Pulsar-related Science with the Early Phase of the LST

Albert Kong
National Tsing Hua University, Taiwan
ICRR, University of Tokyo
University of Oxford

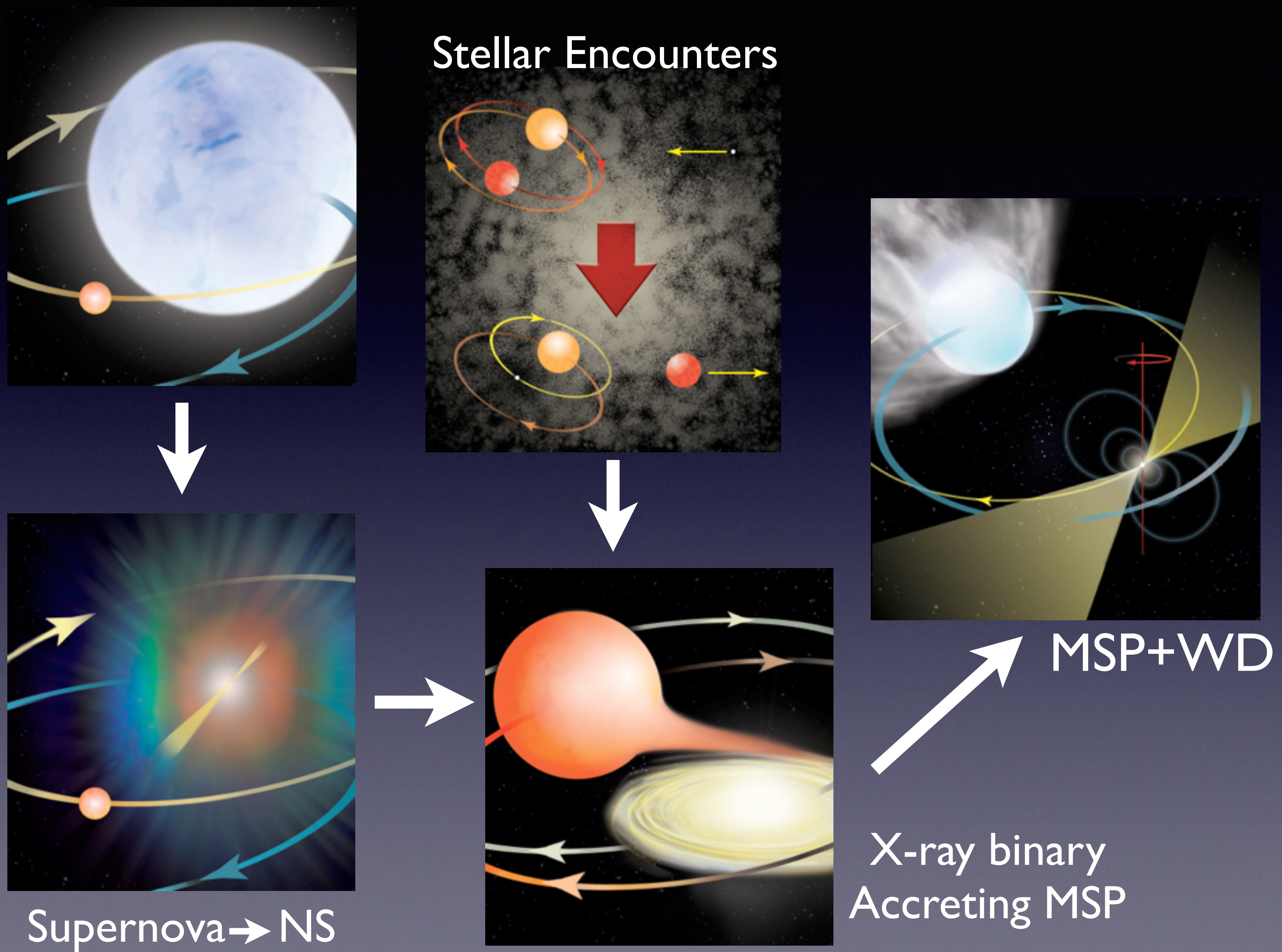
FAN collaboration
K.S. Cheng (HKU), C.Y. Hui (Chungnam), J. Takata (HUST), P.H.T. Tam (SYSU)

Pulsar-related Science in GeV and TeV

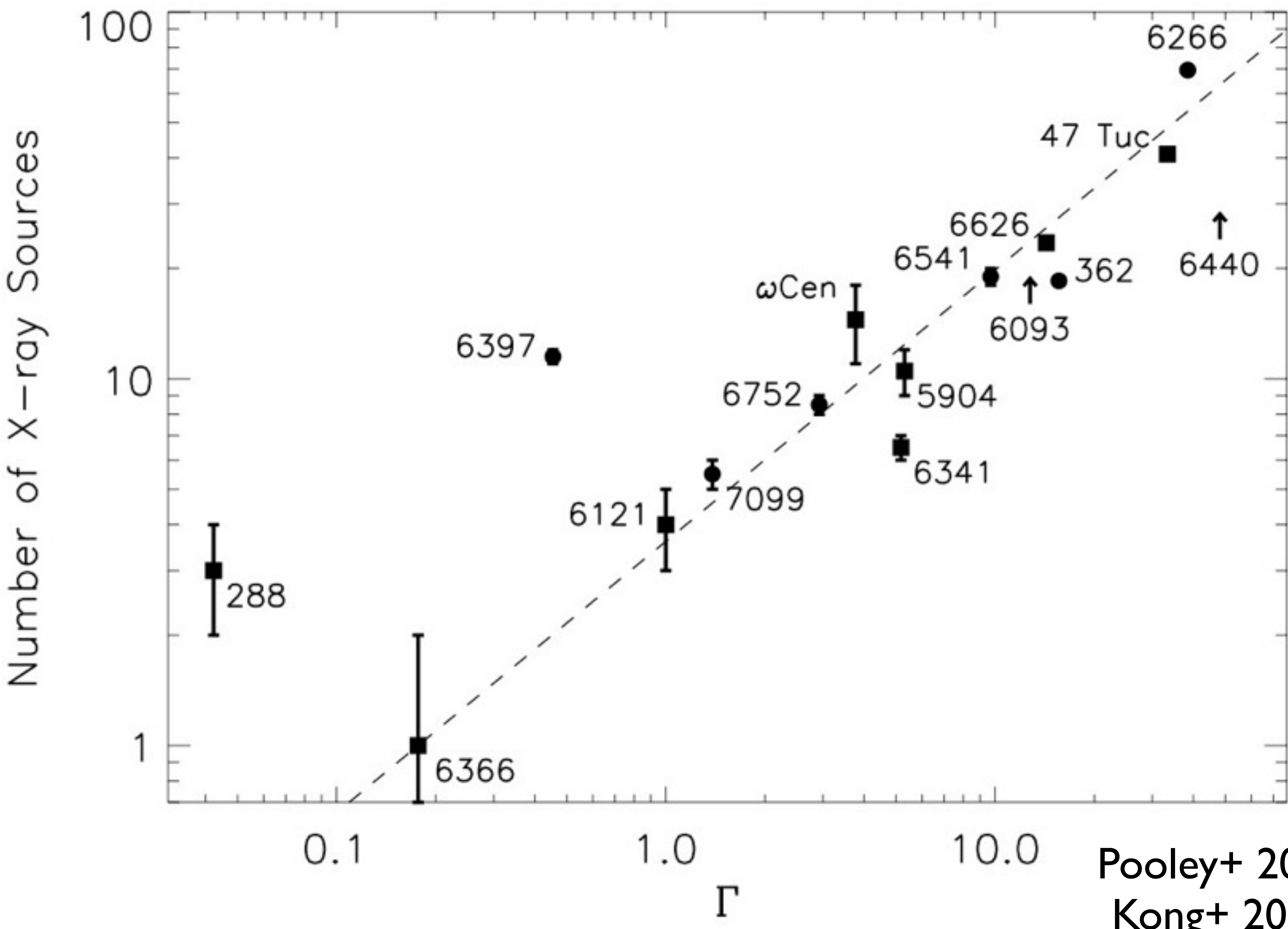
- Pulsars and their vicinity (including pulsar wind nebula and the associated supernova remnants) are some of the best sites to produce GeV and TeV emissions.
- One important implication of GeV and TeV observations of pulsars is to constrain the emission geometry and mechanisms.
- Fermi, H.E.S.S., and MAGIC have already produced many important results (e.g., pulsed gamma-rays from pulsars, gamma-rays from globular clusters, long-term gamma-ray variability of pulsars)
- CTA will bridge the gap between Fermi and MAGIC/H.E.S.S.

Early Pulsar Science with LST

- Pulsed gamma-rays of pulsars
  - Can a single LST perform pulsar timing for bright pulsars?
- Spectral shape of bright pulsars
- Long-term gamma-ray variability
- In this talk, I will focus on gamma-ray emissions from globular clusters that are primarily from a collection of millisecond pulsars

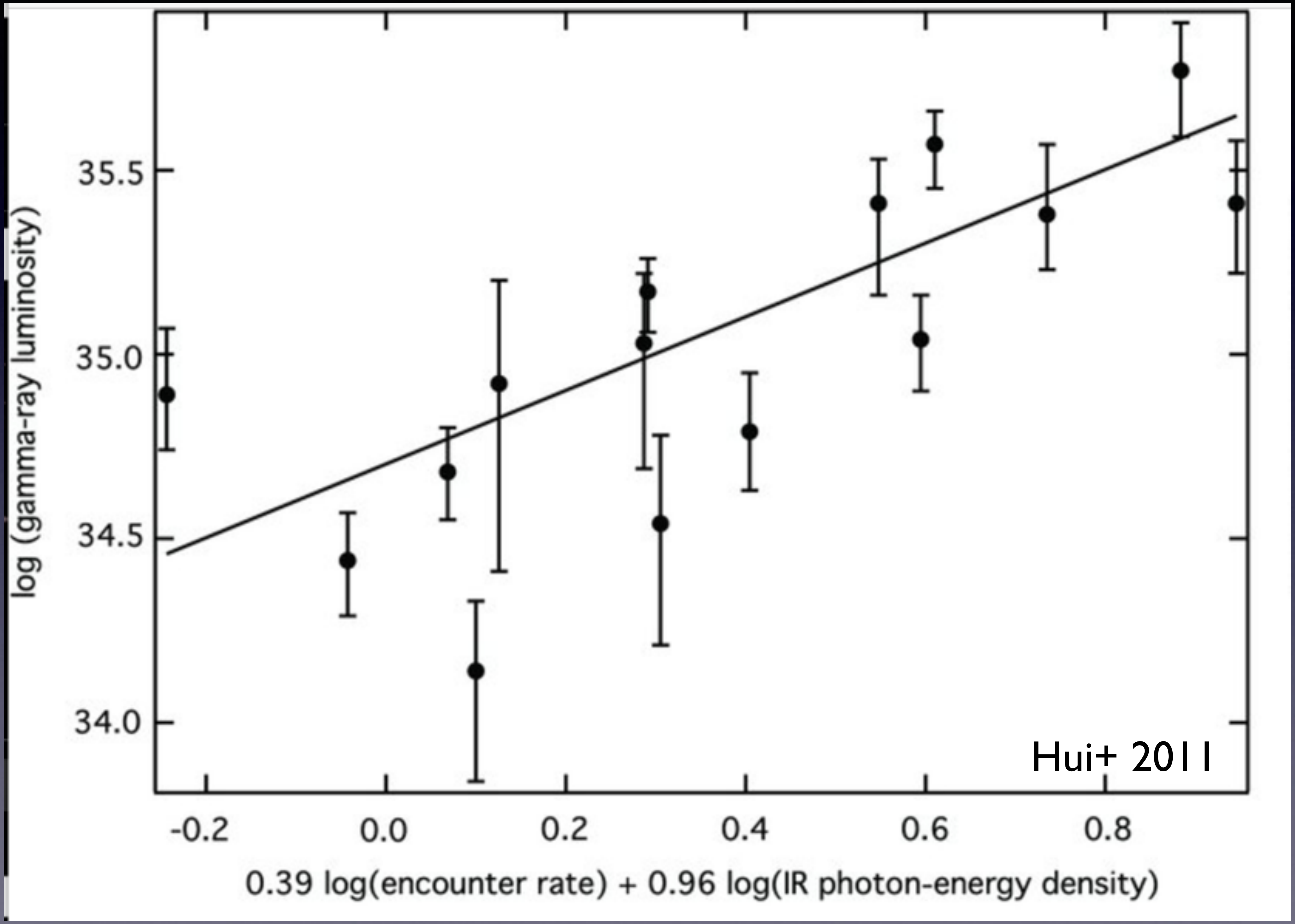

Stellar Encounters
MSP+WD
X-ray binary
Accreting MSP
Supernova→NS

Why Globular Clusters?

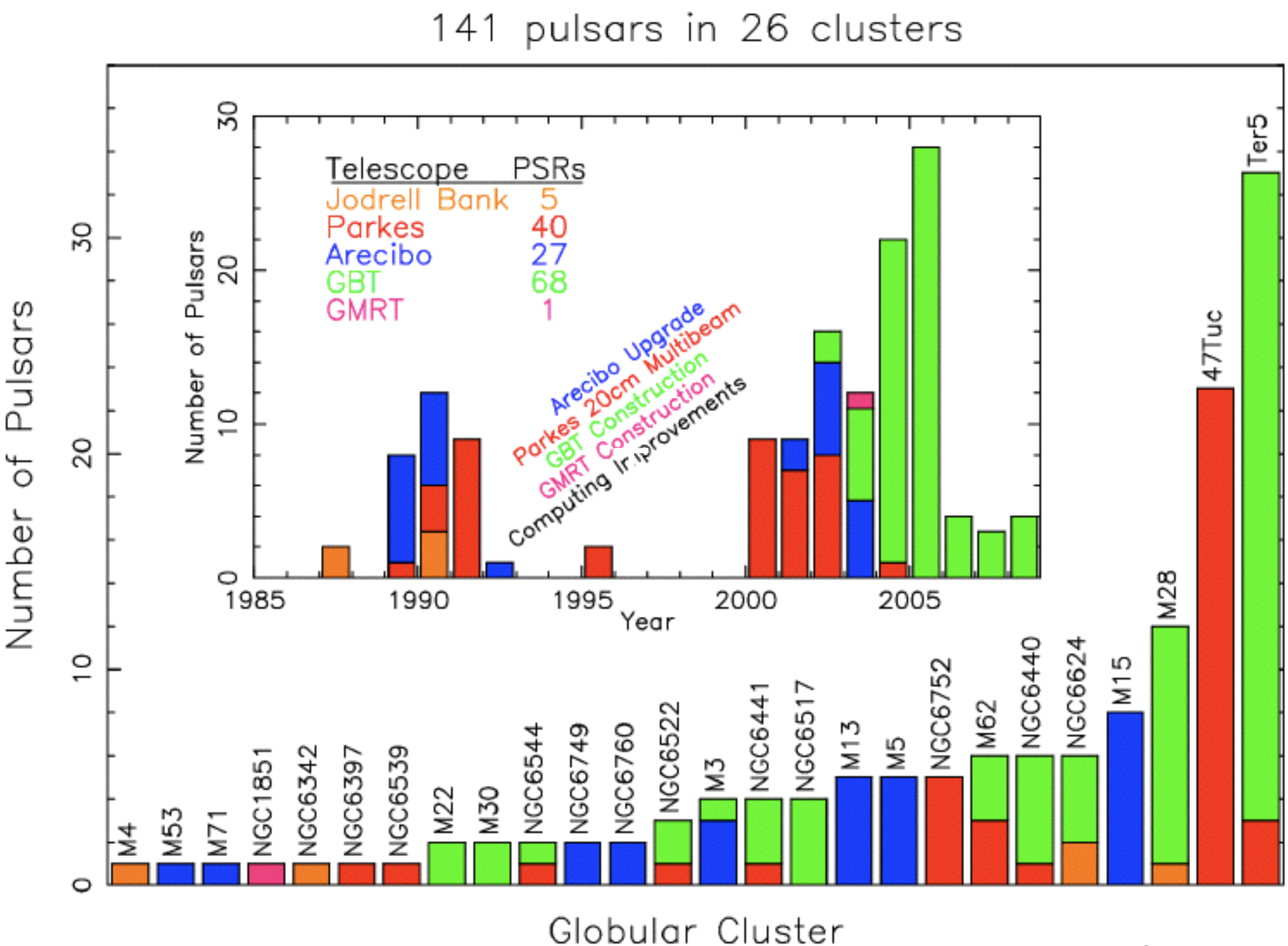


Pooley+ 2003
Kong+ 2006

Why Globular Clusters?



Encounter rate IR photon density

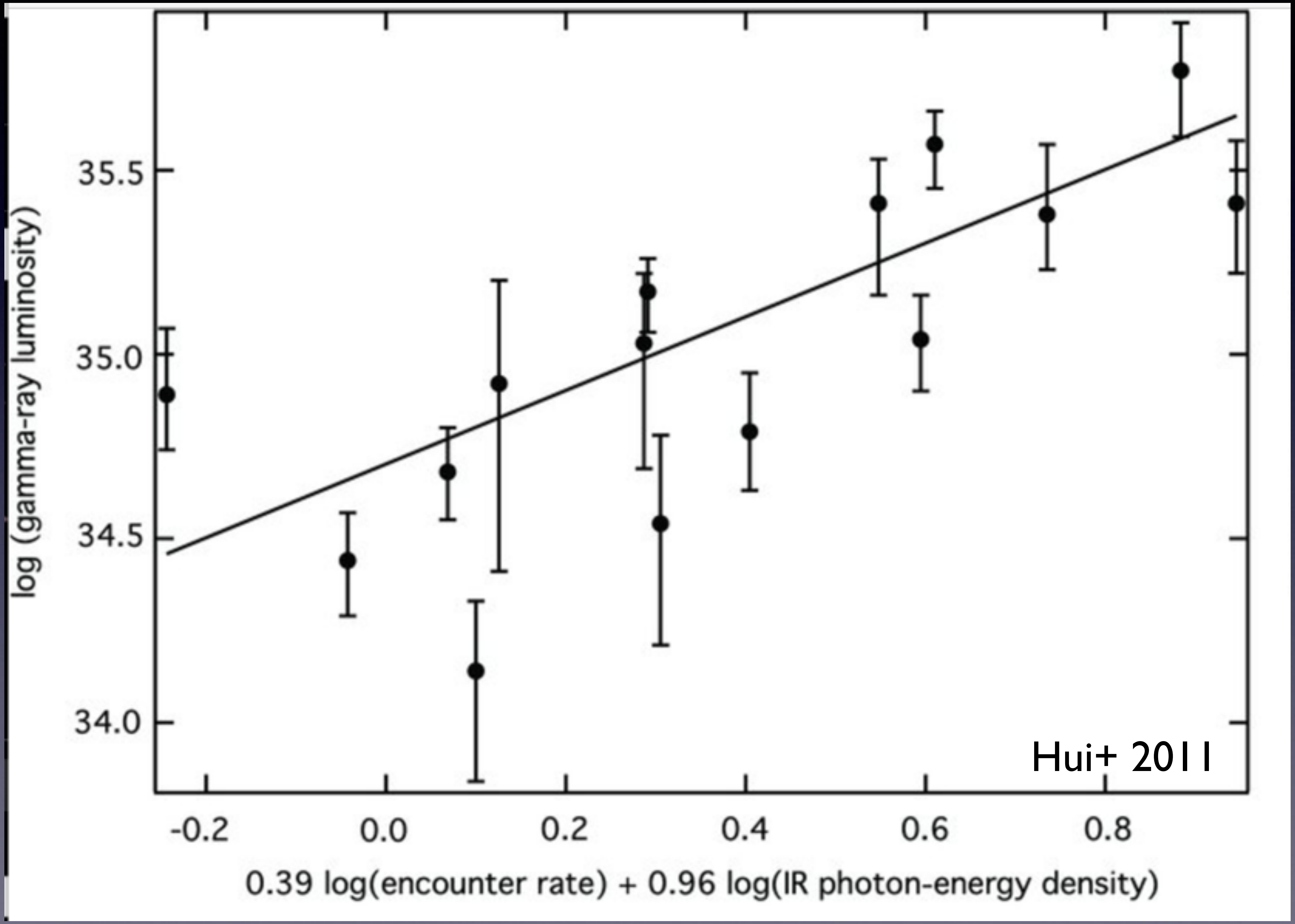


From Scott Ransom

Gamma-ray Emission from GCs

- Gamma-ray (>100 MeV) emission is likely to be from MSPs
- Pulsed curvature radiation arising near the polar cap and /or in outer magnetospheric gaps (e.g., Zhang & Cheng 2003; Harding et al. 2005; Venter & De Jager 2008)
- Inverse Compton scattering photons between the relativistic electrons/positrons in the pulsar winds and the background soft photons (e.g., Bednarek & Sitarek 2007; Cheng et al. 2010)

Why Globular Clusters?

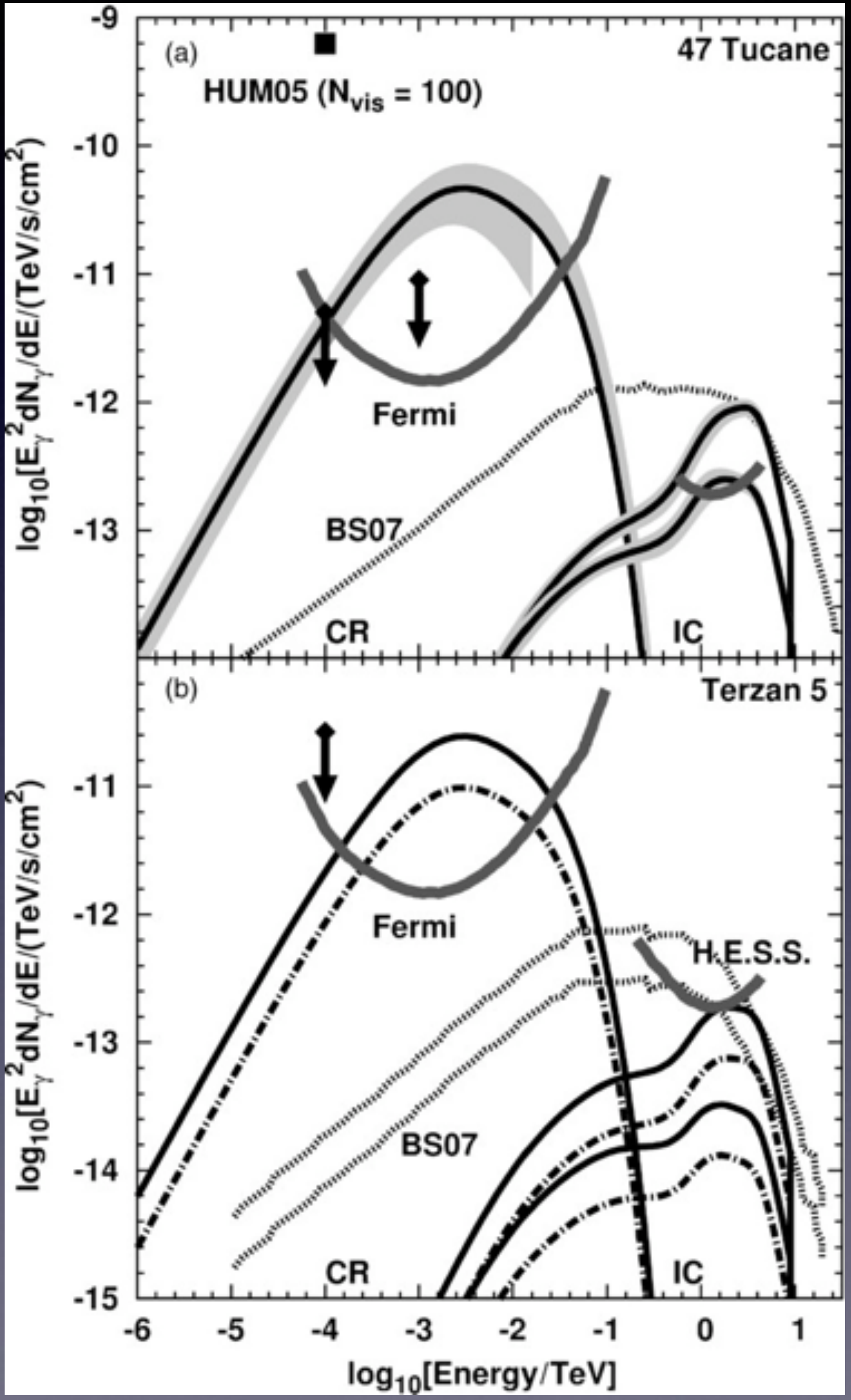


Encounter rate IR photon density

Gamma-ray Emission from GCs

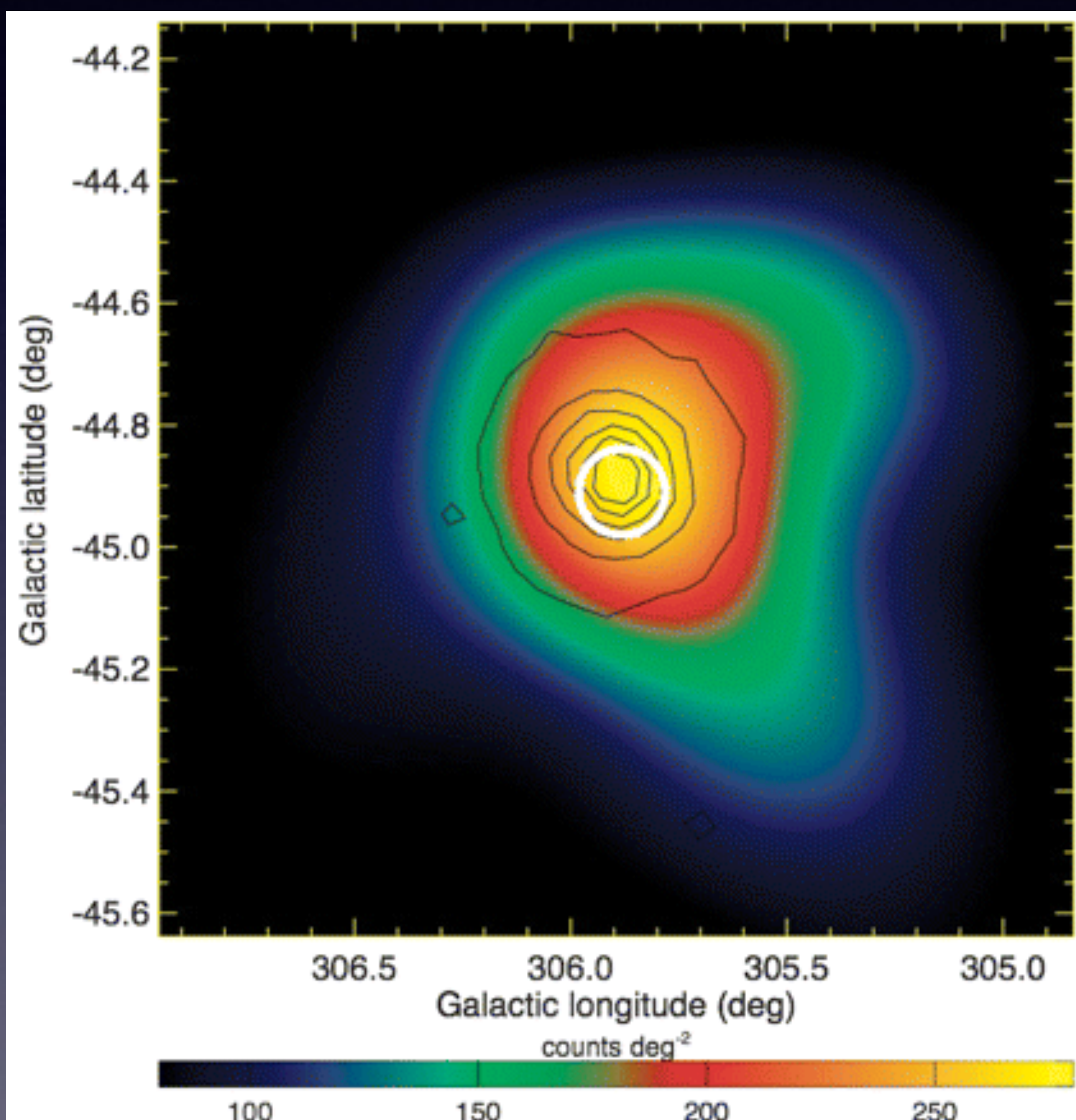
- Most of the gamma-ray MSPs are very nearby (< 1 kpc) => they are very faint.
- The nearest GCs are several kpc from us. It is almost impossible to detect individual gamma-ray MSPs in GCs except from a pulsation search (e.g., NGC 6624 and M28).
- However, GCs can have tens to hundreds of MSPs because of the enhanced dynamical formation. We can detect the collective gamma-ray emission with sensitive instruments.
- Terzan 5 and 47 Tuc are the best candidates since they have the largest number of MSPs in GCs.
- EGRET only obtained upper limits
- Fermi/LAT and H.E.S.S./MAGIC can do much better

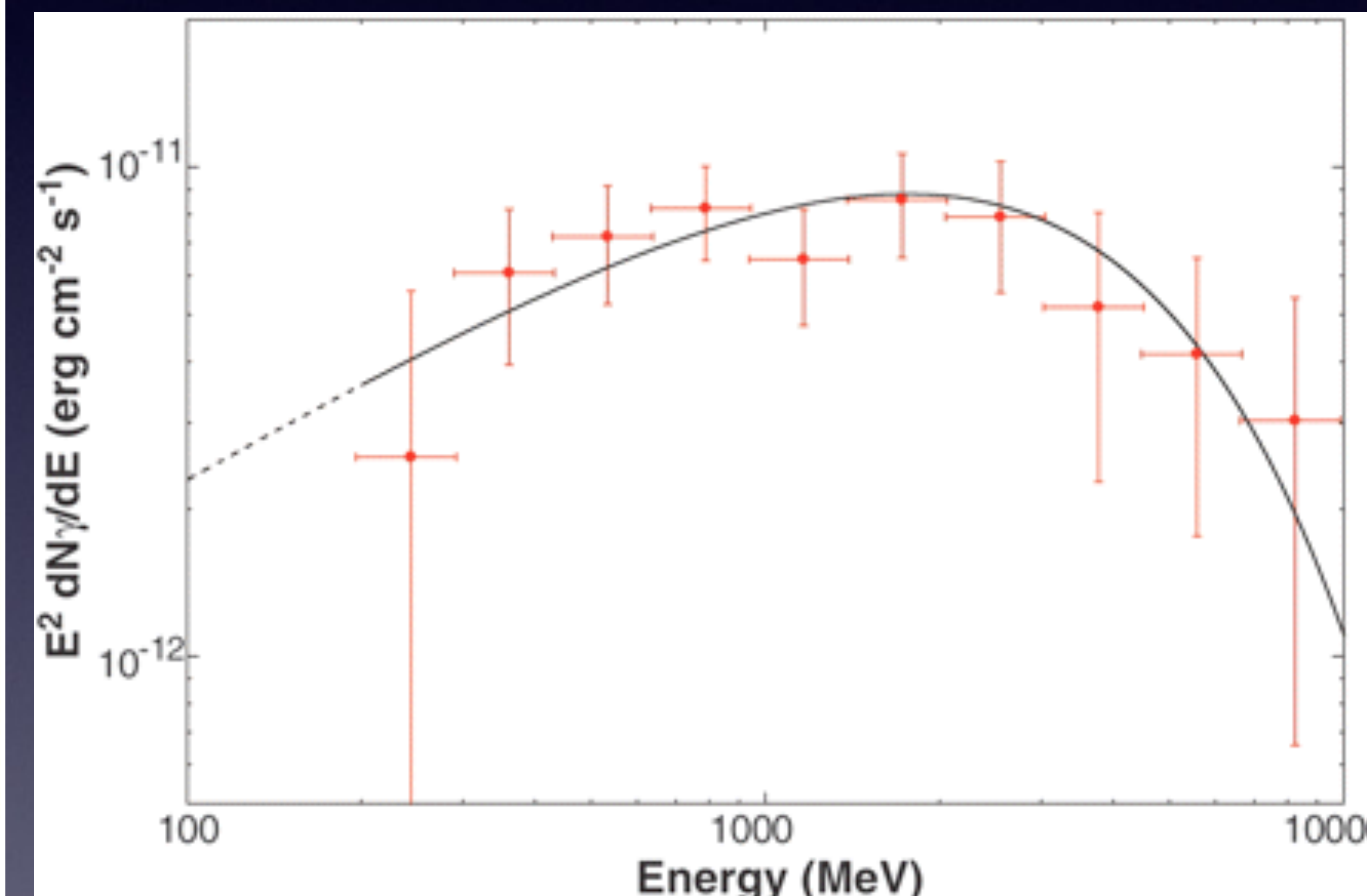
Theoretical Predictions of MSPs in GCs

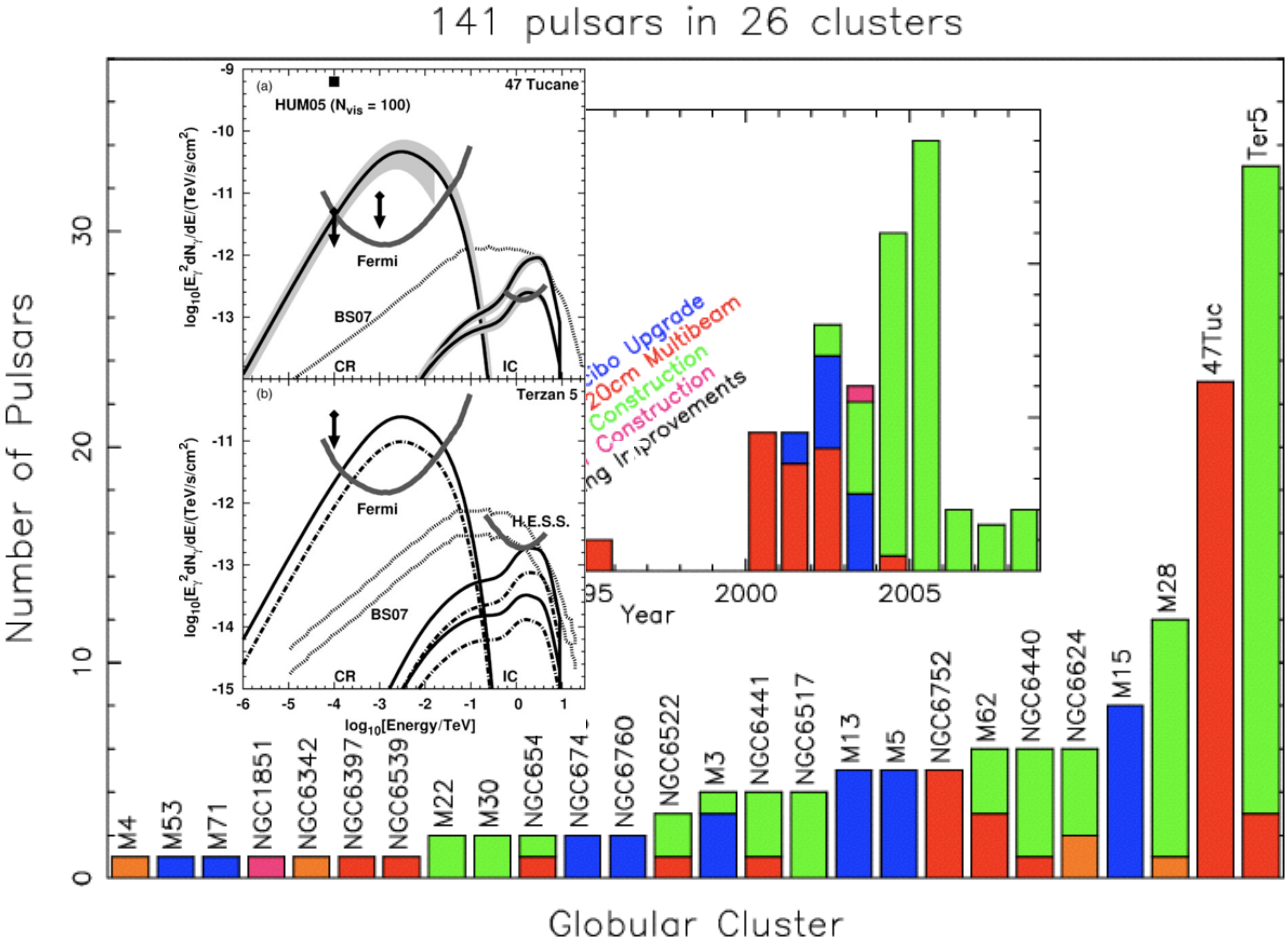


Venter et al. 2009

First Gamma-ray detection from a GC (47 Tuc)
Abdo et al. 2009

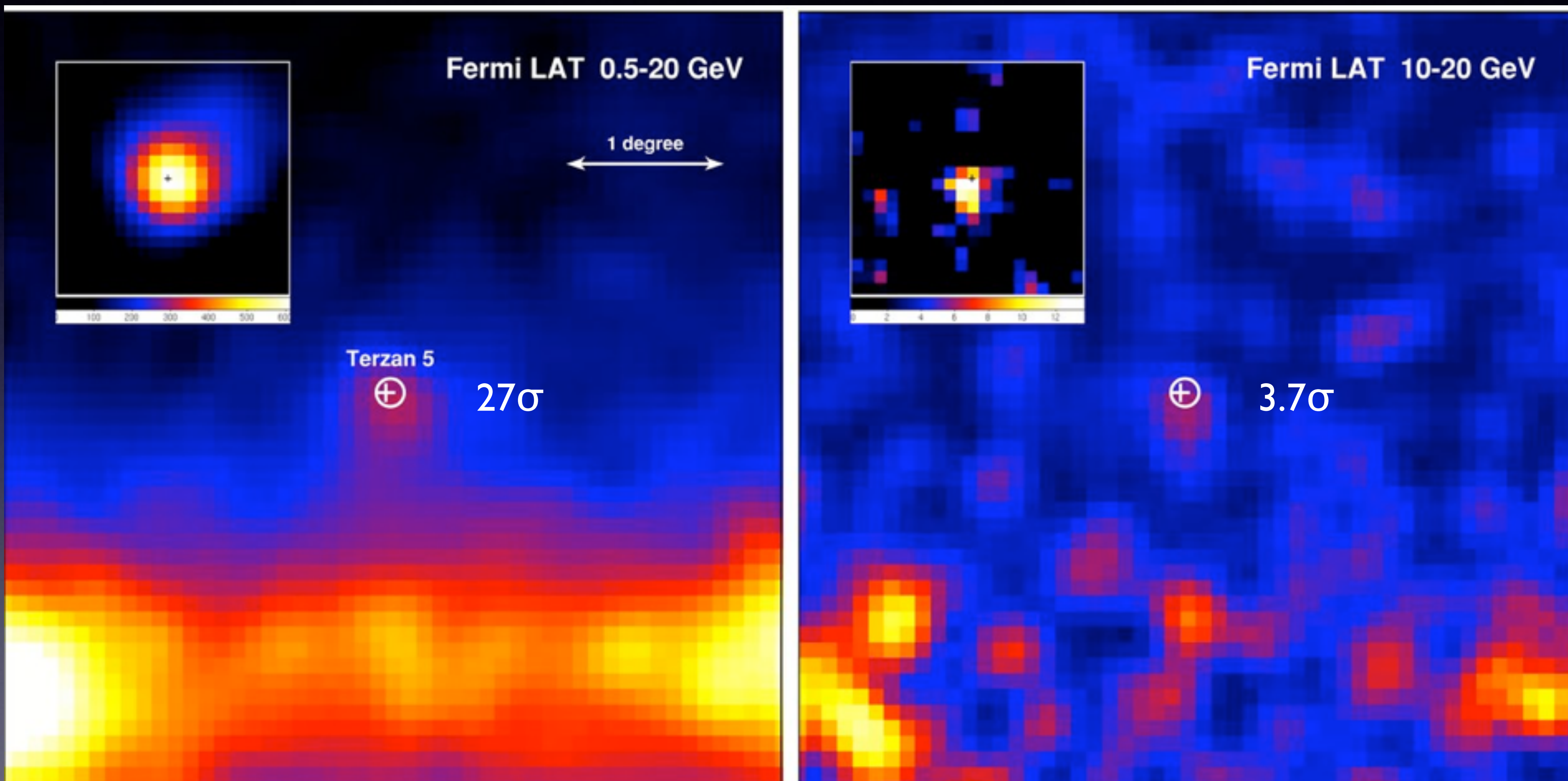






From Scott Ransom

Fermi 17-month Observations of Terzan 5



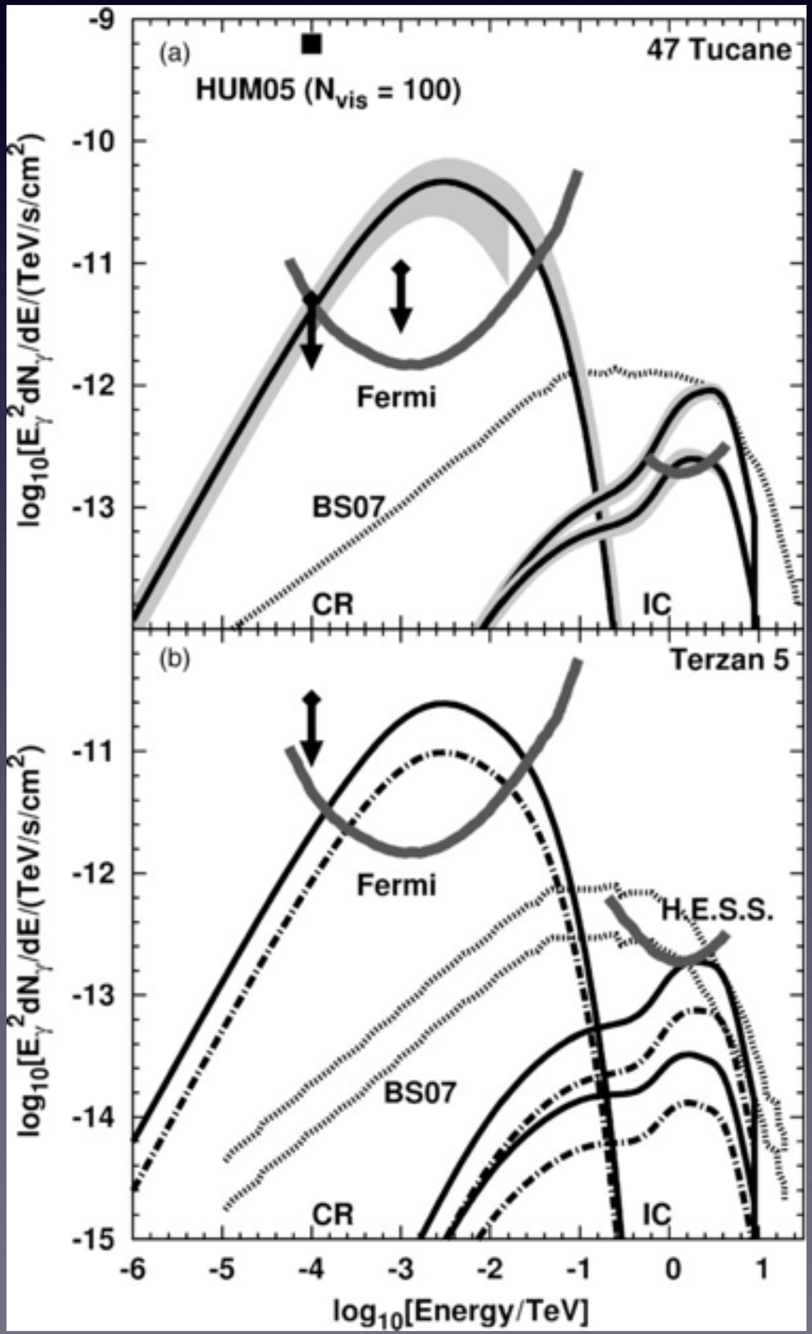
Kong et al. 2010

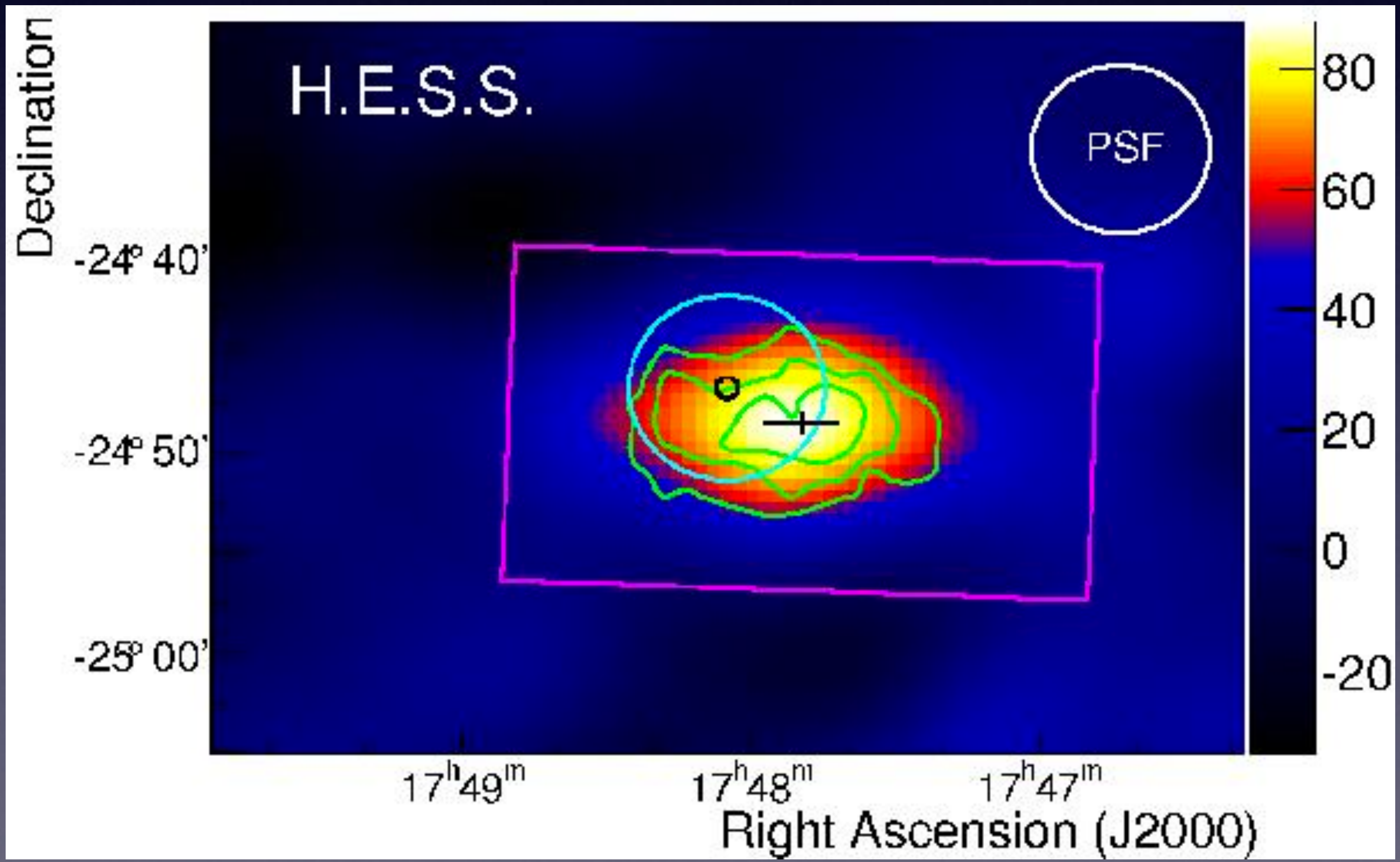
Comparison between Terzan 5 and 47 Tuc

- *If the gamma-rays are from inverse compton scattering (Cheng et al. 2010):*
    - Inverse Compton (IC) scattering between relativistic electrons/positrons in the pulsar wind of MSPs in the GCs and background soft photons including cosmic microwave/relic photons, background star lights in the clusters, the galactic infrared photons, and the galactic star lights.
- The background soft photon intensity from the Galactic plane at the position of Terzan 5 is roughly 10 times that of 47 Tuc (Strong & Moskalenko 1998)
- Terzan 5 should have stronger emission with energies > 10 GeV (Cheng et al. 2010)
- Future CTA observations may tell

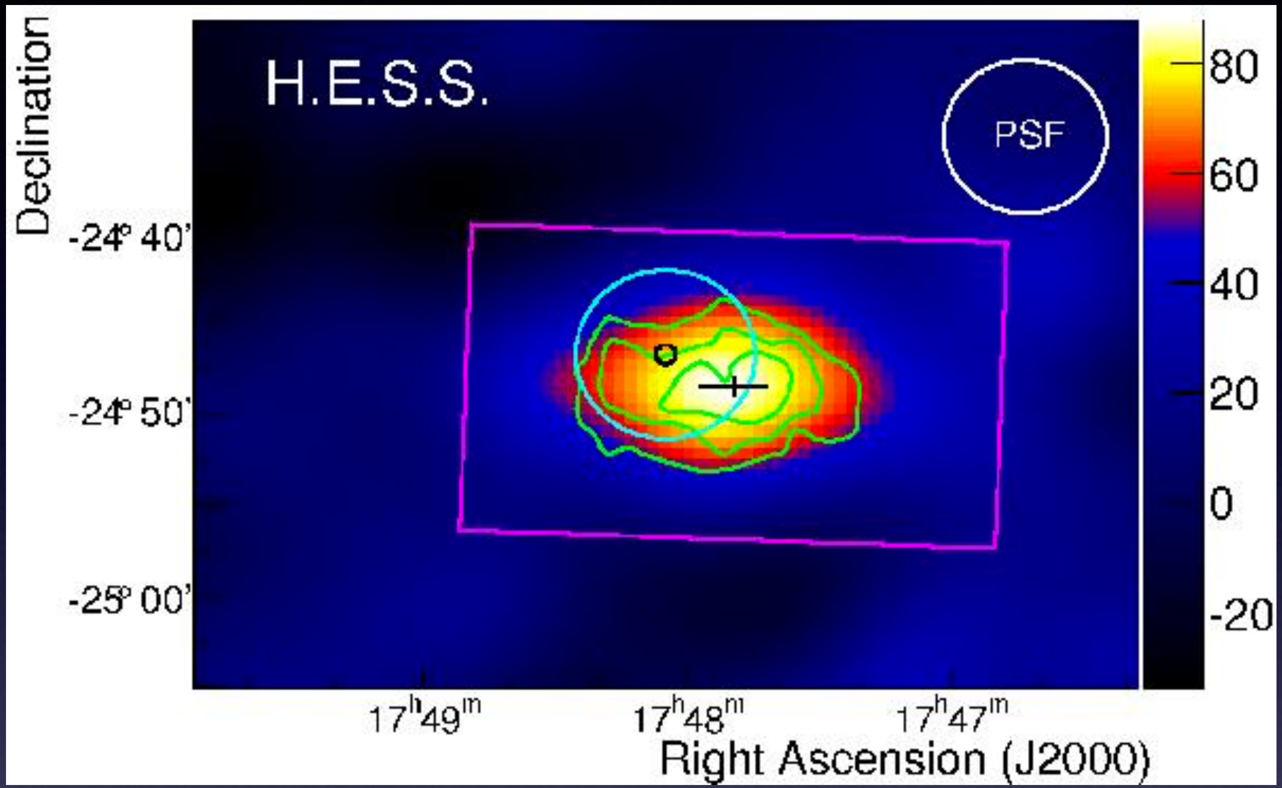
TeV Observations of GCs

- The only confirmed case is Ter 5 detected by H.E.S.S. (Abramowski+ 2011)





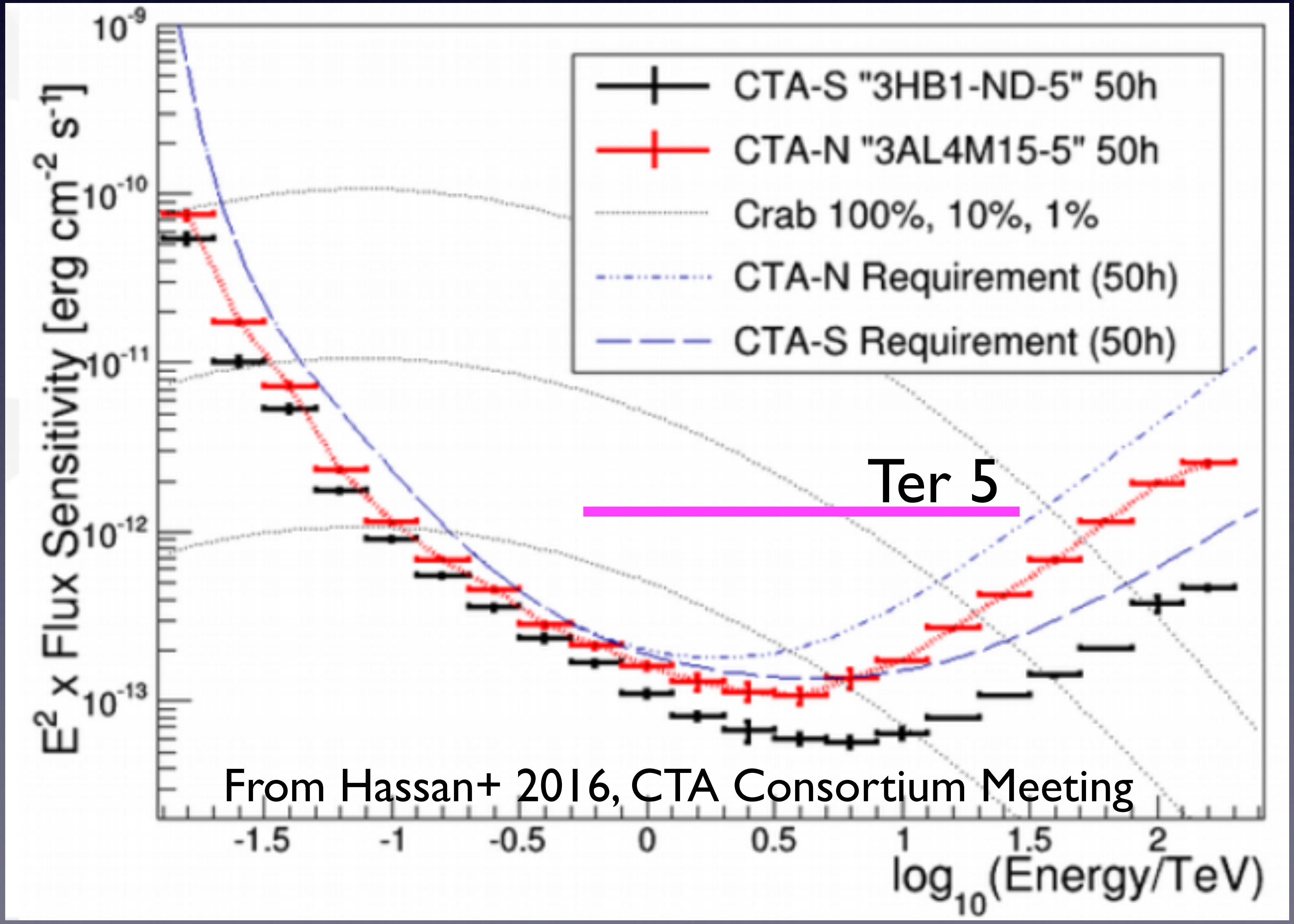
TeV Observations of GCs



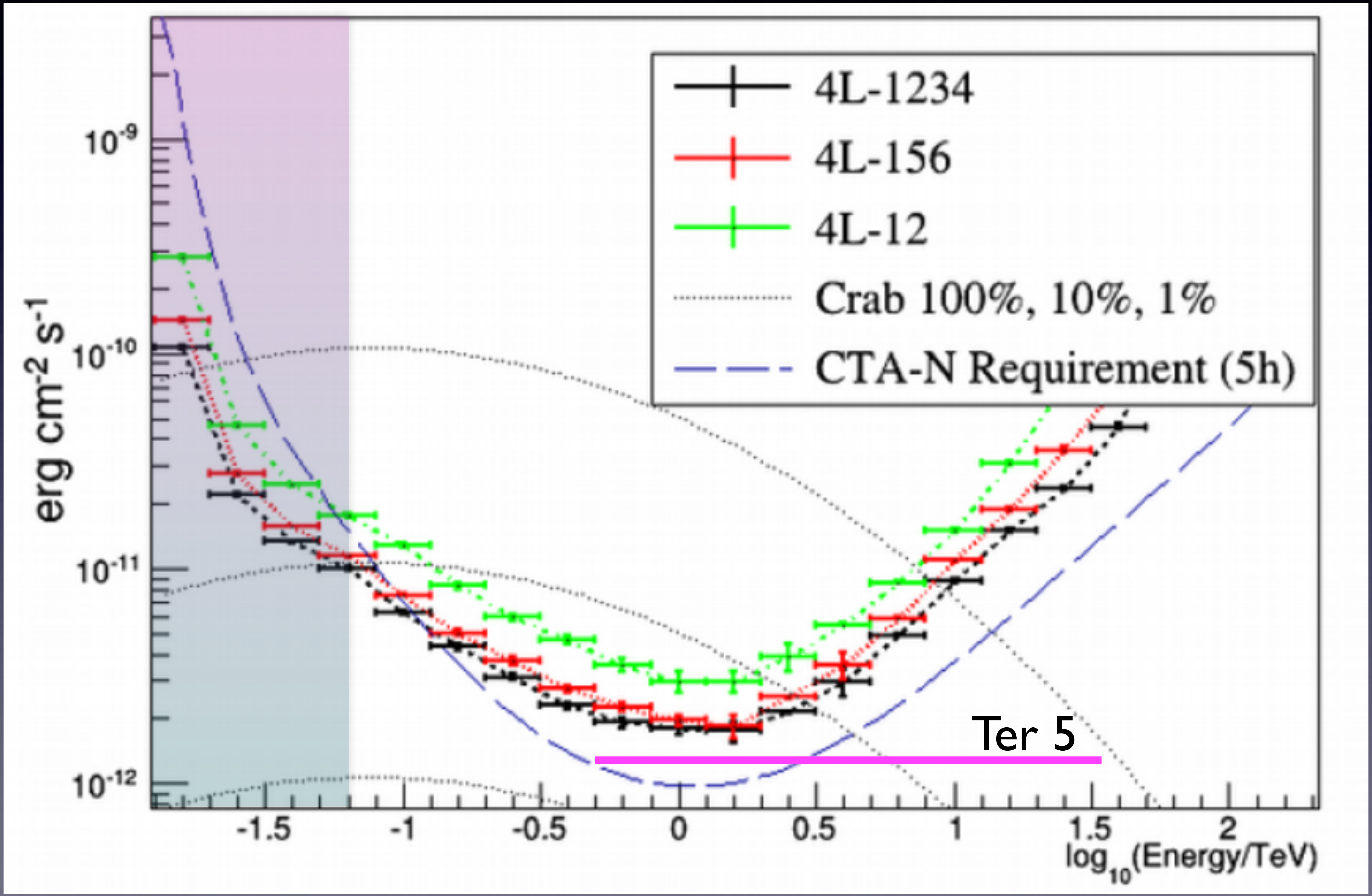
- Is the TeV emission associated with Ter 5?
- The TeV centroid is 4 arcmin from the centre of Ter 5, way outside the half-mass radius
- It is marginally within the tidal radius of the GC
- The TeV emission is extended

Prospects of CTA

- Case study: Ter 5
- Based on H.E.S.S. observations: 0.44-24 TeV photon flux = 1.2×10^{-12} $cm^{-2}s^{-1}$ (1.5% of Crab)



What about LST only?



- With two LSTs, Ter 5 may be marginally detected with 50h exposure time
- Need simulations to verify (response files for LST-only observations are required)
- It can be easily detected with three LSTs in 50h
- The next best target for LST-N is M15 based on H.E.S.S. (Abramowski+ 2013) but an upper limit of 7.2×10^{-13} $cm^{-2}s^{-1}$ indicates that a full array is required
- NGC6440, NGC6388, M62, and 2MS-GC01 (based on Fermi flux from Tam+ 2016) are also worth to try with LST-N but there are no H.E.S.S. limits.
- Timing technique may reveal the pulsations of NGC6624 and M28