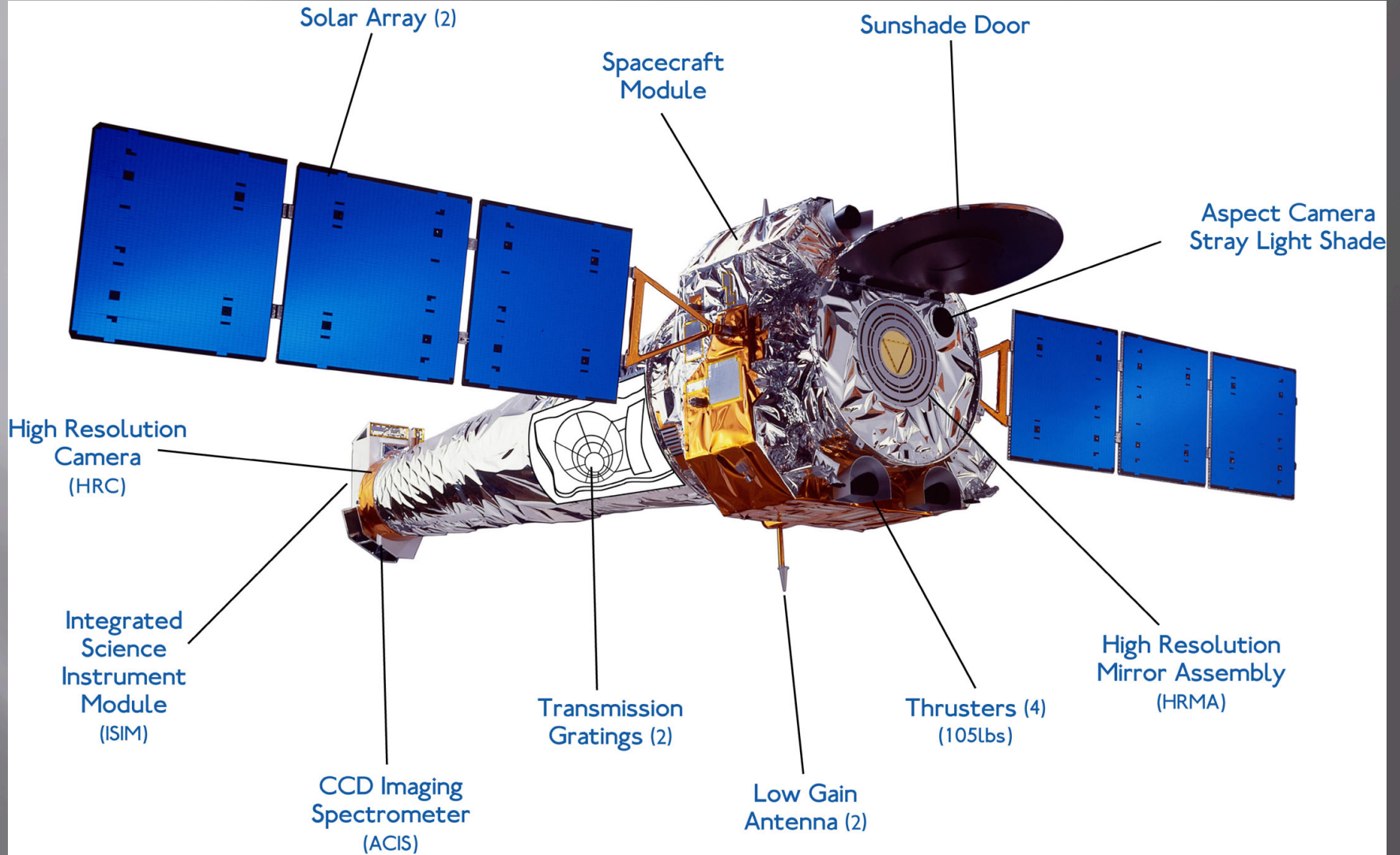


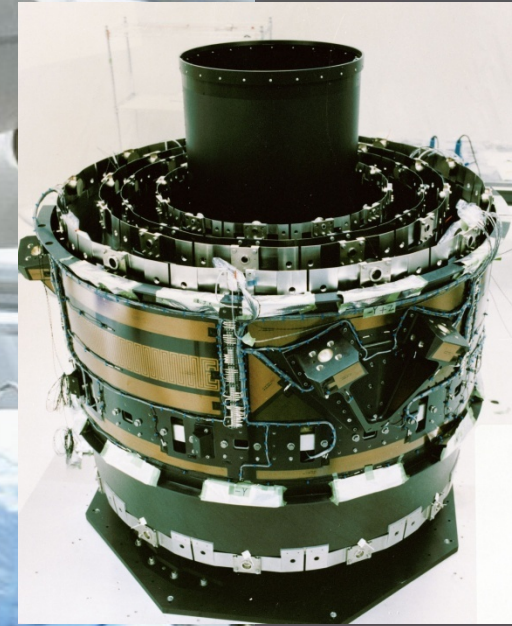
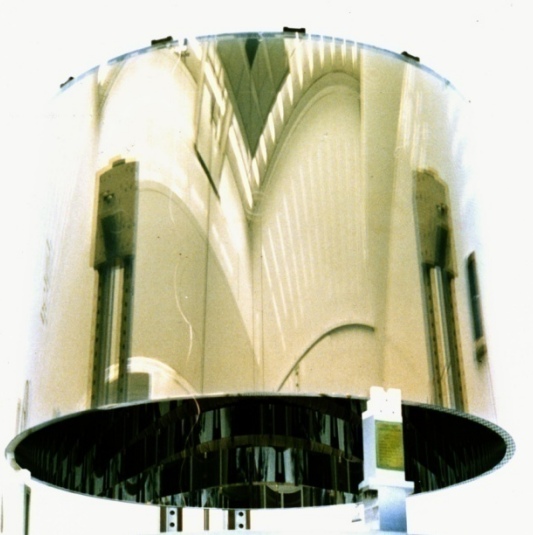
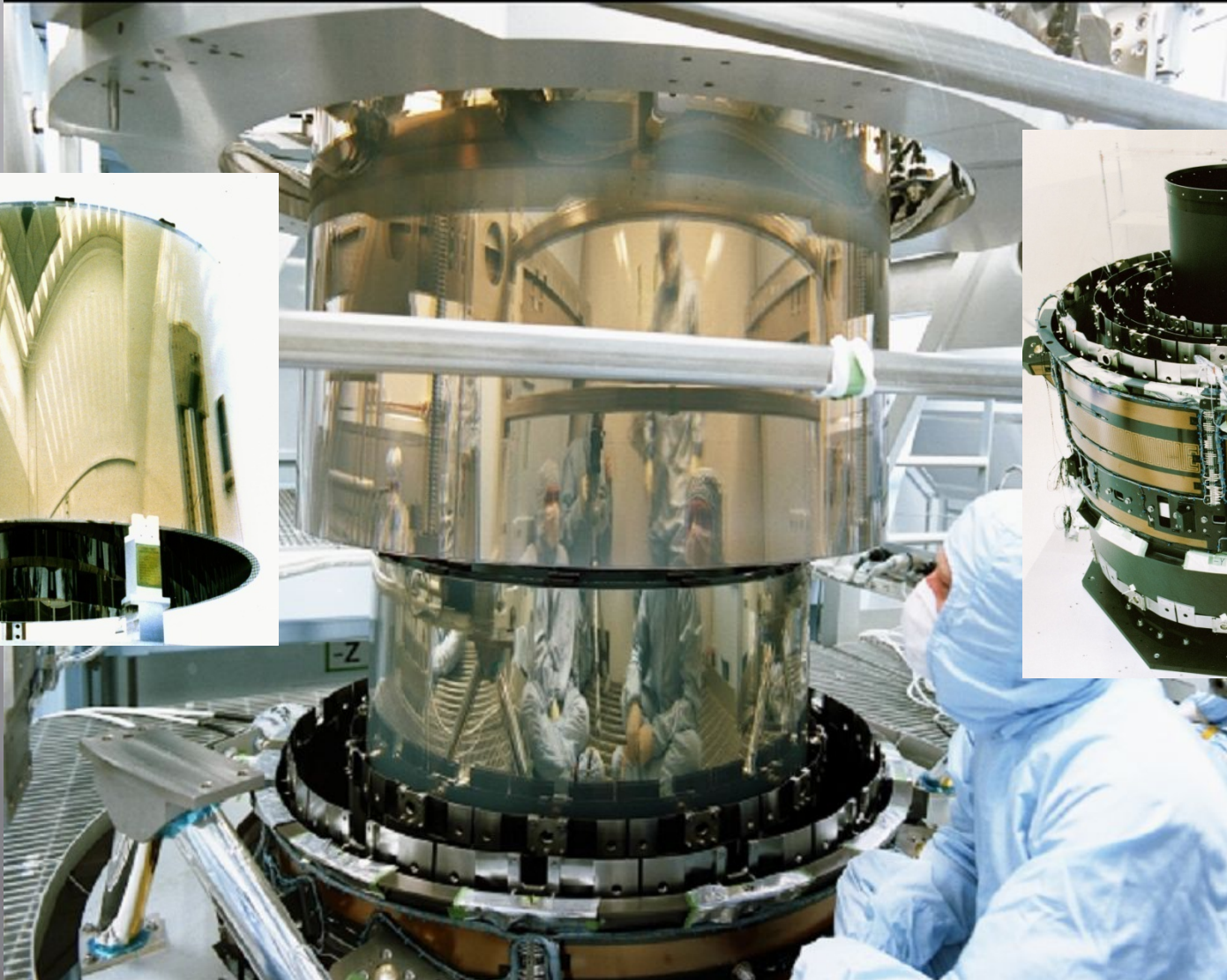
THE CRAB NEBULA AND ITS PULSAR AS SEEN IN X- RAYS WITH CHANDRA

Martin C. Weisskopf
NASA/MSFC
Fermi Summer School
May30, 2012

The Observatory



The Optics



The Test Facility



Topics

Introduction

The geometry

Correlations with the gamma-ray flaring?

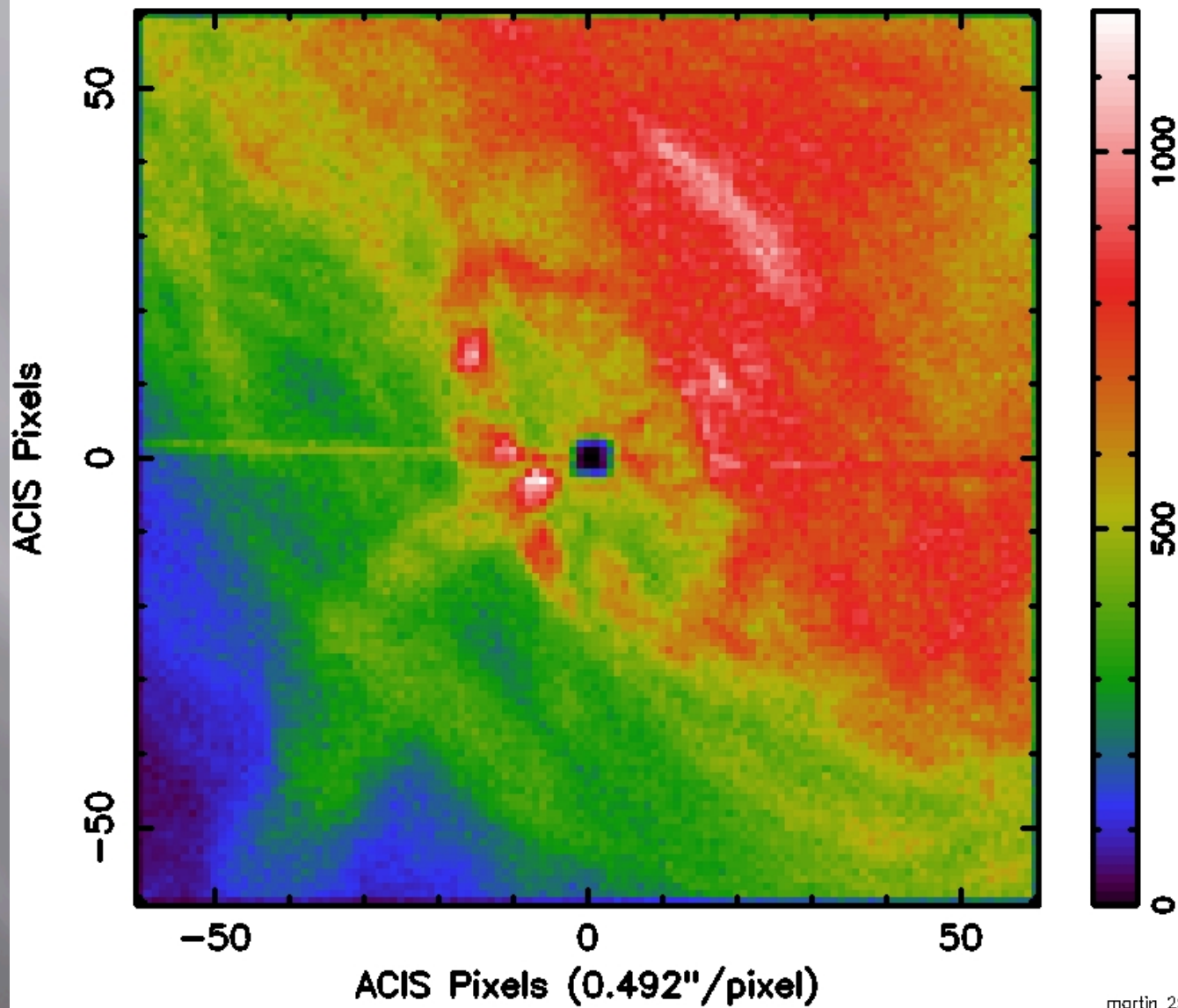
- Where is the beef?

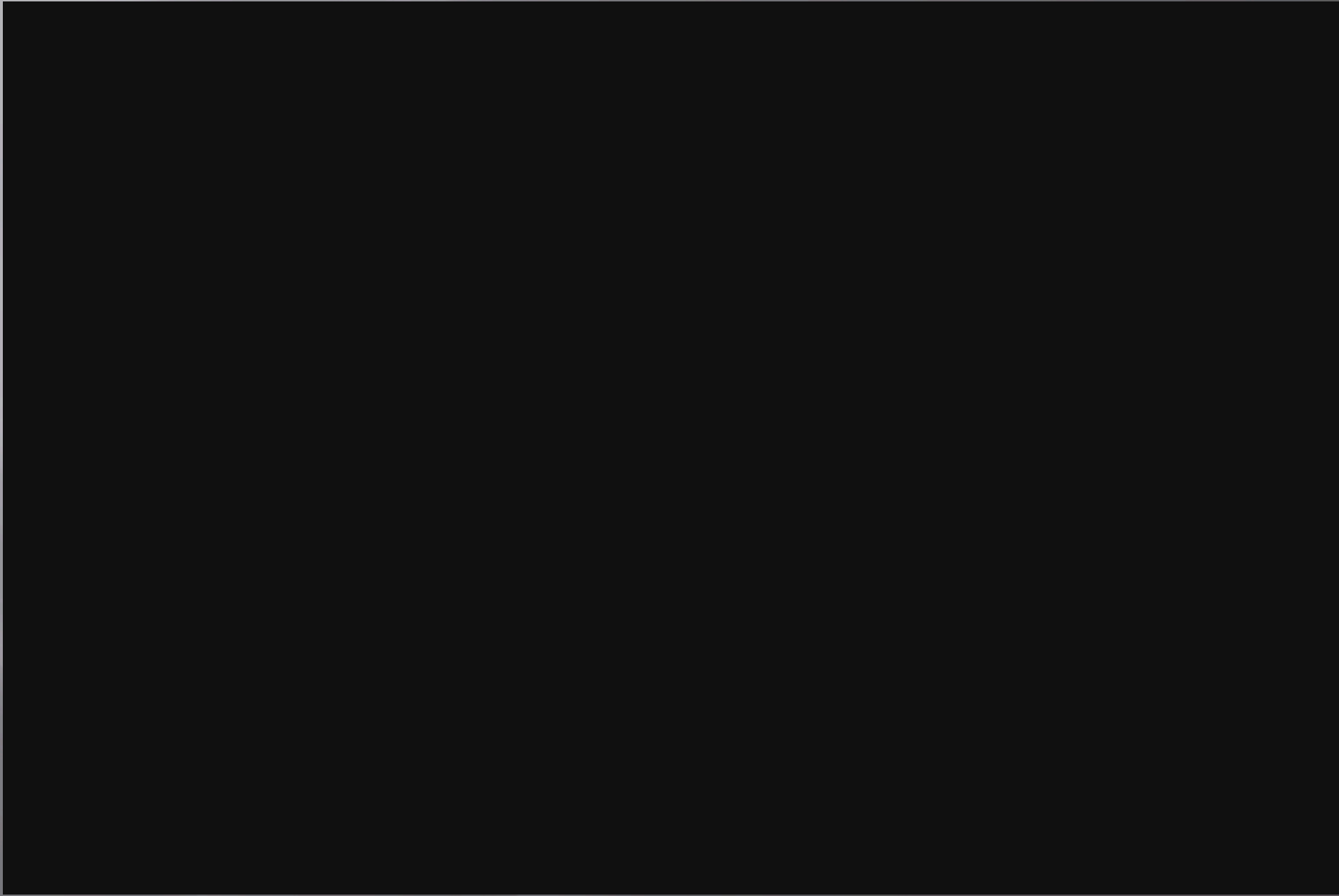
Phase-resolved spectroscopy of the pulsar

- Challenge to theory

The spatial temporal variability of the southern jet

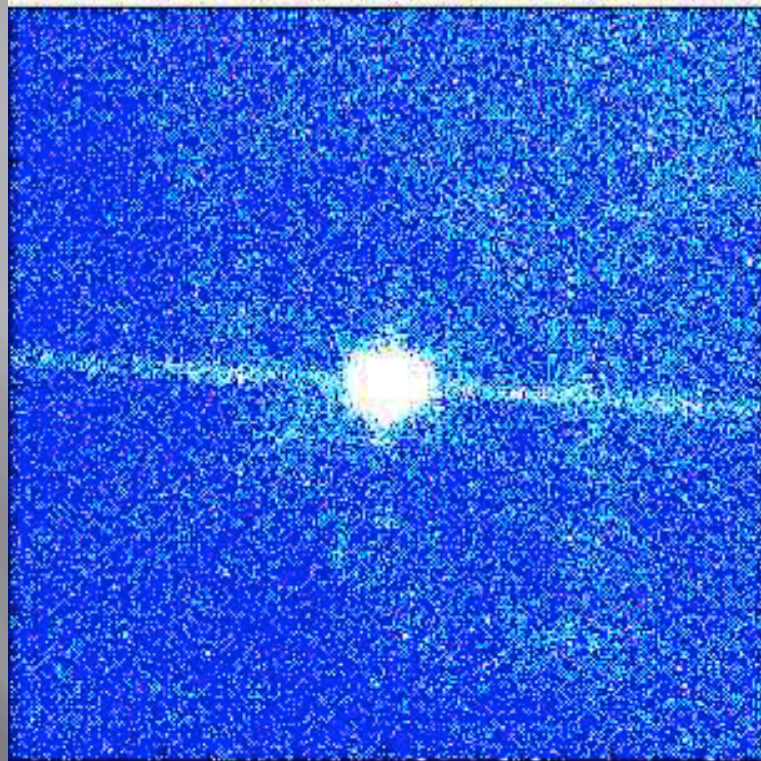
Crab





The pulsar is always on

Phase 0.94..1.02



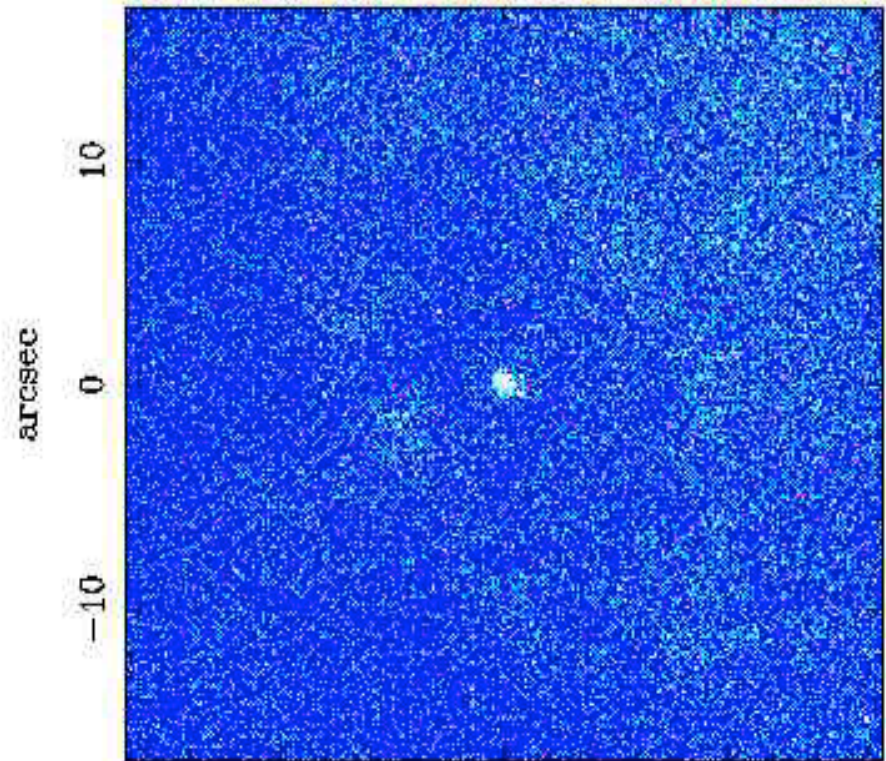
-10

0

10

ARCSEC

Phase 0.72..0.80



10

0

-10

ARCSEC

-10

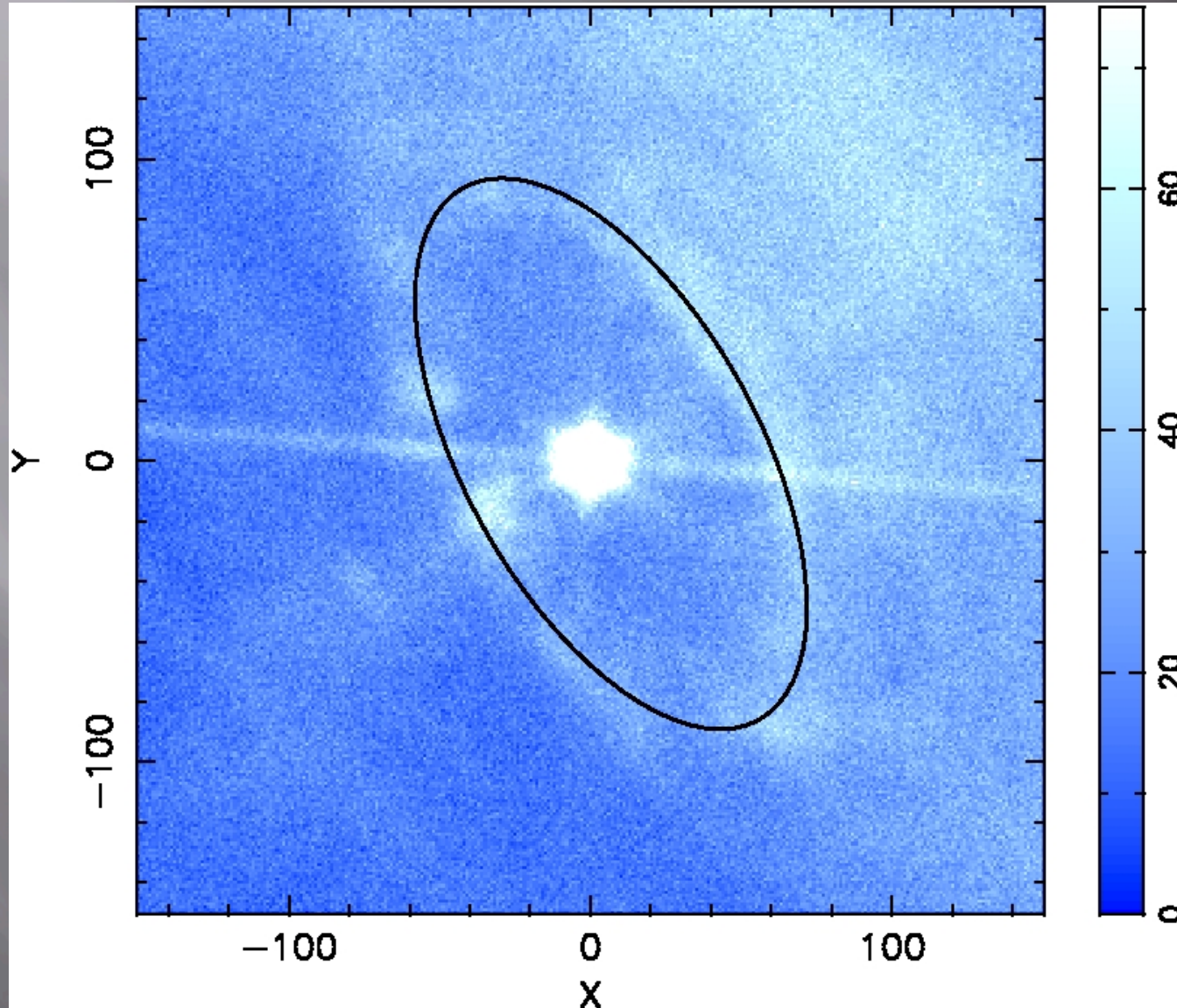
0

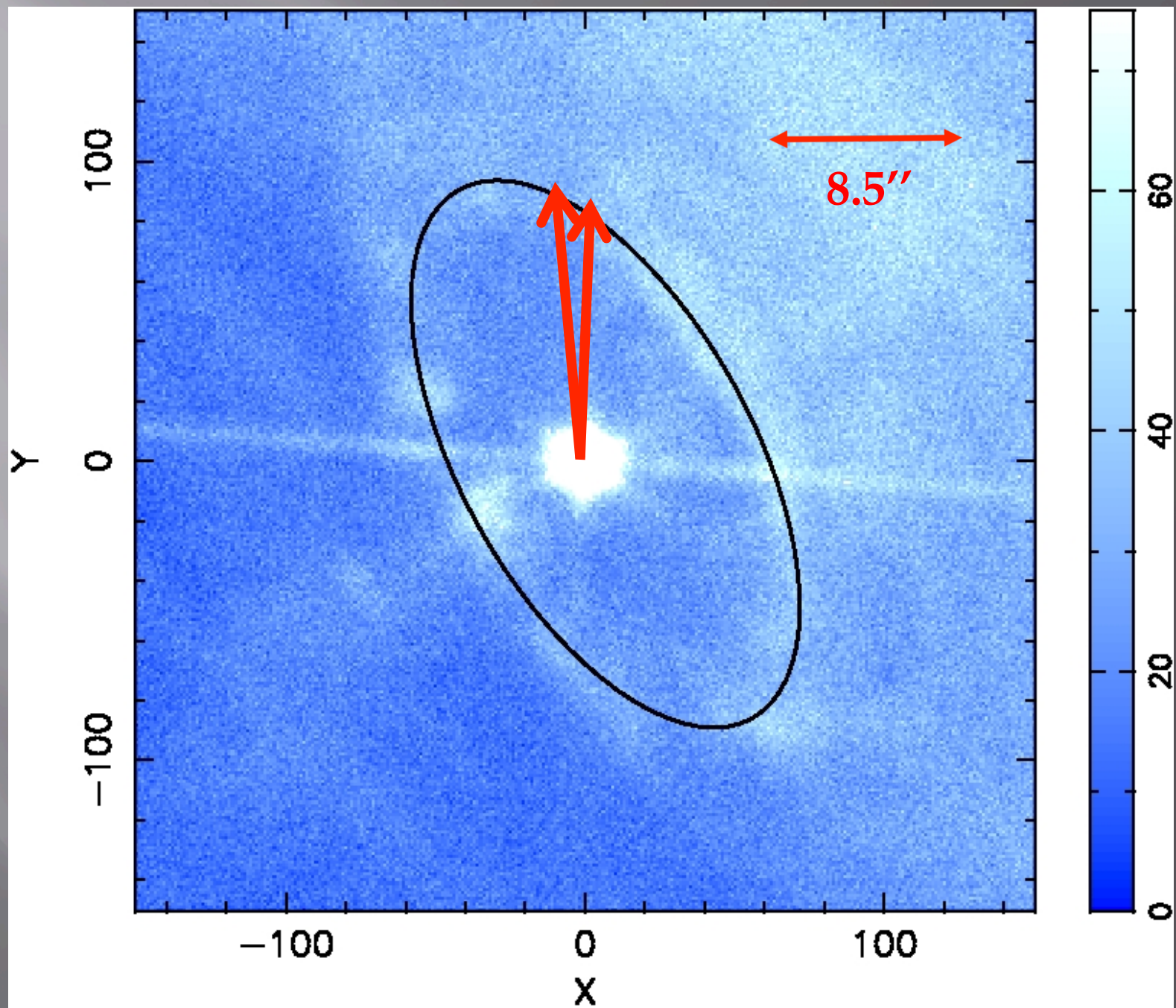
10

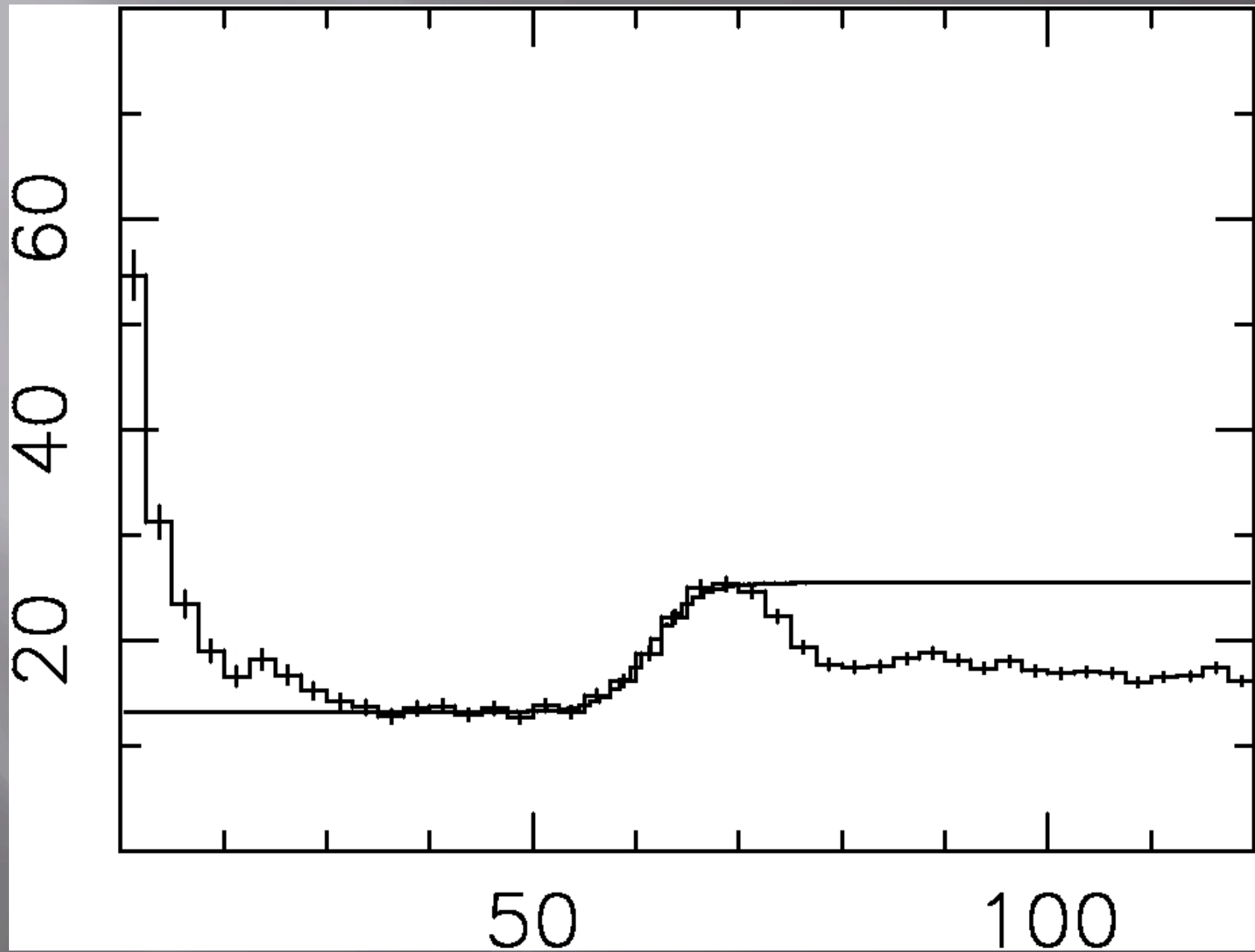
ARCSEC

The inner geometry

The pulsar is not necessarily at the center of the “inner ring”







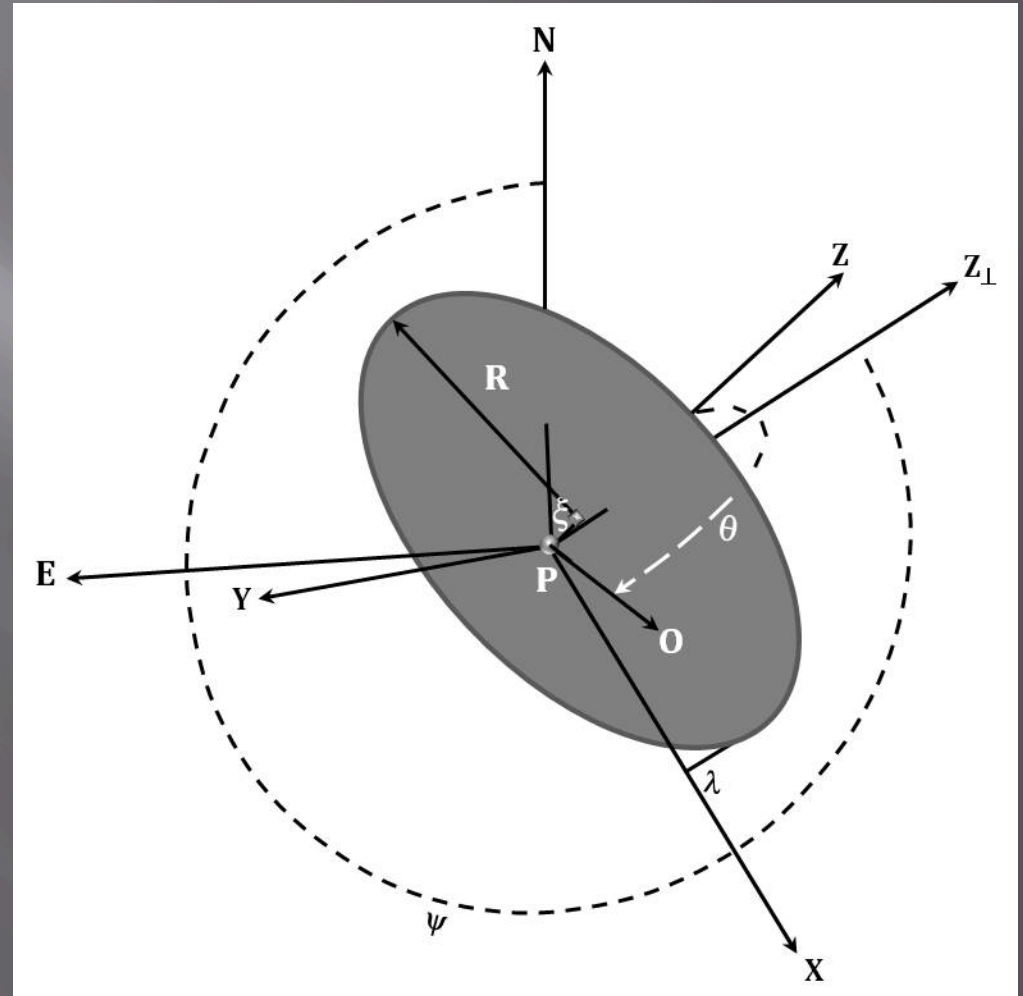
A simple geometrical model

Displace the pulsar
along the spin axis
away from the ring

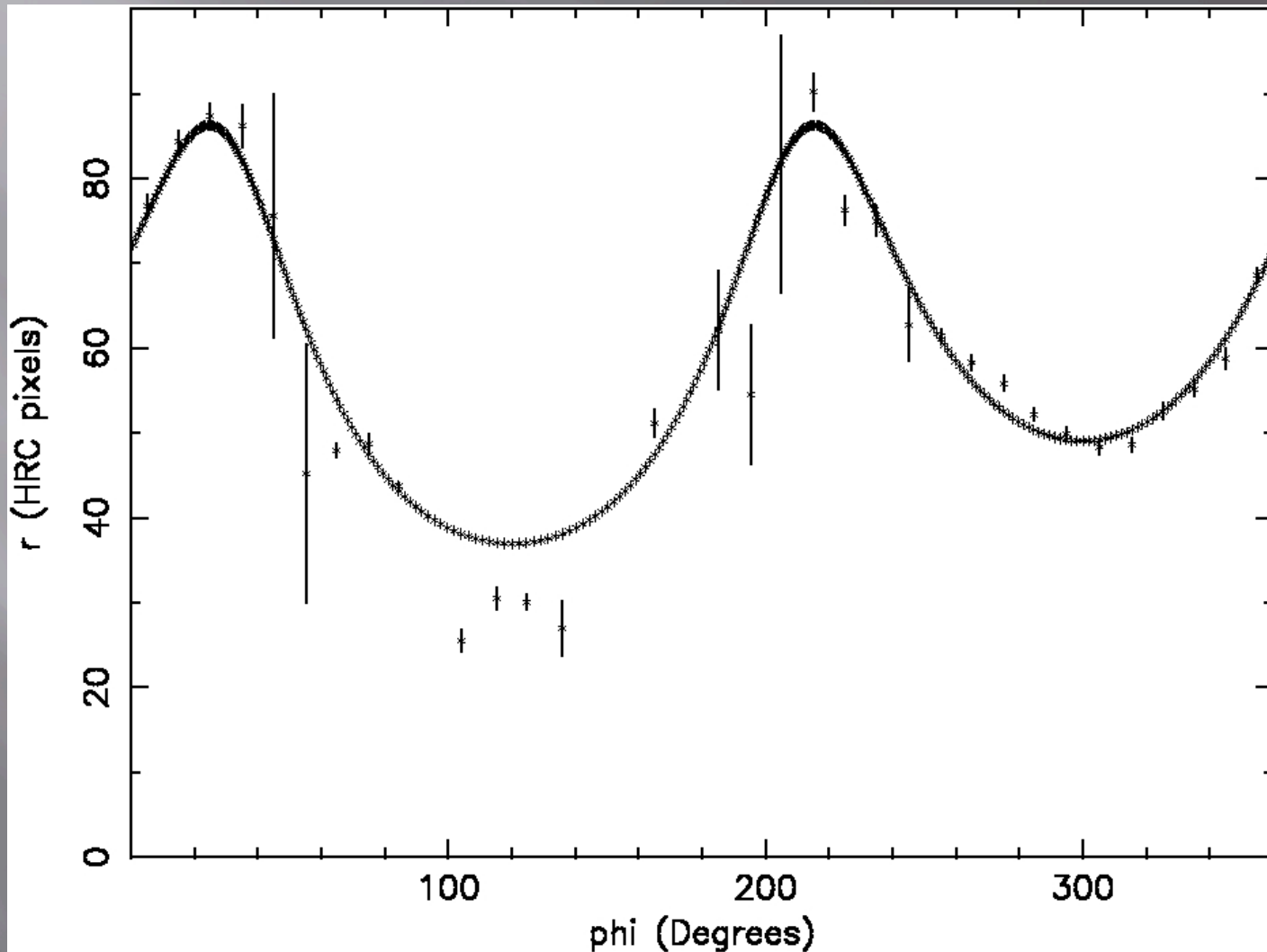
Best fit model implies:

Offset is $0.9''$
i.e. 10 light days

“Disc” is at a latitude
of 4.5°



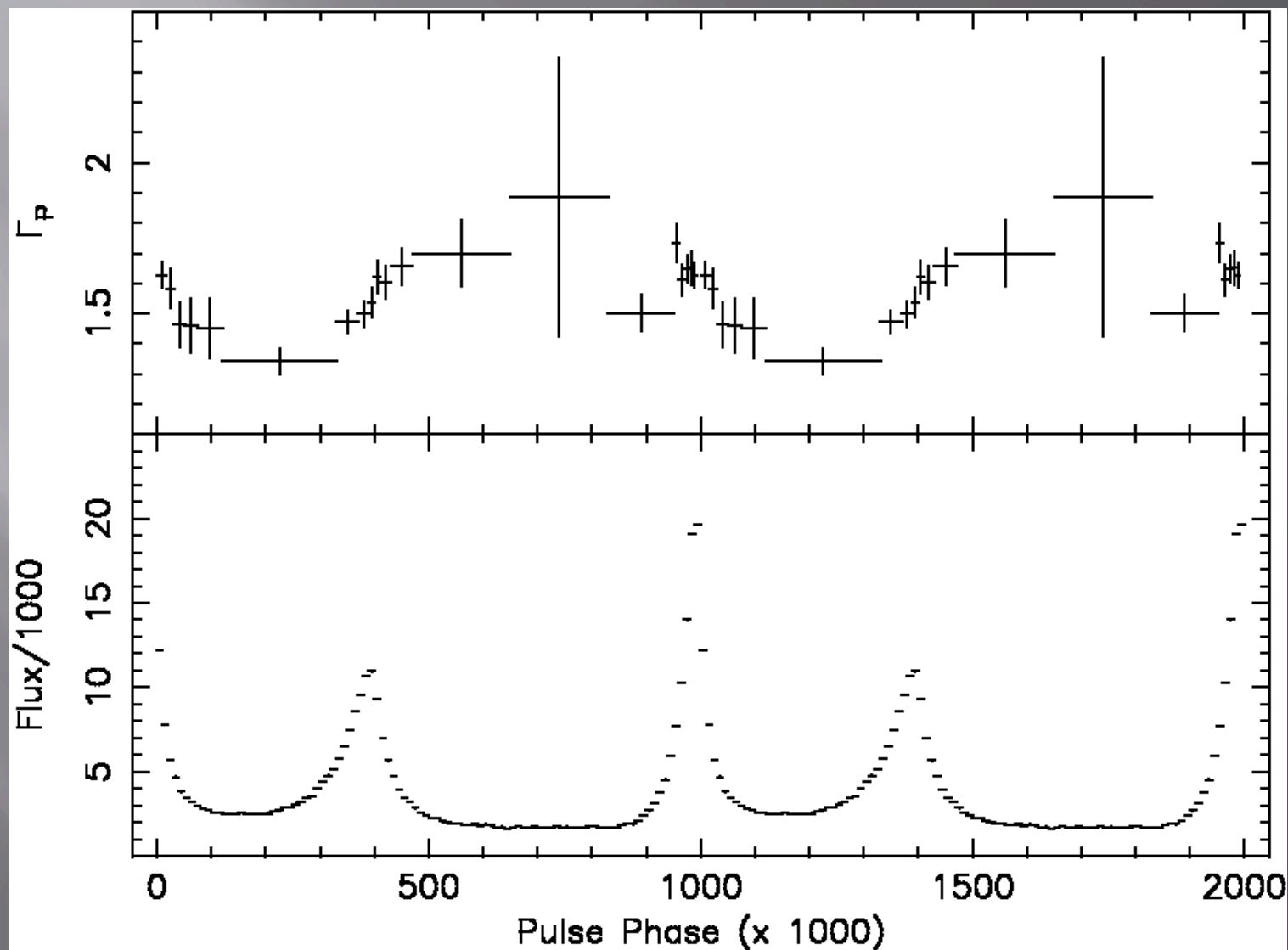
How well does this model fit?



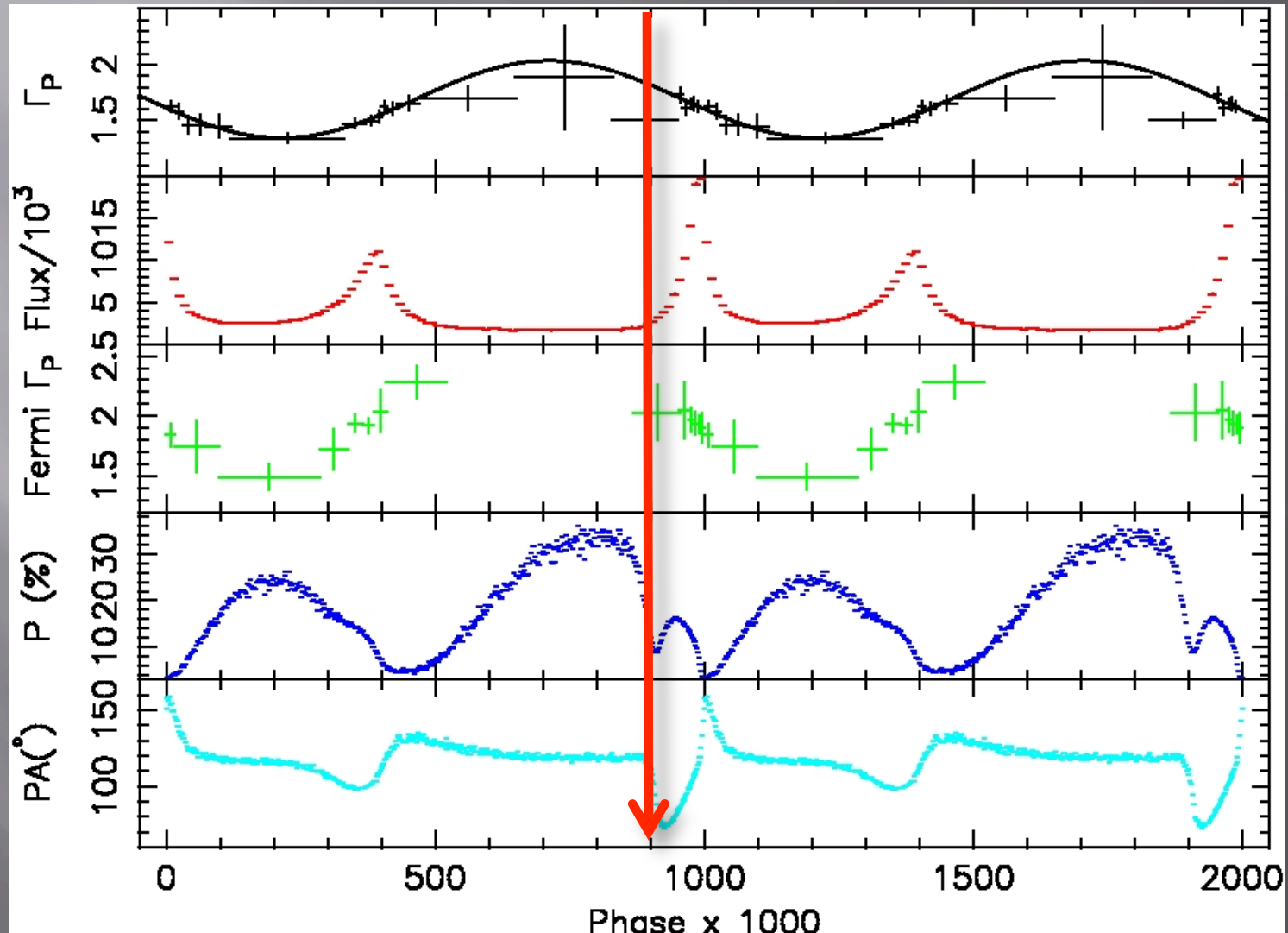
The model is by no means unique!

The Pulsar

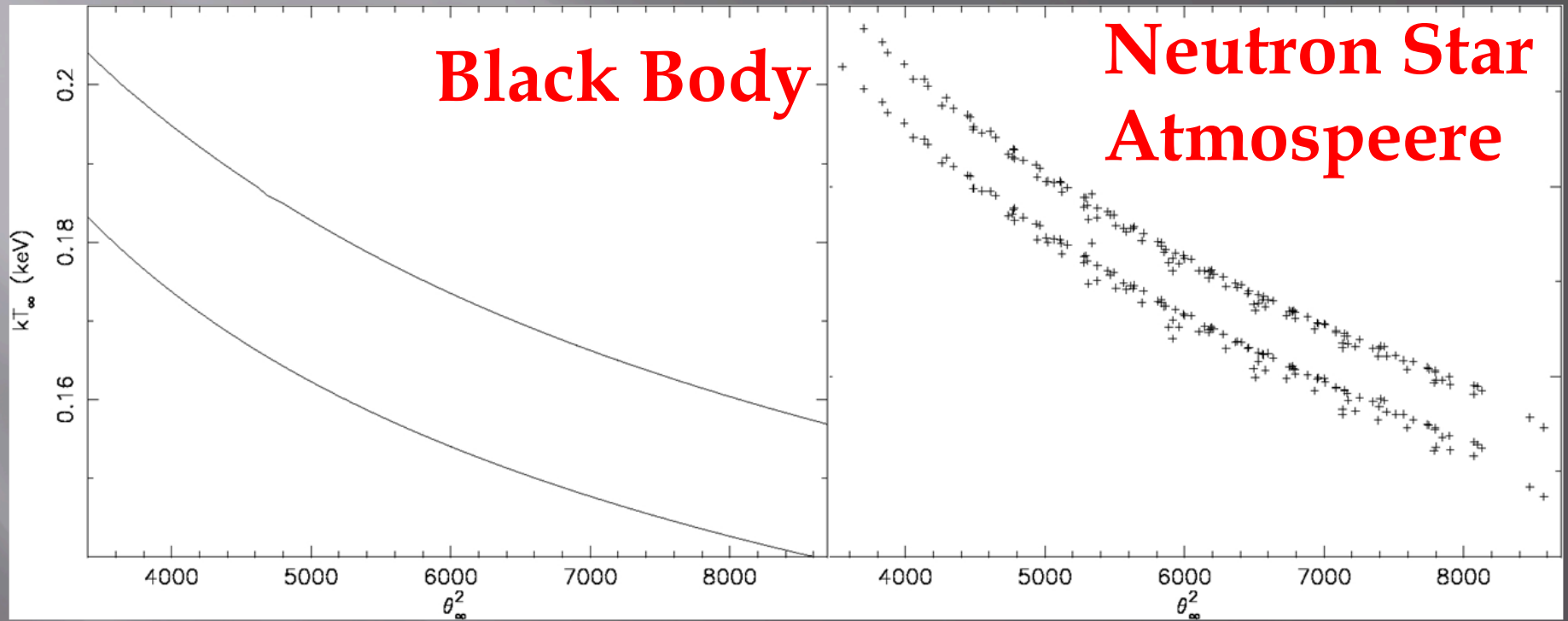
Phase resolved spectroscopy of the pulsar at all phases



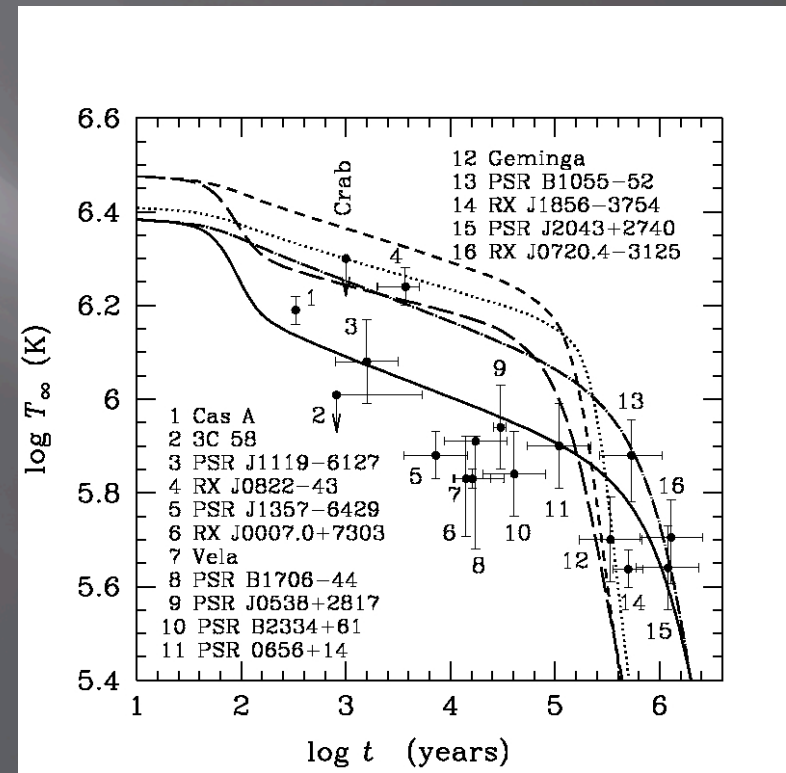
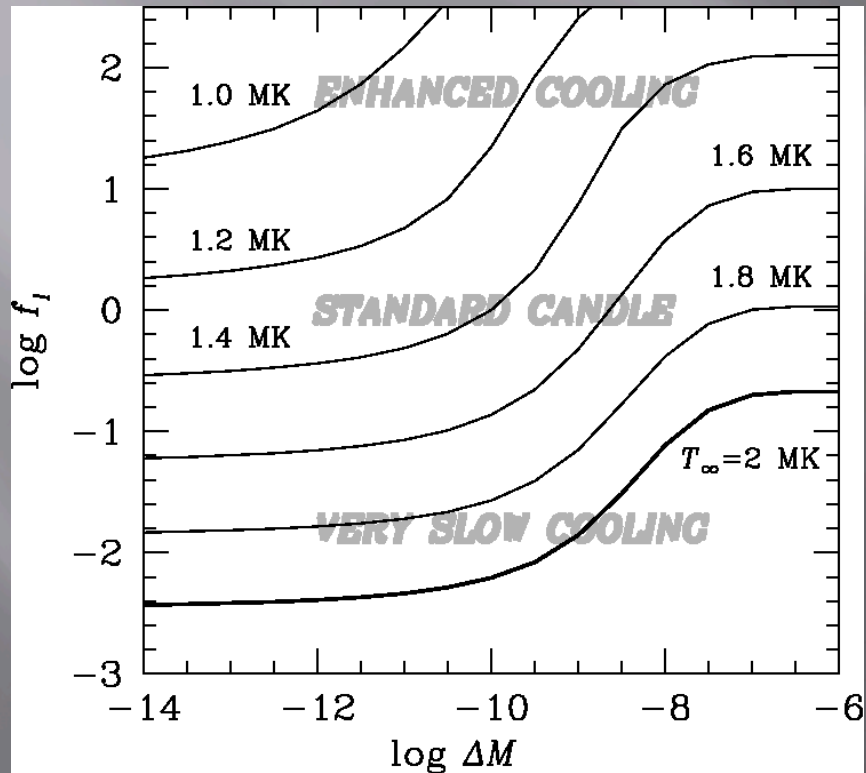
The challenge to theorists



New limits on the thermal emission from the pulsar



Potential implications for cooling and for equations of state



The search for the origin of the gamma-ray flares

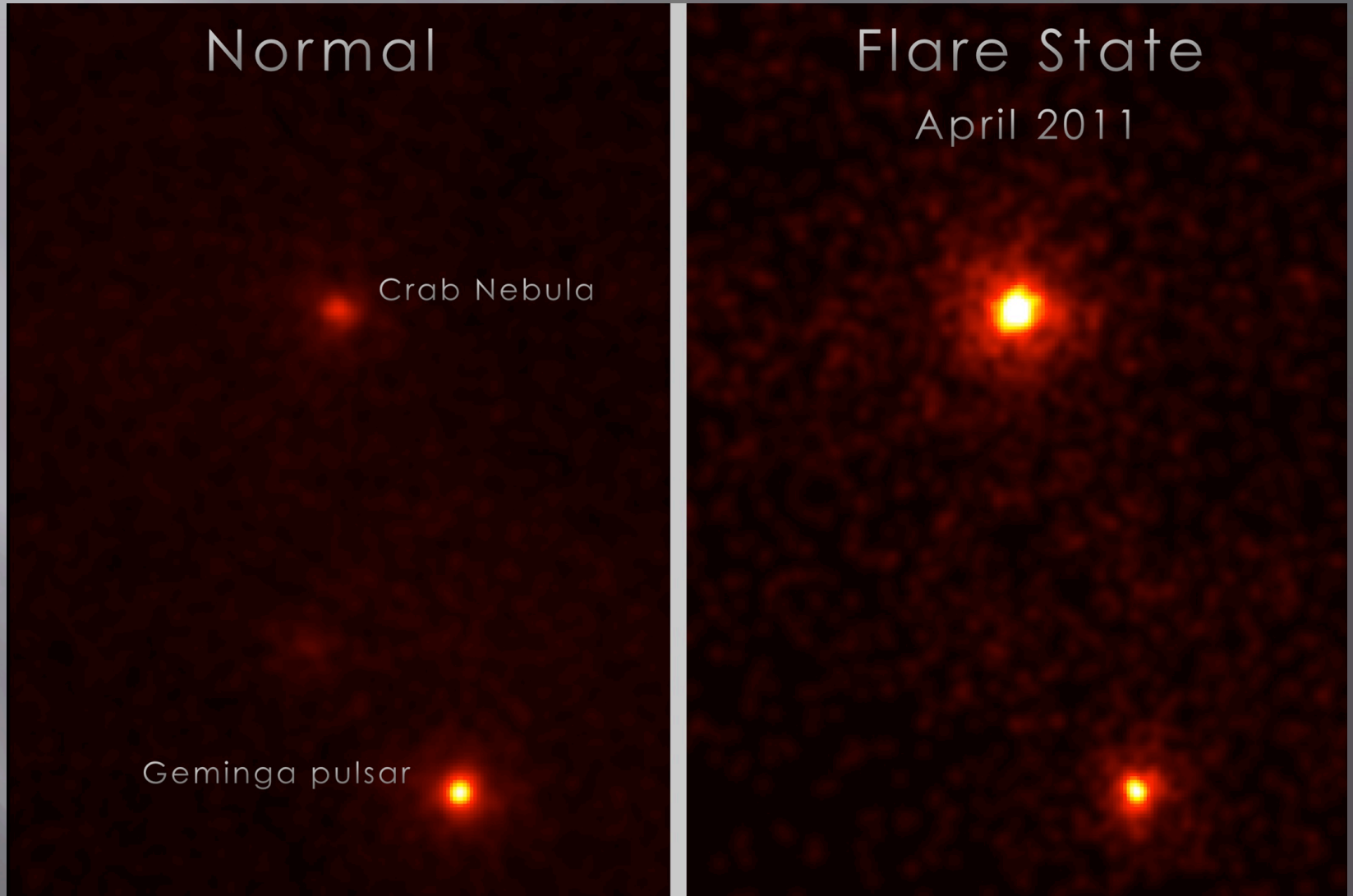
Normal

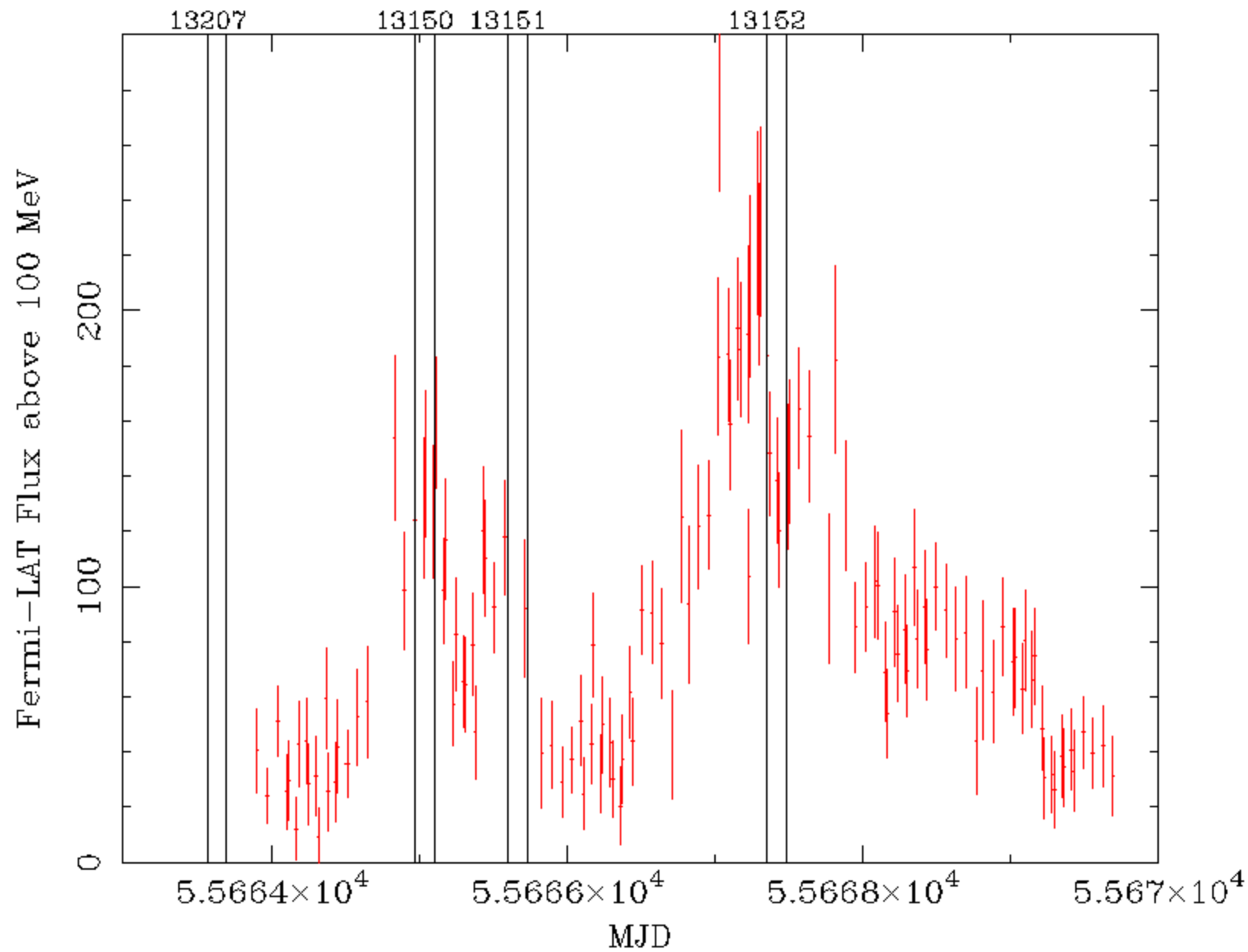
Crab Nebula

Geminga pulsar

Flare State

April 2011





Search for the origin of the γ -ray flares

The rise in X-ray flux may slightly lead γ -ray flaring.

- Accelerated particles typically reach X-ray energies first.

Synchrotron losses will cause the γ -ray flux to decline first .

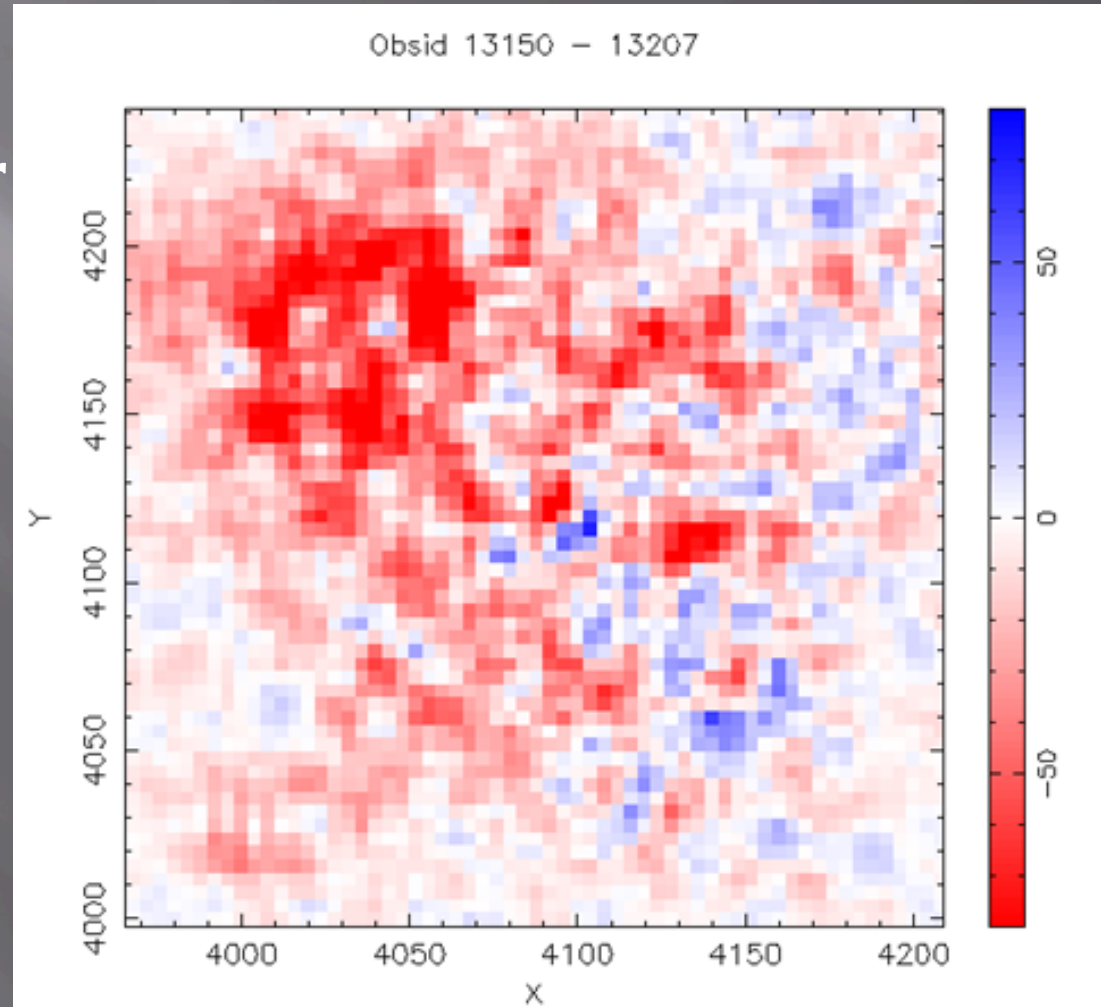
The count rate may decline due to spurious effects such as pileup and/or contamination coupled with a new placement of the image on the detector.

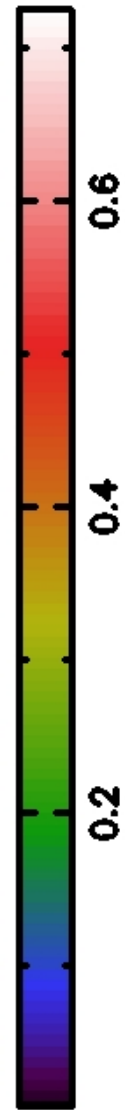
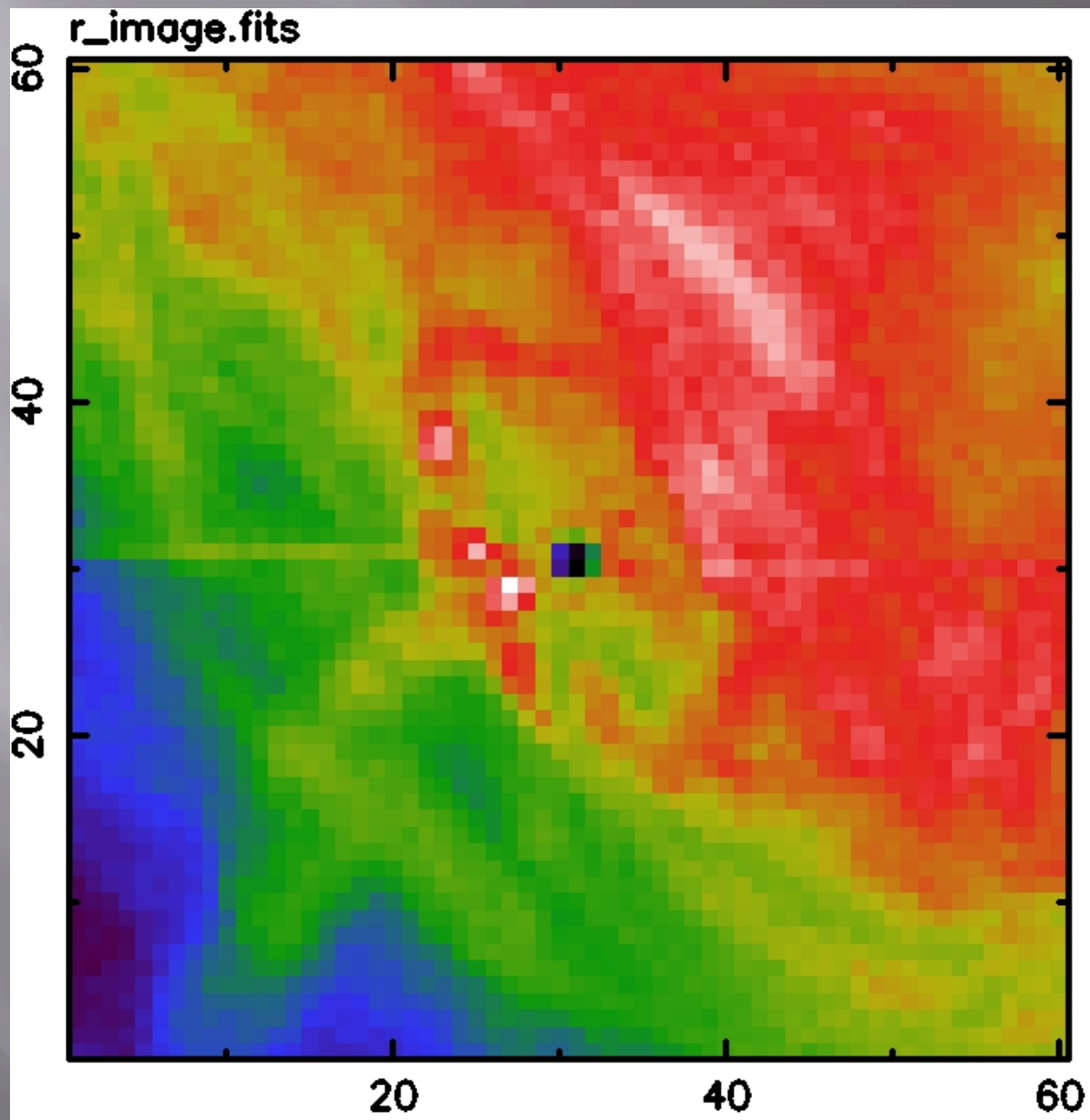
Searching for variations in the Chandra ACIS images is tricky

Huge swath of nebular faded in 33 hours?

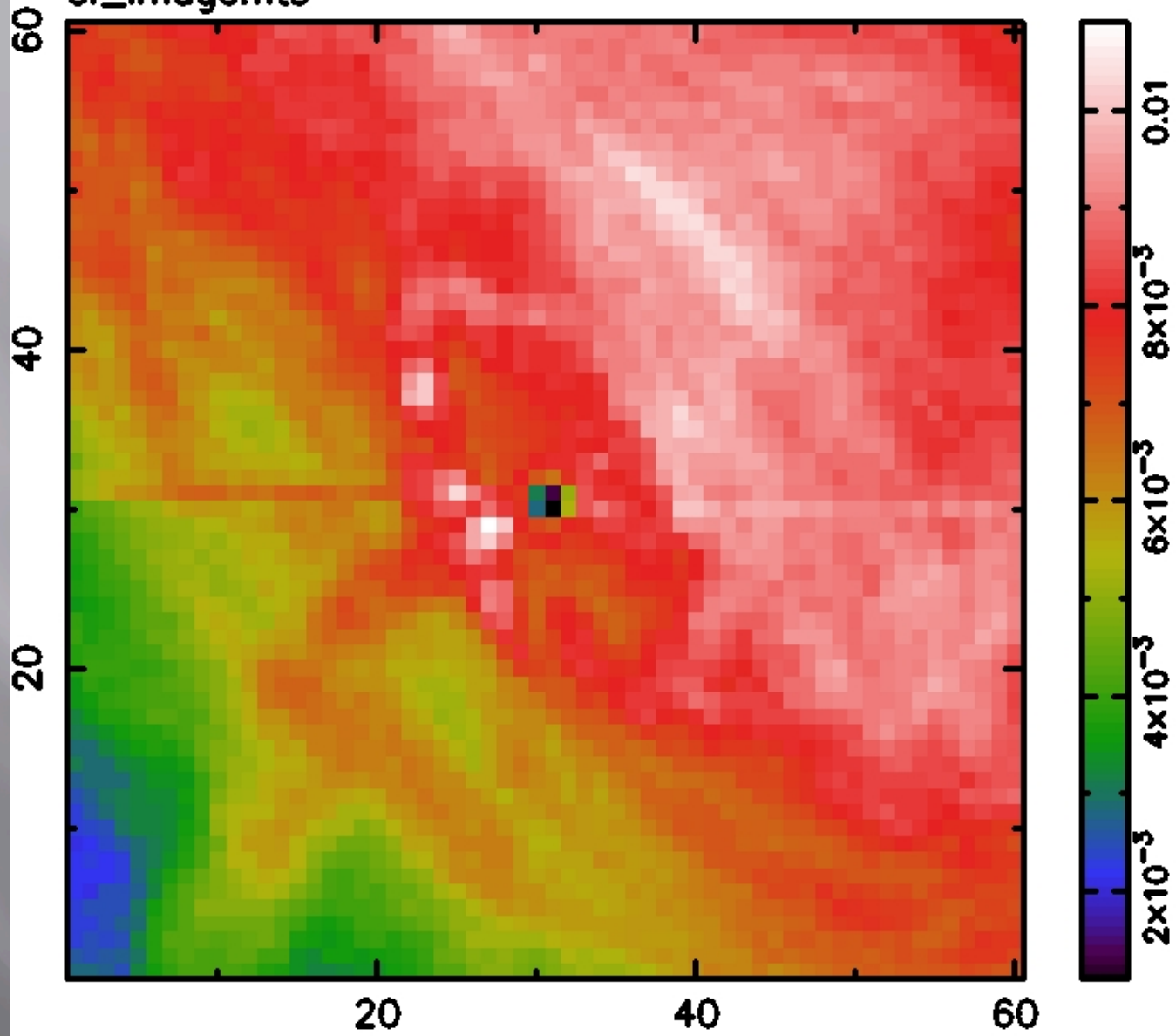
No!

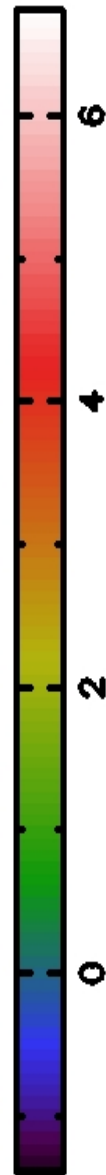
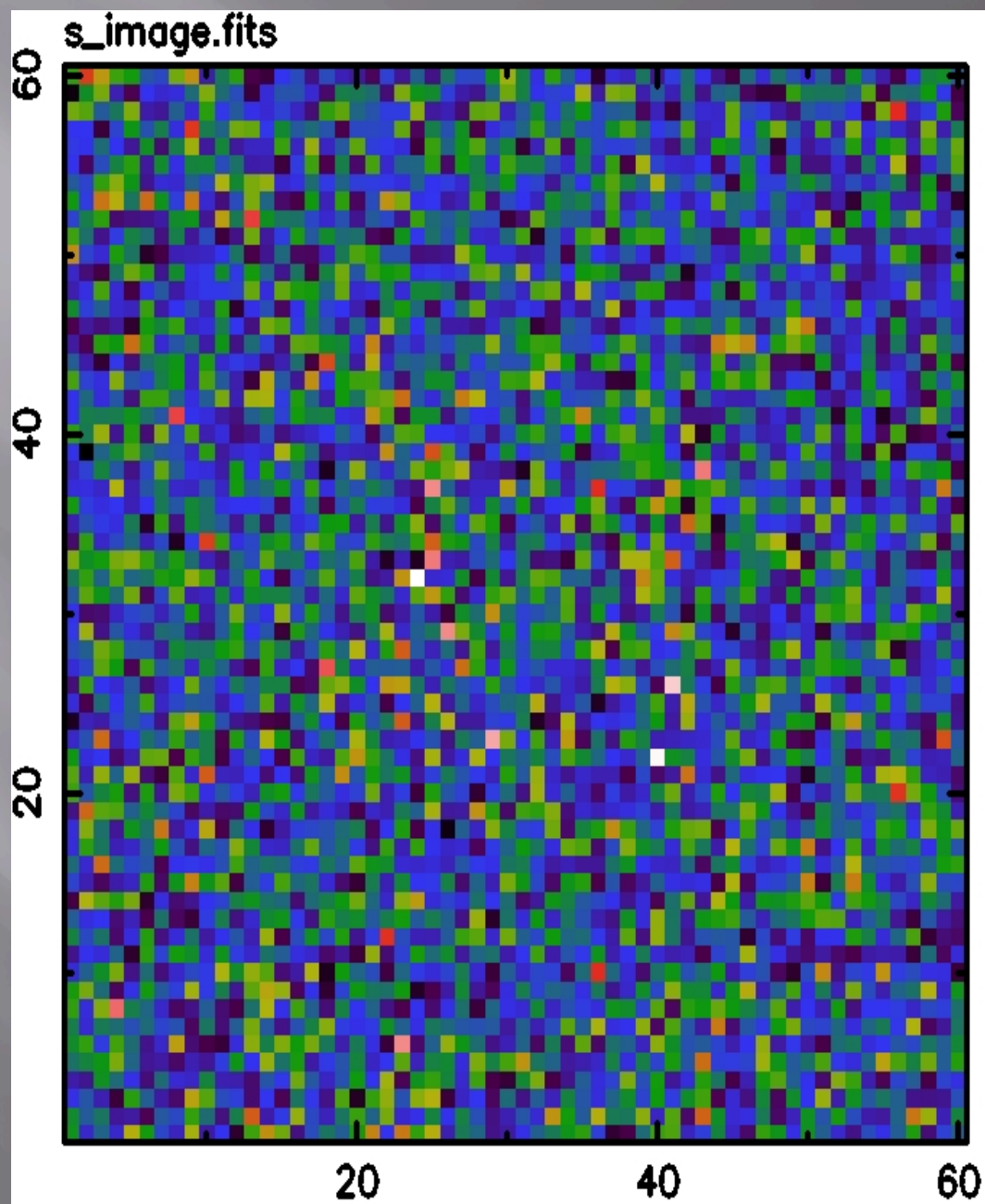
One image is closer to the edge of the detector where the contamination layer is thicker



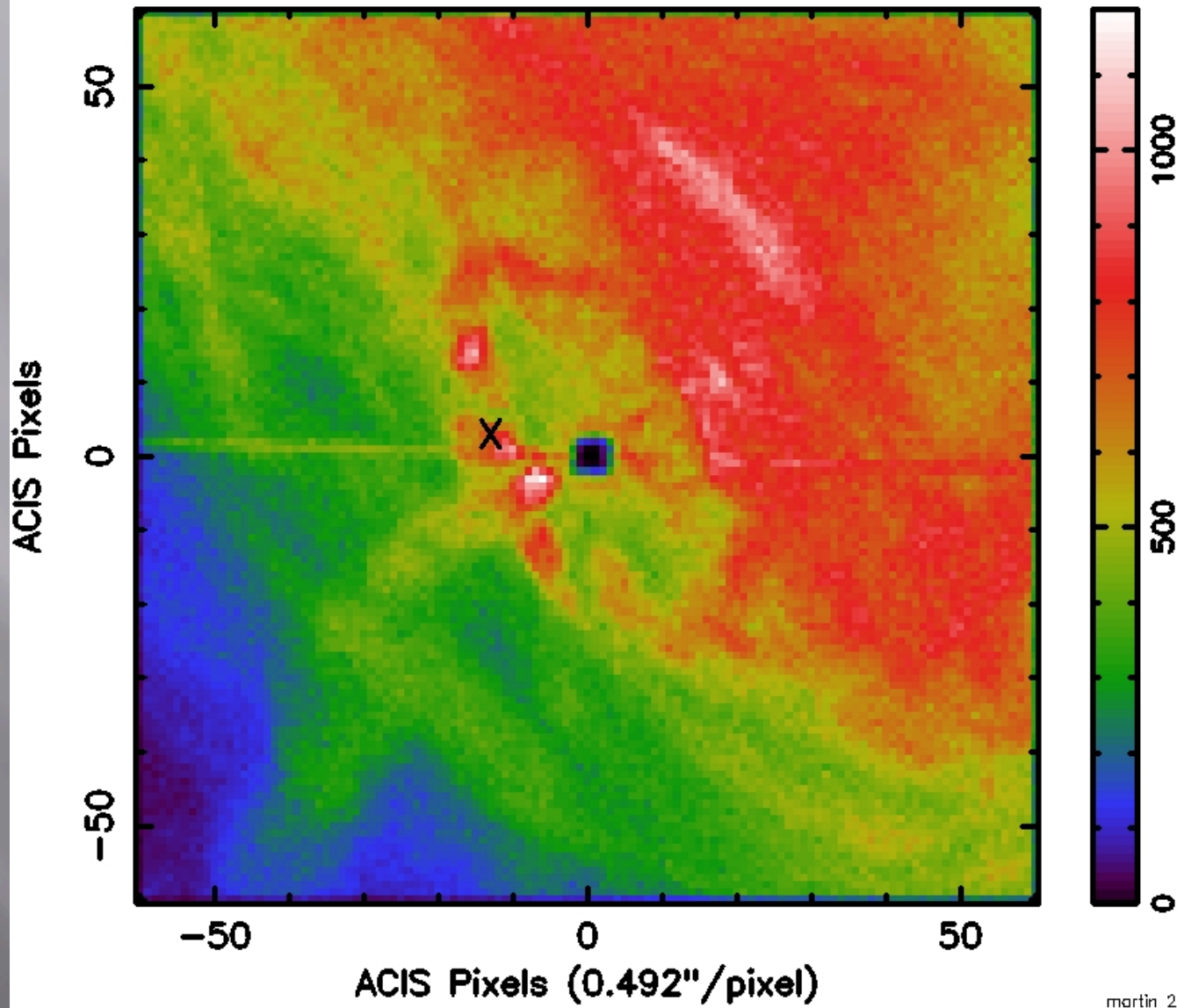


er_image.fits



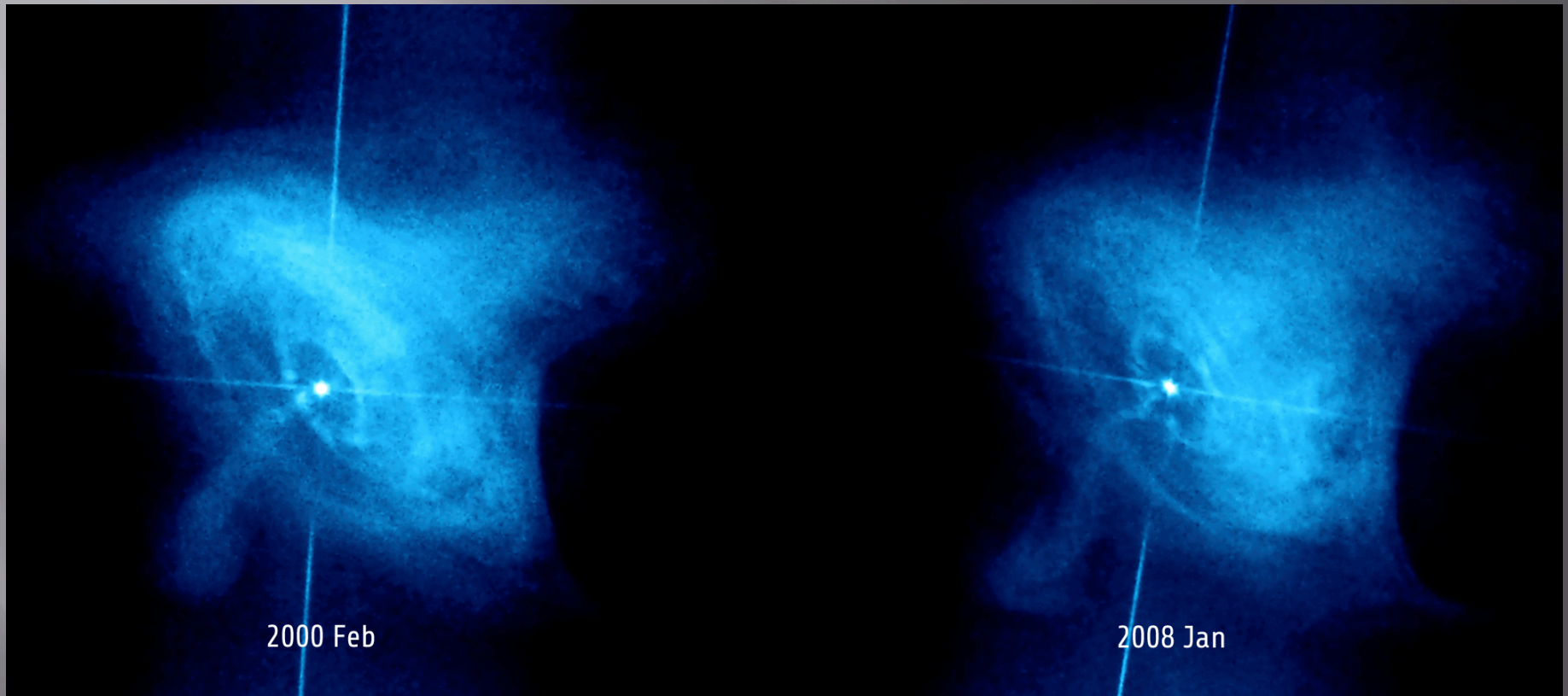


Crab



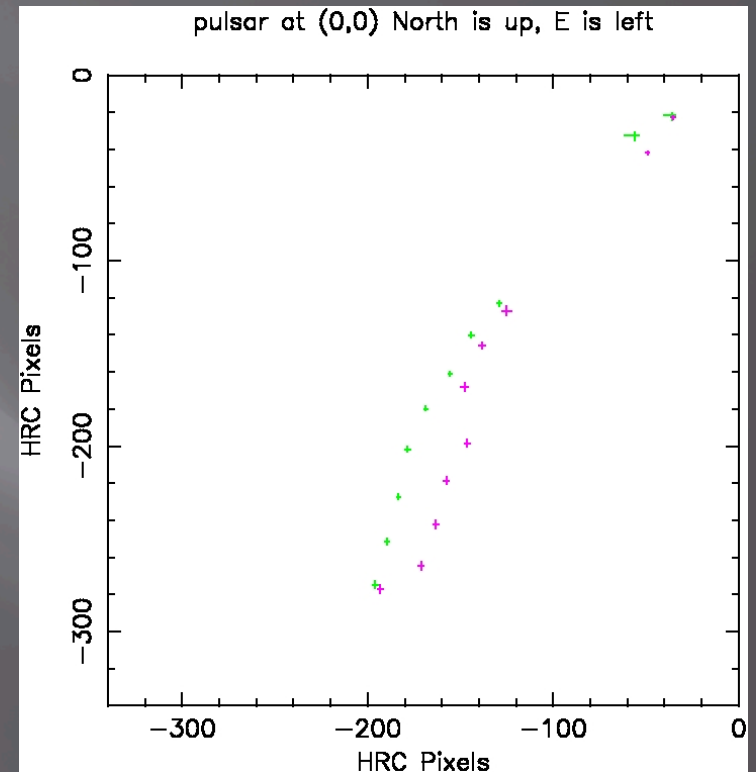
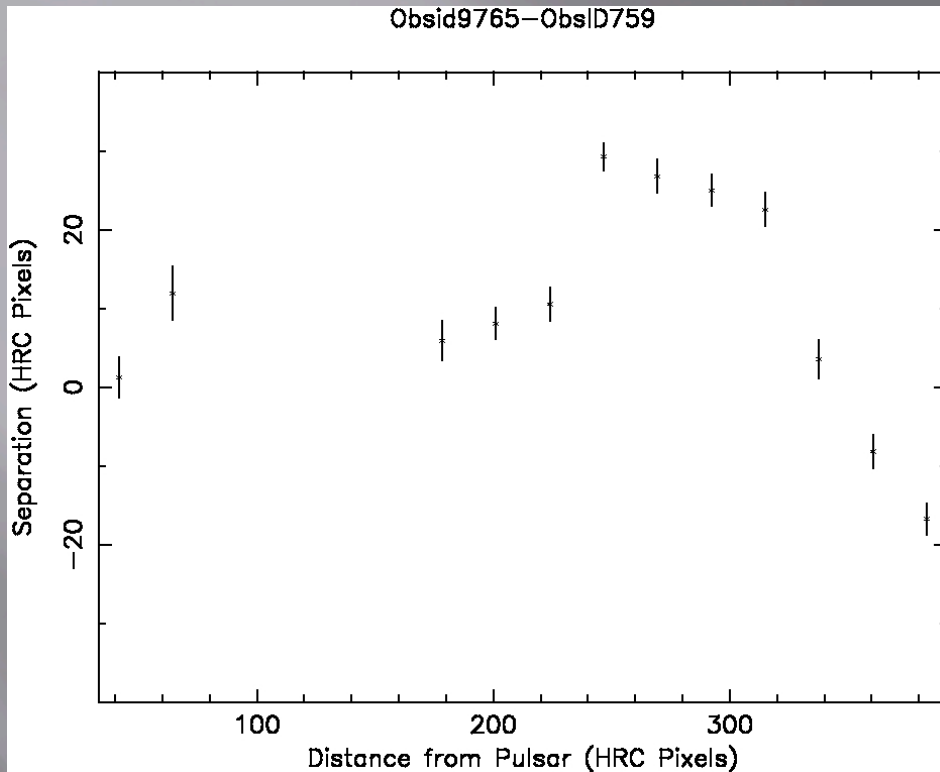
Characterising the southern jet

The southern jet moves!



Instabilities?
Rotates?

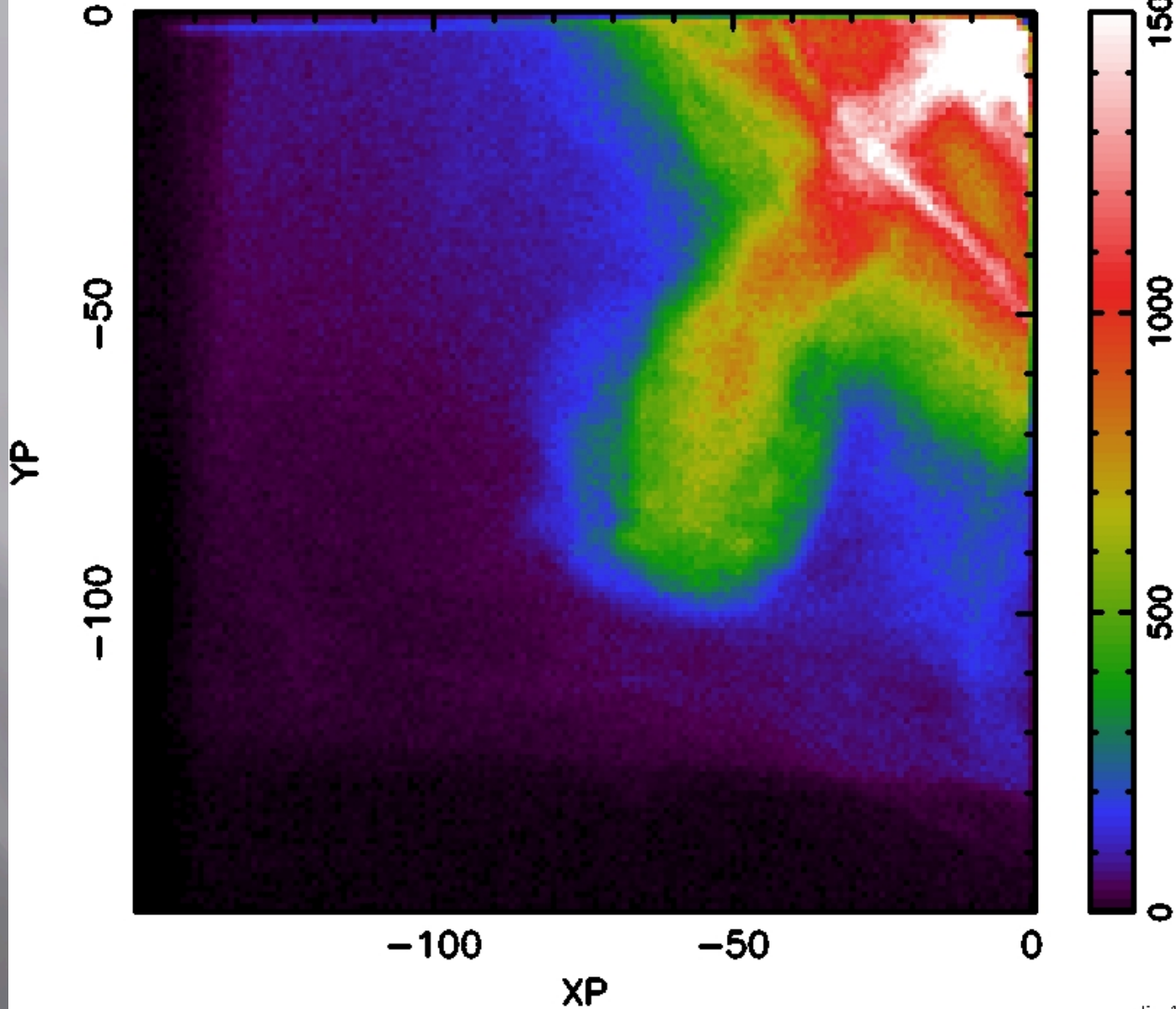
Time scales & velocities



Extremes implies simply that the velocity $> \sim 0.1c$

CRAB NEBULA

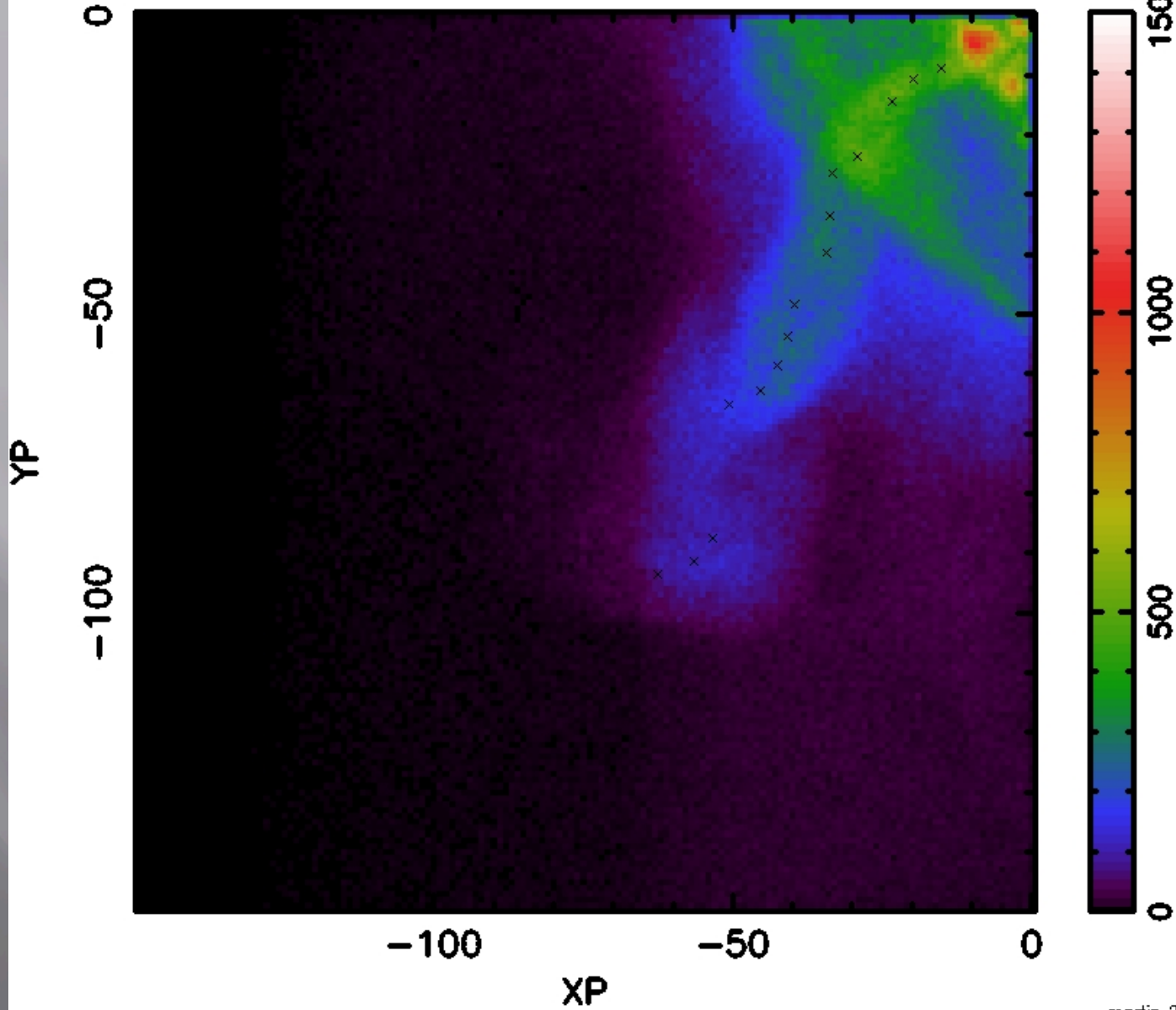
hester_summed_data.fits



2001

The Crab Nebula

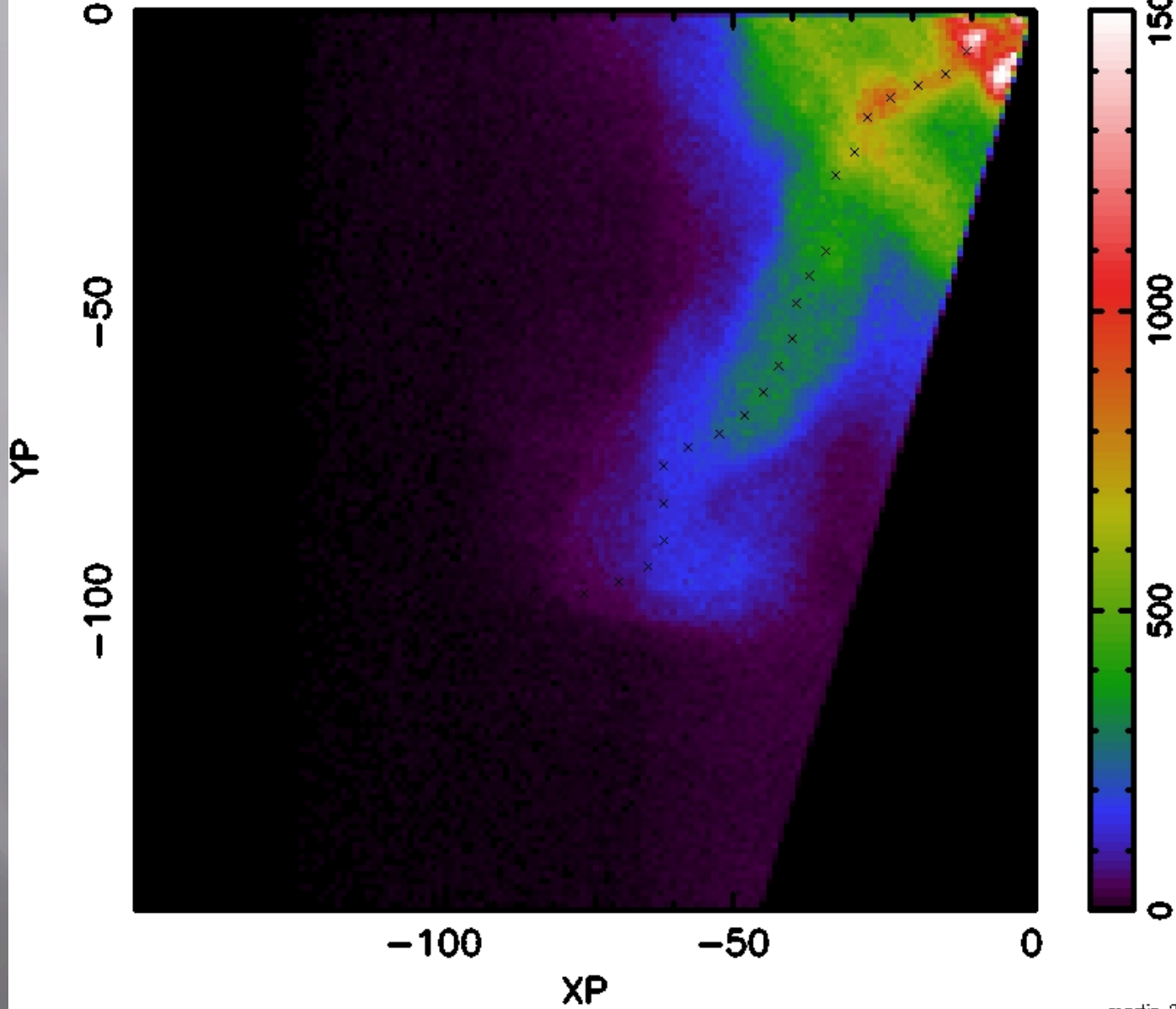
mori1_summed_data.fits



2003

The Crab Nebula

mori2_summed_data.fits

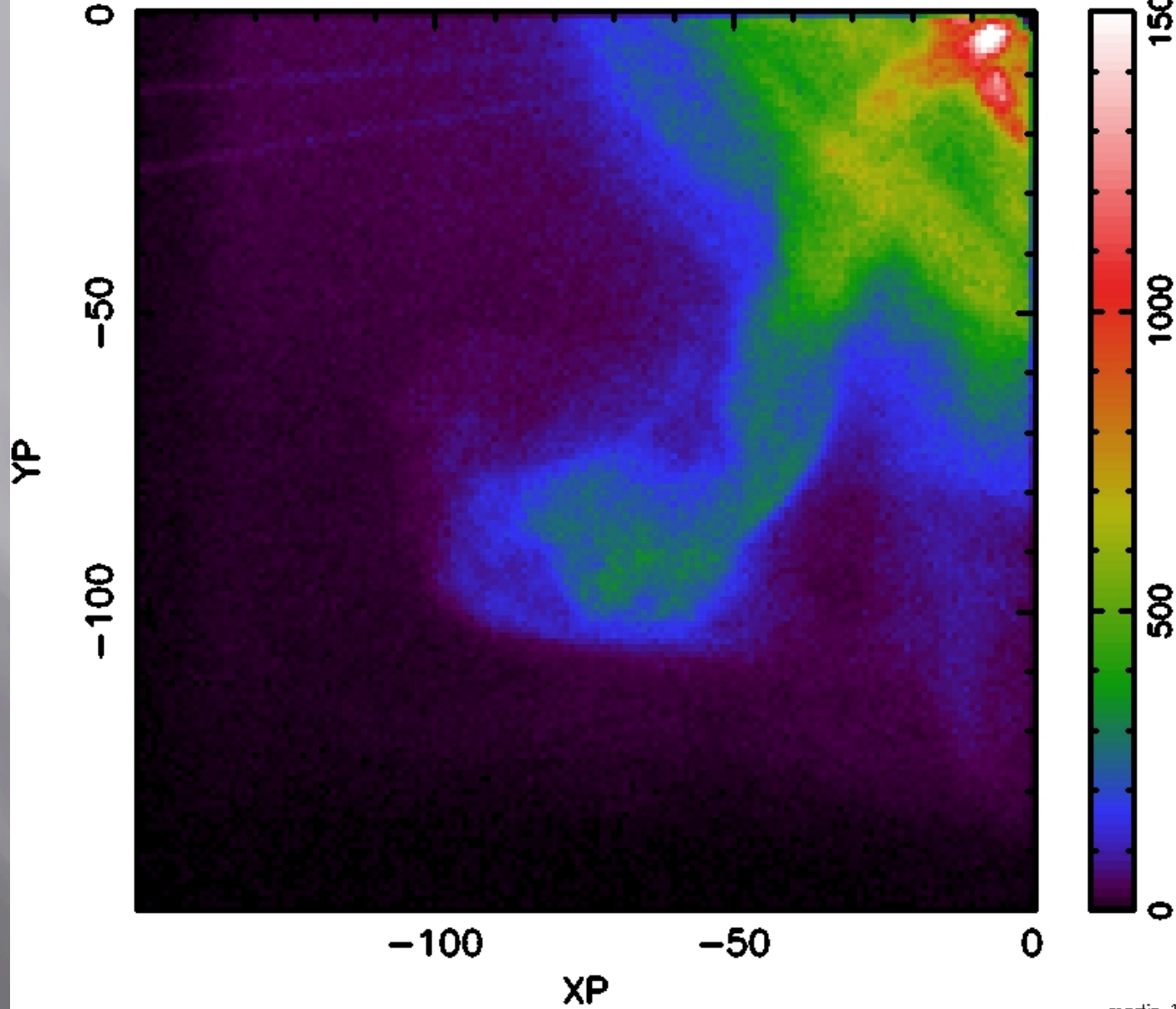


2004

martin 25-May-2012 07:40

Crab

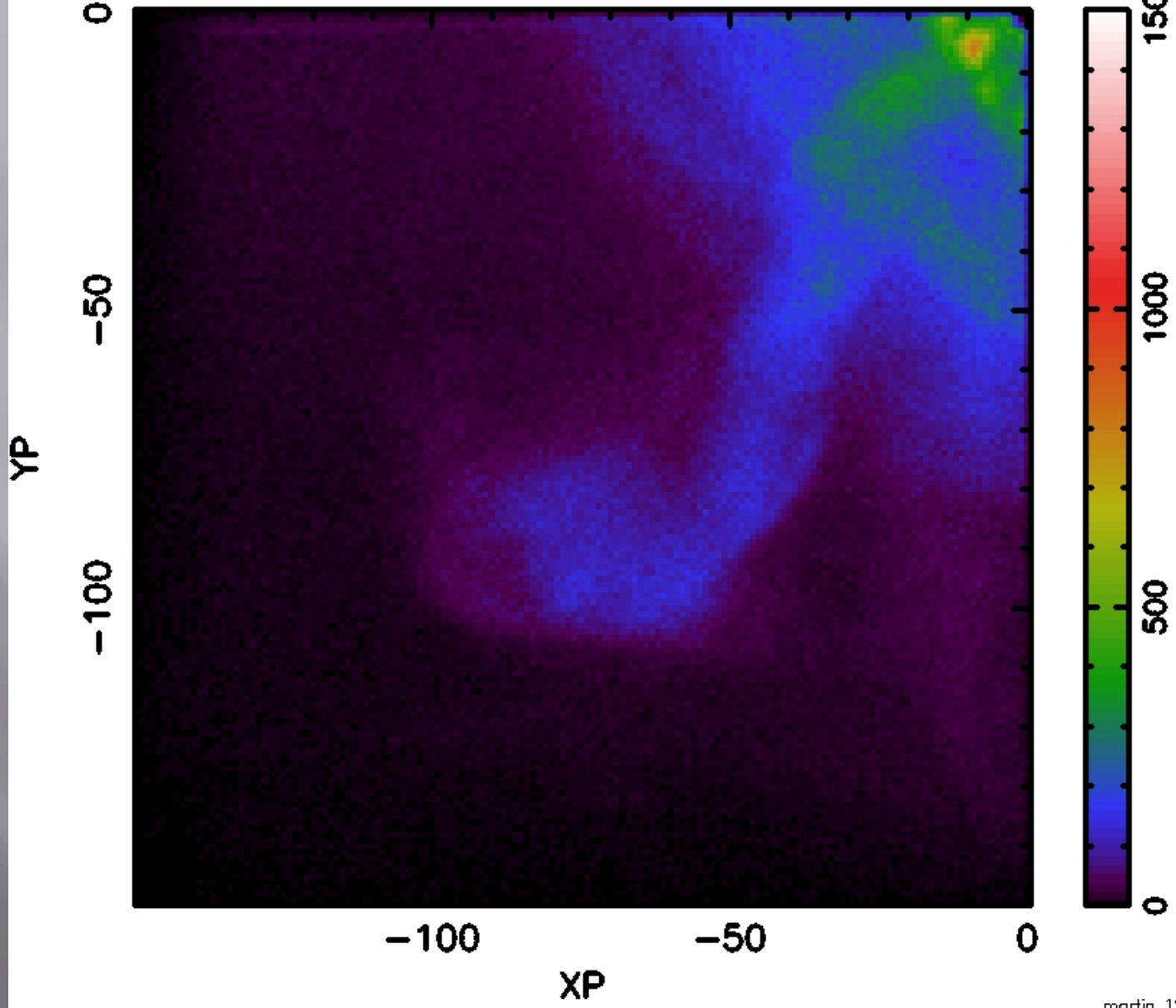
new1_summed_data.fits



2011

Crab

new2_summed_data.fits



2012

Thanks to the following

Pulse-phase spectroscopy:

A. F. Tennant , D.G. Yakovlev, A.Harding, V.E. Zavlin,, S.L. O'Dell, R.F. Elsner, W. Becker

Ring geometry:

R.F. Elsner, J. Kolodziejczak, S.L. O'Dell, A.F. Tennant

Origin of the gamma-ray flaring:

A.F. Tennant, M. Tavani, E. Costa and other members of the AGILE team and R. Buehler, R. Blandford and other members of the Fermi-Lat Team, D. Horns, C. Ferrigno, and other members of the Crab Team

Motion of the southern jet:

A.F. Tennant, S.L. O'Dell, D. A. Swartz, G.G. Pavlov, K. Mori