
***Comments on X-ray
Polarization in
Outer Gap Pulsar Models***
Basic review of Gap Assumptions

RC-like Projection of Local B

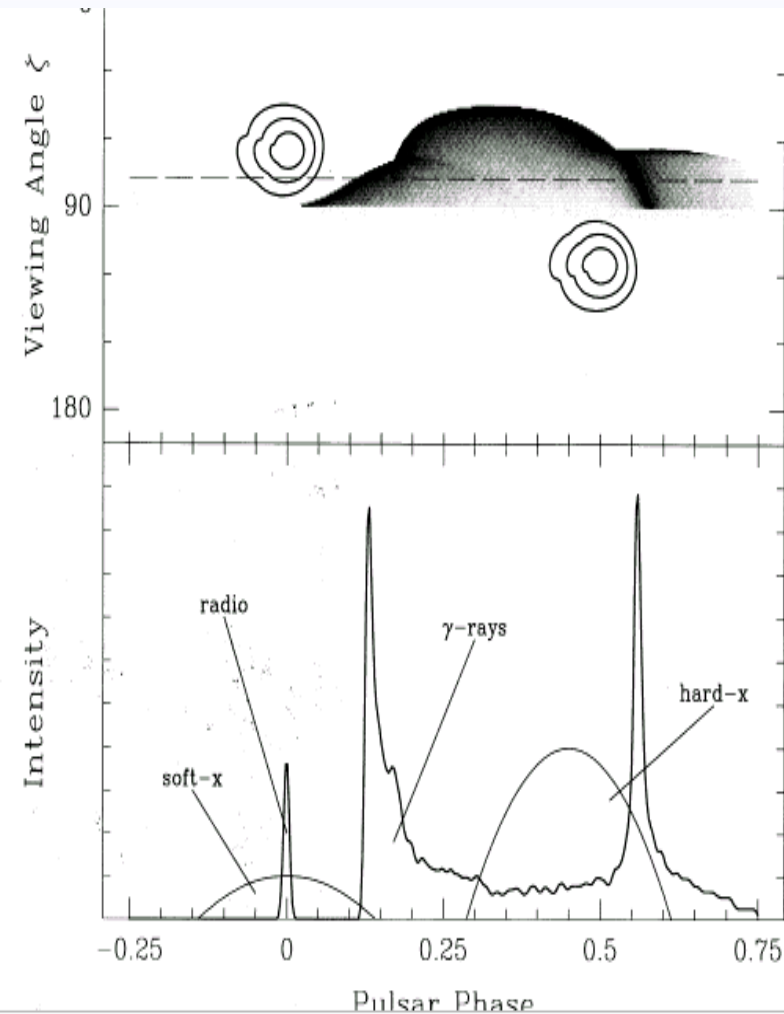
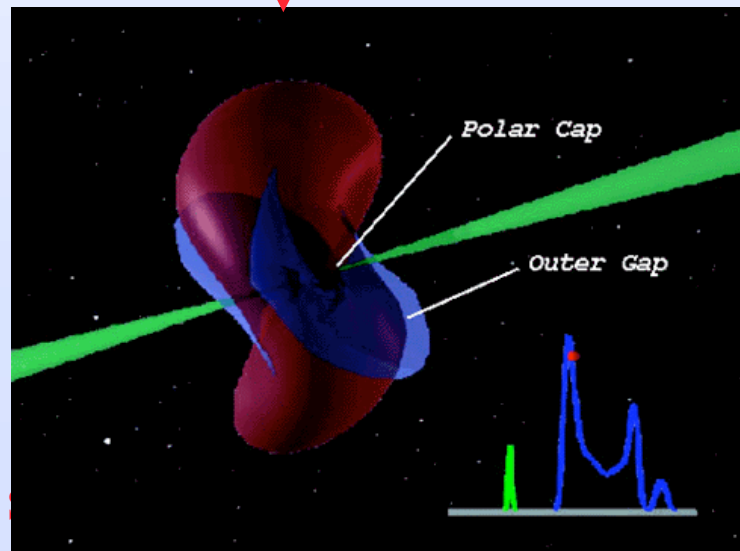
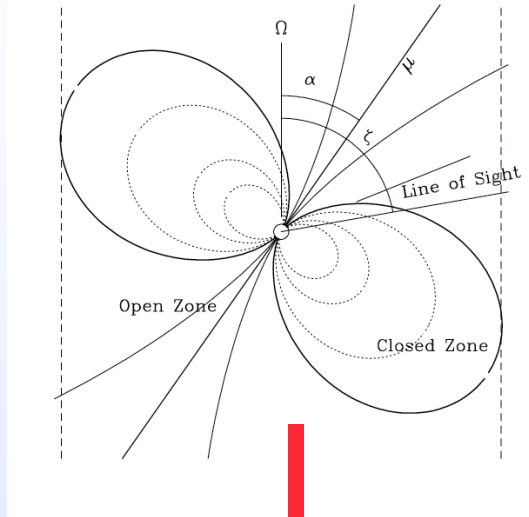
Optical Data from Crab, PSR B0656+14

Optical vs. X-ray vs. Gamma-Ray

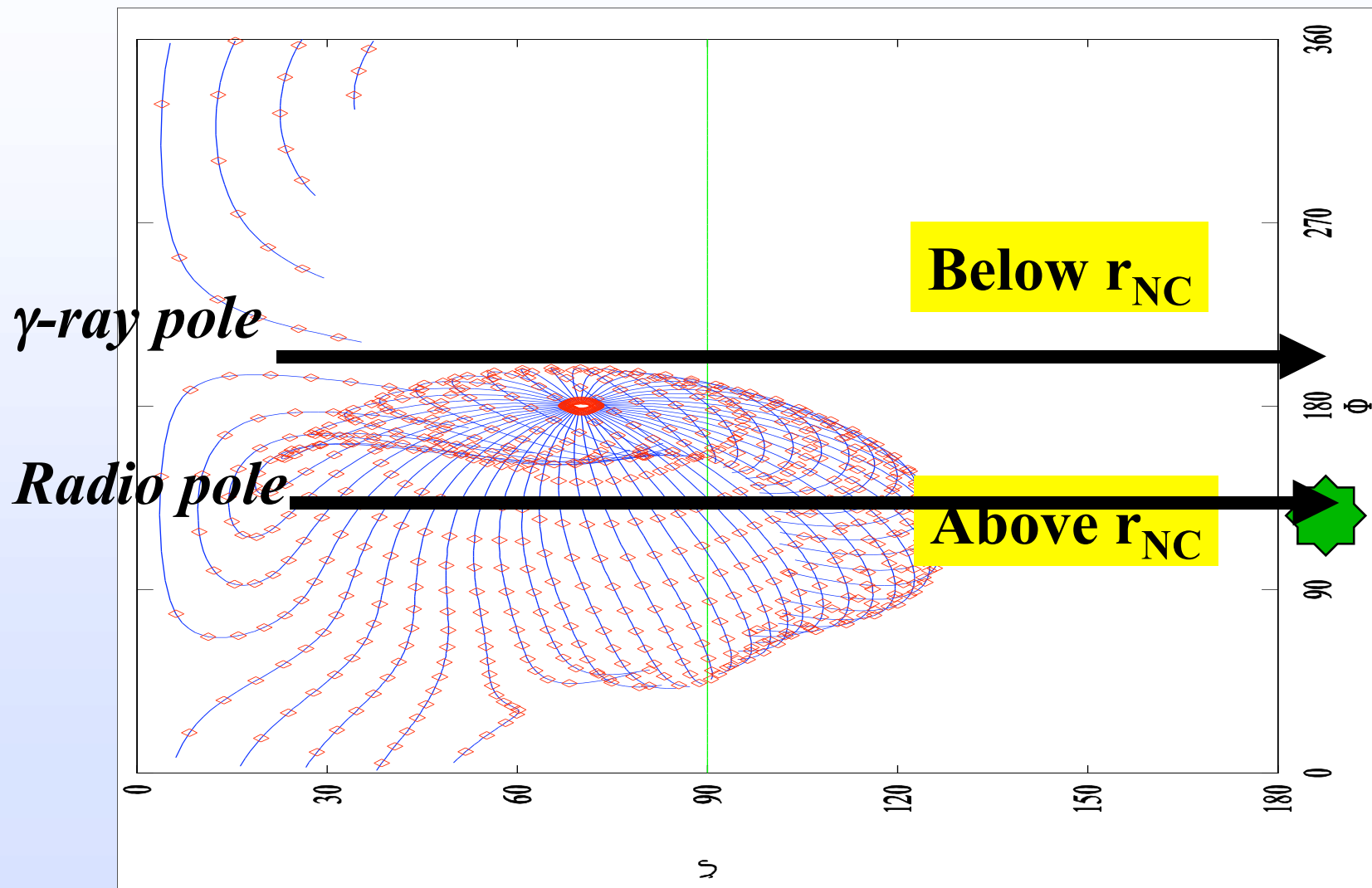
Optical/IR polarization Diagnostics

PC/OG Basic Difference - Geometry

- Here 3-D nature of Gap proves to be essential (RY95,

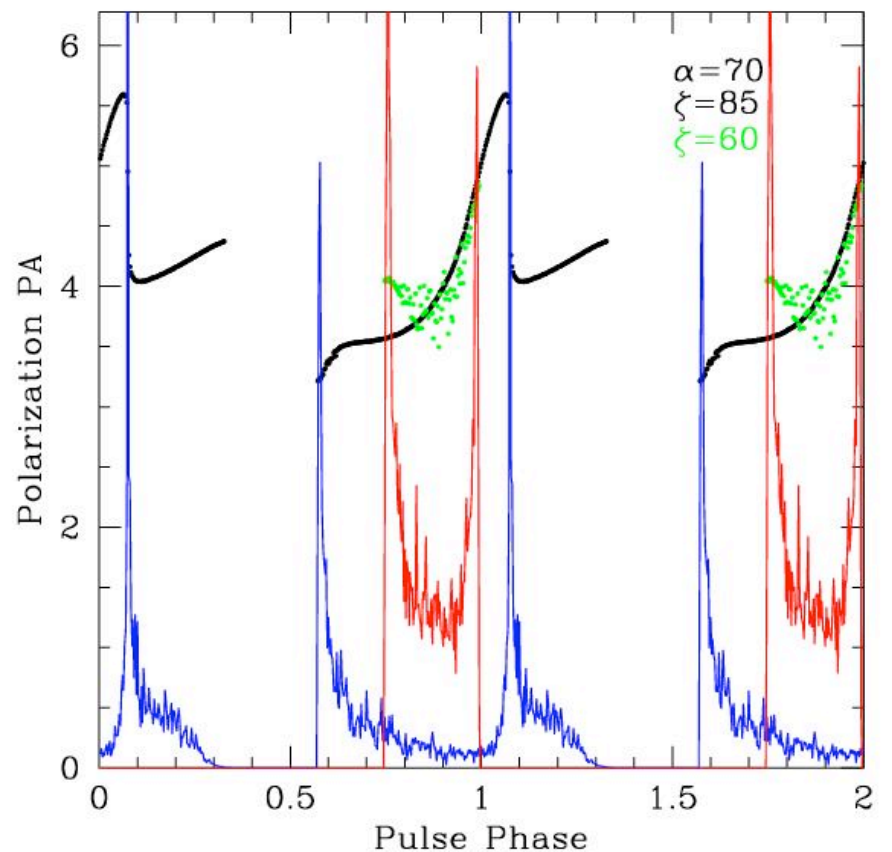


Gap closure above null charge or particles start from cap?



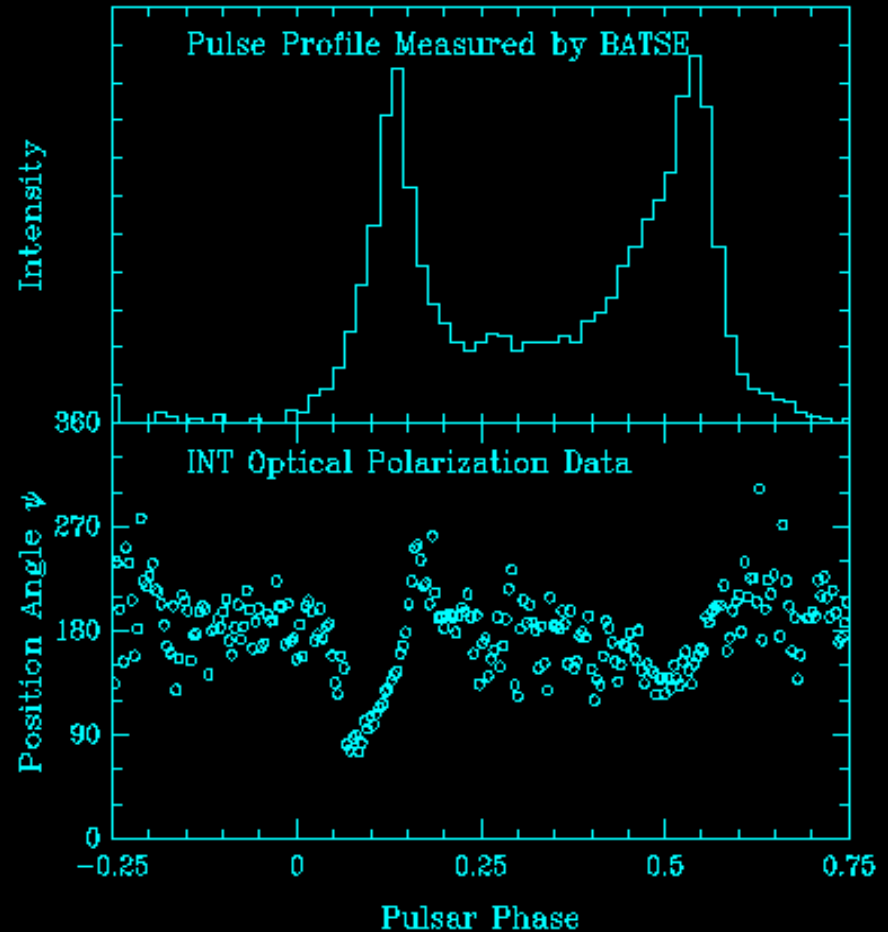
Polarization from OG

- Simple extension of RV model - field lines at each phase projected on the sky - sum flux to get net pol'n & PA
 - Care with aberration, time delay, sweepback near LC...
- Large Ψ synchrotron emission perp. to B
- CR (e.g. high energy Gamma-ray) parallel to B
- General pattern expected
 - Rapid sweep through bridge between pulses
 - Some reversals near peaks (caustics, nodes in beam?)



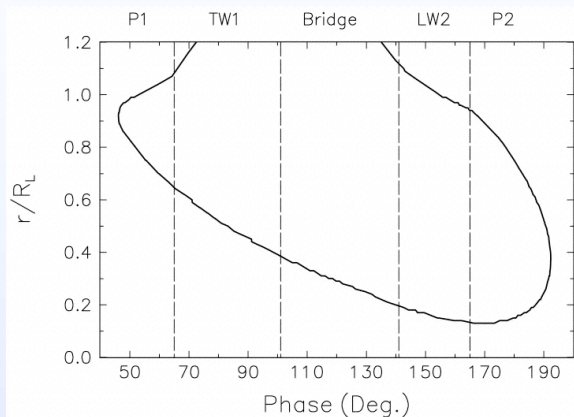
Data are scarce....

- *OSO-8 Polarimeter could not quite get Crab...*
- *However - same or related e^+/e^- population extends to optical/IR*
- *There good data for Crab pulsars.....*
 - *See very nice new results on Kanbach's poster....!*

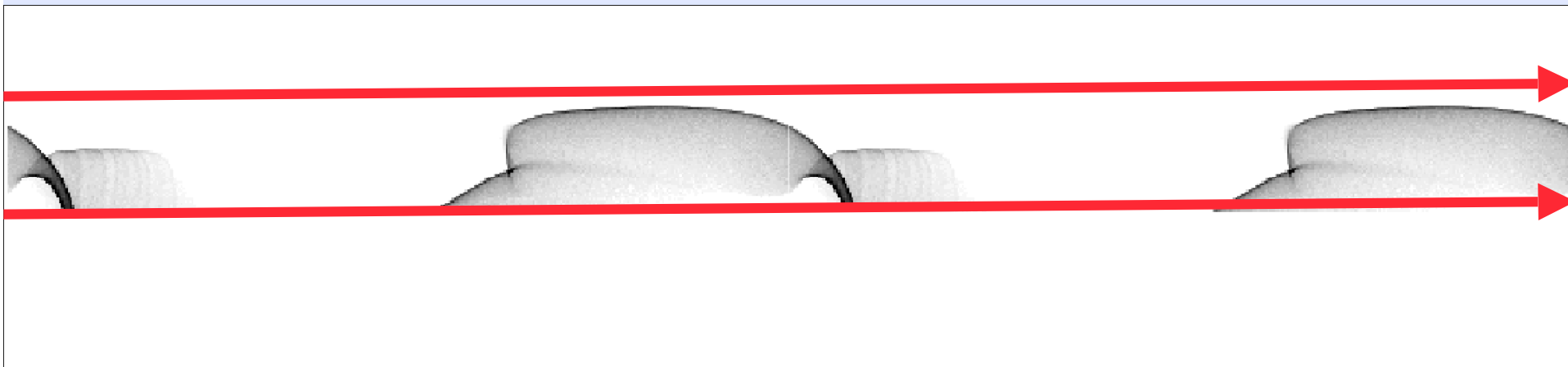
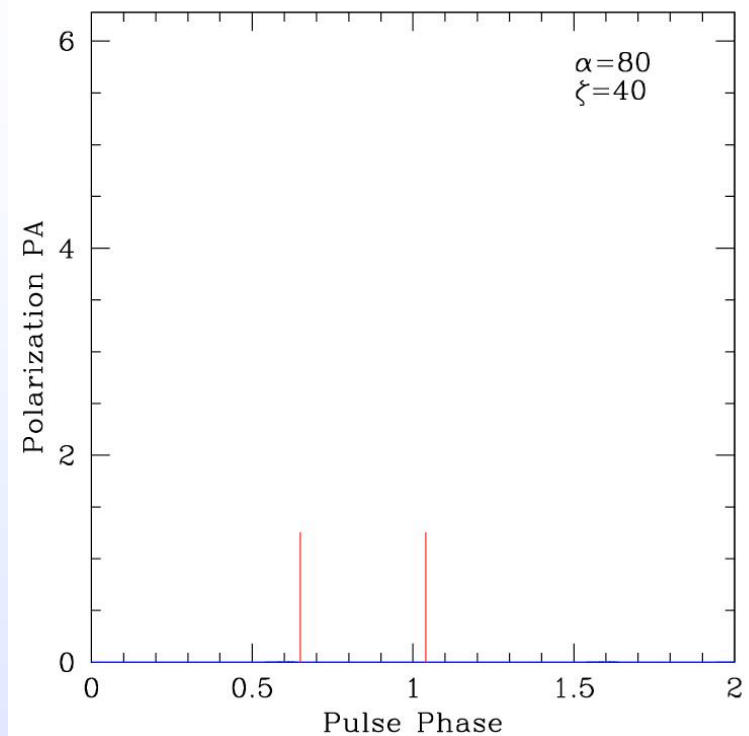


Double Sweep - Two poles?

- Fold-back of field lines at pulse caustics**

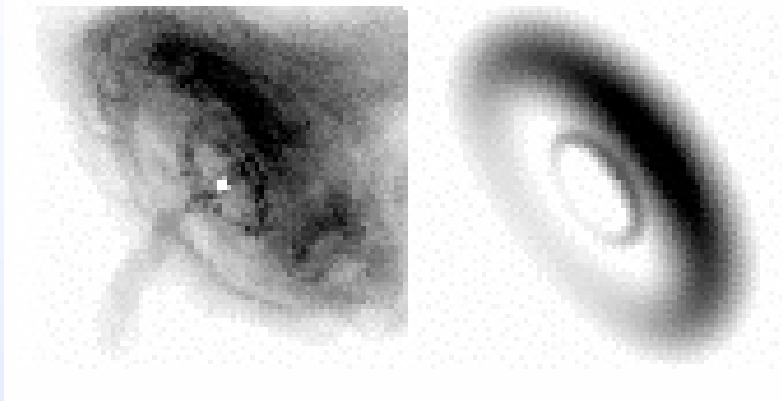


$\alpha = 80, w \sim 0.05$

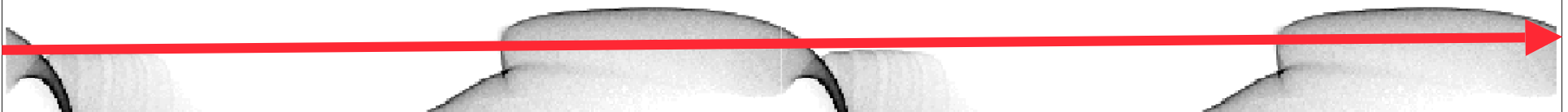
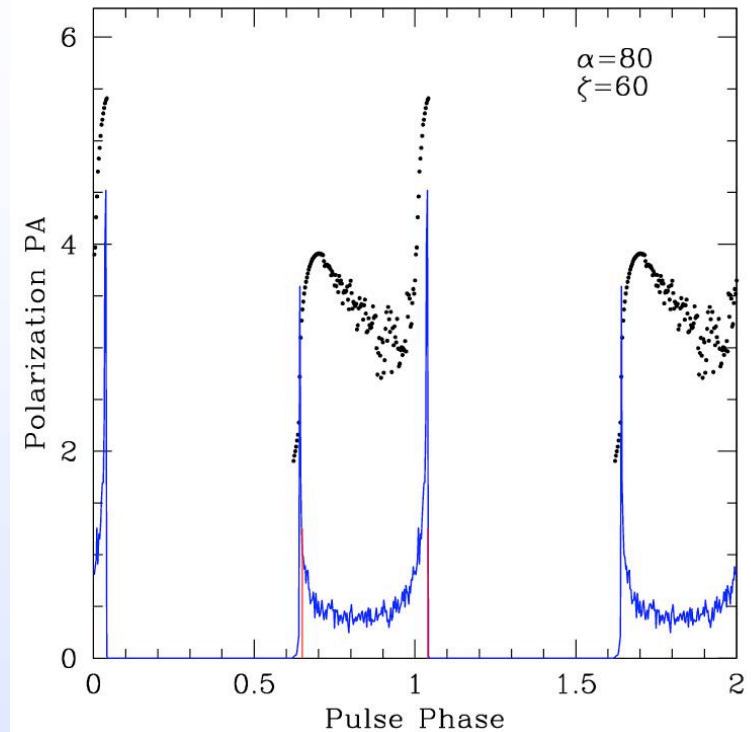


Double Sweep - Two poles?

- So, what is the answer? - X-ray plerion gives $\zeta = 62 \pm 1^\circ$!

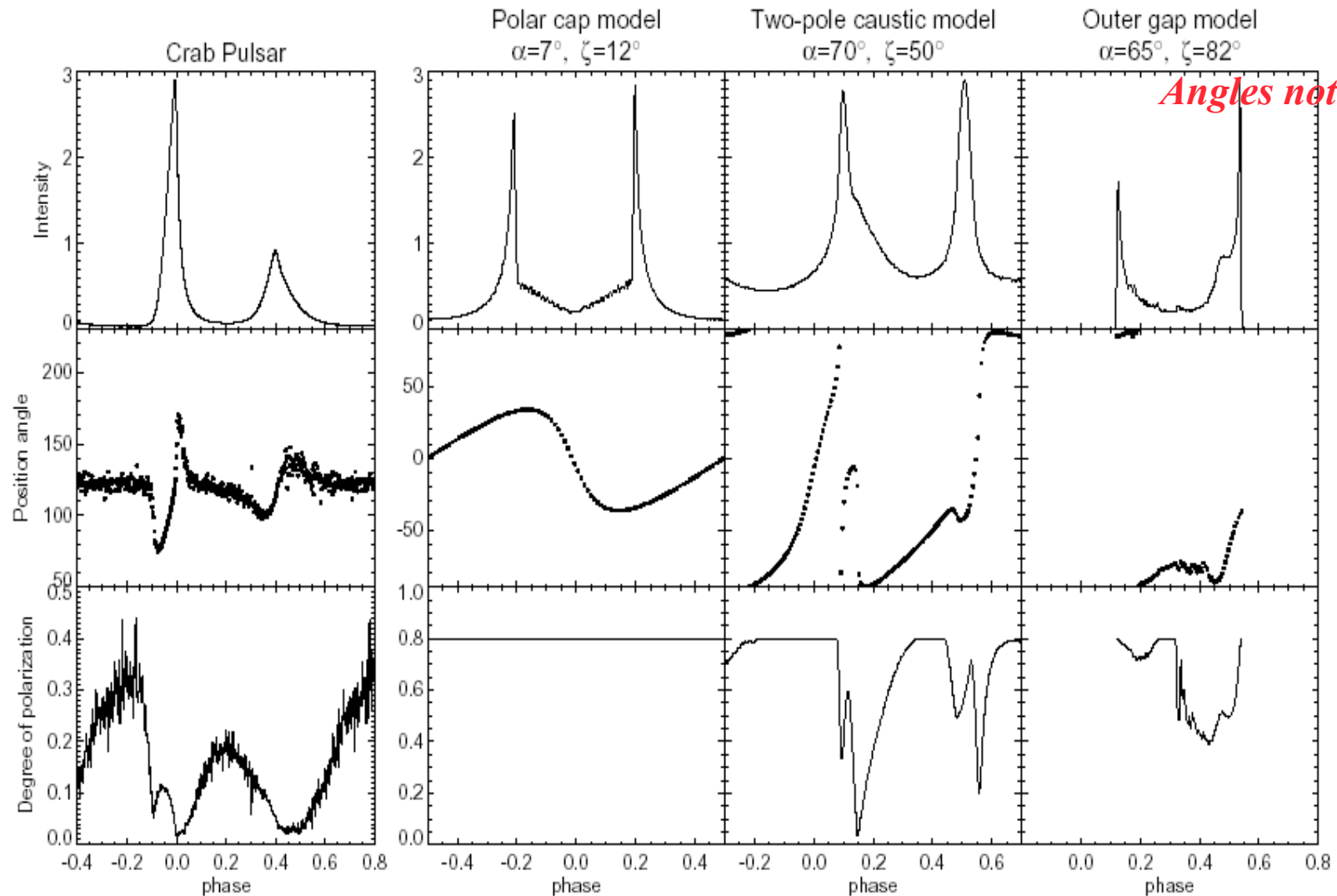


$\alpha = 80, w \sim 0.05$



But see Dyks, et al poster – may not recover this behavior

Polar Cap/Extended Slot Gap/OG?



Dkys, et al 2004 in Kaspi, Roberts & Harding

Other Optical Polarization

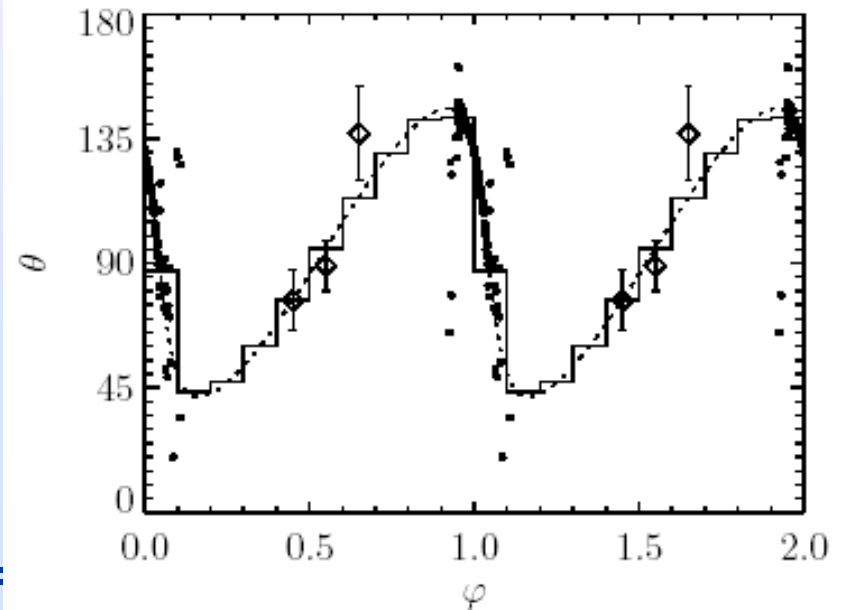
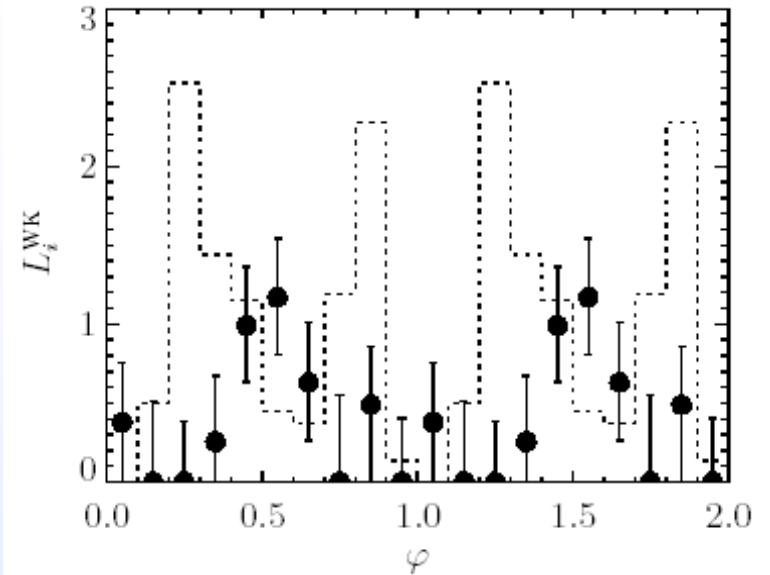
**CCD –based optical polarization of
PSR B0656+14 (Kern, et al 2003)**

10 phase bins

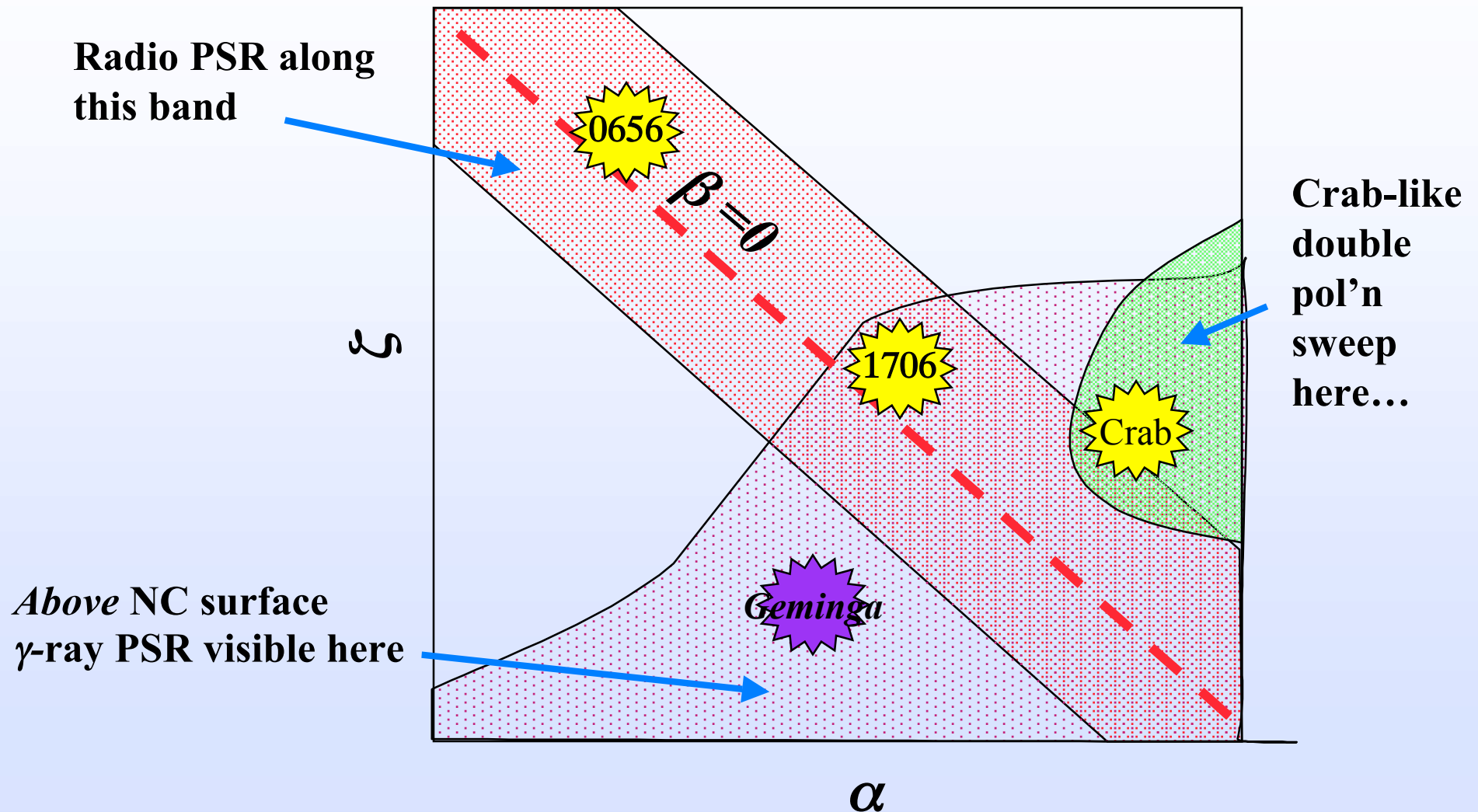
**Bridge emission highly
polarized**

**Peaks low polarization or
rapid caustic sweep**

Consistent with low altitude RVM

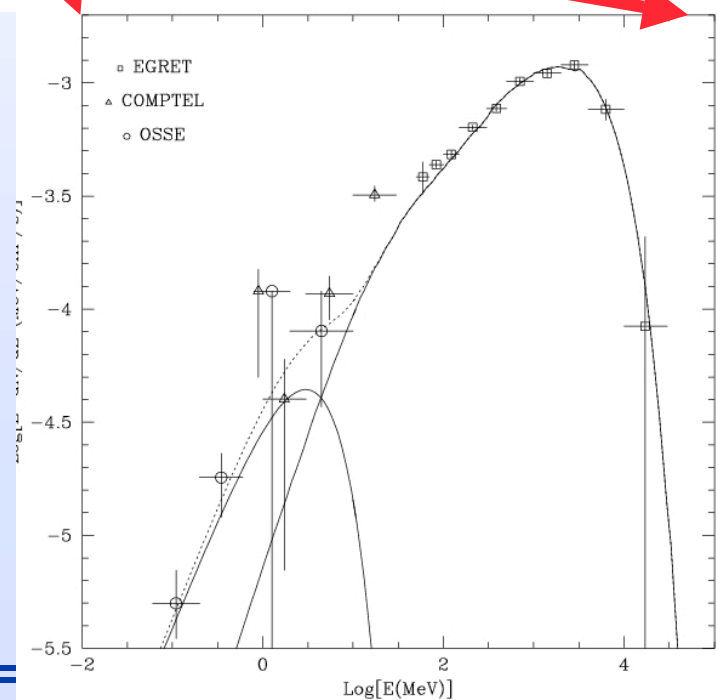
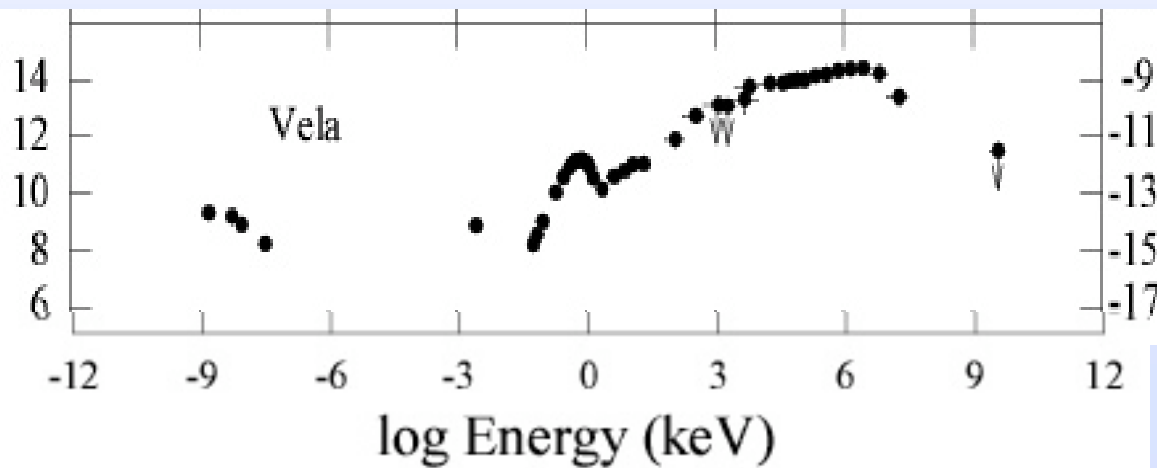
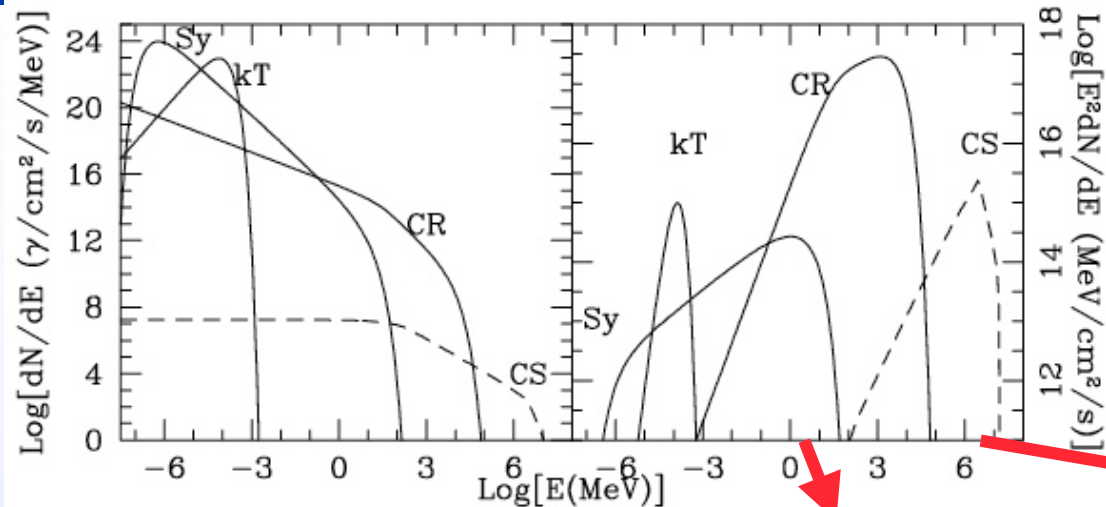


Geometry Determines What you See...



Spectral Components

Radio – coherent
IR-UV, hard X –
synchrotron
Soft X – thermal
GeV -- CR



Polarization Expectations for outer Magnetosphere

- ***Optical/ $>$ keV X-rays - synchrotron from similar PL***
- ***Expect E perpendicular to B , large pol'n in bridge***
- ***Generally single sweep, but not simple structure***
- ***X-ray \rightarrow MeV similar***
 - ***MEGA et sim should see structure similar to optical/X-ray***
- ***CR from GeV γ along B***
 - ***Probably just beyond the do-able w/ GLAST even for Vela, Geminga***

Spectral/Polarization Diagnostics

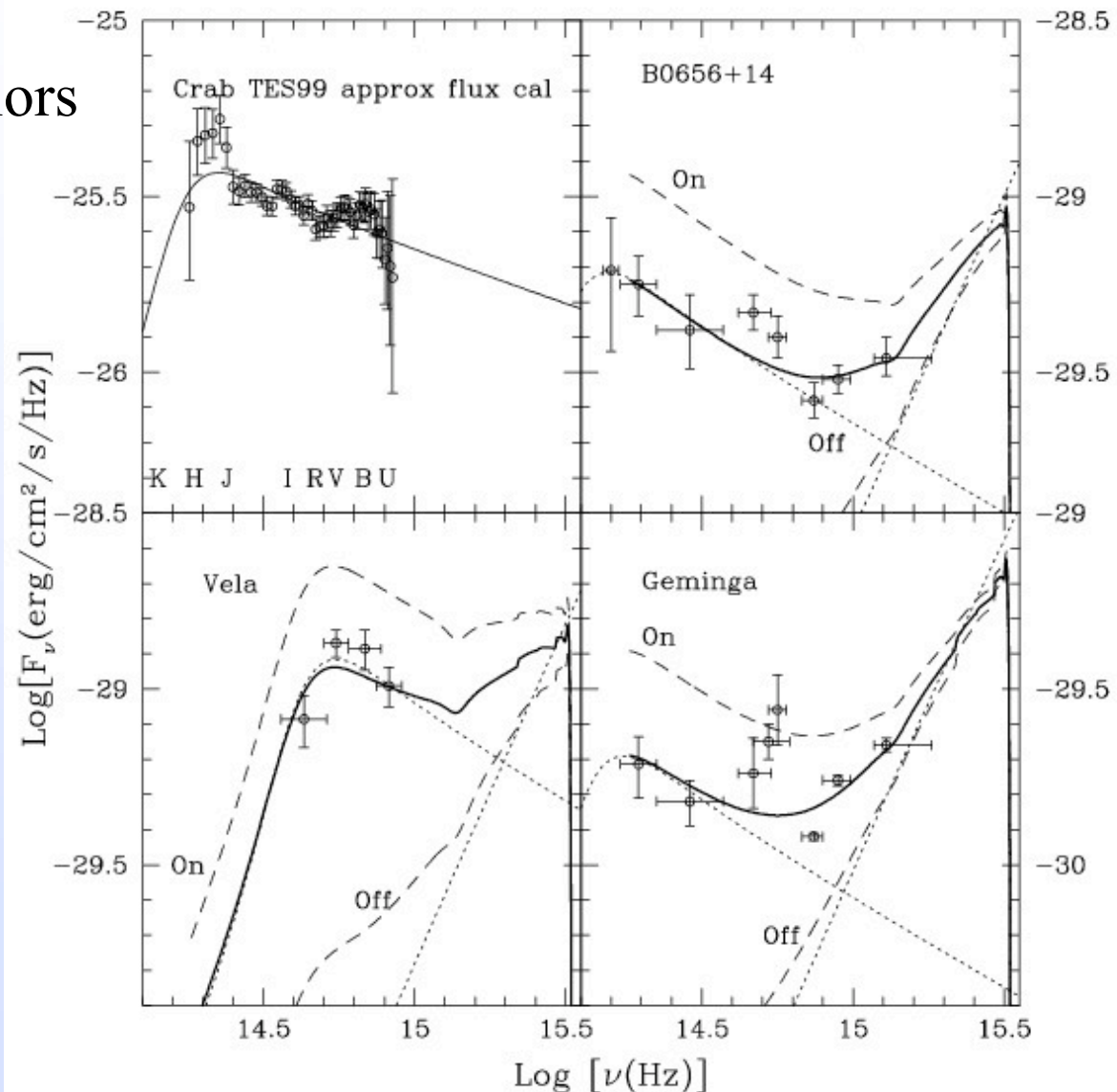
- *X-ray polarization will be really tough*
- *Optical is non-trivial, but doable TODAY*
- *Same N_e population, plus spectral diagnostics*
- *At Null Charge surface:*

$$E_{Cycl} = 0.3 B_{12} \Gamma_{-1} (\tan \alpha / 2.75)^6 \text{ eV} \quad (\alpha = 70^\circ)$$
- *At light cylinder $\sim 10^{-4}$ eV. Expected $e^+/e^- \Gamma \sim 10-1000$*
- *For studying OUTER magnetosphere processes, X-ray is not the way to go...*

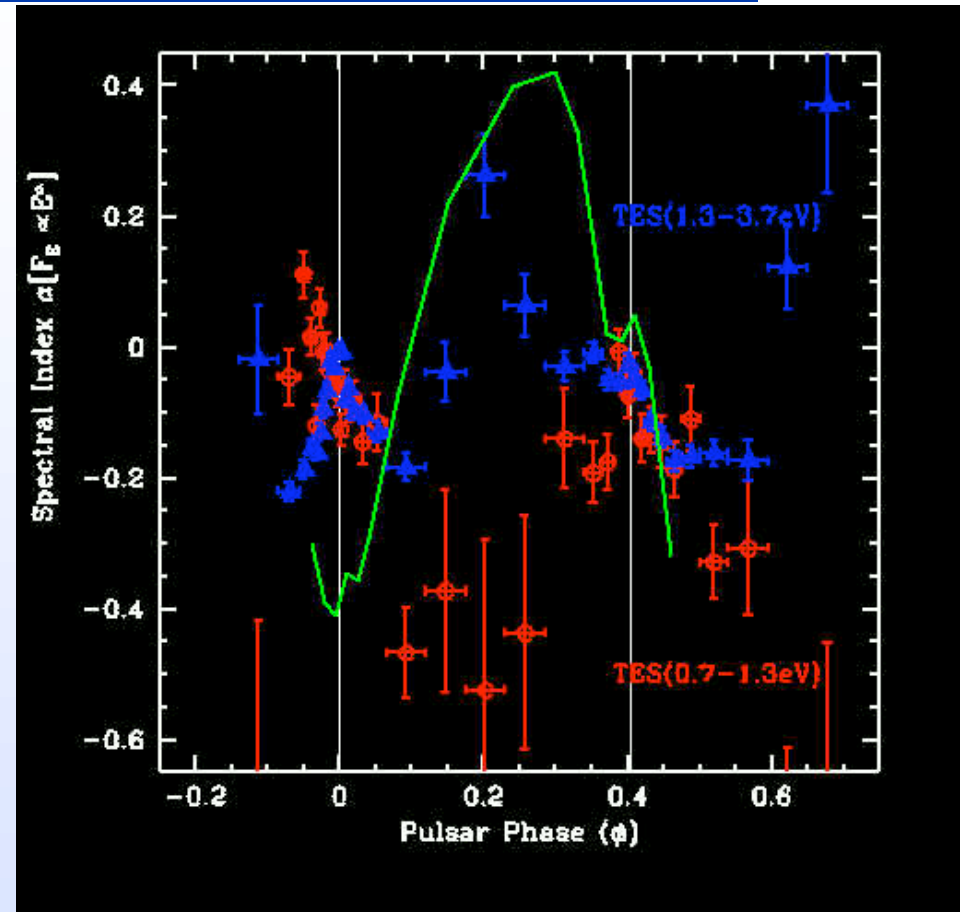
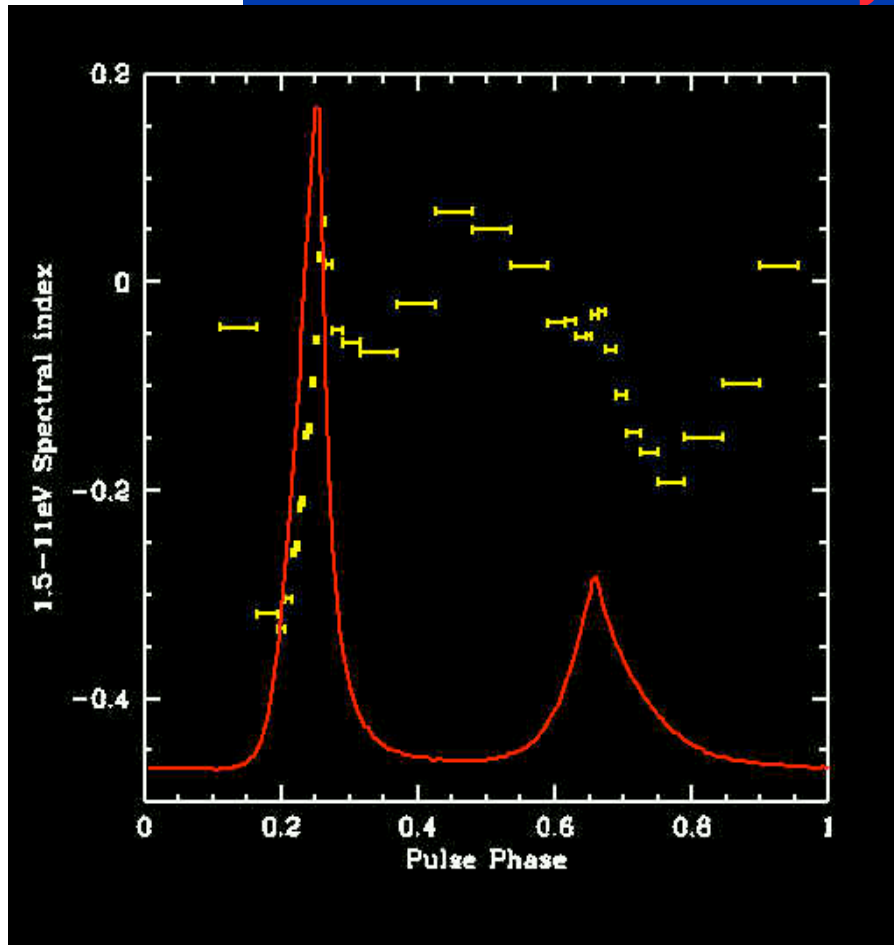
IR-UV a key place for pair diagnostics

Phase-averaged colors
IR break in Crab
B/V bump in
Geminga,
PSR 0656+14
-- E_{Cyc} , Abs tracers
of local B

**To exploit this
component we
need phase-
resolved spectro-
polarimetry! At
 $m_V > 25!!$**



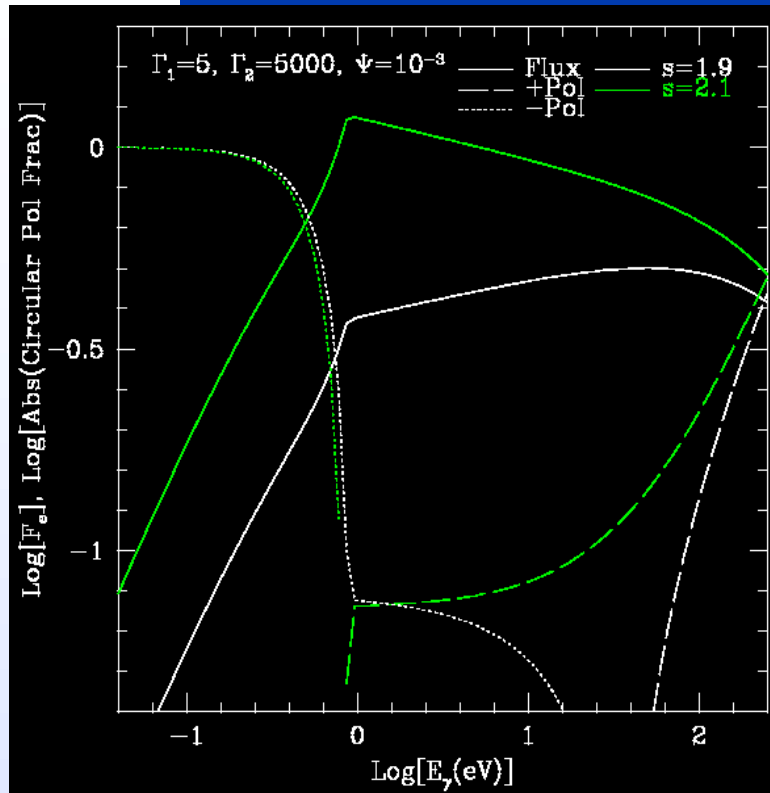
E.g. Puzzling Crab Spectral index variations



Part of explanation, varying e^\pm cascade, SI (incl low Ψ
Cr-W, K&L'01)

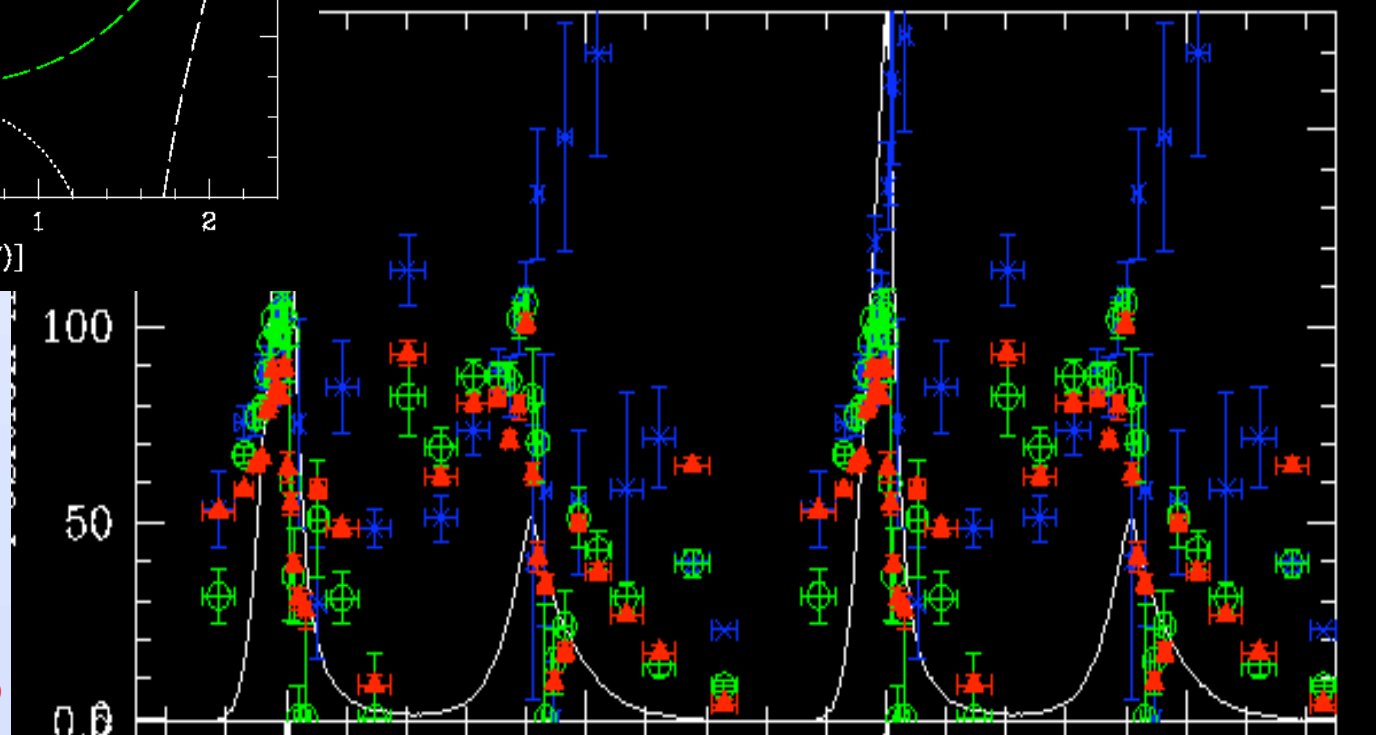
Also need partial sampling of Synch cone, Self-abs leading P1

Low Pitch angle Synchrotron



Low pitch angle synchrotron can have abrupt spectral/pol'n changes at few E_{cyc} break (esp. circular....)

TES Energy-resolved linear pol'n sweep



Conclusions?

- *Outer gap field geometries are complex - rich variety of polarization behaviors*
- *Outer gap synchrotron*
 - *faint*
 - *morphologically tight ties from IR through MeV*
- *Key physics diagnostics are at ~keV energies near surface, at few eV or below in outer magnetosphere*
- *Outer magnetosphere polarization probably **not** a strong driver for next generation X-ray polarimeter*
- *Rich variety of spin-powered pulsars - geometry rules and polarization remains the key to untangling this!*