Searches for Fast Transients with MAGIC

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on behalf of the MAGIC Collaboration

29 June 2018
Astrophysics + MAGIC @ La Palma

MAGIC Transient Physics

MAGIC
Major Atmospheric
Gamma Imaging
Cerenkov Telescopes

- MAGIC Telescopes
- MAGIC Transients Programs
  - **Gamma-Ray Bursts**
  - **Gravitational Wave follow-up**
  - **Neutrino ToO**
  - **Fast Radio Bursts**
  - **TDE, novae, etc.**
- Summary & Future

MAGIC Telescopes

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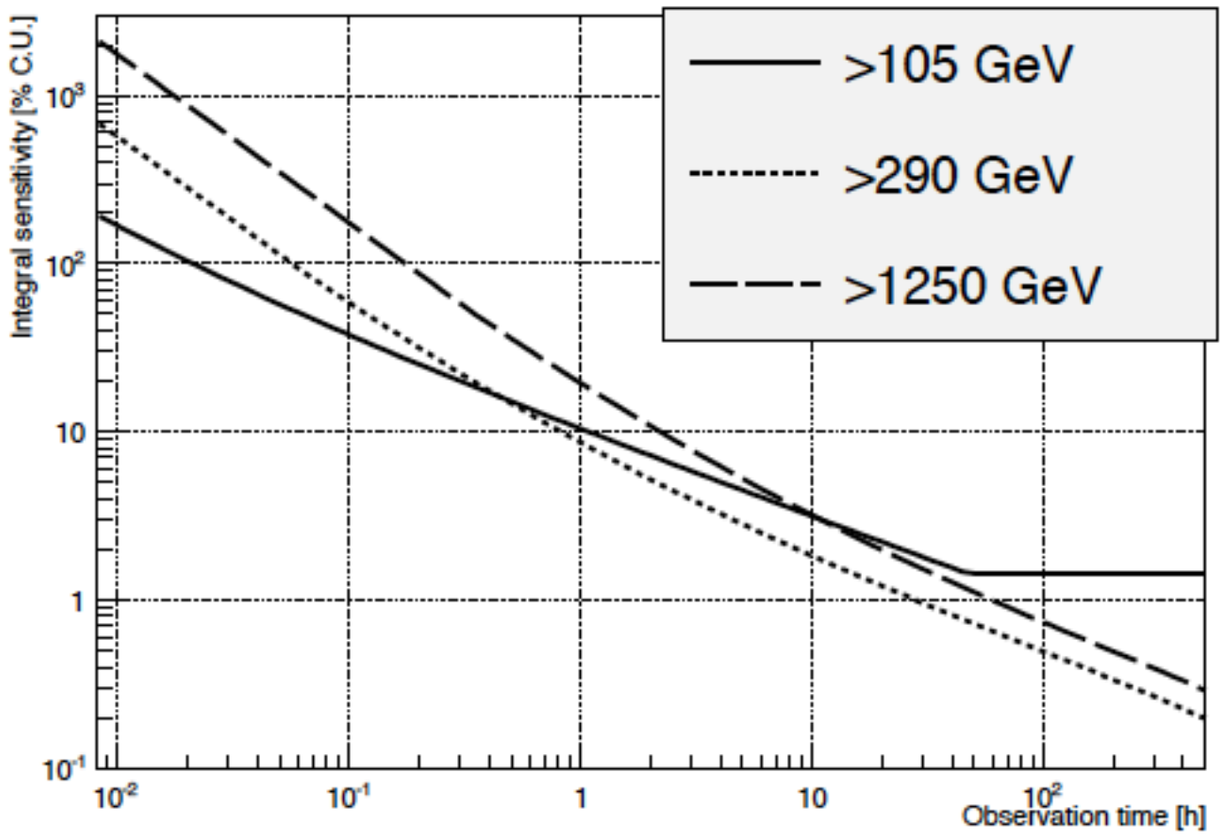
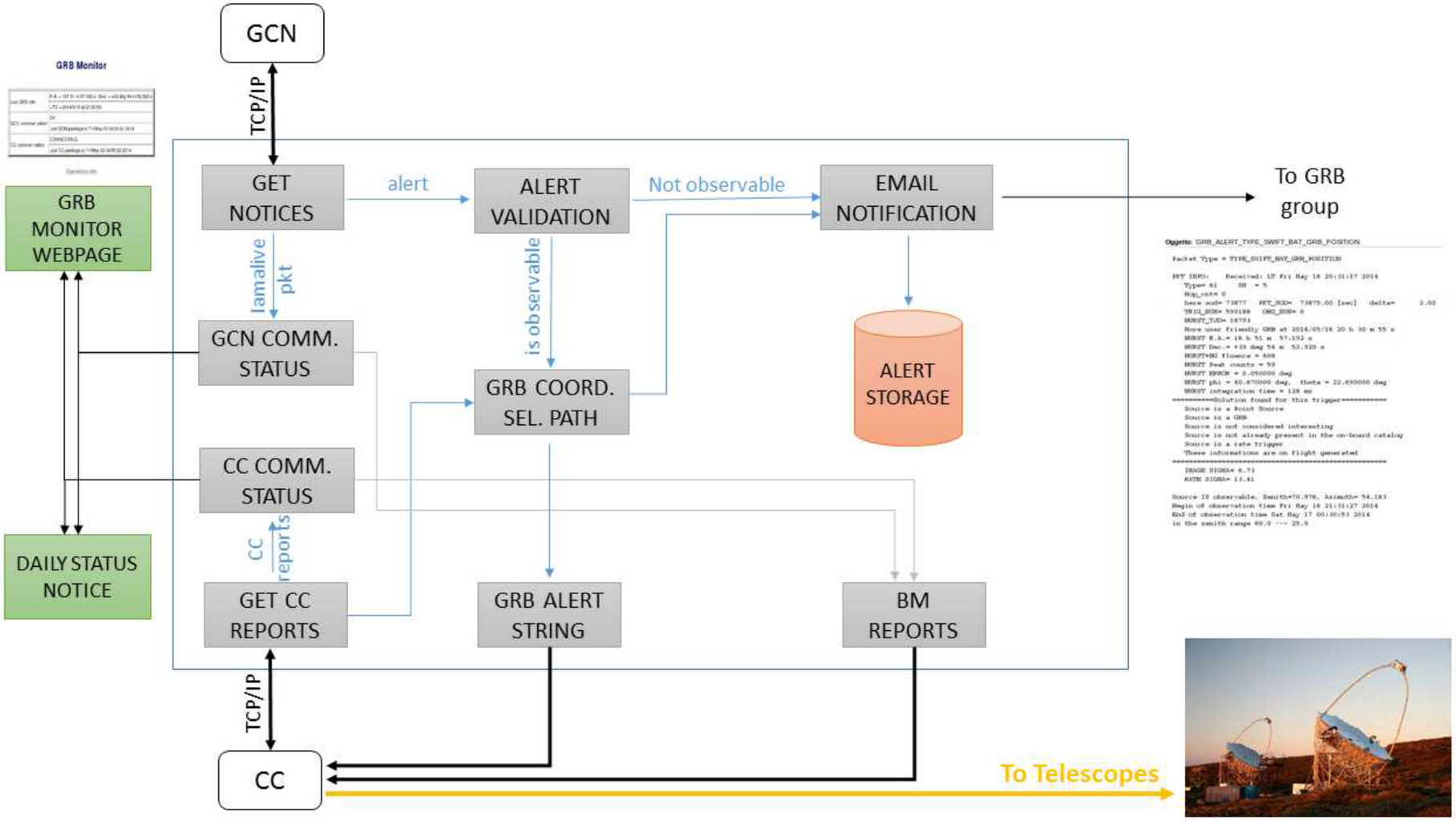
- Stereo system since 2009
- Field of view: 3.5 deg
- **Energy threshold: 50 GeV (30 GeV with Sum-Trig)**
- **Sensitivity: 0.7% Crab > 220 GeV in 50 h (10% Crab > 100 GeV in 1 h)**
- Energy resolution: 15% (@1 TeV), 24% (@100 GeV)
- Angular resolution: 0.06 deg (@1 TeV), 0.1 deg (@100 GeV)
- **Light-weight structure: 70 t**
- **Fast repositioning: 7 deg/s (4 deg/s in std mode)**



MAGIC for transients

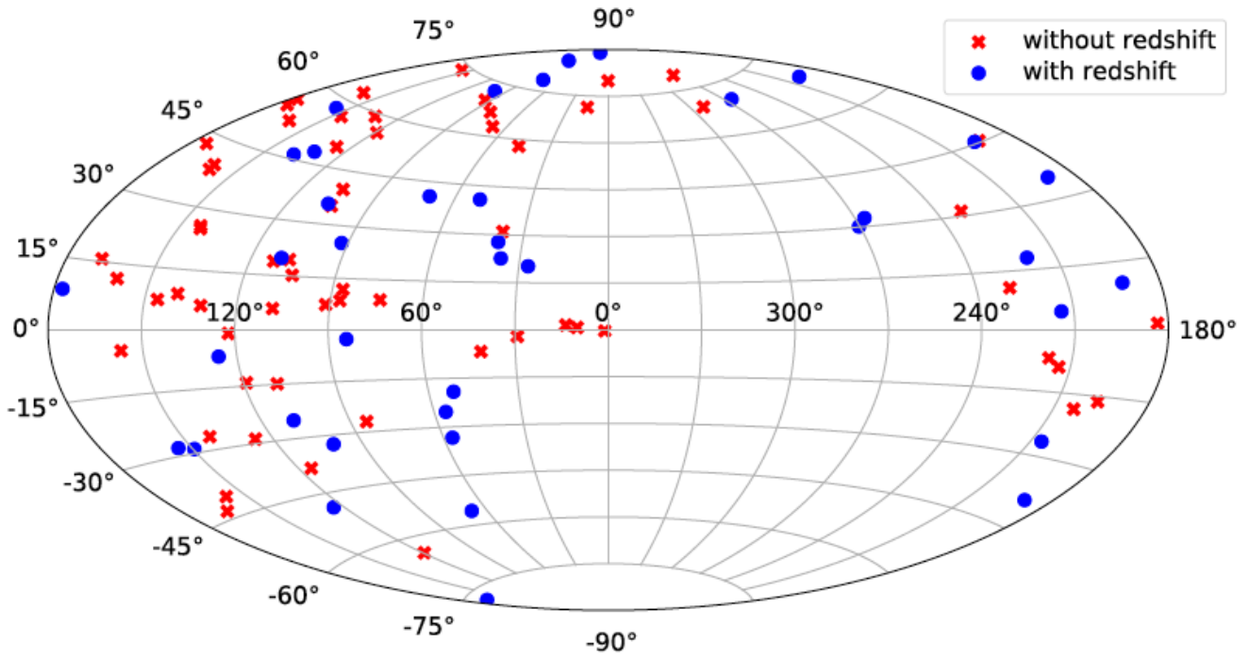
Automatic alert system

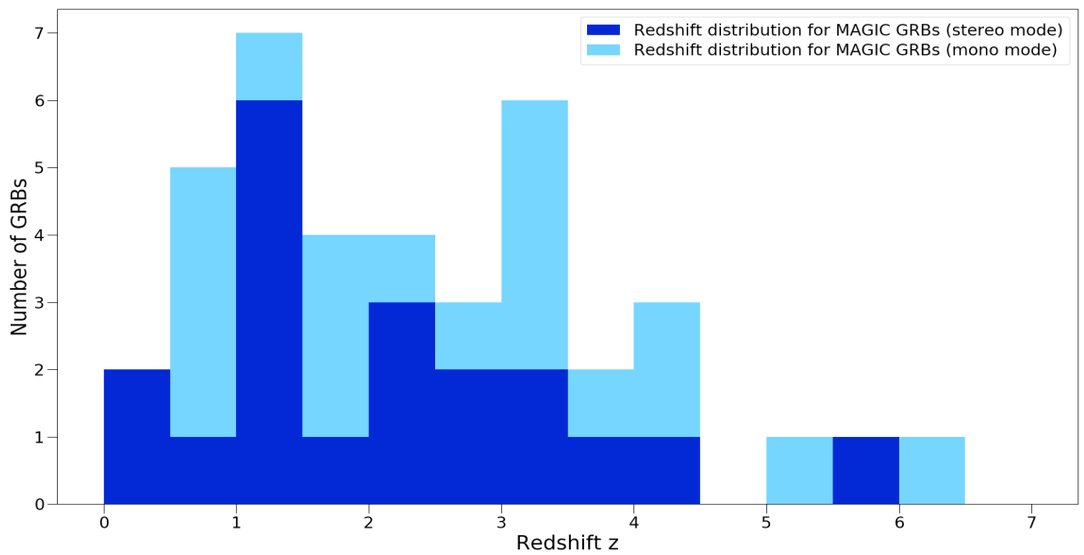


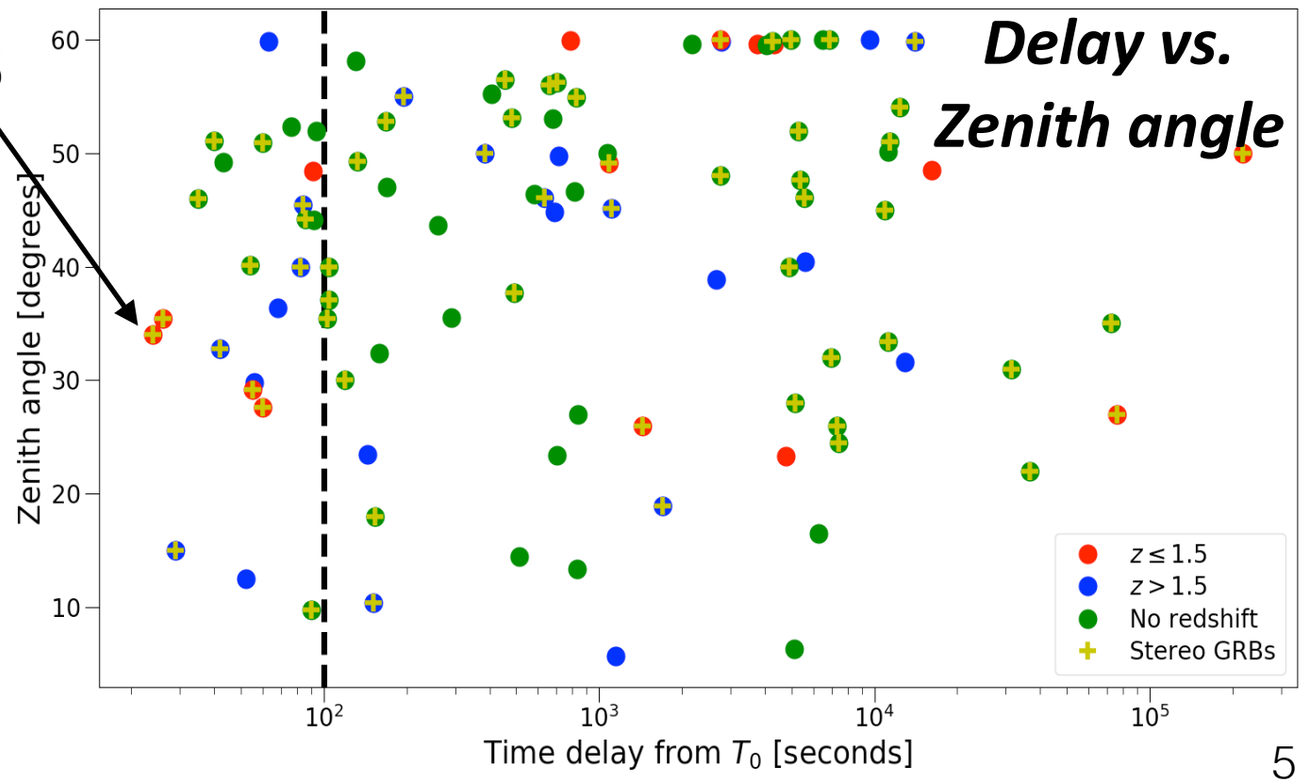
- **Automatic repointing and DAQ**. Active for GCN alerts since 2003.
- **Multi-messenger**: Adapted to neutrino and GW alerts.
  New VOEvent protocol is being implemented.

GRB follow-up obs.

- 101 GRBs observed since 2005
  - 8-10 / yr (50 h allocated)
  - late time obs. since 2013
- 39 with z, 14 with z<1.5
- 14 with < 100 s delay & stereo, out of which 4 with z < 1.5, 1 with z < 0.5 : **GRB160821B**



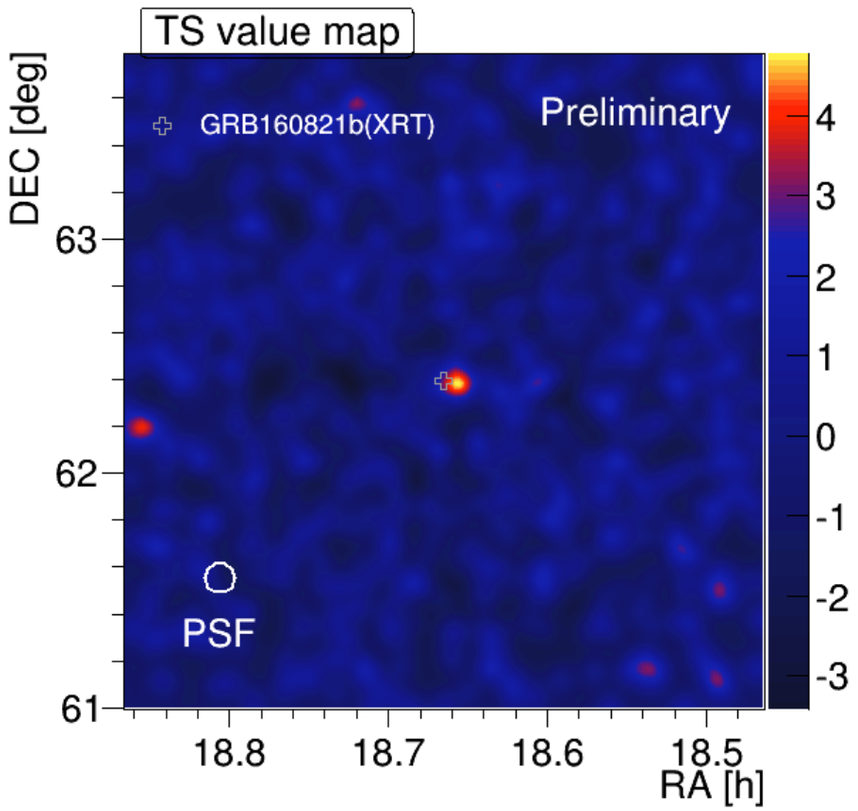


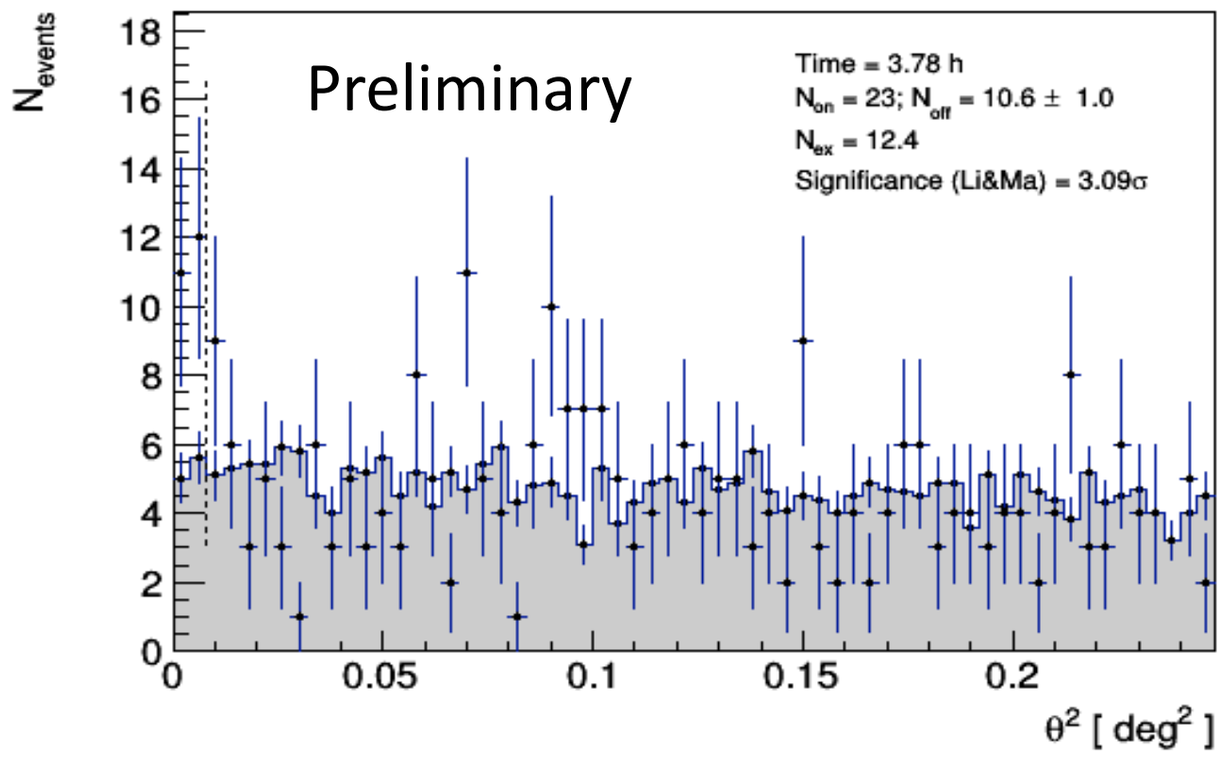


Highlight: GRB 160821B

(ICRC 2017, Texas Symposium, etc., MAGIC Coll. in prep. (2018))

- **Short GRB** (T90 ~= 0.5 s) at **z = 0.16**, triggered by Swift-BAT
- Swift-XRT: t < 300 s extended emission + steep decay, t < 30 ks plateau?
- No LAT detection. HST: **hint of a kilonova?** (Tanvir+, in prep. Gompertz+ 17)
- **MAGIC: 24 s - 4 hr**. Bright moon (3-9 x dark), adverse weather up to 1.5 hr





- **3.1 sigma (post-trial) in >600-800 GeV**. Not firm, but ***a hint of a detection***
- No other potential γ-ray emitter in FoV. Unknown steady source excluded (by an observations ~1 year later)

If the signal is real

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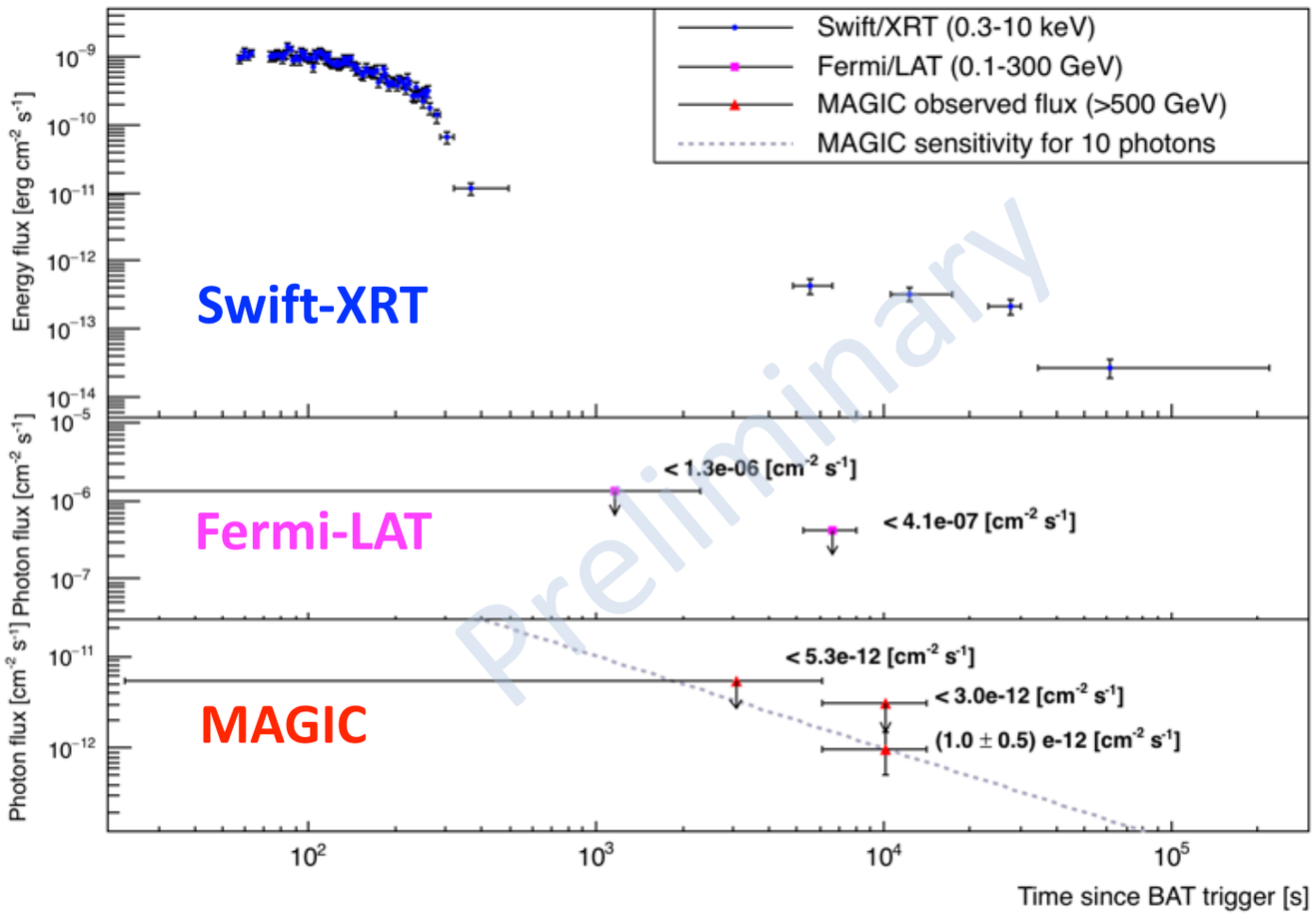
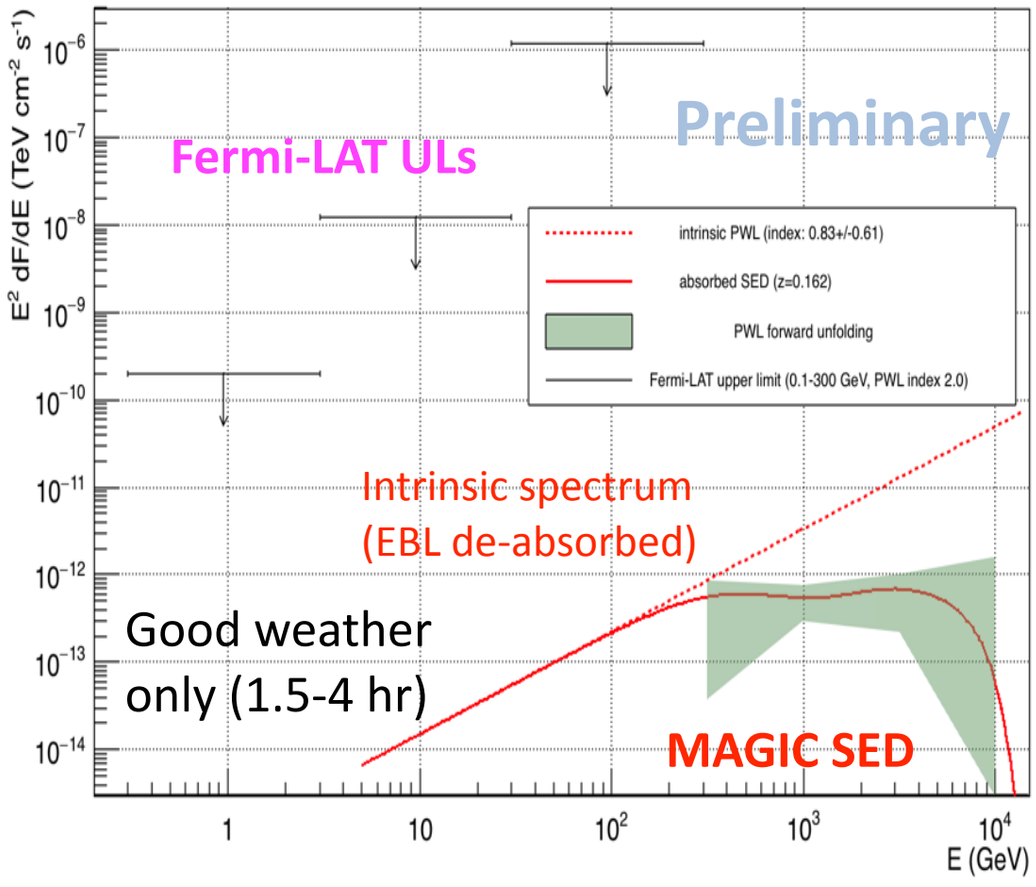
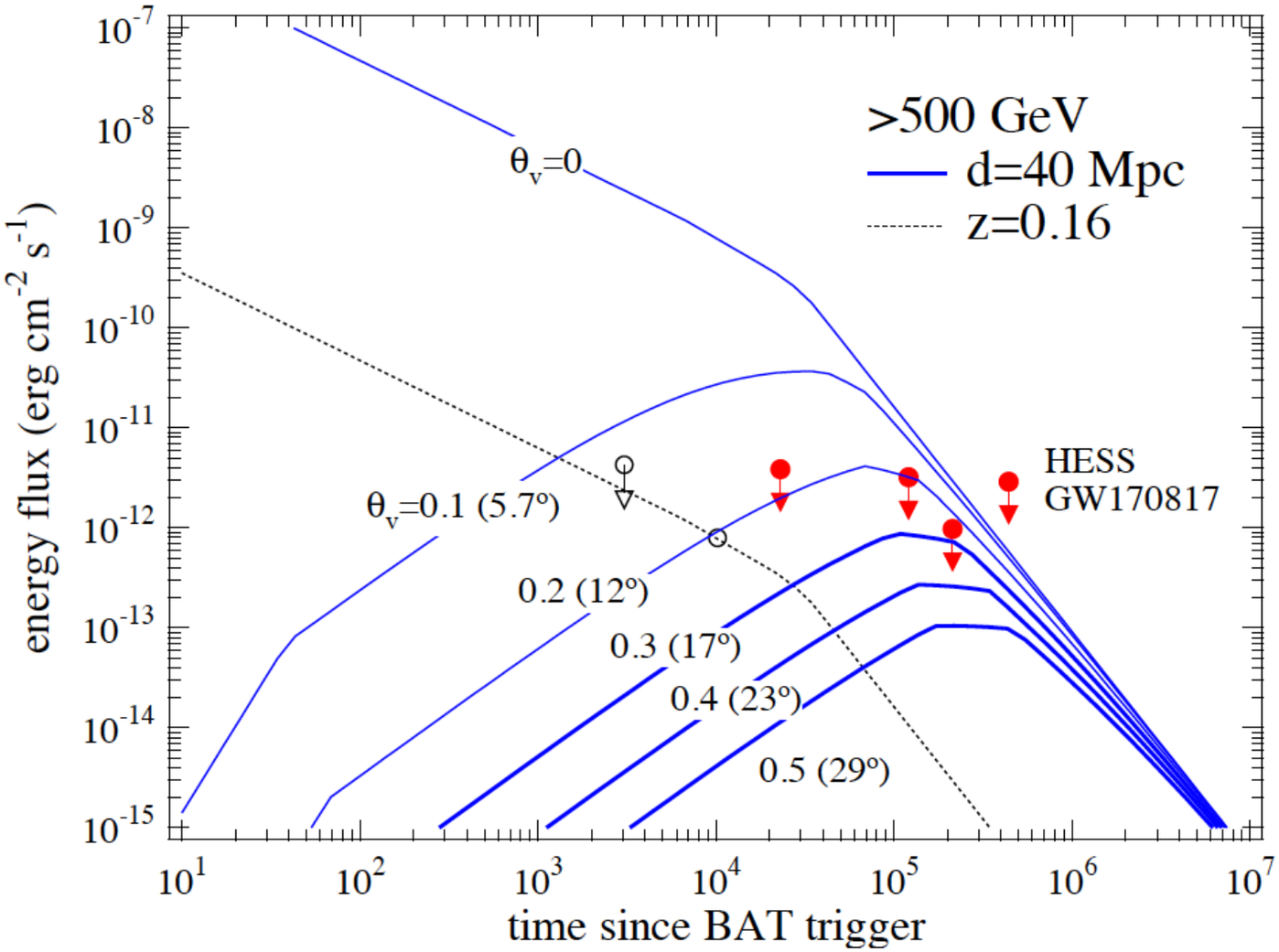




- **compatible with a relatively flat LC** coinciding with a possible X-ray shallow decay (though not constraining much)
- **Suggested flat SED** is OK with the EBL attenuation (Intrinsic PWL spectrum with index 0.8 +/- 0.6). Beyond synchrotron?

Implications for VHE from NS-NS



IF signal real

approximate expectation for simple top-hat jet (point source case of Granot+ 2002)

(By S. Inoue)

- NS mergers favoured as progenitors of short GRBs
- However, GW170817 may or may not have produced a short GRB. Even if it did, the observed afterglow is inconsistent with the simple top-hat structure
- Thus, this implies rather **a potential detection for a future nearby NS merger**

GW follow-up: ex. GW151226

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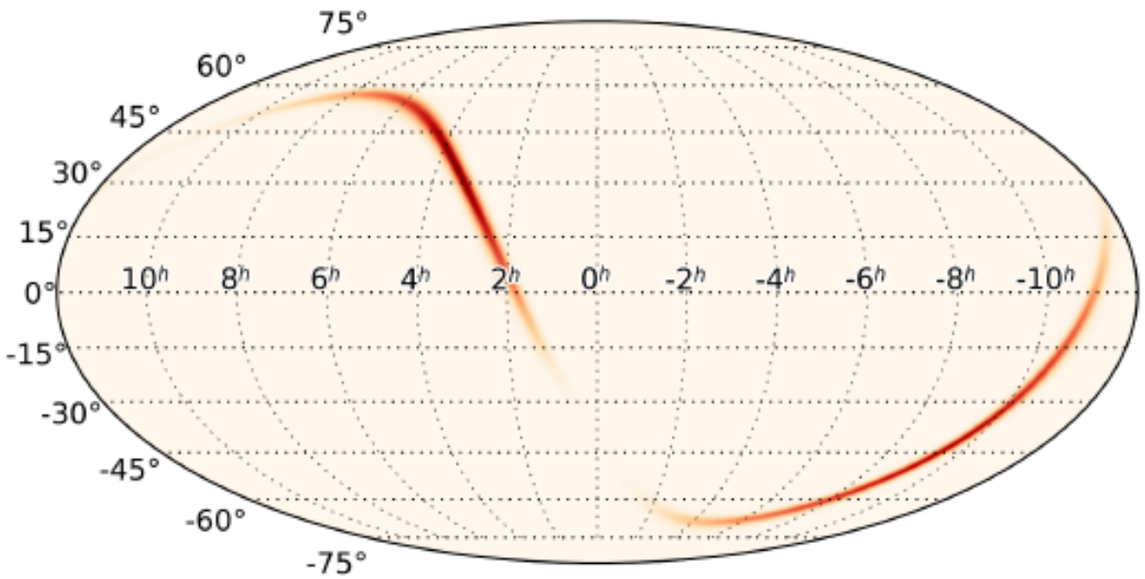
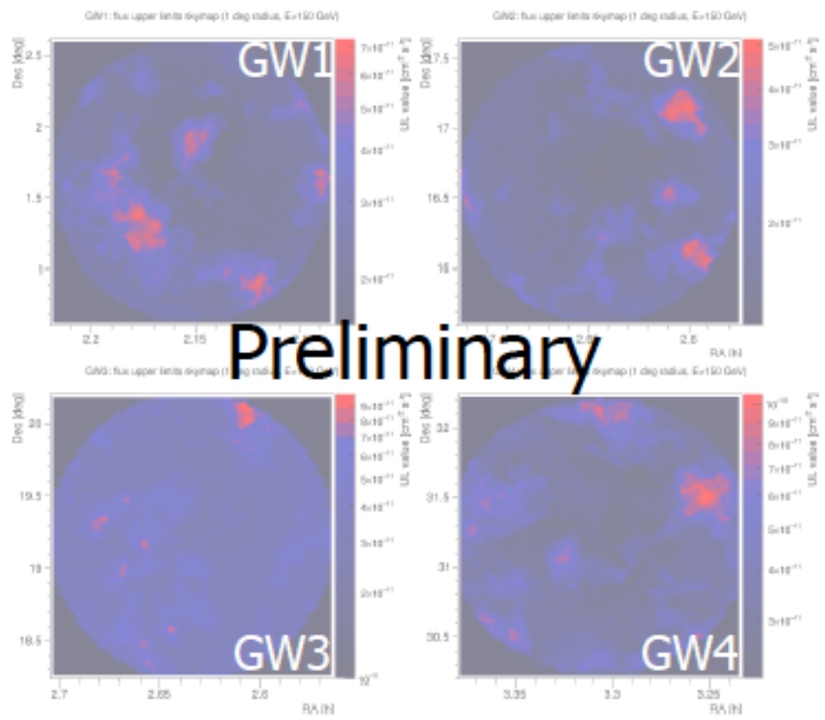


De Lotto et al., Proc. New Frontiers in Black Hole Astrophysics, IAU Symposium 324 (2016)



- t_0: 2015-12-26 03:38:53.648 UT (internal GCN Circular)
- t_{notice}: 2015-12-27 17:40:00 UT
- 90% (50%) credible region: 1337 deg^2 (430 deg^2)
- False Alarm Rate: 1/100 year

- Observation by MAGIC started on 2015-12-28 21:00:00 UT
- Four targets pointed
- Selection by hand according to visibility, probability, EM partners observations and catalogs
- No signal found

- MAGIC plans to improve strategy for O3 from Feb 2019

Neutrino programs

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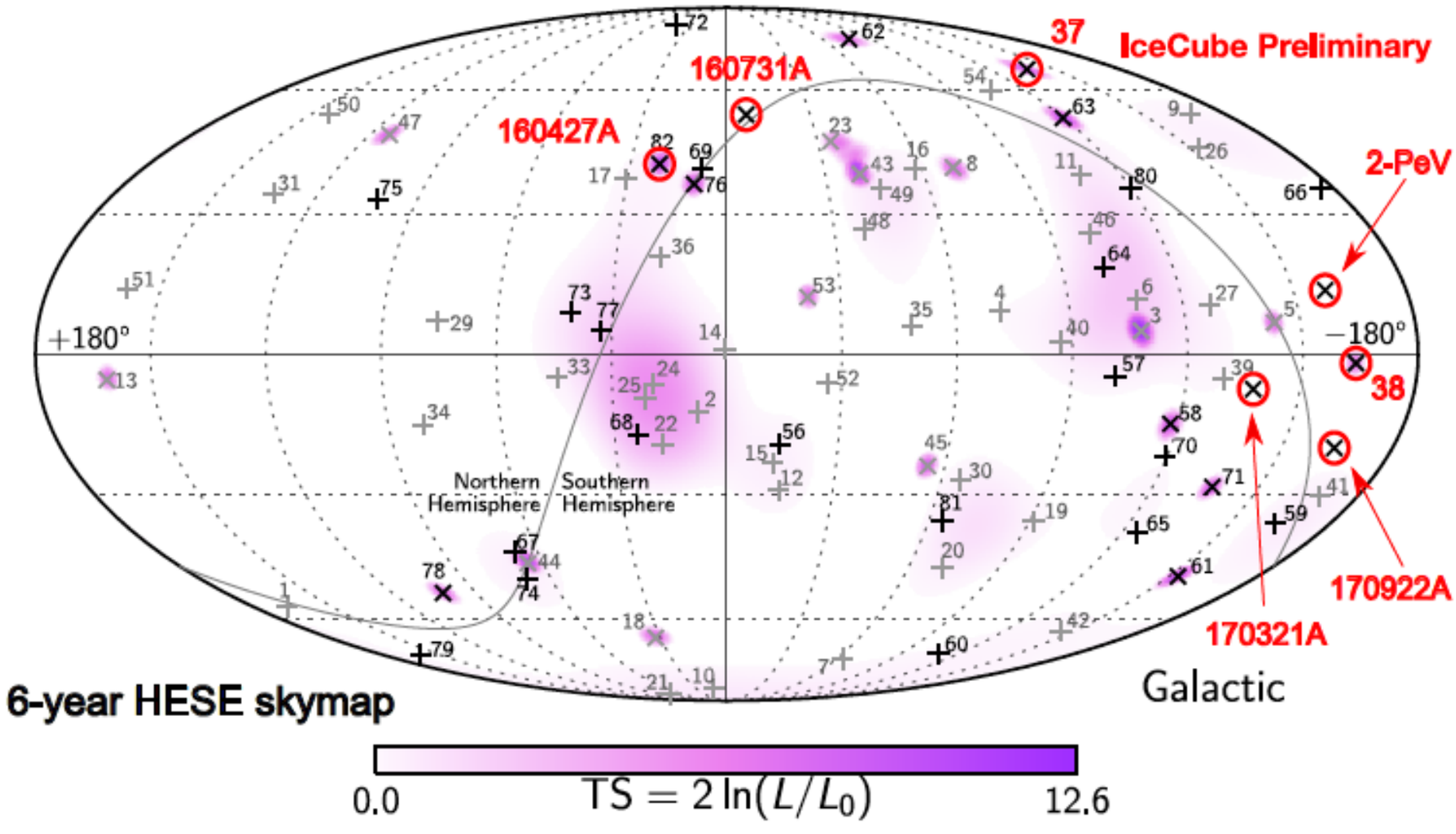
- Since 2012, MAGIC participates the Gamma-ray Follow-Up (GFU) program
- Archival tracks: 2 HESE (37 & 38) and a 2-PeV track observed
- Real-time alerts (HESE+EHE): all the 4 visible for MAGIC were observed. > 30 h obs.



Adapted from Kopper et al., Proc. 35th ICRC 2017

Archival / realtime HESEs

(Gora+ Neutrino 2016; Satalecka+ Gamma 2016; Noda+ TeVPA 2016; Santander+ ICRC 2017)

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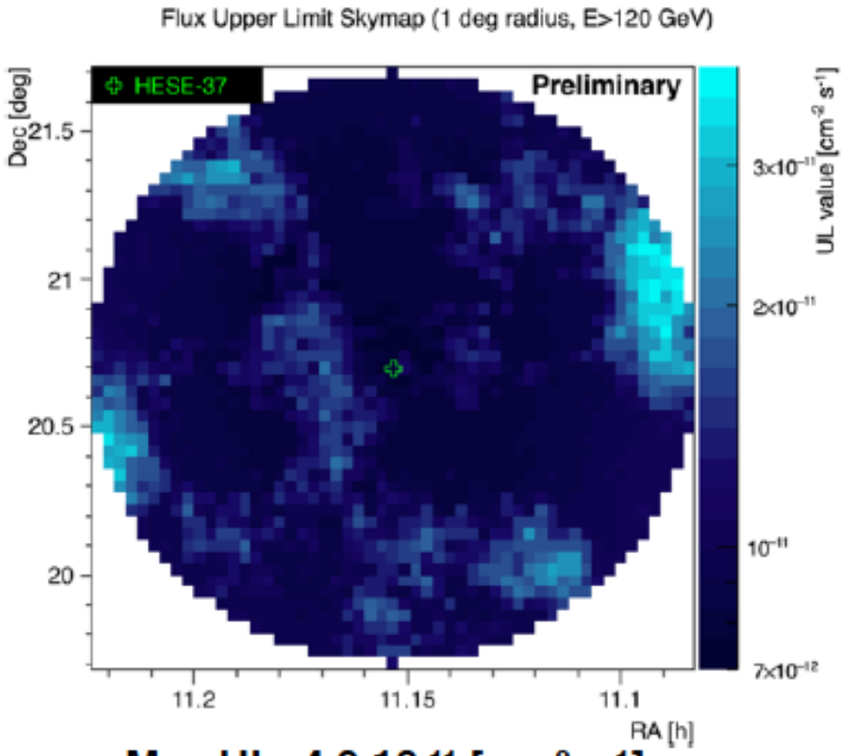

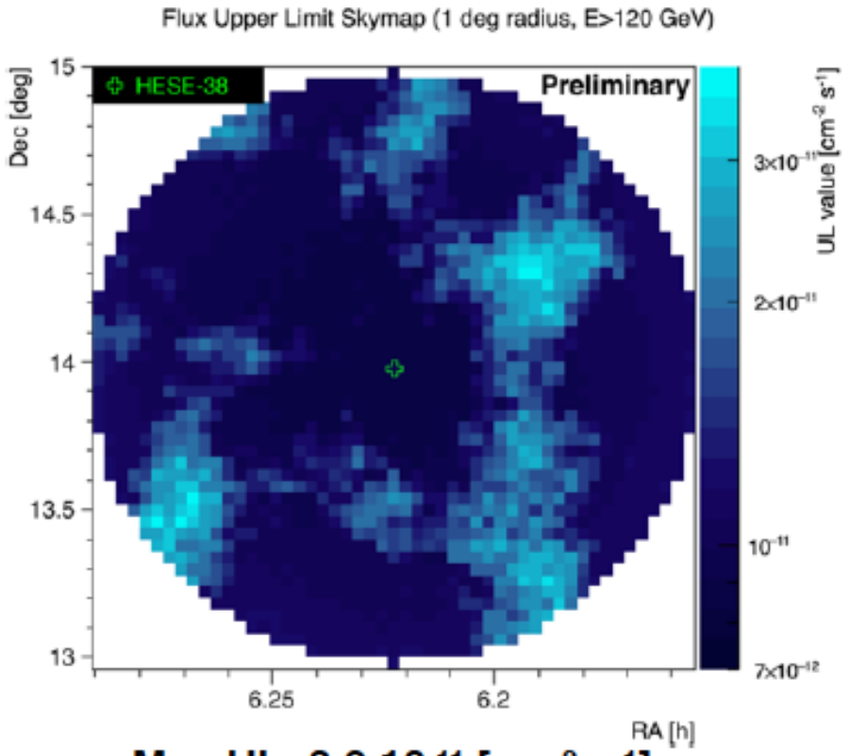

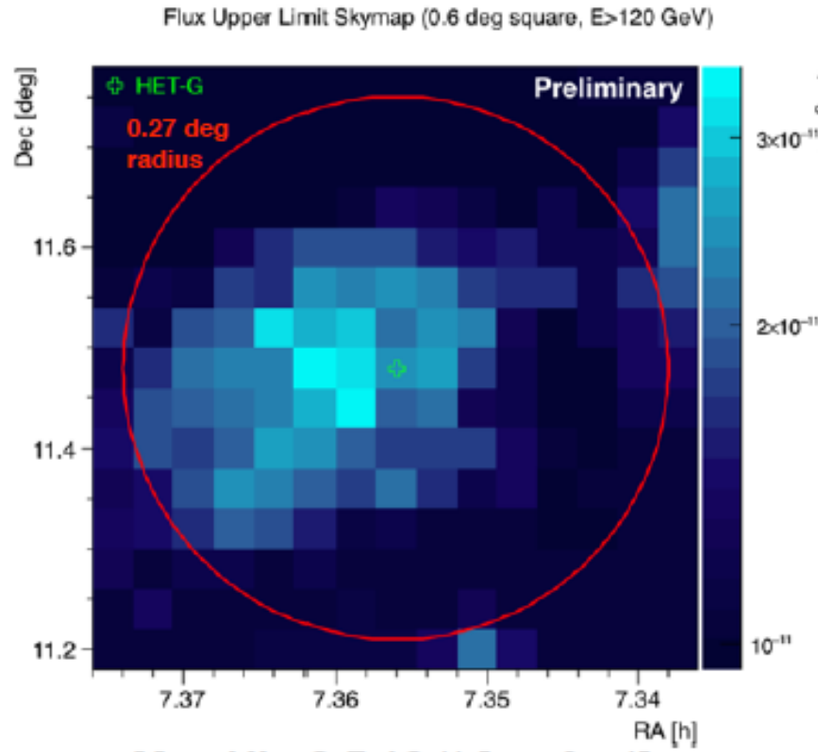

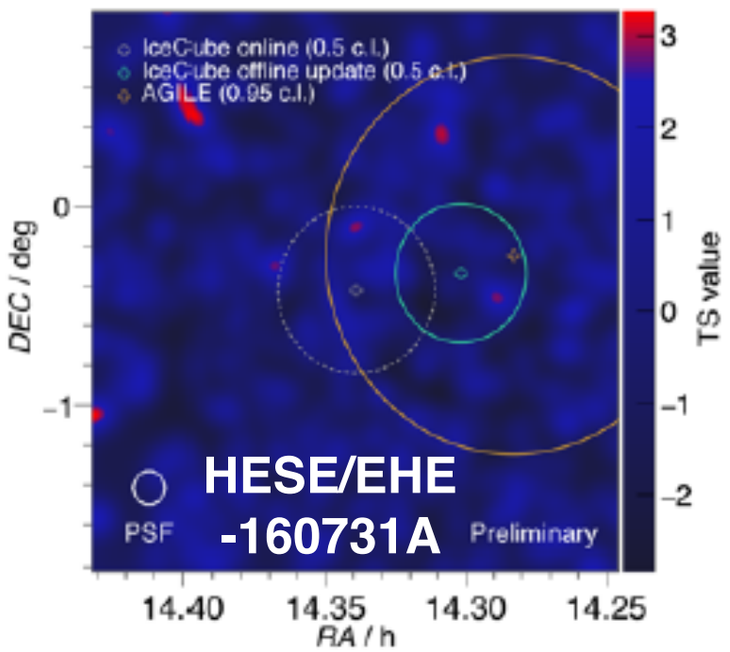

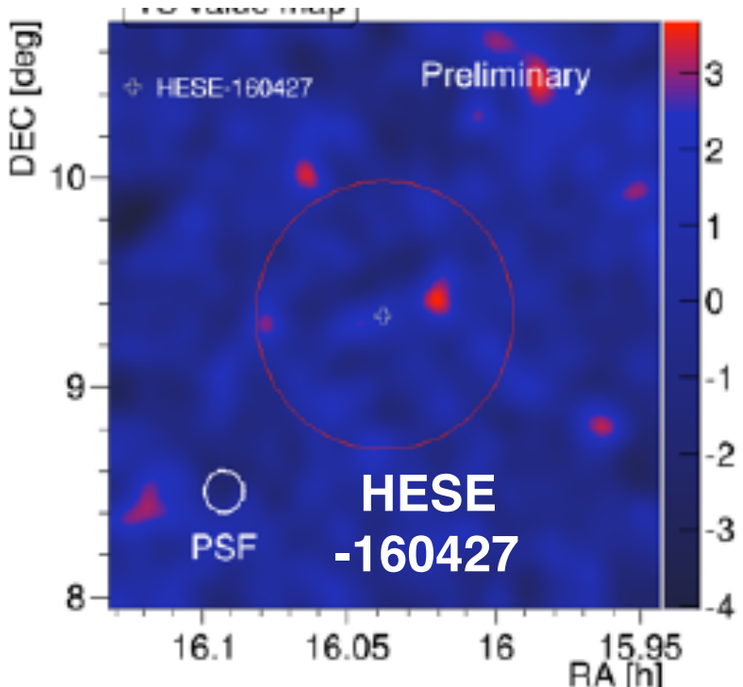

- No signal found
- UL map for alerts with a large localization error
  - Shared analysis tool with the GW group
- **All-IACT paper in prep**

IC-170922A / TXS 0506+056

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- IC neutrino event on 22 Sep 2017, 20:54:30.43 UT
- EHE Notice: t0 + 43 s, GCN Circular on 23 Sep
- Immediate follow-up by other instruments. Bad weather at the MAGIC site
- Within the error circle of the event, a blazar TXS 0506+056 was flaring, in GeV, and also in opt/IR.
- MAGIC observation from 28 Sep. **12 hr data** until 3 Oct**: 5 σ detection**
- Redshift by GTC: 0.3365 (Paiano+ 2018)
- **First time VHE gamma rays detected from a direction consistent with a HE neutrino**

Fermi-LAT detection of increased gamma-ray activity of TXS 0506+056, located inside the IceCube-170922A error region.

ATel #10791; *Yasuyuki T. Tanaka (Hiroshima University), Sara Buson (NASA/GSFC), Daniel Kocevski (NASA/MSFC) on behalf of the Fermi-LAT collaboration*
*on **28 Sep 2017; 10:10 UT***
Credential Certification: David J. Thompson (David.J.Thompson@nasa.gov)

First-time detection of VHE gamma rays by MAGIC from a direction consistent with the recent EHE neutrino event IceCube-170922A

ATel #10817; *Razmik Mirzoyan for the MAGIC Collaboration*
*on **4 Oct 2017; 17:17 UT***
Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)

Subjects: Optical, Gamma Ray, >GeV, TeV, VHE, UHE, Neutrinos, AGN, Blazar

Referred to by ATel #: 10830, 10833, 10838, 10840, 10844, 10845, 10942

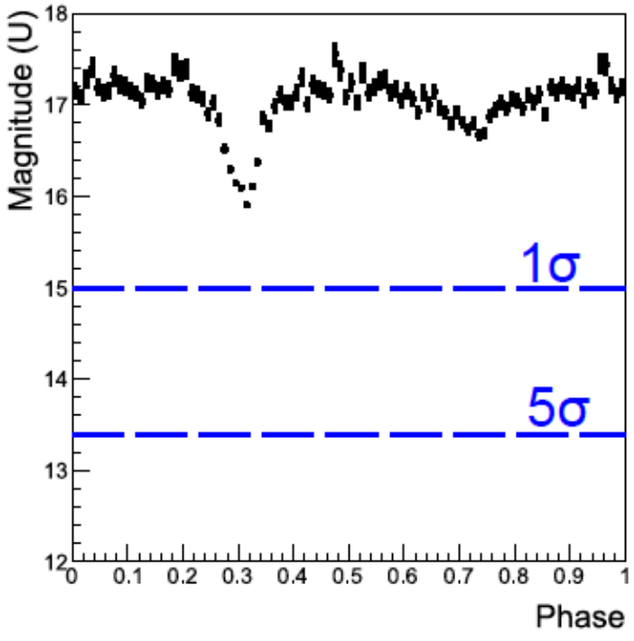
Paper drafting, modelling, revising, etc. 99.9% done

Stay tuned (<1 month!)

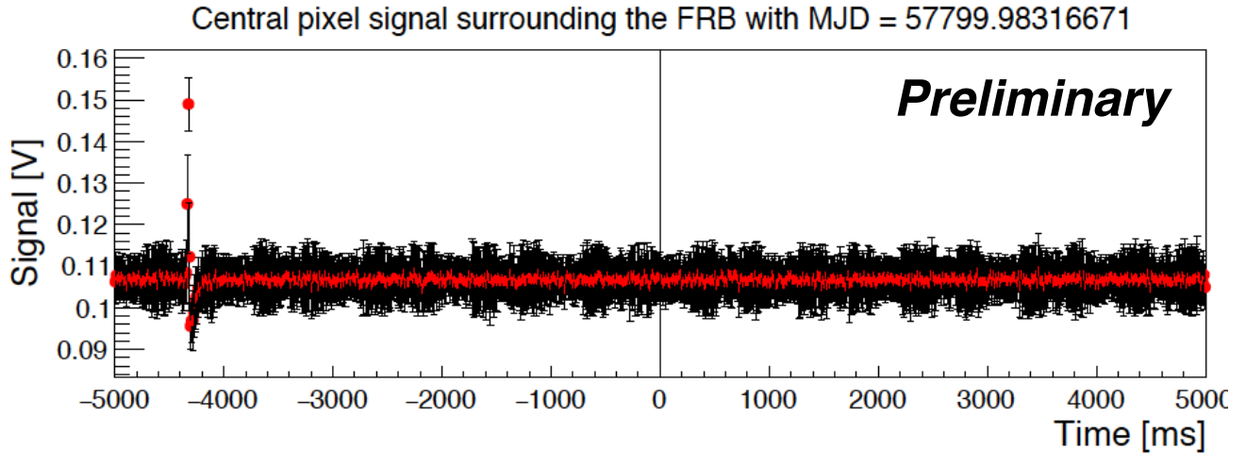
Fast Radio Burst: 121102

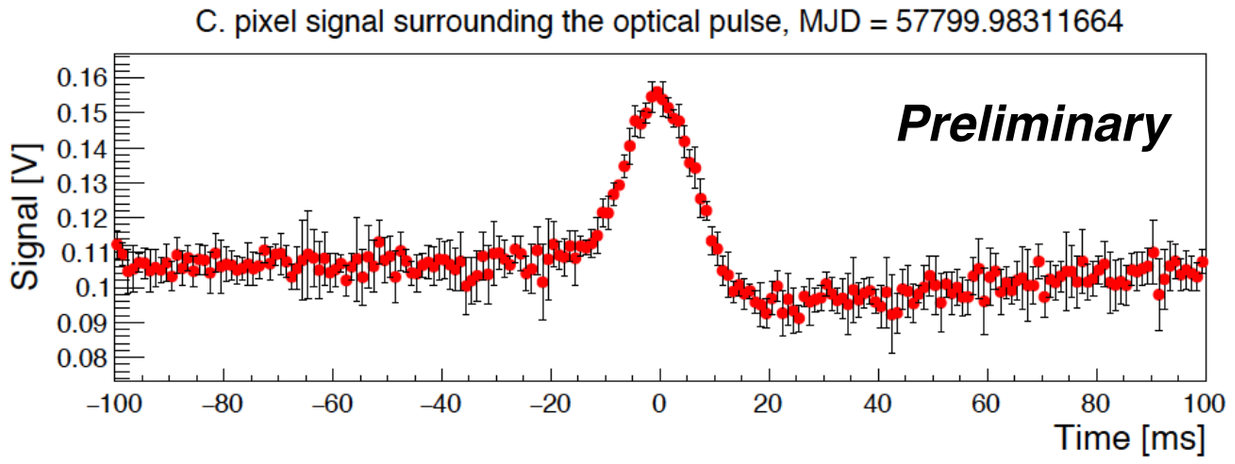
- MAGIC can observe VHE **& optical, using the central pixel**
- **FRB121102:** only known repeating, detected in opt & radio, z=0.193
- MAGIC obs.: Sep 2016, simultaneously with Arecibo and Effelsberg. Sep 2017, with INTEGRAL, Effelsberg, GBT, and Nancay. 20 h in total.
- **No detection. Publication submitted.**

Additional obs. in 2018.



Sensitivity for optical pulses
(m_U~13.4 for msec - sec pulses)





Summary & Future

- **MAGIC is an excellent IACT for transient physics**
- **GRB**: A hint of a detection. Short GRB implication on the near-future GW observations.
- **GW** follow-up: lessons learned for O3
- **Neutrino** follow-up: HESEs & TXS 0506+056 detection, exciting prospects for multi-messenger modelling
- **FRB**: optical and VHE signals explored at the shortest time scales

Backup

GRB160821B models

By S. Inoue. MAGIC Coll. in prep (2018)

- **Implusive**:
  single pulse injection with single Γ
  Not too bad, but marginal with VHE UL.
  Not nice in X-ray (? Jin et al. 2017)

- **Energy injection**: "Refreshed shock"
  (Sari & Meszaros 01, Veres & Meszaros 14)
  Additional injection after the main, with multiple Γ
  Slightly better both in VHE and in X, but inconclusive

- Anyway, need another explanation for the X-ray extended emission.
  Transient ms pulsar?

- Both models work also for SED (backup)