GEMS Science

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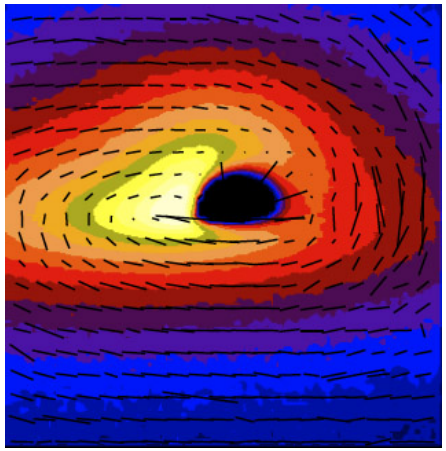
GEMS will open the frontier of X-ray Polarimetry

- "X-ray polarization provides ***unique insight*** into processes occurring near black holes and neutron stars ….. and allows powerful new tests of fundamental physics. ***Its measurement has been a major goal in astrophysics for almost 40 years***" (GEMS TMCO evaluation)
- X-ray polarimetry is listed as a priority for 21st century space astronomy in the NRC report entitled "Connecting Quarks with the Cosmos: Eleven Science Questions for the New Century".
- Polarization in the X-ray band is ***unexplored***; the polarization of only one object outside the solar system has been previously detected.
- GEMS will make the ***first sensitive survey*** of X-ray polarization from many classes of Galactic and extragalactic sources, with an expectation of many discoveries
- GEMS will provide information which cannot be obtained by any other technique or from any existing or planned observatory.

X-ray Polarimetry provides unique information

- Polarization can be used to study spatial structures of black holes, neutron stars and supernova remnants far smaller than can be imaged.
- Polarization will reveal a distinct signature of the spacetime near black holes as predicted by general relativity
- Polarization provides new insight into the geometry and flow of matter in the strongest magnetic fields known.
- X-ray polarimetry will enable the first astrophysical observation of quantum electrodynamic (QED) effects in strong magnetic fields.

< 0.02 micro arc-sec >



Black hole simulation: intensity (color), polarization vectors

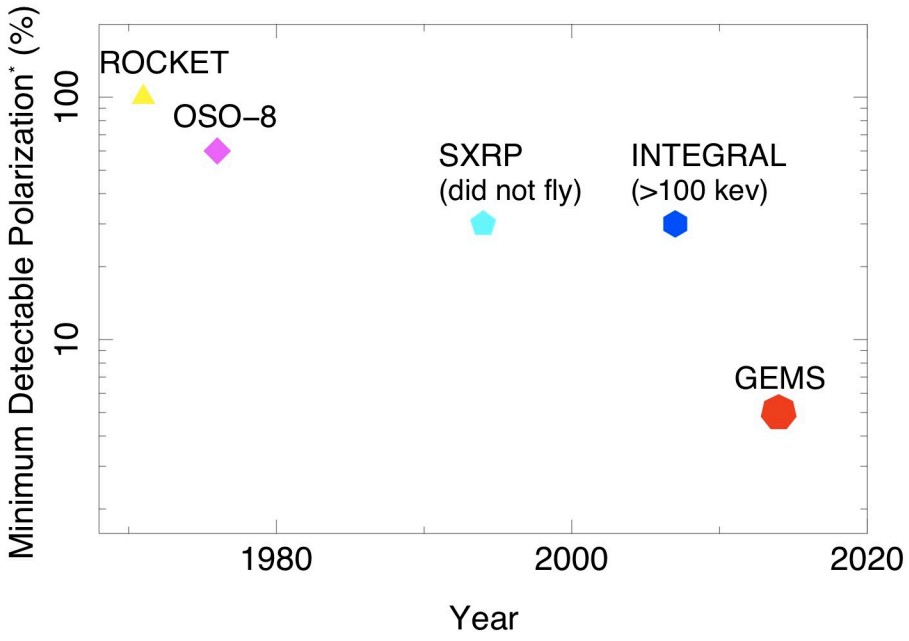
Artist's rendition of a neutron star with magnetar magnetic fields

GEMS provide unique and independent information on many astrophysical phenomena

Astrophysics question	Unique probe	Independent test
Measure the distortion of space-time due to black hole spin		✔
Geometry of black hole accretion flow		✔
Blazar field geometry and radiation mechanisms		✔
Energy release location in rotation powered pulsars	✔	
QED polarization mode switching	✔	
Geometry of X-ray emission from accreting pulsars	✔	
Magnetar field geometry and evolution	✔	
Degree of turbulence in supernova remnant magnetic fields	✔	
Orientation of supernova remnant magnetic fields		✔

The time is right for GEMS

- Many recent concepts from Italy, China, Japan, India, plus US.
- GEMS provides opportunity for US leadership.
- GEMS was selected from among several X-ray polarimetry proposals.
- With technology breakthrough, GEMS has much greater sensitivity than past X-ray polarimeters:
  - ~1000x greater area than OSO-8.
  - ~15x lower minimum detectable polarization.



*100ks observation of 1 mCrab source

- GEMS will complement other high energy missions in the 2014-2016 timeframe – providing crucial polarization information on a wide variety of sources

GEMS observing program will be the first sensitive survey of X-ray polarization

- GEMS will observe >23 targets during the 9-month PI observing program
- Each target will be observed to a sensitivity level (MDP) much less than previous limits or theory predictions.
- Spectra and pulse timing will also be explored.
- With a lifetime extended to 2 years to include a General Observer Program, more than 60 targets are accessible.

Source class	MDP(%)	Number of targets	GO targets
Stellar BHs	1	3	~10
Seyferts	1-2	3	~10
Blazars	2-4	3	~10
Magnetars	5-10	3	~5
Rotation pulsars	10	2	~5
Accreting pulsars	1-2	3	~15
Shell SNRs	5	3	~5
PWN	5	3	~5
Other (CV, lmxb)	various		~50

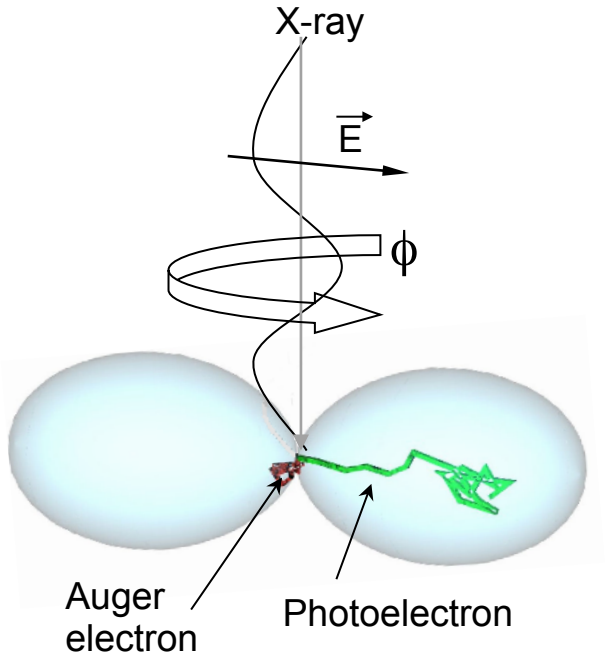
The majority of these observations will generate fundamentally new results.

The astrophysics community is excited about GEMS

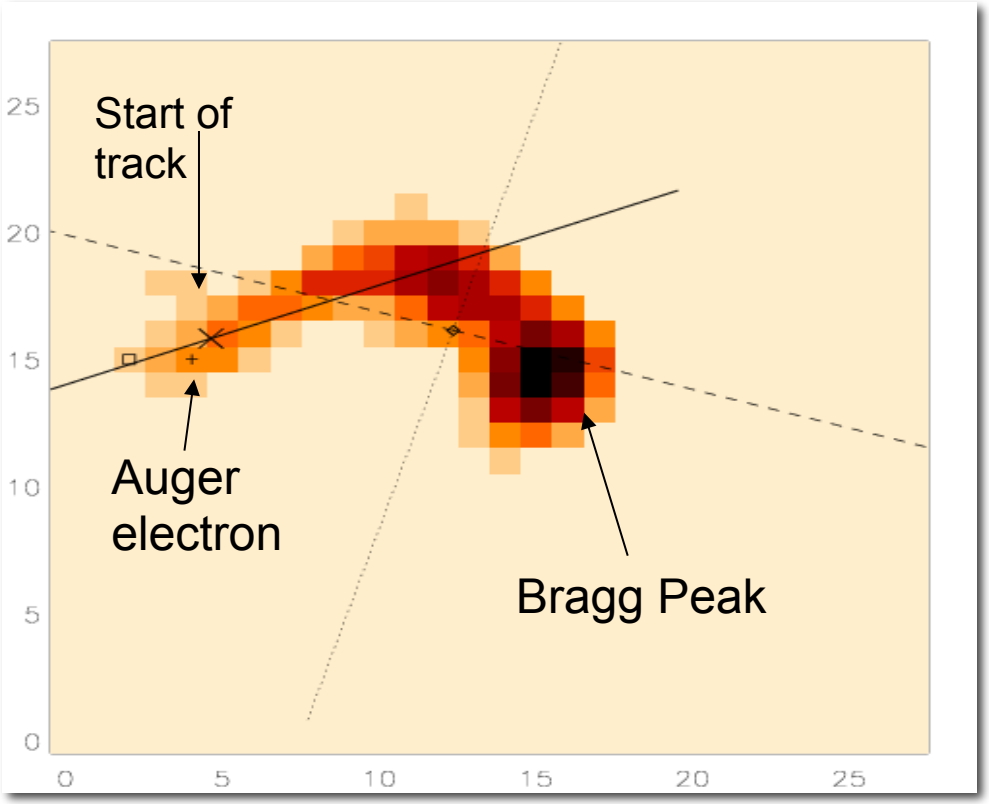
- Astro2010:
  - GEMS science addresses top level themes under ‘Physics of the Universe’, ‘Understanding Cosmic Order’ and ‘Frontiers of Knowledge’.
  - X-ray polarimetry and GEMS mentioned prominently in panel reports ‘Electromagnetic Observations from Space’ and ‘Galaxies Across Cosmic Time’.
  - 6 whitepapers mentioning X-ray polarimetry.
- ~200 papers since 2000 in astrophysical literature on X-ray polarimetry.
- Dedicated X-ray polarimetry conference sessions:
  - Stanford 2004; Rome 2009; Snowpac 2010 (Utah); HEAD 2011 (Newport RI); Cospar 2012 (India); IAU 2012 (China).
- Leaders of world astrophysics have written papers devoted to X-ray polarization: Rees, Blandford, Fabian, Sunyaev.

GEMS Instrument Technology Status

GEMS polarimeters use the polarization sensitivity of the photoelectric effect



- Each event creates a track image which can be used to reconstruct the photon polarization.

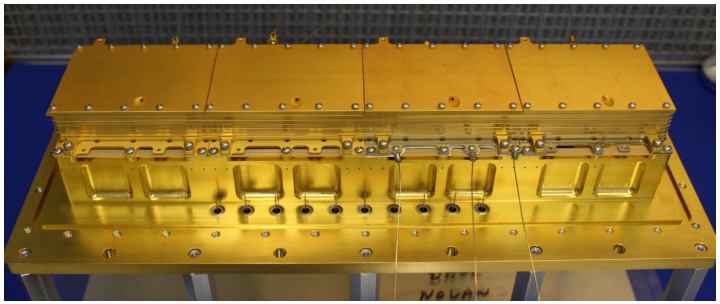


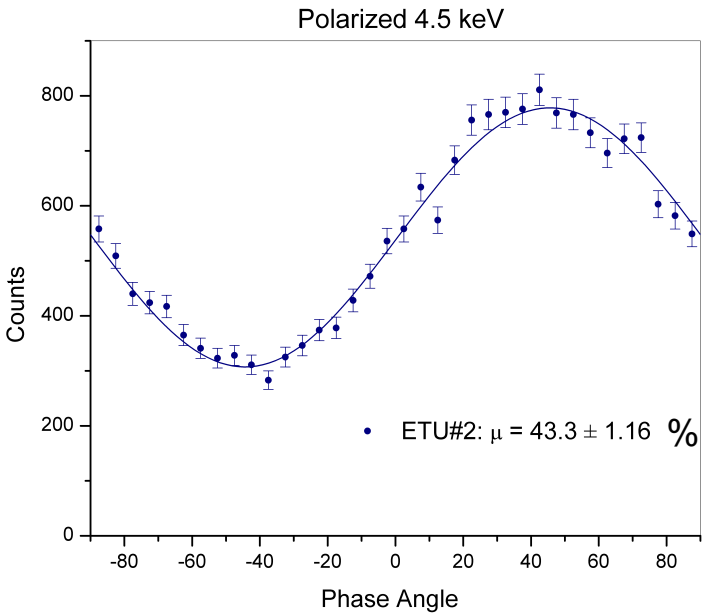
The Polarimeter is Ready for Flight Fabrication

The polarimeter concept has been robustly implemented, vibrated and thermal cycled.

The polarimeter passed a Goddard TRL-6 review on October 13, 2011:

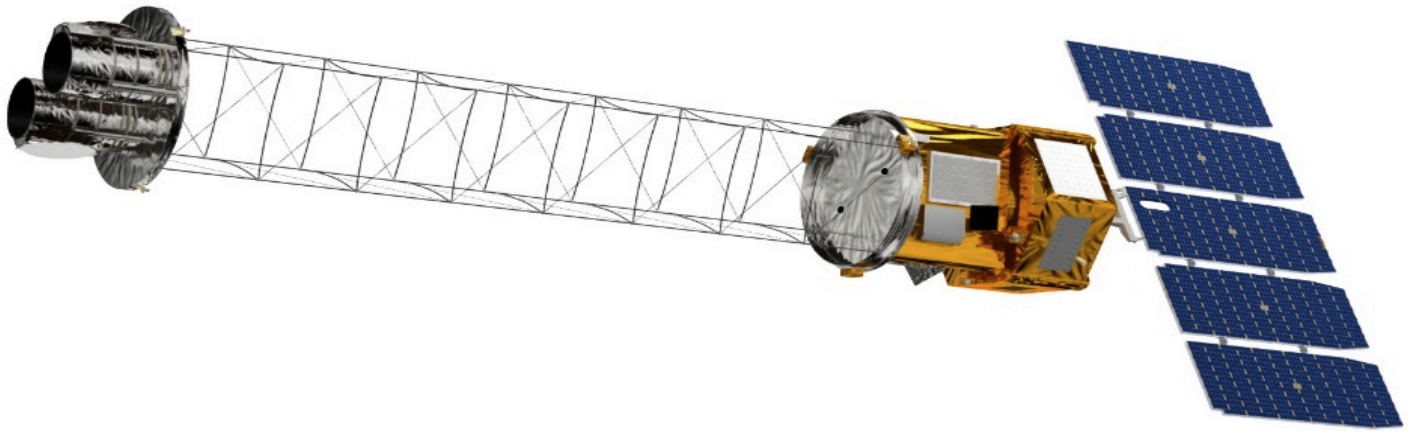
"The independent team's assessment is that the GEMS Polarimeter is currently at a TRL-6. The review team felt that the project properly bounded the technology demonstration program, and did an excellent job describing requirements as they flowed down to the polarimeter. The project thoroughly demonstrated performance through modeling, analysis and test." -- *Michael Hagopian, TRL-6 review panel chair and GSFC AETD Chief Engineer.*





GEMS polarimetry requires deployed mirrors and a rotating observatory

- The polarimeters are sensitive in the 2-10 keV range
- They are at the foci of grazing incidence X-ray mirrors
- A “Coilable” boom extends the mirrors for a focal length of 4.5 m
- Rotation about the science axis at 0.1 rpm for > 100 rotations per target provides measurement and control of systematics.
- A U. Iowa Student Experiment uses the rotation for a Bragg Reflection Polarimeter at 0.5 keV.
- Pointing 90±25 degrees from sun allows the long observations needed for high priority faint targets.



Critical GEMS technology challenges have been overcome

Instrument Requirement	GEMS Design	Status
High sensitivity polarimeter	Time Projection Chamber provides images of photoelectron tracks.	TRL-6 achieved; EPR, MRR successful; Drawings will be fully released by PDR; procedures approved.
Low background	Anti-coincidence; rise time discrimination; shielding.	Predicted rate has 25% margin. Lab confirmation in process.
Stable long term performance	Clean materials and processes; sufficient bake-outs; getter.	Measurements in progress to determine bake-out time required, finalize getter. Investigating C-seals.
High rate	Focusing optics.	Suzaku mirror design (Goddard)
4.5 m focal length	Extendable optical bench.	Successful ETU and PDR.
Calibrations	Detailed ground calibration; continuous in-orbit calibration.	Specialized sources made; TRL-6 achieved for in-orbit source.
Low systematics	Uniform polarimeter fields; rotating spacecraft (0.1 rpm).	No false polarization in ETU; SC PDR verified capability.