A High Sensitivity Balloon-Borne Polarimeter PoGOLite

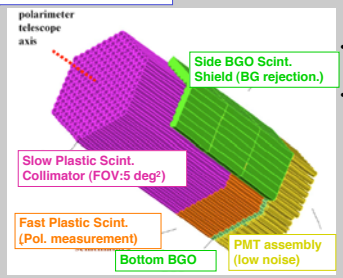
T. Mizuno, T. Tanaka, K. Yamamoto, H. Takahashi, Y. Fukazawa (Hiroshima Univ.), Y. Kanai, M. Arimoto, M. Ueno, J. Kataoka, N. Kawai (Titech), S. Gunji (Yamagata Univ.), Y. Saito, T. Takahashi (ISAS/JAXA), T.P. Ylinen, H. Tajima, T. Kamae (SLAC), M. Kiss, C. Bettolo, M. Pearce (KTH) and PoGOLite collaboration

Abstract:

Polarization measurements in the hard X-ray range can be completely different probes on various high energy astrophysical objects and reveal the emission mechanism in an unambiguous way. PoGOLite is the light-weight version of Polarized Gamma-ray Observer (PoGO) to measure the polarization of gamma-rays in 25-100 keV energy range with unprecedented high sensitivity, being scheduled to be launched in year 2009. The instrument uses Compton scattering and photo-absorption in an array of 217 well-type phoswich detector units which incorporate an active and passive collimation to a narrow field-of-view of about 5 square-degree. With 54 side anticoincidence shields, the background is suppressed to 10mCrab level and sensitivity to <10% polarization of a 100 mCrab source is achieved in a single 6-hour balloon observation. A prototype of 7-19 units was constructed and has been tested in detail in laboratory and by a series of accelerator beam test to prove the detector concepts. Computer simulation based on Geant4 toolkit with polarized dependences included has also been developed extensively through these measurements and proves the expected performance. Here we report the PoGOLite concepts, expected performance and scientific results, laboratory and accelerator tests as well as the future plan.

PoGOLite Mission:

Detector Concept

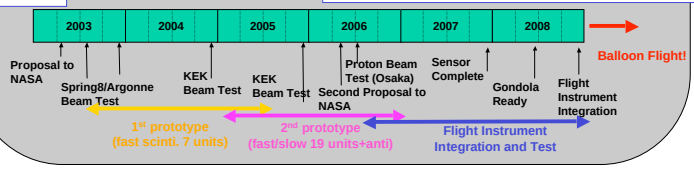


- Compton Polarimeter made of plastic scint.
  - ➢High modulation factor
  - ➢Optimized for Hard X-ray (25-100keV)
- Adopt phoswich detector design with narrow FOV
  - ➢Well proven through balloon missions/Suzaku HXD
  - ➢Very low background
- Read-out through low noise PMT assembly
  - ➢Sensitive down to 1-2 keV Compton events

Internationall Collaboration

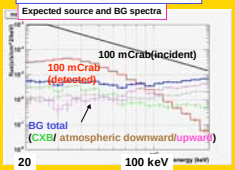
- Japanese Consortium:
  - PMT, Beam test, DAQ, Performance modeling
- Stanford University:
  - ➢Detector array, DAQ, Gondola and attitude control system, Payload integration and testing
- Swedish Consortium:
  - ➢Side-anticoincidence Shield, Observation planning
- Ecolo Polytechnique:
  - ➢Scintillator and crystal reflective material

Schedule

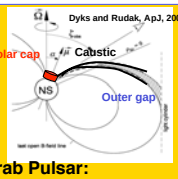


Expected Performance/Science:

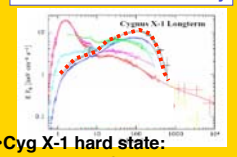
Low BG/High Sensitivity



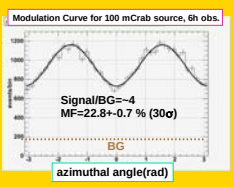
Pulsar Emission Mechanism

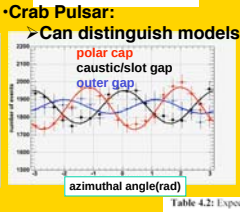


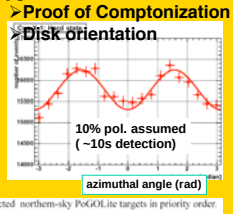
Accretion Disk Geometry



- Cyg X-1 hard state:
  - ➢Proof of Comptonization
  - ➢Disk orientation
- Crab Pulsar:
  - ➢Can distinguish models







- Lots of science by each 6 hr. flight
- Collaboration with Swift/GLAST
- Long duration flight between Sweden and Canada

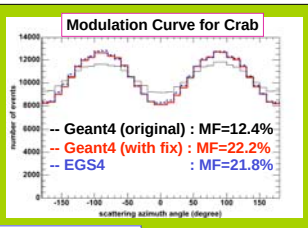
Table 4.2: Expected northern-sky PoGOLite targets in priority order.

Object	Counting Rate	MDP (3σ)
Crab (total)	13.7/s	3%
Cyg X-1	Hard 13.3/s, Soft 4.6/s	Hard 3%, Soft: 5%
Her X-1	2.5/s	8%
Mkn 501 (flare)	0.65/s	14%
V0332+53 (burst)	~4/s	5%
4U0115+63 (burst)	~4/s	5%
GRS 1915 (burst)	~4/s	5%

Hardware/Software Development:

Monte Calro Simulation

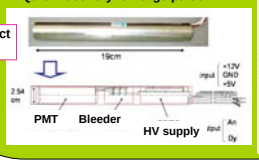
- Geant4 toolkit
  - ➢World Standard
- Polarized Compton Scattering
  - ➢PoGO-fix process
- Rayleigh Scattering
  - ➢Implement Pol. dependence

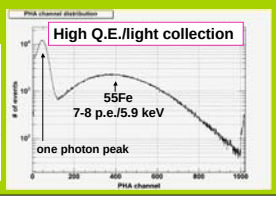


PMT assembly

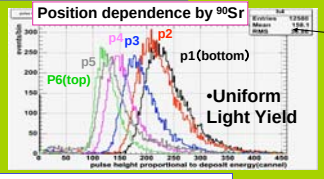
- Kataoka et al. 2005, SPIE
- Bleeder circuit based on Suzaku HXD-II
  - ➢Low power(~300mW/unit; 65W total)
  - ➢Low noise
  - ➢Quick recovery for large pulse

Compact Design

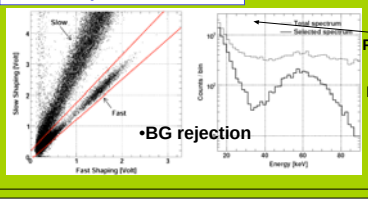


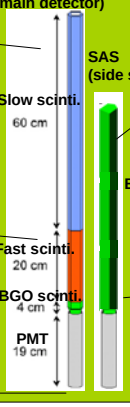


Slow Scintillator tube

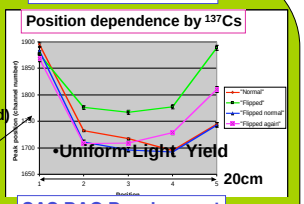


Pulse Shape Discrimination

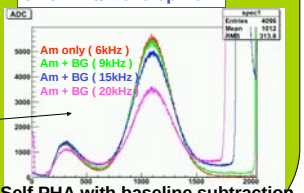




Side BGO Scintillator



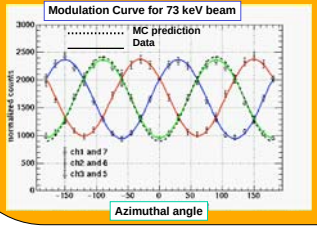
SAS DAQ Development



- Self PHA with baseline subtraction
- Stable up to 20kHz

Argonne Beam Test (2003)

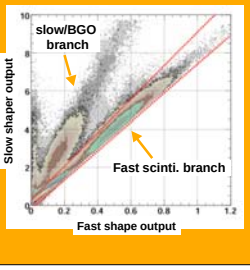
- Mizuno et al. 2004, NIMA
  - ➢Proof of detector concept
  - ➢G4 simulation development

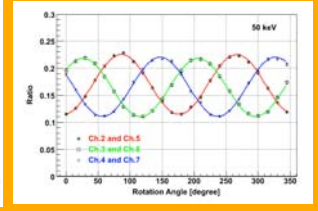


Synchrotron Beam Tests:

KEK Beam Test (2004/2005)

- Kataoka et al. 2005, SPIE
- Kanai et al. 2006, NIMA submitted
  - ➢Realistic configuration
  - ➢proof of pulse shape discrimination
  - ➢Low energy response (30-70 keV)





Future Plan:

- DAQ Development
  - ➢SpaceWire readout
  - ➢Waveform digitizer (PDC): BG rejection, pol. measurement
  - ➢Self PHA (SAS): BG monitor
- Proton Beam Test at Osaka Univ. (this summer)
  - ➢Test of analog/digital electronics
- Sensor mass production
  - ➢217 units (PDC), 54 untis (SAS)
- G4 simulation development
  - ➢Performance modeling
  - ➢Laboratory test/beam test
- Gondolla andPointing System

Summary :

- Polarization measurement in Hard X-ray
  - ➢Unambiguous determination of emission mechanism
- PoGOLite Mission
  - First balloon flight in year 2009 (Crab/Cyg X-1)
  - Unprecedented high sensitivity
  - Unique science by collaboration with GLAST/Swift
  - Extensive Hardware/software development