THE JOINT-CRAB PROJECT: TOWARDS OPEN AND REPRODUCIBLE MULTI-INSTRUMENT ANALYSIS IN GAMMA-RAY ASTRONOMY

Workshop on Open-Source Software Lifecycles

C. Nigro [cosimo.nigro@ifae.es] on behalf on the authors in A&A 625, A10 (2019)

27 July 2020

γ-ray Data Format and Science Tools

> **Until early 2010s**

> gamma-ray telescopes operated as **experiments**;

   $\rightarrow$ small collaborations (~ 100) with private data and tools (*Fermi*-LAT exception);

> neither data format nor software shared between instruments;

   $\rightarrow$ data combination $\rightarrow$ custom expansion of private software,
   $\rightarrow$ no legacy data w/o legacy software;

> `ROOT` for data and science tools (*Fermi*-LAT exception).

> **Late 2010s and beyond**

> Next-generation Cherenkov telescopes (CTA) operated as **observatory**,

   $\rightarrow$ large collaboration (~ 1000), data open to the astronomy community;

> community-started effort to define a common data format for IACTs:
Data formats for gamma-ray astronomy forum

   $\rightarrow$ github repo containing `sphinx` documentation, discussion via issues and PRs;
   $\rightarrow$ observations reduced to list of γ-ray events $+$ instrument response
      stored in `FITS` files ($\sim 100 \, \text{kB}$ for $\sim 30 \, \text{mins}$);
   $\rightarrow$ space instruments data adaptable to this scheme.

> open-source science tools developed: `gammapy`, `ctools`;

> `FITS` for data, `python` (or `C++` w/ `python` API) for science tools.

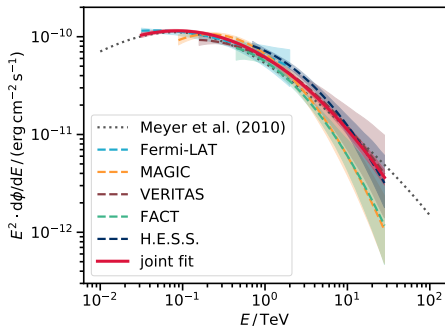# The joint-crab project

> Converted current γ-ray data to this preliminary common format, performed the first **fully-reproducible multi-instrument** gamma-ray analysis;
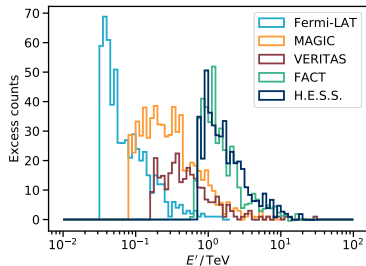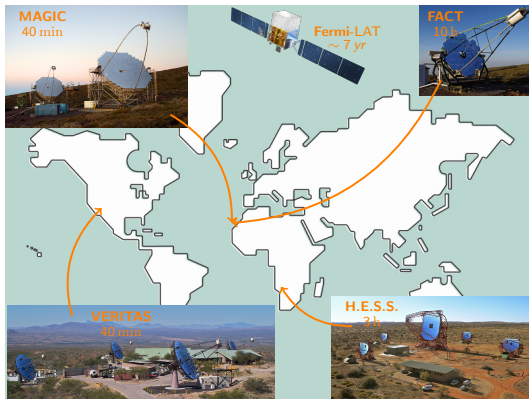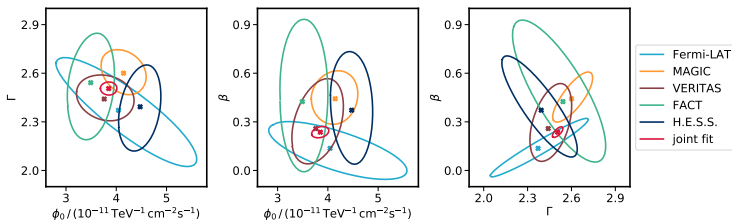

> open-access tools for analysis (gammapy) and dissemination (github, docker, zenodo), check Thomas' talk;

> published in Astronomy and Astrophysics!

Results

> **First Crab spectrum** combining data from *Fermi*-LAT and **all the operating Cherenkov telescopes**.

> $\frac{d\phi}{dE} = \phi_0 \left(\frac{E}{E_0}\right)^{-\Gamma + \beta \log_{10}\left(\frac{E}{E_0}\right)}$;

Conclusions

> **Multi-instrument, reproducible** γ-ray analysis are already possible;

> two papers published using data in this same format (A&A 632, A102 (2019), A&A 632, A72 (2019));

> FITS format starting to be used for science projects within and between IACT collaborations;

> A novel approach: