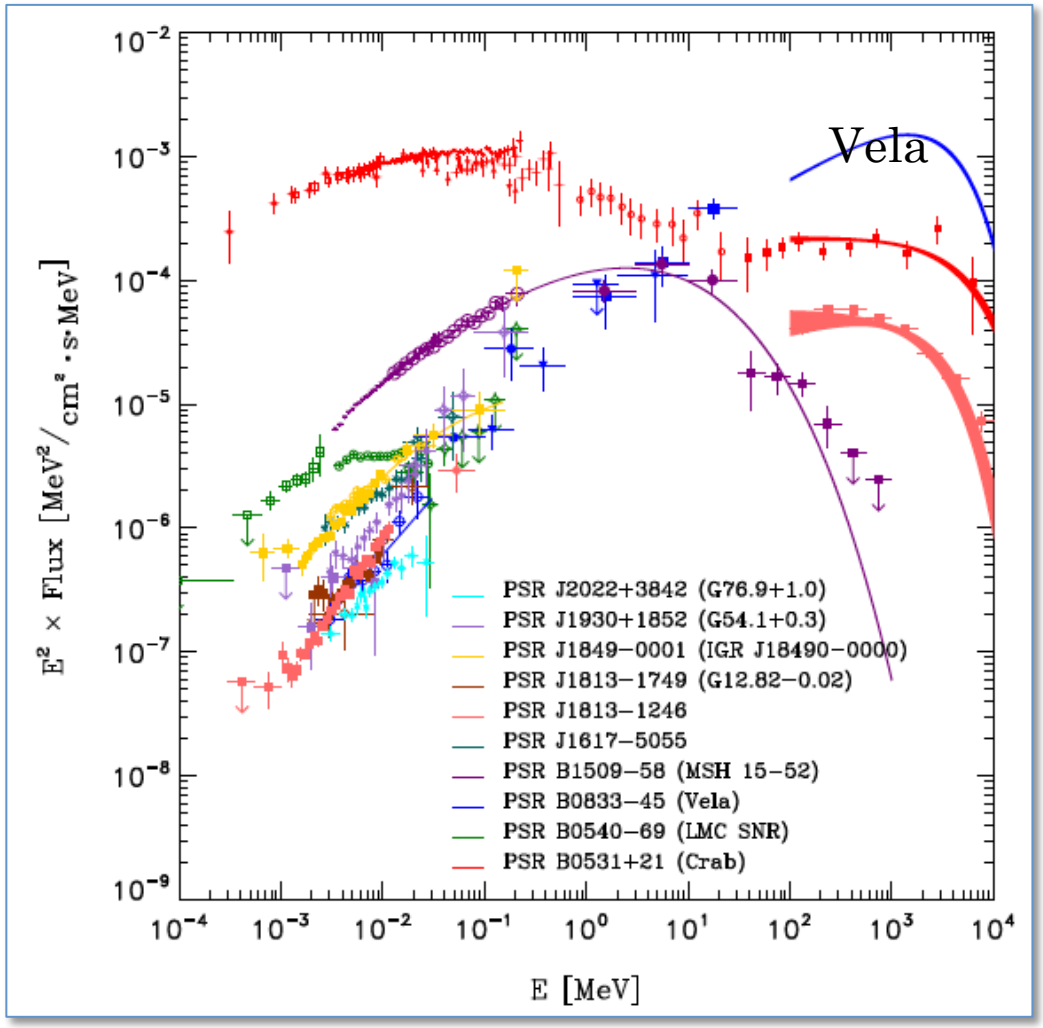
MeV-Band Pulsar and Magnetar Science

- GammaSig subgroup: Matthew Baring, Alice Harding, Paul Ray
- Pulsars: need very sensitive telescope in 100 keV- 50 MeV band.
  - Science deliverables enhanced by probing at least a dozen PSRs.
  - Must address Vela-like and Crab-like pulsars, and also "transition" PSRs like J1513 (B1509-58).
  - Need polarimetric capability to map polarization swing profiles, discerning between curvature (primary) and synchrotron (cascade) components.
  - Super-LAT at E>100 MeV would be acceptable too!
- Magnetars: sensitivity down to 100 keV is desirable/essential.
  - Must address quiescent emission turnovers at ~150-300 keV and general absence of signal above this.
  - Polarimetric capability at 100 keV-5 MeV will (a) help discern emission locales in giant flares and quiescent signals, and (b) probe pair exotic QED physics in strong fields.

Pulsar science at 0.3–100 MeV

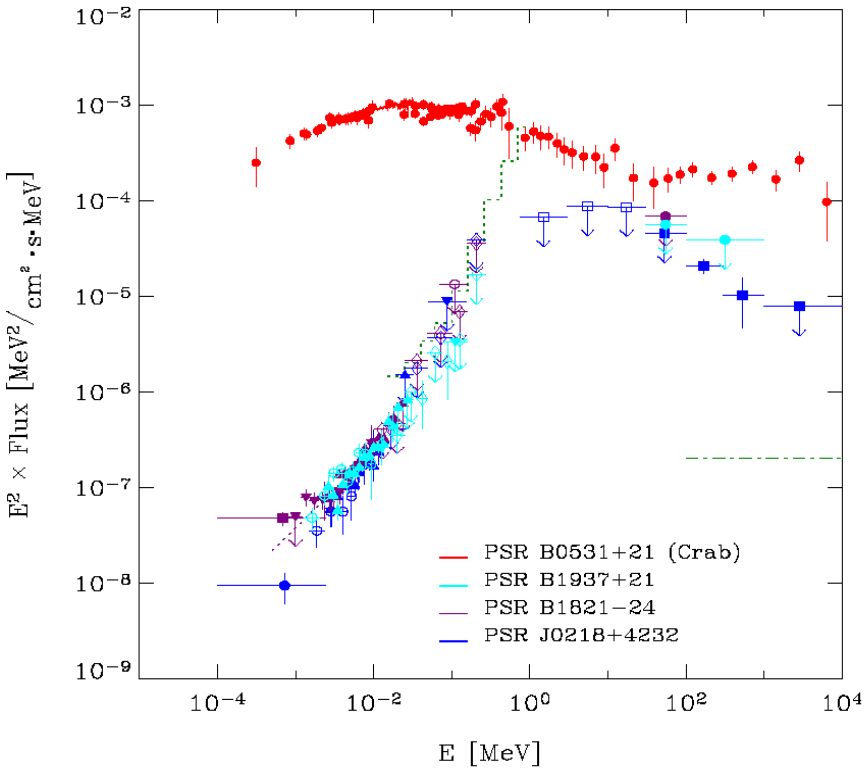
- Need to understand the where and why of softer gamma-ray pulsars – how is PSR B1509-58 different from magnetars with lower Emax?
- Kin: also a number of pulsars (11) are seen only in hard X-rays but not with *Fermi*:
  - Edot > 10^{36} erg/s
  - emission may probe a different part of the magnetosphere does the than GeV band;
  - look for high energy spectral cutoff and discern its shape.
- Polarization physics?

Kuiper & Hermsen (2015)



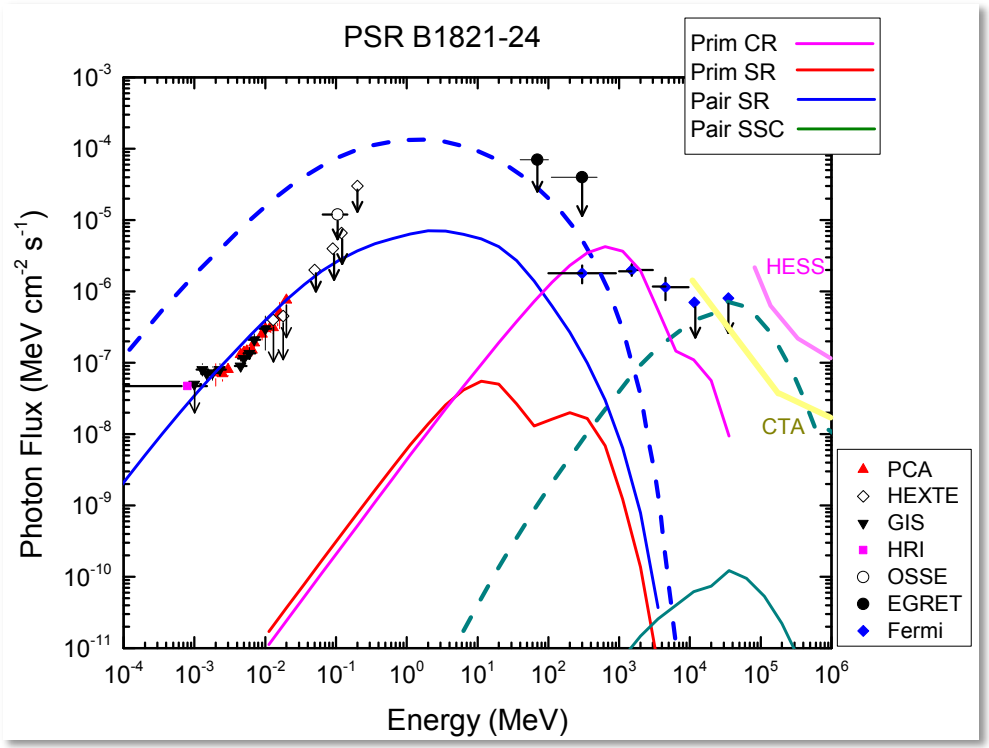
HE spectra of millisecond pulsars

SEDs of MSPs may peak ~ 1-10 MeV



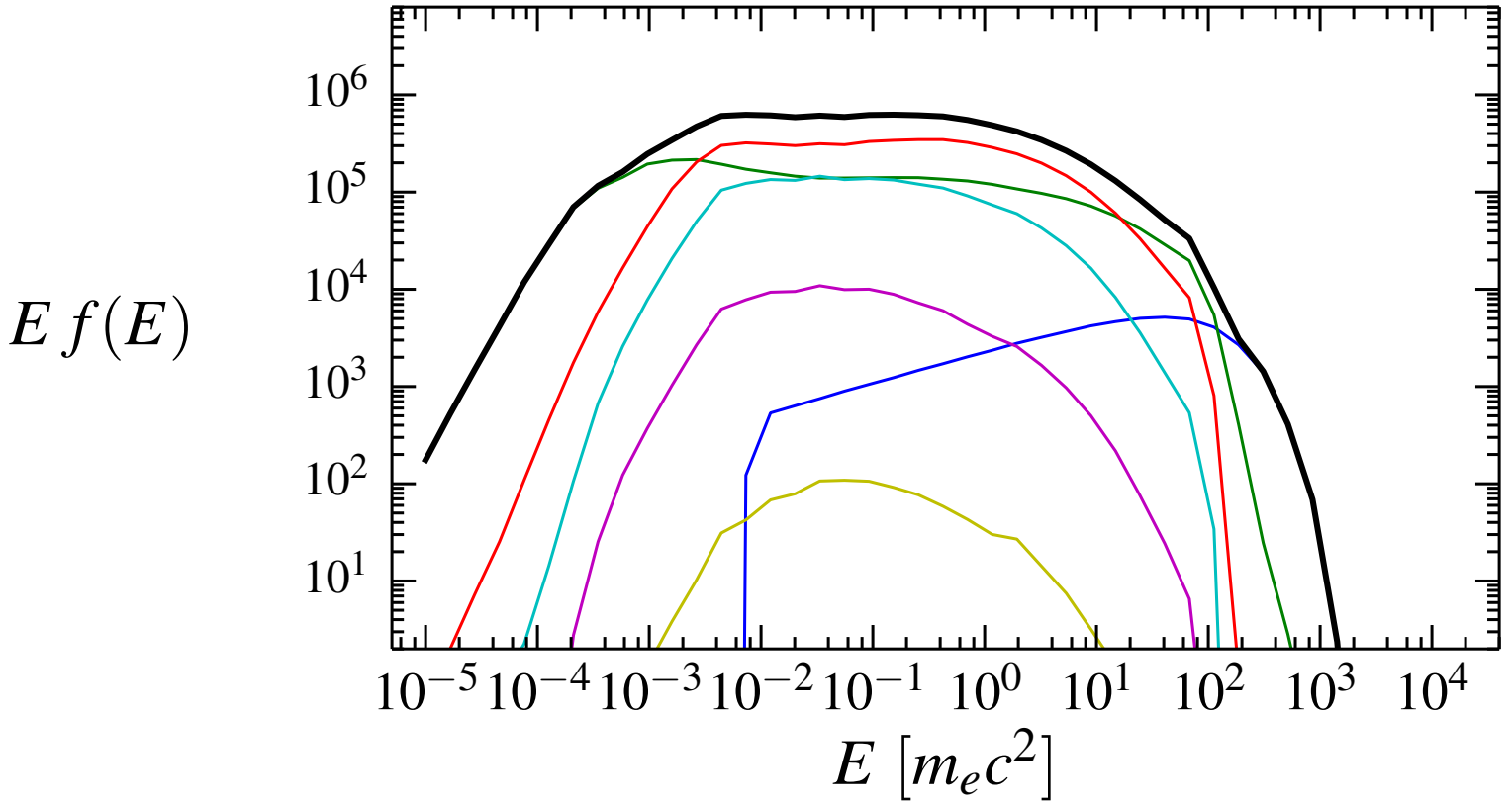
Kuiper & Hermsen (2003)

Harding & Kalapotharakos (2015)



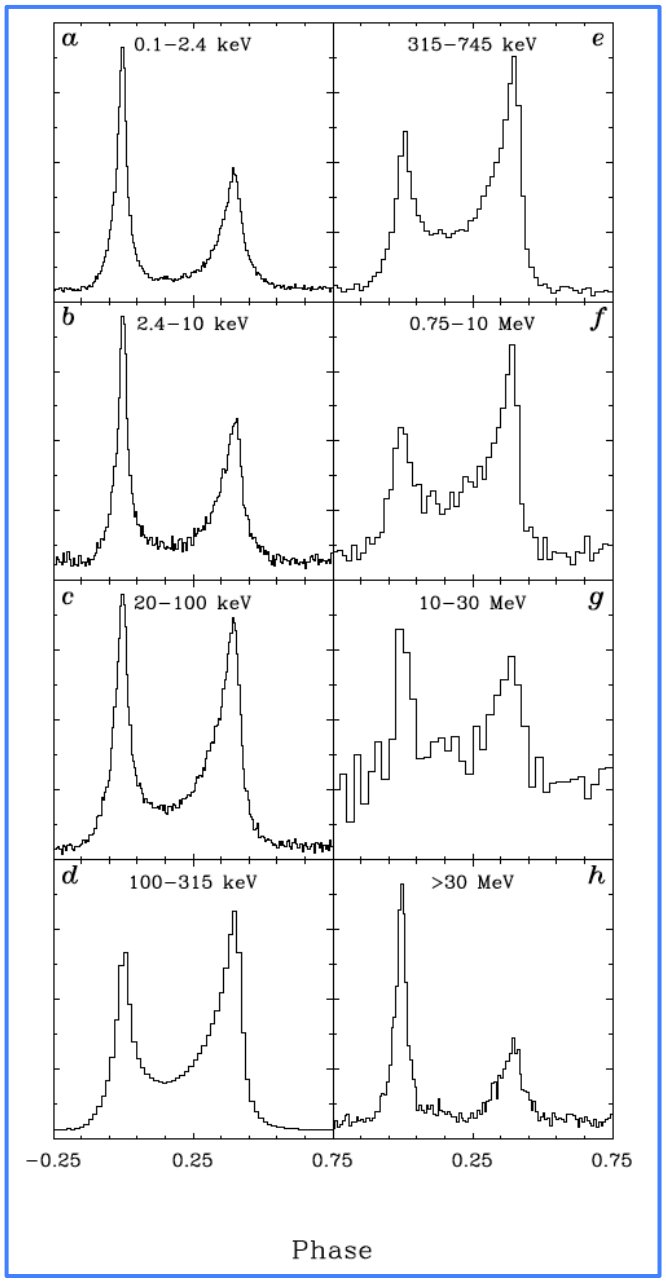
Polar cap pair cascade spectra

Timokhin & Harding 2015



- Need to discriminate between curvature radiation and synchrotron components;
- Pair cascade photon spectra have HE turnovers below 100 MeV;
- Look for turnovers at 10 – 100 MeV;
- Polarization measurements may show transition between emission mechanisms.

Pulse Profile Energy Evolution - Crab



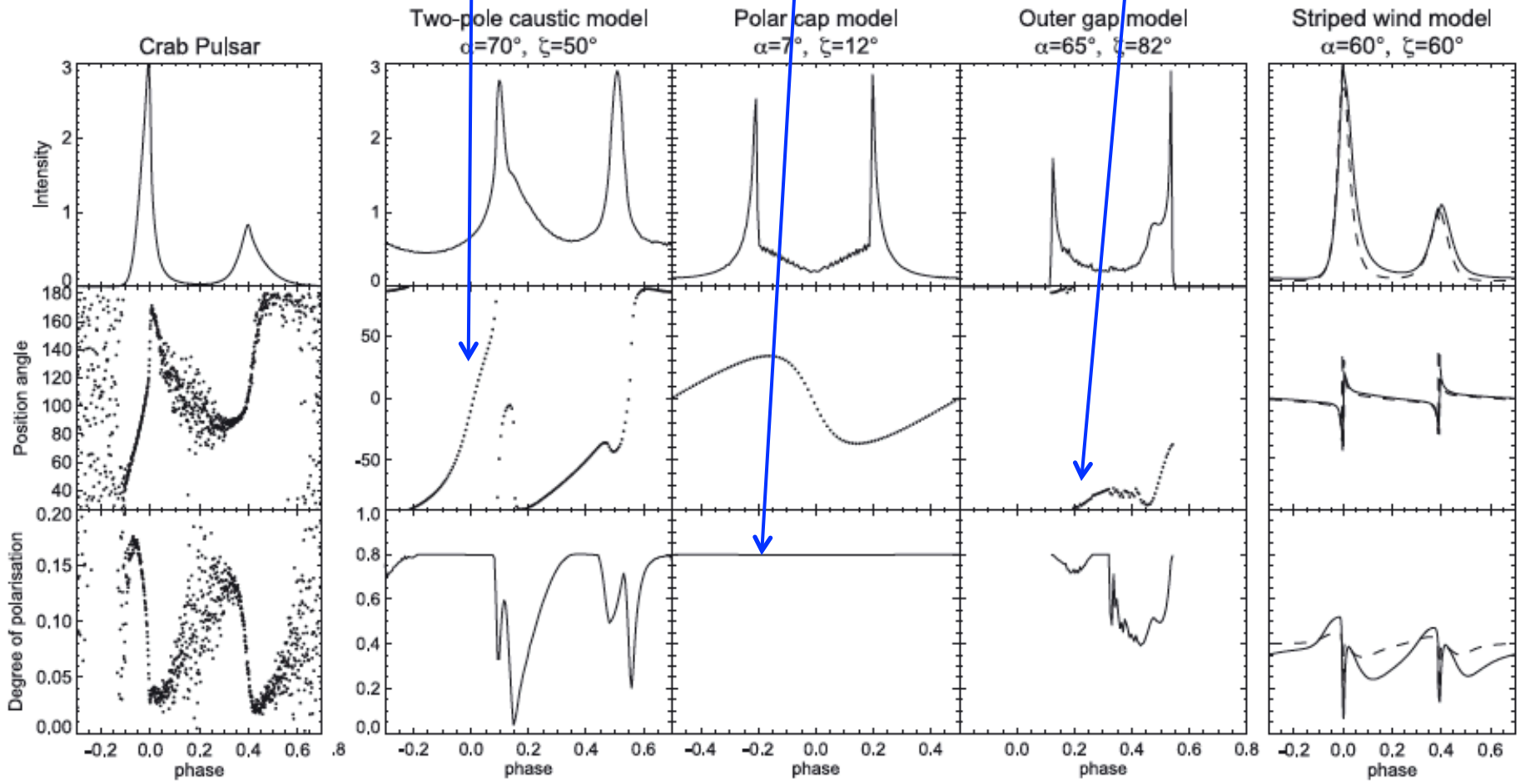
- Light curve undergoes shape between 100 keV and 50 MeV – signalling change in emission mechanism?
- Bridge emission is highest around 500 keV - where in magnetosphere is it from?
- Polarization measurements may show emission mechanism transition.
- Polarimetry may also discern magnetic geometry and sites for P1 and P2 generation.
- Diagnostics clearly possible for B1509-58;
  - need sensitive telescope to study Vela.

Crab pulsar: models vs. optical data

PA sweep direction a < 90^0!

No strong PA sweep

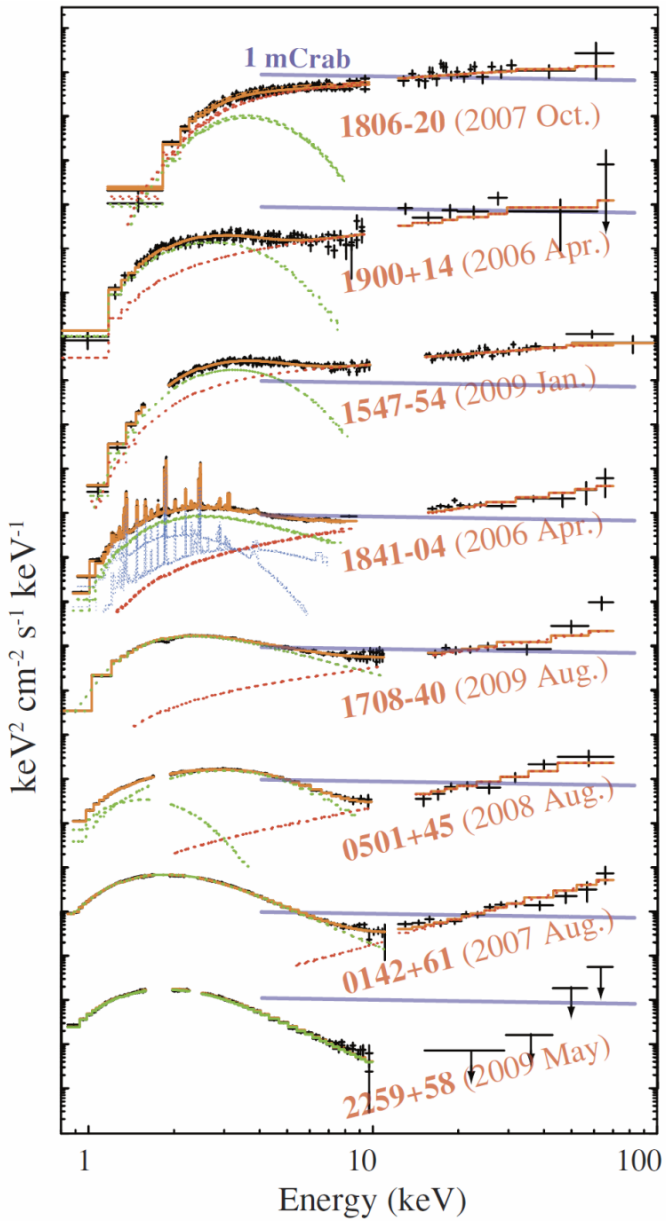
PC model ruled out

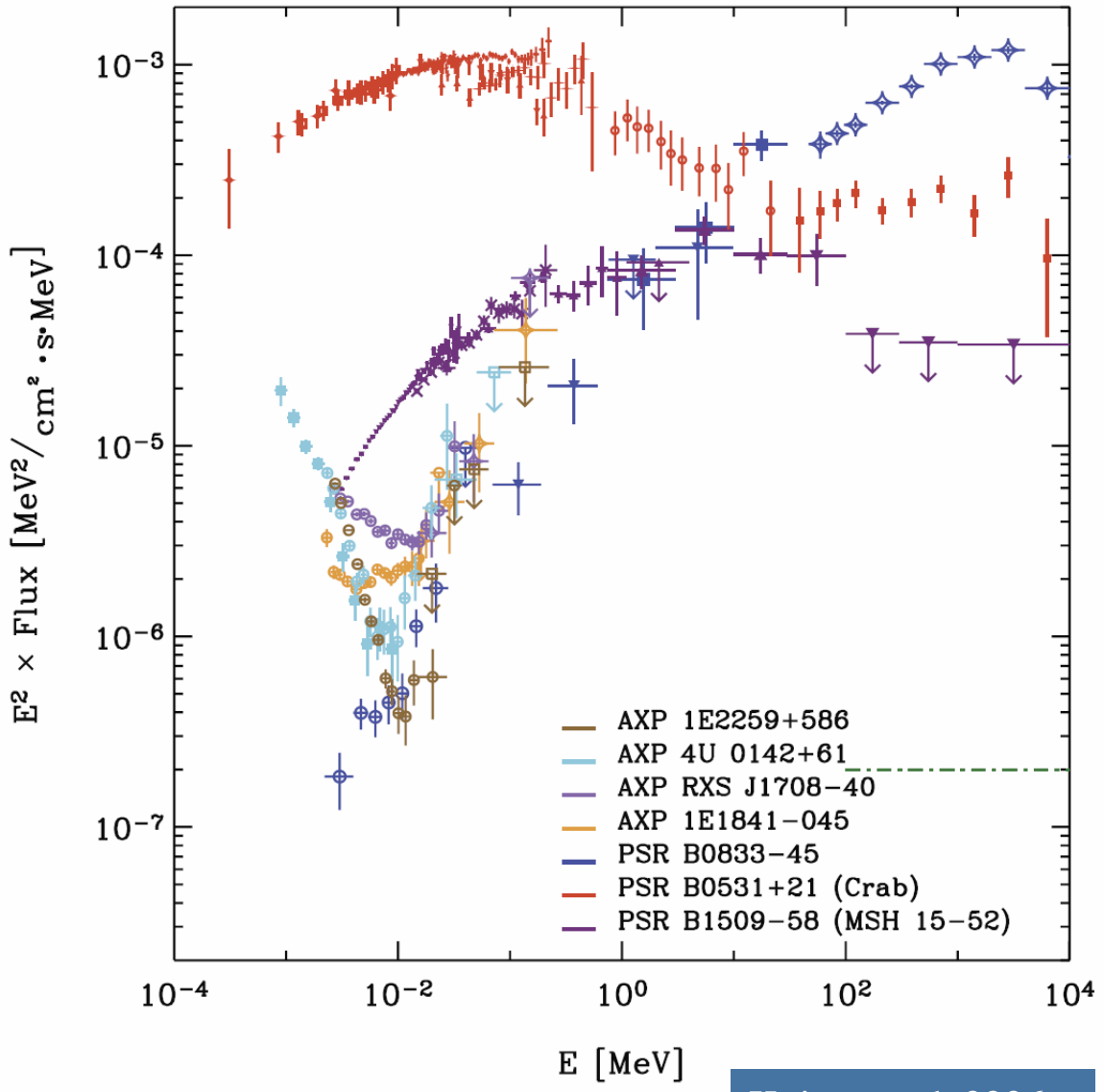


From Slowikowska et al. 2009 Dyks, Harding & Rudak 2004 Petri & Kirk 2005

Magnetar Hard X-ray Tails

Enoto et al. 2010



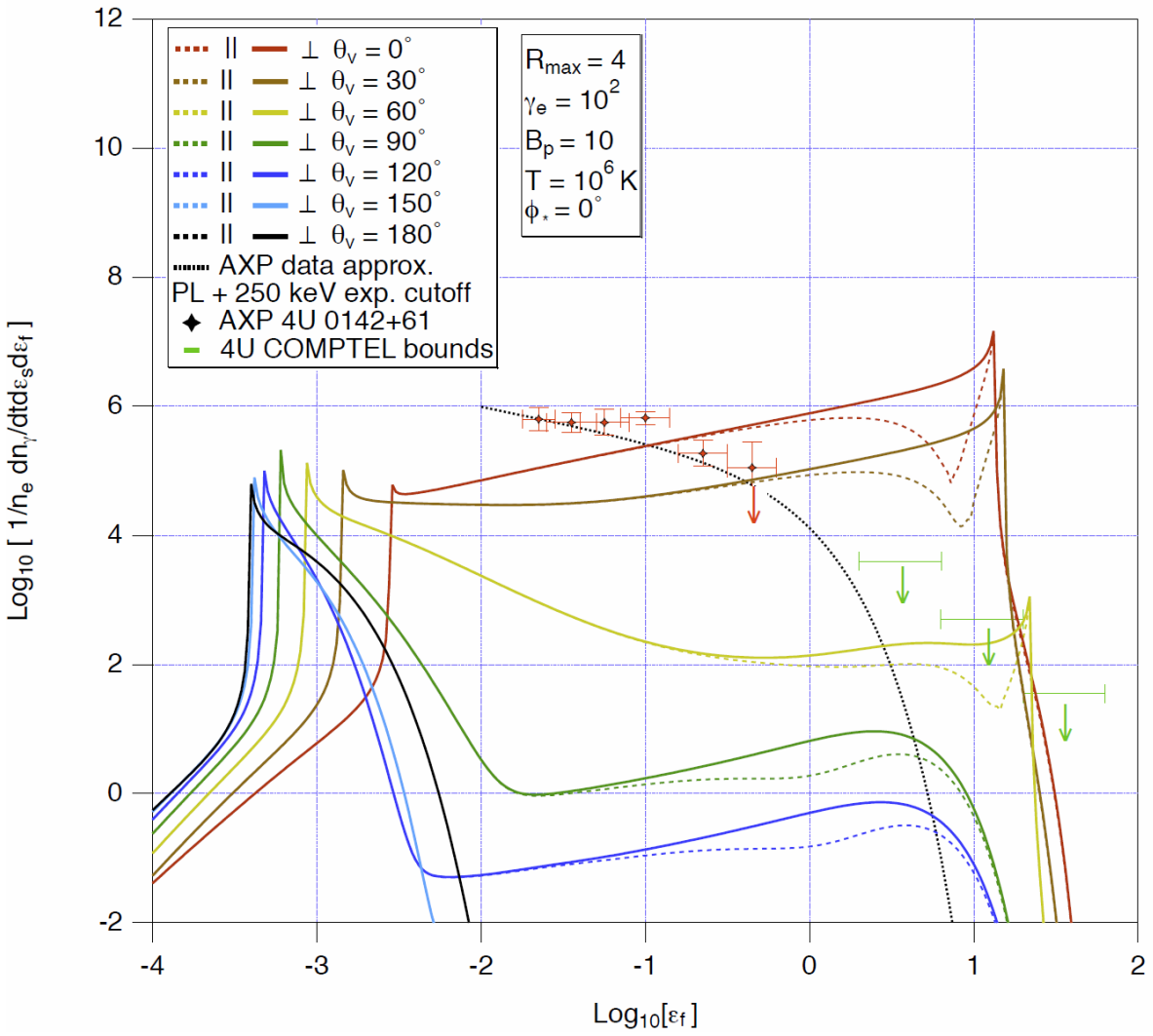


Kuiper et al. 2006

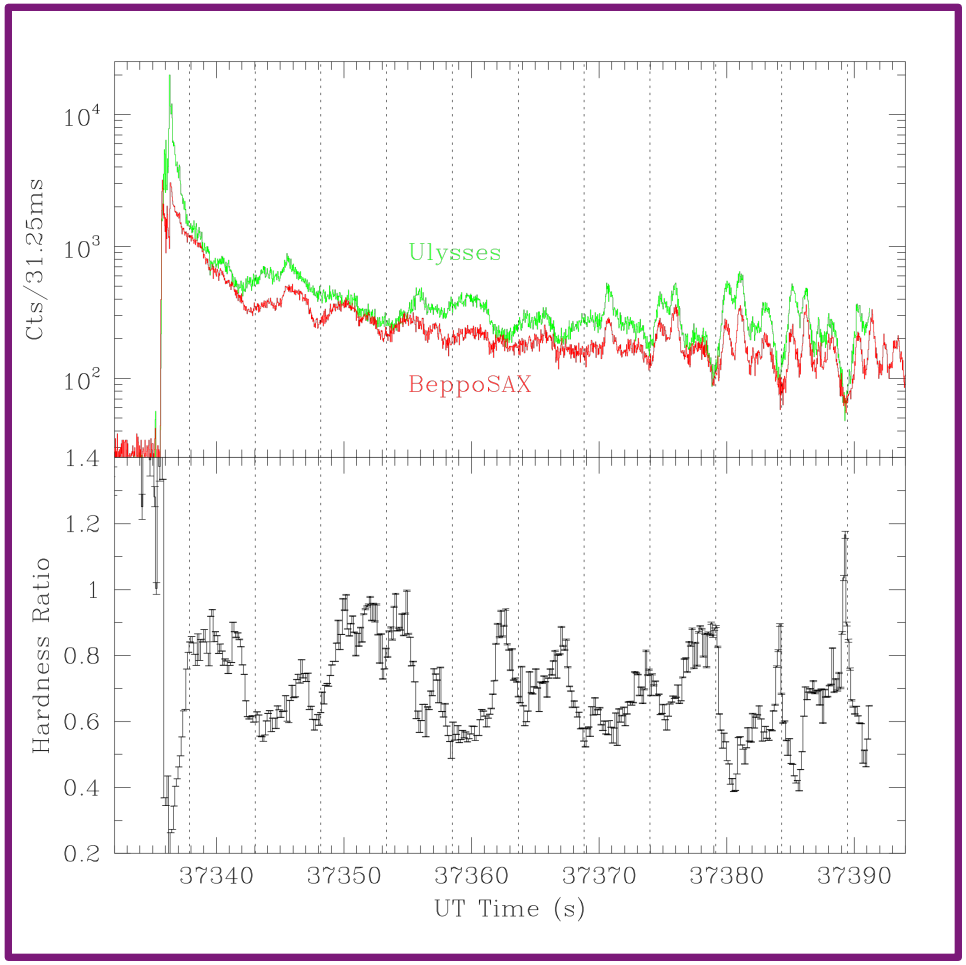
Polarization in Magnetar X-ray Tails?

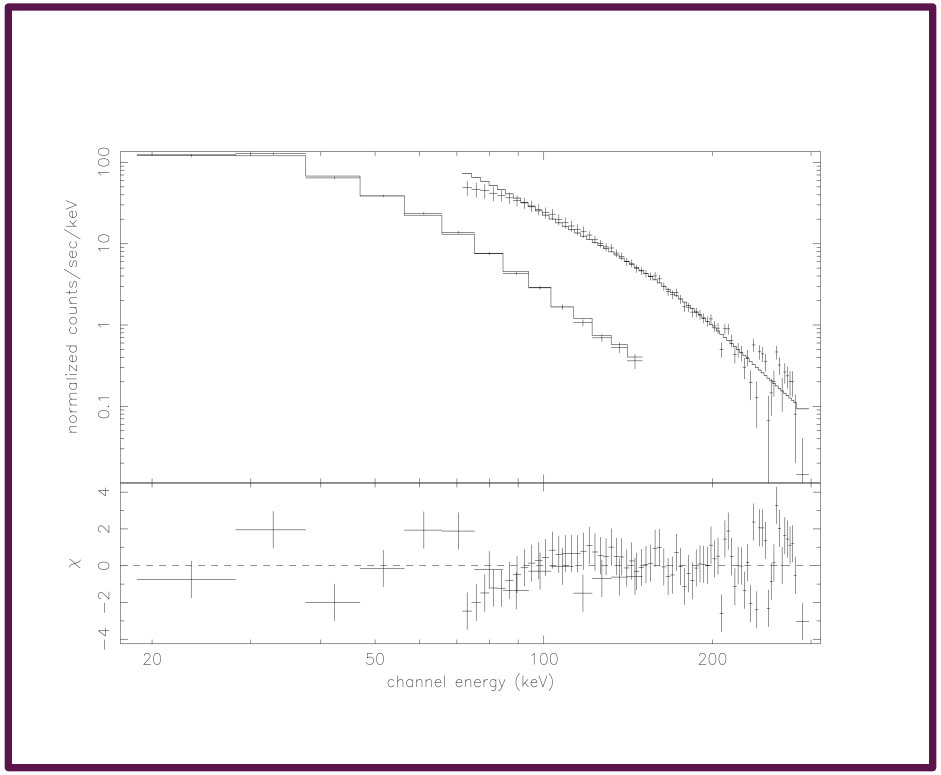
Wadiasingh, Baring & Gonthier (in prep)

- Resonant Compton upscattering models.
- Convolution of emission profiles is expected.
- Phase-resolved spectra can yield diagnostics on α.
- Perpendicular exceeds parallel polarization at the highest energies.
- The polarization signature may be exhibited in phase-resolved observations of magnetars.



SGR 1900+14
August 27 1998, Giant Flare Tail



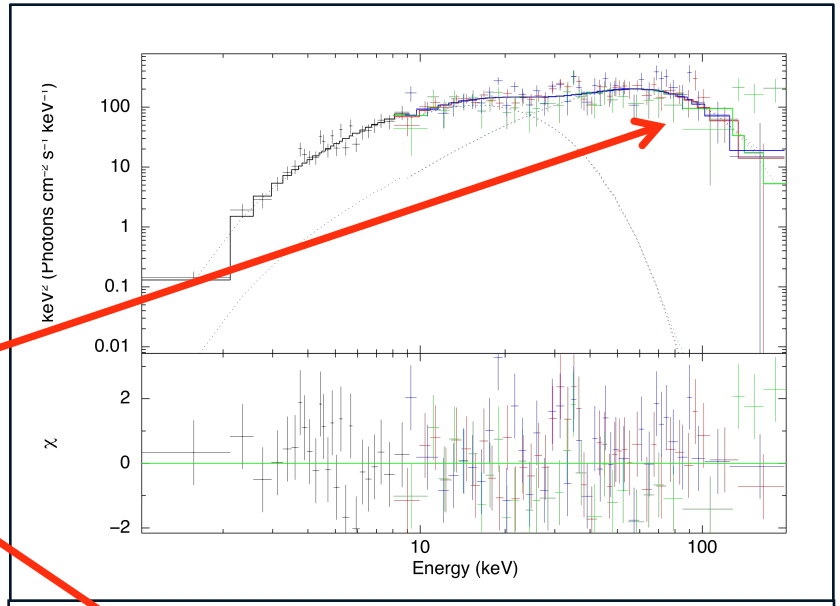


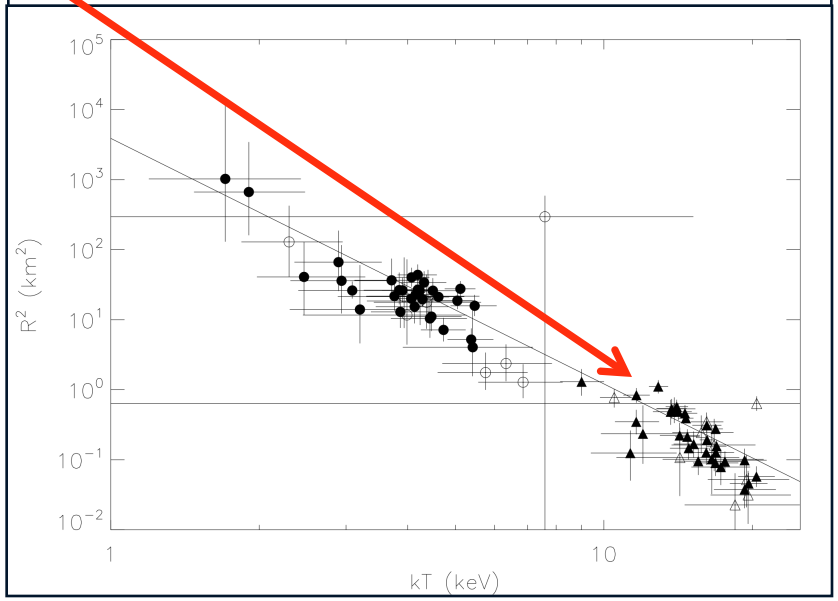
- Feroci et al. ApJ 2001; Ulysses + BeppoSAX (P=5.2 sec)
- 2xBB or OTTB @ 20-30 keV + PL @ index ~ 2.7-3.4

Magnetar flares: energy-dependent polarization signal expected

BB+BB

- Cooler zones (higher r) and hotter zones should be of different polarization; due to resonant Compton;
- || polarization mode more dominant at high energies if photon splitting is active.



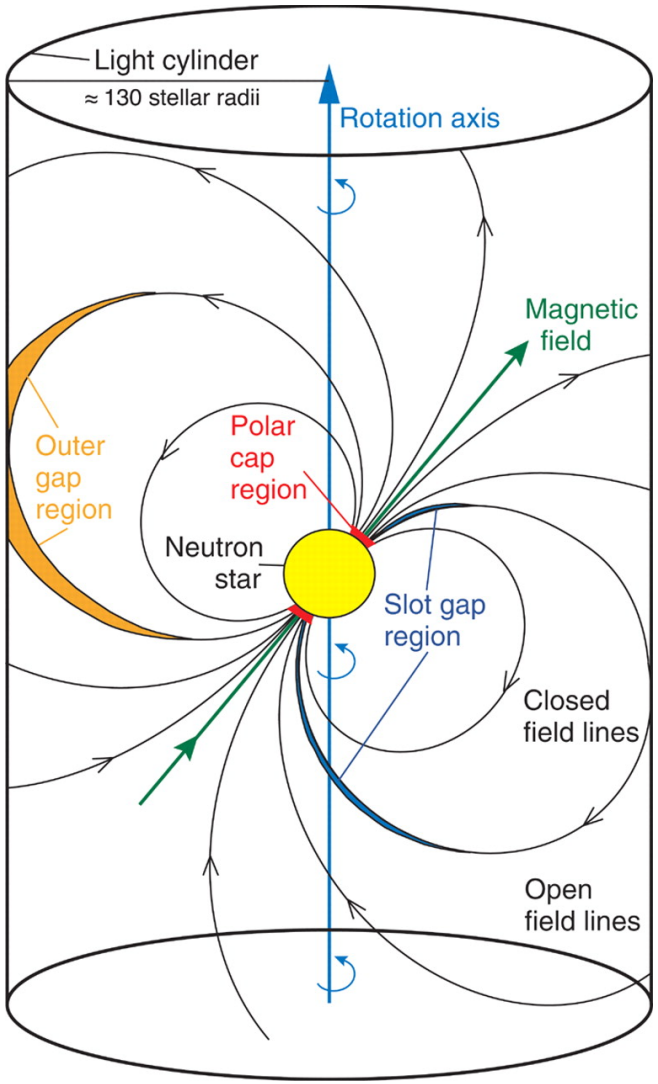


- Lin et al. (ApJ, 756, 2012): BB+BB fits can work well (*Fermi*-GBM + Swift) for SGR J1550-5418 .

Instrument Requirements

- Need flux sensitivity ~30 times better than Comptel;
- Bandwidth should cover 100 keV – 100 MeV;
- Energy resolution does *not* need to be at Ge level;
- Polarization sensitivity should aim for 10% MDP;

Pulsar High-Energy Emission Model Geometries



From Aliu et al. (2008)

- *Fermi*–LAT cannot yet cleanly discriminate between:
  - slot gap ($3\ R_{NS} < r < 0.1\ R_{LC}$)
  - outer gap ($r > 0.1\ R_{LC}$).
- Acceleration and therefore polarization orientation of synchrotron emission *is locally perpendicular* to that of curvature radiation
  - => different polarization degree and position angle profiles.
  - => **emission process diagnostic potential for next-generation MeV facility**.