Particle acceleration in EtaCarinae: the Expected and Unexpected

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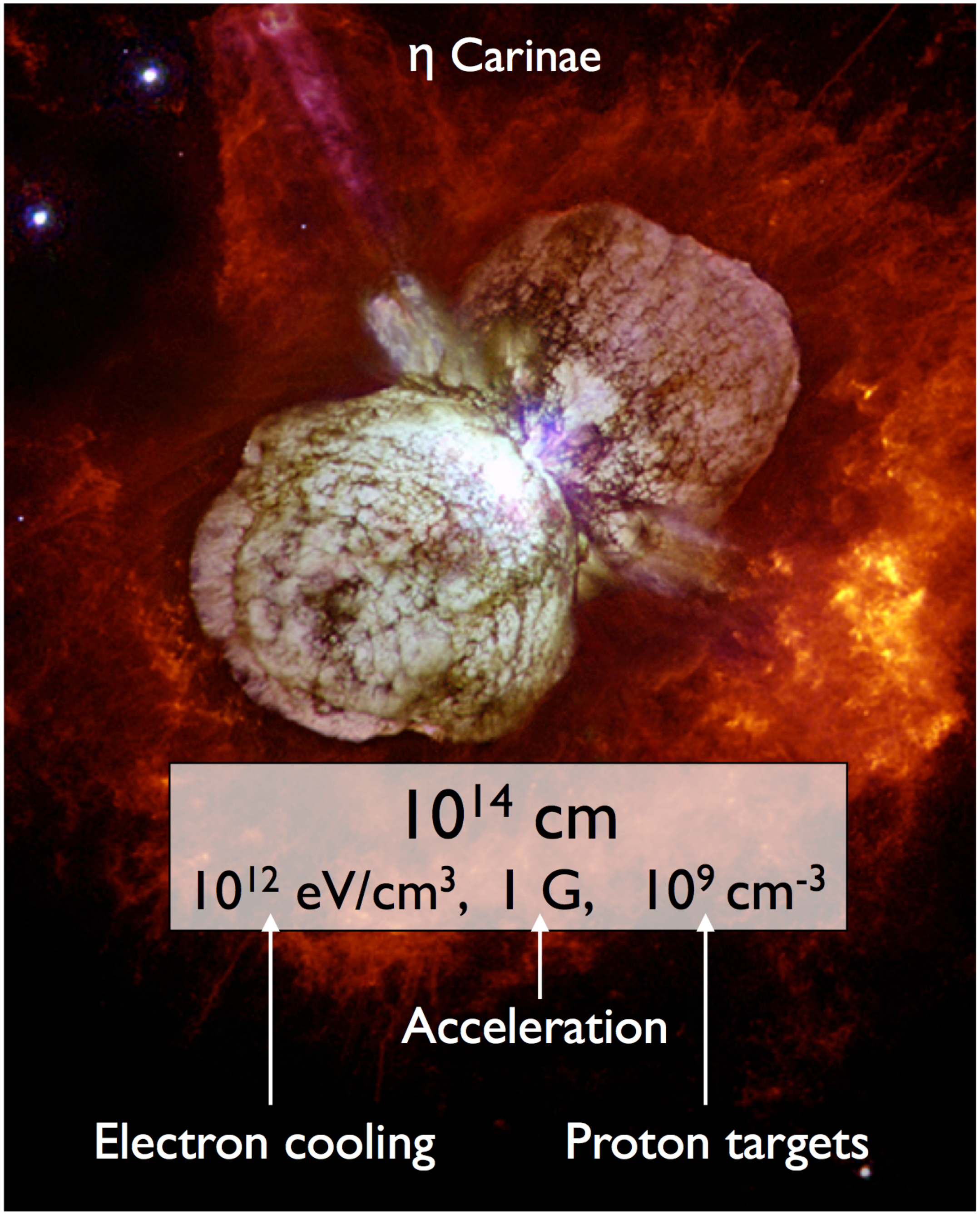
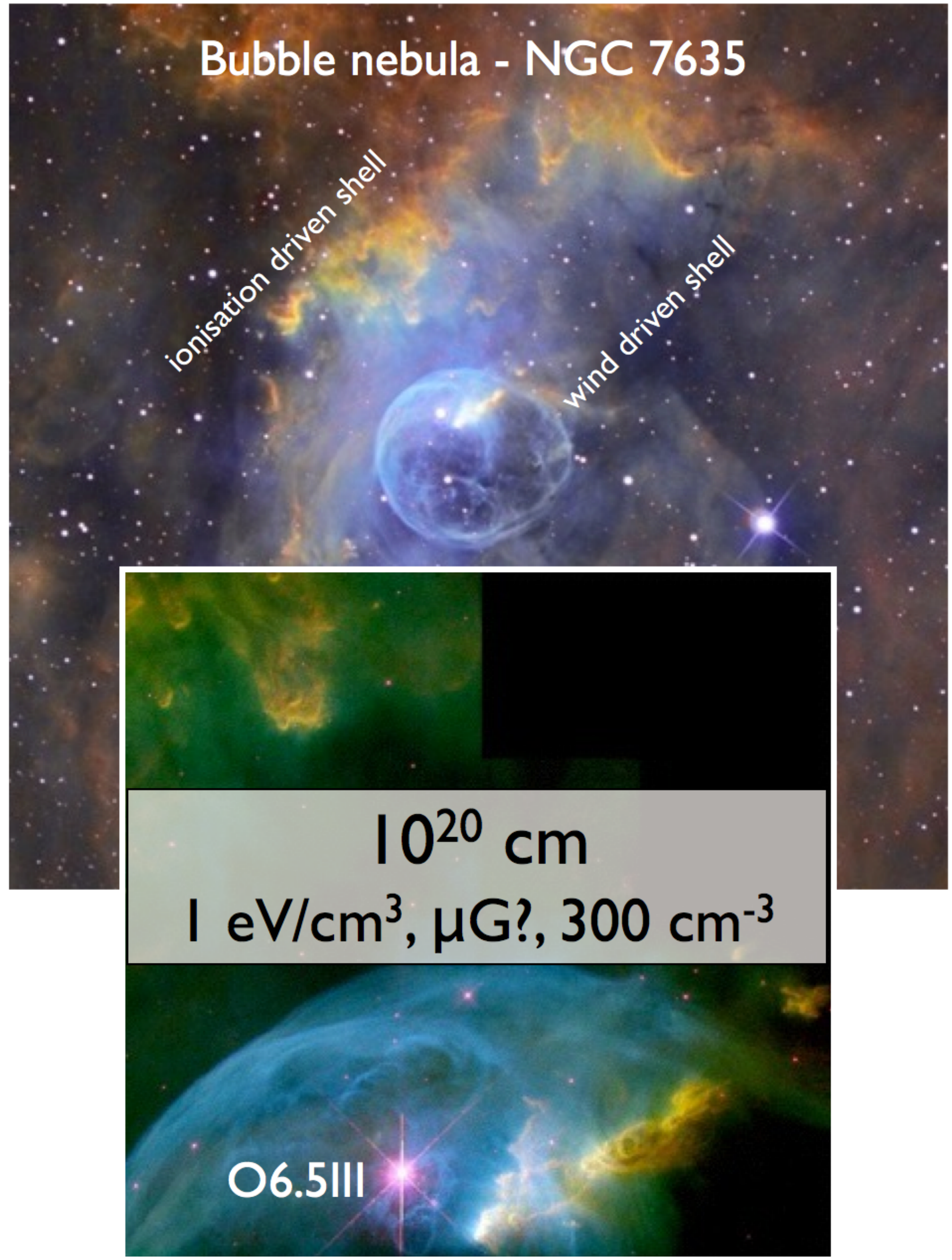
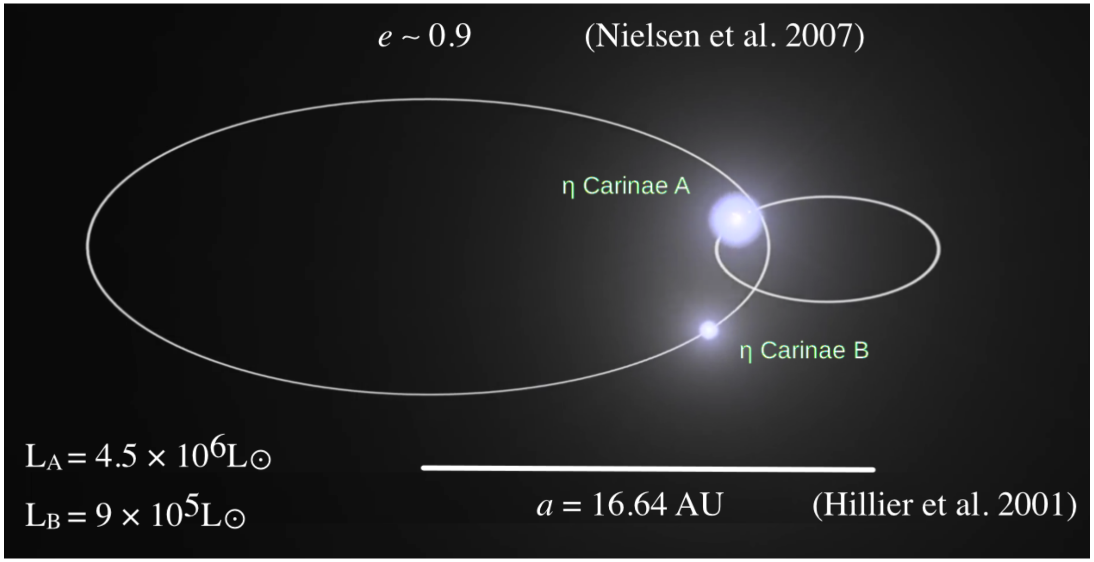
6th International Fermi Symposium, November 9-13 2015, Washington DC

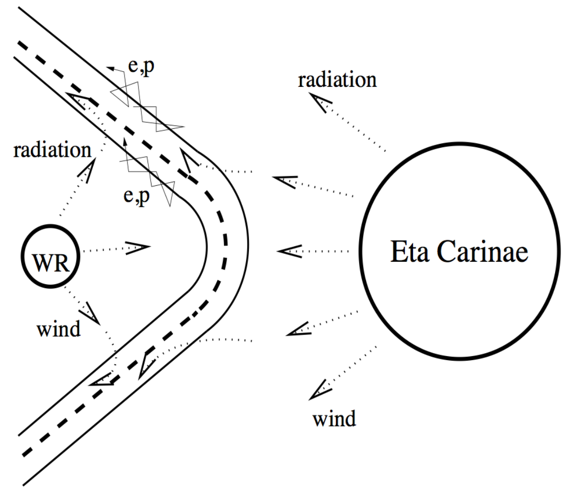
γ-rays from Wind Driven Shocks



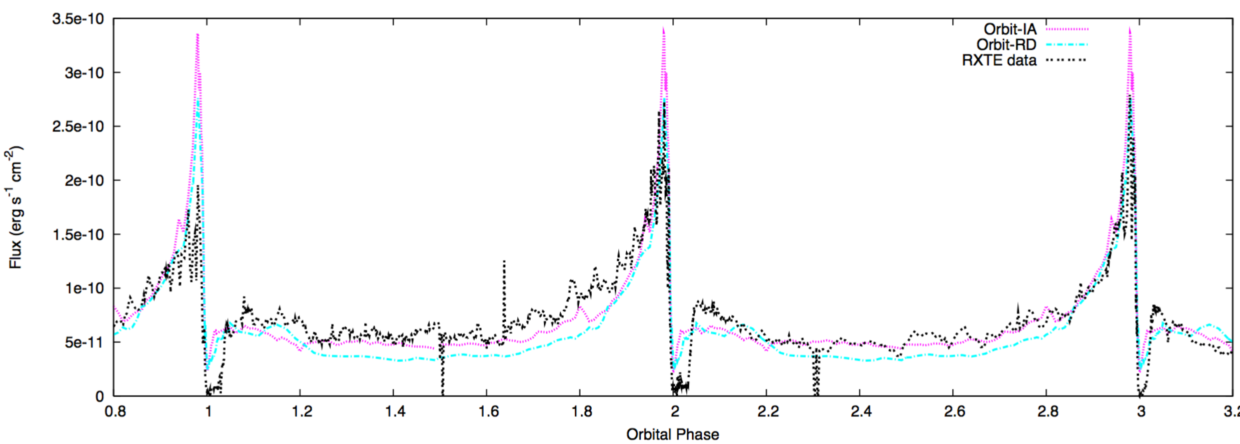


Who is ηCar?





d	2.3 ± 0.1 kpc	Davidson & Humphreys (1997)
P	2022.7 ± 1.3 d	Daminelli (2008)
M_A	$90\ M_\odot$	Hillier et al. (2001)
M_B	$30\ M_\odot$	Verner et al. (2005)
$\dot{M}_A$	$2.5 \times 10^{-4}\ M_\odot\ \mathrm{yr}^{-1}$	Pittard & Corcoran (2002)
$\dot{M}$	$1.5 \times 10^{-5}\ M_\odot\ \mathrm{yr}^{-1}$	Parkin et al. (2009)
$V_{\infty,A}$	$500\ \mathrm{km\ s^{-1}}$	Hillier et al. (2001)
$V_{\infty,B}$	$3000\ \mathrm{km\ s^{-1}}$	Pittard & Corcoran (2002)

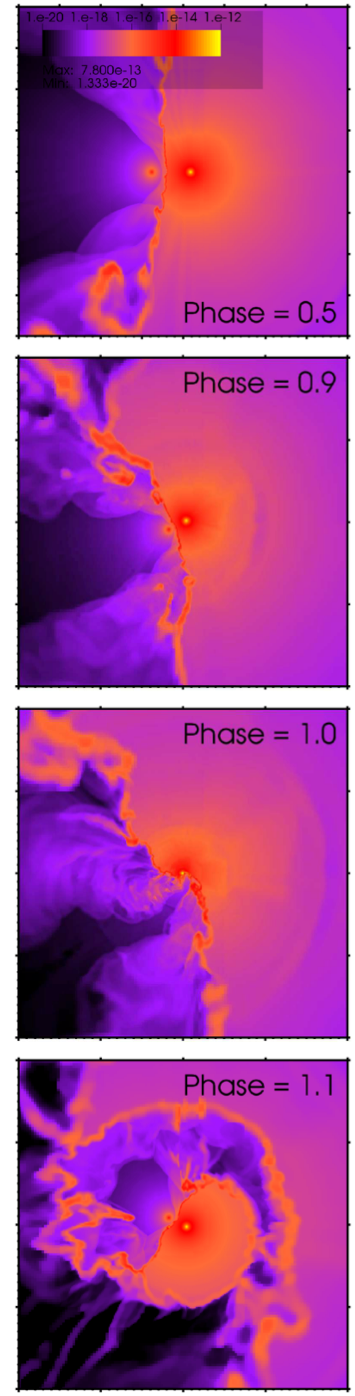


Variability signatures are expected in the γ-ray domain

Reimer (2006) AJ 644,1118

Bednarek (2011) A&A 530,A49+

Parkin (2011) ApJ 726, 105



The physics behind ηCar

$$\tau_{\rm acc} = E/\dot{P}_{\rm acc} \approx 10E/(\xi_{-5}B) \quad {\rm s}$$

$$\tau_{\rm adv} = 3R_{\rm sh}/v_{\rm w} \approx 3\times10^5 R_{13}/v_3 \quad {\rm s}$$

electrons:

$$\tau_{\rm syn} = \frac{E_{\rm e}m_{\rm e}^2}{4/3c\sigma_{\rm T}U_{\rm B}E_{\rm e}^2} \approx \frac{3.7\times10^5}{B^2E_e} \quad {\rm s}$$

$$\tau_{\rm IC/T} = \frac{E_{\rm e}m_{\rm e}^2}{4/3c\sigma_{\rm T}U_{\rm rad}E_{\rm e}^2} \approx \frac{170}{E_{\rm e}}\left[\left(\frac{T_4^4}{R_{\rm sh}^2}\right)_{\rm comp} + \left(\frac{T_4^4}{R_{\rm sh}^2}\right)_{\rm EC}\right]^{-1}$$

$$\tau_{\rm br} \approx X_{\rm o}/c \approx 4.3\times10^4 R_{13}^2 v_3/M_{-4} \quad {\rm s}$$

hadrons:

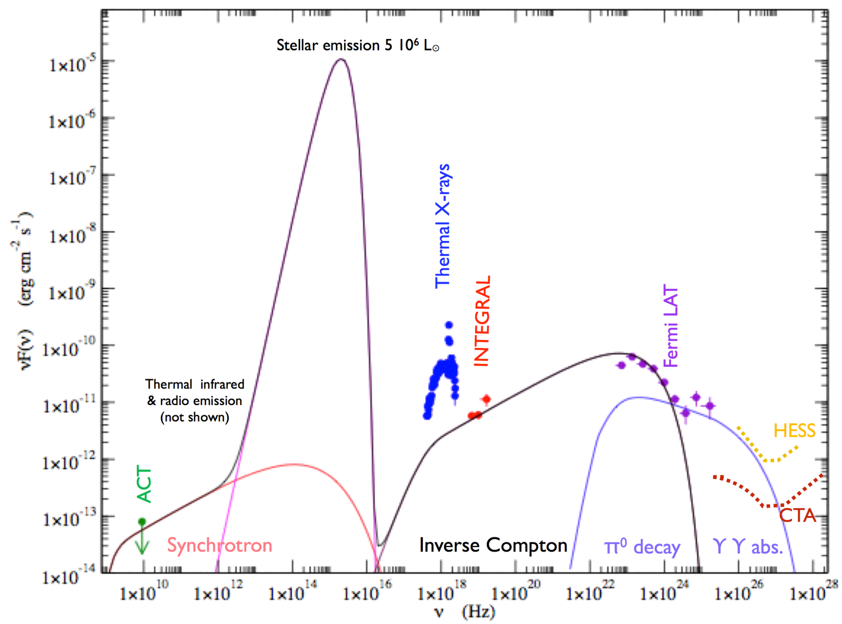
$$\tau_{\rm pp} = (\sigma_{\rm pp}kc\rho_{\rm w})^{-1} \approx 6.3\times10^4 R_{13}^2 v_3/\dot{M}_{-4} \quad {\rm s}$$

γ-γ absorption

Bednarek (1997) A&A 322, 523

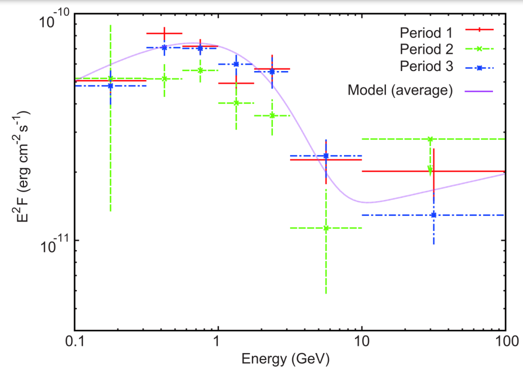
They depend on several poorly known parameters

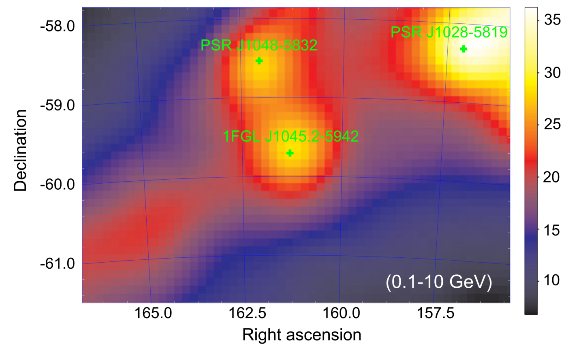
(orbital component, acceleration efficiency,injection fraction of e&p, magnetic field, diffusion coefficient, region of the shocks, …)



(A&A, 526, A57)

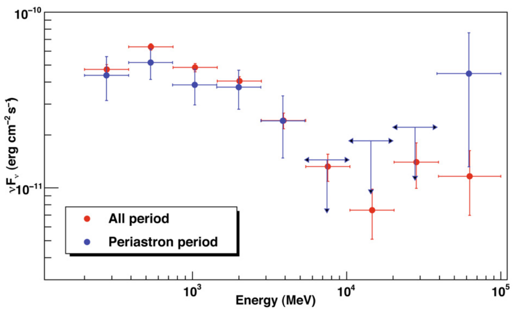
Past analyses of ηCar

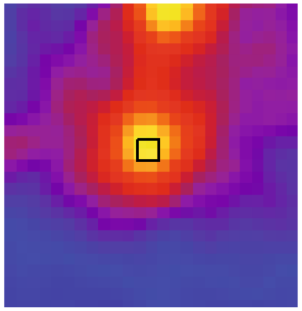




From 2008 August 4
to 2009 July 23
ST: *v9r11*
IRF: *P6_V3_DIFFUSE*
Catalogue: *1FGL*

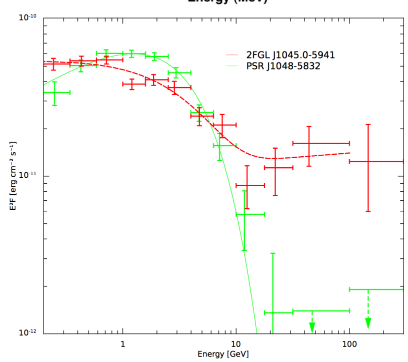
Abdo (2010)
AJ 723:649-657

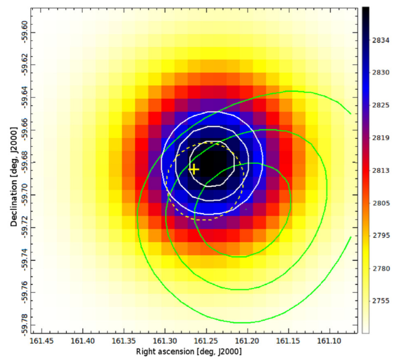




From 2008 August 4
to 2010 April 3
ST: *v9r11*
IRF: *P6_V3_DIFFUSE*
Catalogue: *1FGL*

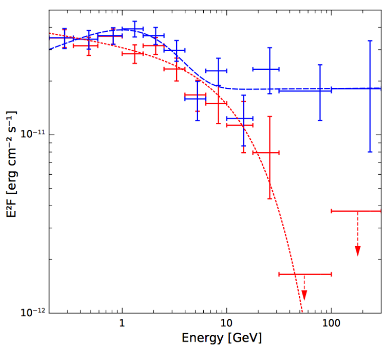
Farnier (2011)
A&A 526, A57

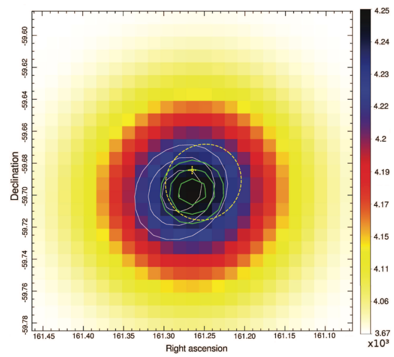




From 2008 August 4
to 2011 July 5
ST: *v9r23*
IRF: *P7SOURCE_V6*
Catalogue: *2FGL*

Reitberger (2012)
A&A 544, A98



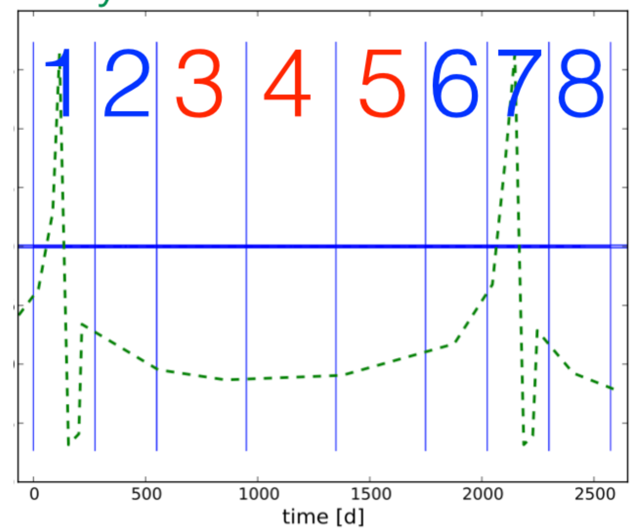


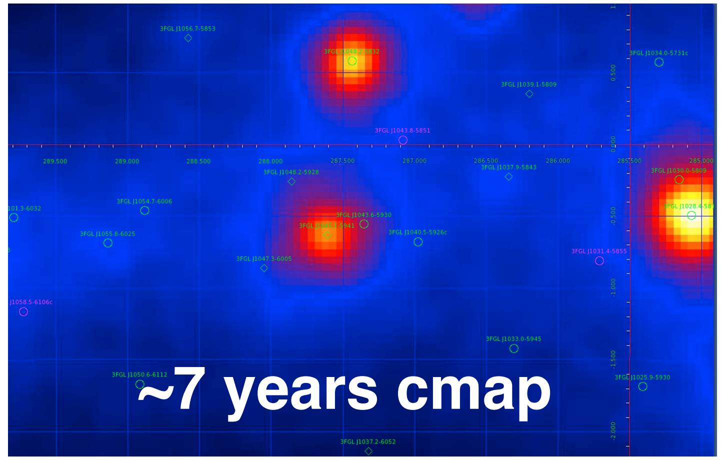
From 2008 August 4
to 2014 February 18
ST: *v9r31*
IRF: *P7REP_SOURCE_V15*
Catalogue: *3FGL*

Reitberger (2015)
A&A 577, A100

Our analysis of ηCar

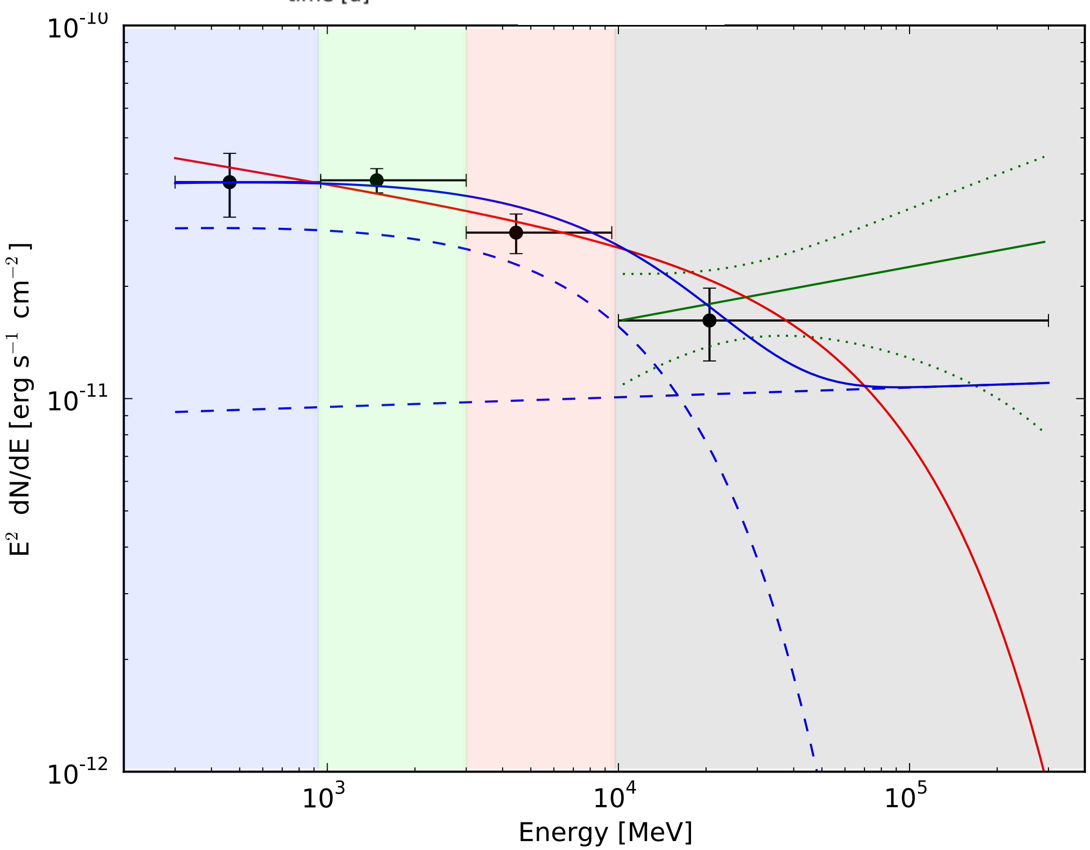
X-ray theoretical modulation





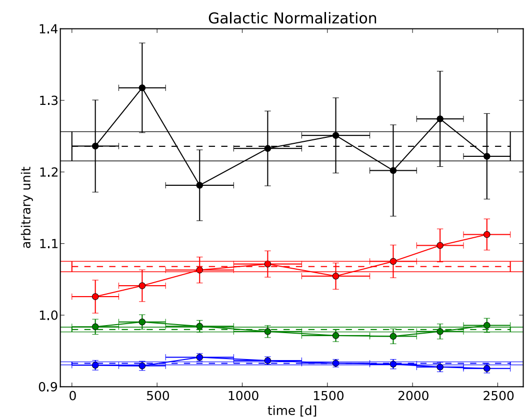
From 2008 August 4
to 2015 July 1
ST: *v10r0p5*
IRF: *P8R2_SOURCE_V6*
Catalogue: *3FGL*

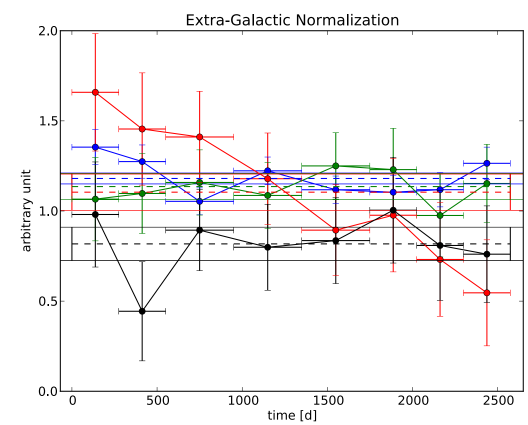
E: 300 MeV - 300 GeV
ROI: ~15°
Sources: ~171 (1 ext.)



average *GAL* **varies** by more than **30%**

average *EXGAL* **varies** by more than **50%**





Problems with the Galactic model

Abdo (2015)
AJSS 218:23

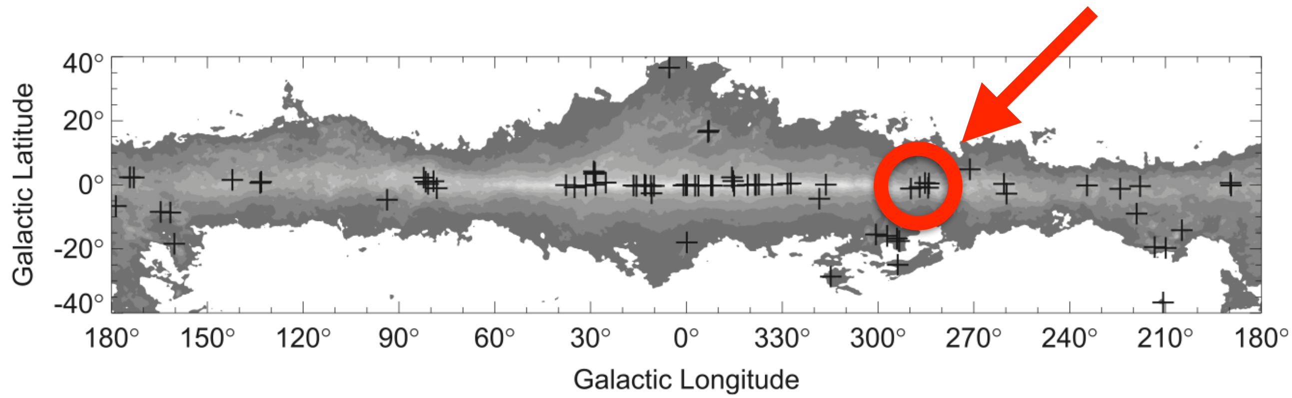


Figure 14. Locations of the c sources in the 3FGL catalog overlaid on a grayscale representation of the model for the Galactic diffuse γ-ray emission used for the 3FGL analysis (see Section 2.3). The plotted symbols are centered on the locations of the sources. The model diffuse intensity is shown for 1 GeV, and the spacing of the levels is logarithmic from 1% to 100% of the peak intensity.

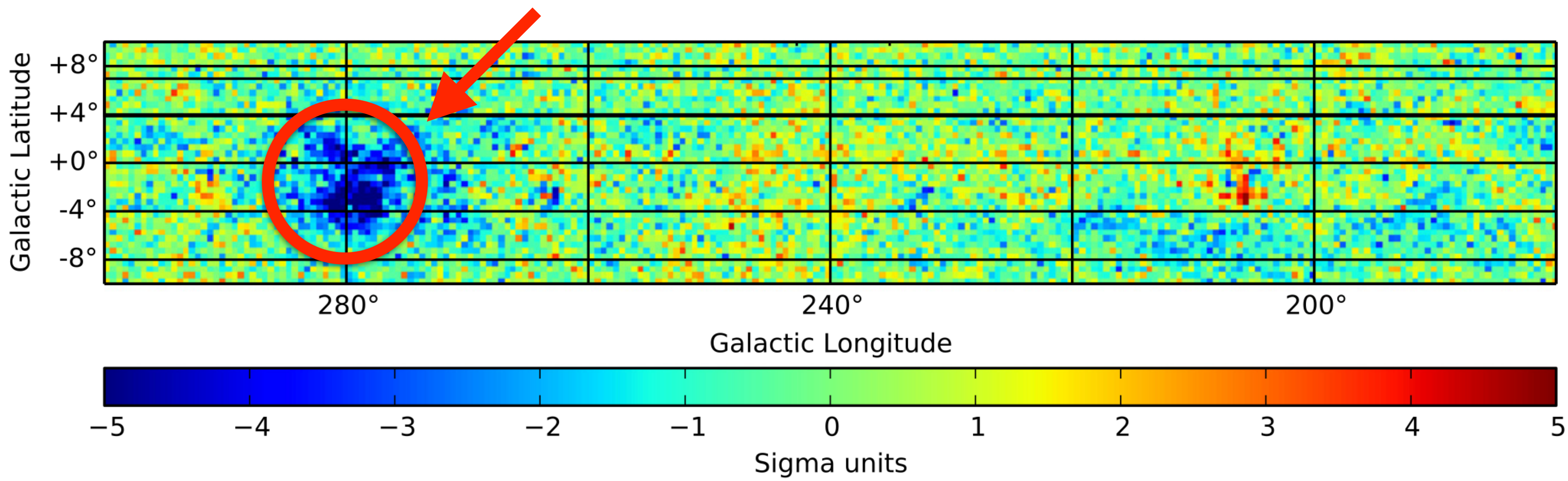
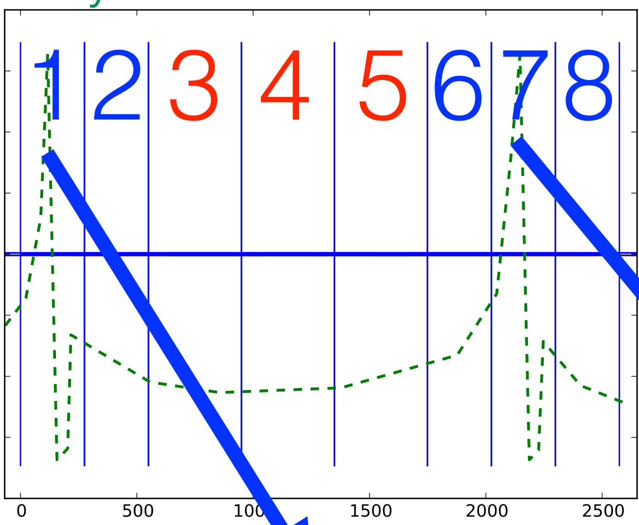


Figure 26. Residuals when setting the diffuse model normalizations to 1 and no power-law correction, integrated from 100 MeV to 100 GeV and expressed in sigma units over 0°.5 pixels.

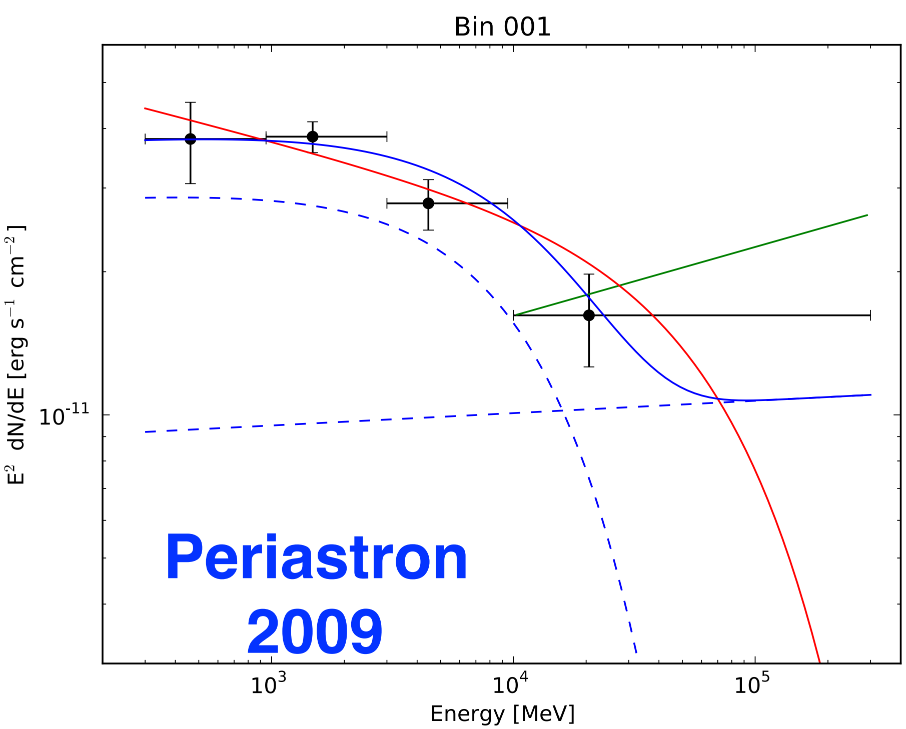
Variability in the spectrum

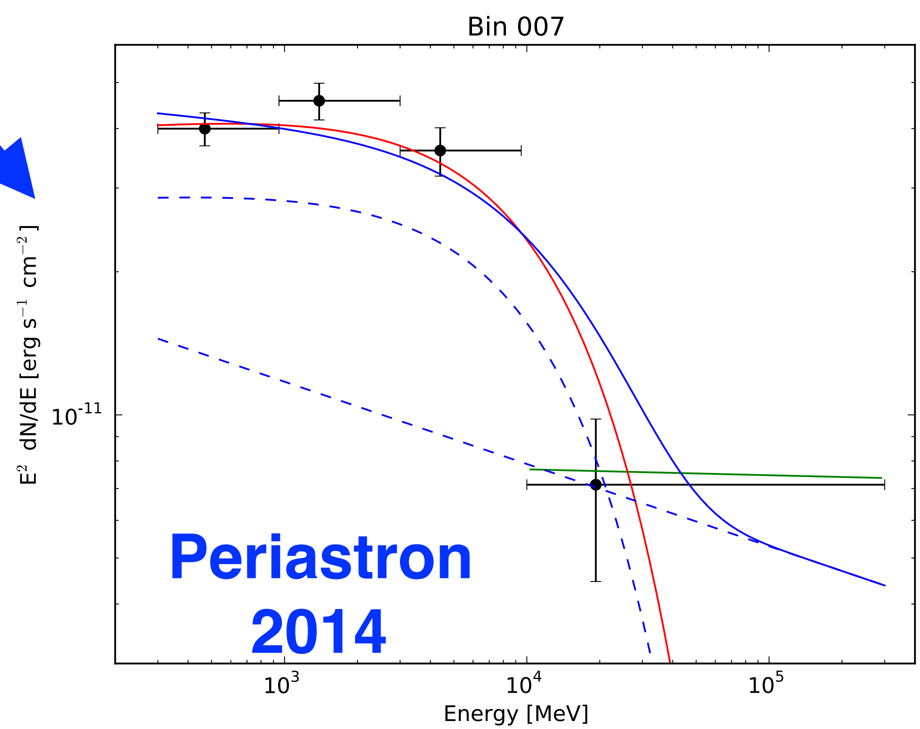
X-ray theoretical modulation



Tab 1	Normalization	Index	Cut-off
PL2	(11.1 ± 2.5) e-10	-1.86 ± 0.27	
PL2	(1.96 ± 0.48) e-08	-1.97 ± 0.11	
PLEC	1.89e-11 (fixed)	1.970 (fixed)	1.36e+04 (fixed)
PLEC	(2.36 ± 0.13) e-11	2.13 ± 0.04	> 100 GeV

Tab 7	Normalization	Index	Cut-off
PL2	(4.6 ± 1.8) e-10	-2.01 ± 0.48	
PL2	(2.56 ± 0.50) e-08	-2.17 ± 0.11	
PLEC	1.893e-11 (fixed)	1.970 (fixed)	1.36e+04 (fixed)
PLEC	(2.73 ± 0.19) e-11	1.96 ± 0.09	(1.38 ± 0.59) e+04





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Variability in the spectrum

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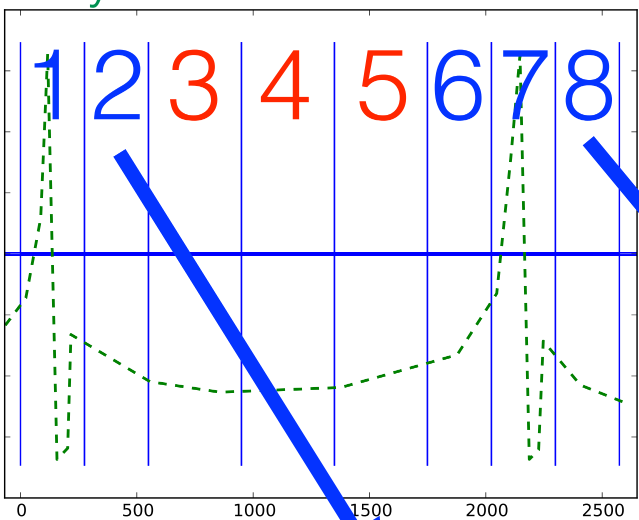
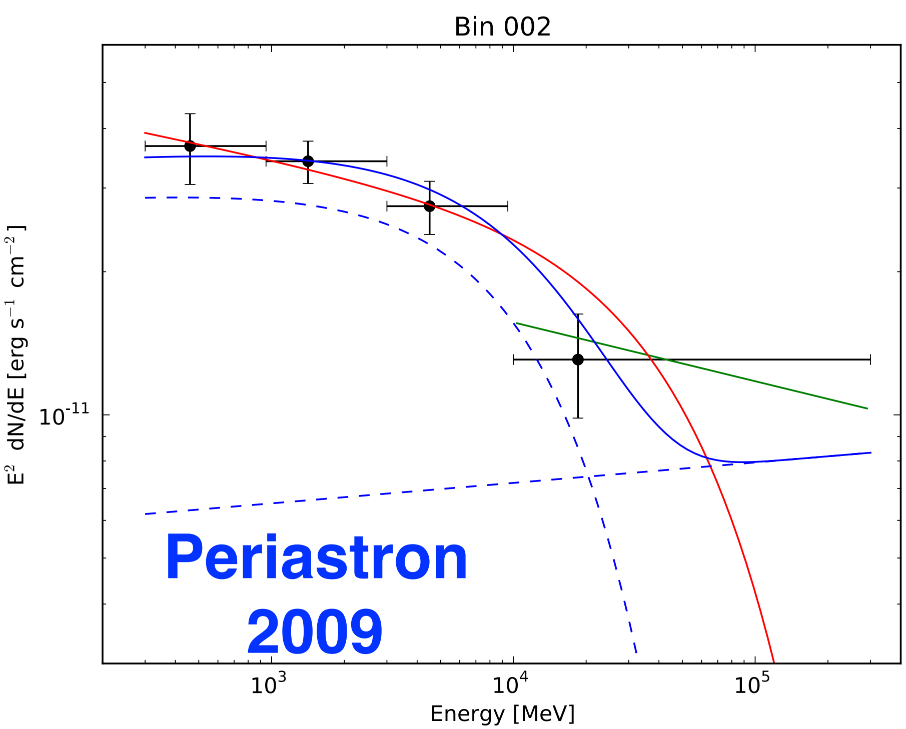
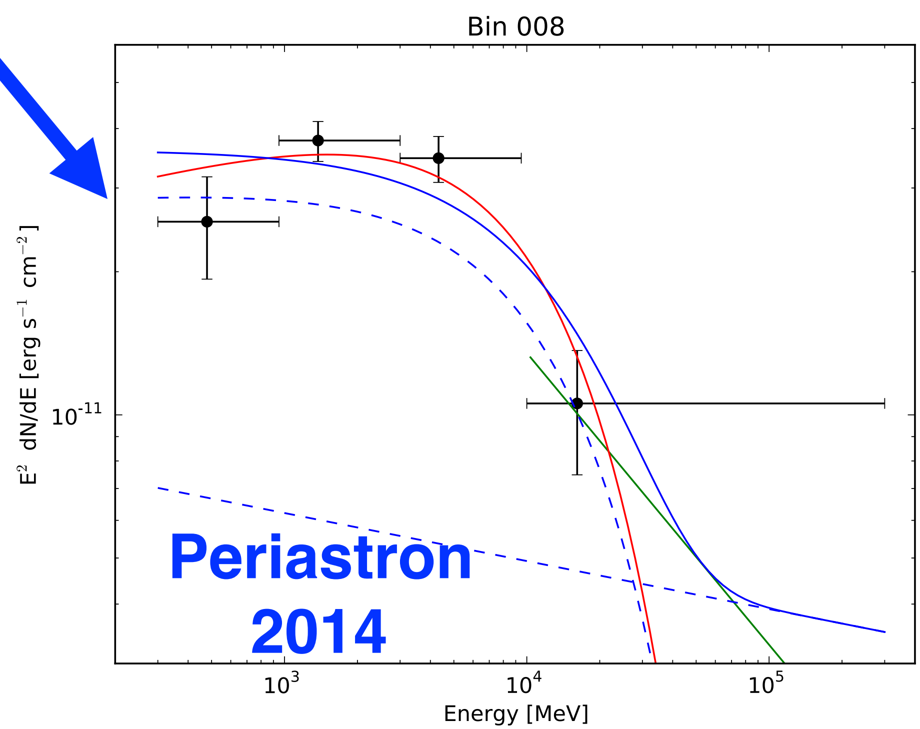
X-ray theoretical modulation



Tab 2	Normalization	Index	Cut-off
PL2	(8.5 ± 2.2) e-10	-2.12 ± 0.39	
PL2	(1.34 ± 0.46) e-08	-1.96 ± 0.15	
PLEC	1.893e-11 (fixed)	1.970 (fixed)	1.36e+04 (fixed)
PLEC	(2.17 ± 0.14) e-11	2.10 ± 0.07	(6.1 ± 5.8) e+04

Tab 8	Normalization	Index	Cut-off
PL2	(5.2 ± 1.6) e-10	-2.61 ± 0.58	
PL2	(1.33 ± 0.44) e-08	-2.10 ± 0.14	
PLEC	1.893e-11 (fixed)	1.970 (fixed)	1.36e+04 (fixed)
PLEC	(2.38 ± 0.17) e-11	1.87 ± 0.09	(1.13 ± 0.35) e+04





Variability in the spectrum

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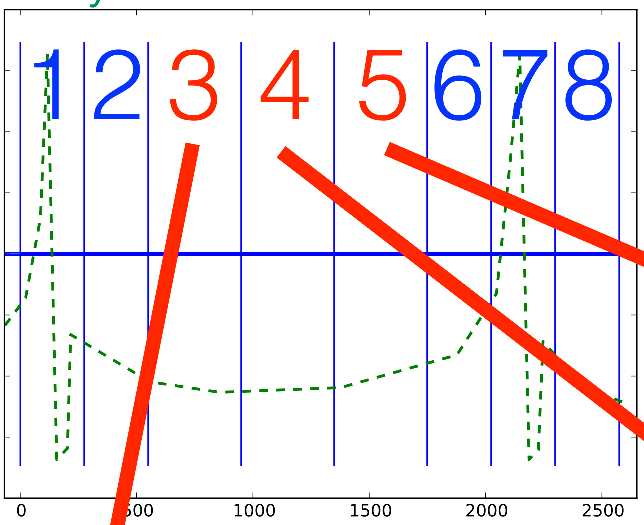
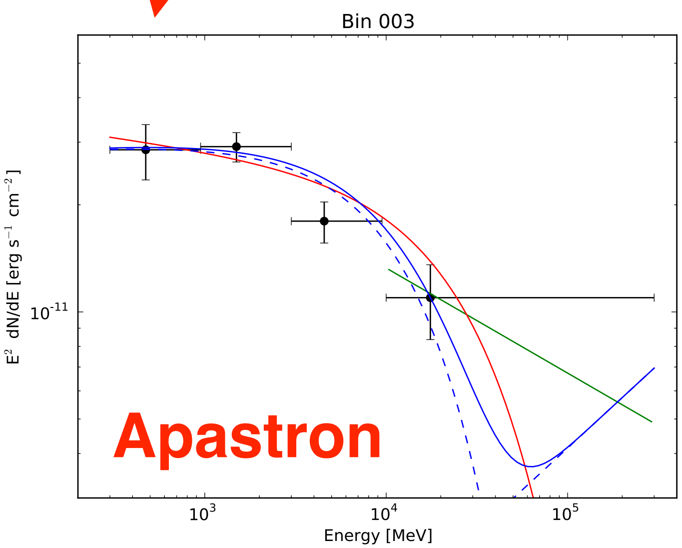
X-ray theoretical modulation

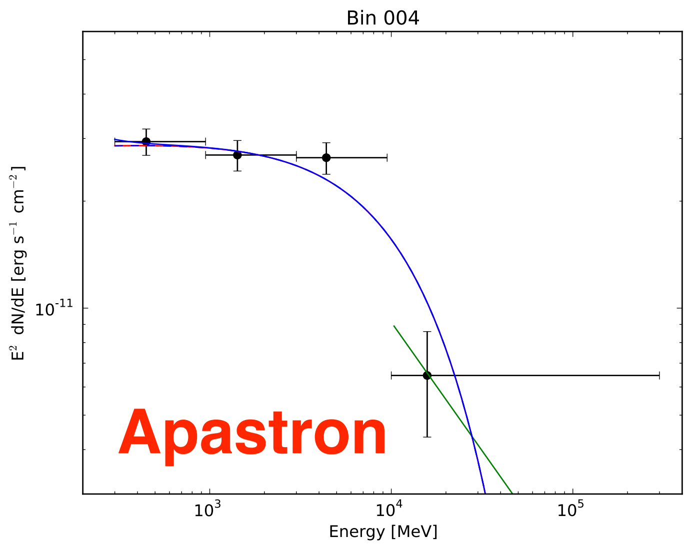


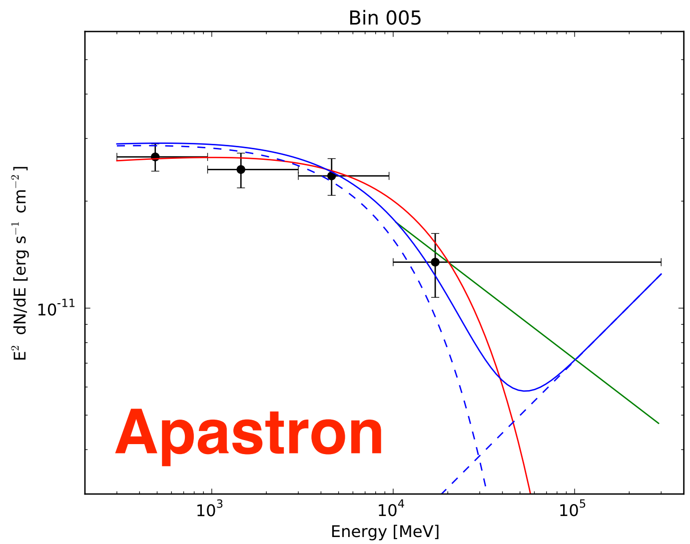
Tab 3	Normalization	Index	Cut-off
PL2	(6.3 ± 1.5) e-10	-2.30 ± 0.36	
PL2 PLEC	(1.03 ± 1.8) e-09 1.893e-11 (fixed)	-1.53 ± 0.48 1.970 (fixed)	 1.36e+04 (fixed)
PLEC	(1.797 ± 0.11) e-12	2.07 ± 0.07	(3.3 ± 1.8) e+04

Tab 4	Normalization	Index	Cut-off
PL2	(3.3 ± 1.2) e-10	-2.72 ± 0.71	
PL2 PLEC	(7.09 ± 0.33) e-10 1.893e-11 (fixed)	-4.596 ± 7 1.970 (fixed)	 1.36e+04 (fixed)
PLEC	(1.89 ± 0.13) e-11	1.97 ± 0.09	(1.36 ± 0.52) e+04

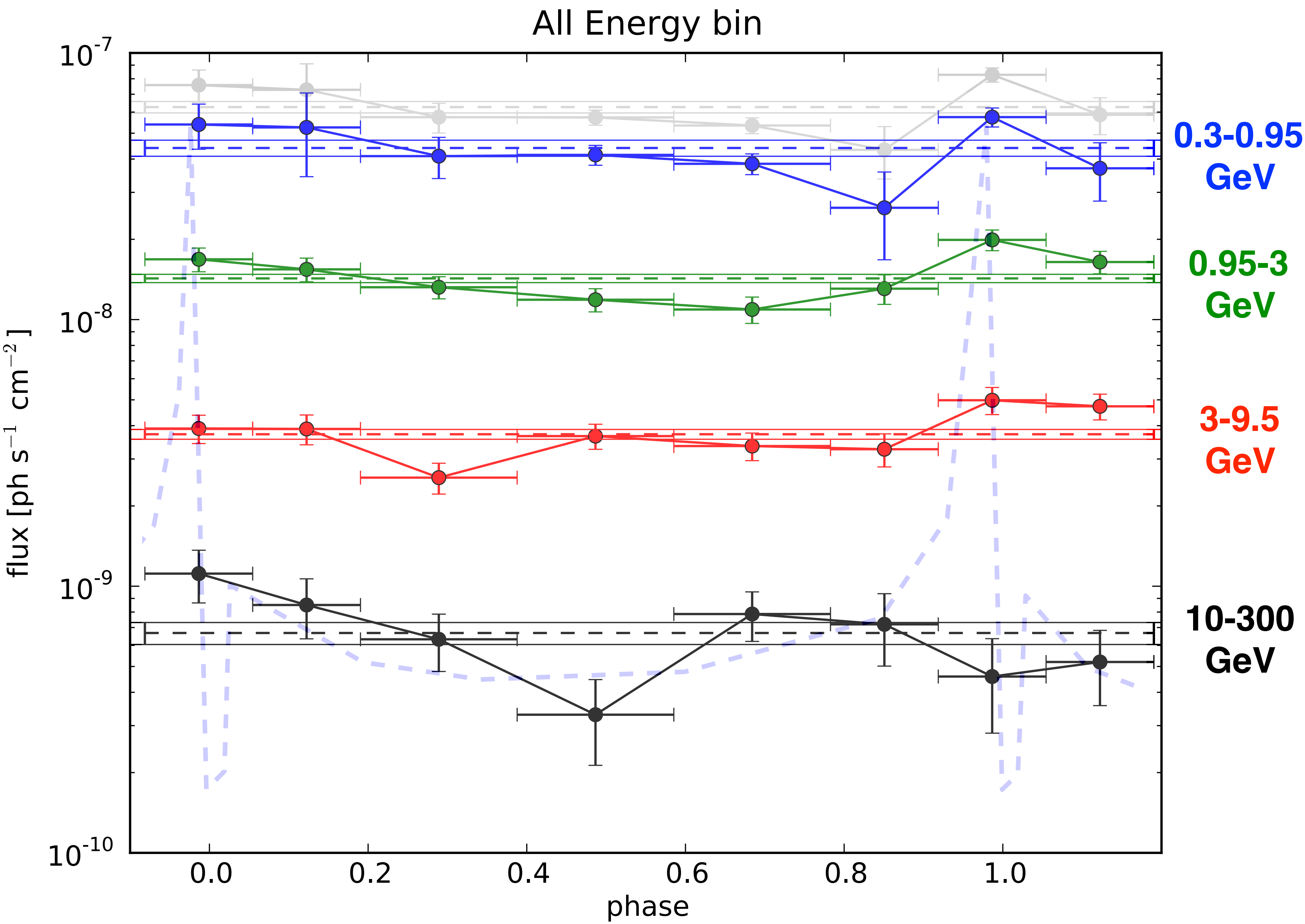
Tab 5	Normalization	Index	Cut-off
PL2	(7.9 ± 1.7) e-10	-2.40 ± 0.34	
PL2 PLEC	(1.5 ± 1.6) e-09 1.893e-11 (fixed)	-1.49 ± 0.29 1.970 (fixed)	 1.36e+04 (fixed)
PLEC	(1.73 ± 0.12) e-11	1.96 ± 0.08	(2.39 ± 1.04) e+04



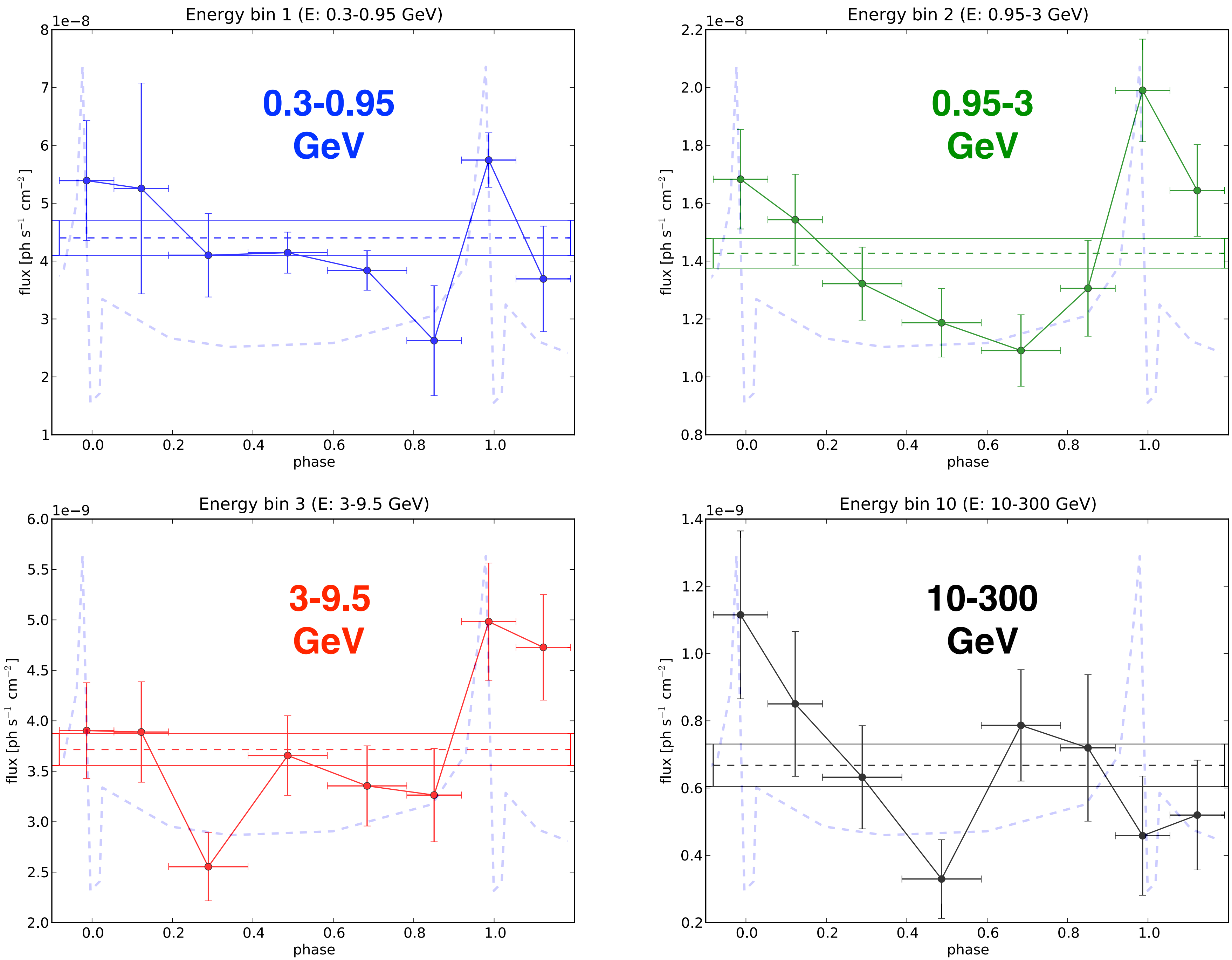




Variability in the light curve

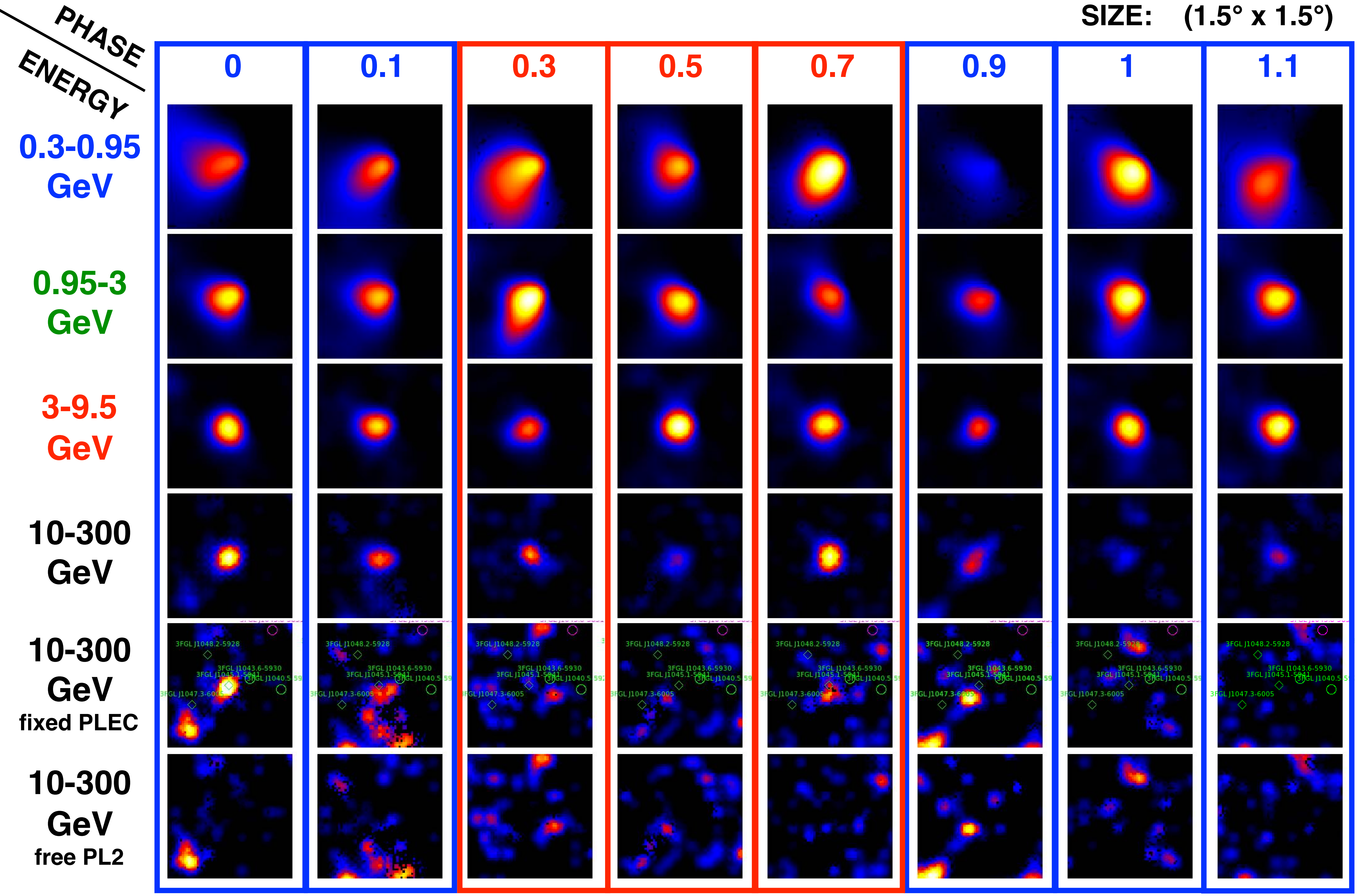


Variability in the light curve



Test Statistic maps

SIZE: (1.5° x 1.5°)



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Summary and Conclusion

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Summary

- We clearly have γ-ray emission (at all energies) from a region coincident with the nominal position of ηCar
- Our choice of the galactic model parameters affects by at least 10% ηCar avg flux
- Furthermore, we need to be careful estimating EtaCarinae flux:
    - at low energy: J1043 closer than θ_{REF} (TS maps —> J1043 flux variations —> ηCar flux affected by a factor 0.5-4)
    - at high energy: TS map enhance residual flux not coming from EtaCarinae nominal position (not included in the xml model)
- The flux variations of ηCar depend on the model we choose to describe it (PL, PLEC, PLEC+PL, LOGP, …)

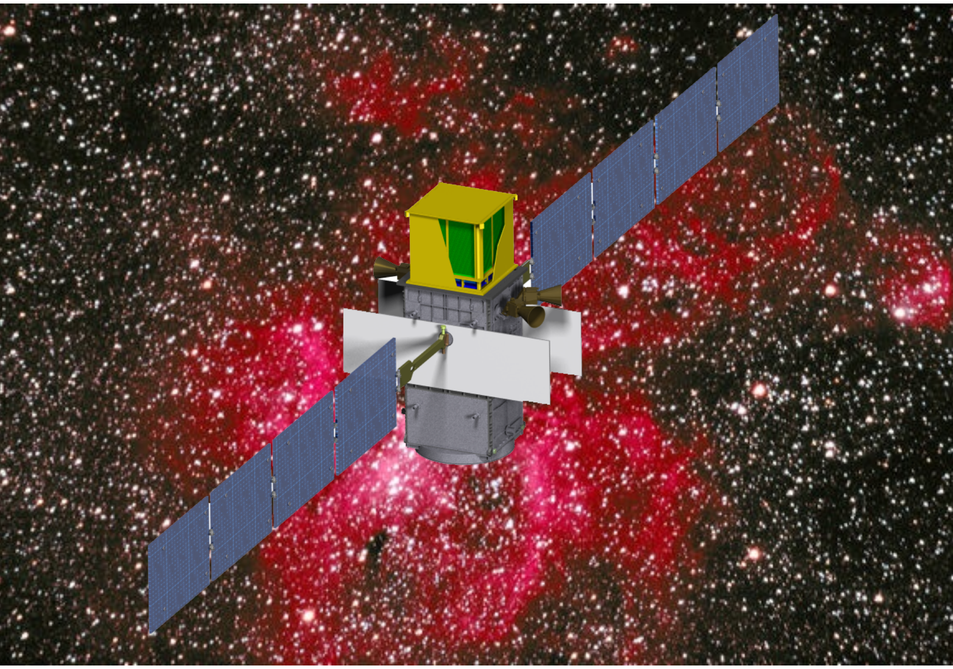
…nevertheless

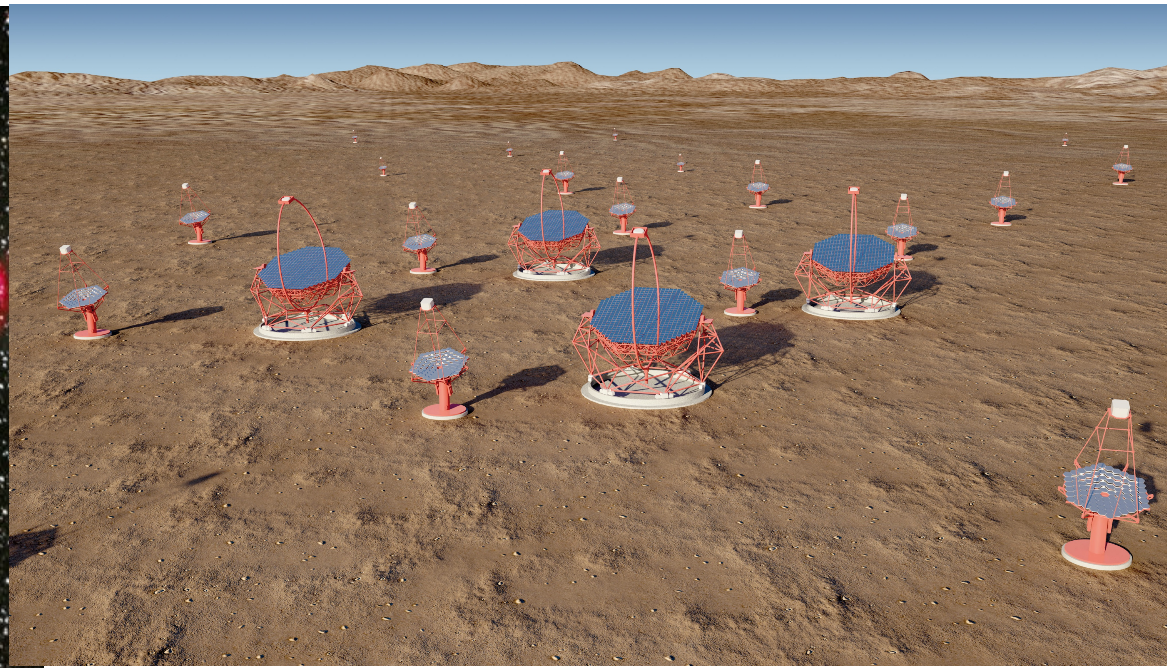
- we see a variability on ηCar flux of a factor 2-3… (expected)
- …but we see also a “variability on the variable” ηCar flux @ HE (unexpected)

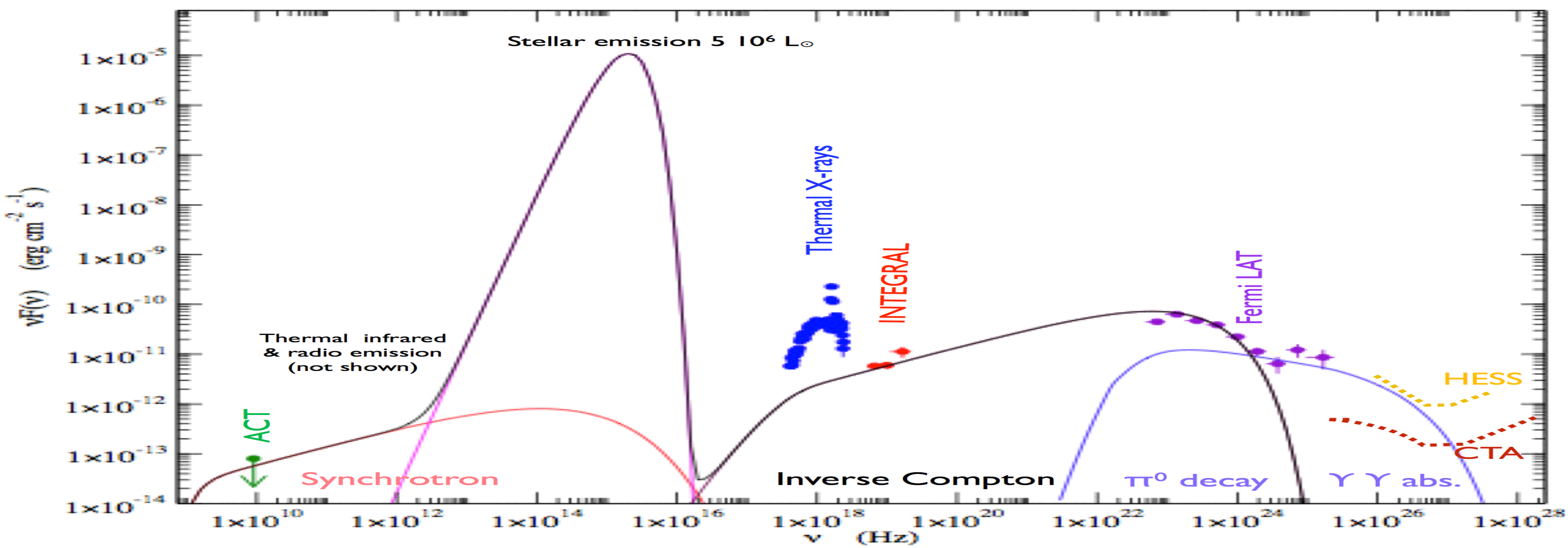
1. ***gamma-ray pulsar & PWN*** *(Abdo et al, 2010)*
2. ***external shock*** *(Ohm et al, 2010)*
3. ***electrons & hadrons*** *(Eichler & Usov, 1993; Farnier & Walter, 2011)*
4. ***two electrons populations*** *(Bednarek & Pabich, 2011)*

…staying hungry and staying foolish…

Looking at the Future







Looking at the Future