Search for long term variability of HESS J1745-290 at the center of the Galaxy

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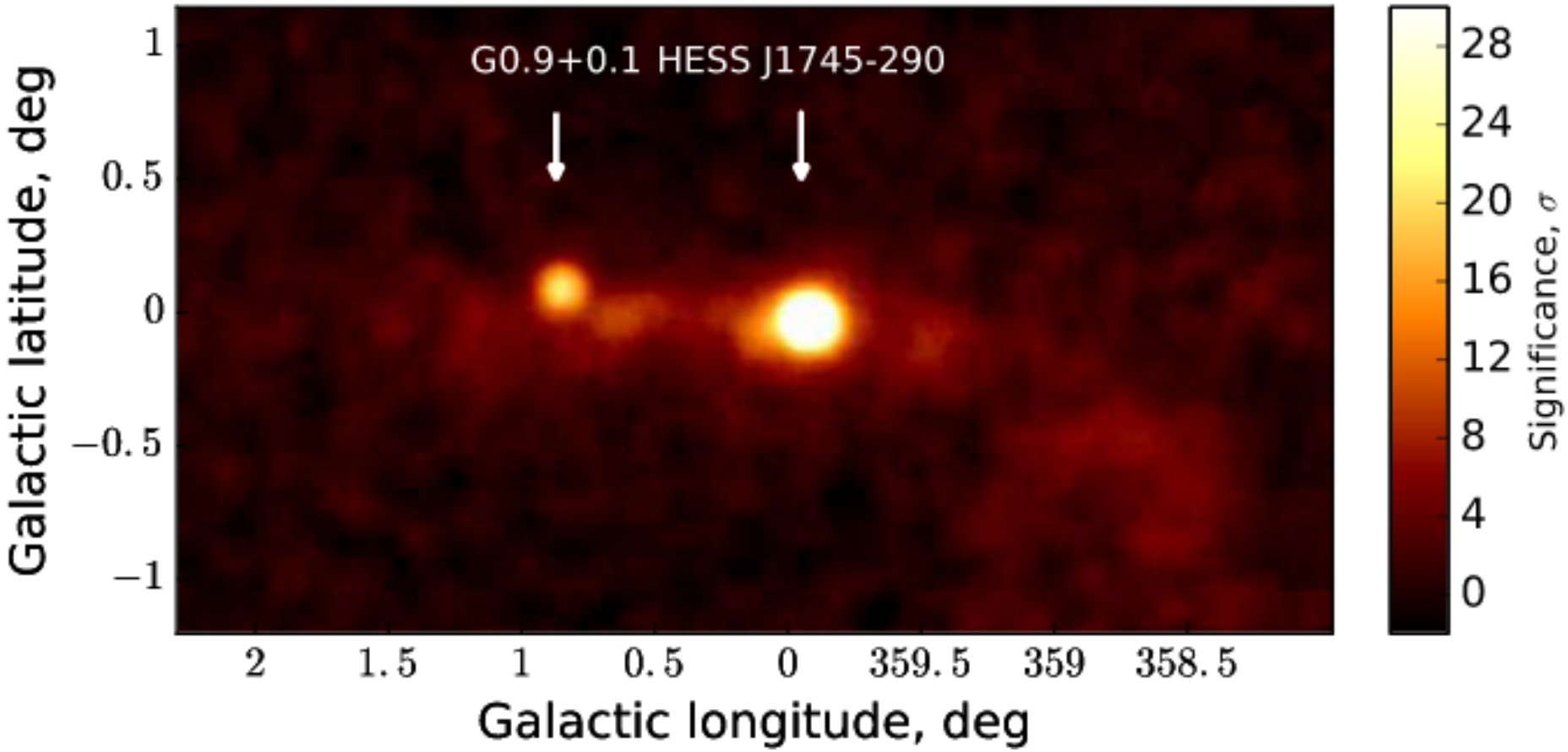
The Galactic Center (GC) at Very High Energies

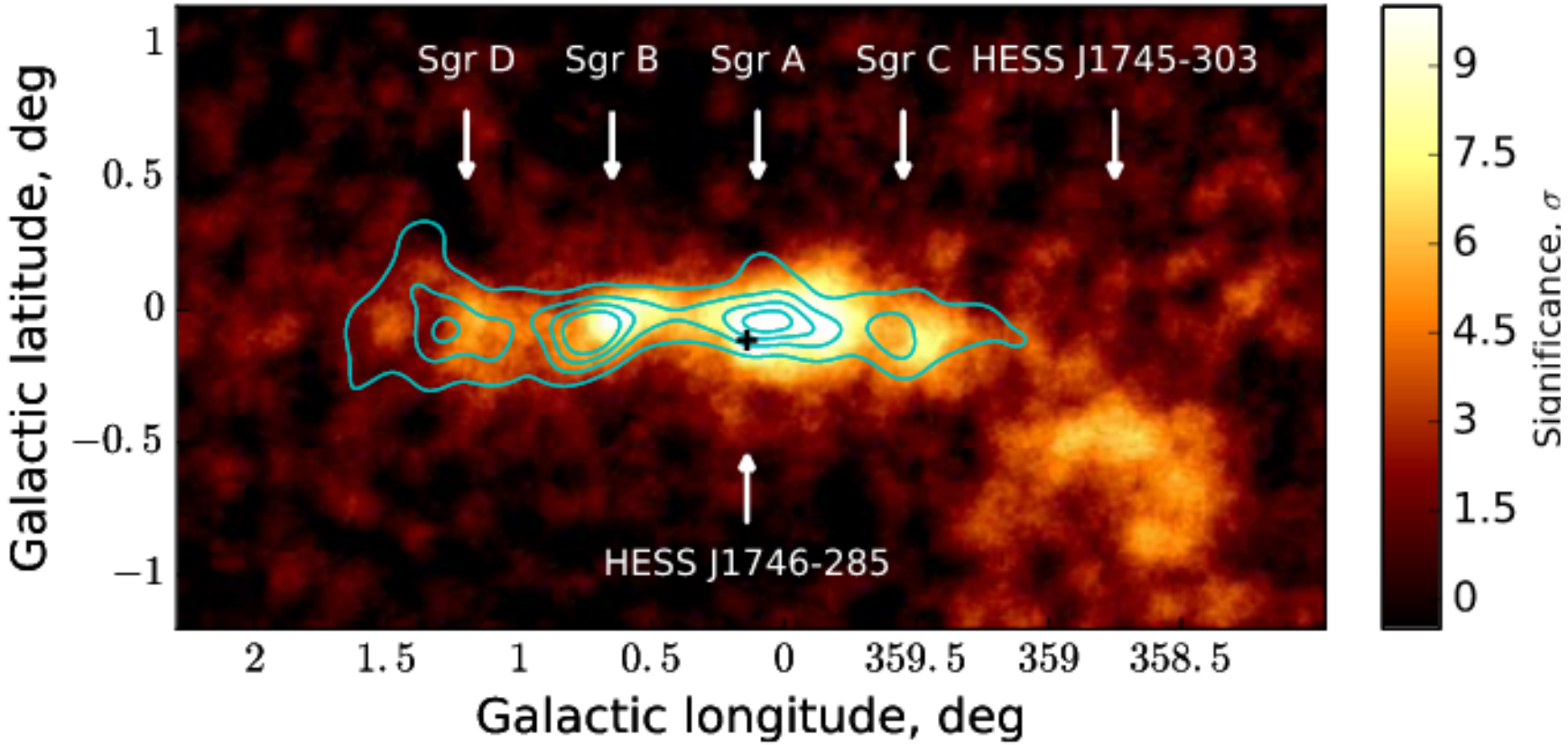
Since 2004, H.E.S.S. has observed this source at the GC for over 400 hours



H.E.S.S. significance map. Source : H.E.S.S Collaboration 2018

The Diffuse Emission (DE)

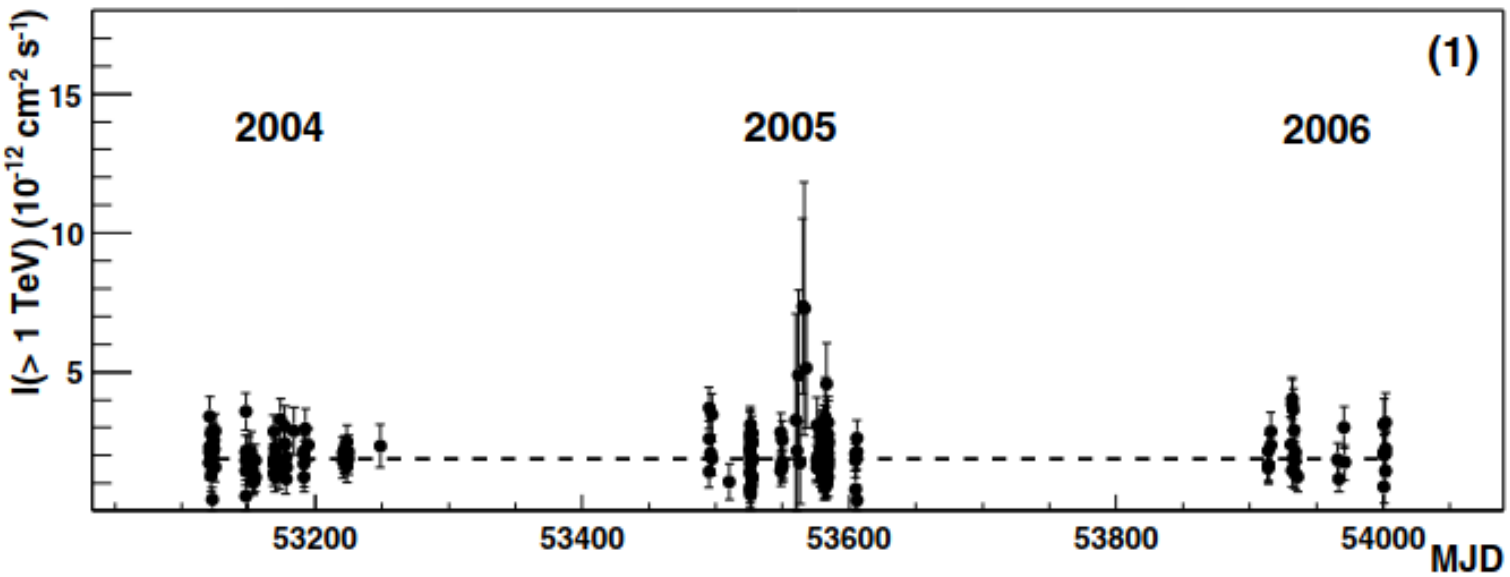
A diffuse emission is also detected : due to interaction between cosmic rays and the dense gas of the inner 300 pc.



Residual significance map with CS gas outline. Source : *ibid*

The HESS J1745-290 source

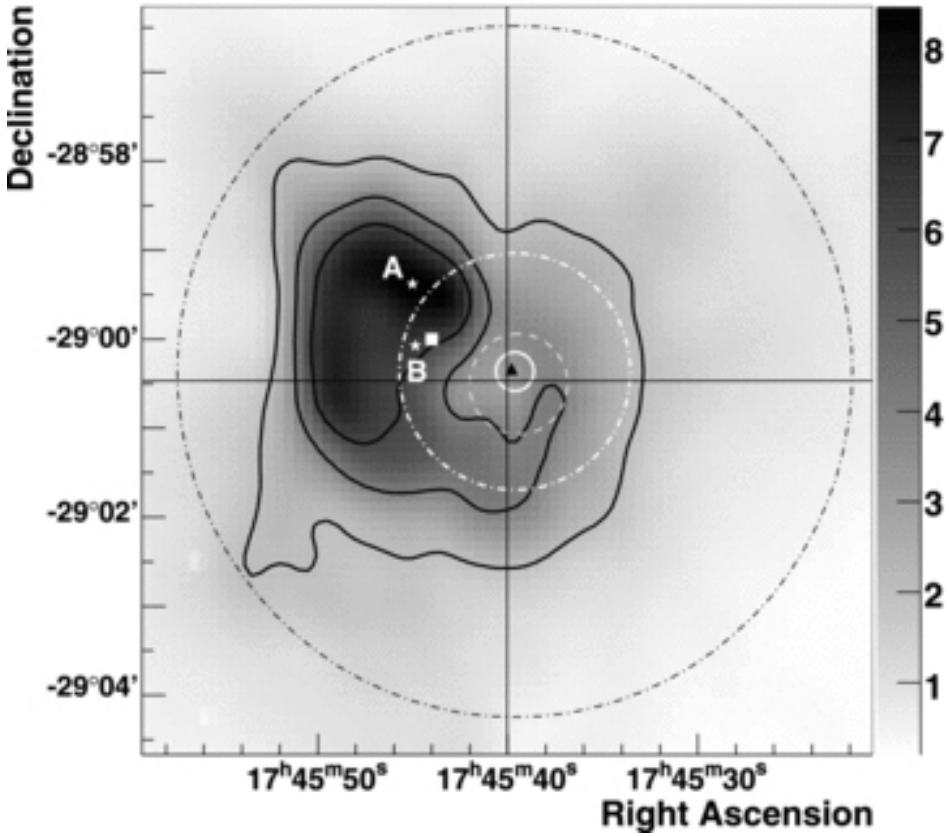
- compatible with SgrA*
- luminosity of $\sim 10^{35}$ erg.s^{-1}
- index of ~ 2.1
- cutoff energy $\sim 10 - 15$ TeV.
- No variation was detected between 2004 and 2006



From Aharonian et al. 2009

Identifying HESS J1745-290

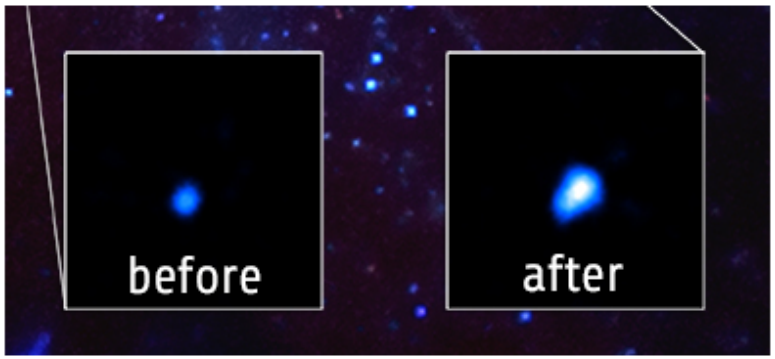
Origin of HESS J1745-290 is still unknown : SMBH Sgr A* is one solid candidate, but PWN G359.95-0.04 is also compatible.



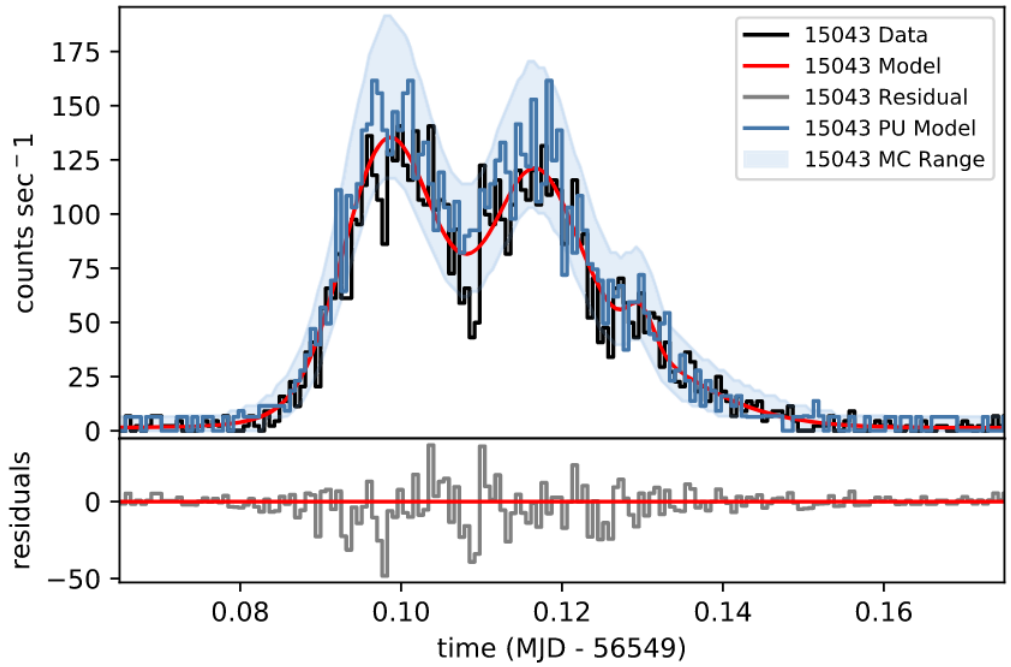
VLA observation with HESS J1745-290 position (13" precision, full white line), cross is SgrA*, triangle is G359.95-0.04, from Acero et al. 2010

Fast variability of SgrA*

Sgr A* is a rapidly variable source in X-ray and IR (few hours long, daily flares), with luminosities up to $\sim 10^{35}$ erg.s^{-1}

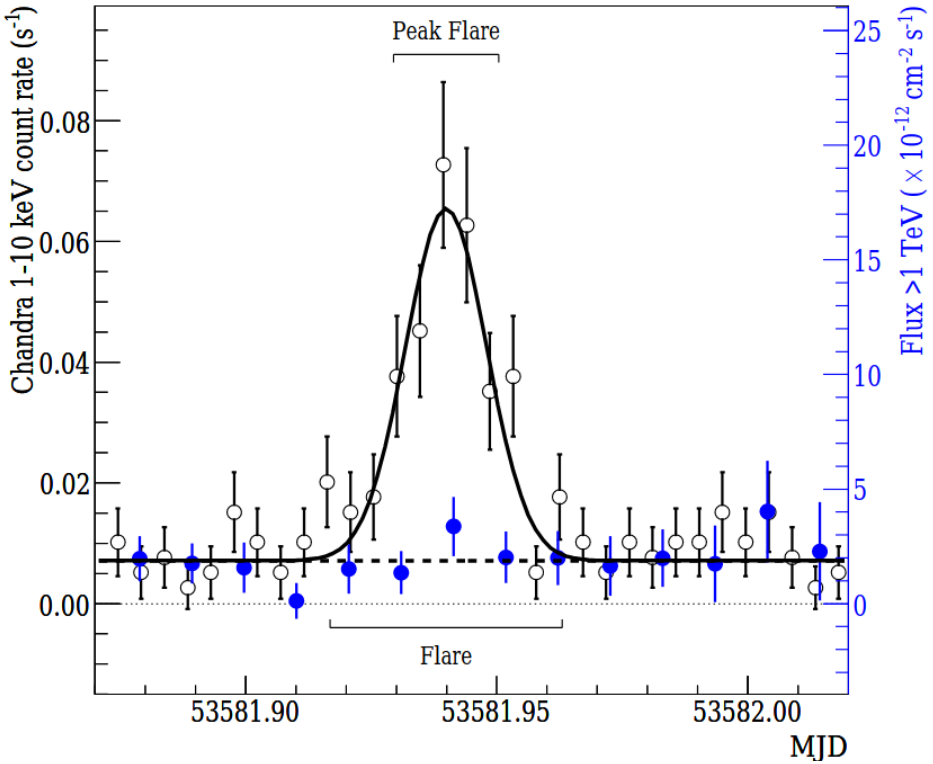


From Chandra powerful flare on September 14, 2013



SgrA* X-ray flare detected by Chandra on September 14th 2013. Haggard et al. 2019

Fast variability in gamma-rays ?

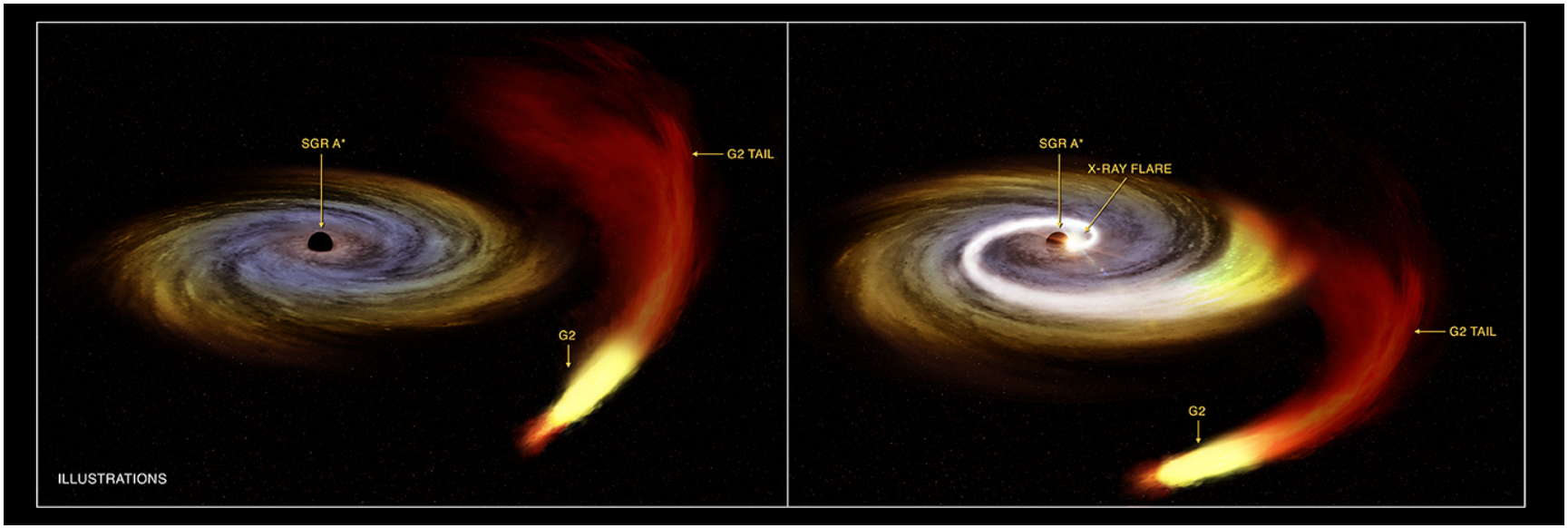


Result of a simultaneous H.E.S.S.-Chandra observation of SgrA*/HESS J1745-290 during a X-ray flare. Aharonian et al. 2008

So far no similar variability has been found for HESS J1745-290.

Long term variability

- The accretion flow isn't a constant process
- nearby objects can influence it and thus high energy emissions
- in 2012-2013 the near passage of a gas cloud motivated searches for an evolution of the emission from SgrA*

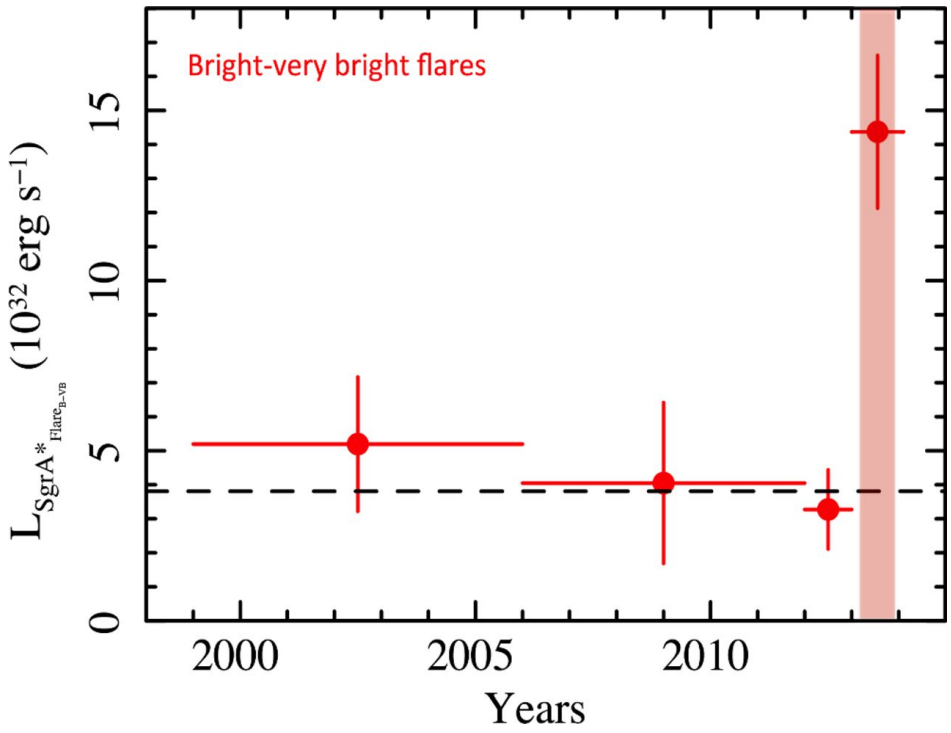


Representation of possible interactions between the G2 cloud and SgrA*. From Chandra

Long term variability - X-ray flares

For instance, bright flare rate in X-ray has significantly increased since 2013-2014

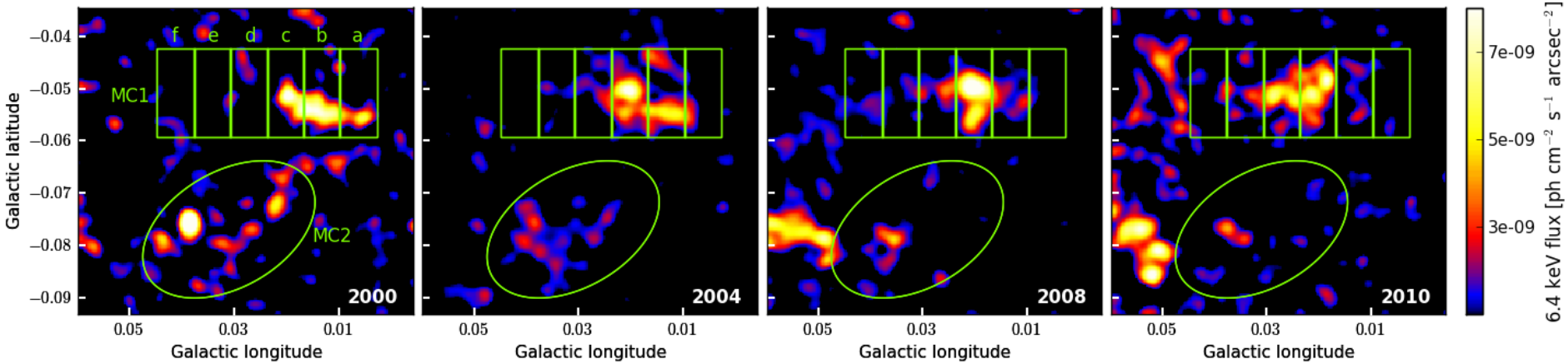
$\rightarrow$ the G2 cloud pericentre passage in 2013-2014 has been suggested as a possible cause



Evolution of the luminosity emitted as "bright flares" by SgrA*, the red period shows the G2 passage, from Ponti et al. 2015

Long term variability - X-ray echoes

Observed nearby X echoes suggest an outburst ($\times 10^5$) of activity in the Galactic Center about a 100 years ago (Clavel et al 2013, Churazov et al. 2017)



Fe Kα flux maps showing the evolution of the MC1 cloud near SgrA*, likely due to signal propagation in the cloud, from Clavel et al 2013

$\Longrightarrow$ If the activity of Sgr A* has evolved over the last decades, it is worth searching for gamma-ray flux over large time scales.

Goals

After recent work from VERITAS and MAGIC on the GC at VHE, we want to update H.E.S.S. findings on the HESS J1745-290 (spectrum, variability) with the latest data and techniques.

- **We want to test whether the emission from HESS J1745-290 is variable, in general and according to different evolution scenarios**
- in this work, we chose to study the year scale
- first we need an estimate of the spectra of the source HESS J1745-290, and of the diffuse emission, as well as spatial models for them (spectral and spatial shapes won't be allowed to vary with time)

Approach

Main problems :

1. time dependent systematic effects, due to variable observation time and change of instruments, and atmospheric conditions.
2. difficulty to estimate the background level in the region, since a diffuse emission dominates most of the central few degrees

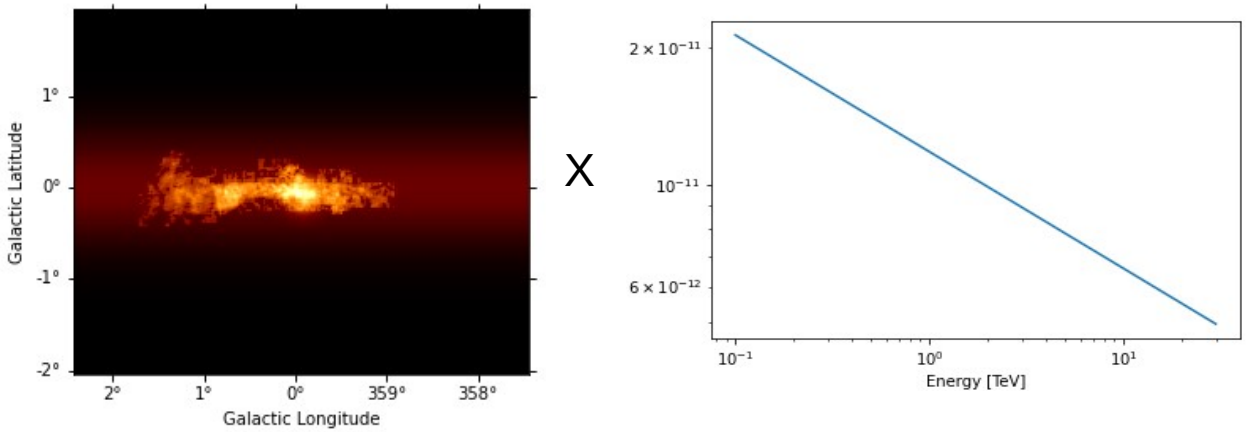
Solutions :

1. we use the diffuse emission to calibrate the central point source (time dependent systematic effects that impact both in a similar way should thus be removed)
2. need to rely on background *modeling* instead of direct estimation

$\Rightarrow$ A spectral-morphological (3D) analysis allows for both

Source model

Diffuse emission model



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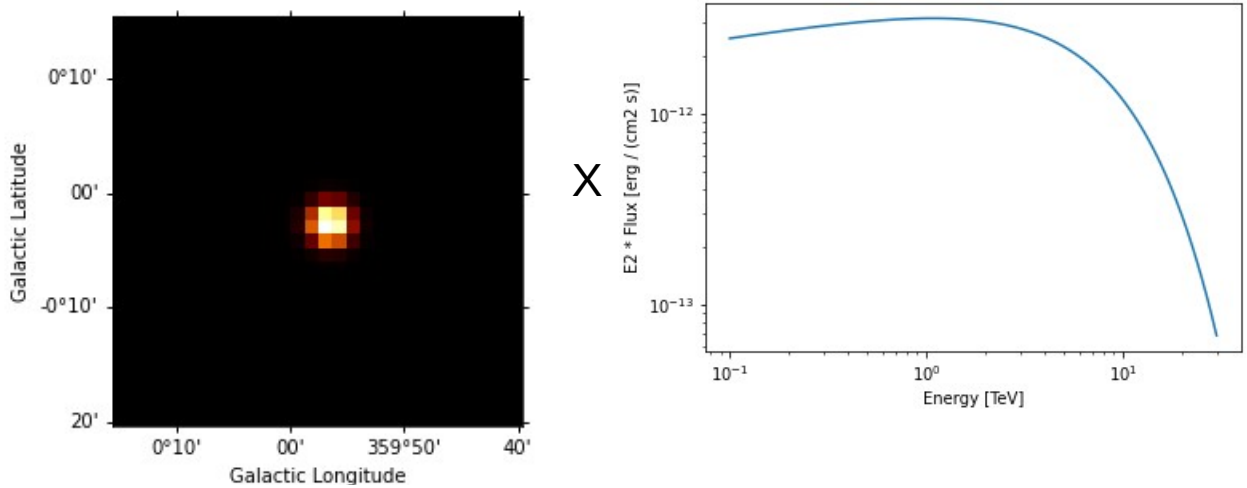
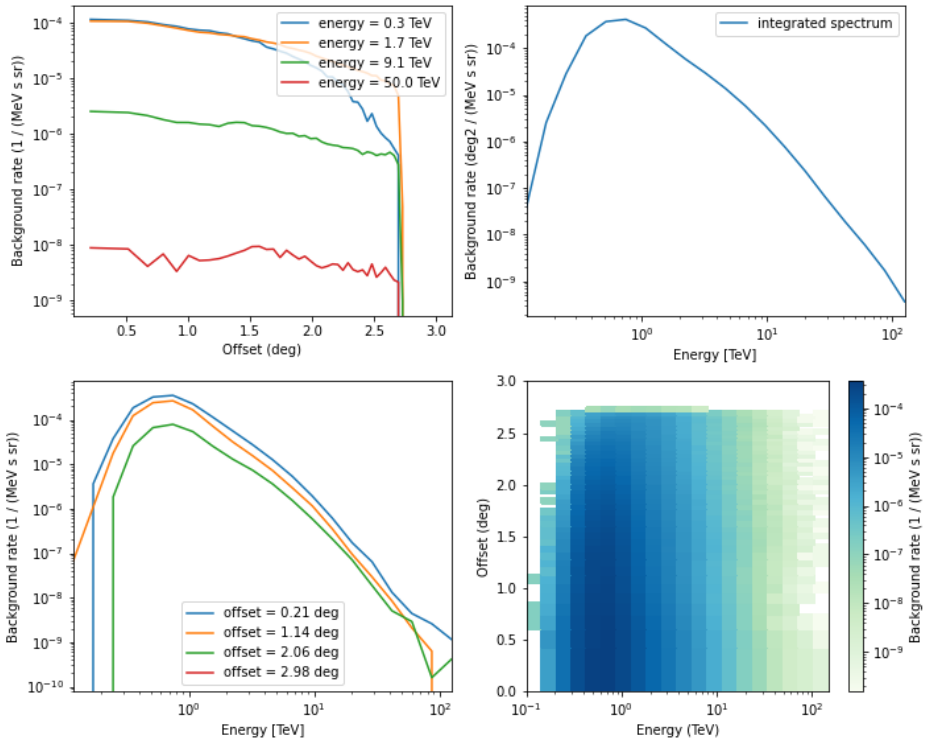
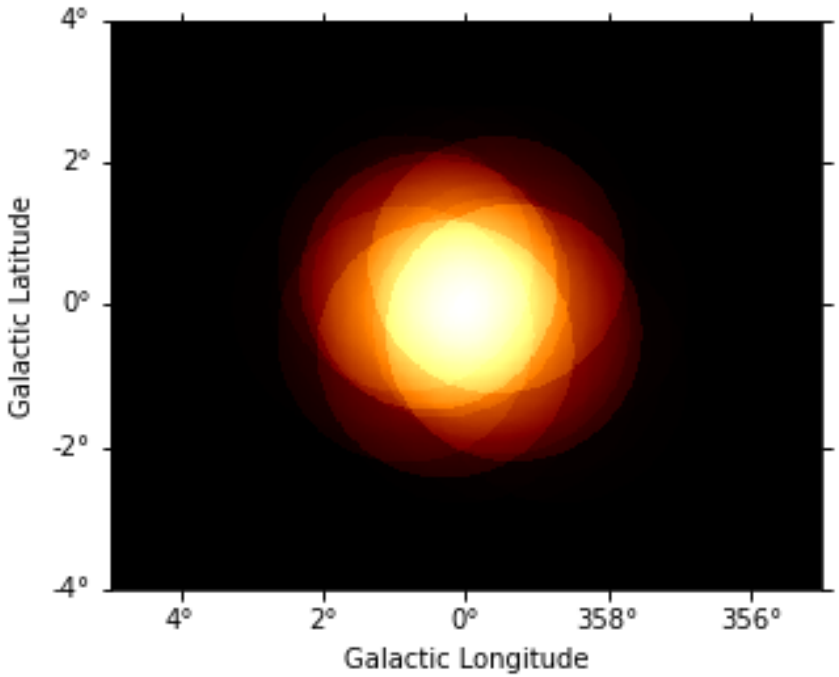
HESS J1745-290 model



Background modeling

Background models are created using observation runs on empty regions (high galactic latitudes), for an array of observational parameters, and then interpolated for each run.

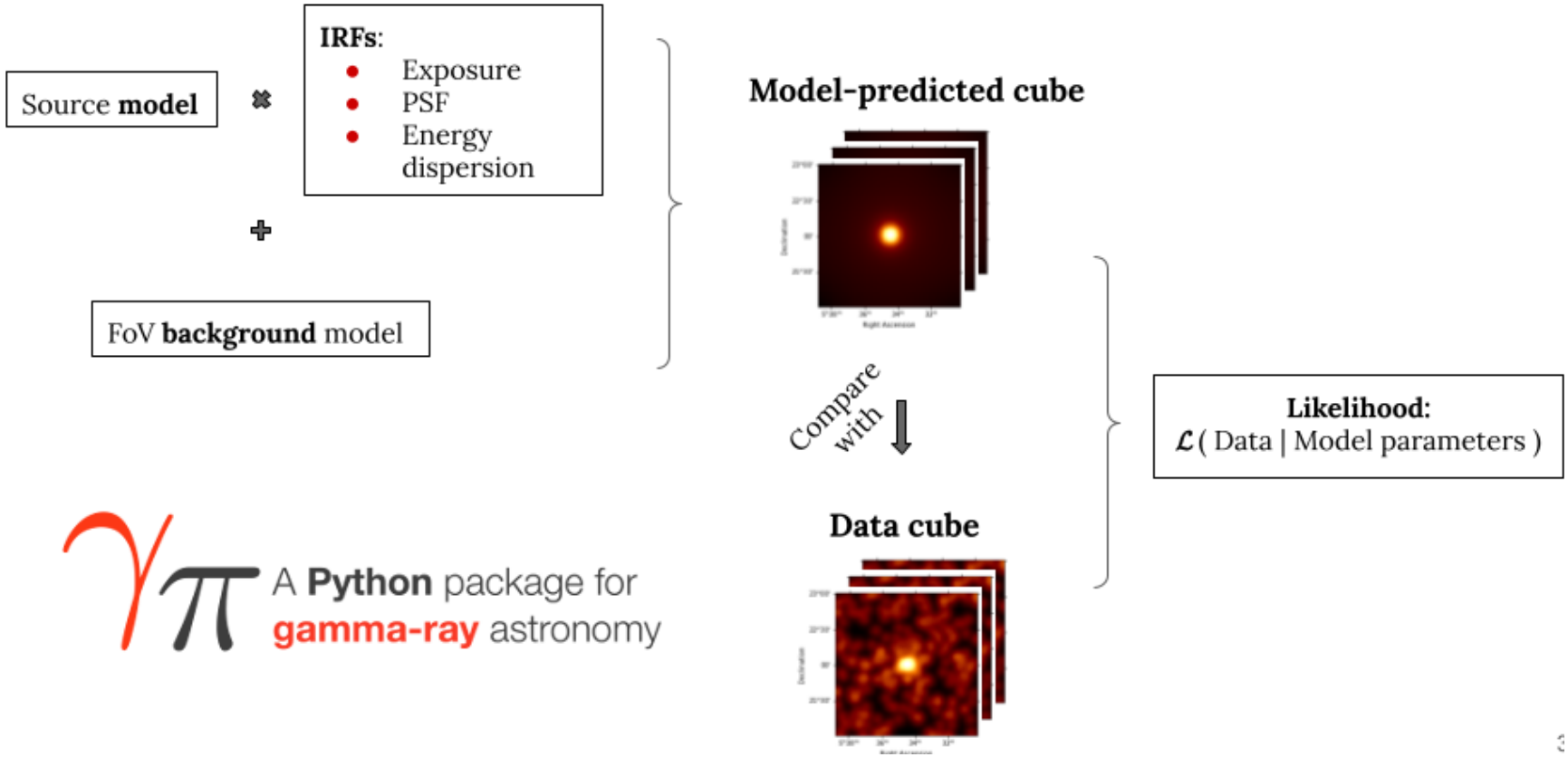




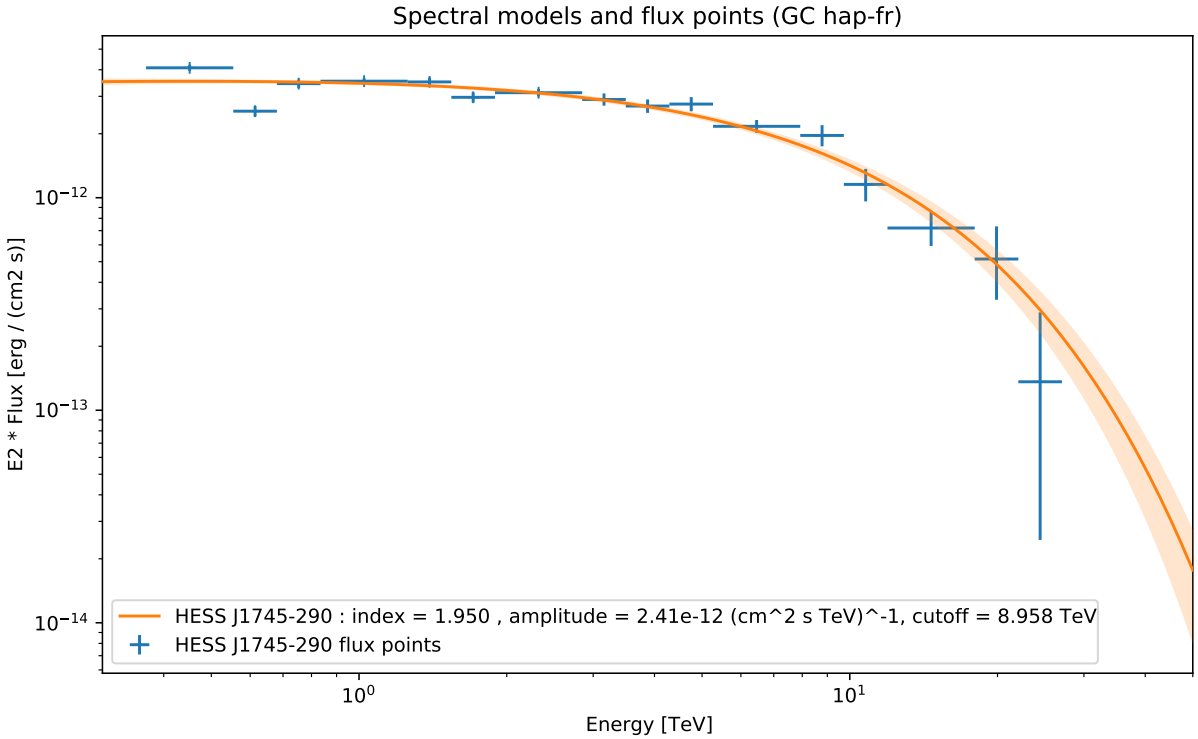
Left : background model for 1 observation run.
Right : Total background map

Spectral-morphological ("3D") likelihood analysis

data cube = spatial binning (2D) $\times$ spectral binning (1D)



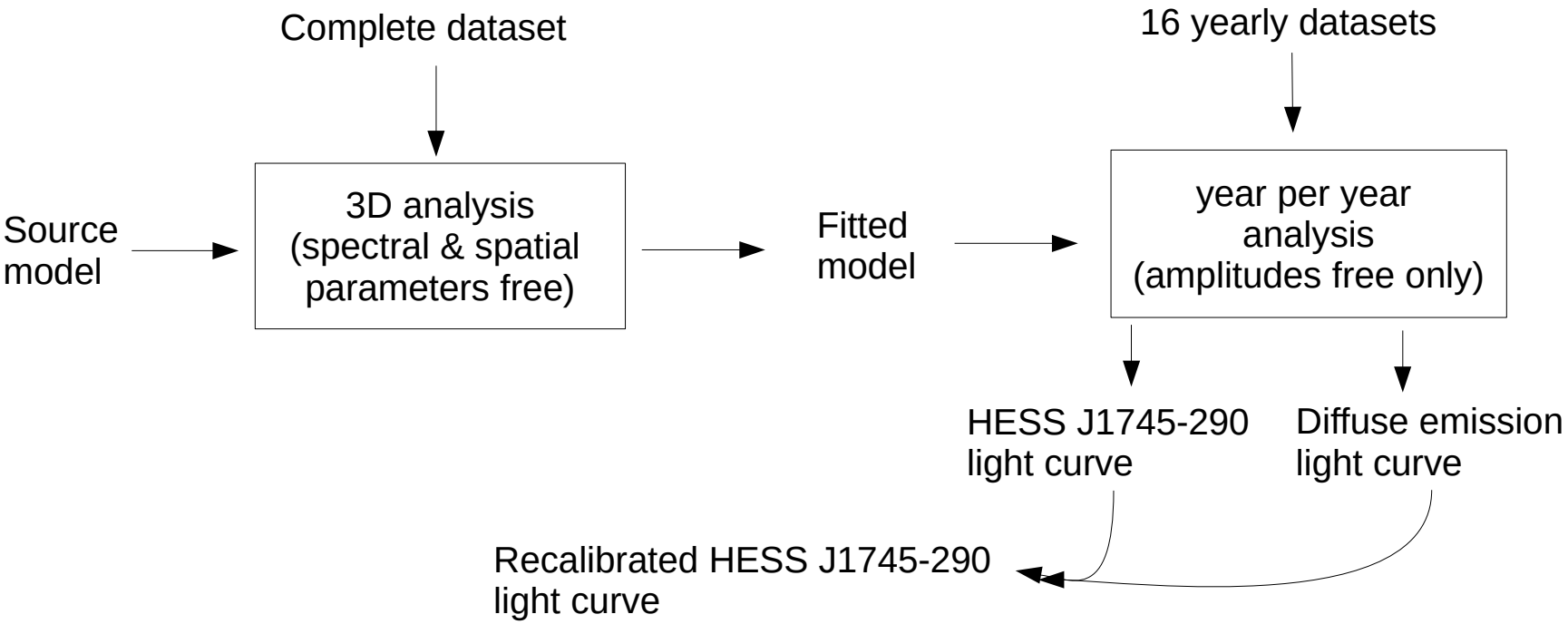
HESS J1745-290 intrinsic spectrum (**PRELIMINARY**)



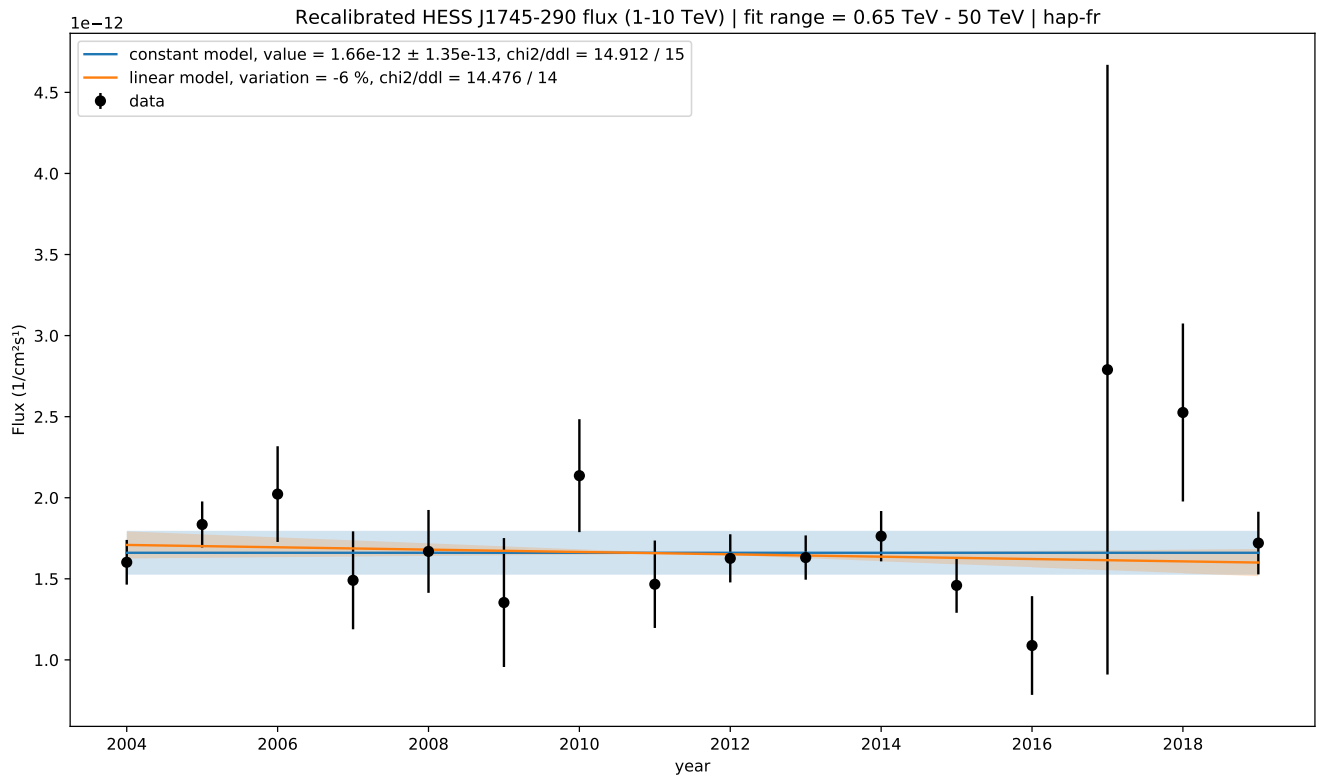
Intrinsic spectrum and flux point for the 3D fit of HESS J1745-290

Amplitude	$(2.41 \pm 0.06_{stat} \pm 0.3_{sys}) \times 10^{-12}$	$\mathrm{cm}^{-2}\ \mathrm{s}^{-1}\ \mathrm{TeV}^{-1}$
index	$1.95 \pm 0.03_{stat} \pm 0.1_{sys}$	
cutoff energy	$8.9 \pm 1.1_{stat} \pm 0.5_{sys}$	TeV

From the 3D analysis to the light curves



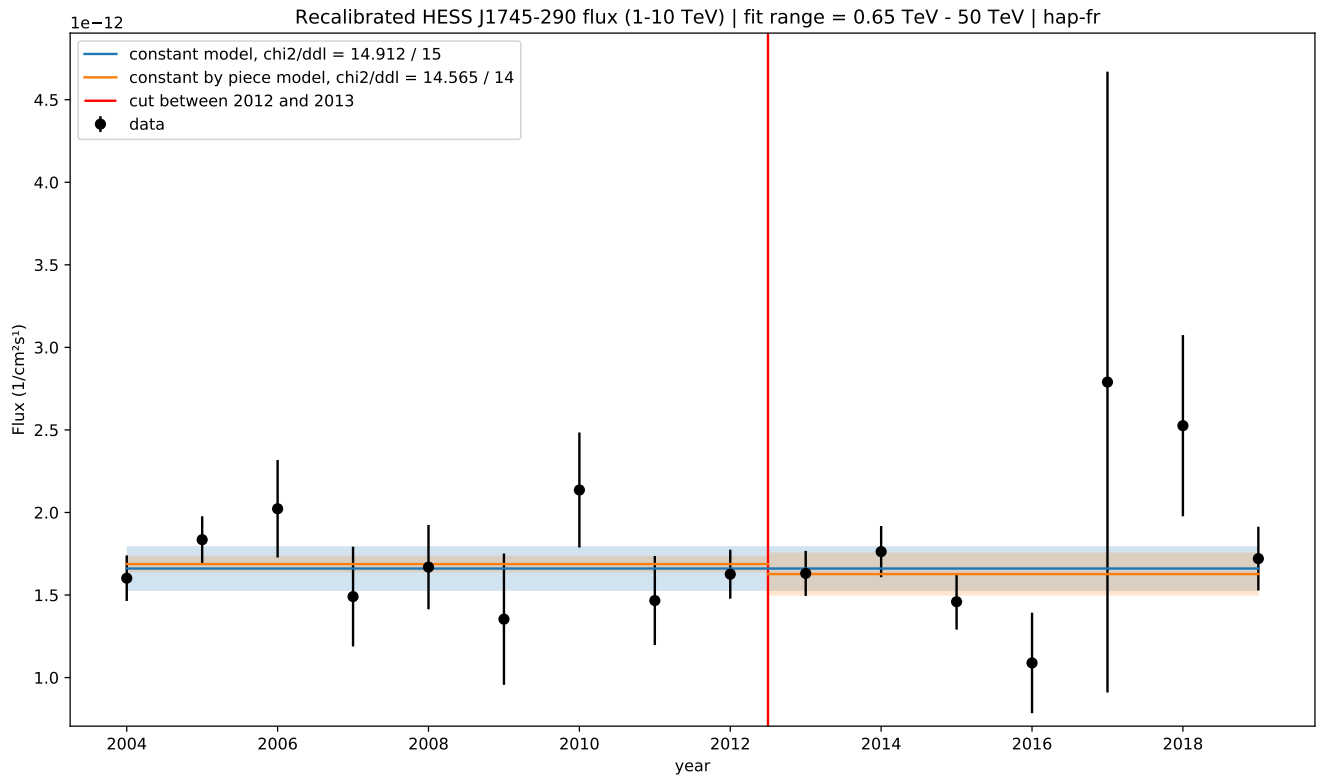
HESS J1745-290 long term evolution (**PRELIMINARY**)



Light curve of HESS J1745-290, re-normalized by the diffuse emission

$\rightarrow$ Best fit is a constant model, preferred to linear variation model

HESS J1745-290 long term evolution (**PRELIMINARY**)



Light curve of HESS J1745-290, re-normalized by the diffuse emission

$\rightarrow$ No sign of variations at the time/after the passage of the G2 cloud in 2012-2013

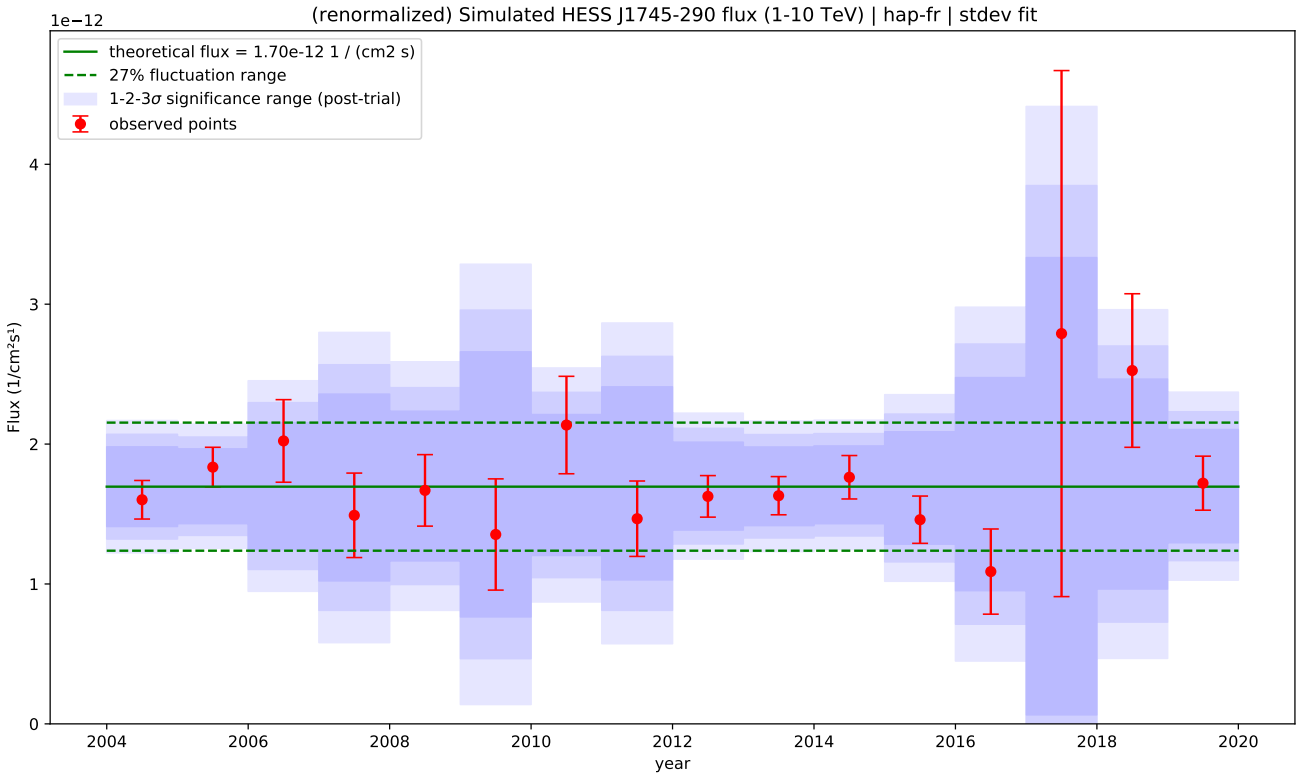
H.E.S.S. sensitivity study with gammapy

- Gammapy allows to simulate maps from any theoretical model (random Poissonian process)
- by inputing a given time evolution model, we can estimate the range of statistical (non-significant) fluctuations around it

We want to test :

- Fluctuations around a *constant time model*
- Fluctuations around various *linear variation models*, to see which would have implied a detection by H.E.S.S. (but haven't)

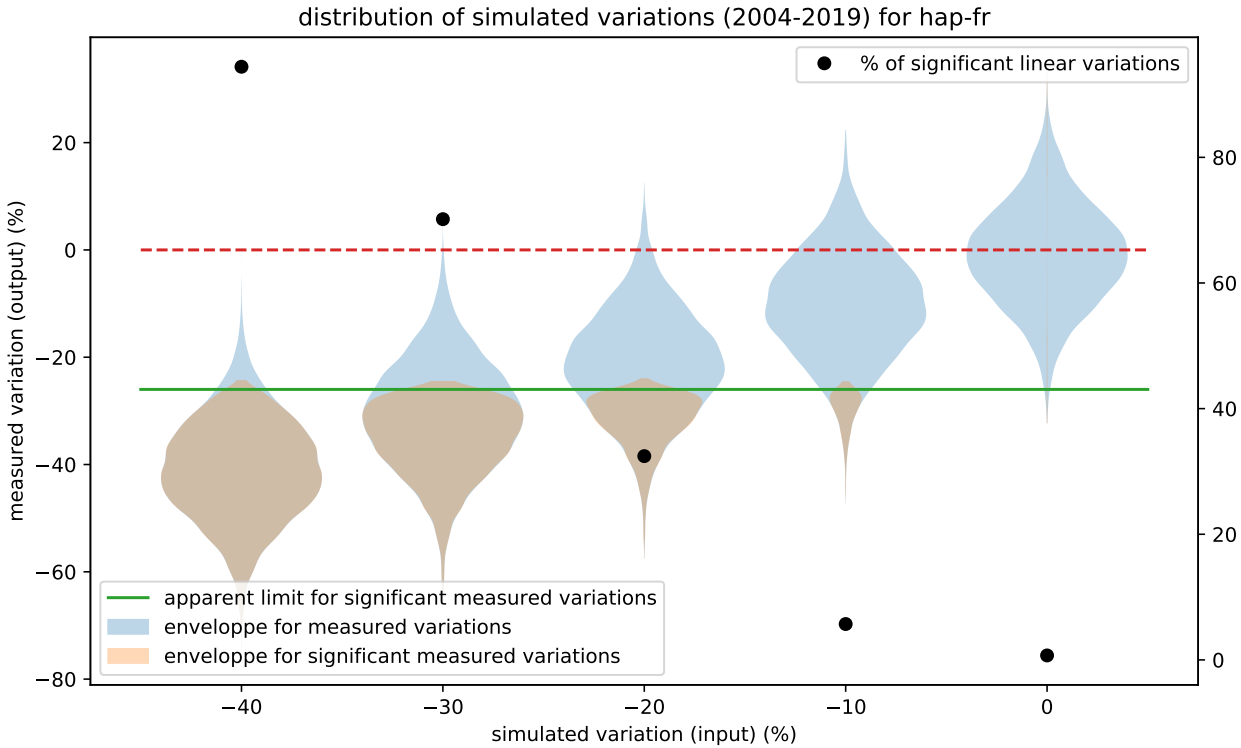
H.E.S.S. sensitivity to yearly variability (**PRELIMINARY**)



Fluctuation range for a constant HESS J1745-290 source

→ Smallest year-to-year variation detectable is ∼ 25-30% of 16-year average.

Sensitivity to linear variations (**PRELIMINARY**)



Results of 5 simulations with different theoretical variations, and their outcomes

$\rightarrow$ intrinsic linear variation of $< 25\%$ over 16 years cannot be significantly detected

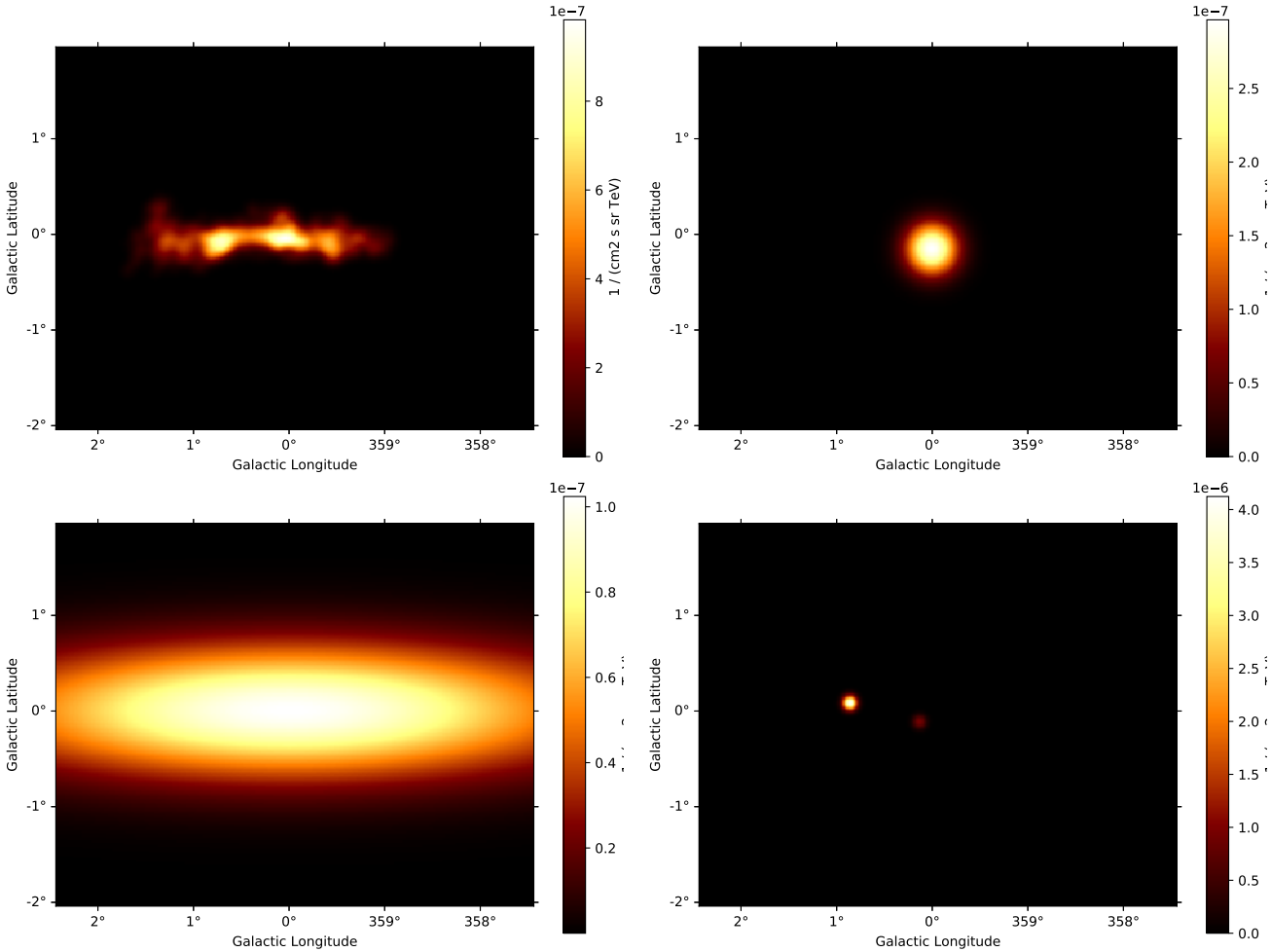
Conclusions

- We implemented the first 3D analysis of HESS J1745-290 flux
- 3D analysis allows an re-estimation of spectral parameters
- No evidence for yearly variability found
- No evidence for linear variation over 16 years either
- No evidence for variation concomitant with the G2 passage
- Study of the sensitivity to variations of H.E.S.S shows that yearly flux variations lower than 25% have not yet been ruled out
- Linear variations of more than 25% over the last 16 years are likewise ruled out

Thank you for your attention

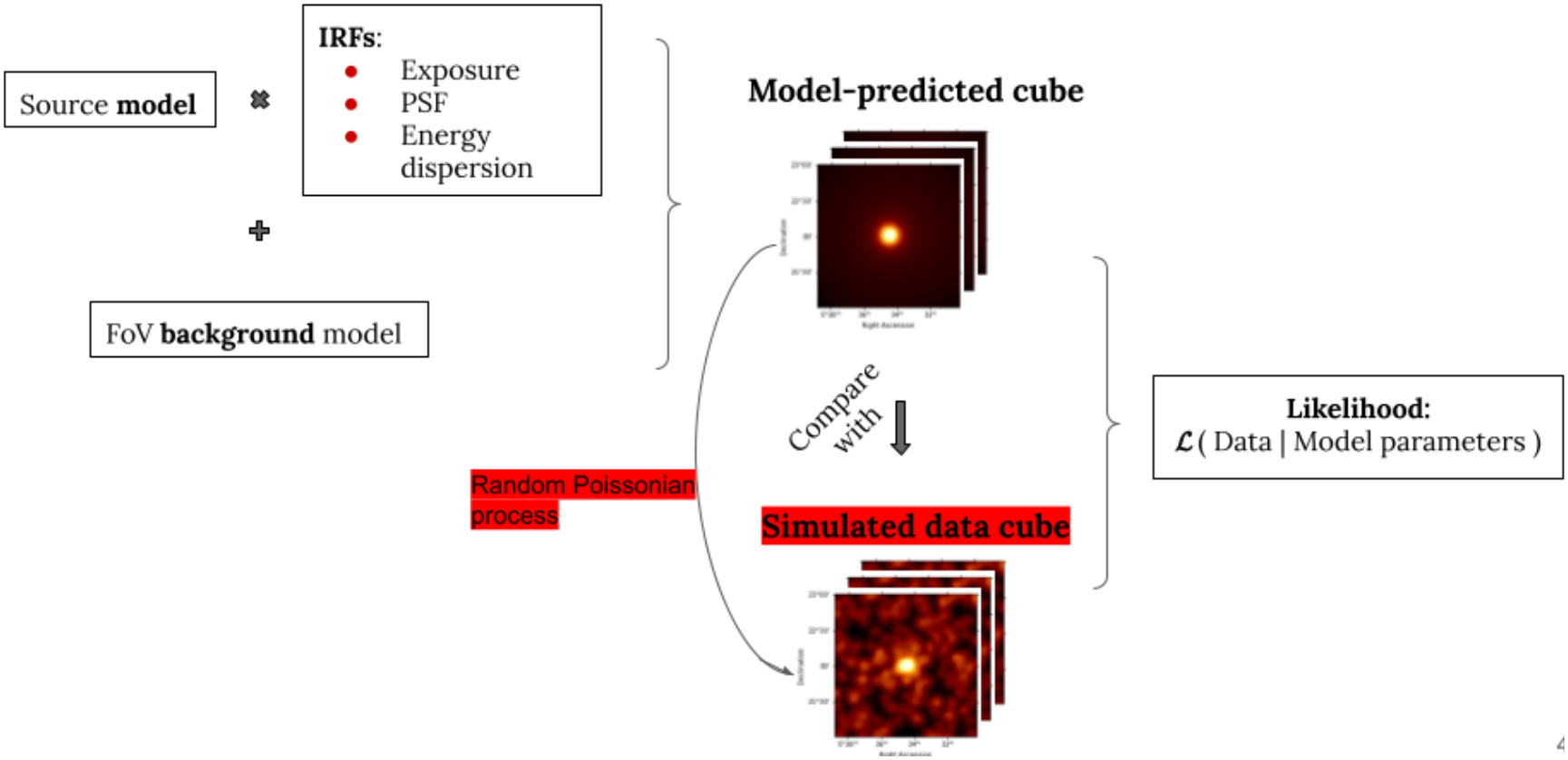
Backup

Spatial diffuse emission model



We update the previous ad hoc description for the DE (from H.E.S.S Collaboration 2018) overhauled for a 3D modeling and the extra data.

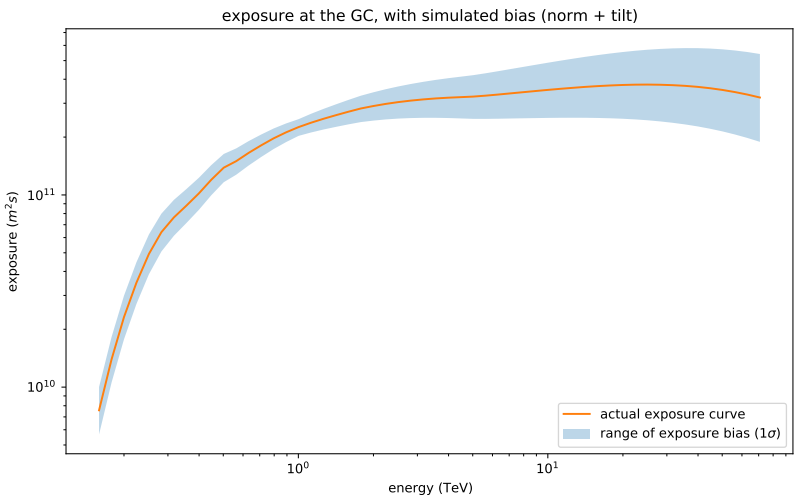
Monte-Carlo simulations with gammapy



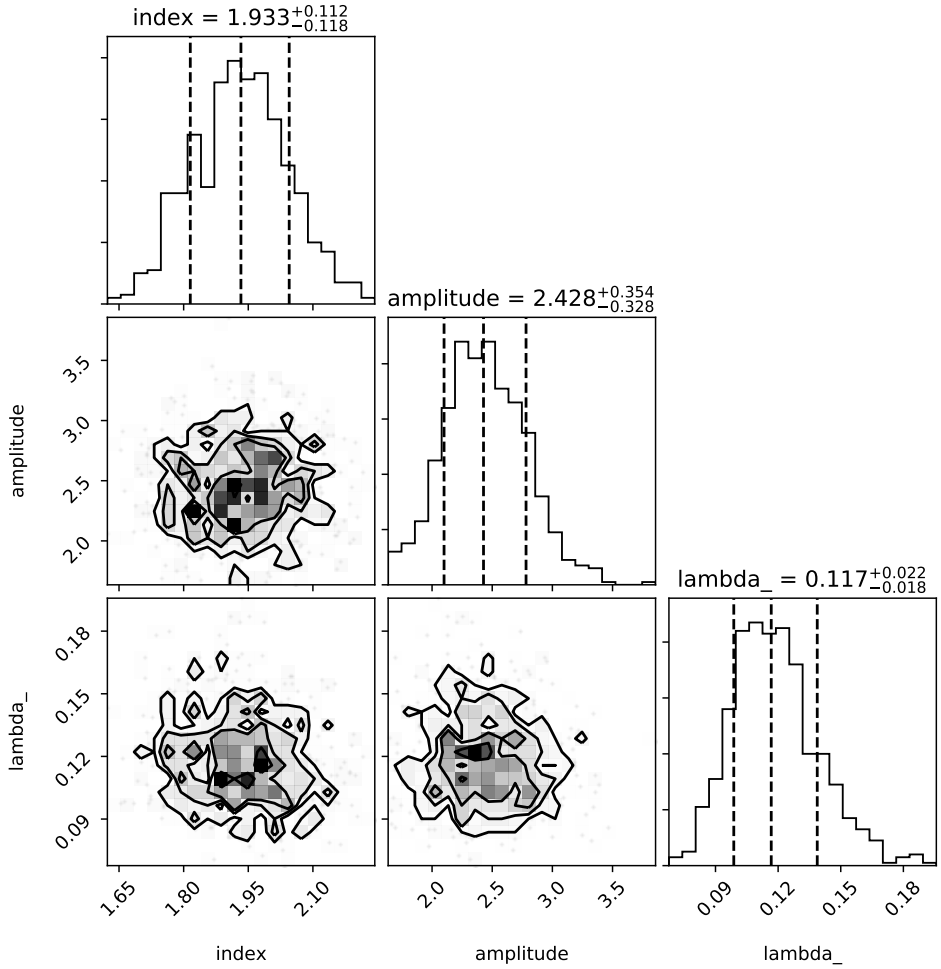
Systematic errors estimation

Effects simulated :

- energy bias
- effective area bias (norm and tilt)
- background bias (norm and tilt)

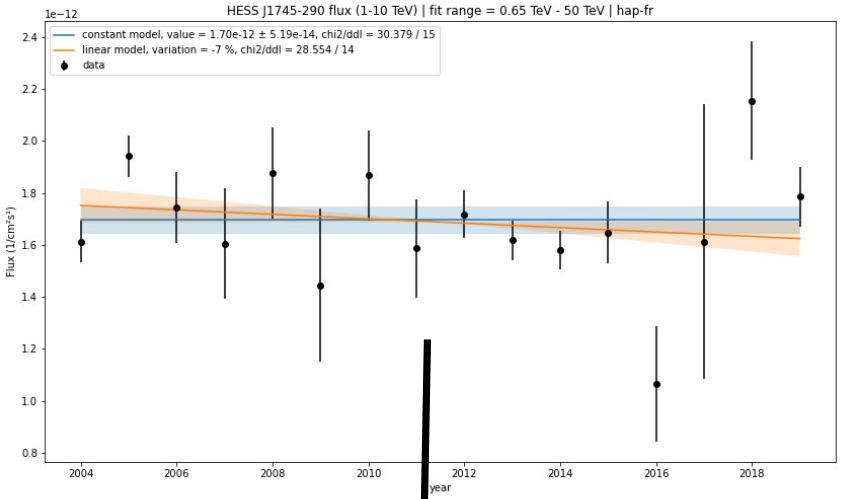


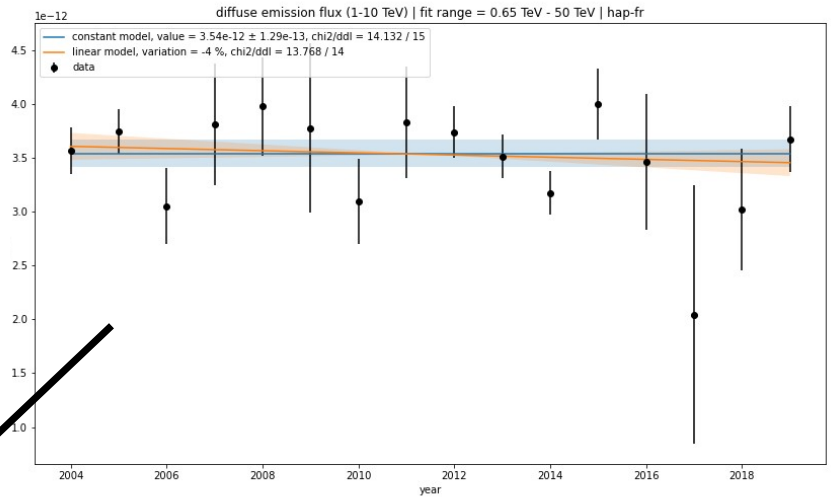
Range of bias on effective area (via exposure)

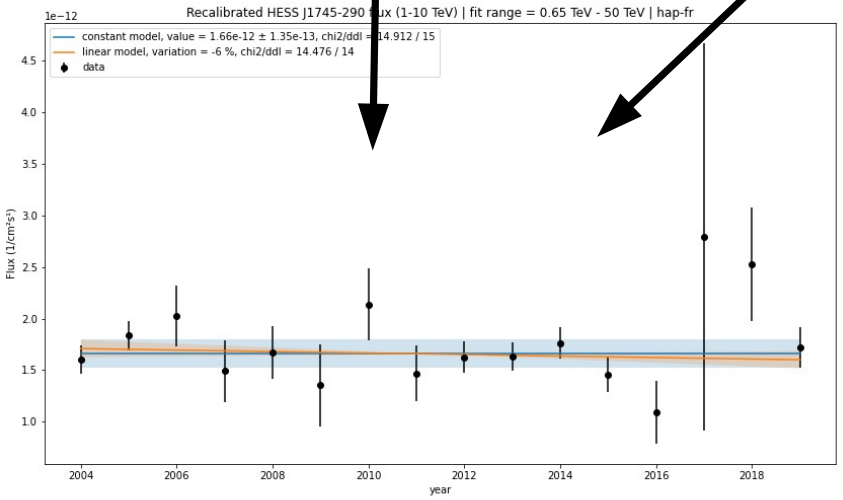


Distribution of fluctuations of parameters, index, amplitude, and $\lambda = 1/E_{cutoff}$

Re-calibration of HESS J1745-290







$$LC_{GC\ recalib}(t) = (LC_{GC}(t)/LC_{diff}(t)) * Ref\_Flux_{diff}$$

$$Ref\_flux_{diff} = avg(LC_{diff})$$