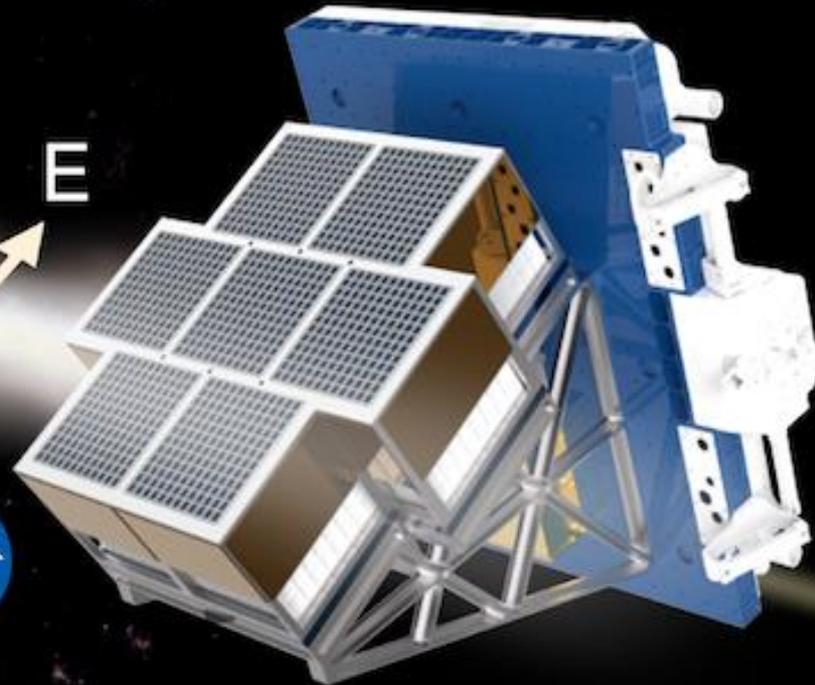


LARGE AREA BURST POLARIMETER

LEAP



Colleen Wilson-Hodge (NASA/MSFC)
on behalf of the LEAP collaboration



LEAP Science Team

PI : Mark McConnell (UNH/SwRI)

Deputy PI : Jessica Gaskin (MSFC)

Project Scientist : Colleen Wilson-Hodge (MSFC)

Matthew Baring (Rice)

Peter Bloser (UNH)

Michael Briggs (UAH)

Joseph Dwyer (UNH)

Francois Foucart (UNH)

Adam Goldstein (USRA)

Eric Grove (NRL)

Shuichi Gunji (Yamagata Univ)

Dieter Hartmann (Clemson)

Joanne Hill-Kittle (GSFC)

Michelle Hui (MSFC)

R. Marc Kippen (LANL)

Fabian Kislak (UNH)

Daniel Kocevski (MSFC)

Merlin Kole (Univ of Geneva)

John Krizmanic (GSFC)

Tyson Littenberg (MSFC)

Maxim Lyutikov (Purdue)

David Mattingly (UNH)

Sheila McBreen (UCD) Chip Meegan (UAH)

William Paciesas (USRA)

Mark Pearce (KTH)

Rob Preece (UAH)

Chanda Prescod-Weinstein (UNH)

Nicolas Prodiut (Univ of Geneva)

Jim Ryan (UNH)

Felix Ryde (KTH)

Steve Sturmer (GSFC)

Kenji Toma (Tohoku Univ)

W. Thomas Vestrand (LANL)

Bing Zhang (UNLV)

Haocheng Zhang (Purdue)





LEAP will Tell Us About...

1 – JET COMPOSITION

Is the jet dominated by matter or radiation?

2 – JET MAGNETIC FIELD STRUCTURE

Are the magnetic fields oriented at random or do they have an ordered structure?

3 – JET ENERGY DISSIPATION PROCESS

Is the jet energy dissipated through internal shocks or reconnection?

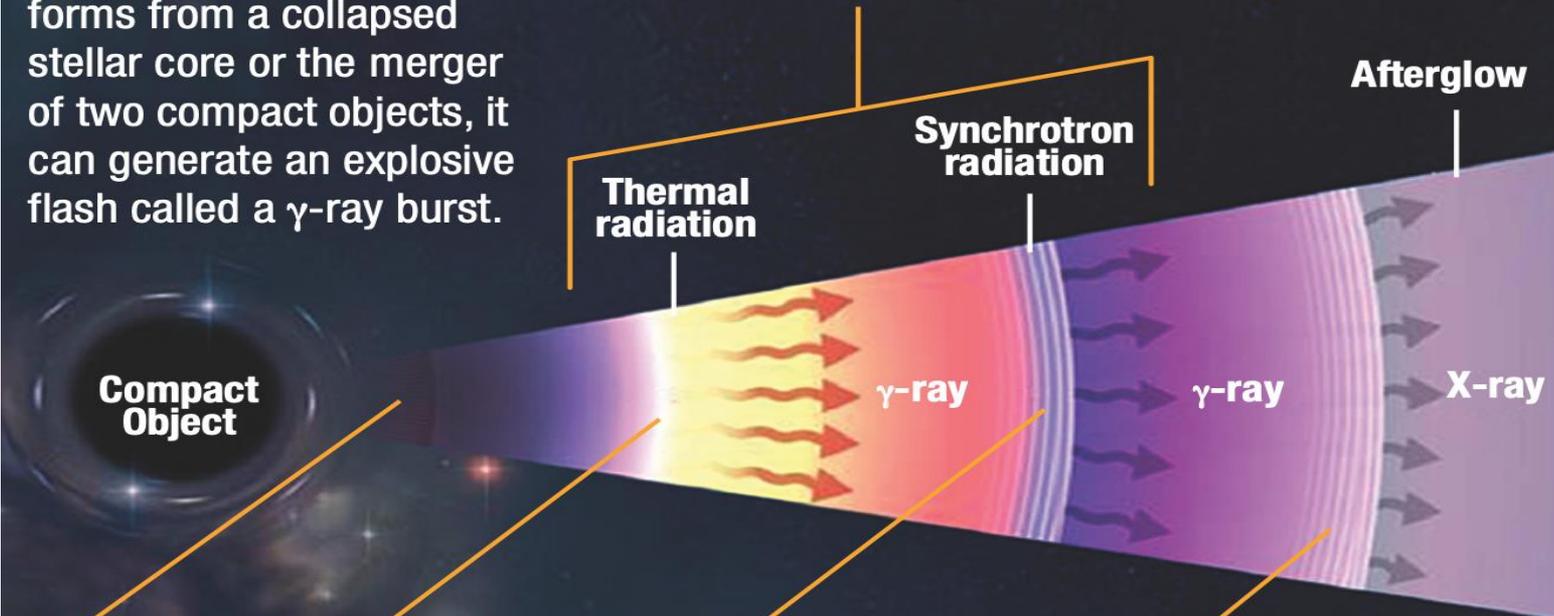
4 – PROMPT EMISSION MECHANISM

What roles do synchrotron, inverse Compton, and thermal emission play?

Anatomy of a Gamma-Ray Burst

When a compact object forms from a collapsed stellar core or the merger of two compact objects, it can generate an explosive flash called a γ -ray burst.

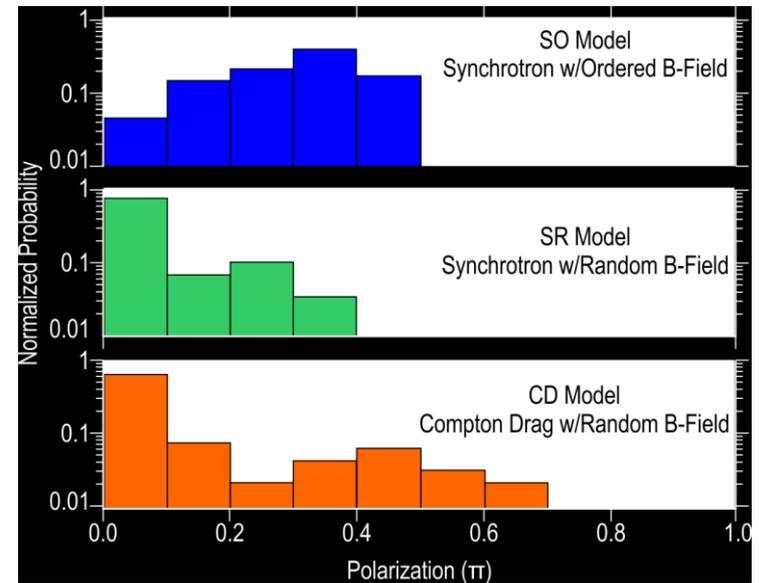
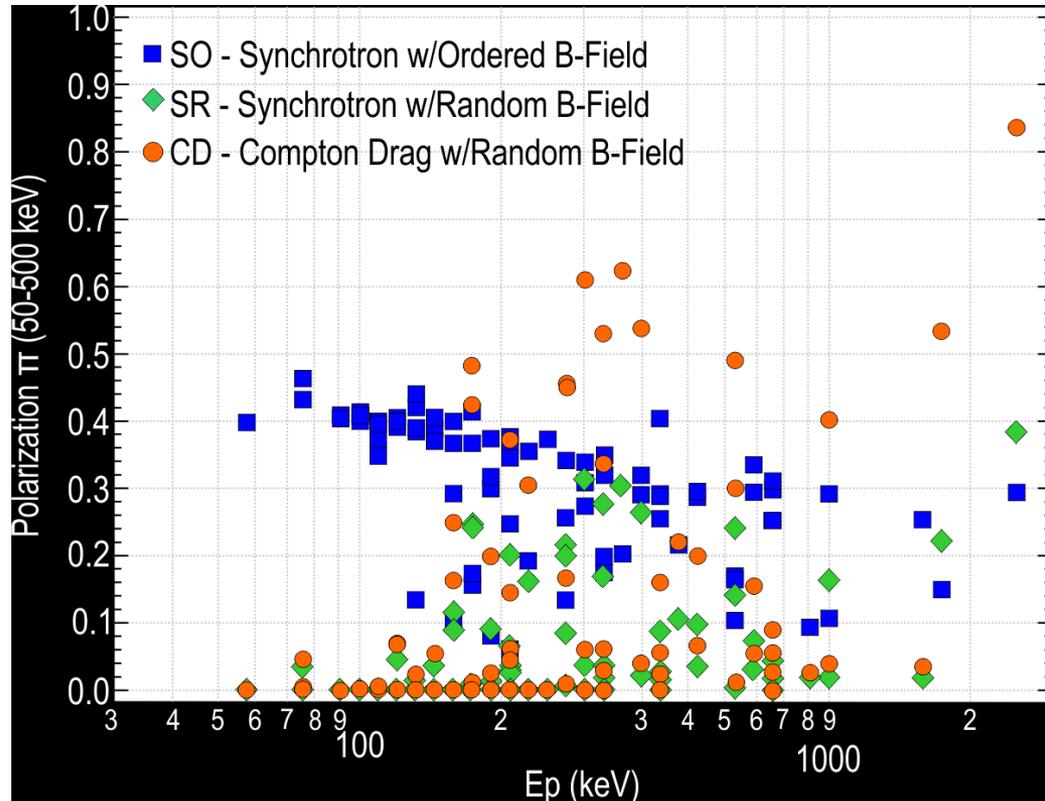
LEAP will probe this region.



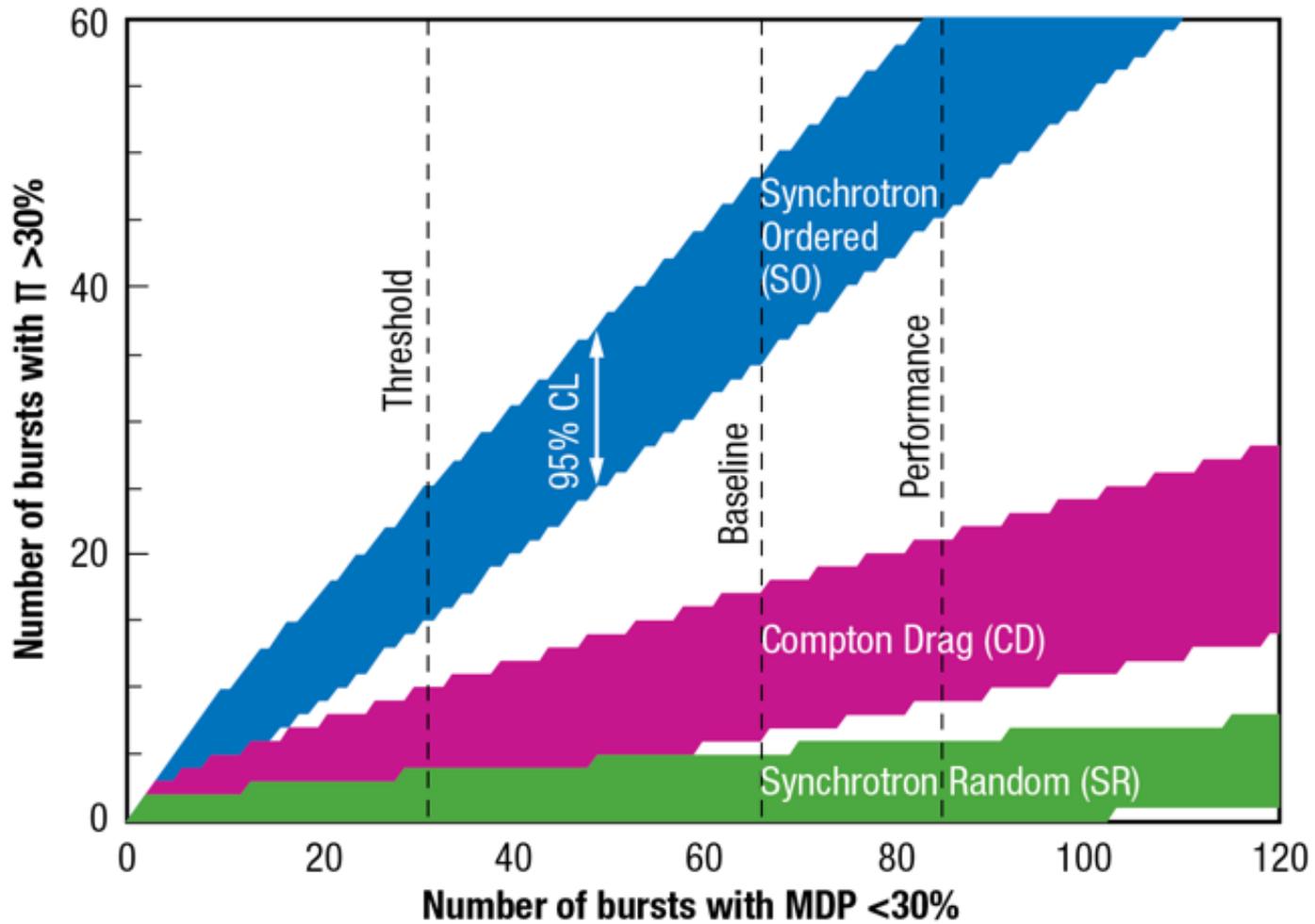
- 1 Fireball is Opaque**
 Electron-photon interactions prevent light from escaping.
- 2 Fireball is Transparent**
 Thermal radiation includes γ -rays emitted by high-temperature plasma.
- 3 Shock Waves Accelerate Electrons**
 γ -rays are emitted by accelerated electrons and boosted to high energies through scattering.
- 4 Electrons Hit Interstellar Medium**
 They rapidly decelerate, emitting optical light and X-rays.

Polarization Distributions

Toma et al., ApJ, 698, 1042 (2009)



Polarization Distributions



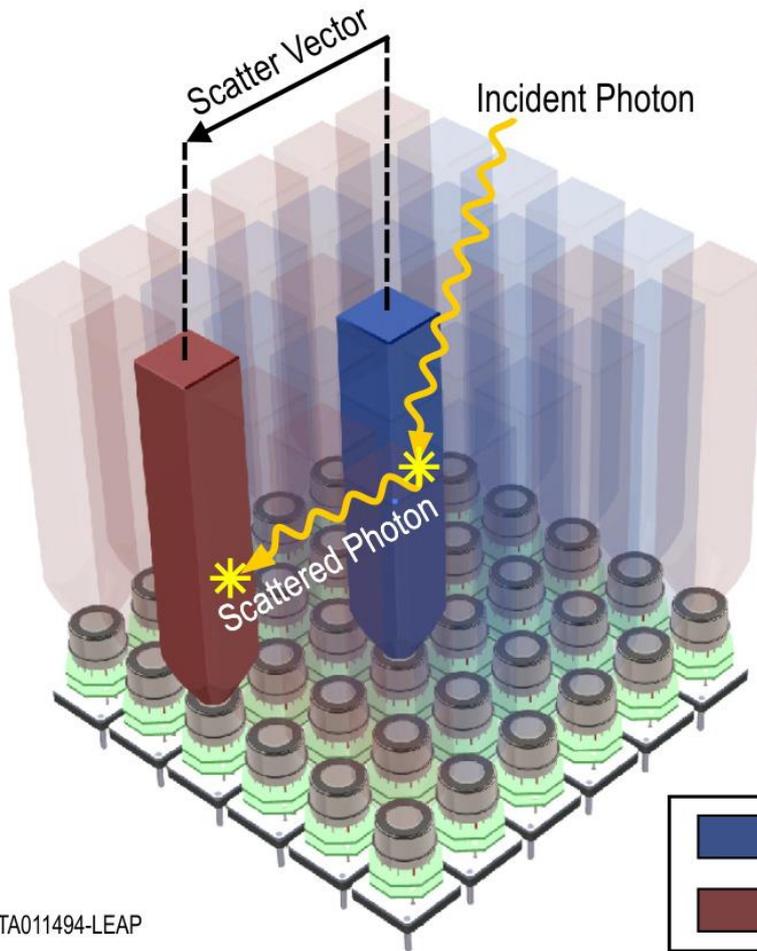
What is LEAP?

- NASA Mission of Opportunity Selected for Phase A study
- Large-Area, Wide-FoV Compton Polarimeter
- 50-500 keV polarimetry
- 20 keV - 5 MeV spectroscopy
- Externally attached to ISS
- Launch date ~2025
- Minimum 2.5 year mission

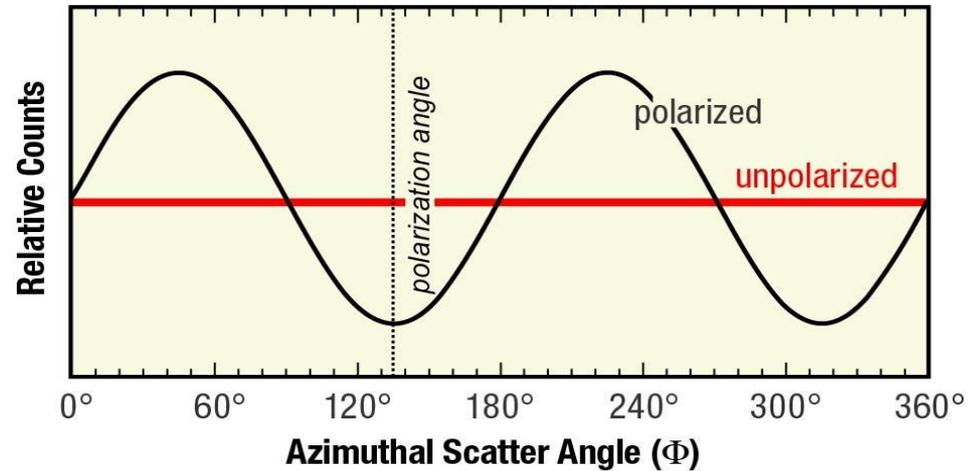


*LEAP in
Dragon trunk*

LEAP is a Compton Polarimeter



$$MDP = \frac{4.29}{\mu_{100} F_S A_{eff}} \left(\frac{F_S A_{eff} + R_B}{t} \right)^{1/2}$$

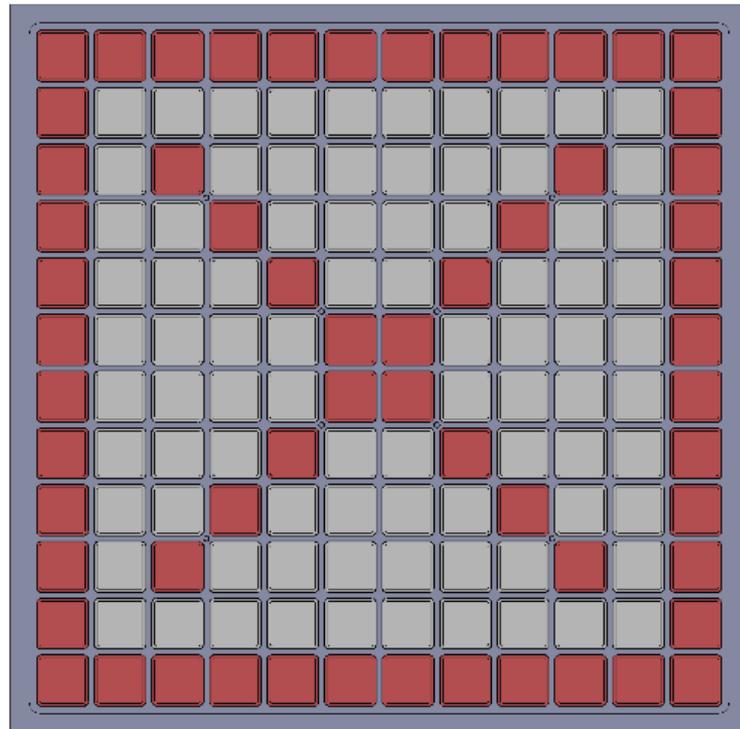


The LEAP instrument design is based on GRAPE balloon payload developed at UNH.

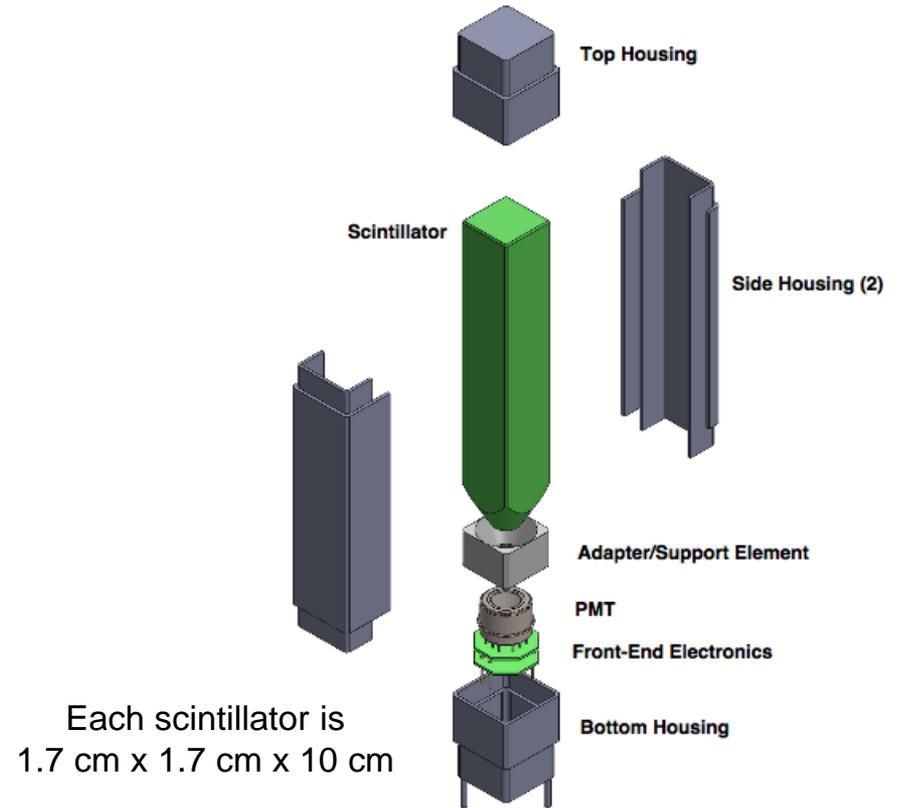
TA011494-LEAP

LEAP Scintillator Geometry

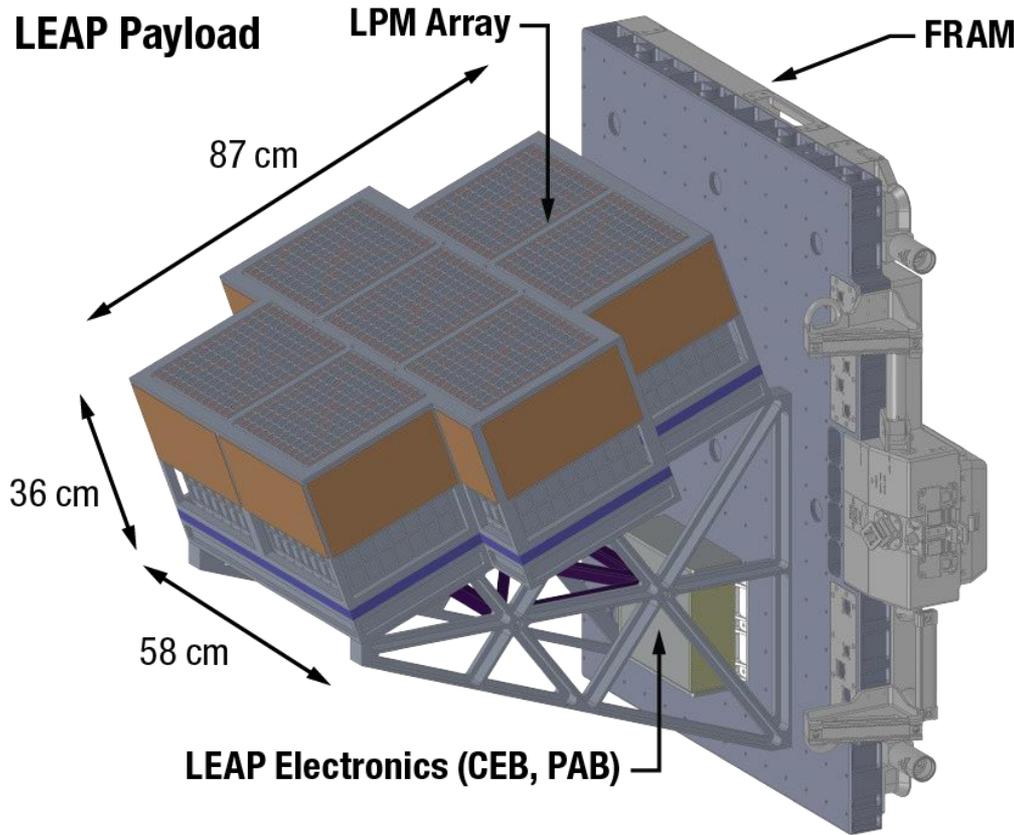
A single module consists of 144 discrete detector elements



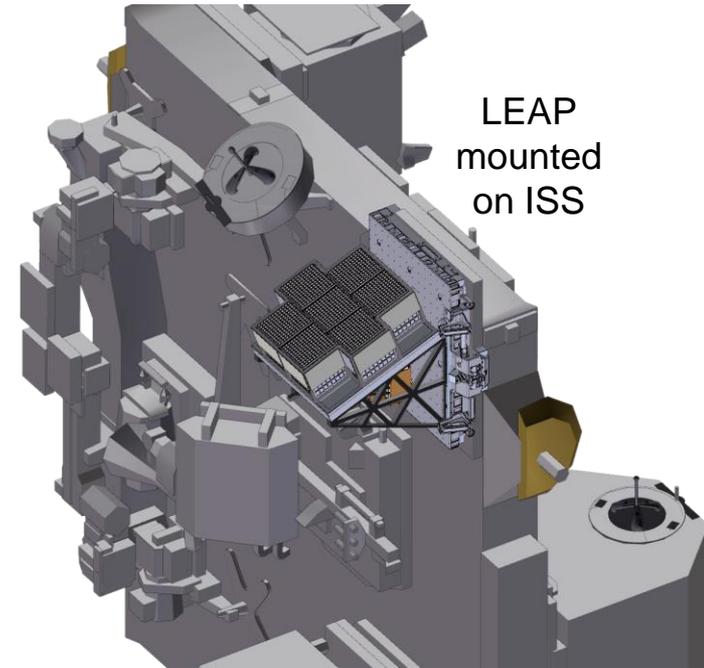
CsI
 plastic



LEAP Polarimeter Array



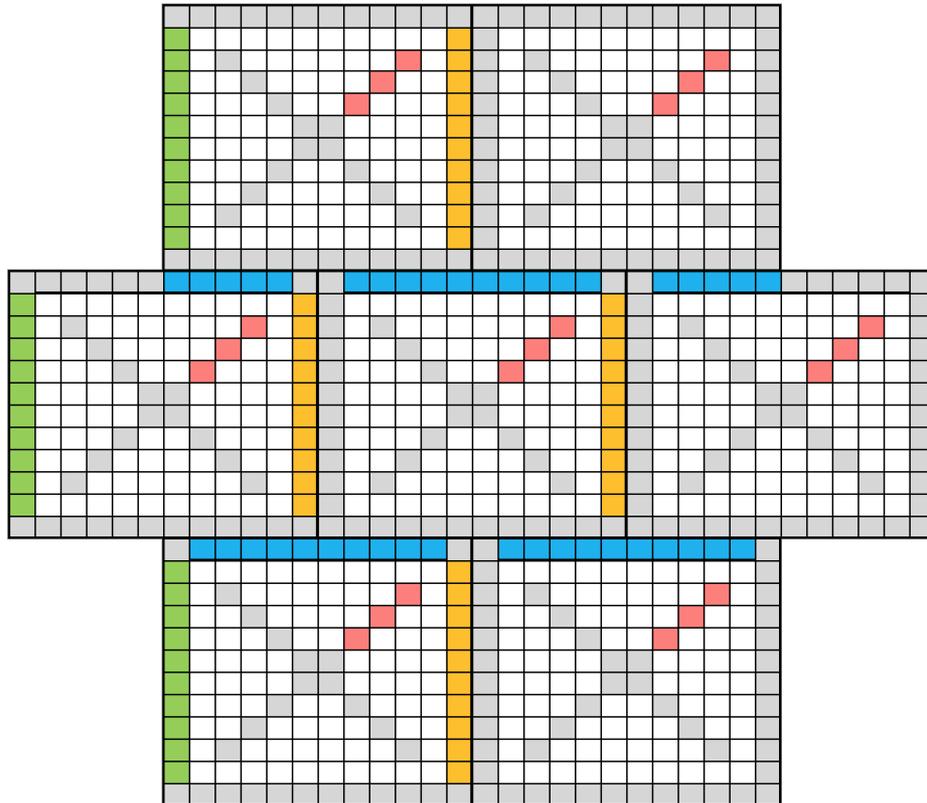
Full LEAP instrument consists of 7 independent polarimeter modules surrounded by passive Pb shielding on sides and bottom.



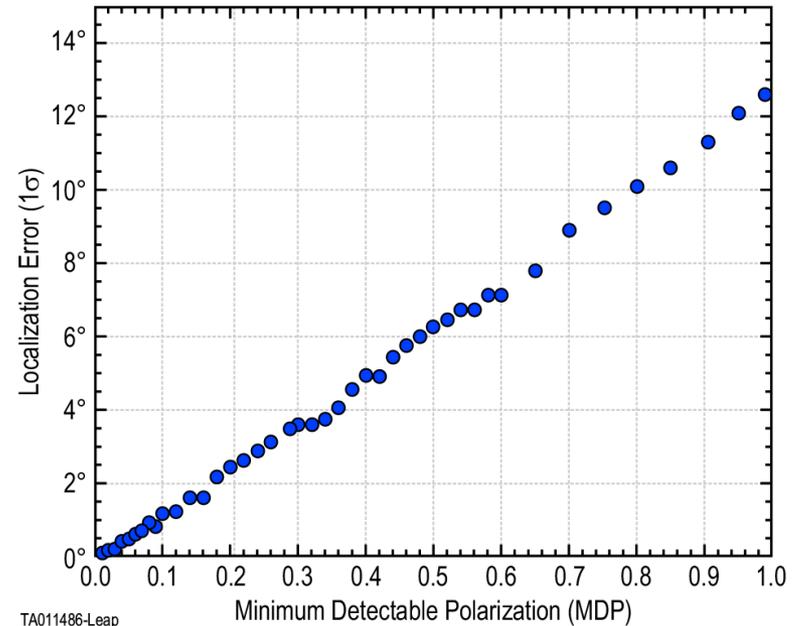


LEAP GRB Localization

LEAP uses virtual detector groups for localization

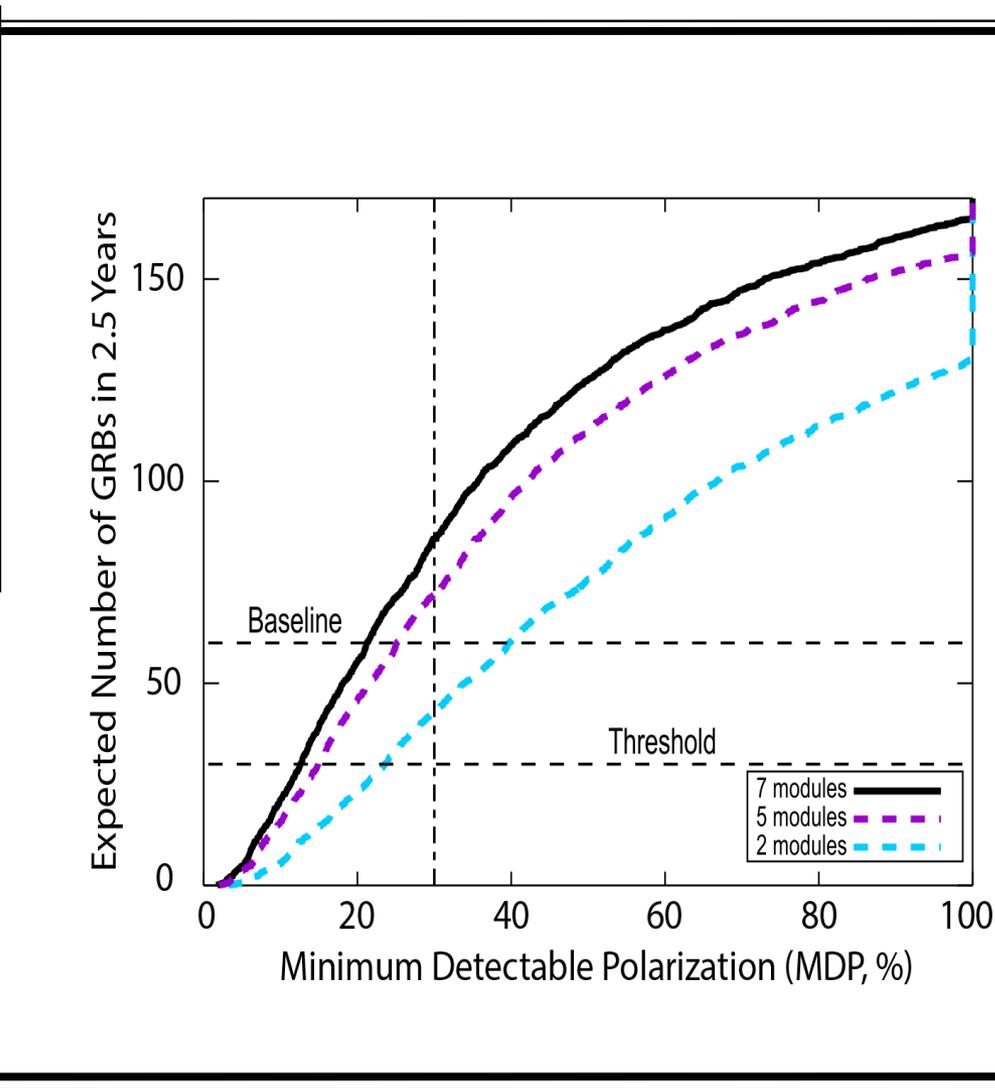
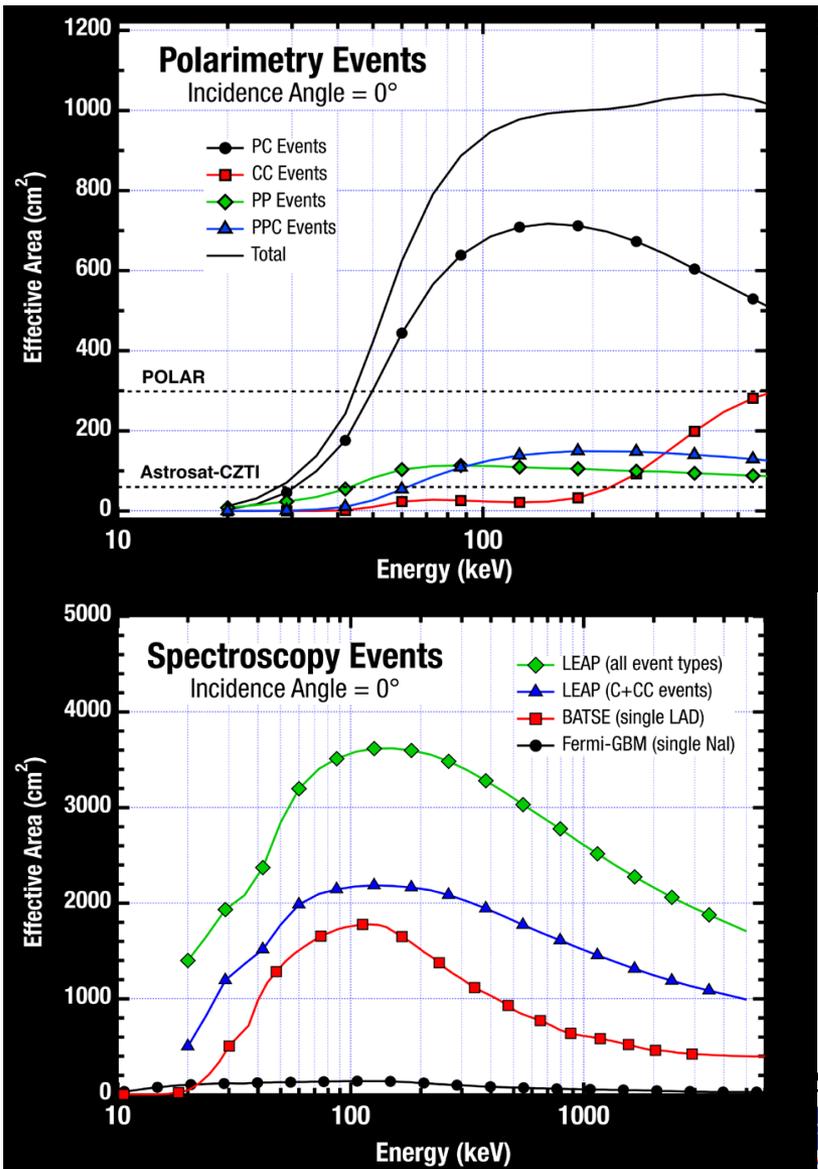


Minimum detectable polarization is well correlated with statistical localization uncertainty



TA011486-Leap

LEAP Instrument Performance

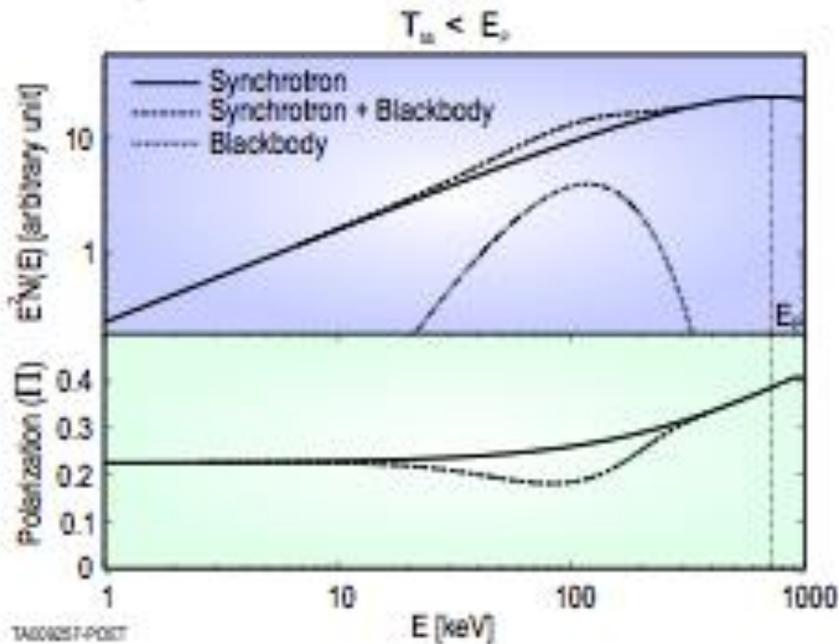


The Importance of LEAP

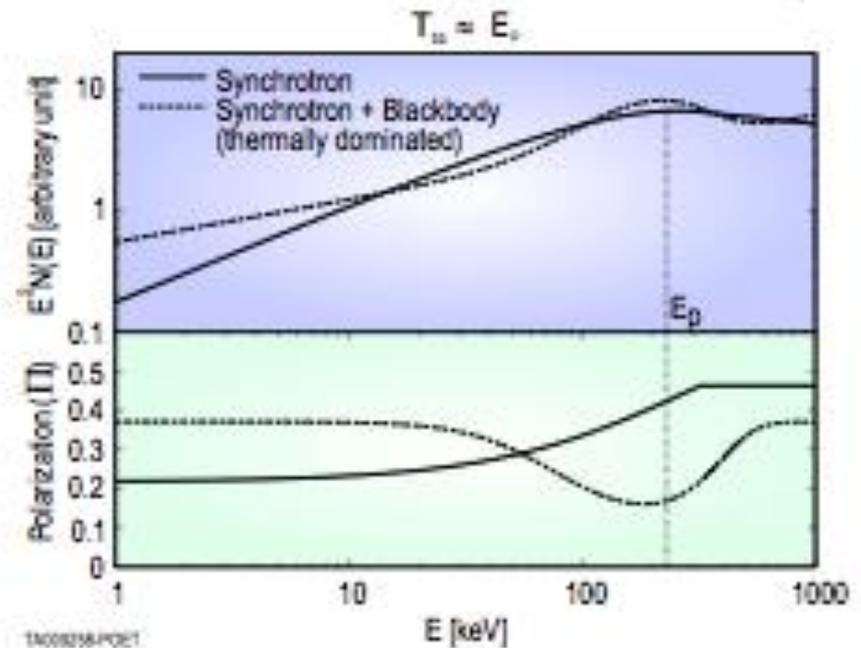
- ◆ Polarimetry is the next step towards our understanding of the GRB physics. Until now, studies have concentrated on time histories and spectra. Now is the time to move forward with polarimetry.
- ◆ Probing the central engine of GRBs provides insight into the nature of astrophysical jets, which are ubiquitous in the Universe.
- ◆ LEAP will provide correlated measurements of GRBs with gravitational wave observatories at a time when Swift and/or Fermi may no longer be available.

Energy-Dependence of GRB Polarization

Different emission mechanisms predict a different dependence of polarization on energy. If the typical Band spectrum is synchrotron-dominated, E_P would correspond to a break in the non-thermal electron spectral distribution, with a characteristic change in Π near E_P .

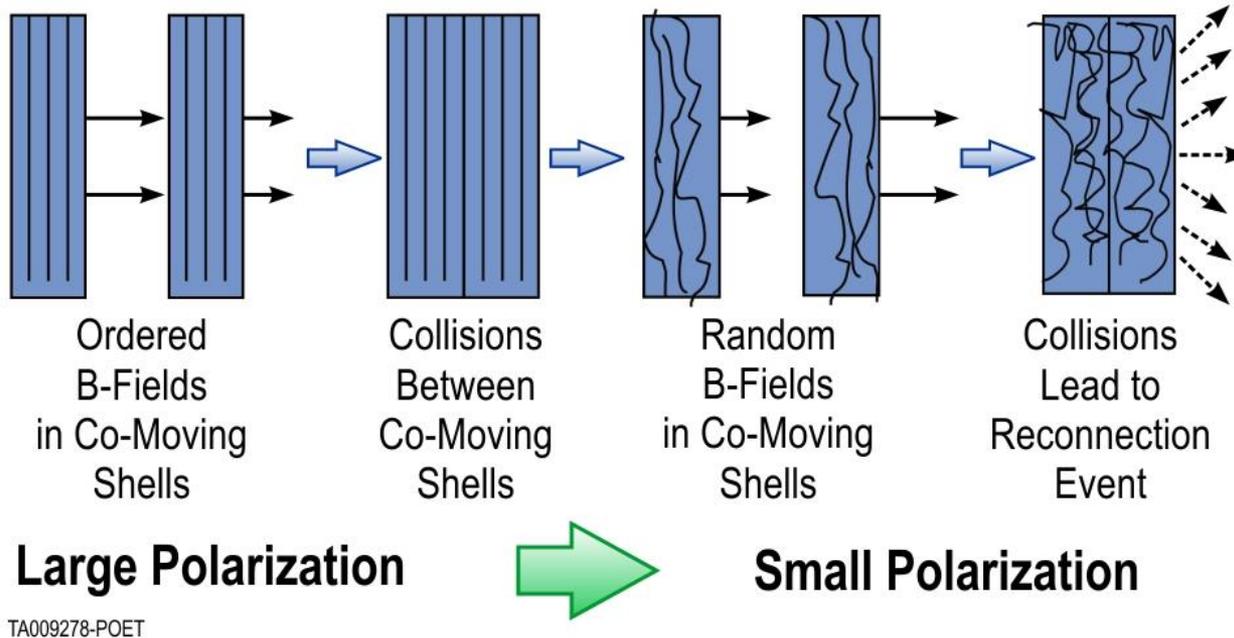


A simple blackbody component, seen in some GRBs, results in a reduction of P near the location of the blackbody peak.



A modified blackbody spectrum approximates the Band spectrum, but exhibits very different polarization properties.

Time-Dependence of GRB Polarization

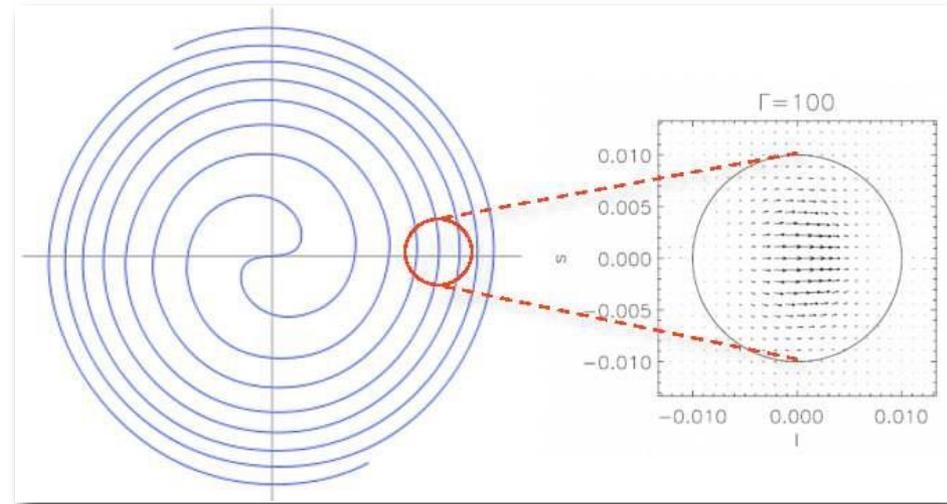


The ICMART model (Zhang and Yan, 2011) predicts that interacting shells within the outflowing jet will lead to increasingly random magnetic field structures that eventually produce reconnection events.

Toroidal Magnetic Field Model

In the canonical view of a twisted magnetic field within the jet, the magnetic field is largely toroidal.

If observer sees the whole jet, polarization will average out to zero.



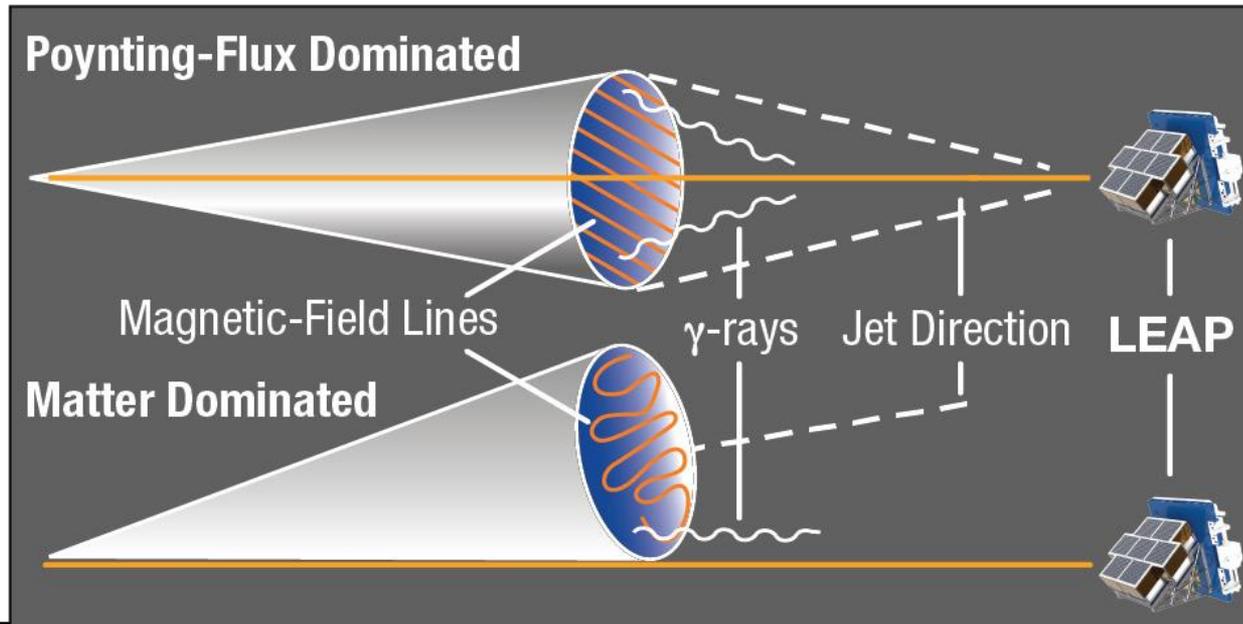
In a relativistic jet, the observers sees only a fraction of the total cross section, where the net polarization may be positive.

This model predicts large levels of polarization in almost all GRBs.

Importance of Viewing Angle

The viewing angle between the jet and the observer can also influence the degree of polarization.

A randomly oriented B-field structure may not average out the polarization signal if seen from off-axis.



Modified from Waxman, Nature, 423, 388 (2003)