Joint Crab: towards an open source, reproducible gamma-ray astronomy

C. Nigro[1]

[1]DESY Zeuthen

coding sprint 2018, MPIK Heidelberg

Introduction

The joint-crab project

- combined analyses (Fermi + IACT, IACT + IACT) already exist
  - → no standard format
  - → case-by-case analysis method (= hacking / new implementations of collaboration softwares)
- joint-crab is the first Crab Nebula spectrum with Fermi, MAGIC, VERITAS, FACT, HESS event lists
- joint-crab intends to be the **first fully reproducible multi-intrument VHE analysis**!
- **no scientific paper**, purpose is:
  - → attract interest in DL3 activities in IACTs
  - → continue the effort started with Data formats for gamma-ray astronomy

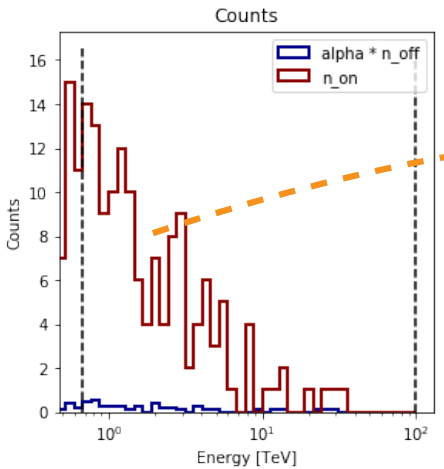
How is reproducibility achieved?

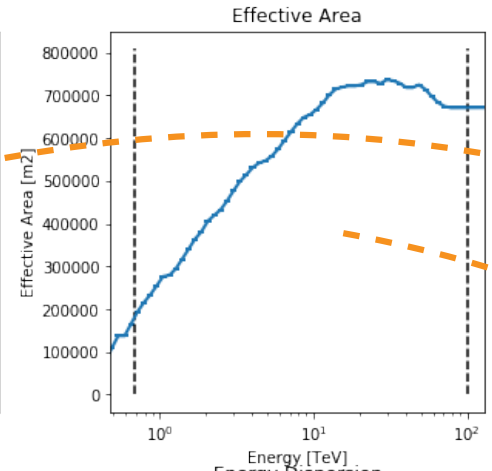
- open source code used for the analysis: `gammapy` + `sherpa`
- all the code will be publicly available in https://github.com/gammasky/joint-crab
- the size of the data is $\sim$ MB, can be provided along with the code in github
- packages managed via `anaconda` environment
- it may happen that the `conda` virtual environment is not enough to guarantee reproducibility, a Docker container will be provided on Docker Hub
- long term archiving (journal, data center)?

Analysis

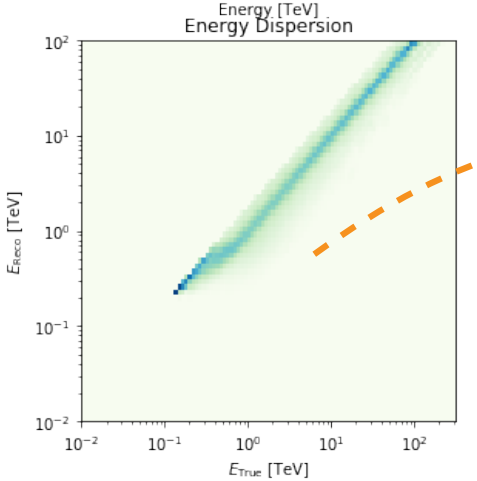
The analysis

- analysis method: **simple 1D analysis** (standard in IACT), ingredients:






```
*** Observation summary report ***
Observation Id: 23523
Livetime: 0.439 h
On events: 139
Off events: 44
Alpha: 0.091
Bkg events in On region: 4.00
Excess: 135.00
Excess / Background: 33.75
Gamma rate: 0.13 1 / min
Bkg rate: 0.00 1 / min
Sigma: 22.28
energy range: 0.68 TeV - 100.00 TeV
```



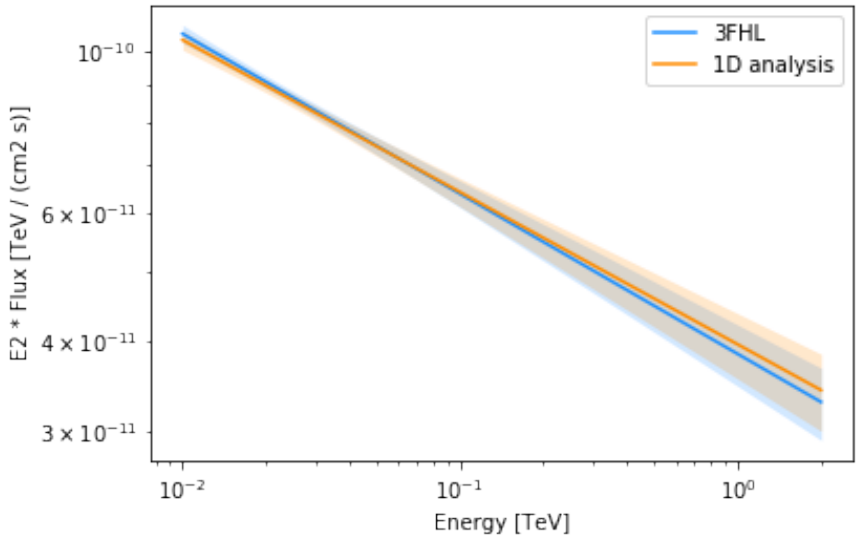
signal, bkg counts vs energy

energy dependent IRFs

- OGIP files produced to be used with `sherpa`

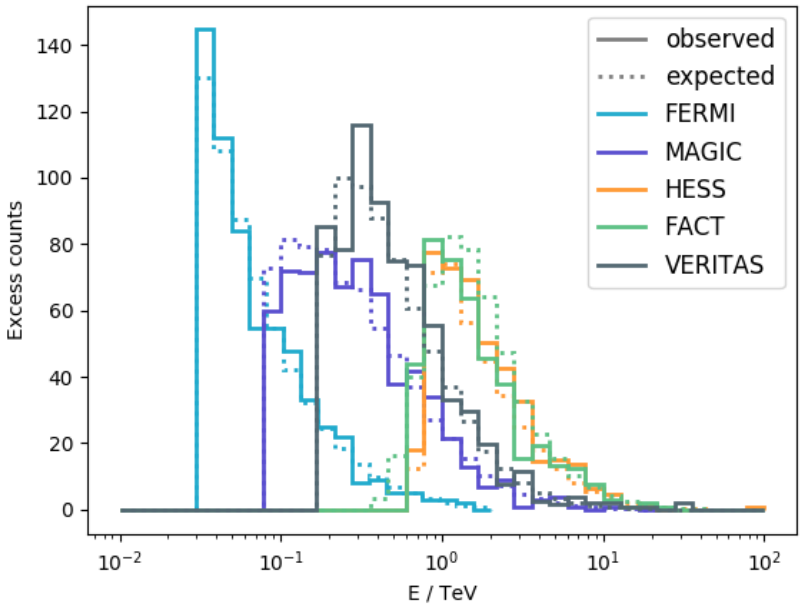
Fermi-LAT 1D analysis

- 3FHL event list
- $N_{\rm ex}$ estimated via **ring background**
  - → 0.3 deg On region
  - → $[1, 2]$ deg ring Off region
- exposure @ Crab position (`gtexpcube2`) PSF corrected $\sim A_{\rm eff} \times t_{\rm eff}$
- spectral distortion less than 5% at these energies $\approx$ EDISP with bias 0 and dispersion 0.05



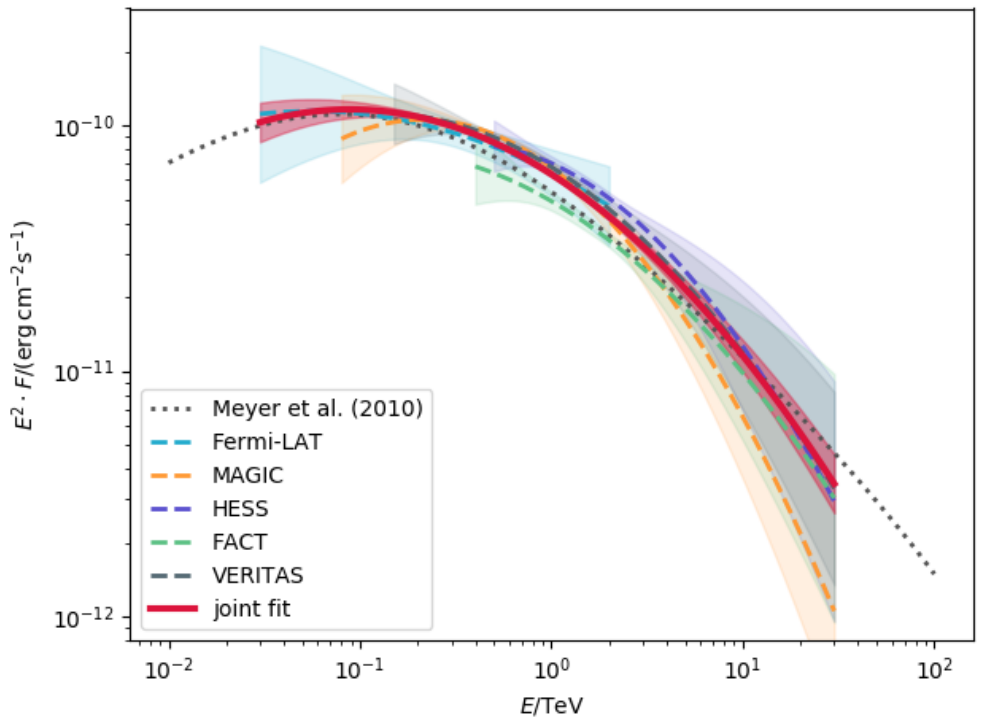
Datasets

- first (Fermi + MAGIC + VERITAS + FACT+ HESS) combined analysis (@ event list level)
  - → 3FHL event list + E > 30 GeV (avoid contamination from Pulsar)
  - → 2 MAGIC runs (∼ 40 mins) from 2013 (used for post-upgrade performance paper)
  - → 4 HESS runs from DL3 public data release 1
  - → FACT data from their already public Crab data release
  - → new! VERITAS data being finalized...



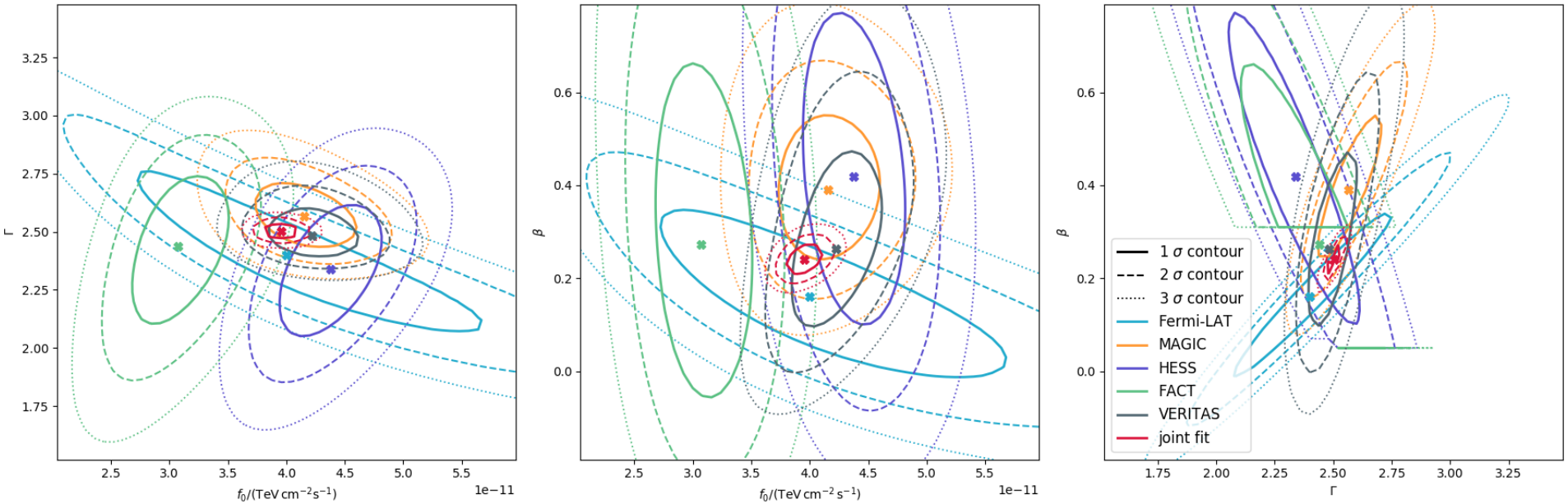
Spectrum

- log-parabola fit: $\frac{d\phi}{dE} = f_0 \times (\frac{E}{1\,TeV})^{-\Gamma+\beta\times\log(E/(1\ TeV))}$



- a fit with naima can also be performed (physical instead of analytical function for flux)

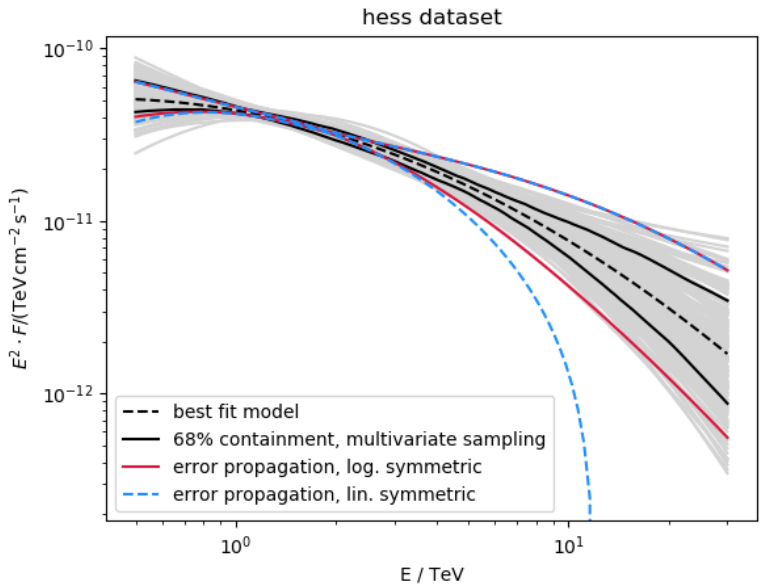
Parameters contours

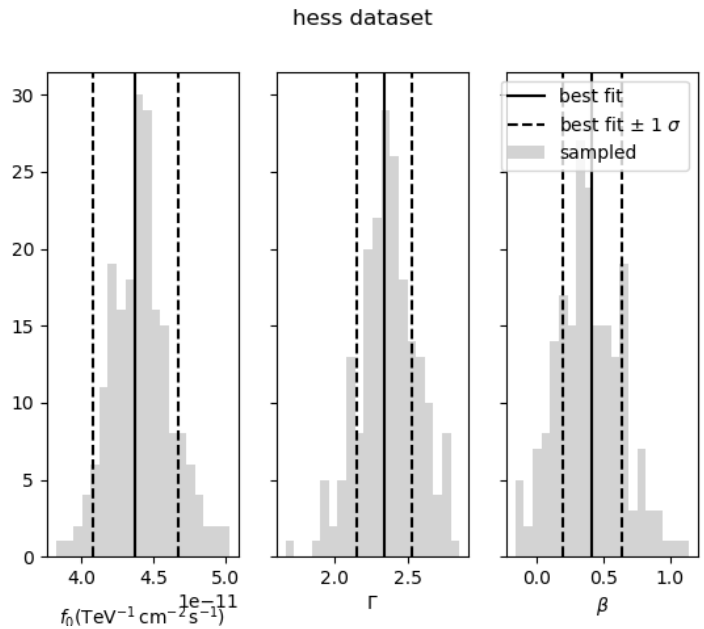


About this coding sprint...
(“what do you want from us?”)

A possible to-do list (`joint-crab` → `gammapy`)

- there are some features that I have already implemented in the `joint-crab` project and that can be useful and already integrated in `gammapy`:
  - → 1D spectrum extraction for *Fermi*-LAT data
    discussion in issue #7
  - → better evaluation of the flux vs energy error band (butterfly) via multivariate sampling (instead of error propagation)
    discussion in issue #58





A possible to-do list (gammapy → joint-crab)

- there are features that would help us in the paper and are not yet implemented
  - → GTI handling for the event lists
    discussion in issue #57
- there are some issues open in our project, looking into them usually helps us to spot problems in gammapy
  - → results still differ when using gammapy's SpectrumFit or sherpa
    discussion in issue #71
  - → we have broken likelihood contours in sherpa
    discussion in issue #50

Action!

- this project is a big opportunity to test `gammapy` on real data, from all the existing gamma-ray instruments!
- talk to me or Cristoph if you want to help with any of this issues / features