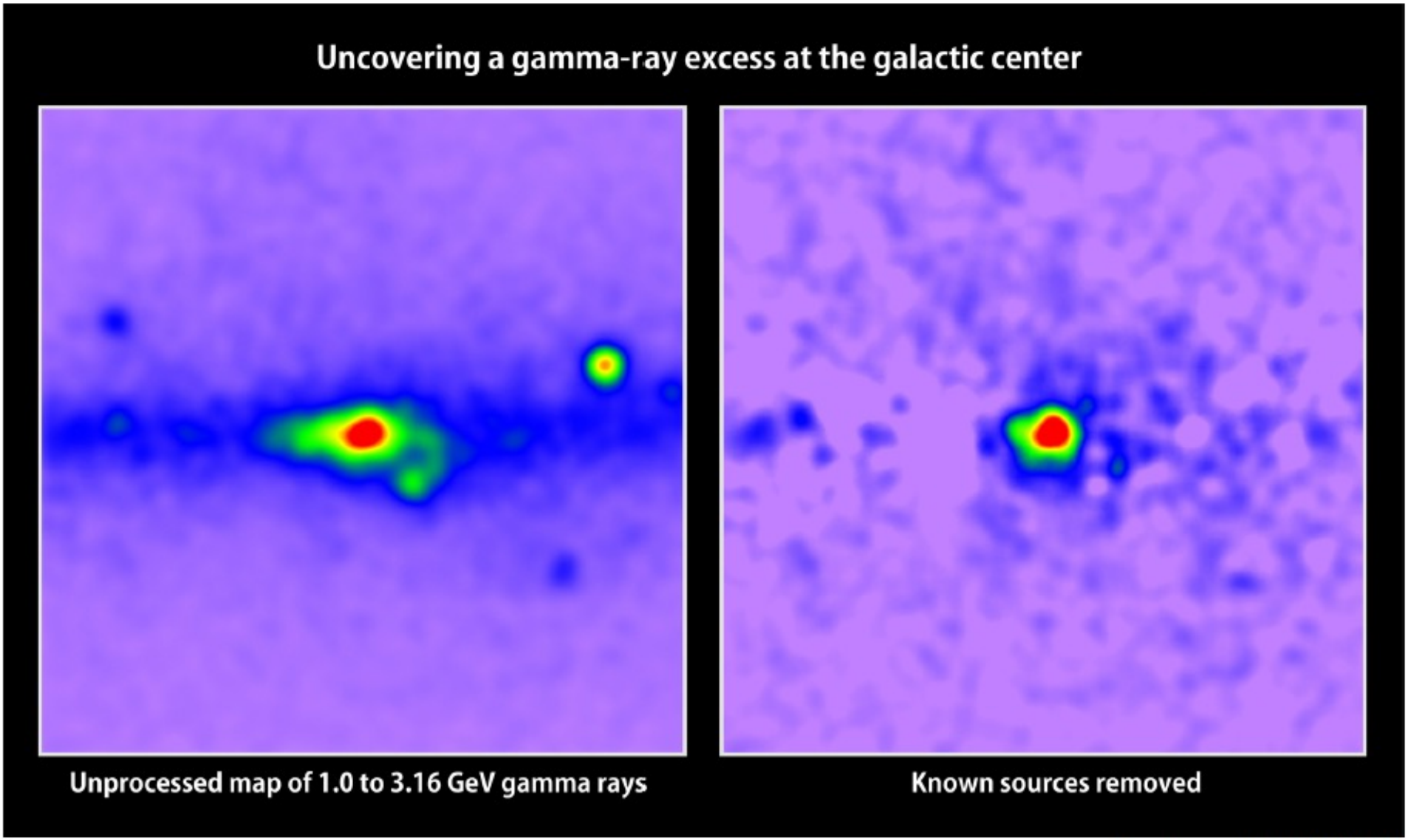
Disrupted globular clusters explain gamma-ray excess in the Galactic Center

Bence Kocsis

IAS → Eotvos University, Budapest

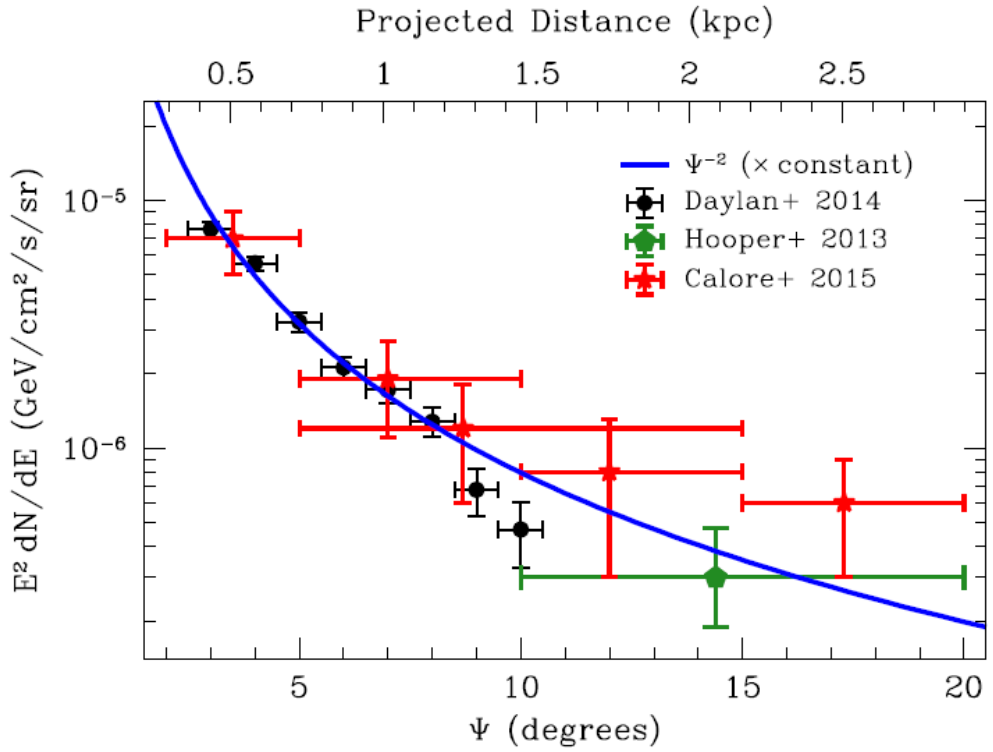
ERC Starting Grant Project Leader

with Tim Brandt (IAS)

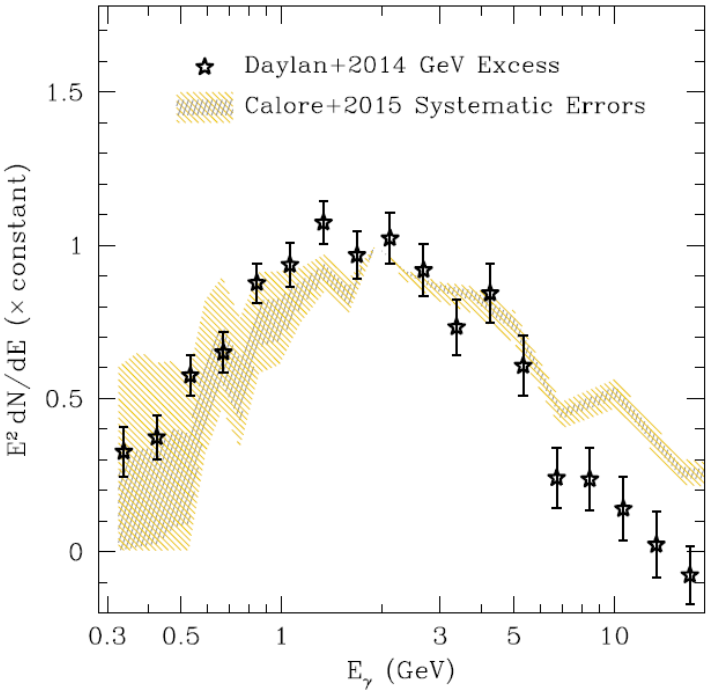


Daylan et al. (2014)

Surface Brightness at 2 GeV



$\propto \nu F_\nu$



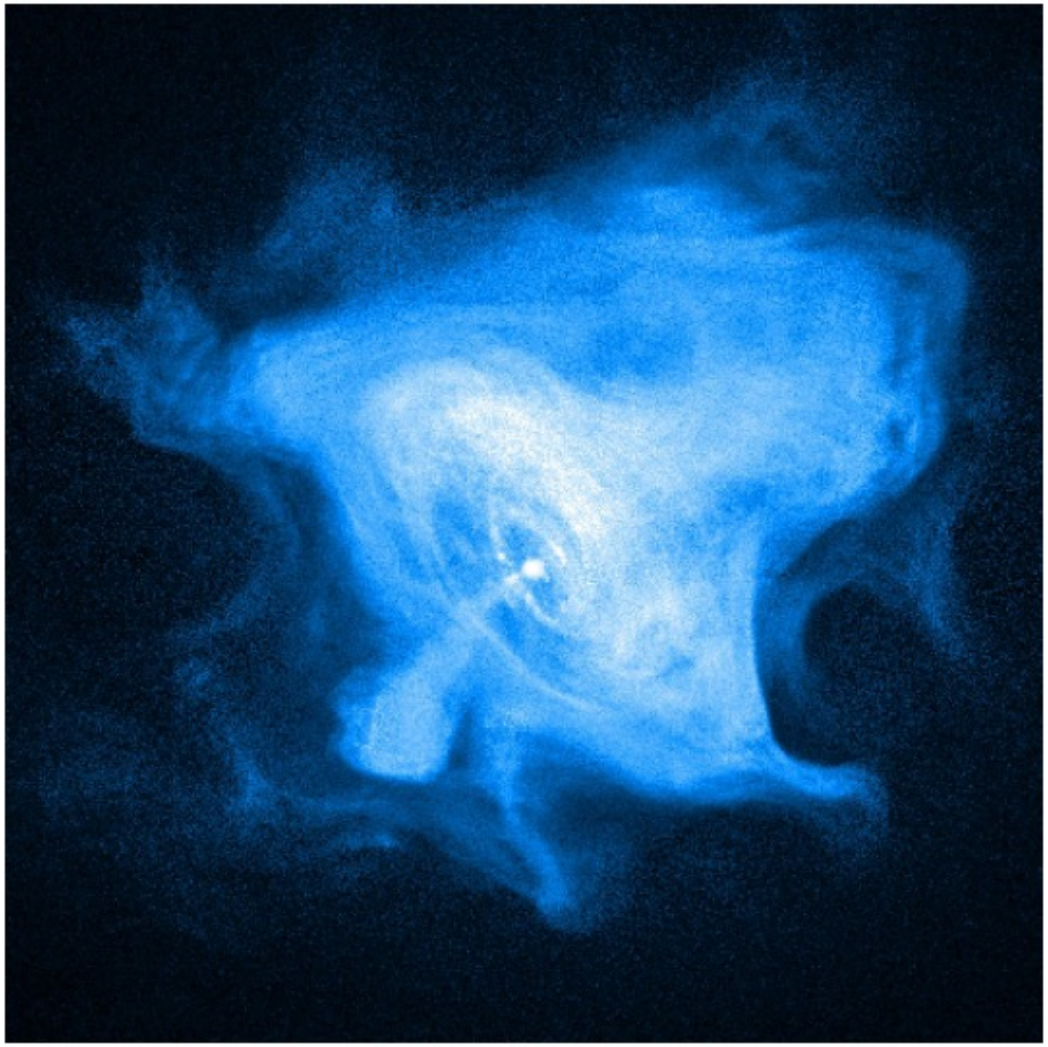
- Dark matter annihilation?
- Young pulsars?
- Cosmic ray outbursts?
- Background systematics?
- Millisecond pulsars?

Millisecond pulsars?

- How do we explain the observed **morphology**?
- Why aren't the millisecond pulsar **progenitors** there?
- Shouldn't we have seen **individual pulsars**?
- Is the **spectrum** consistent?

Normal pulsars

- P ~ 1 sec
- B ~ 10^{12} G
- mostly single
- $t_{spindown}$ ~ 10^{5} yr



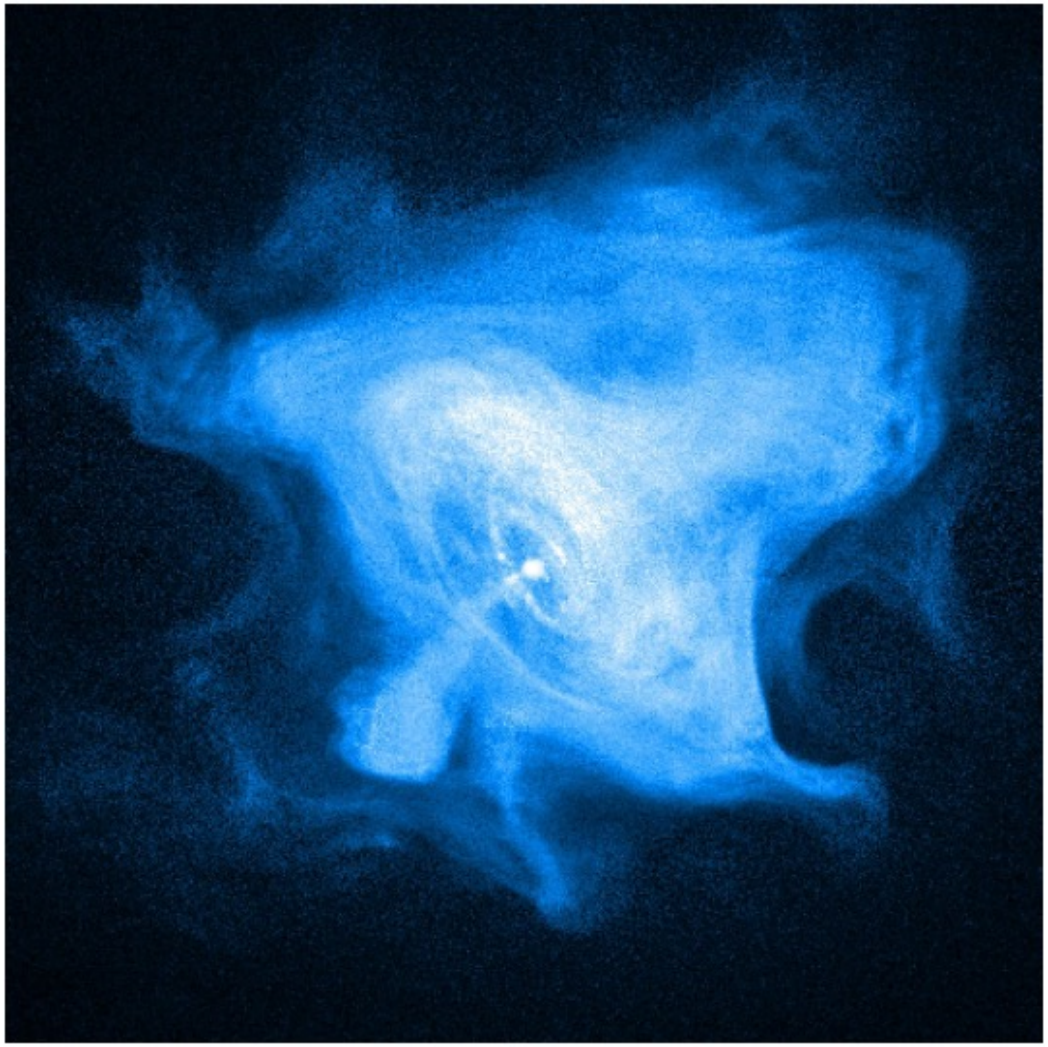
Crab pulsar, *Chandra* (X-ray)

Normal pulsars

- P ~ 1 sec
- B ~ 10^{12} G
- mostly single
- $t_{spindown}$ ~ 10^{5} yr

Millisecond pulsars

- P ~ 10 ms
- B ~ 10^{8} G
- Mostly in binaries
- $t_{spindown}$ ~ 10^{10} yr



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Origin of millisecond pulsars

- "recycled pulsars" spun up by mass transfer

- accretion phase: 10^6 yr

low mass X-ray binary (LMXB)

- MSPs, LMXBs

much more common in globular clusters

47 Tucana, Dieter Willasch

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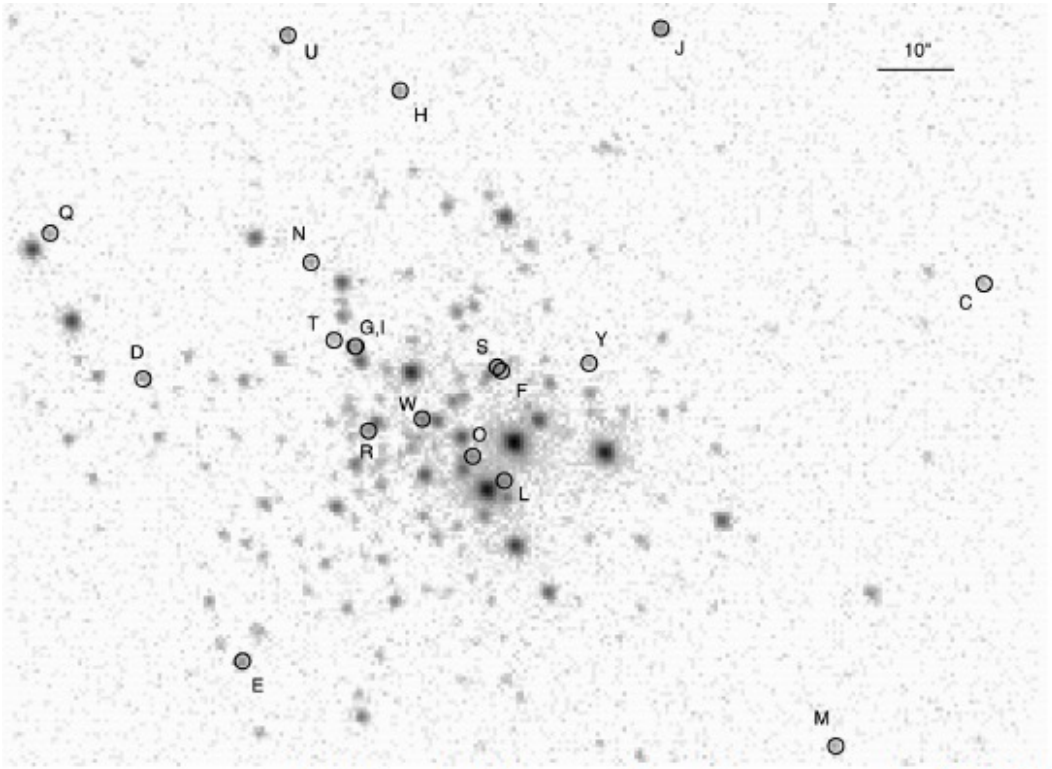


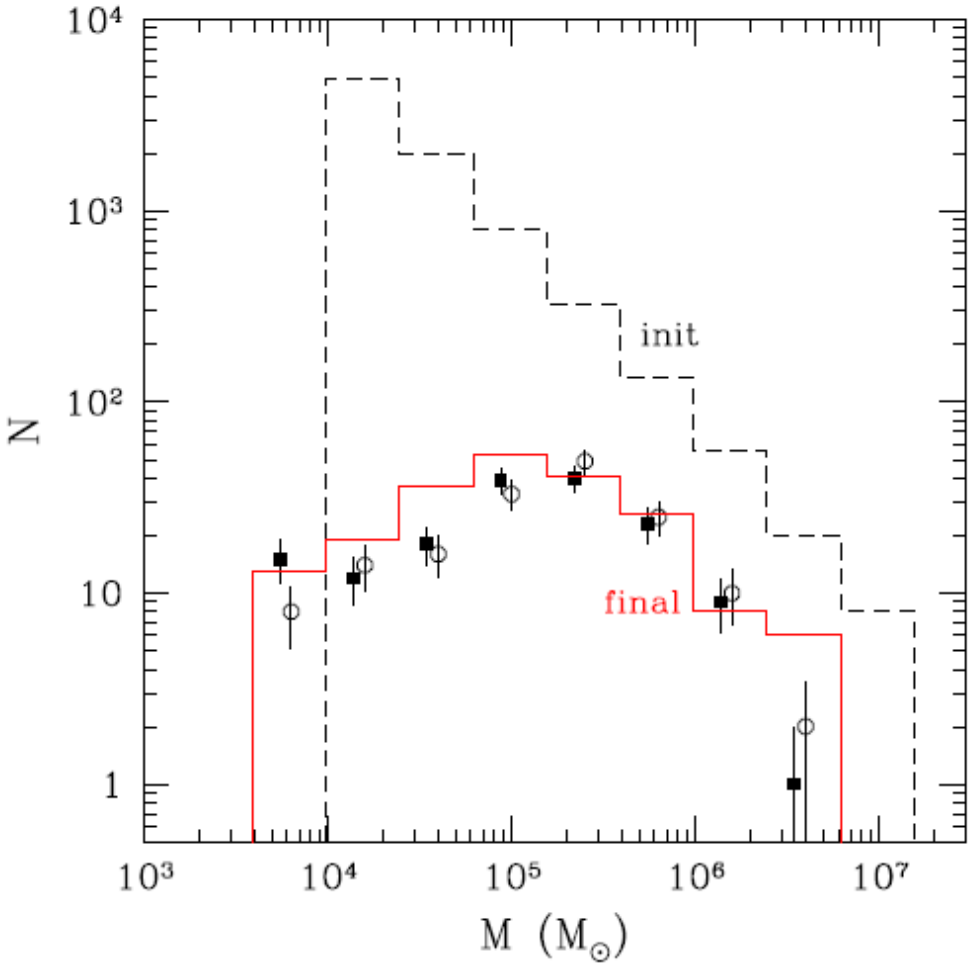
47 Tuc in X-rays, Bogdanov et al. (2006)

GCs are dynamical systems with long but finite lifetimes

6144 stars, credit Simon Zwart & Frank Summers

Most of the primordial GCs may be gone

- Evaporation
- Dynamical friction
- Tidal disruption



Gnedin et al. (2014)

The clusters may be gone but the stars and MSPs remain.

Where are they now?

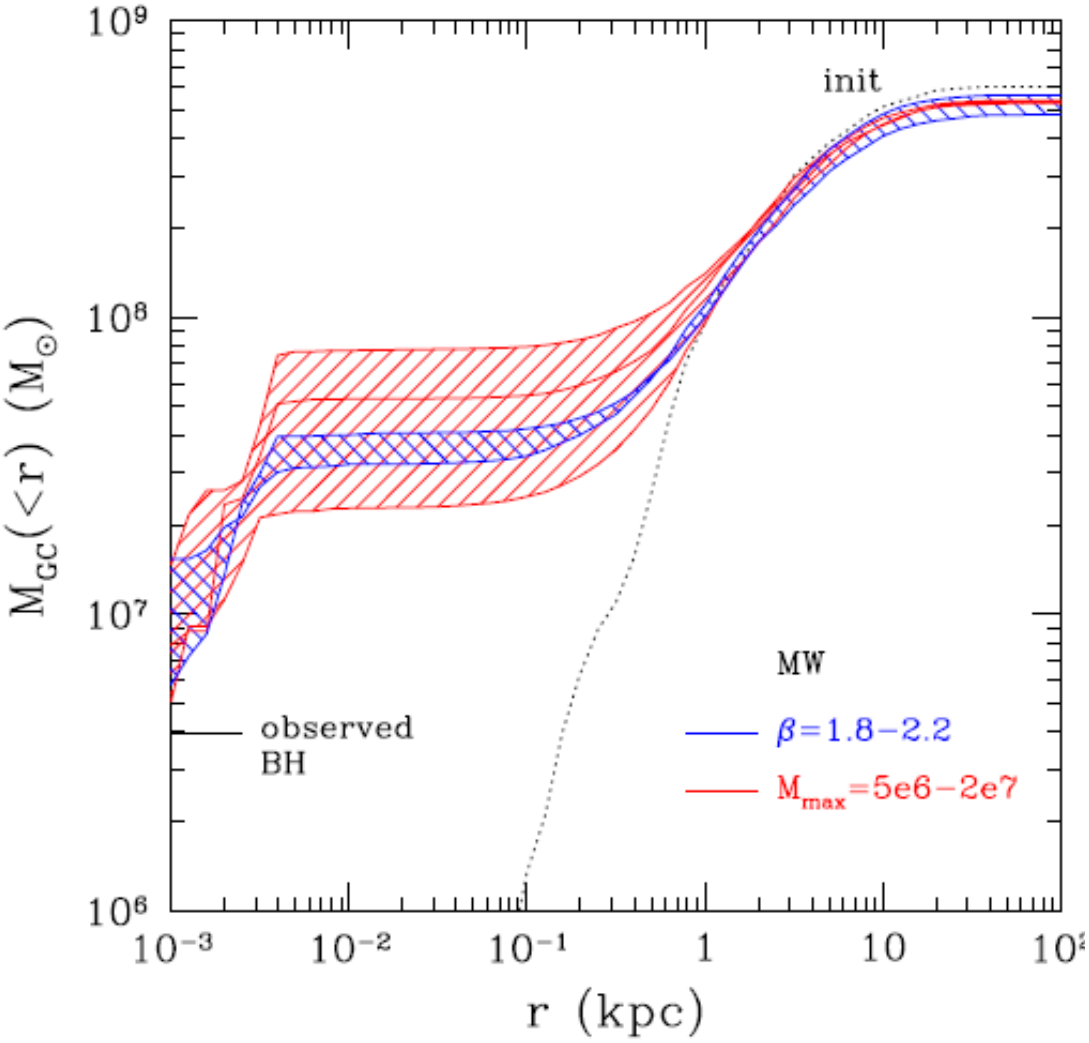
- Utilize evolutionary models which recover current GC properties

Gnedin, Ostriker, Tremaine (2014)

- Scale L_γ / M_* of extant GCs

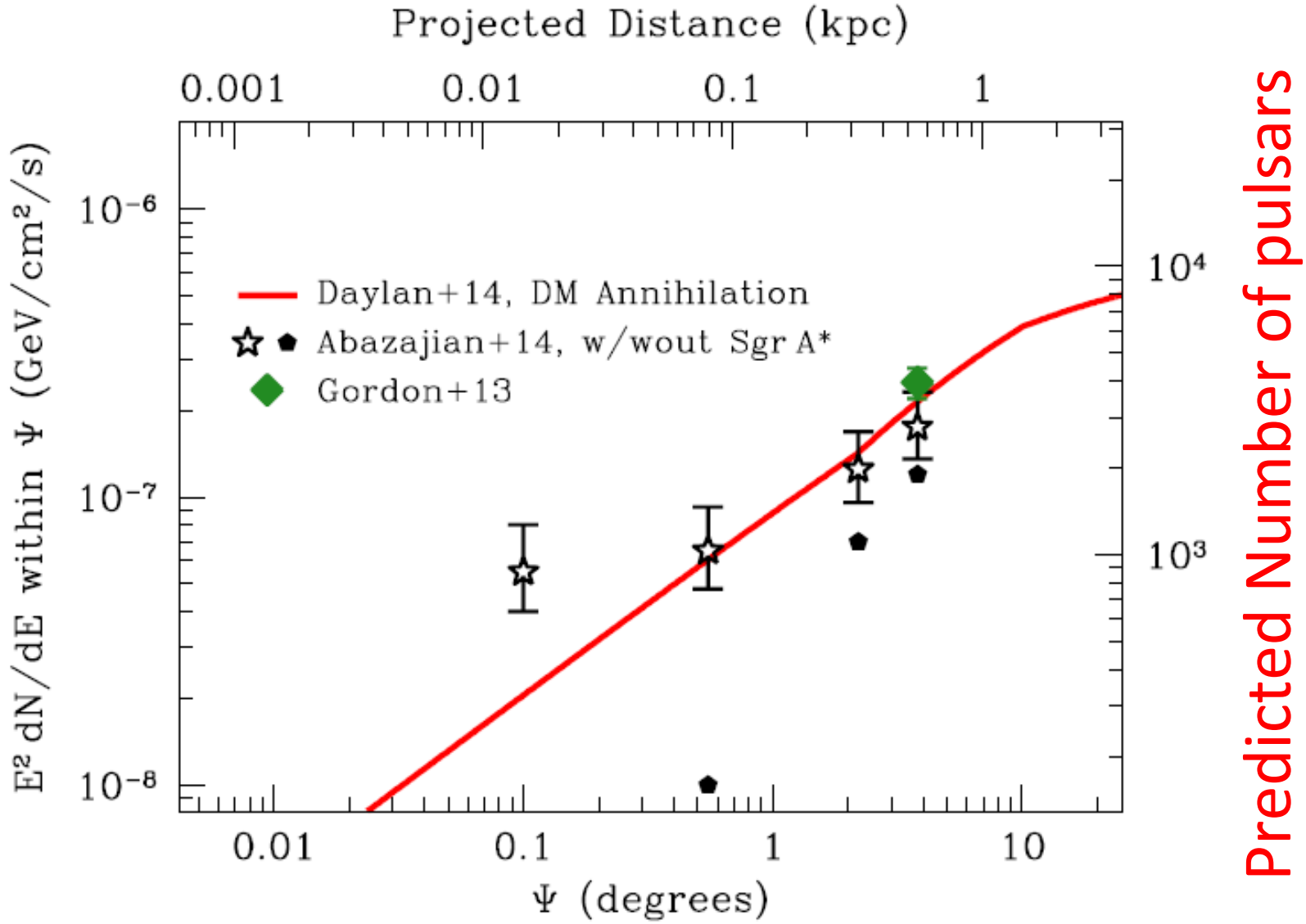
- Zero free parameters!

Mass deposited by disrupted GCs



Gnedin et al. (2014)

Results: 2GeV Flux within aperture of radius Ψ



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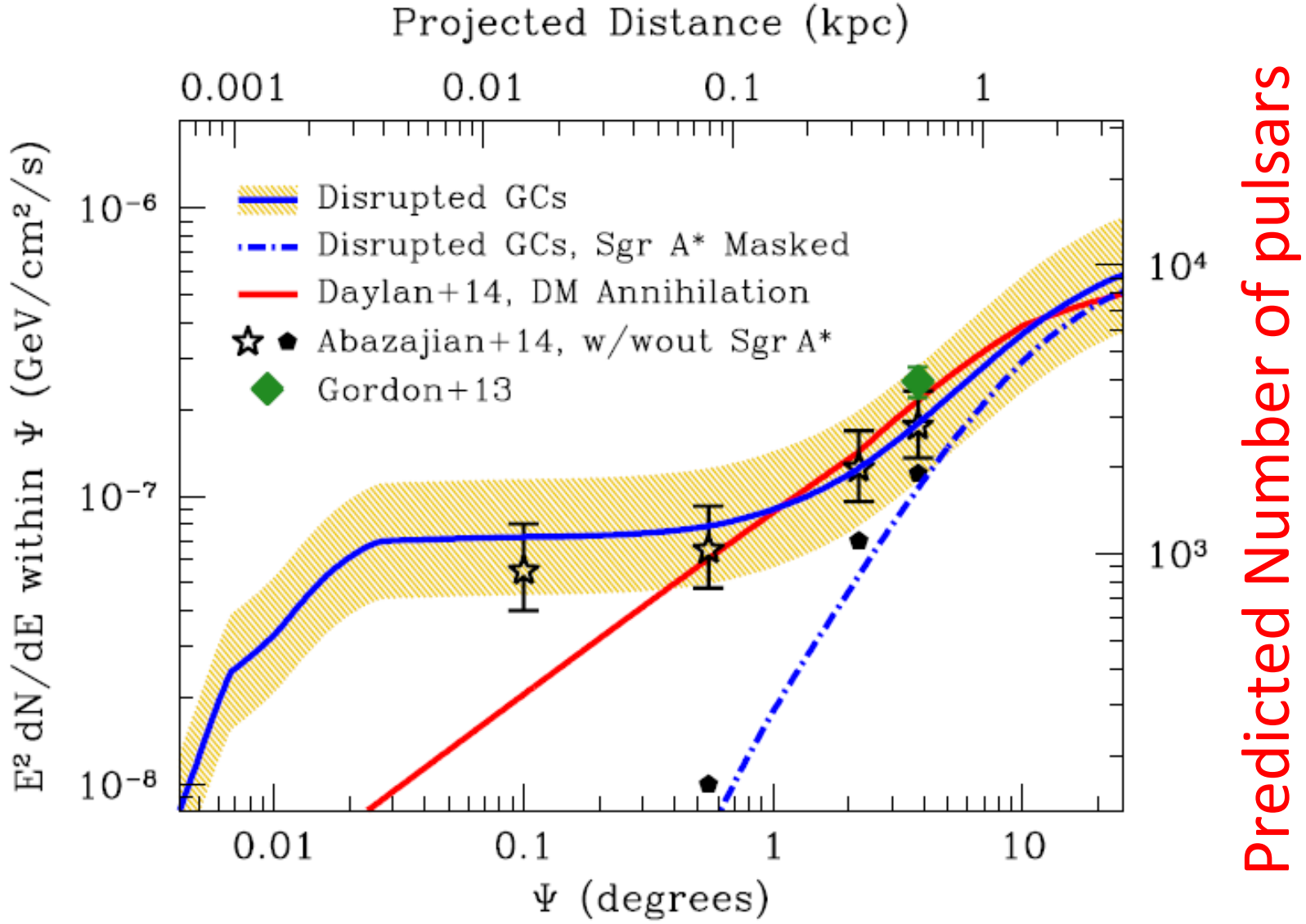
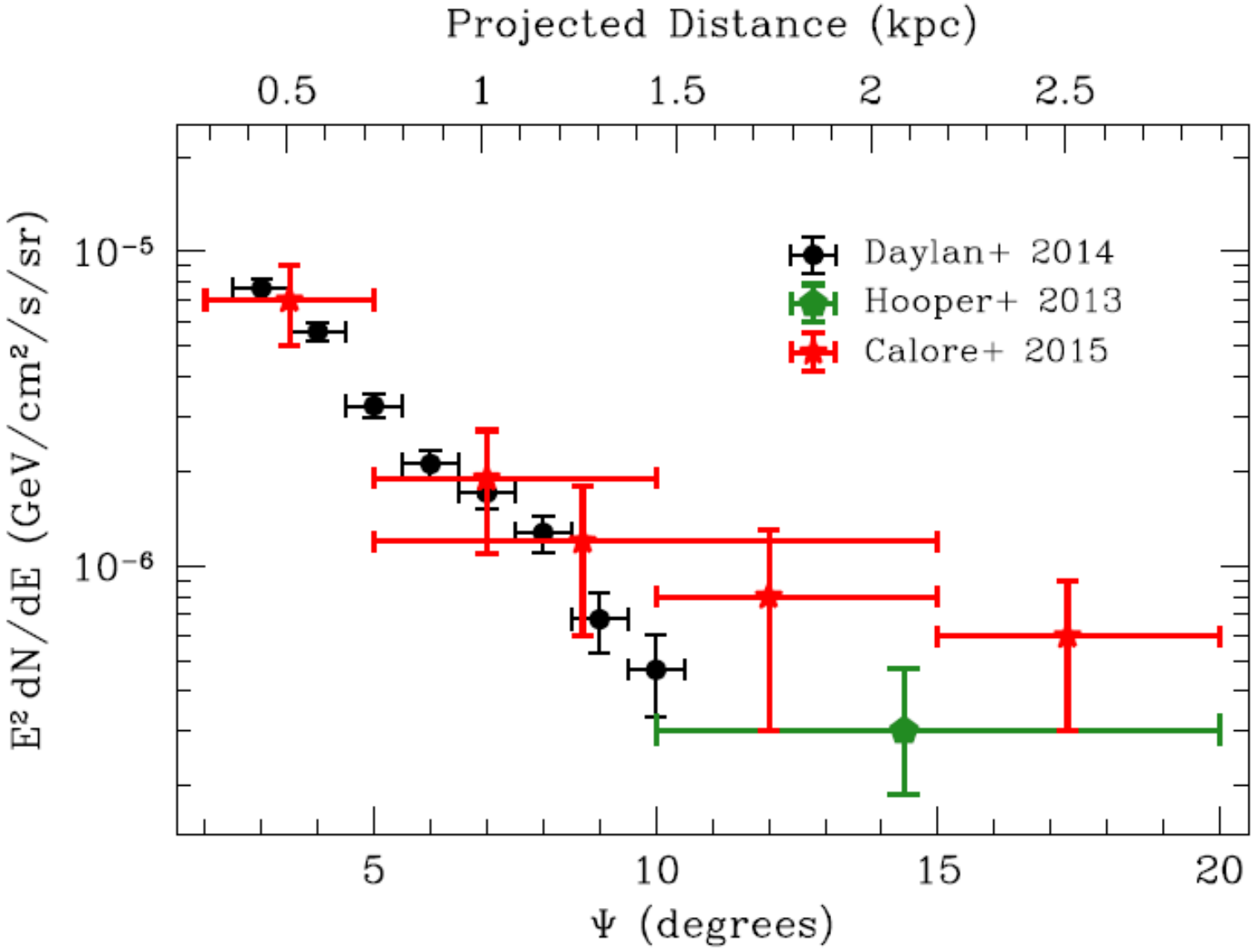


Results: 2GeV Surface Brightness



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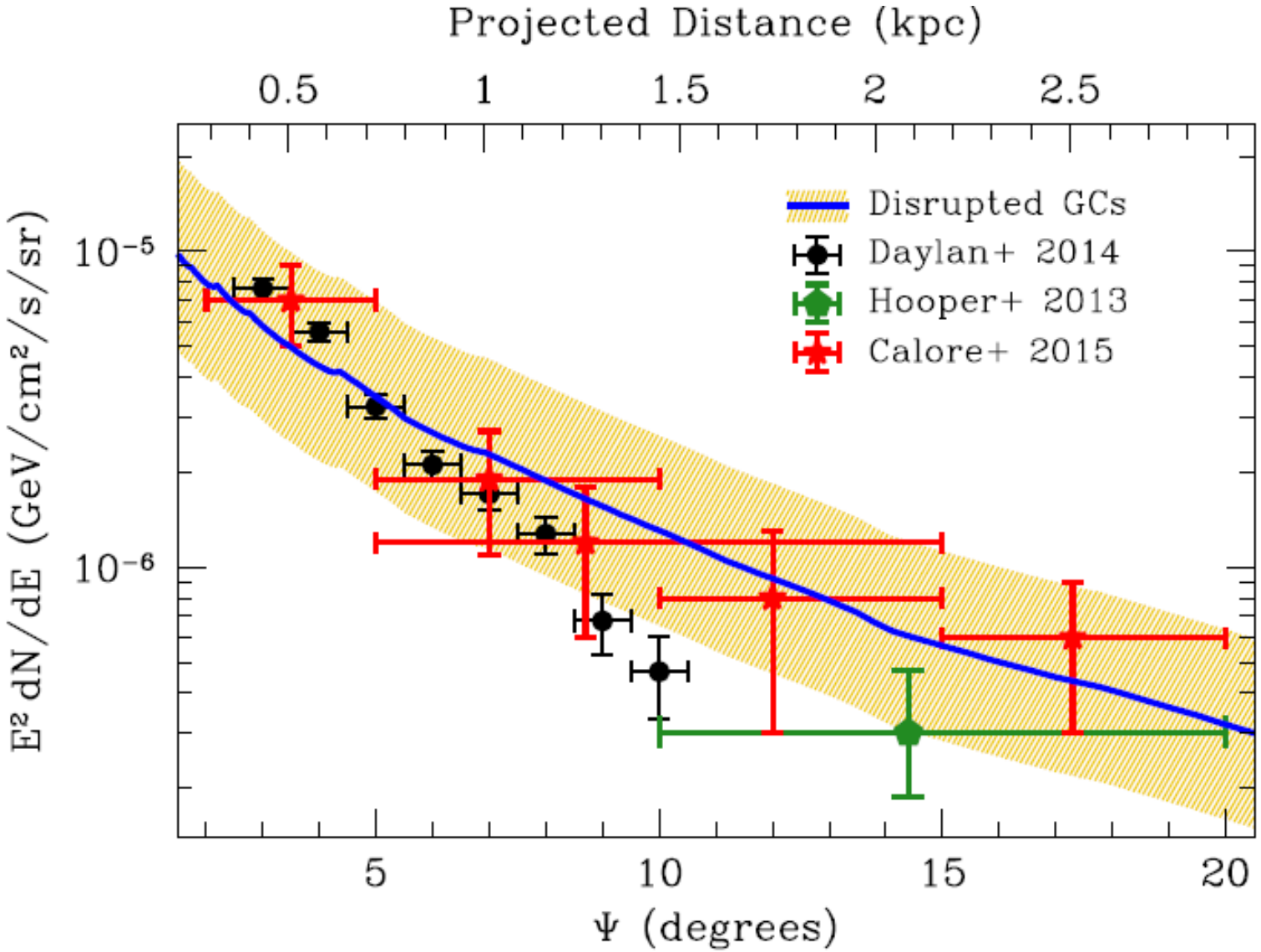
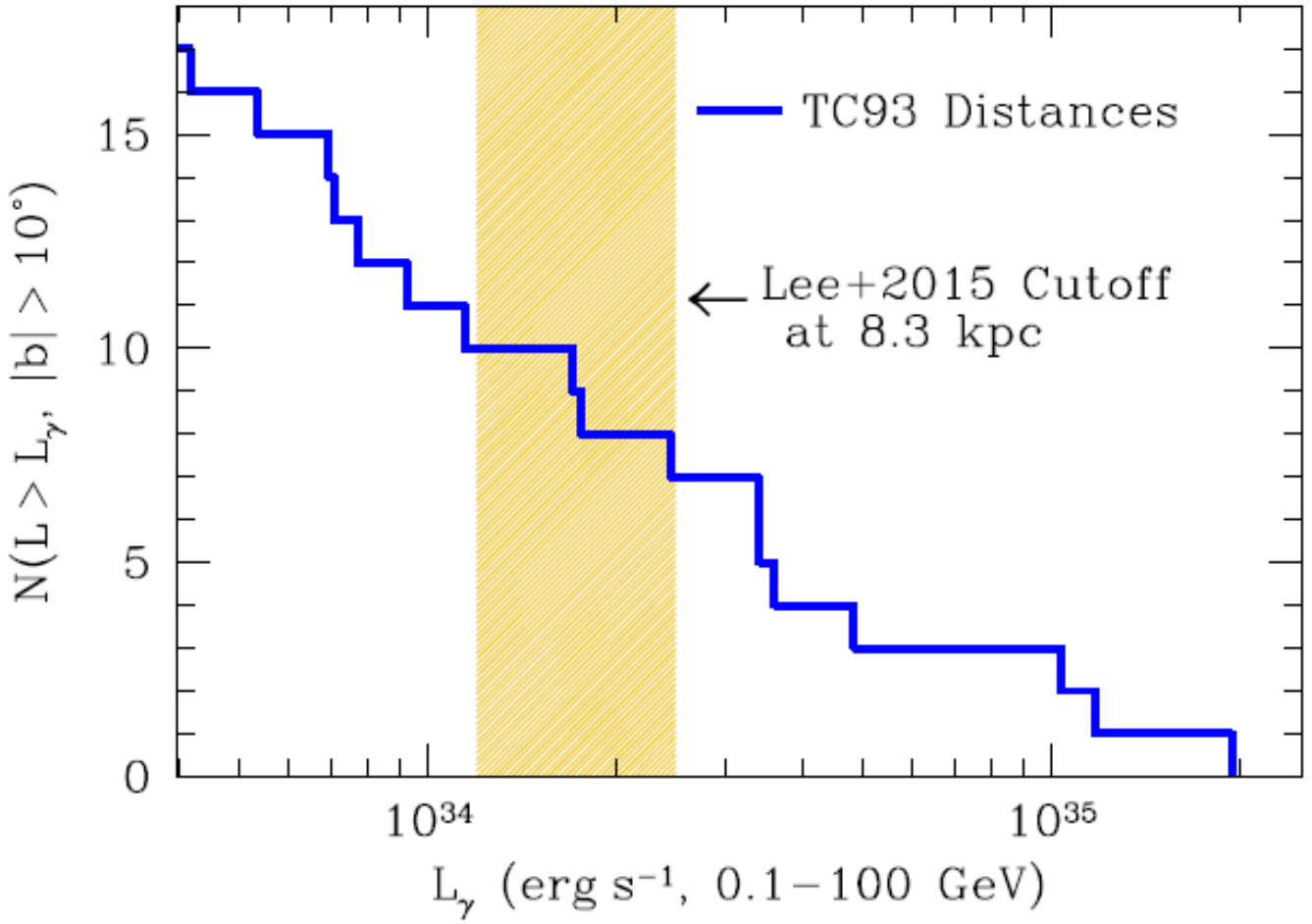


Should we have seen individual MSPs *at 2 GeV*?



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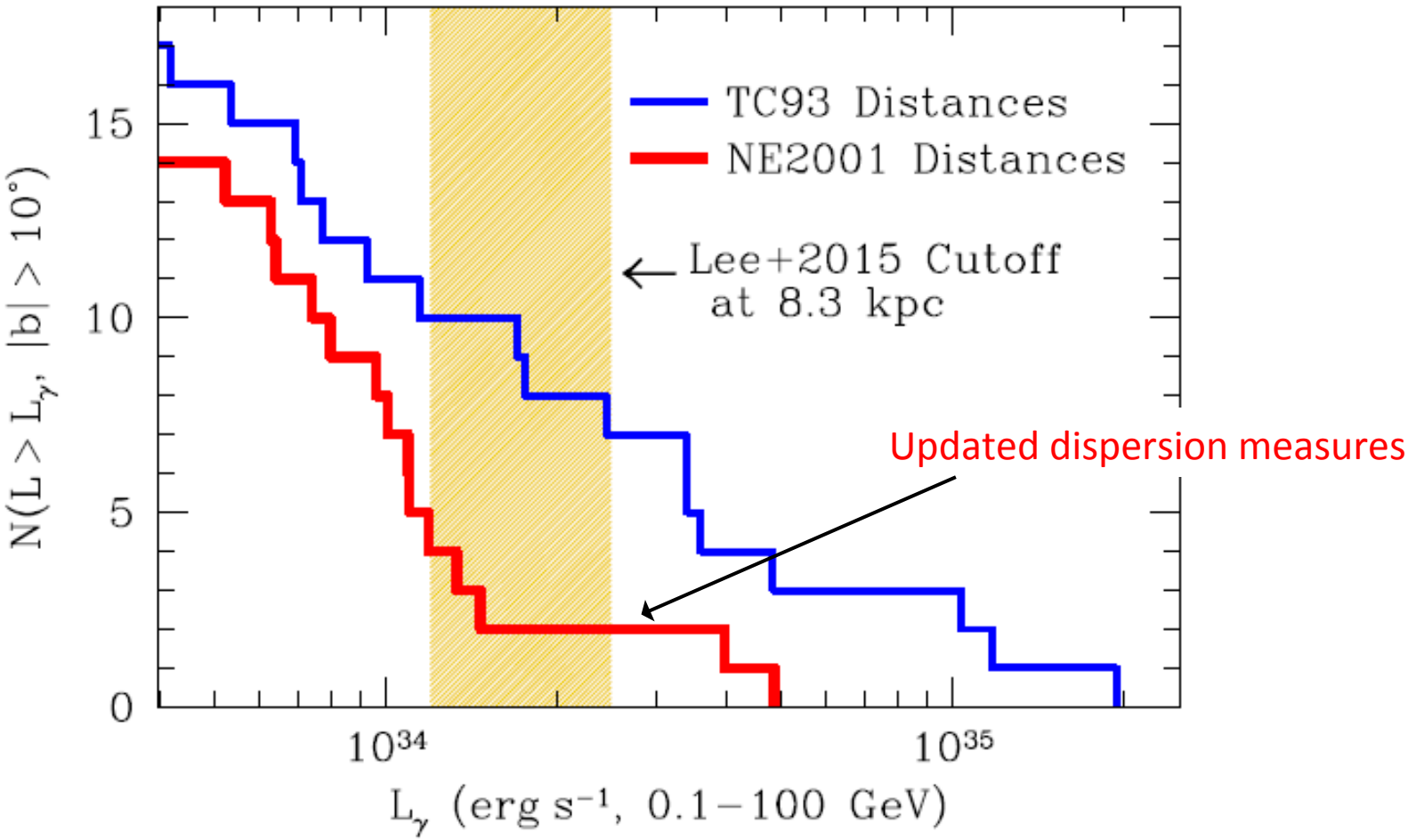
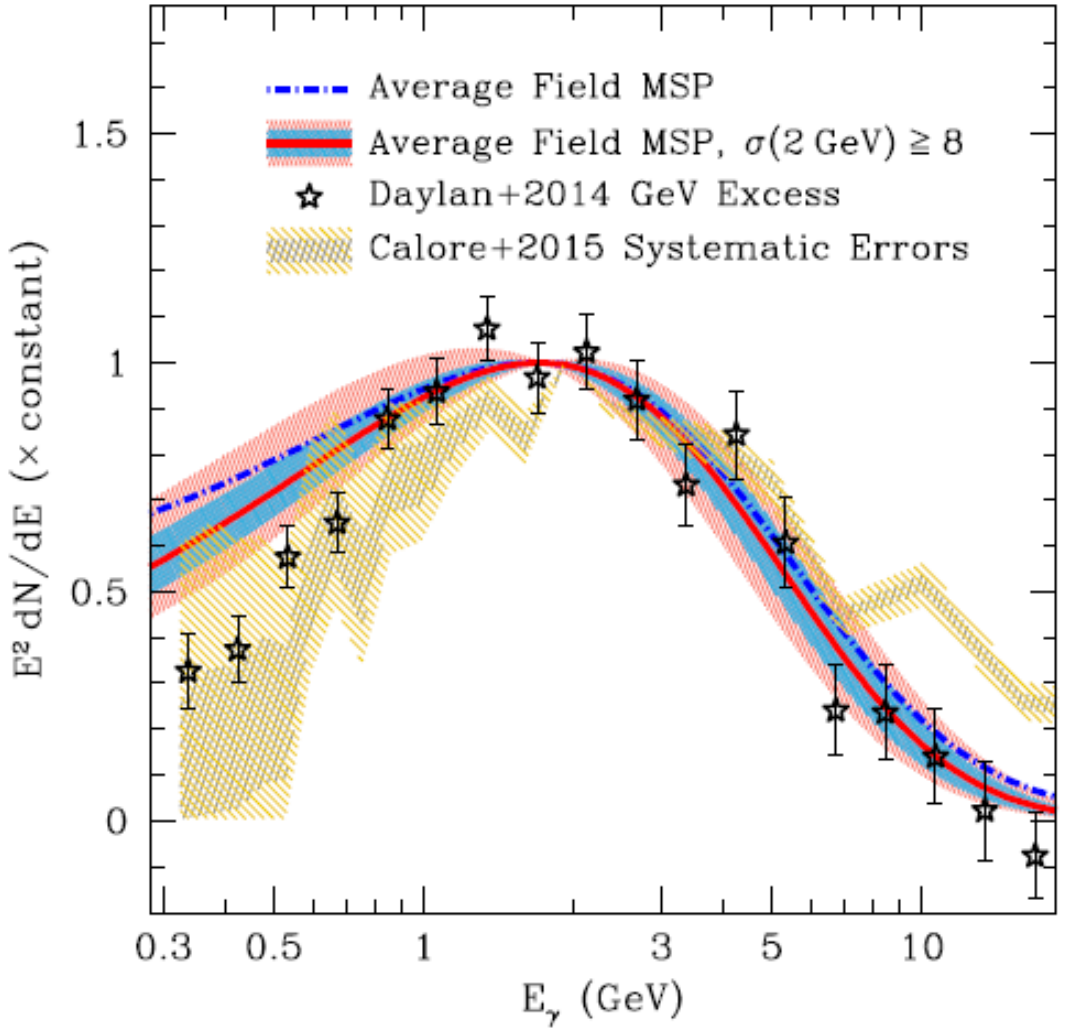


Based on known pulsars in the galactic field: two *could* have been seen in the GC
But these 2 have large systematic distance errors. → OK if we see none at 2 GeV

Is the spectrum consistent?

- Yes! 1GeV – 20 GeV
- Slight (2σ) discrepancy at <800 GeV
  - Note: correlated errors
  - low signal-to-noise
  - biases/confusion not included



Millisecond pulsars?

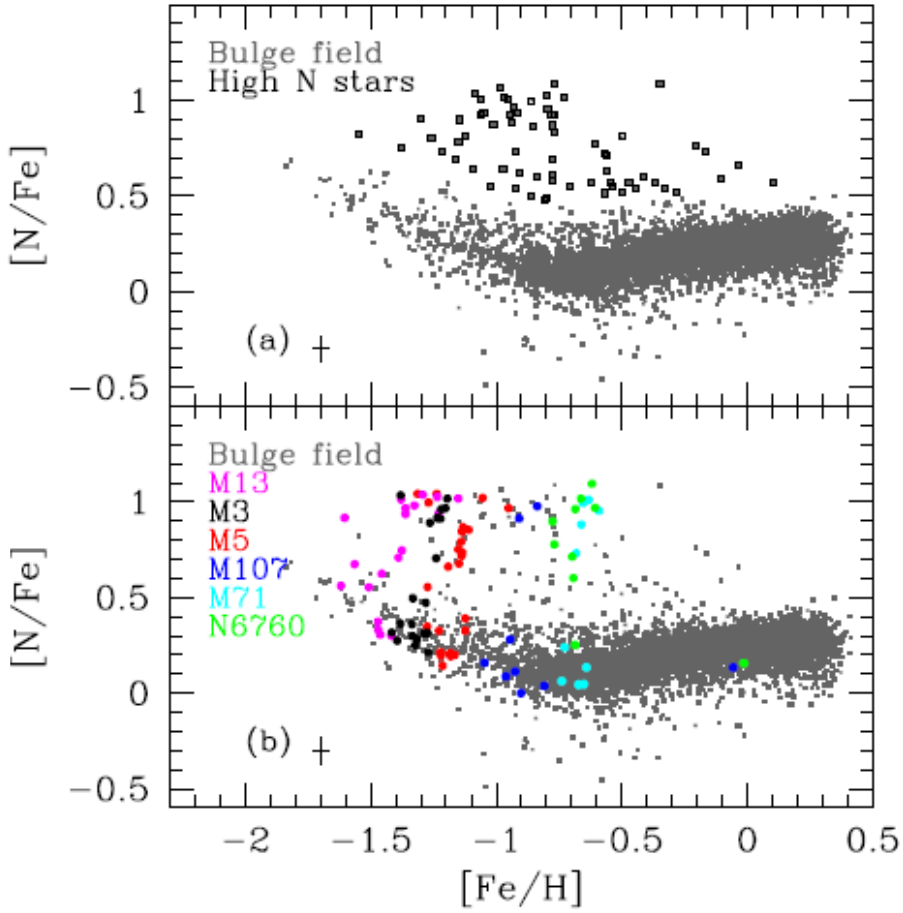
- ✓How do we explain the observed morphology?
  - Disrupted globular clusters
- ✓Why aren't the millisecond pulsar progenitors there?
  - Density is no longer high enough to form new LMXBs
- ✓Shouldn't we have seen individual pulsars?
  - Not with the latest estimates of dispersion measures
- ✓Is the spectrum consistent?
  - Less than 2σ discrepancy

Other evidence

Bulge chemistry

- 1% of bulge stars
  show Al, N enhancements
- ½ of globular cluster stars show Al, N enhancements

→ 2% of bulge mass from GCs?



Schiavon et al. (2015), submitted

Flux statistics

- of Fermi excess looks like unresolved point sources
  - Diffuse contribution is **zero**

(Lee et al. 2015, see also Bartels et al. 2015)

How can we confirm this scenario?

- Find the MSPs within ~ 1 kpc
  - high-radio frequency radio surveys
  - pulsing X-rays, gamma-rays
- Further chemical evidence of dissolved GCs?

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Is the Fermi excess the first direct evidence for globular cluster destruction?