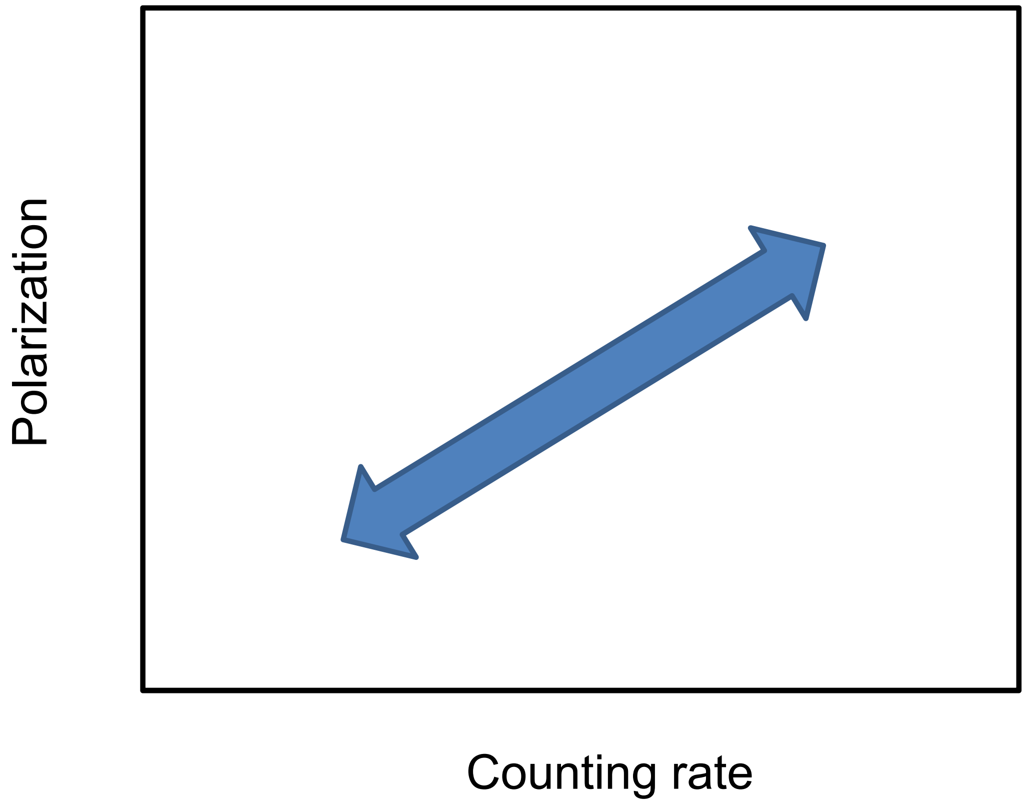


Fig. 8. (a) The HP (high phase; black) and LP (low phase; red) spectra of Cyg X-1 recorded by XIS2, HXD-PIN, and HXD-GSO, while XIS0+XIS3 data are used in the intensity judgement. The corresponding HXD backgrounds have been subtracted. (b) The ratios between the HP and LP spectra.

J. Wilm, M. Boeck, et al. arXiv:0811.2357



Correl. btwn counting rate & polarization?



Background: Cosmic Ray Intensity by ACE

The Astrophysical Journal Letters, 723:L1–L6, 2010 November 1

R. A. Mewaldt[1], A. J. Davis[1], K. A. Lave[2], R. A. Leske[1], E. C. Stone[1], M. E. Wiedenbeck[3], W. R. Binns[2], E. R. Christian[4], A. C. Cummings[1], G. A. de Nolfo[4], M. H. Israel[2], A. W. Labrador[1], and T. T. von Rosenvinge[4]

http://www.srl.caltech.edu/ACE/ASC/DATA/level3/sis/

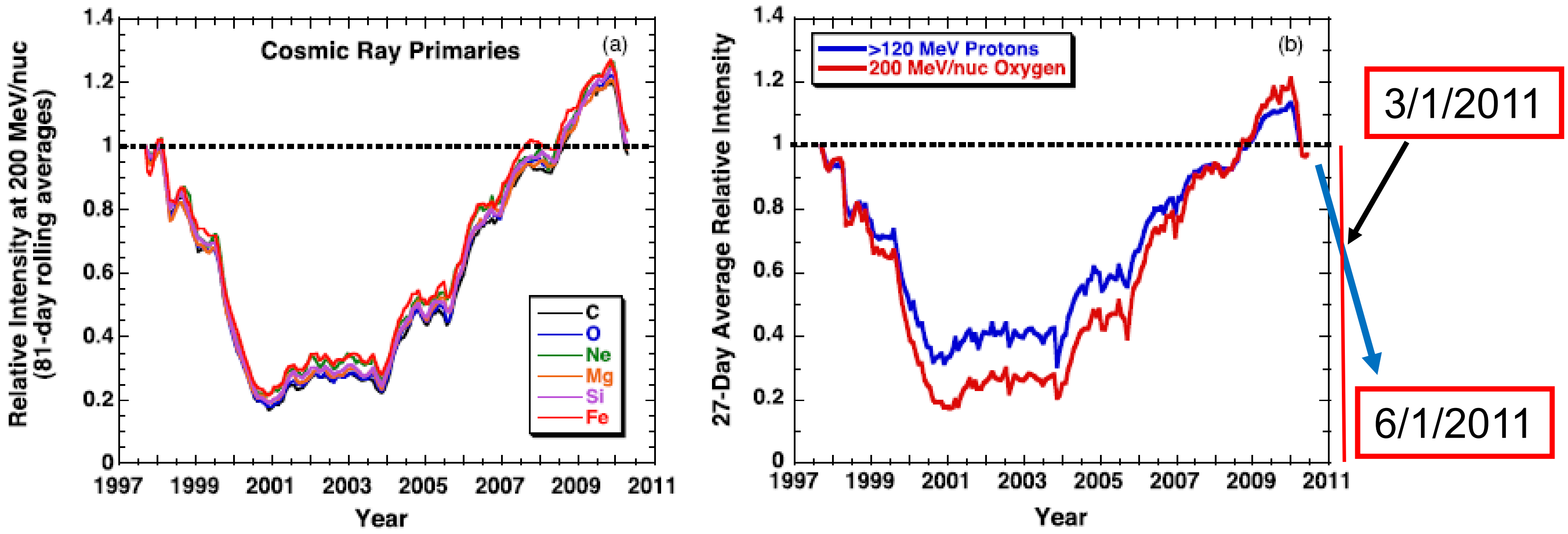


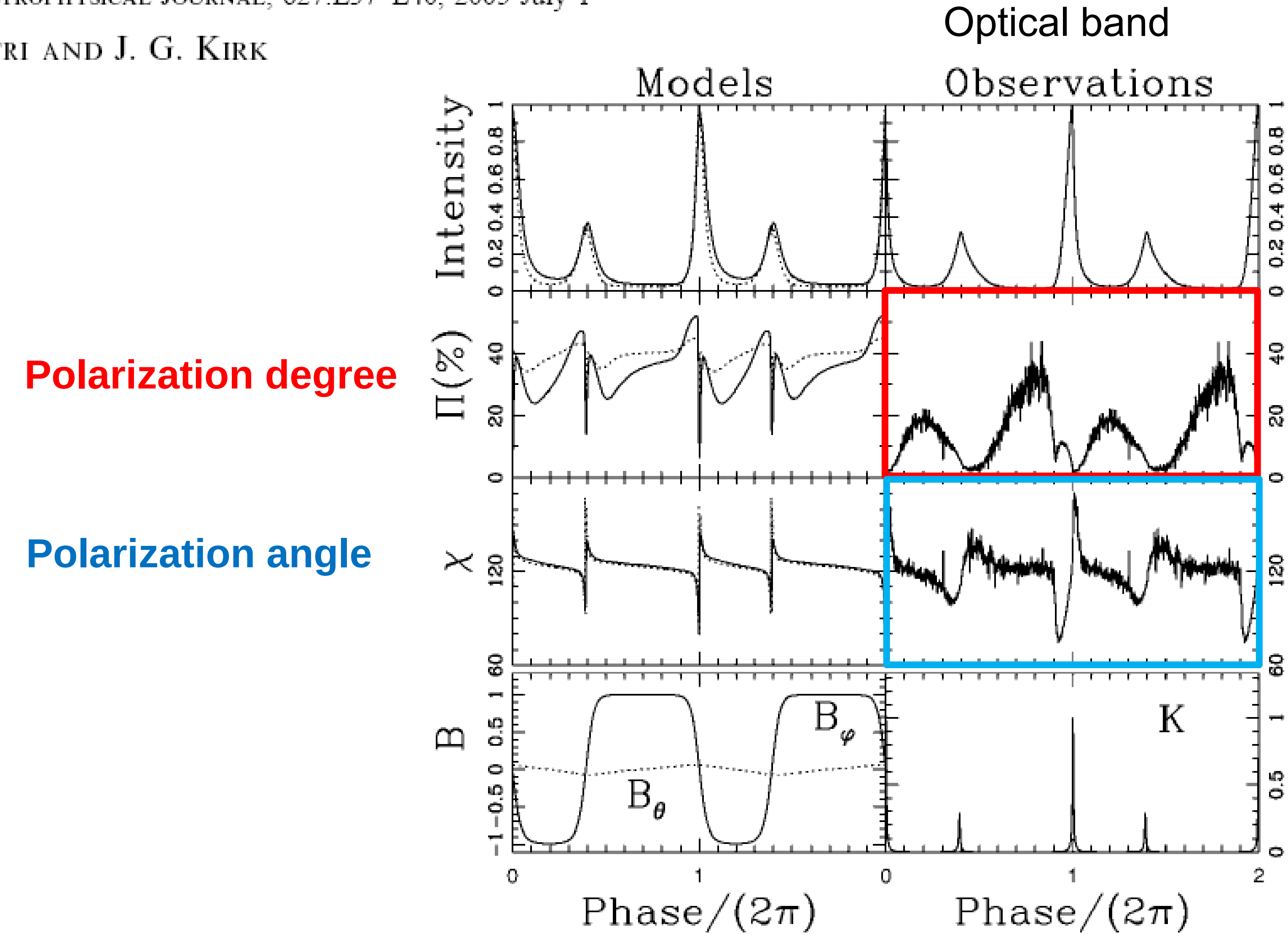
Figure 2. (a) Intensity of six abundant cosmic-ray species at ~200 MeV nucleon^{-1} (rolling averages of three Bartels rotations) with each normalized to the first three rotations of the *ACE* mission (rotations 2240–2242). (b) Twenty-seven day average intensities of >120 MeV protons (see the text) and ~200 MeV nucleon^{-1} oxygen, both normalized to unity during Bartels-rotation 2240 in 1997.

Technical details

Crab pulsar: polarizarion

THE ASTROPHYSICAL JOURNAL, 627:L37–L40, 2005 July 1

J. PÉTRI AND J. G. KIRK



PoGOLite217 effective area

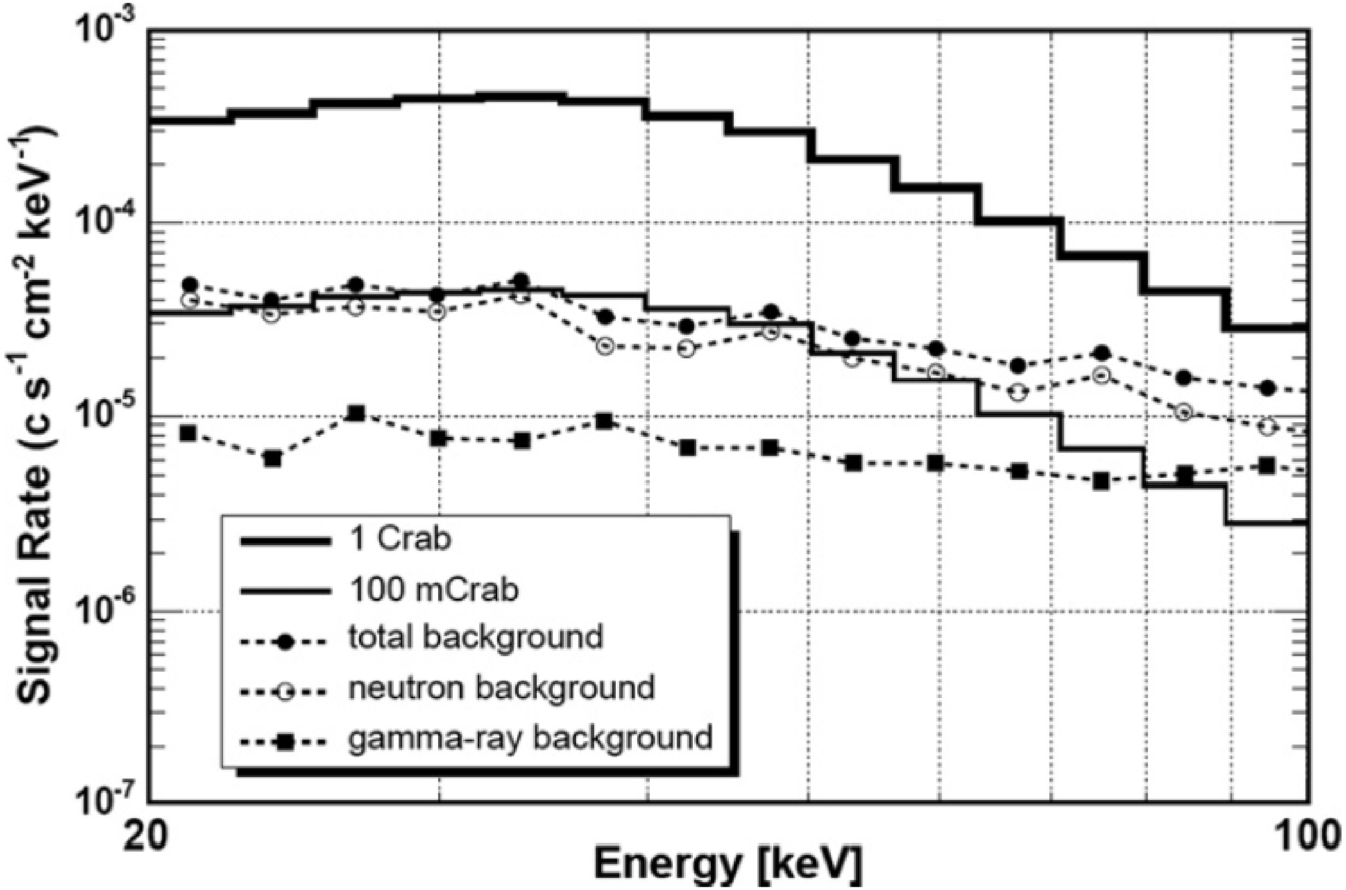


Fig. 11. Expected background rates at an atmospheric overburden of 4 g/cm^2 compared with signal rates expected for a Crab source (thick solid histogram) and a 100 mCrab source (thin solid histogram). (●) total background, (○) neutron background and (■) gamma-ray background.