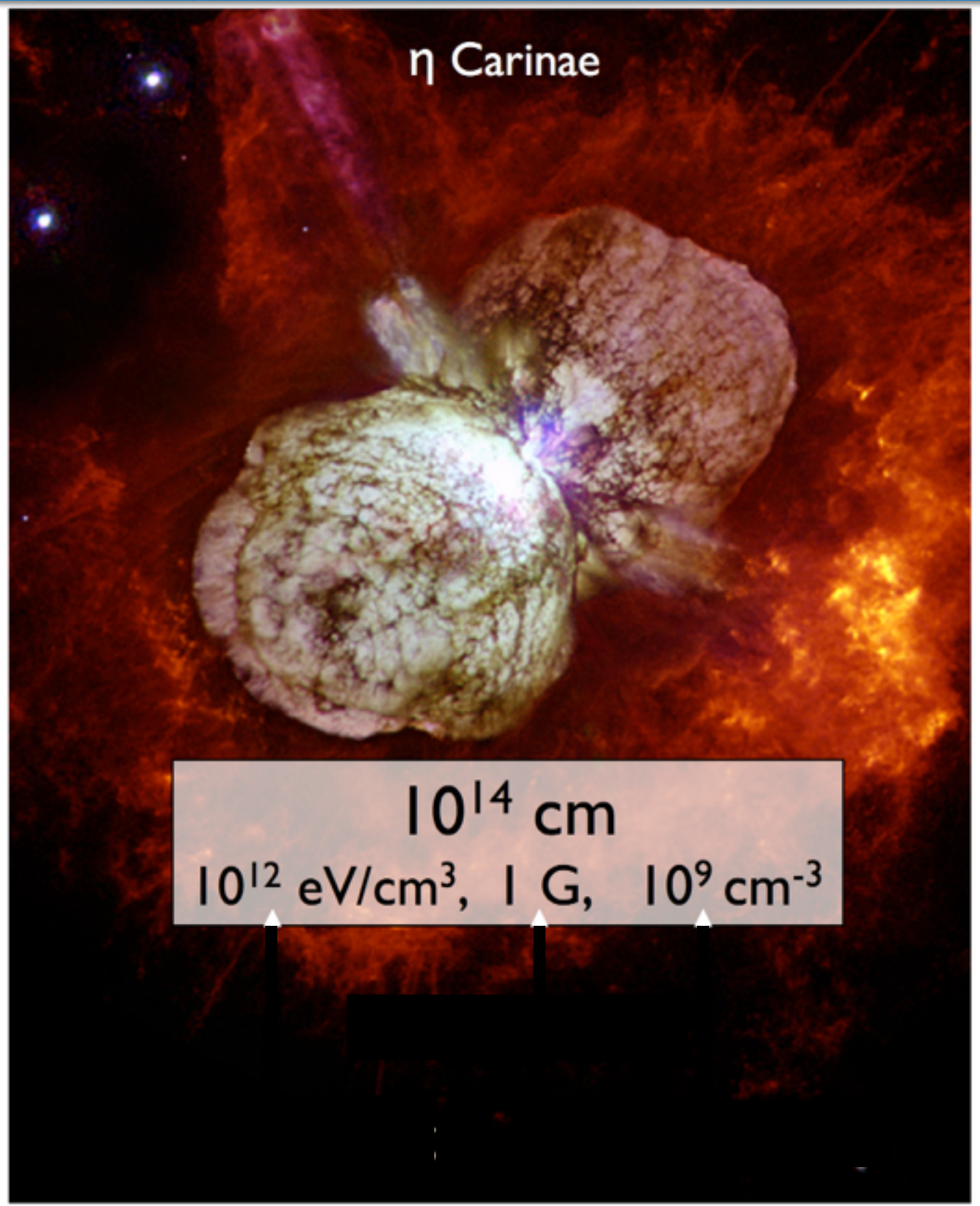
Particle acceleration in ηCarinae: the Expected and Unexpected



Matteo Balbo,
ISDC, Switzerland

Roland Walter,
ISDC, Switzerland

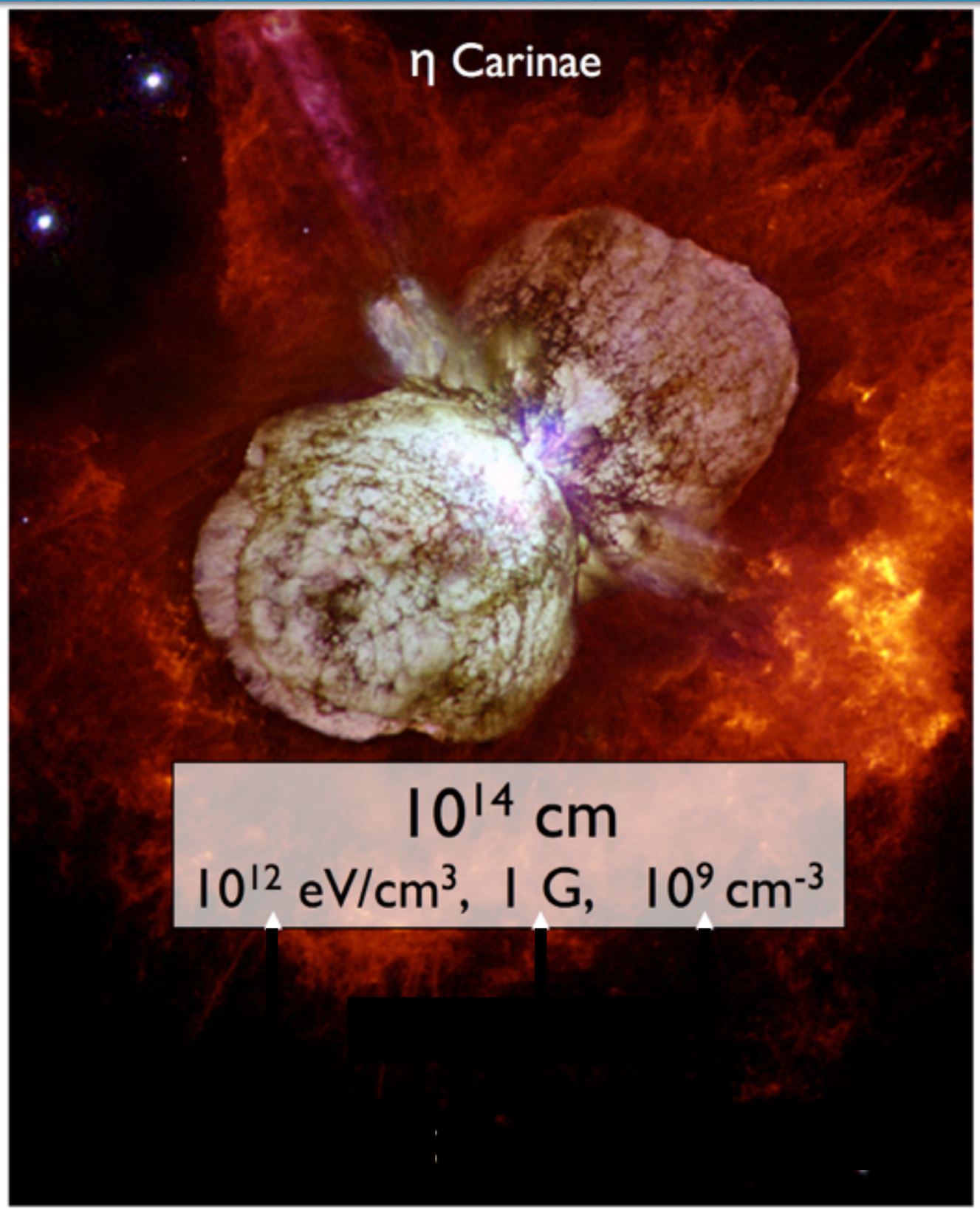
28th Texas Symposium on Relativistic Astrophysics

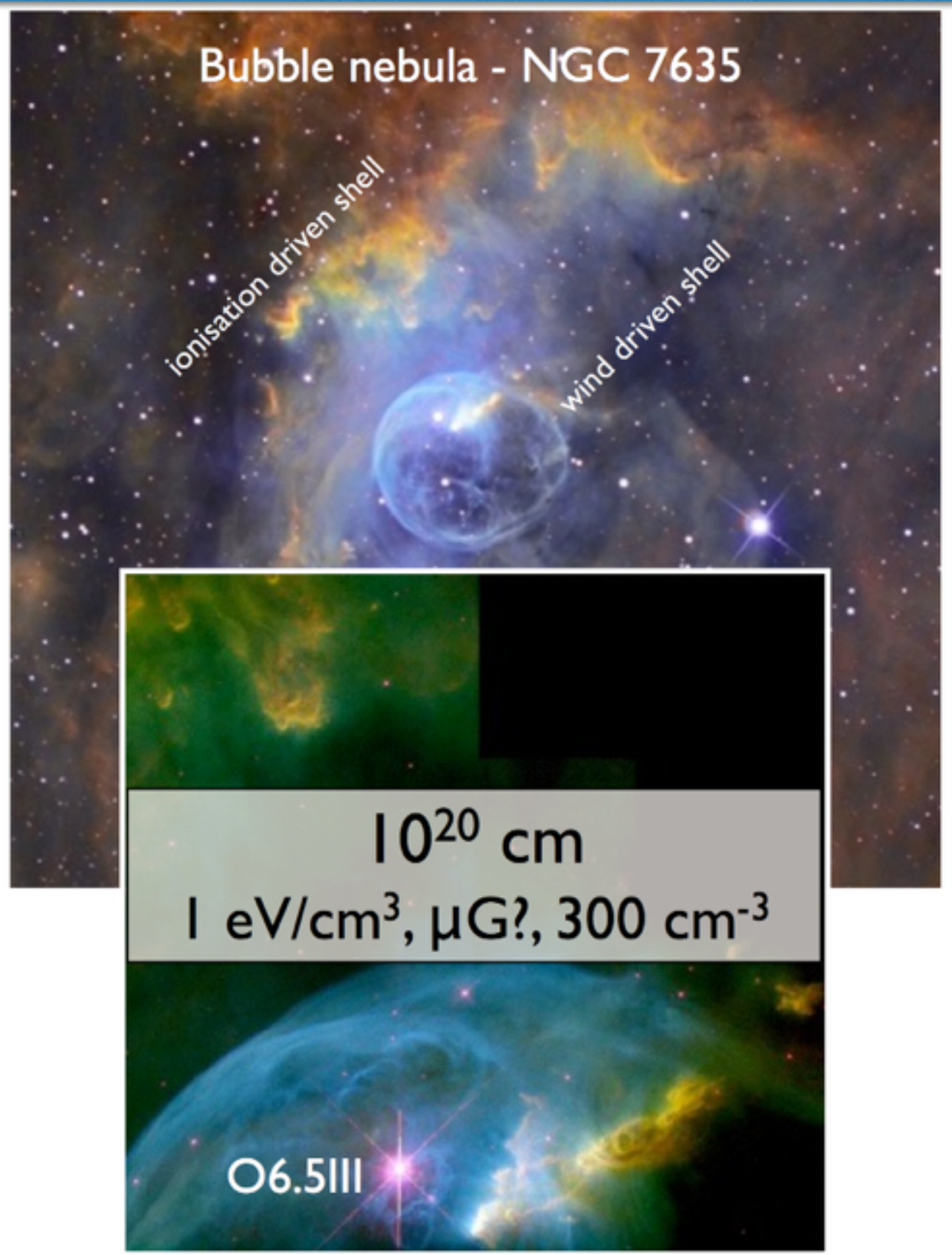
13-18 December 2015, Geneve

UNIVERSITÉ DE GENÈVE

Particle acceleration in ηCarinae: the Expected and Unexpected

ISDC





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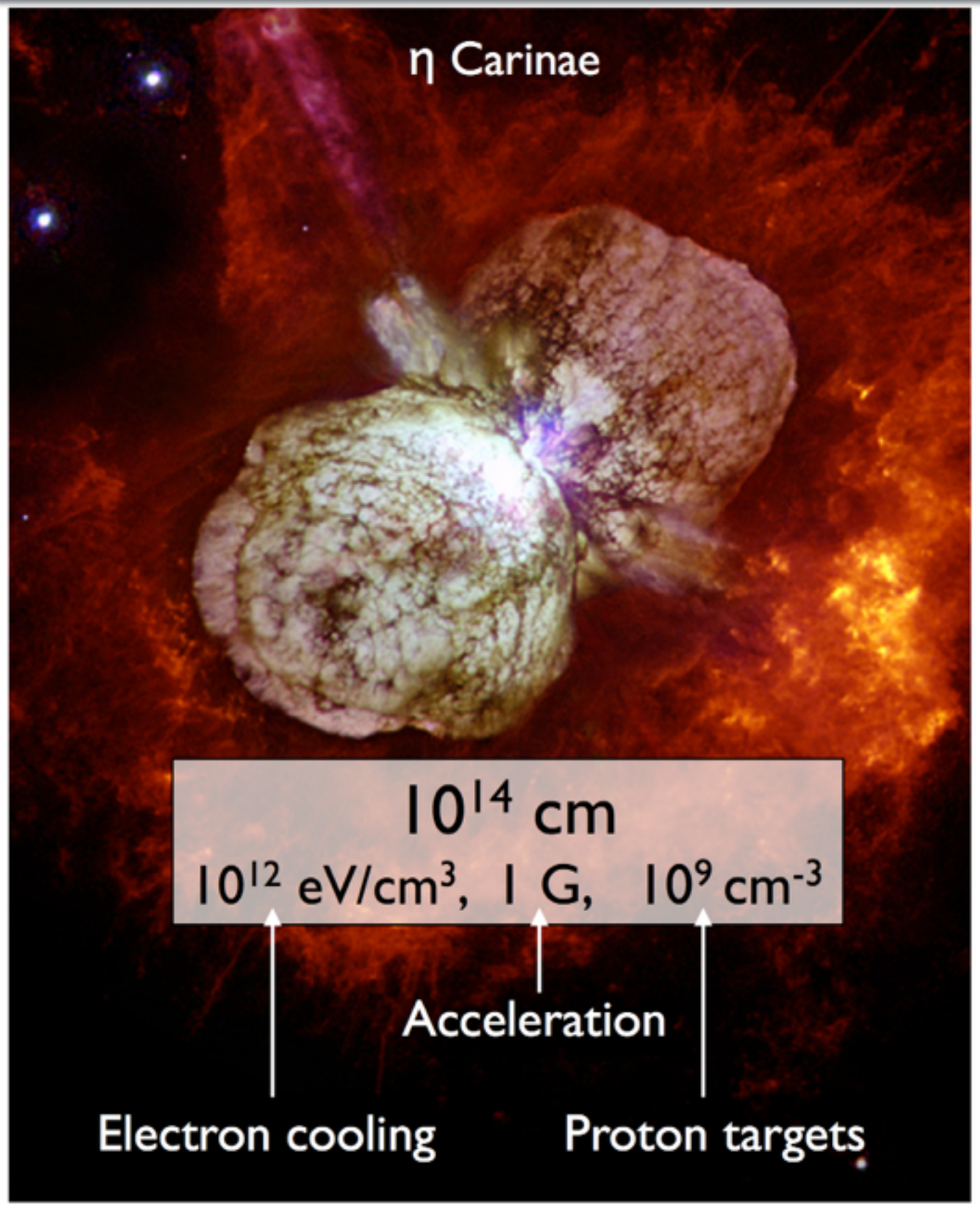
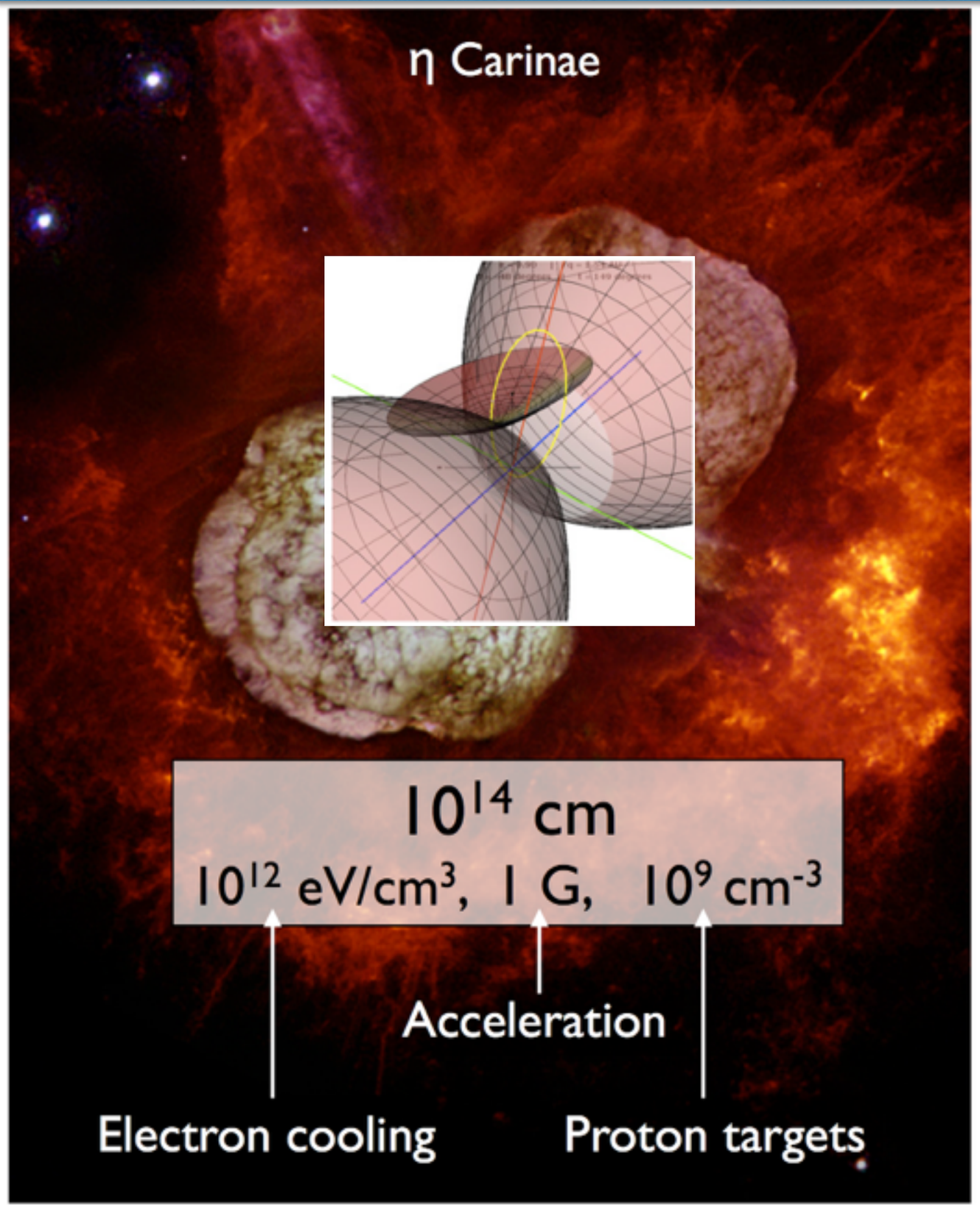


Colliding Wind Binaries are predicted to be potential sites of HE γ-ray emission through strong shocks due to colliding winds

Eichler & Usov (1993) ApJ 402, 271

Particle acceleration in ηCarinae: the Expected and Unexpected



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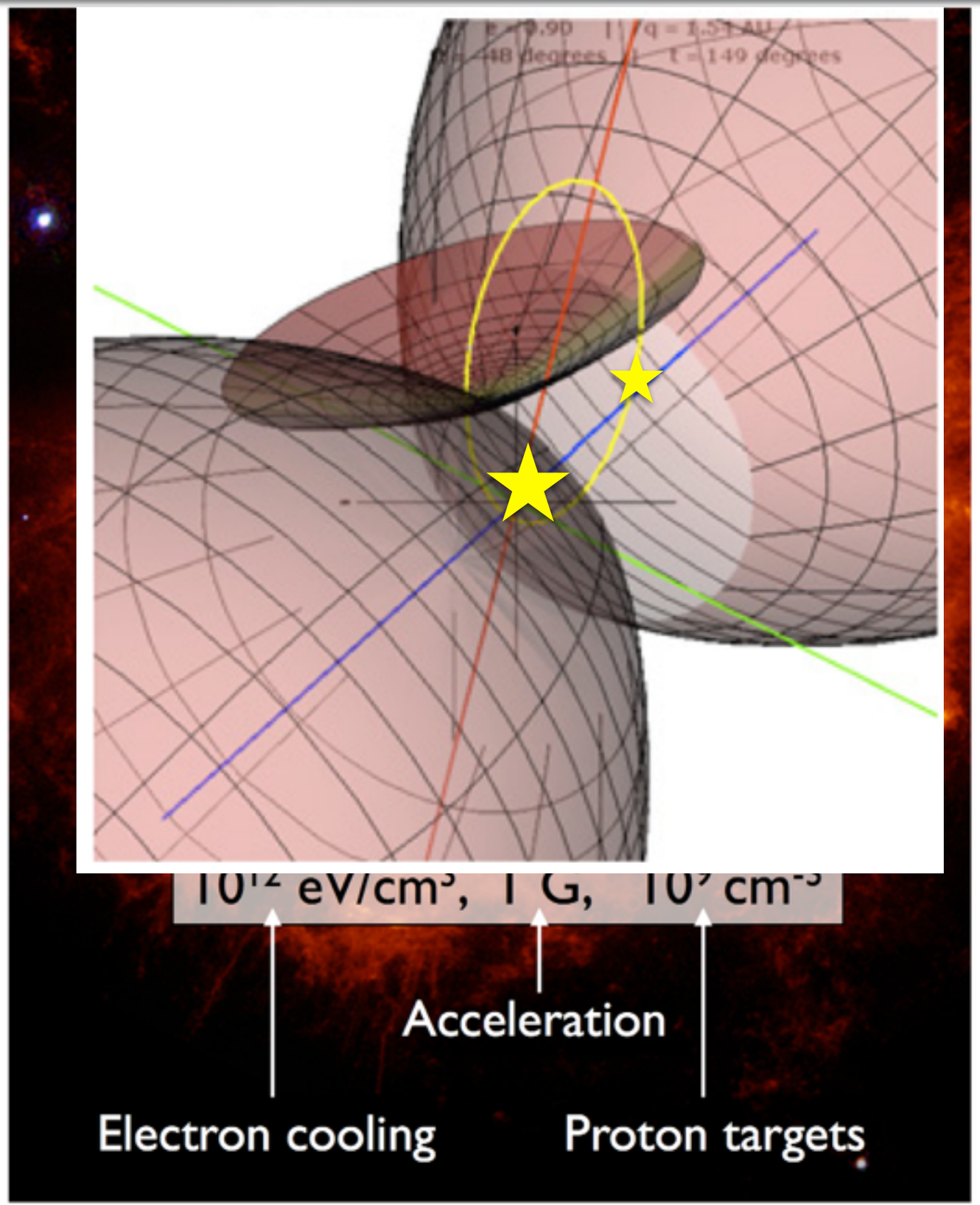

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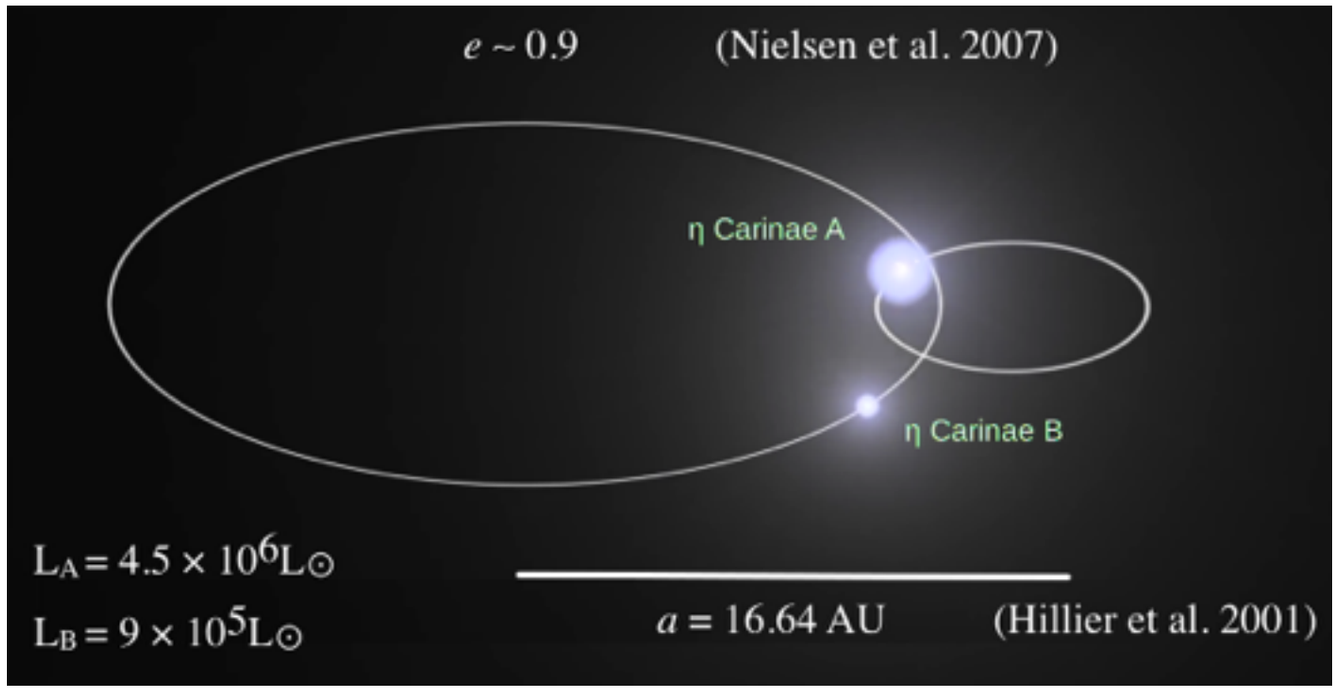
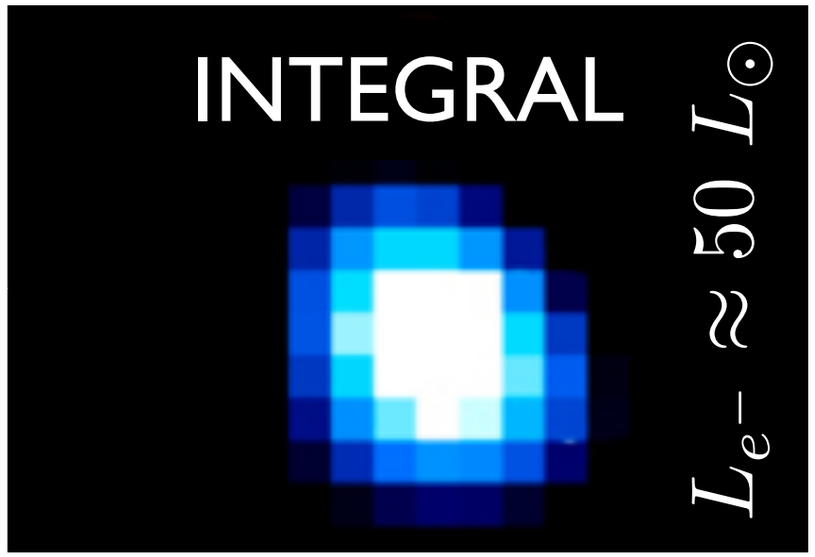
Eichler & Usov (1993) ApJ 402, 271

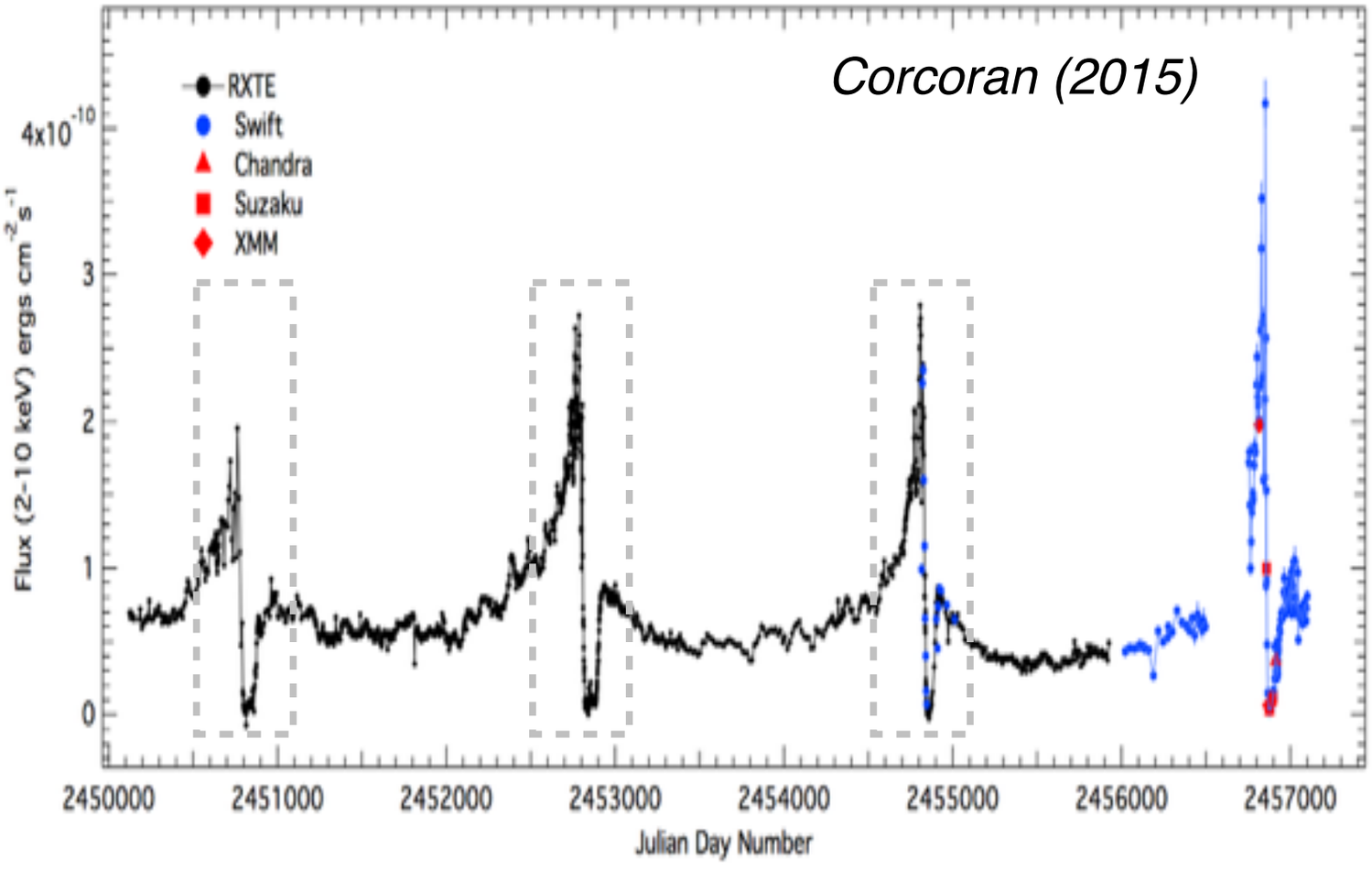
Who is ηCar?



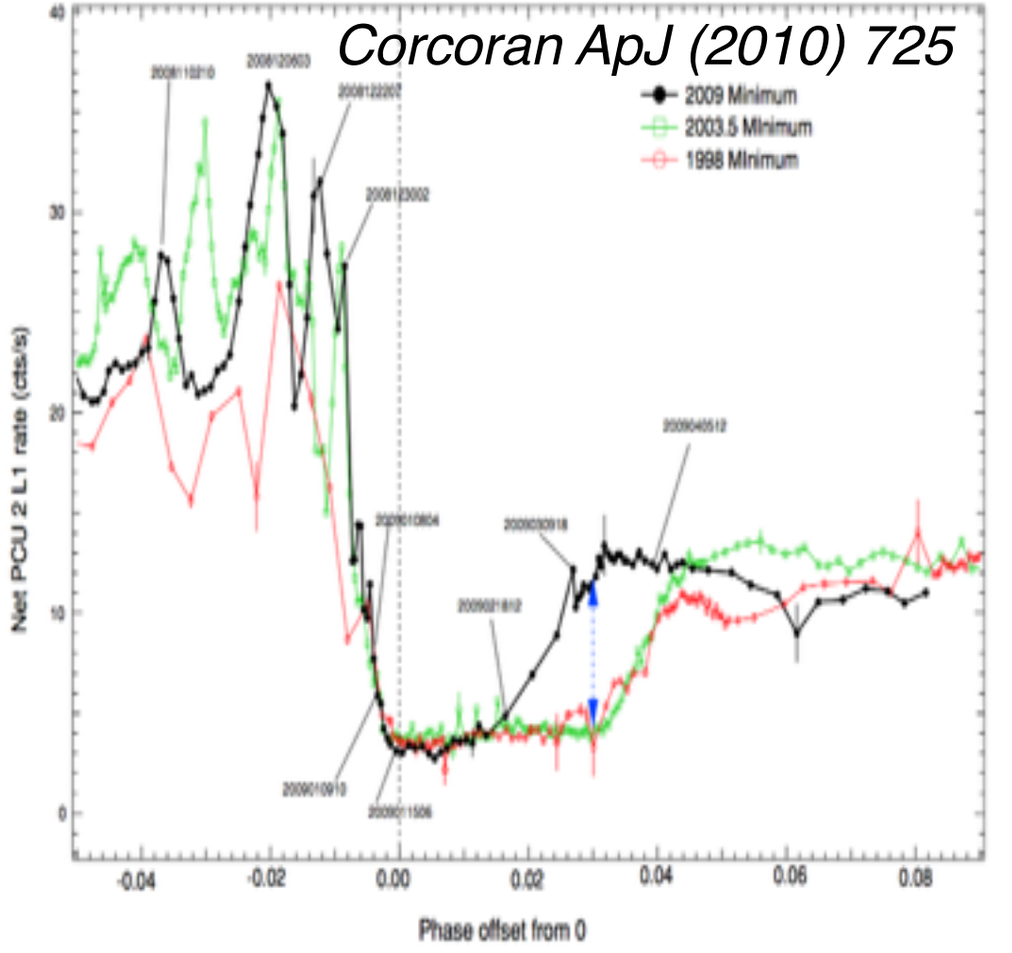


A&A (2008) 477, L29
A&A (2010) ApJ, 718 L161

Corcoran (2015)



Corcoran ApJ (2010) 725



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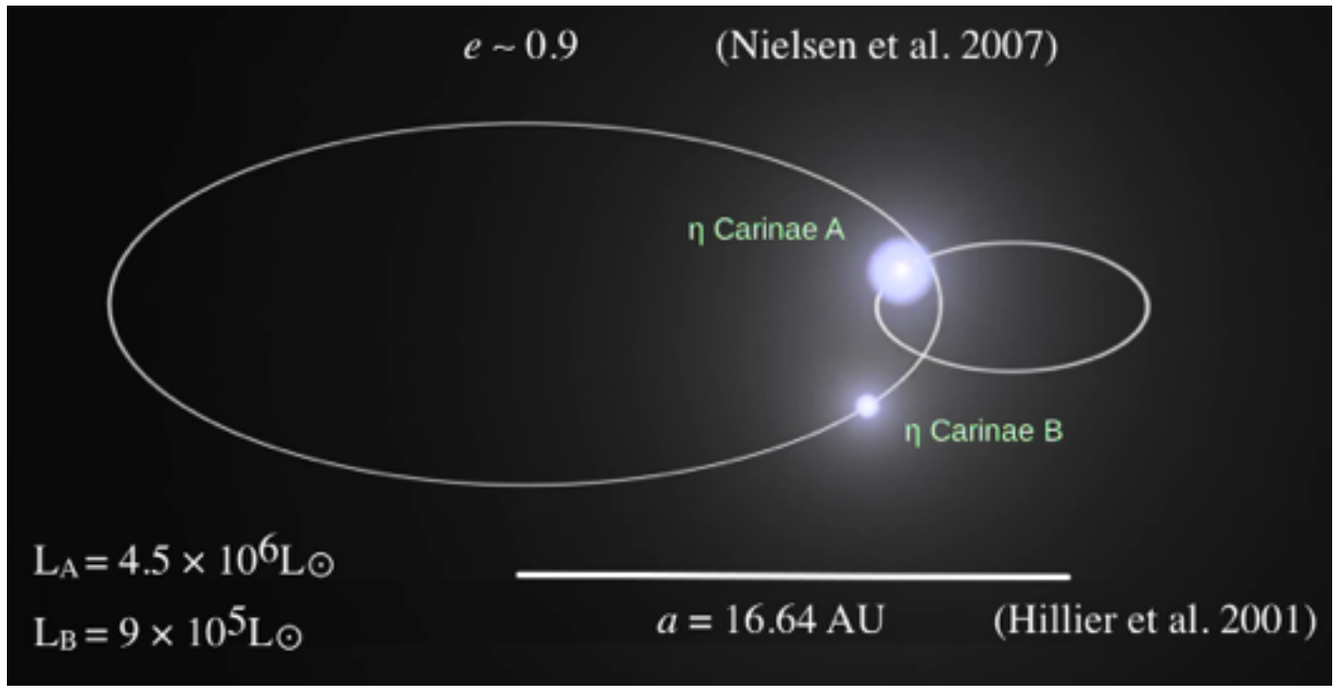
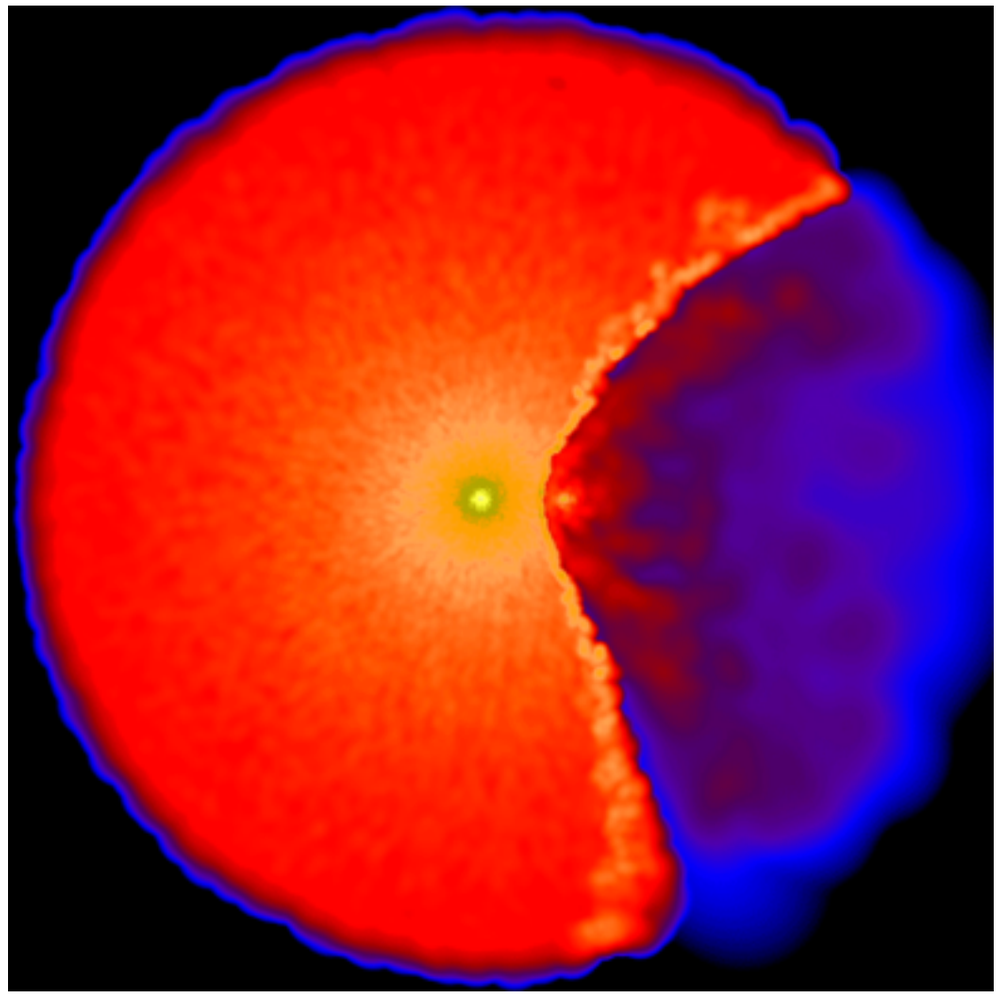
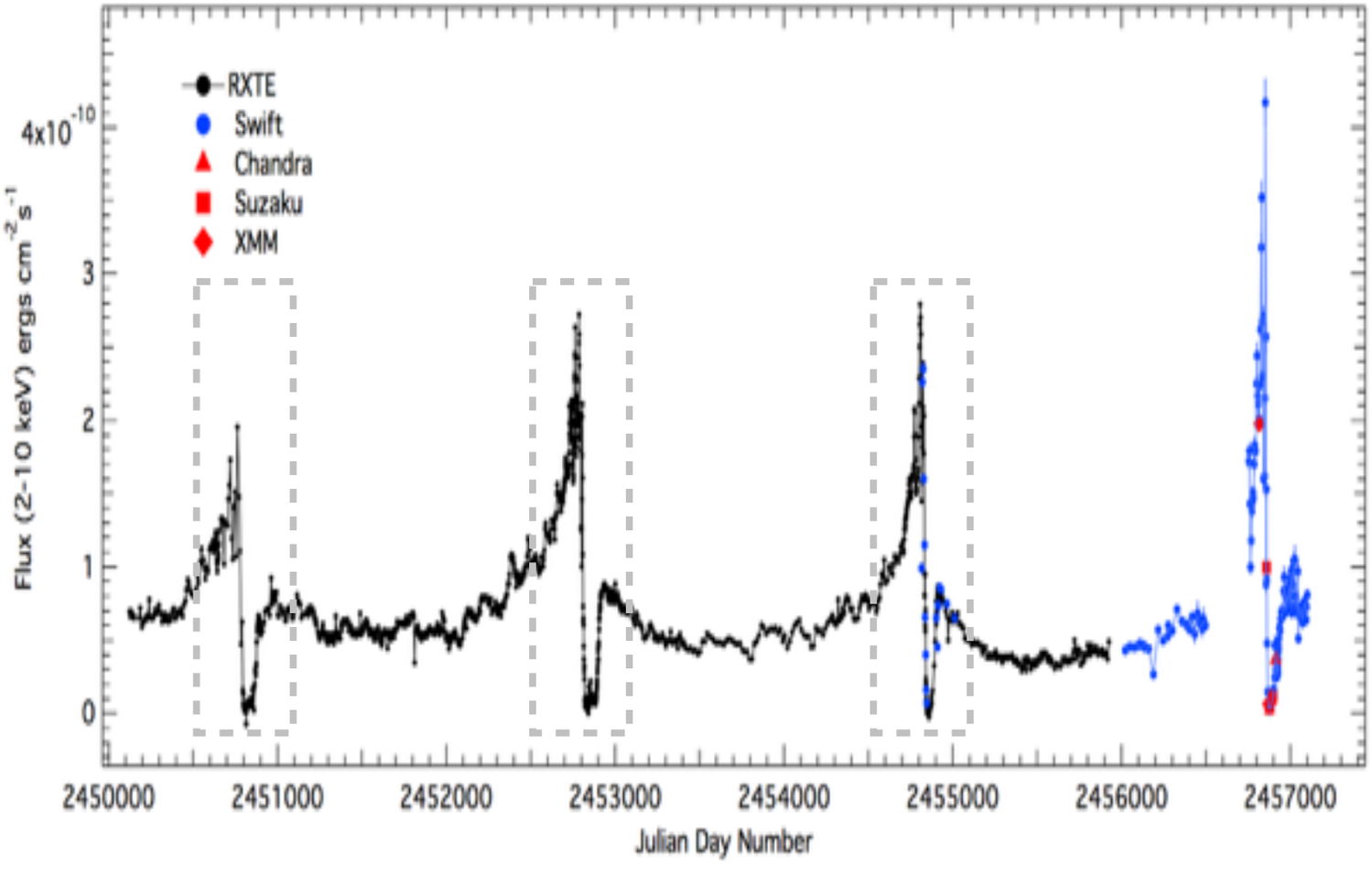
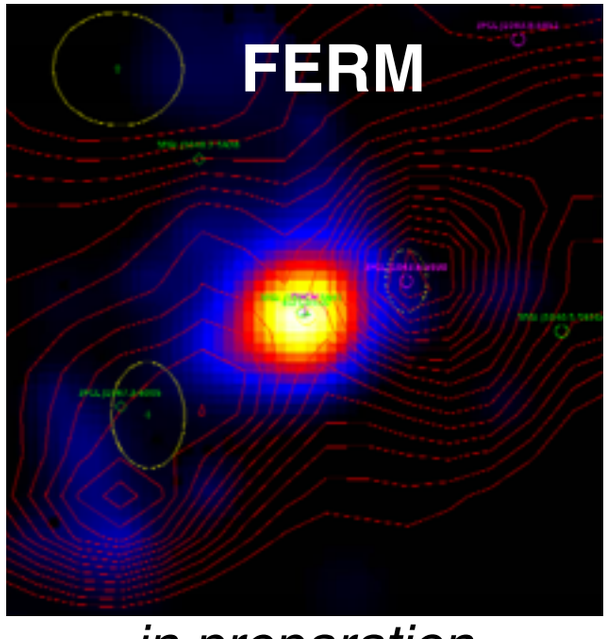








in preparation

$L_{\pi 0} \approx 10\ L_\odot$

The physics behind ηCar

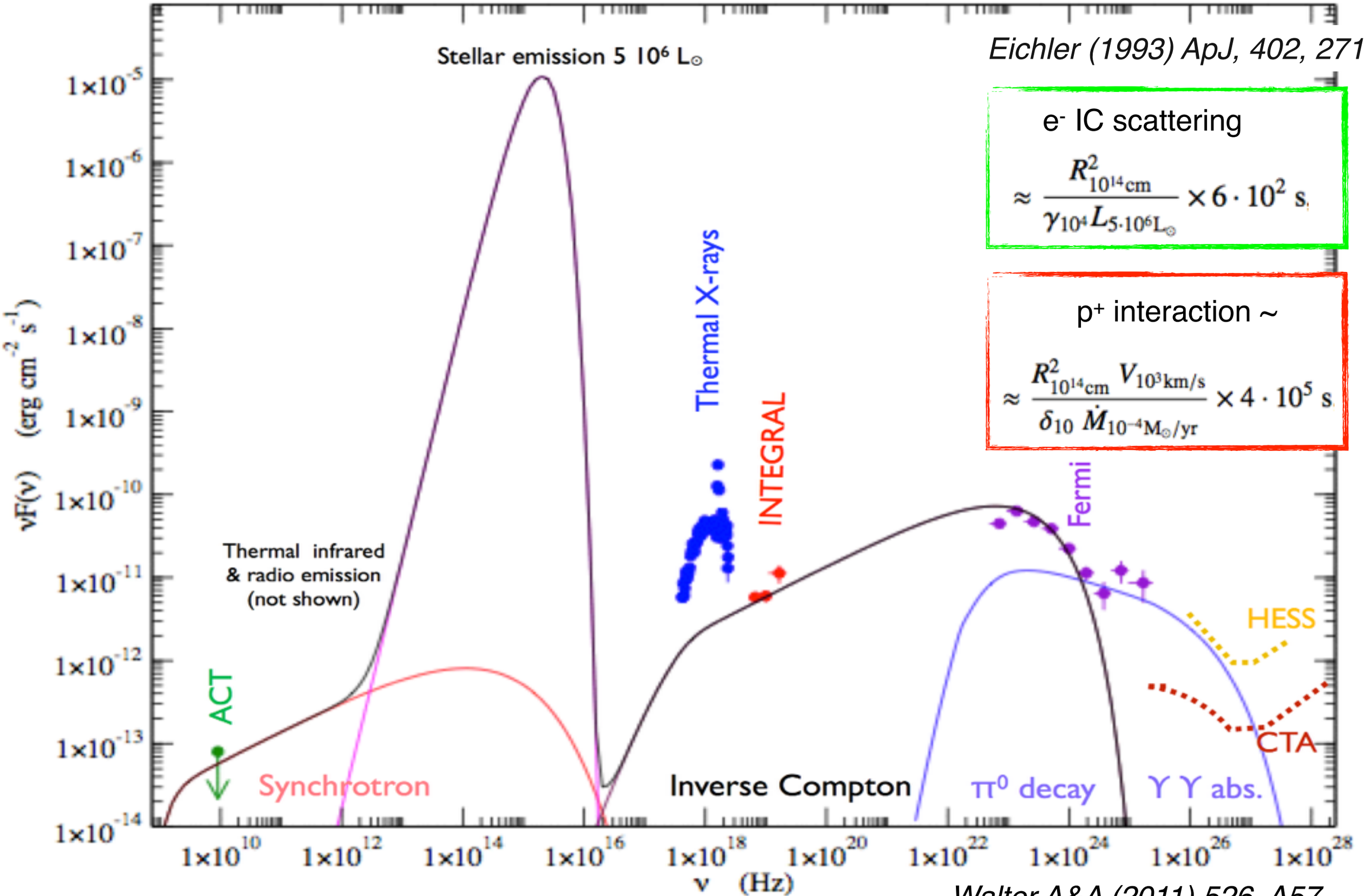
Eichler (1993) ApJ, 402, 271

e^- IC scattering

$$\approx \frac{R^2_{10^{14}\mathrm{cm}}}{\gamma_{10^4} L_{5\cdot10^6 L_\odot}} \times 6 \cdot 10^2 \ \mathrm{s}$$

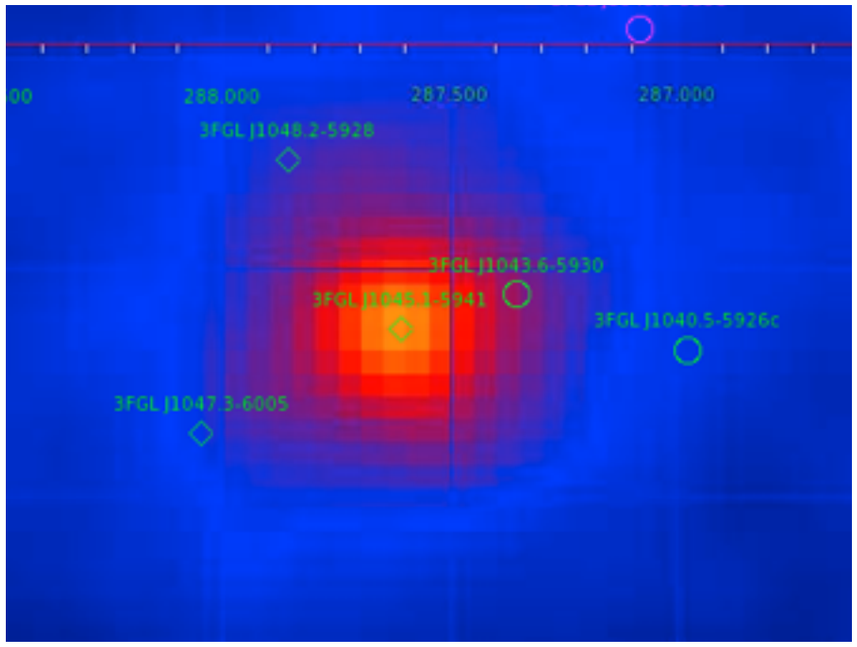
p^+ interaction ~

$$\approx \frac{R^2_{10^{14}\mathrm{cm}}\, V_{10^3\mathrm{km/s}}}{\delta_{10}\, \dot{M}_{10^{-4}M_\odot/\mathrm{yr}}} \times 4 \cdot 10^5 \ \mathrm{s}$$



Walter A&A (2011) 526, A57

Our analysis of ηCar



From 2008 August 4
to 2015 July 1
ST: *v10r0p5*
IRF: *P8R2_SOURCE_V6*
Catalogue: *3FGL*

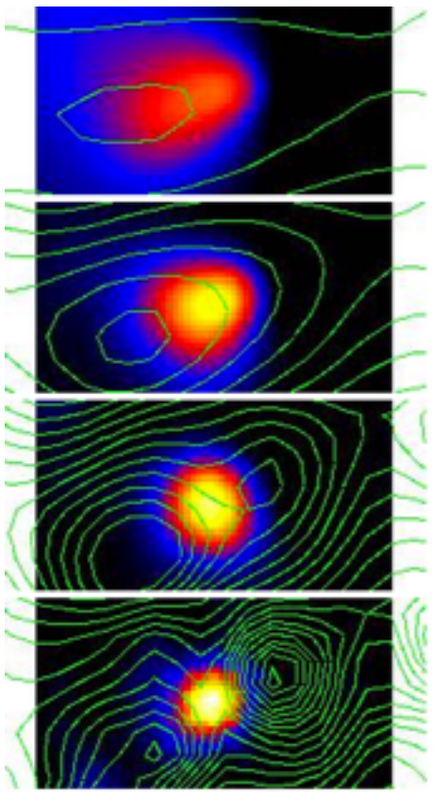
E: 300 MeV - 300 GeV
ROI: ~15°
Sources: ~171 (1 ext.)

0.3-0.95 GeV

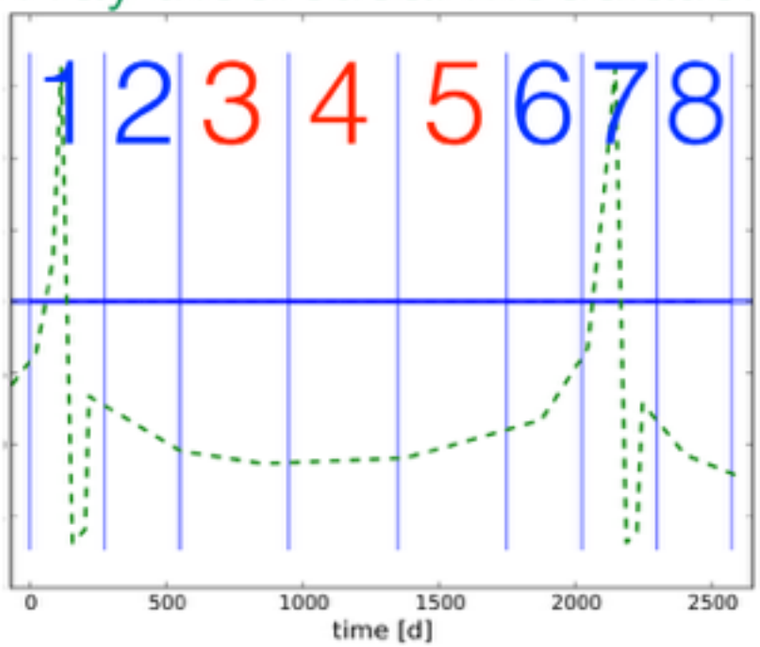
0.95-3 GeV

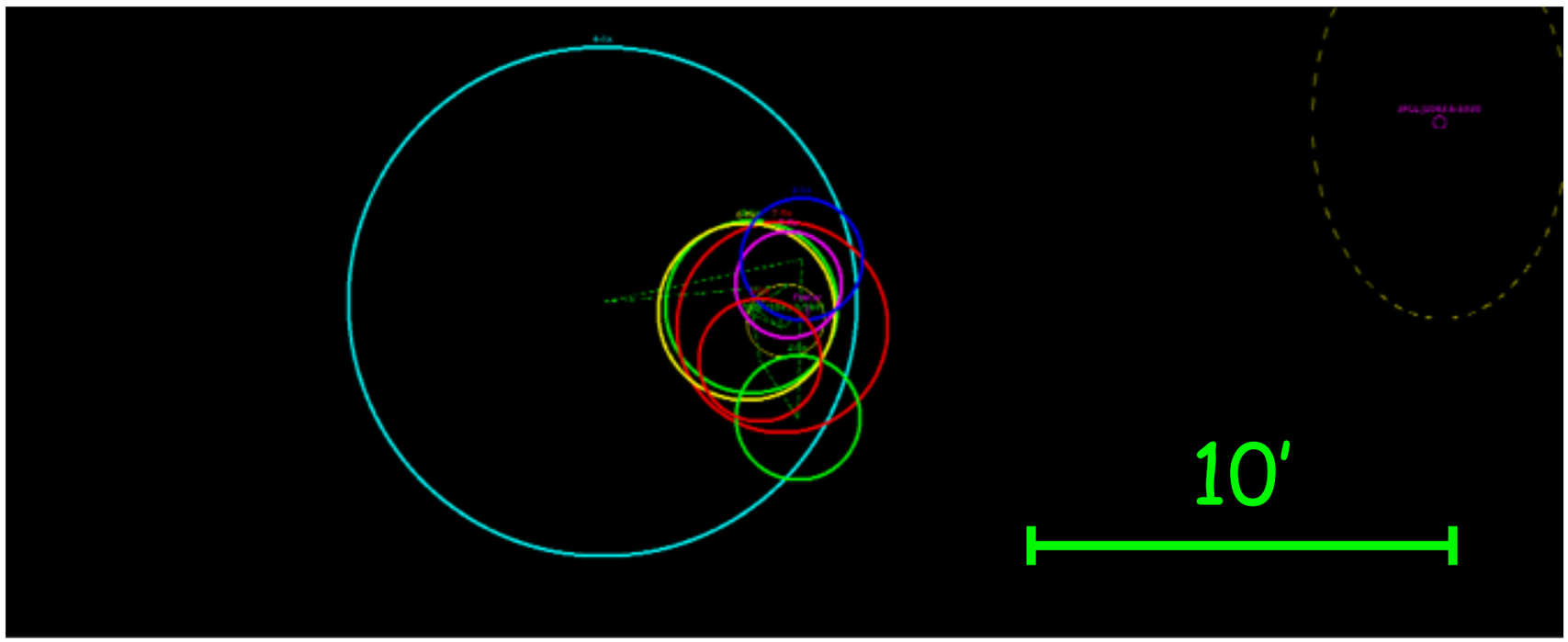
3-9.5 GeV

10-300 GeV



X-ray theoretical modulation





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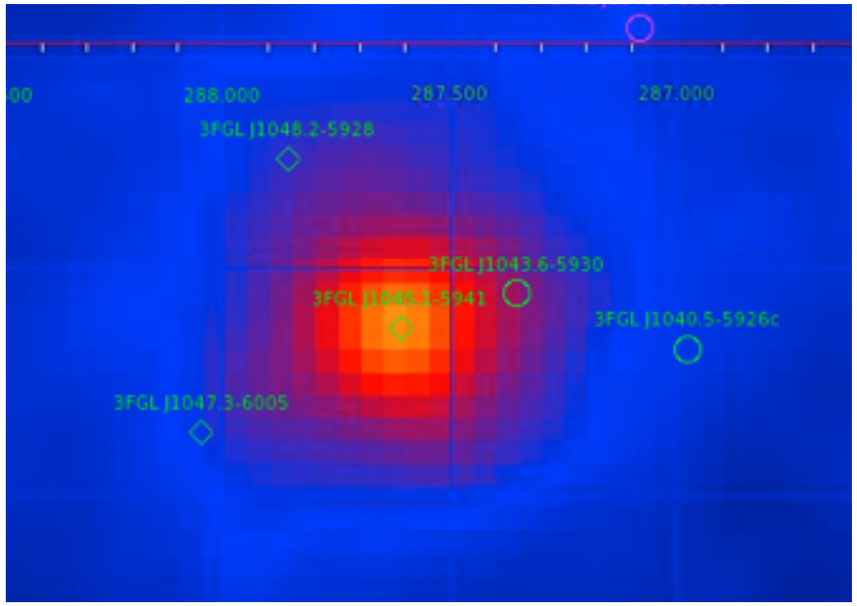

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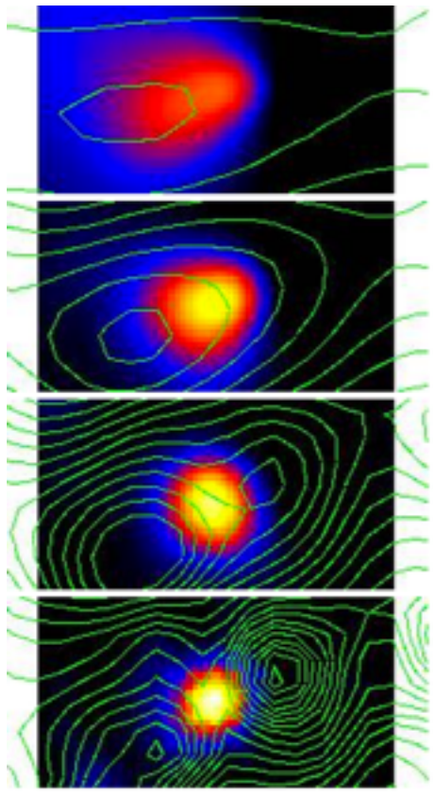

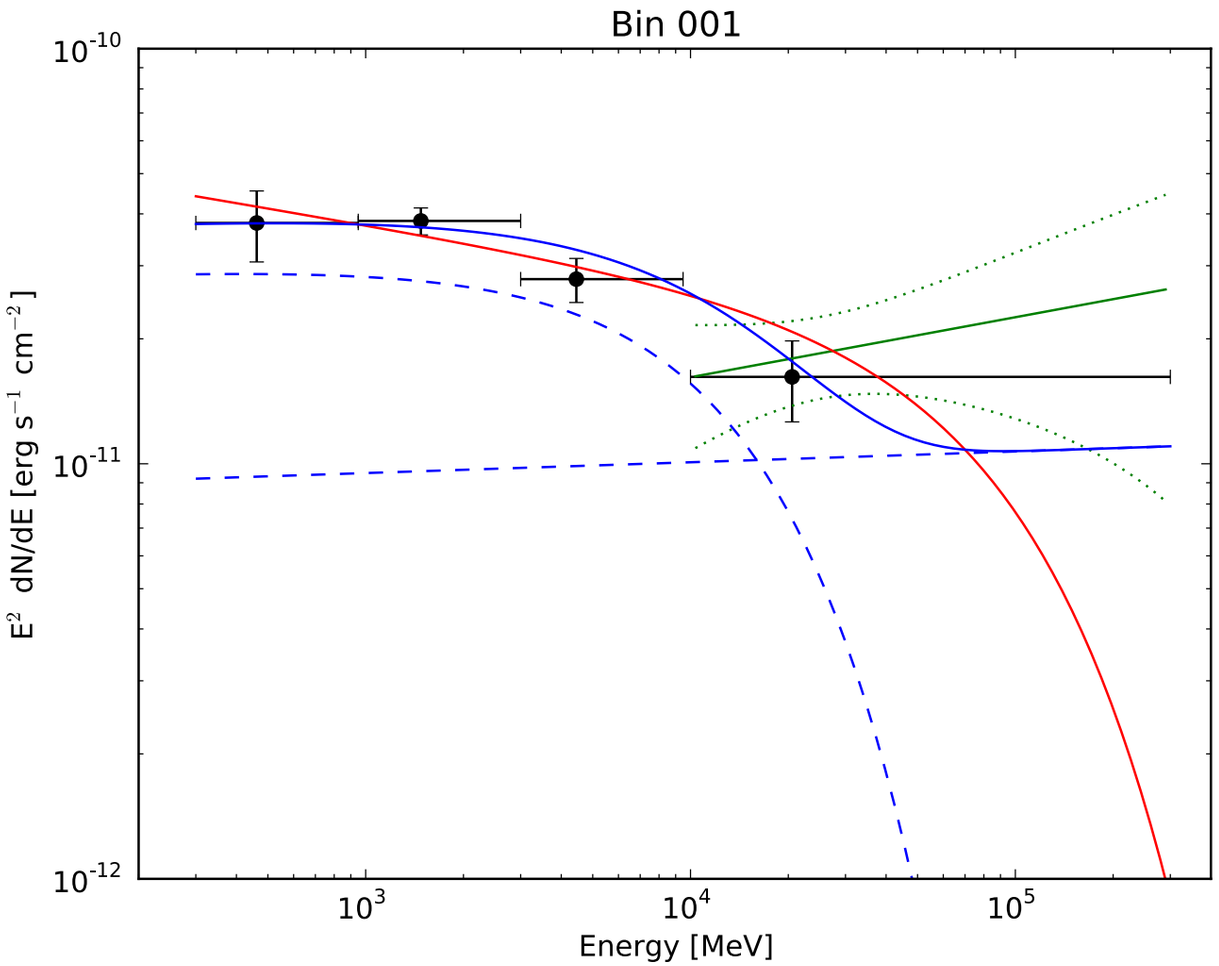

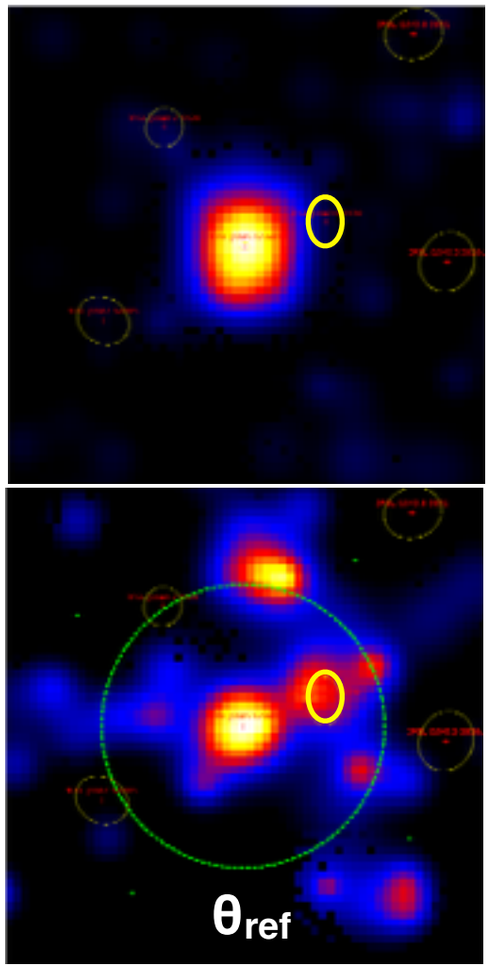

Sistematic uncertaintes:

★ Presence of a variable HE source closer than θ_{ref} (*J1043.6-5930*)

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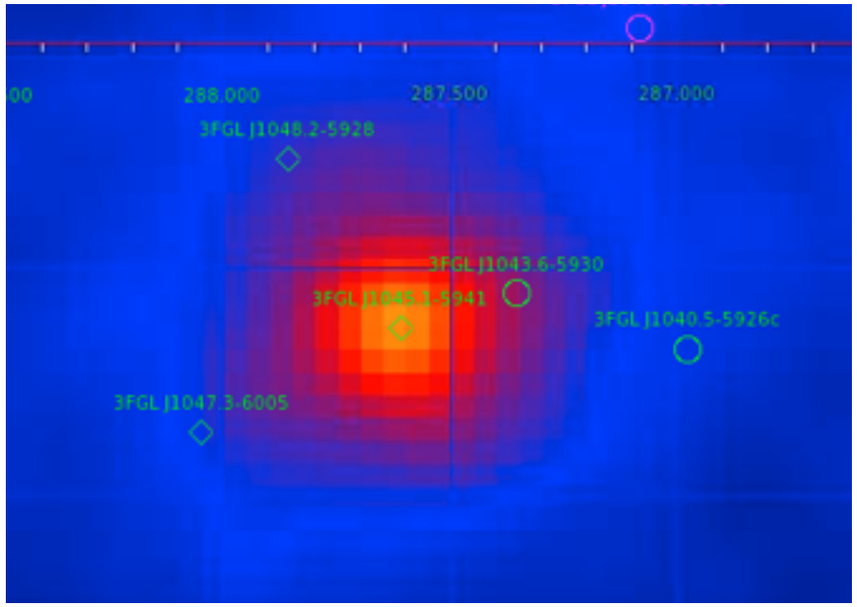

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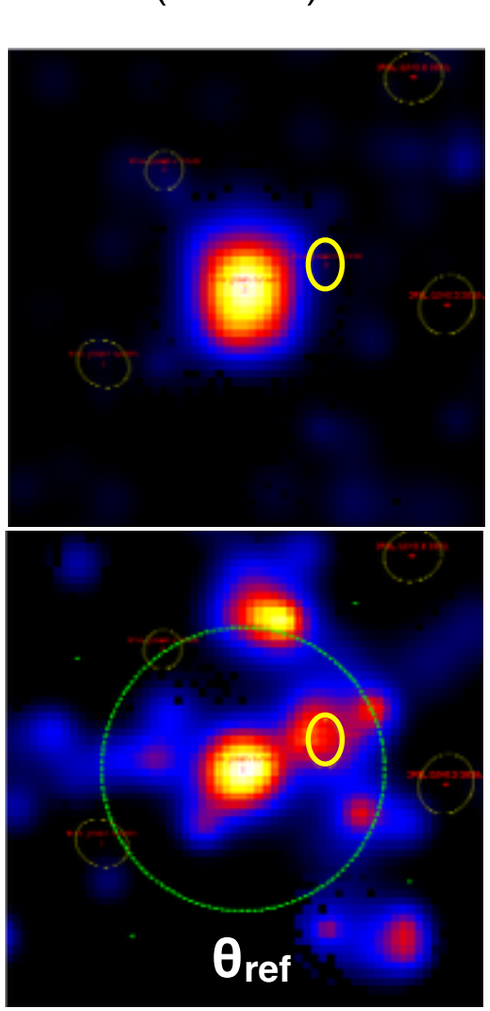

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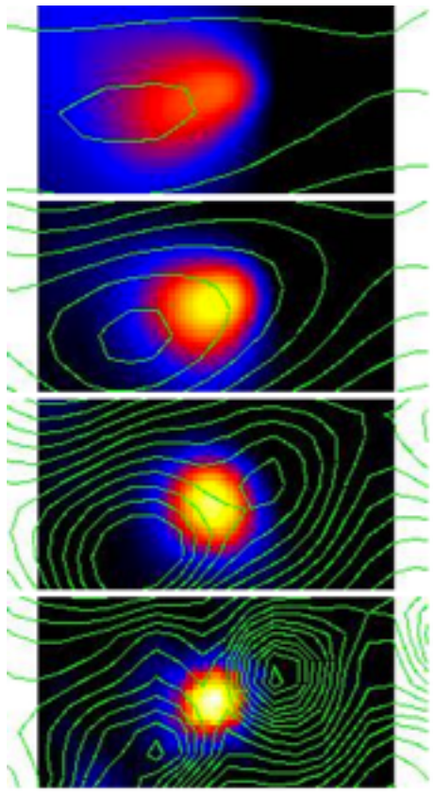
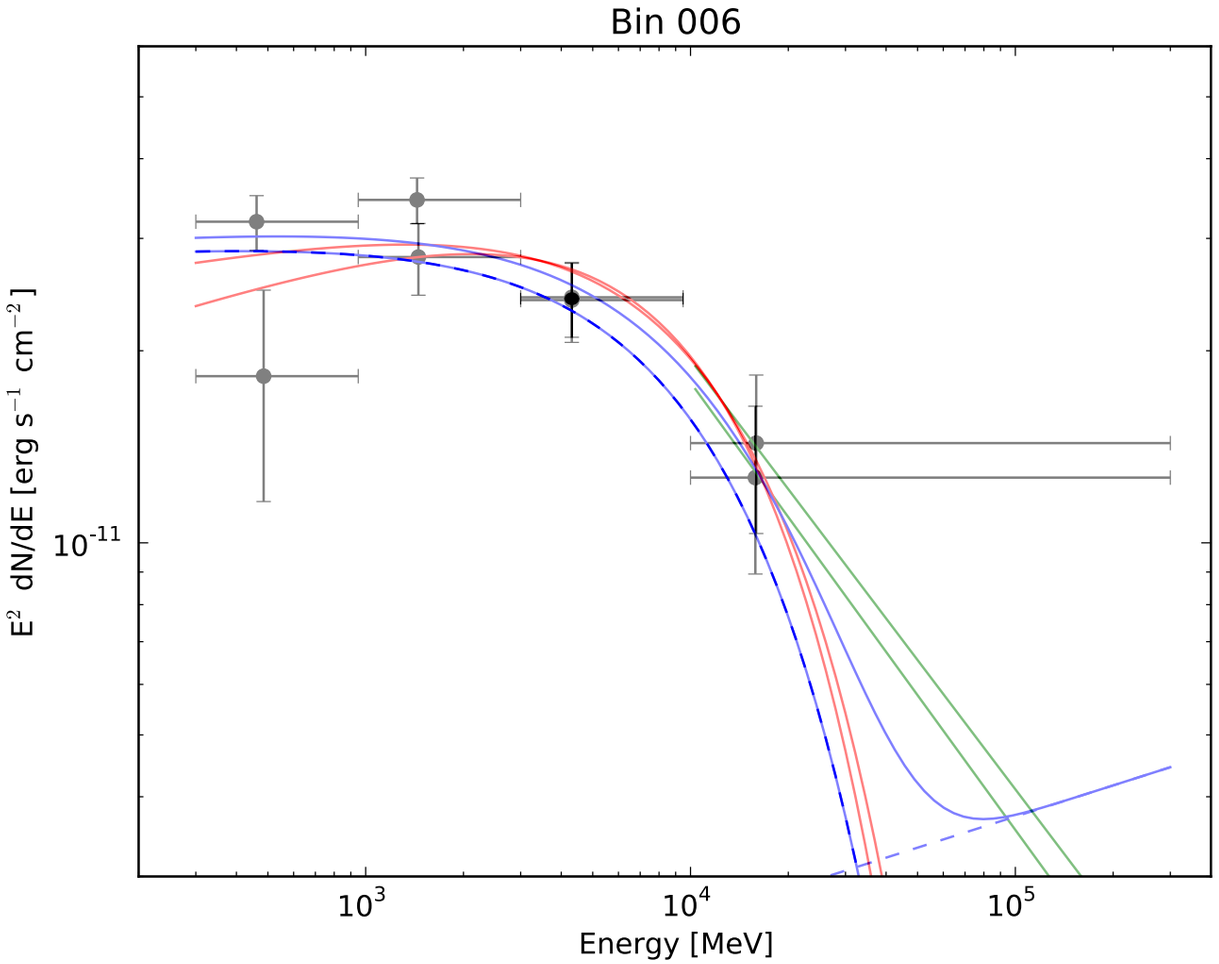
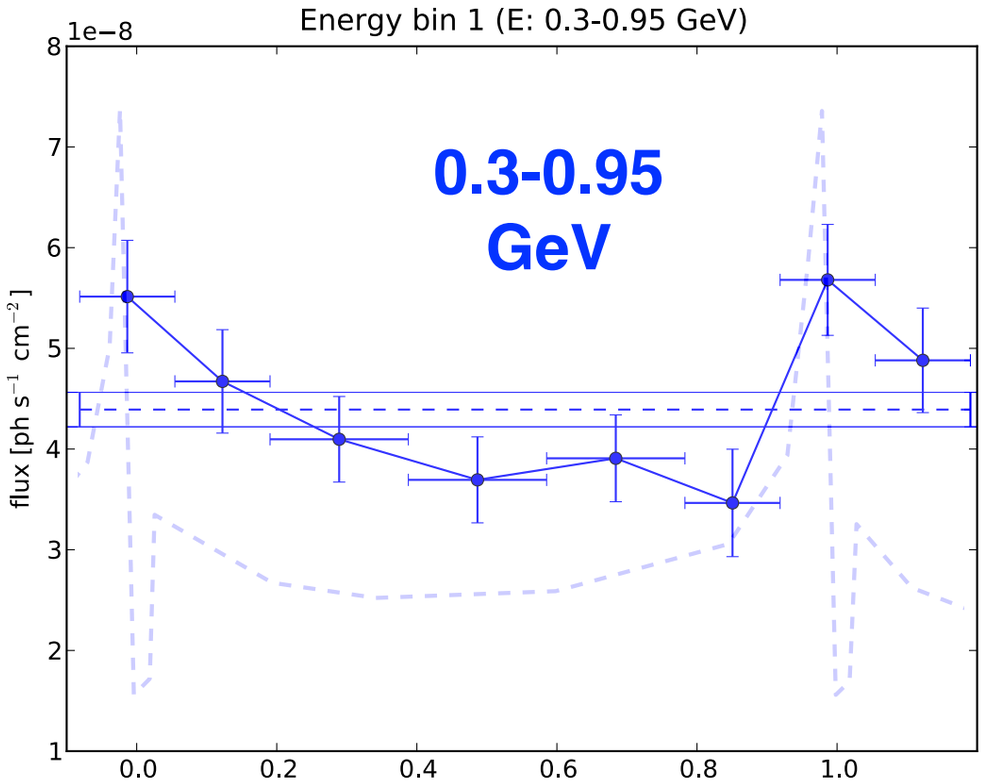


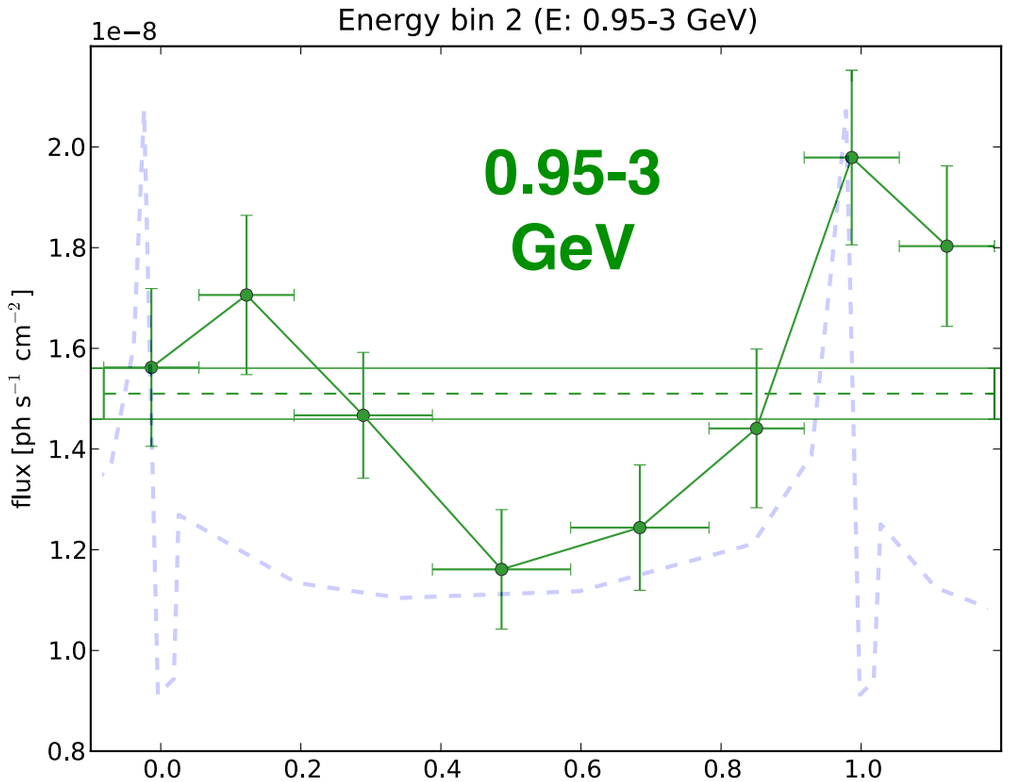


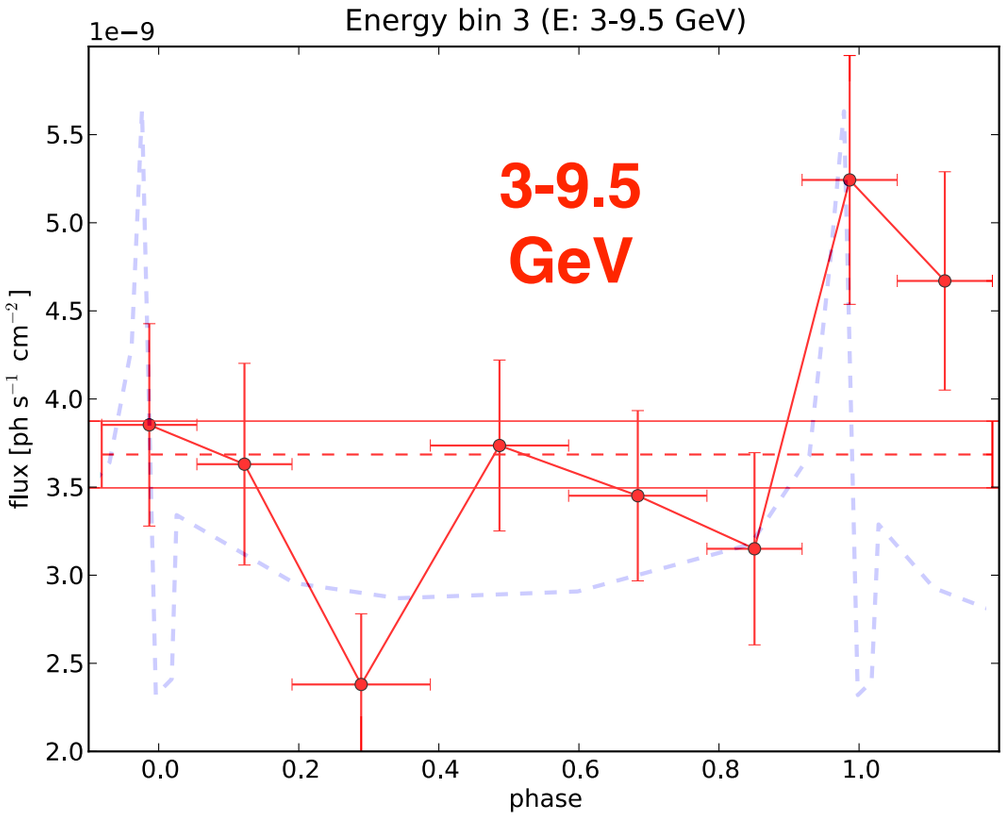
Sistematic uncertaintes:

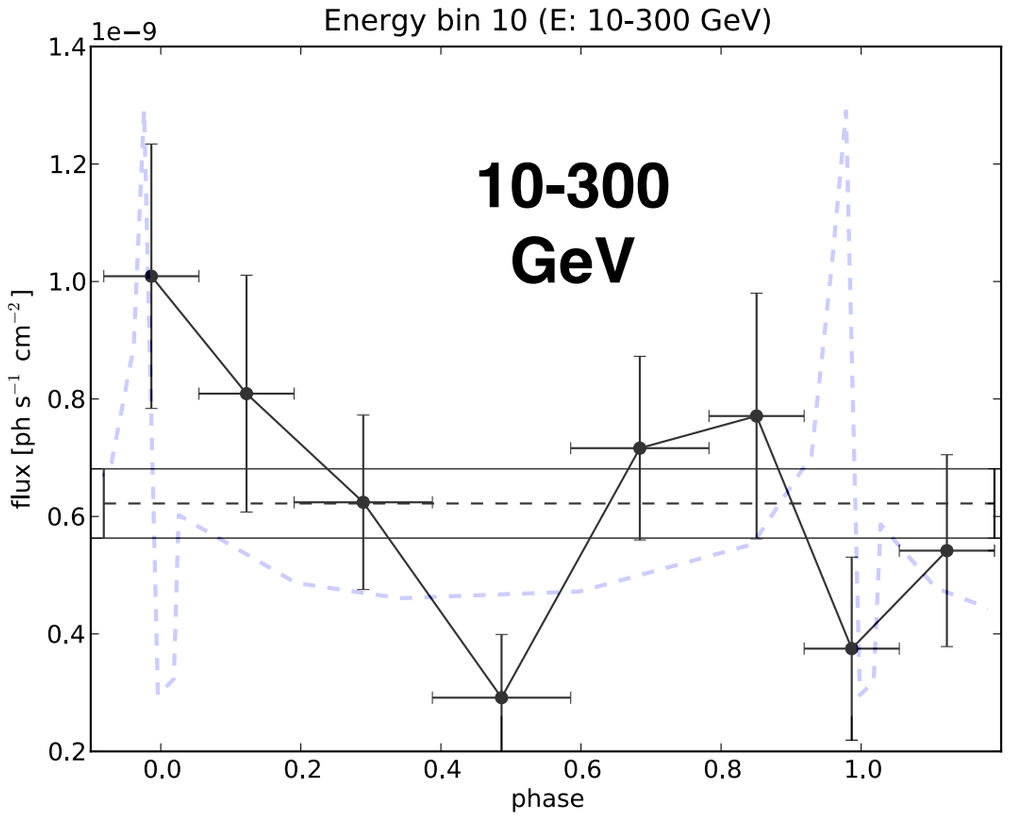
- ★ Presence of a variable HE source closer than θ_{ref} (*J1043.6-5930*)
- ★ Galactic diffuse emission model

ηCar γ-ray lightcurve









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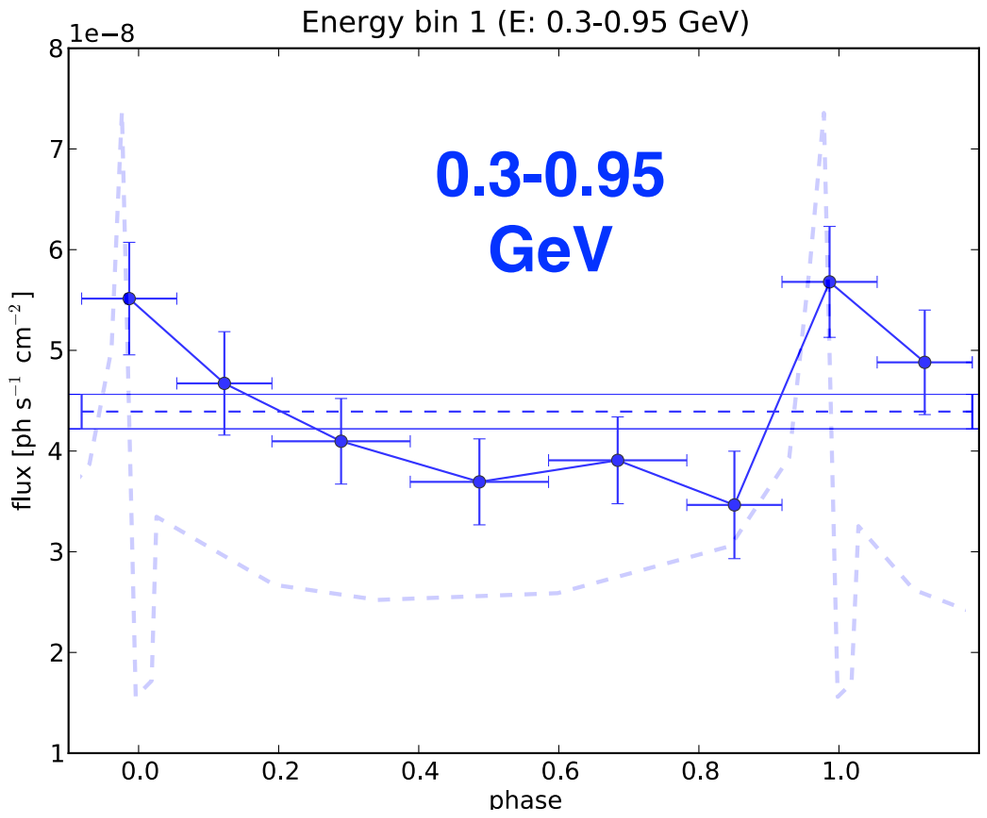
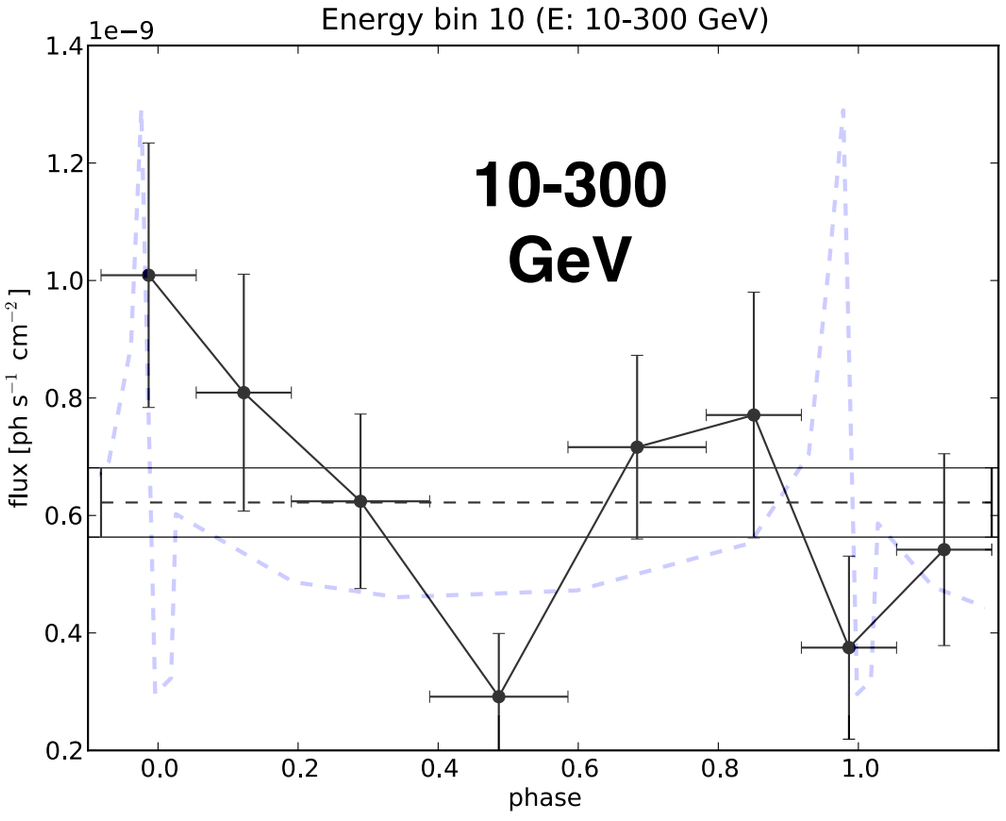


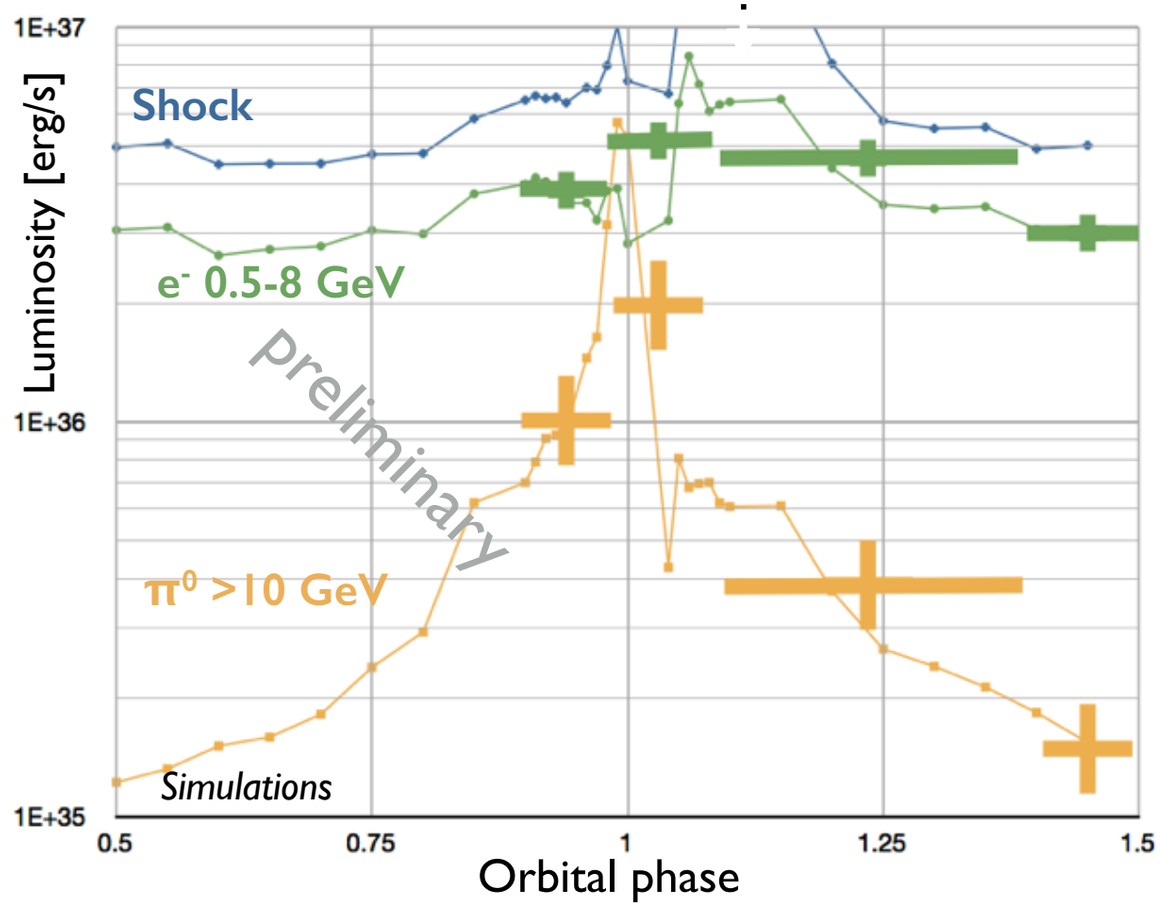


The **X-ray** emission varies by ~ 4

The **sub-GeV** emission varies by < 2

Above **10 GeV** emission varies by > 3

A&A (2011) 526, A57



Fermi acceleration time scale $t_{acc} = \frac{R_L}{c}\left(\frac{c}{V}\right)^2$

$$\gamma_{max,e} = \sqrt{\frac{3\pi e c^2}{\sigma_T \beta^2}} \sqrt{\frac{B \cdot R^2}{L}} \frac{V}{c} \approx \sqrt{\frac{B_{1G} \cdot R^2_{10^{14}cm}}{L_{5\cdot10^6 L_\odot}}} V_{10^3 km/s} \times 3 \cdot 10^4$$

The pionization conversion efficiency ~ D^{-1}

Eichler & Usov (1993) ApJ, 402, 271

Proposed models

1. **gamma-ray pulsar & PWN** *(Abdo et al, 2010)*
   Variability excludes the PWN
   Pulsar not detected by Chandra
   Coincidence probability ~ 10^{-5}

2. **external shock** *(Ohm et al, 2010)*
   Does not explain more than 20% of the 50 keV component.
   Cannot explain the >10 GeV component, nor its variability
   A contribution is possible

3. **two electron populations** *(Bednarek & Pabich, 2011)*
   Acceleration parameters vary along the shock surface resulting in a smooth electron spectrum
   Observed variations of the cutoff energy are much smaller than predicted

4. **electrons & hadrons** *(Eichler & Usov, 1993; Farnier & Walter, 2011)*

Energetics

Observations

- In the **sub-GeV** the orbital modulation is < 2
- Above **10 GeV**, the flux variability is > 3

Wind collision simulations

- The total electron spectrum is smooth
- The **mechanical luminosity** available to accelerate **electrons** is **not** strongly **modulated**
- The **π^0** decay emission **depends** on the **density** and could be **modulated** in a **similar** way as the **X-ray** emission

Energetics

- **Thermal X-rays:** 25 $L_\odot$ (2% L_{shock})
- **Synchrotron:** < 0.1 $L_\odot$
- **Electron acceleration:** 50 $L_\odot$ (6% L_{mec})
- **π^0 emission:** 10 $L_\odot$ (2% L_{mec})

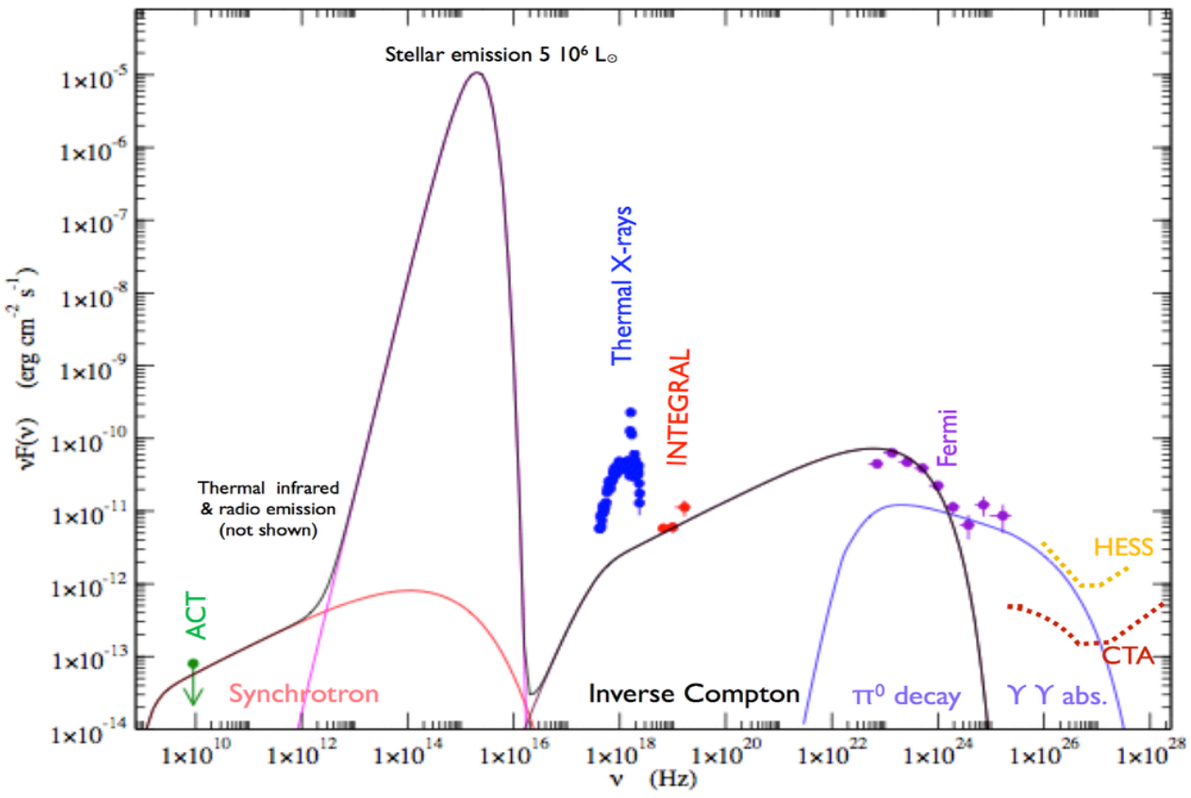
- **η Carinae** shows evidences for **electronic** and **hadronic** acceleration
- **Proton cutoff energy** $\gtrsim 10^{13}$ eV, *higher than measured in middle aged SNR*
- **Efficiency** of particle **acceleration ~ 5%** (Spitkovsky's simulations: 10%)

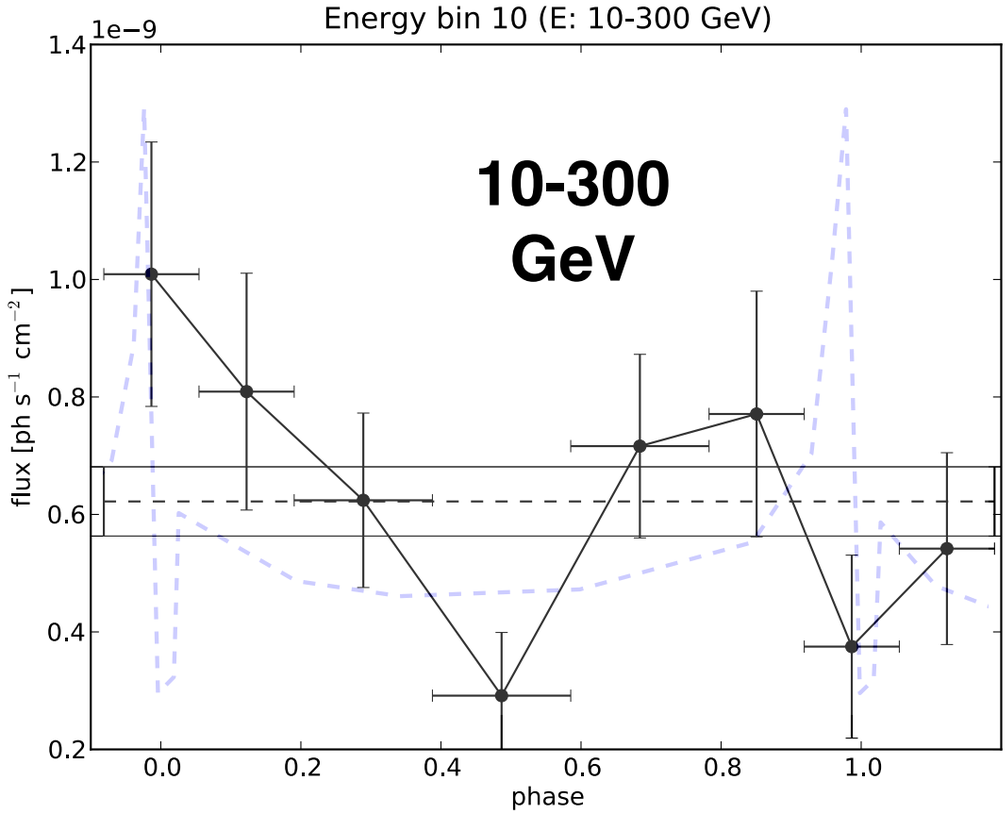
ηCar is a Large Hadron Collider

Summary

- We clearly have γ-ray emission (at all energies) from a region coincident with the nominal position of ηCar
- There are two main source of systematic errors:
  - Diffuse galactic model contribution
  - Variable source @ HE closer than θ_{REF}
- The variation of the sub-GeV and super-GeV component are in agreement with the simulation and the model (IC and π^0)

…nevertheless





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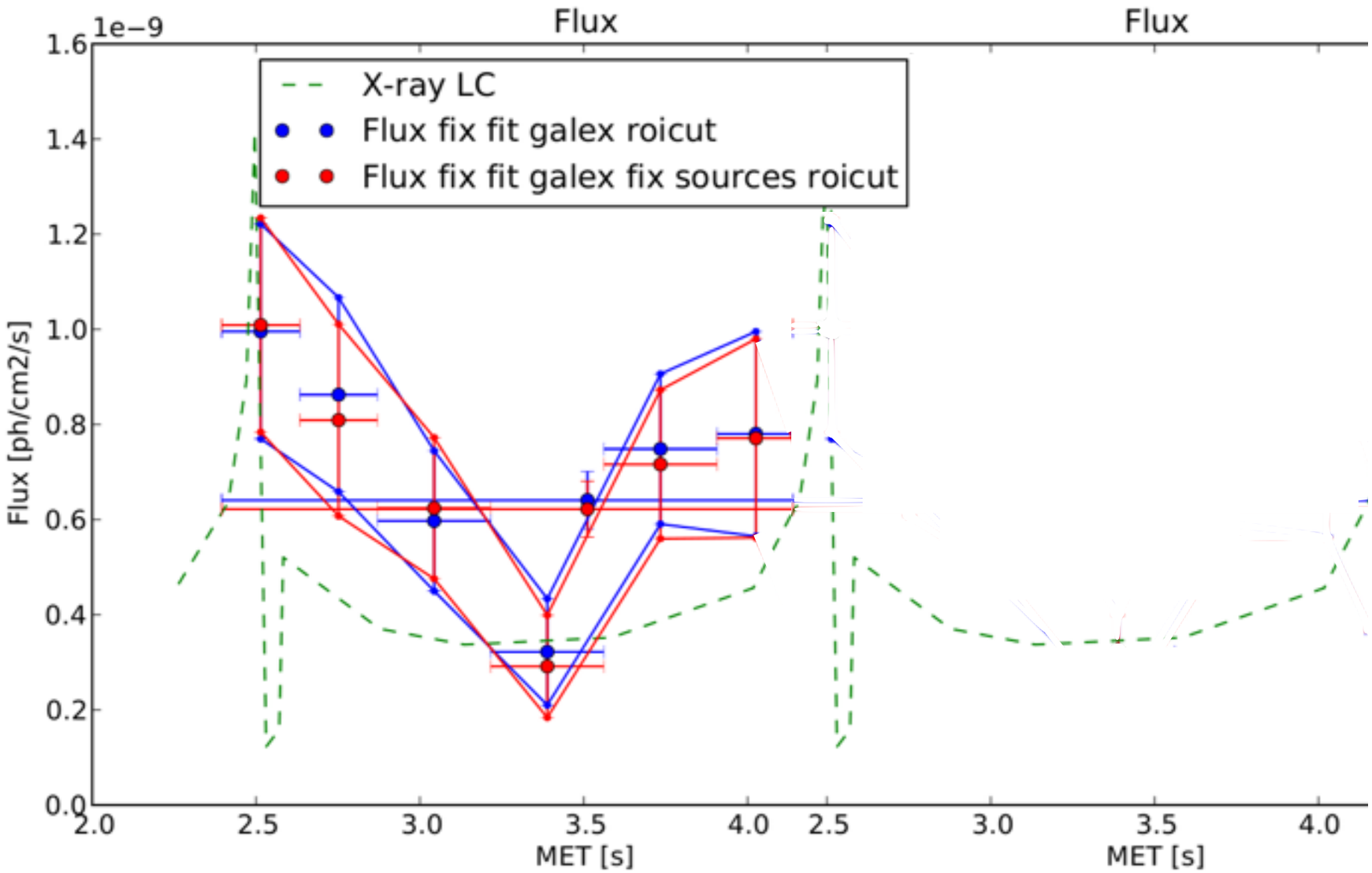

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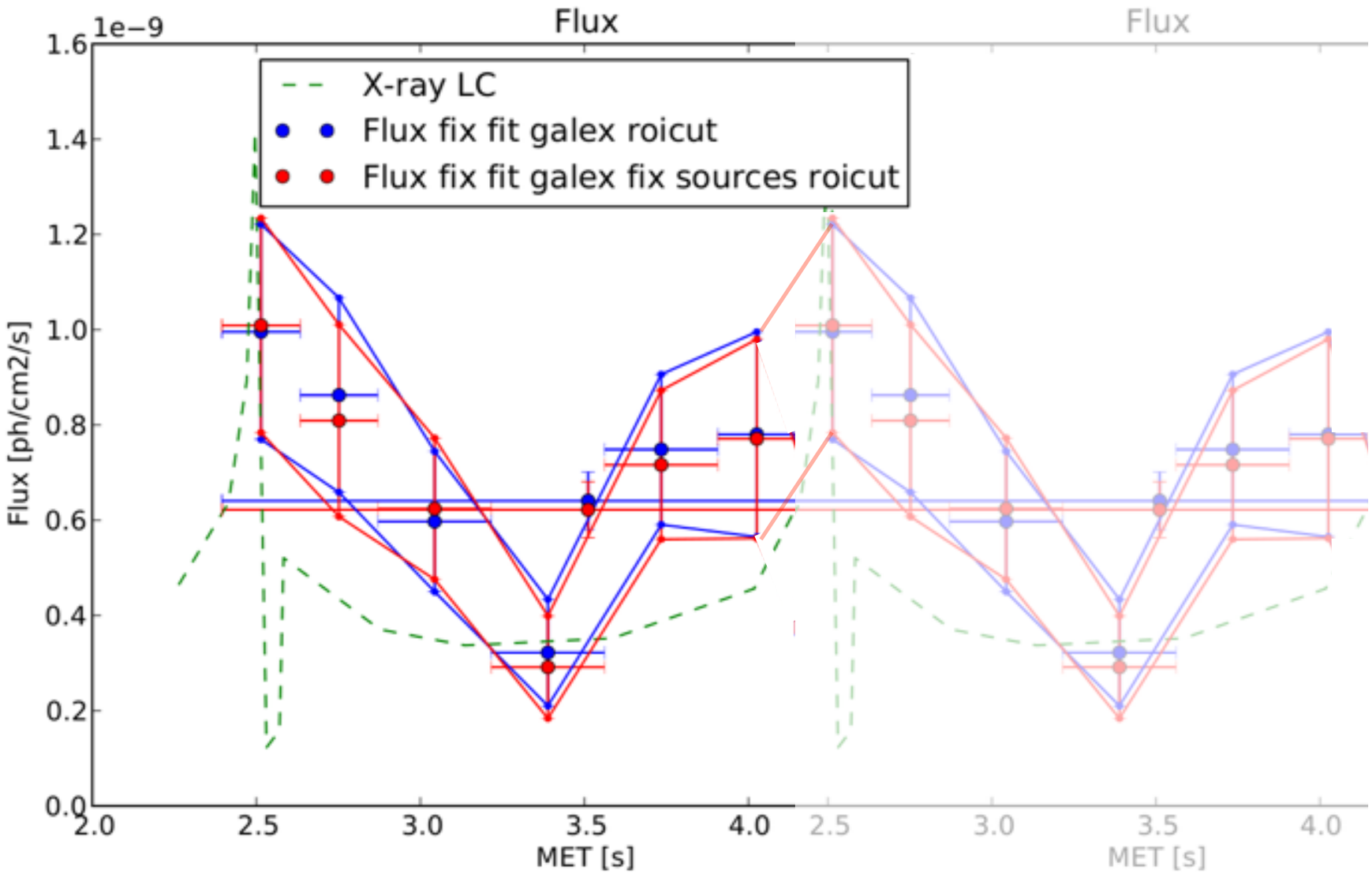

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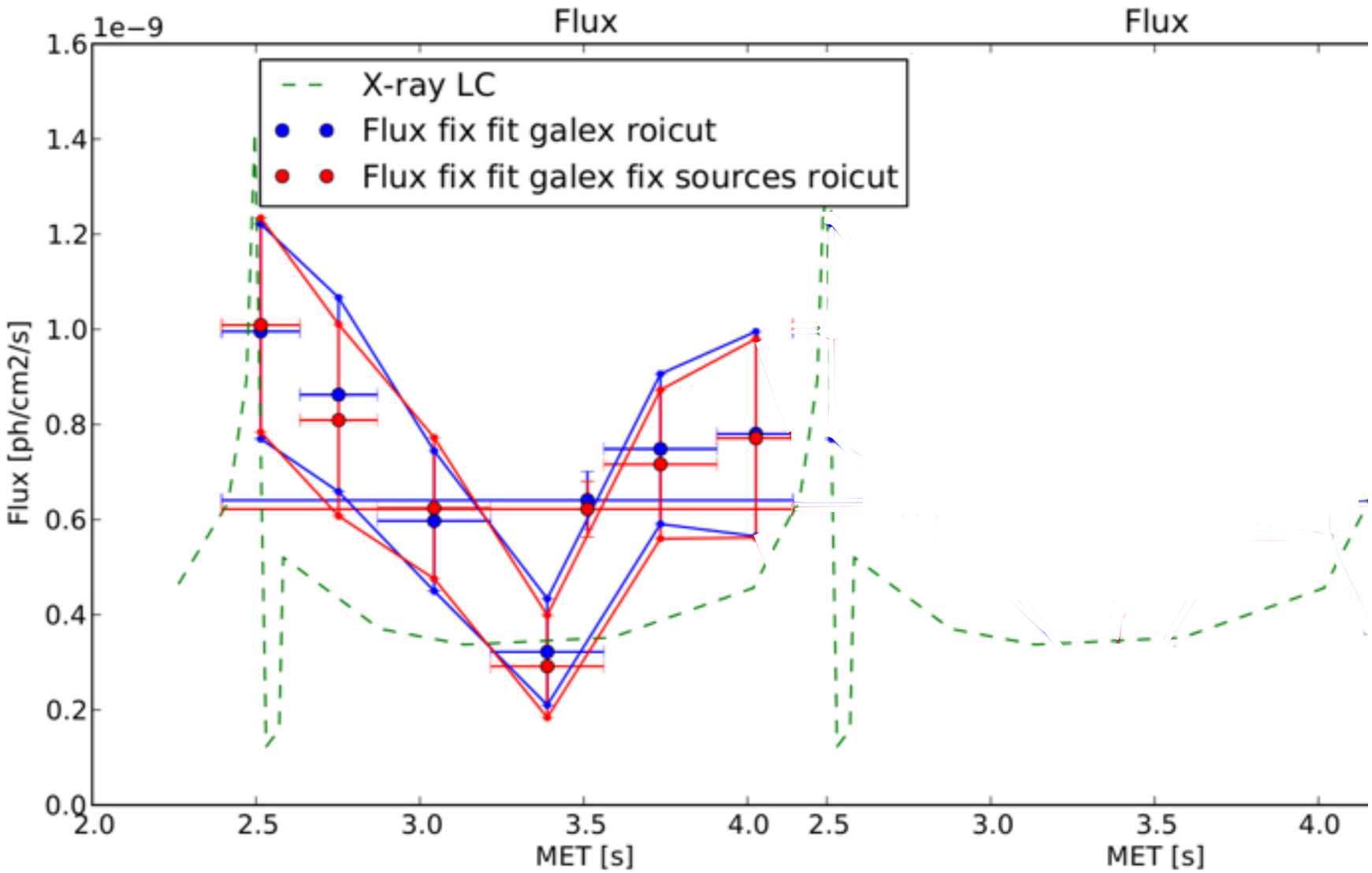

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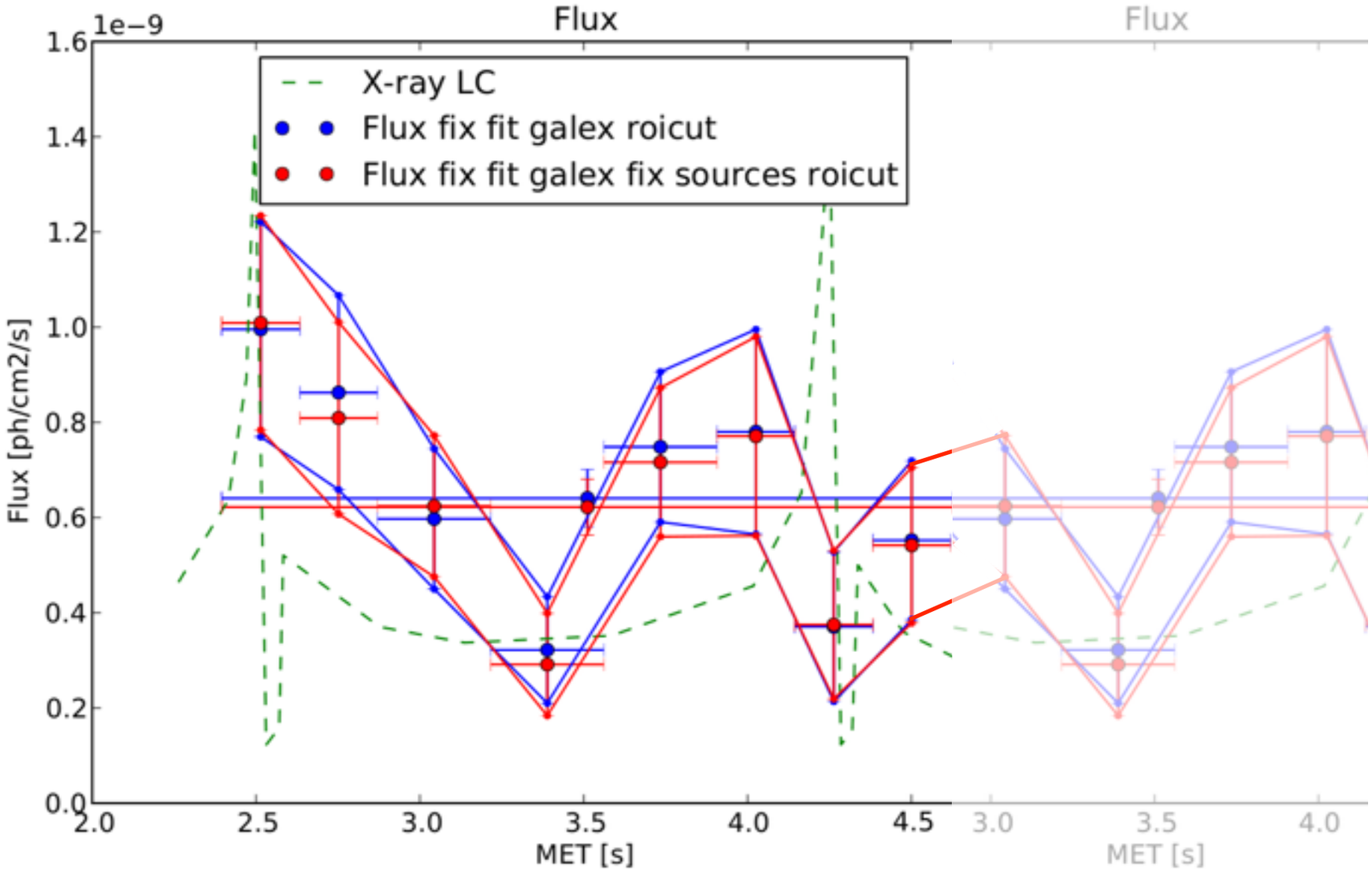
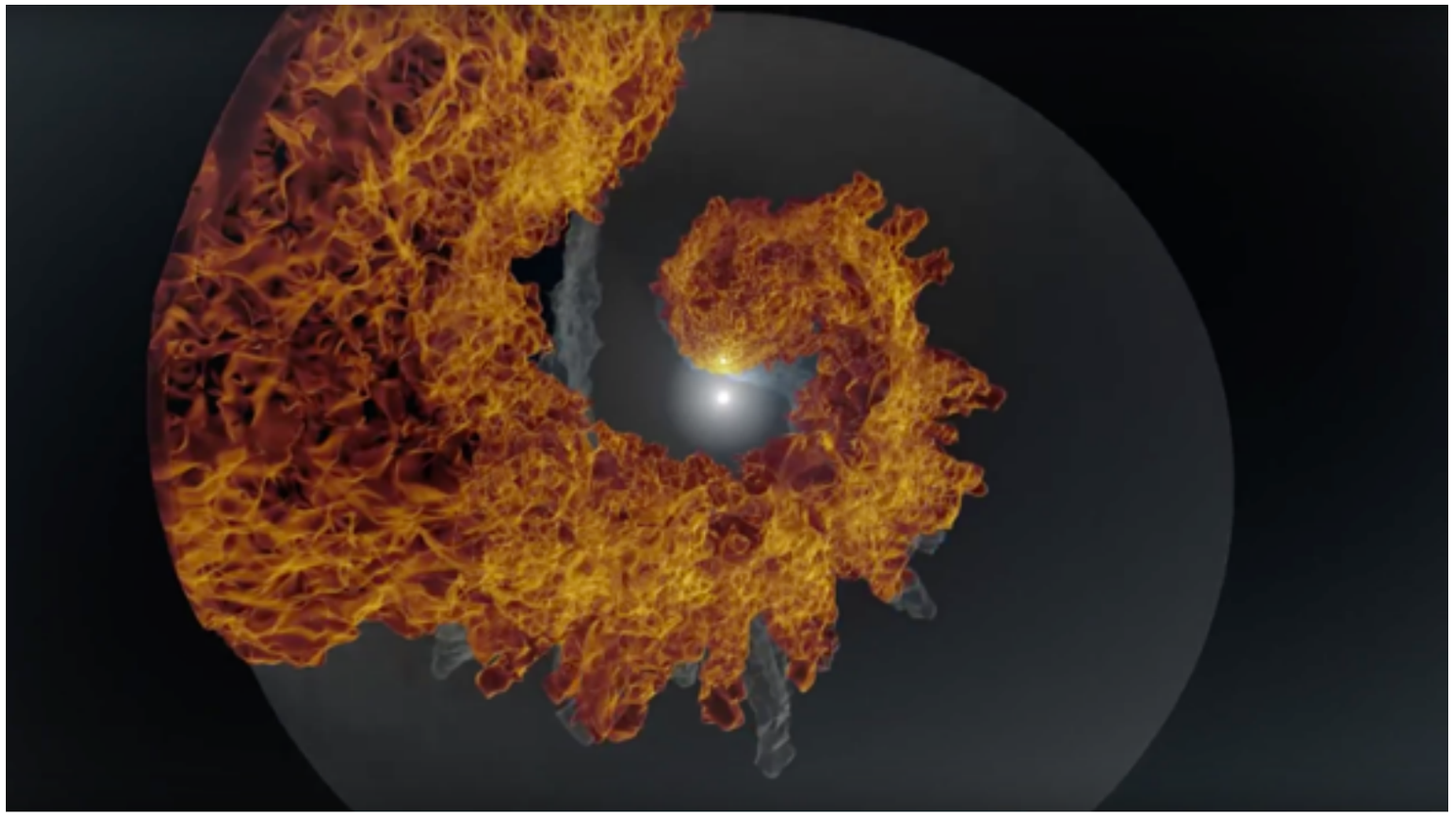
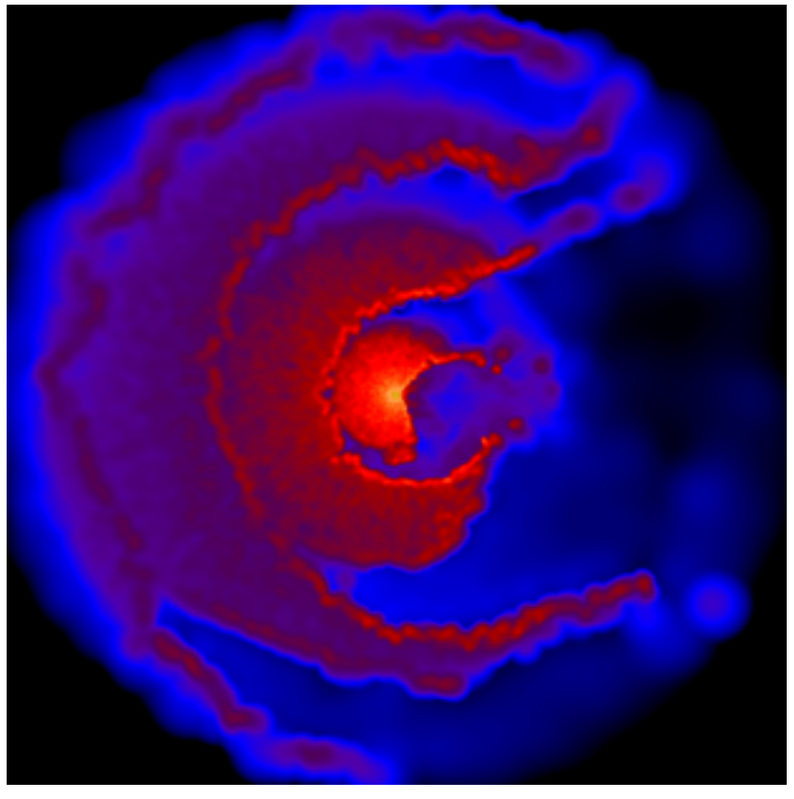


Inhomogeneities

- X-ray intensity much bigger on the last periastron (Corcoran et al. 2015) suggesting structural changing in the dueling wind
- No significant variation on the Γ index, statistically consistent with a constant ~ -2.25+-0.17 (BINNED) ; 2.34+-0.14 (UNBINNED)
- “Anomalous” (not straightforward) behavior during last periastron





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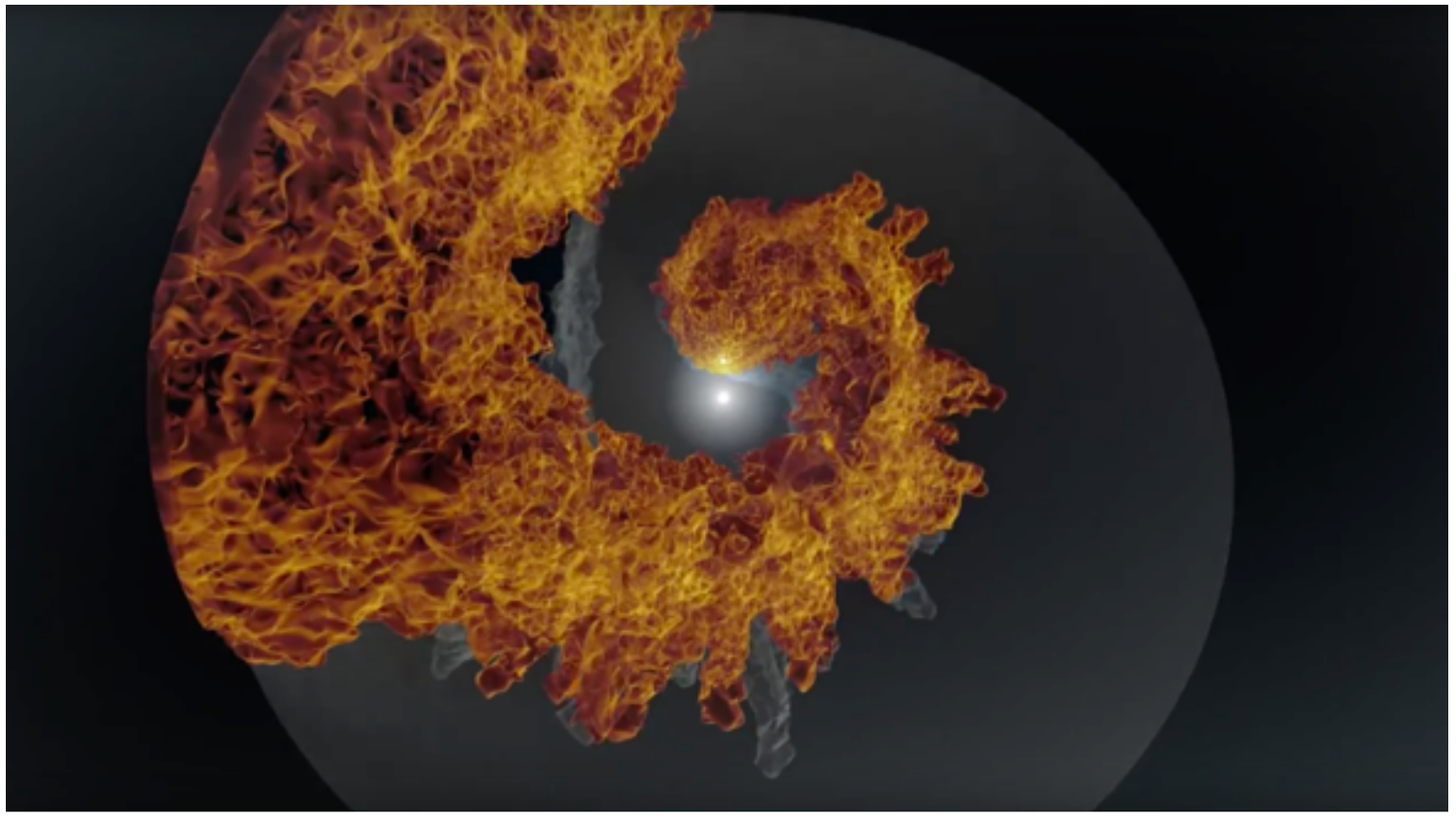

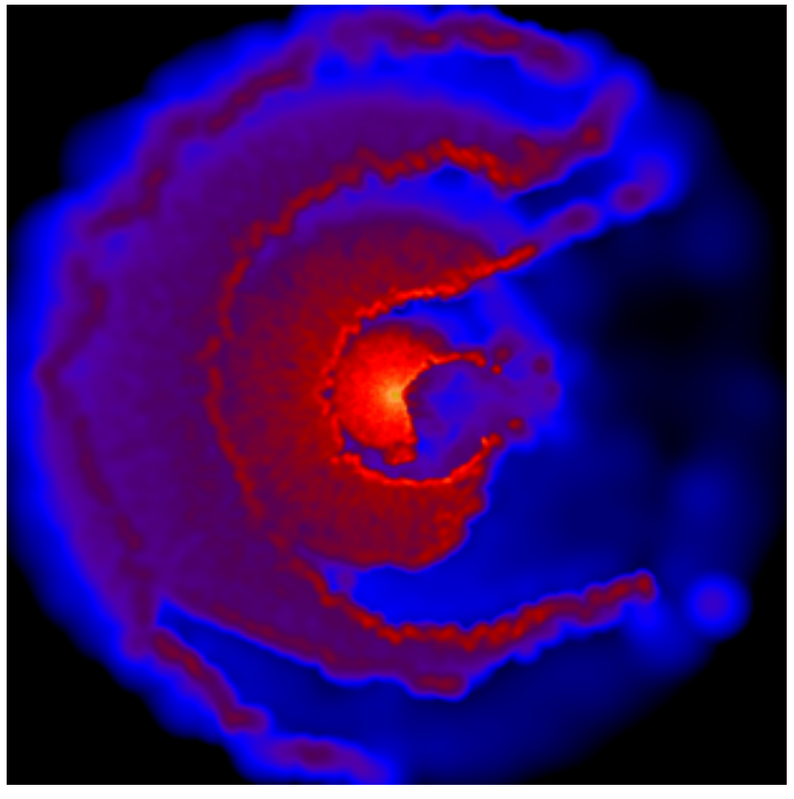

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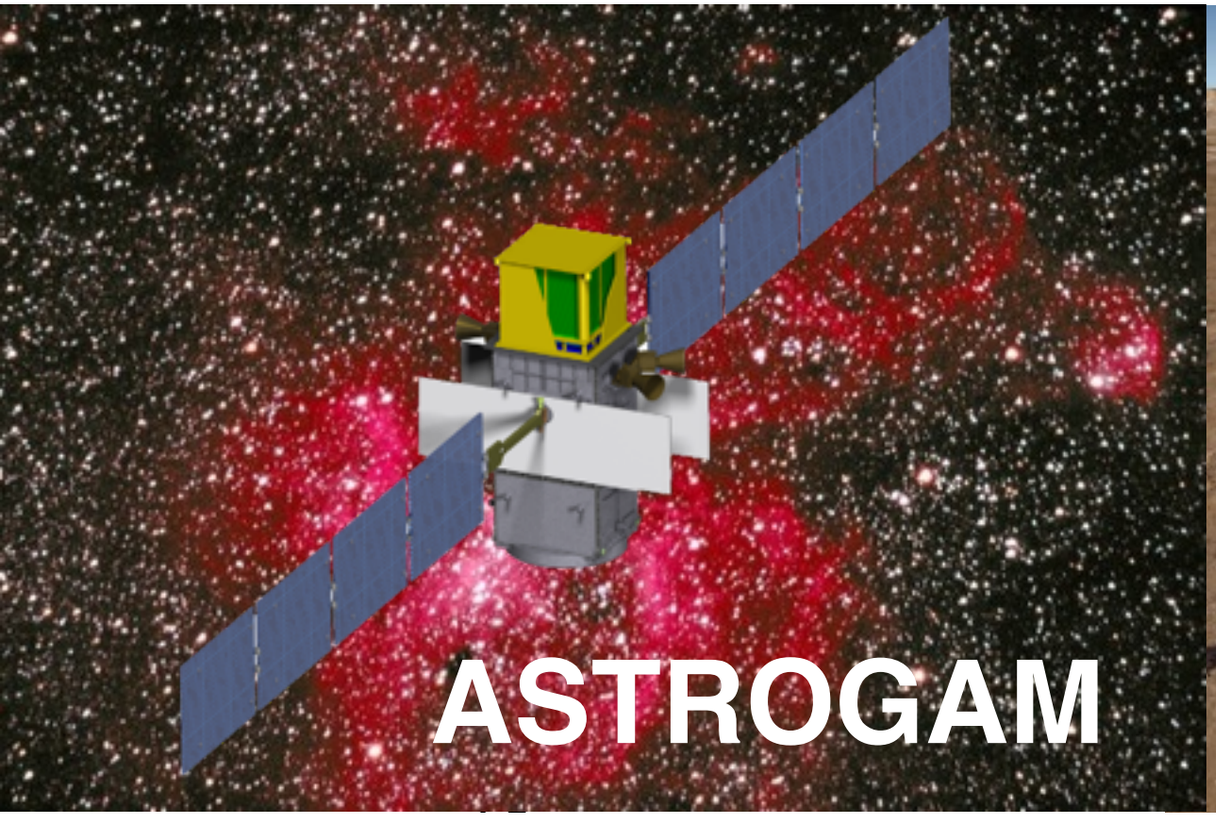
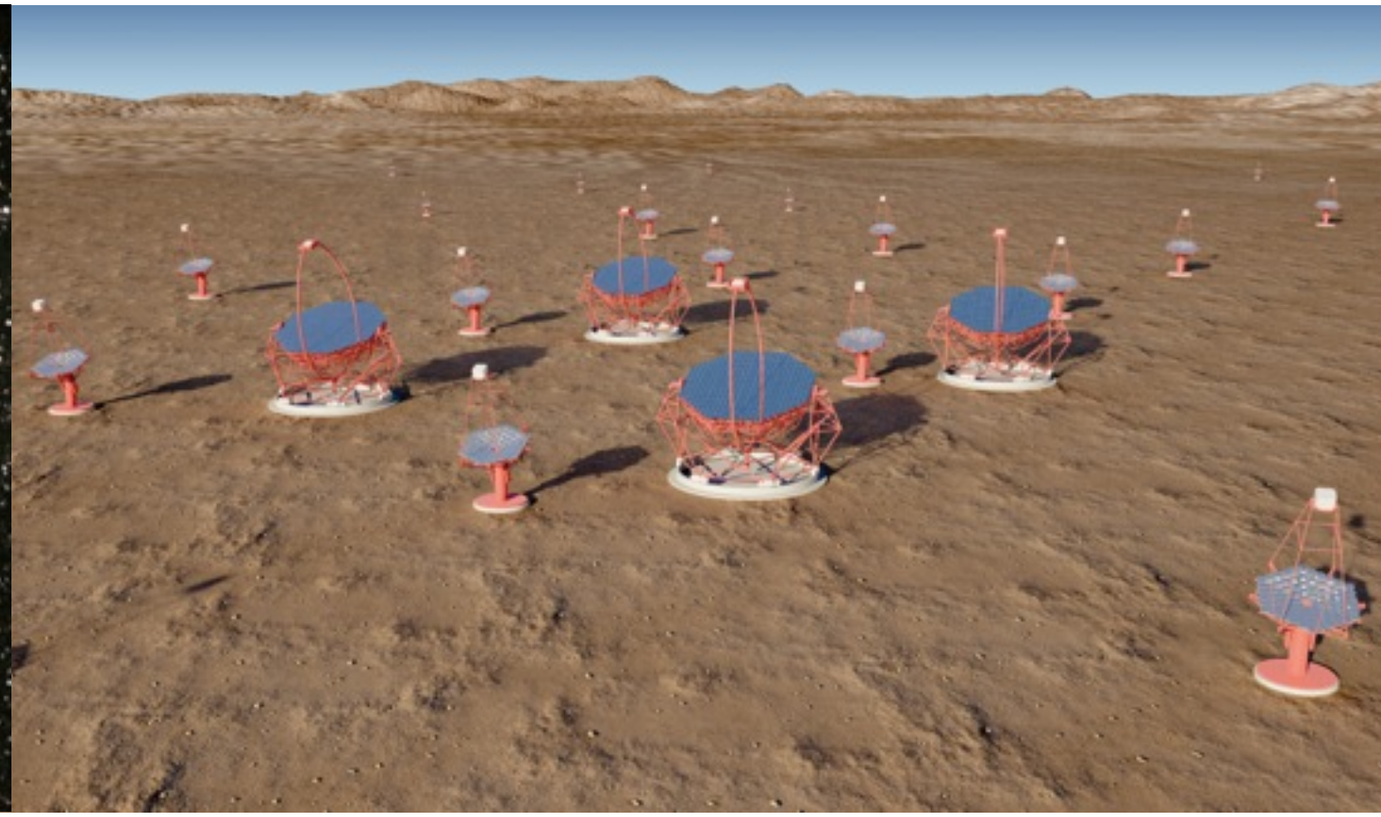
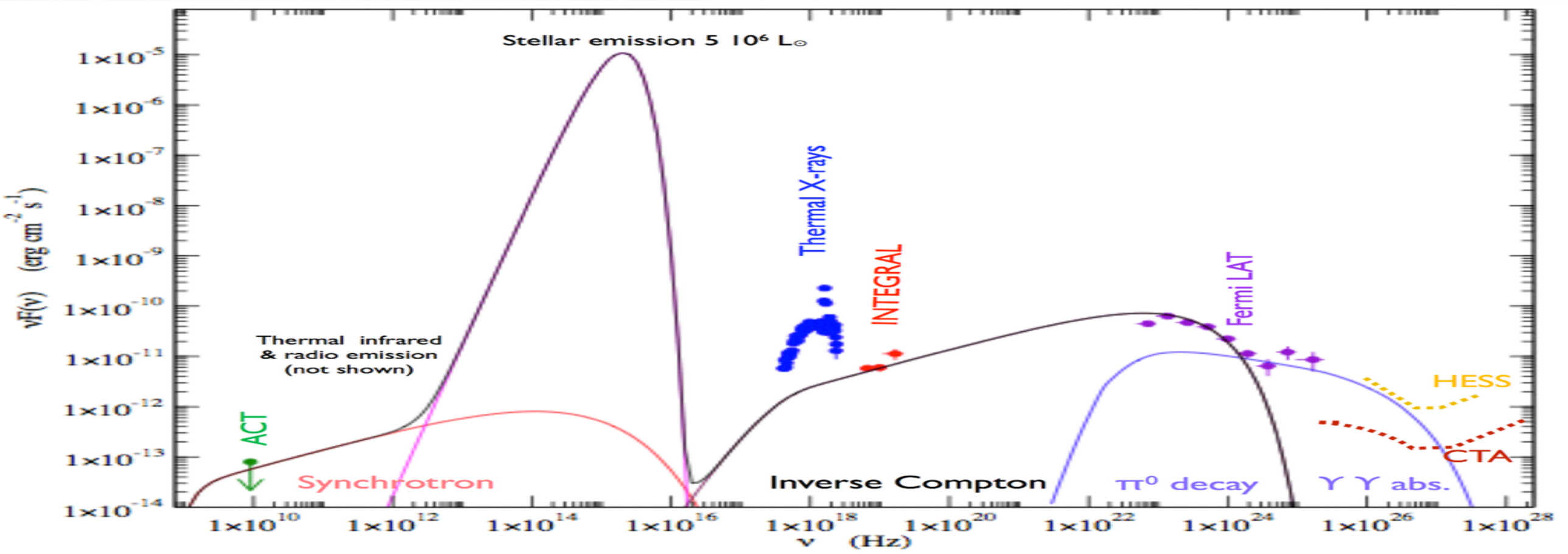
...staying hungry and staying foolish...

ISDC







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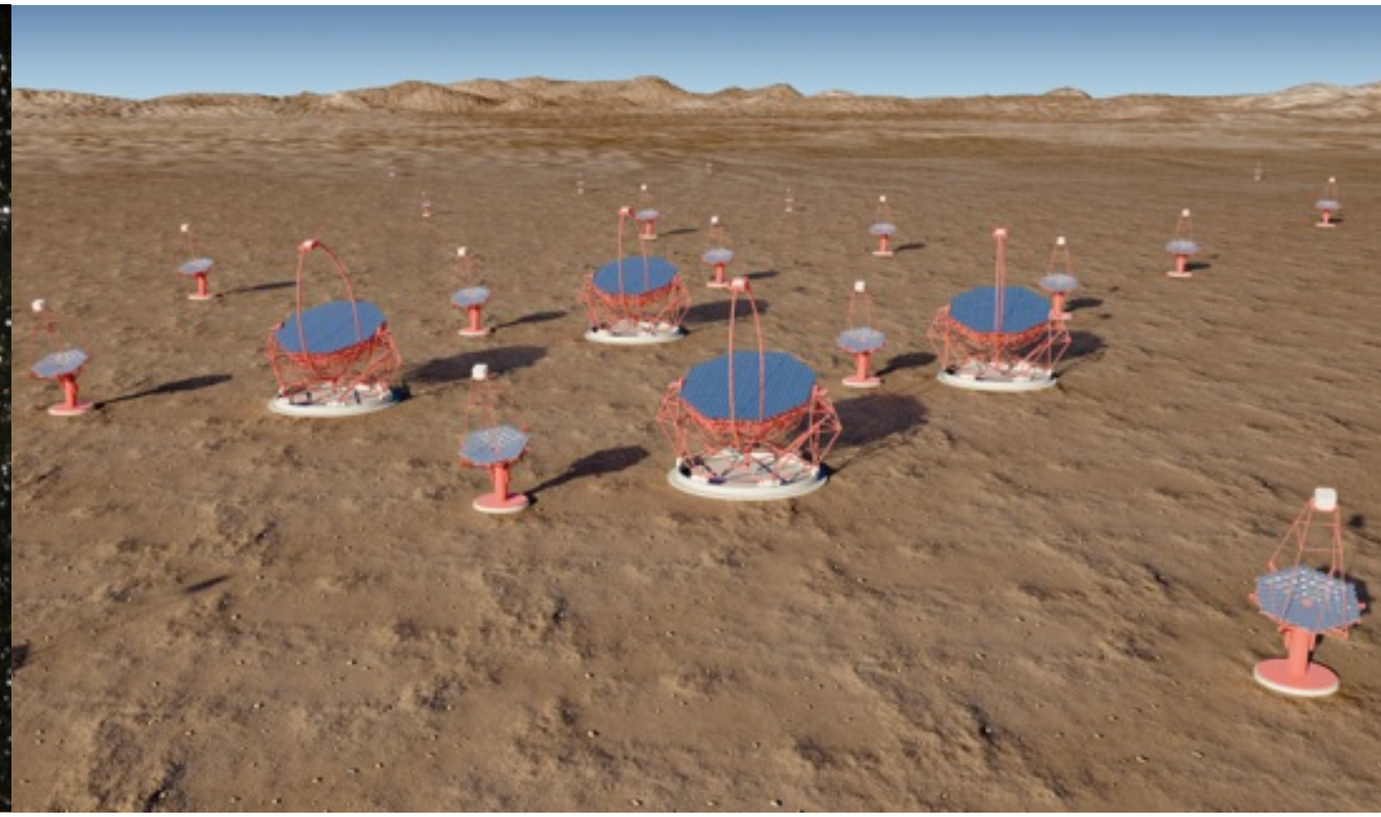

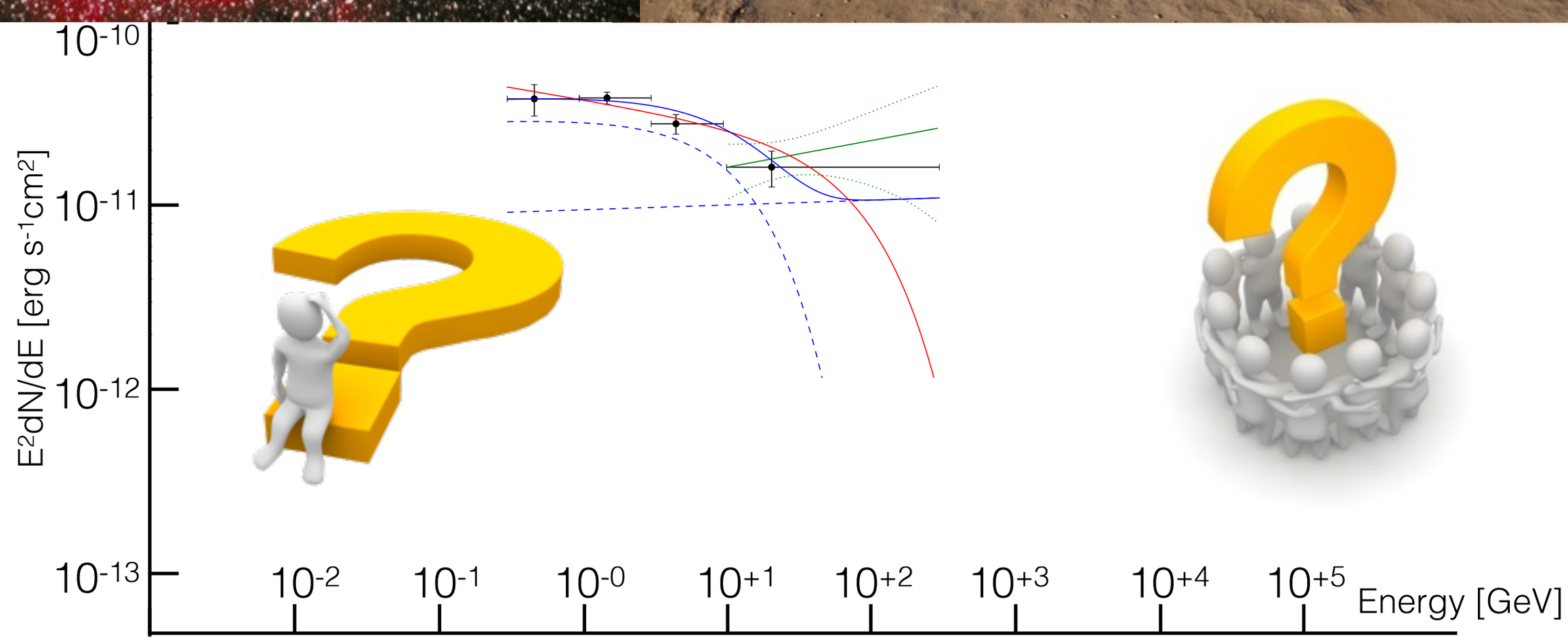

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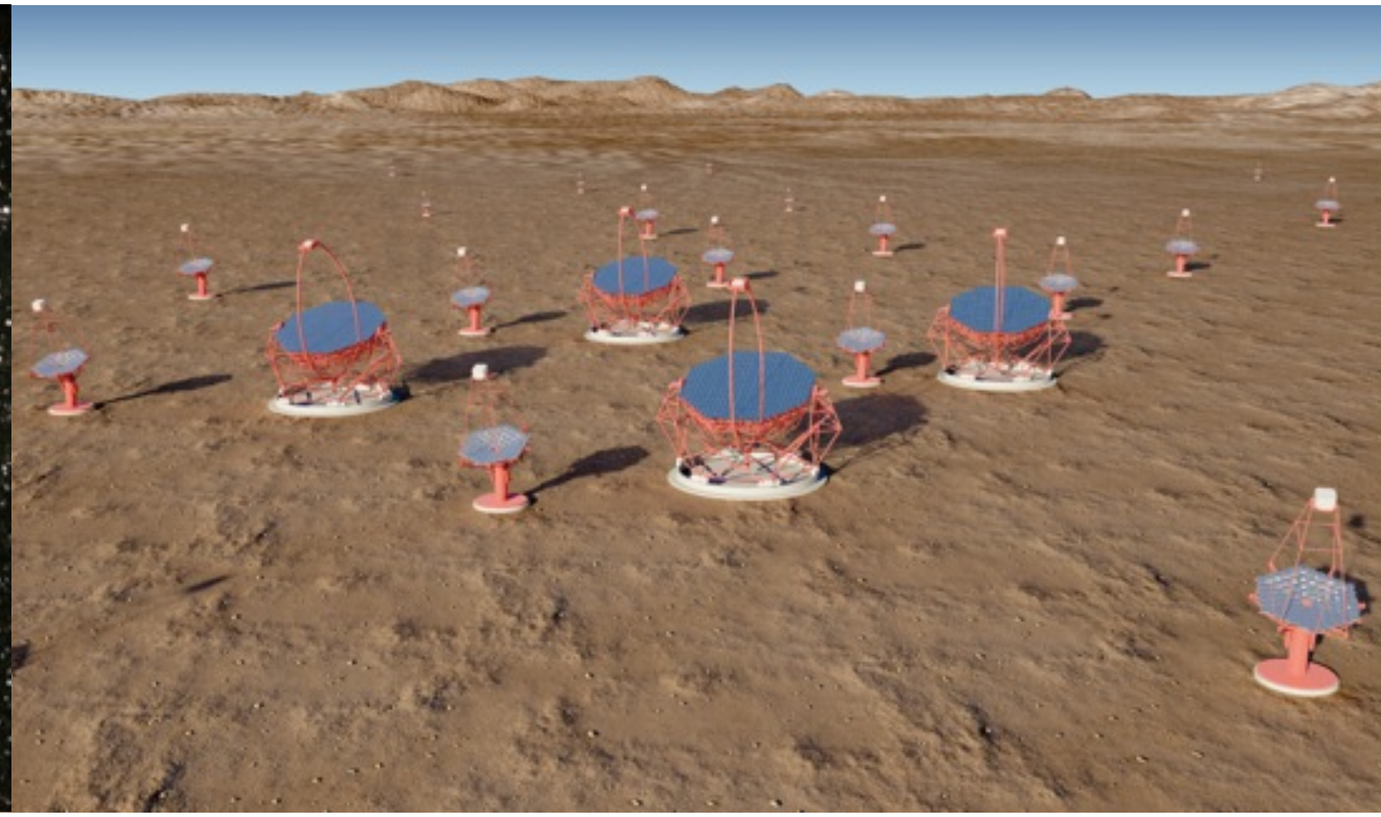

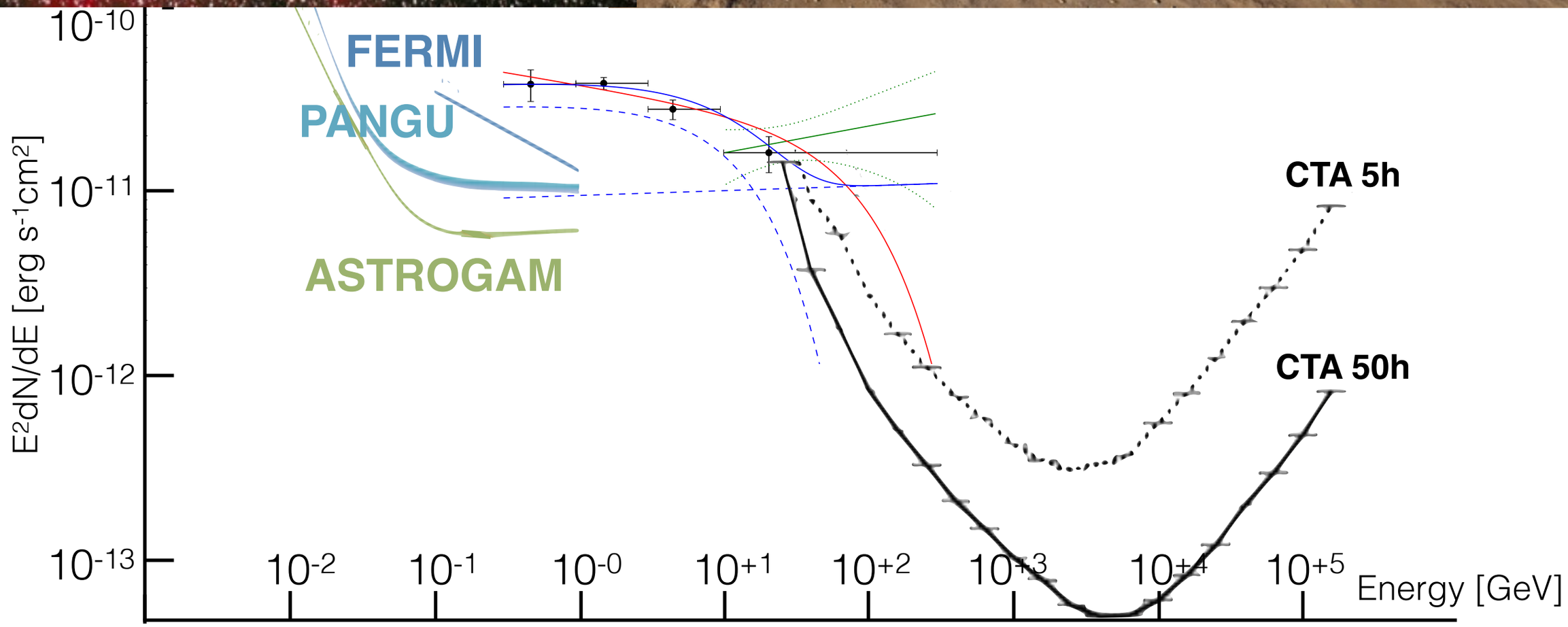

Thank You