Monitoring the magnetar SGR1935+2154 with the MAGIC telescopes

Alicia López Oramas (IAC)

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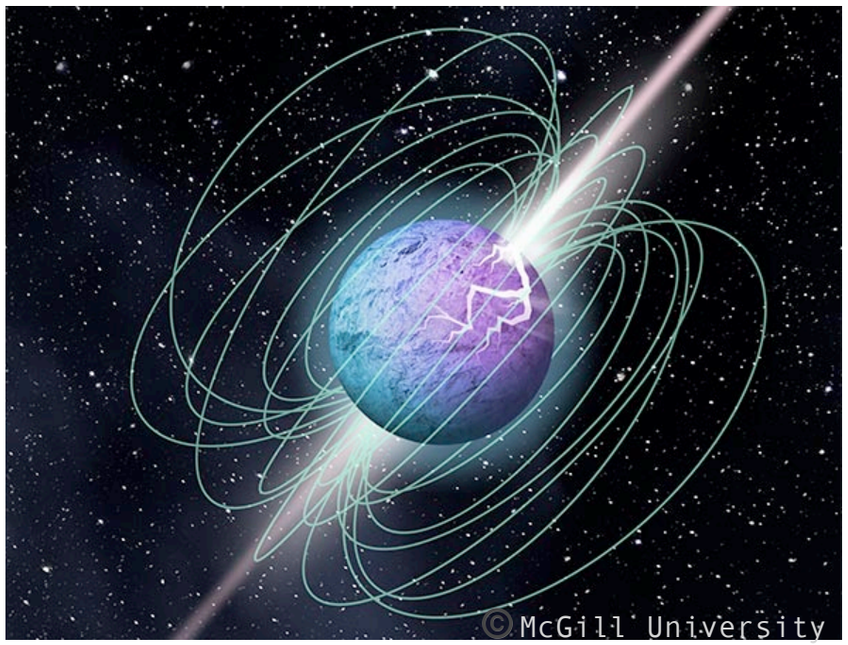
for the MAGIC collaboration

Collaborators: F. Ambrosino, A. Borghese, F. Coti-Zelati, J.W.T. Hessels, F. Kirsten, B. Marcote, O.S. Ould-Boukattine, A. Papitto and M.P. Snelders

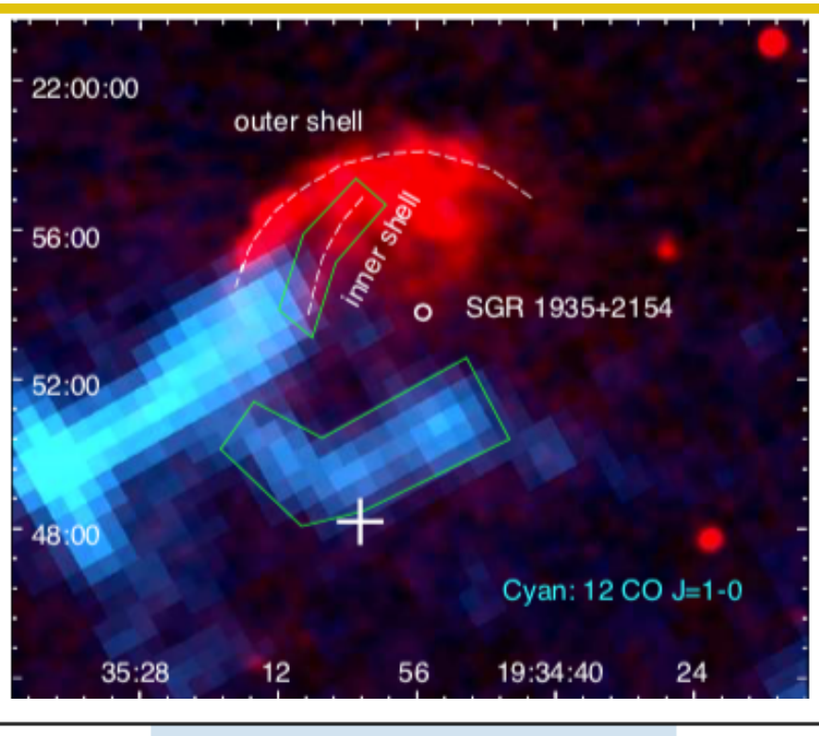
Magnetars

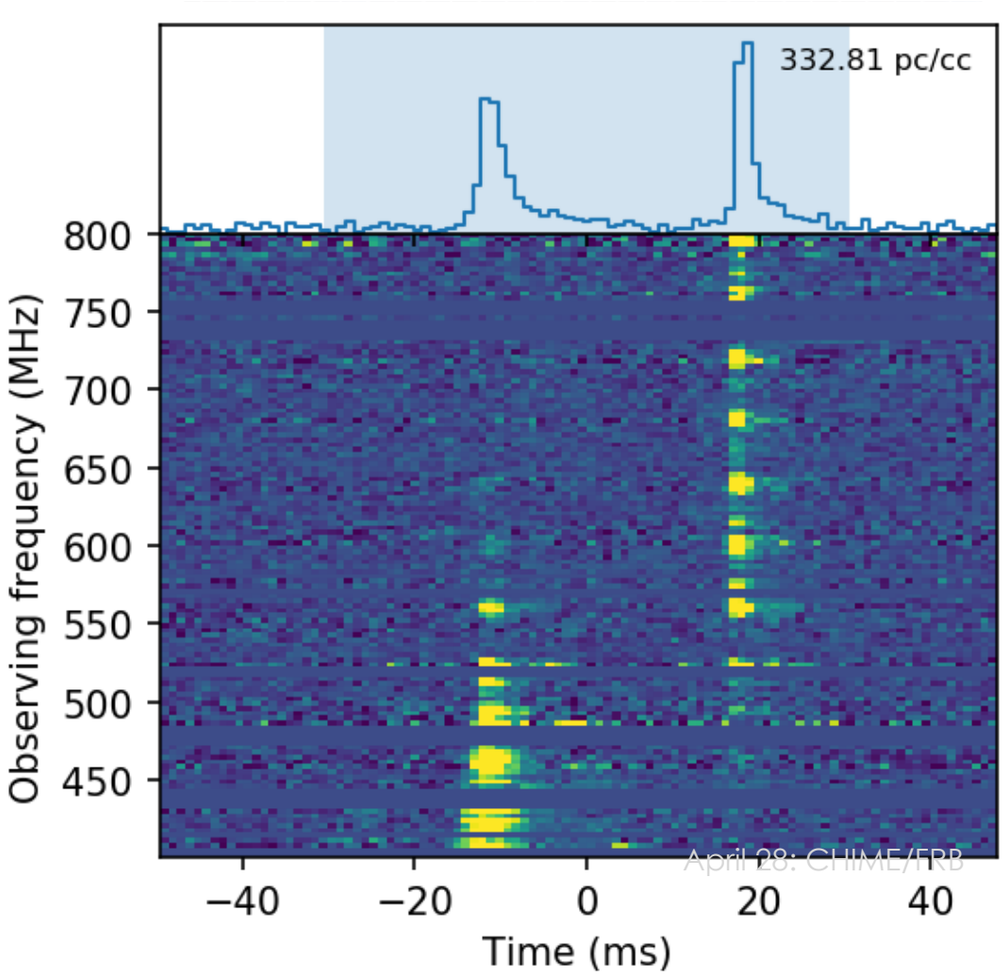


- **Isolated neutron stars with ultra-high magnetic fields** (B ~ 10^{14}-10^{15} G)
- "About twenty objects" with spin **periods between 0.3 and 12 s**

- Types of emission:
  - **Bright persistent X-ray emission** (L_X ~ 10^{33} – 10^{35} erg s^{-1})
    - Powered by **magnetic field decay** (see Mereghetti 2008 for a review)
    - Modeled by **thermal emission** from the neutron star hot surface (about 0.2–0.6 keV)
    - **Not detected above few KeV** (Abdo et al. 2010, AleksiĆ et al. 2013)
  - **Peculiar flares and outbursts on several timescales**
    - Likely caused by large-scale rearrangements of the surface/magnetospheric field, accompanied or triggered by **displacements of the neutron-star crust**
    - Giant flares:
      - Short very energetic (~10^{44}–10^{47} erg s^{-1}) hard spikes followed by pulsating tail.
      - Very rare events: only three events in the last 40 years in the Galaxy
      - **Extragalactic giant flare detected by Fermi-GBM** (Roberts et al. , Nature Astronomy, 2021)**and Fermi-LAT up to 1.7 GeV** (Fermi-LAT coll. , Nature Astronomy, 2021)

SGR 1935+2154





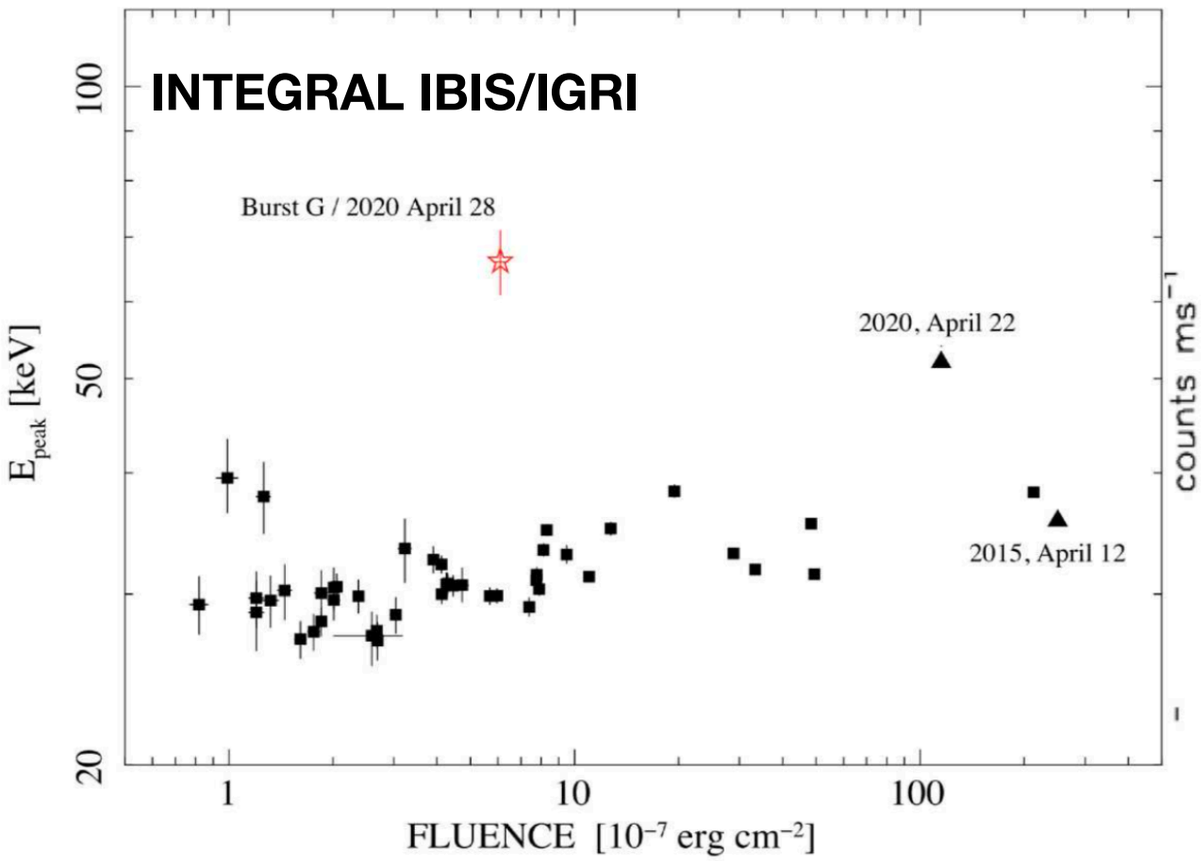
- Galactic magnetar located at 6.6 kpc (Zhou et al. 2020)
- **Hosted in an evolved SNR** (GG57.2+0.8) and (likely) interacting with a **surrounding molecular cloud**

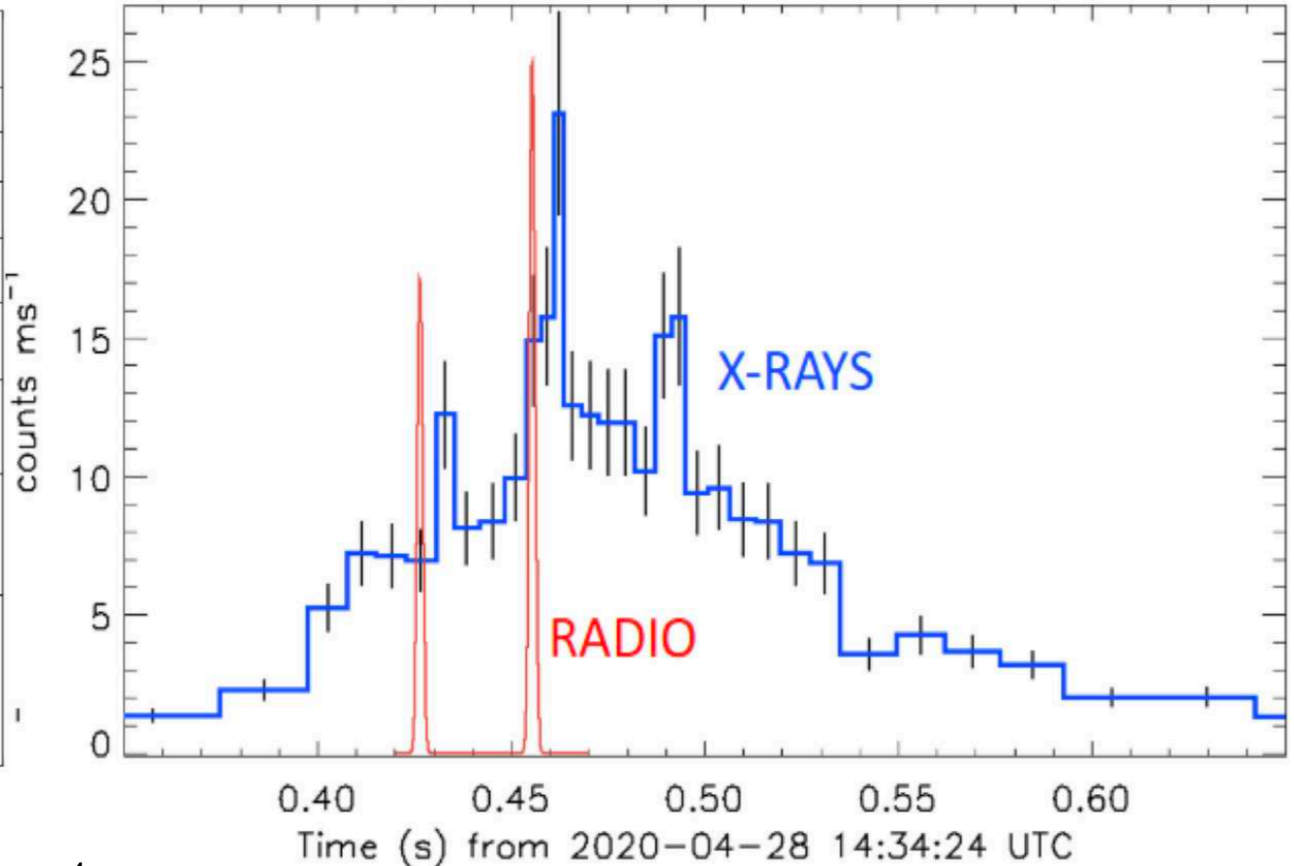
- April 2020: **a fast radio burst (FRB) is detected by CHIME/FRB** in coincidence with this magnetar (Andersen et al. 2020)
  - The burst had a **double-peak** structure with two components ~5 ms wide separated by ~30 ms
- Confirmation by STARE2 (Bochenek et al. 2020) and European dishes: Westerbork, Onsala, Toruń (Kirsten et al. 2020)
- **X-ray bursts** by Swift (Barthelmy et al. 2020), INTREGRAL (Mereghetti et al. 2020), AGILE (Tavani et al. 2021), Konus-Wind (Ridnaia et al. 2021),NICER (Younes et al. 2021), Insight HXMT (Li et al. 2021)
- MAGIC could not observe due to pandemic lockdown

SGR 1935 +2154 is the first FRB in the Galaxy and the first identified FRB source

April FRB event

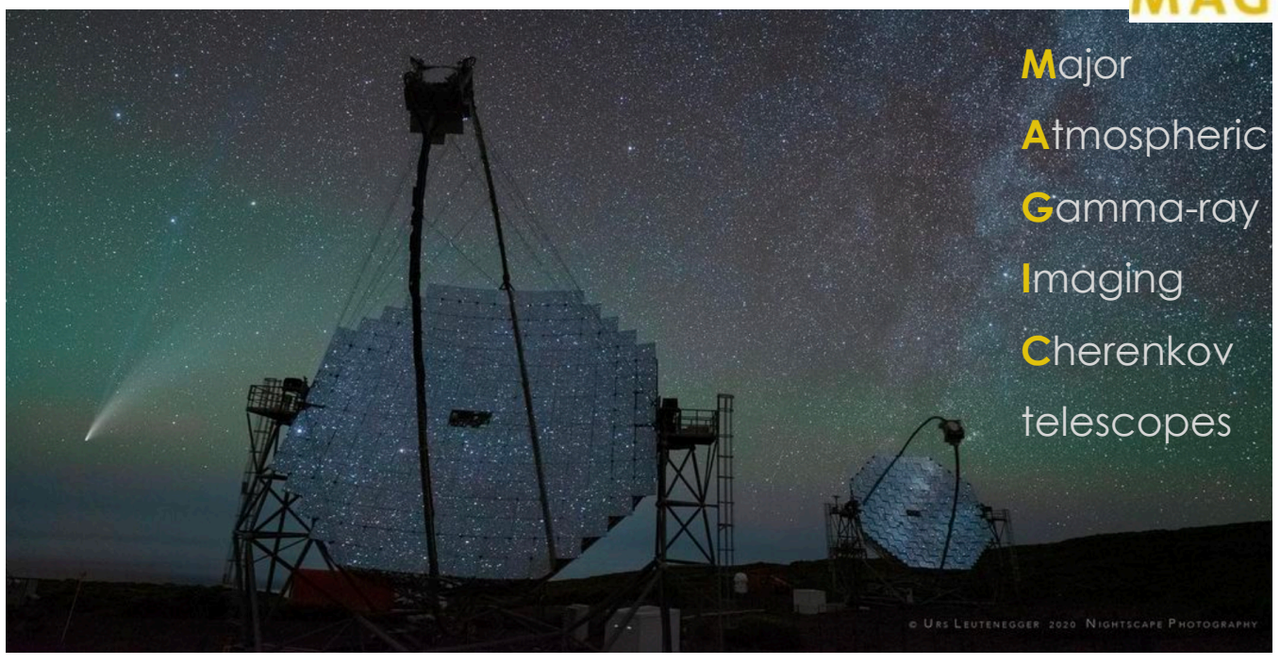
- It was not a giant flare but **intermediate**
- The X-ray burst was **not especially energetic but it was harder than other flares** (Mereghetti et al. 2020)
- Different models for the site of emission (see Zhang 2020 for a review):
  - inside magnetosphere
  - relativistic outflow interacting with surrounding ISM
- TeV emission can be expected according to theoretical models (Lyubarsky 2014, Murase et al. 2016, Metzger et al. 2020)

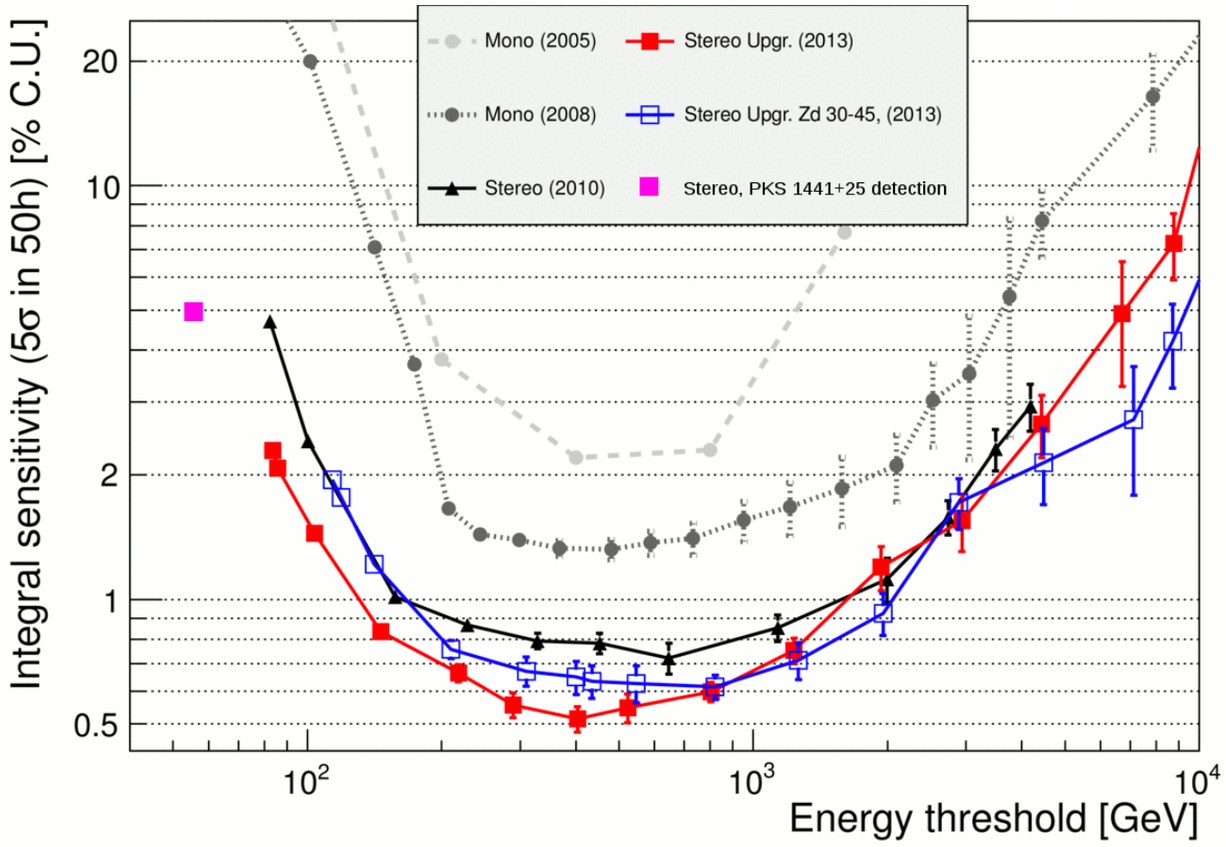




from Mereghetti et al. 2020

The MAGIC telescopes





Alekić et al. 2016

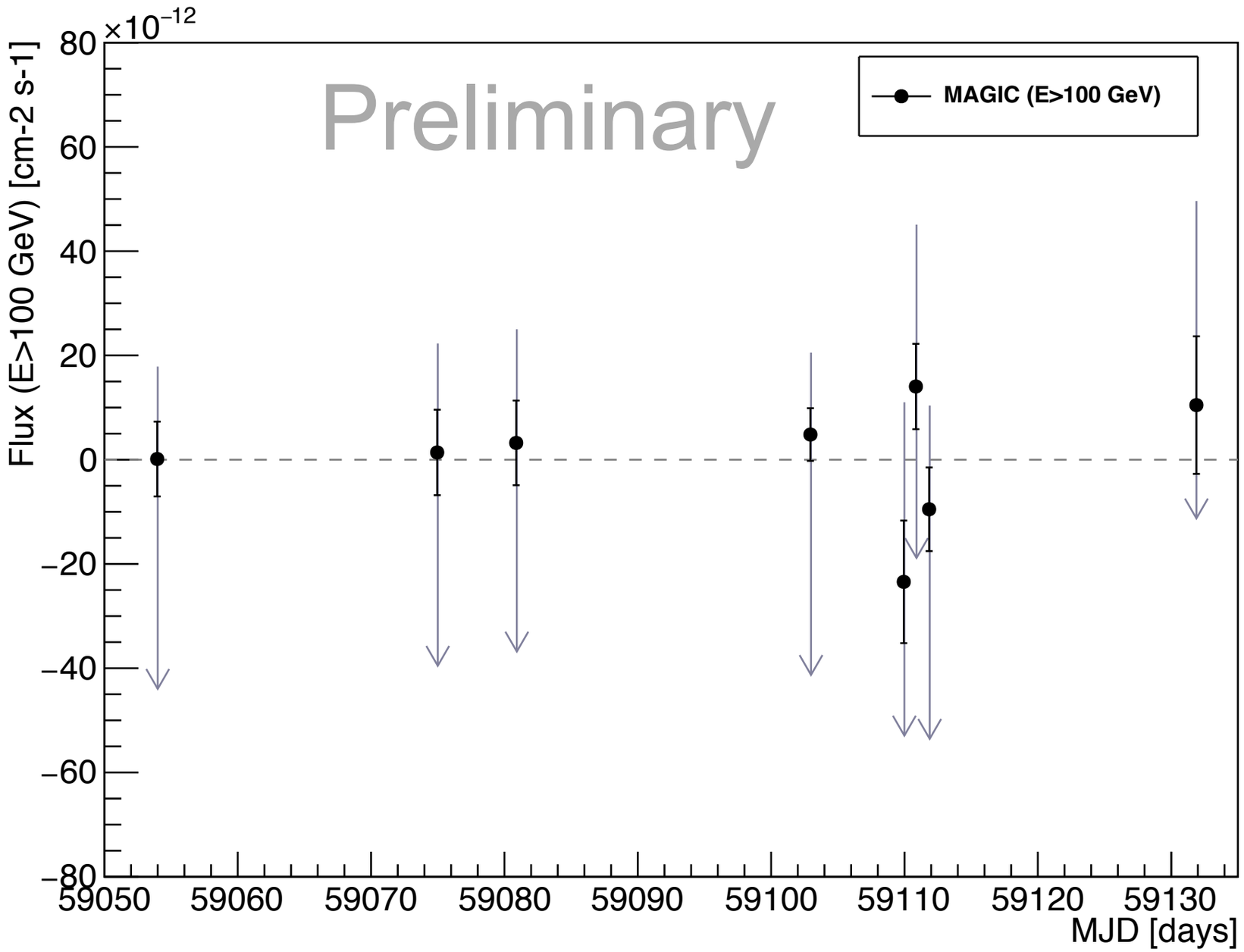
- **Two Cherenkov telescopes** of 17 m diameter in the Northern hemisphere
- Detection of **very-high-energy (VHE) gamma rays**
- **Energy threshold (trigger) ~50 GeV**
- Integral sensitivity E >290 GeV: (0.67 ± 0.04)% of Crab Nebula flux in 50 hours (Alekić et al. 2016)
- Energy resolution: 15-23 %
- Angular resolution: ~0.1°

MAGIC as optical telescopes

- **Magnetars can emit fast optical bursts (FOBs)** (Yang et al. 2019)
  - Spectral extension of the same radiation mechanism that generate FRBs
  - Inverse Compton upscattering
- The **MAGIC telescopes are able to operate simultaneously both as VHE and optical telescopes**
- The central pixel has been adapted to perform optical observations
  - Capable to detect **isolated 1-ms** optical flashes **as faint as ~ 8 mJy (13.4 mag)** with **maximum sensitivity at 350 nm** (Hassan et al. 2017)
- MAGIC central pixel is an optimal system to **search for short optical flares (FOBs)**

Gamma-ray observations

- **Total MAGIC integration time: ~15 h (July-October 2020)**, 8 different nights of observations
  - **No significant VHE signal detected** (neither daily nor total)
  - Two observation modes tested:
    - Wobble: optimal for VHE detection
    - ON: to allow for simultaneous optical cpix adquisition



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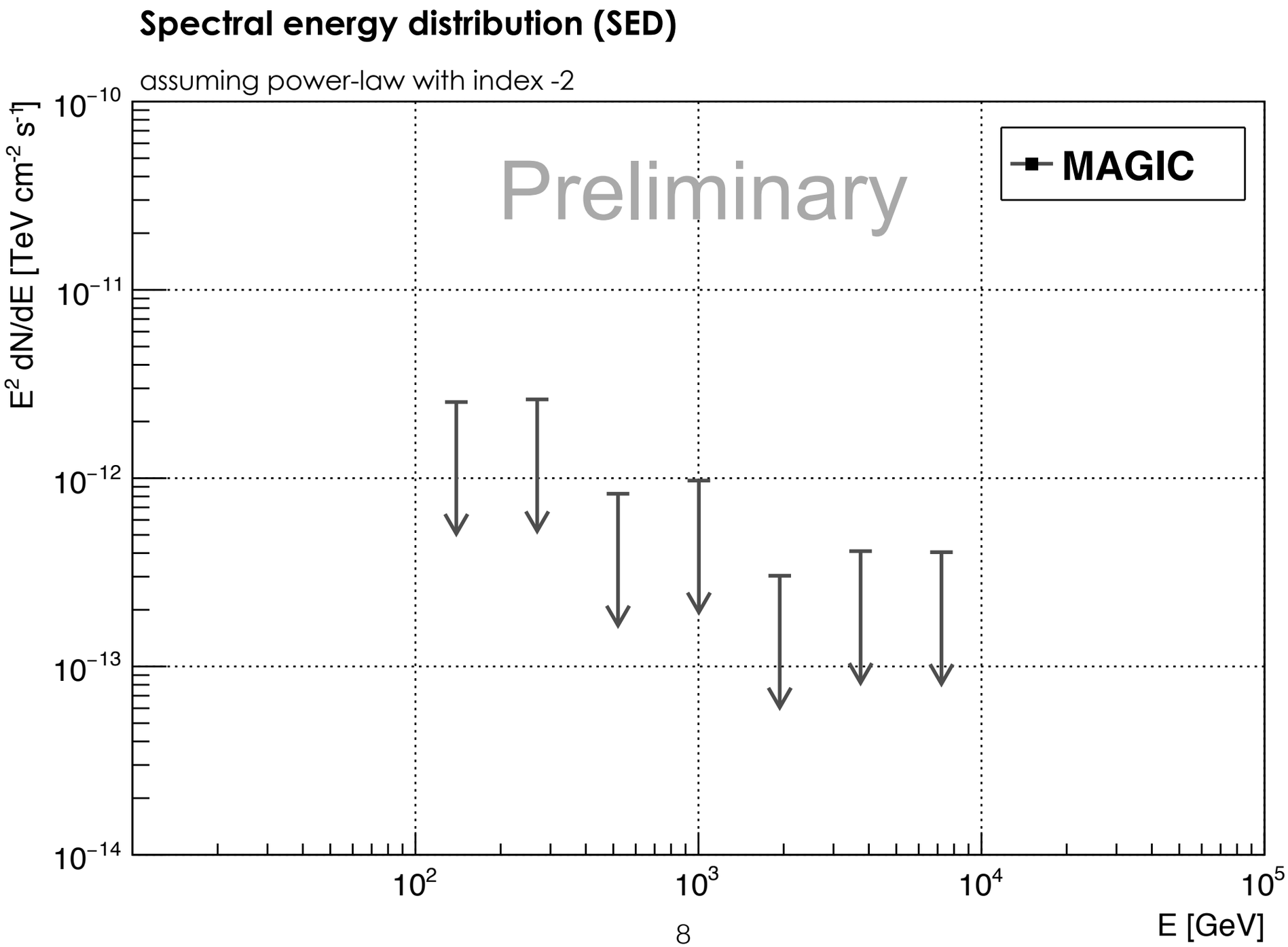
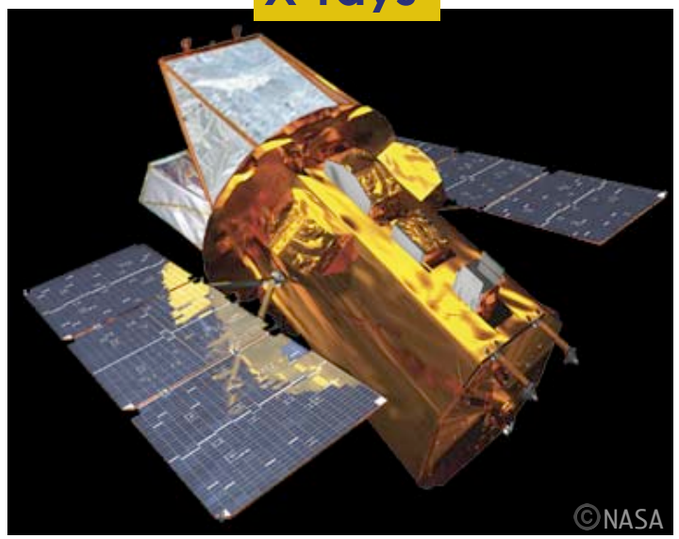


MWL collaboration

Gamma rays

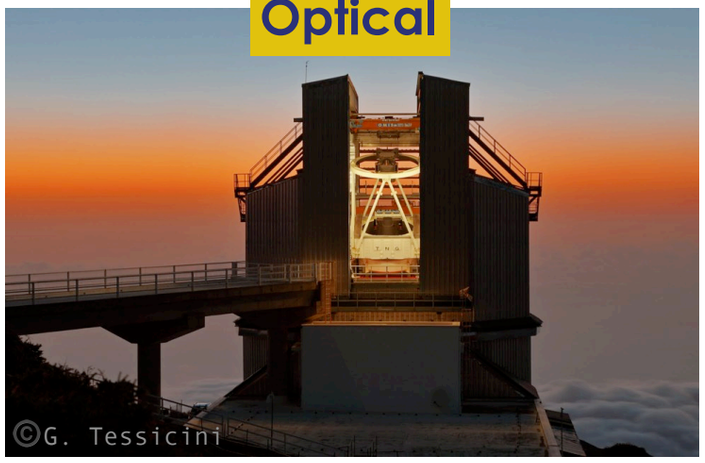
Fast optical

X-rays



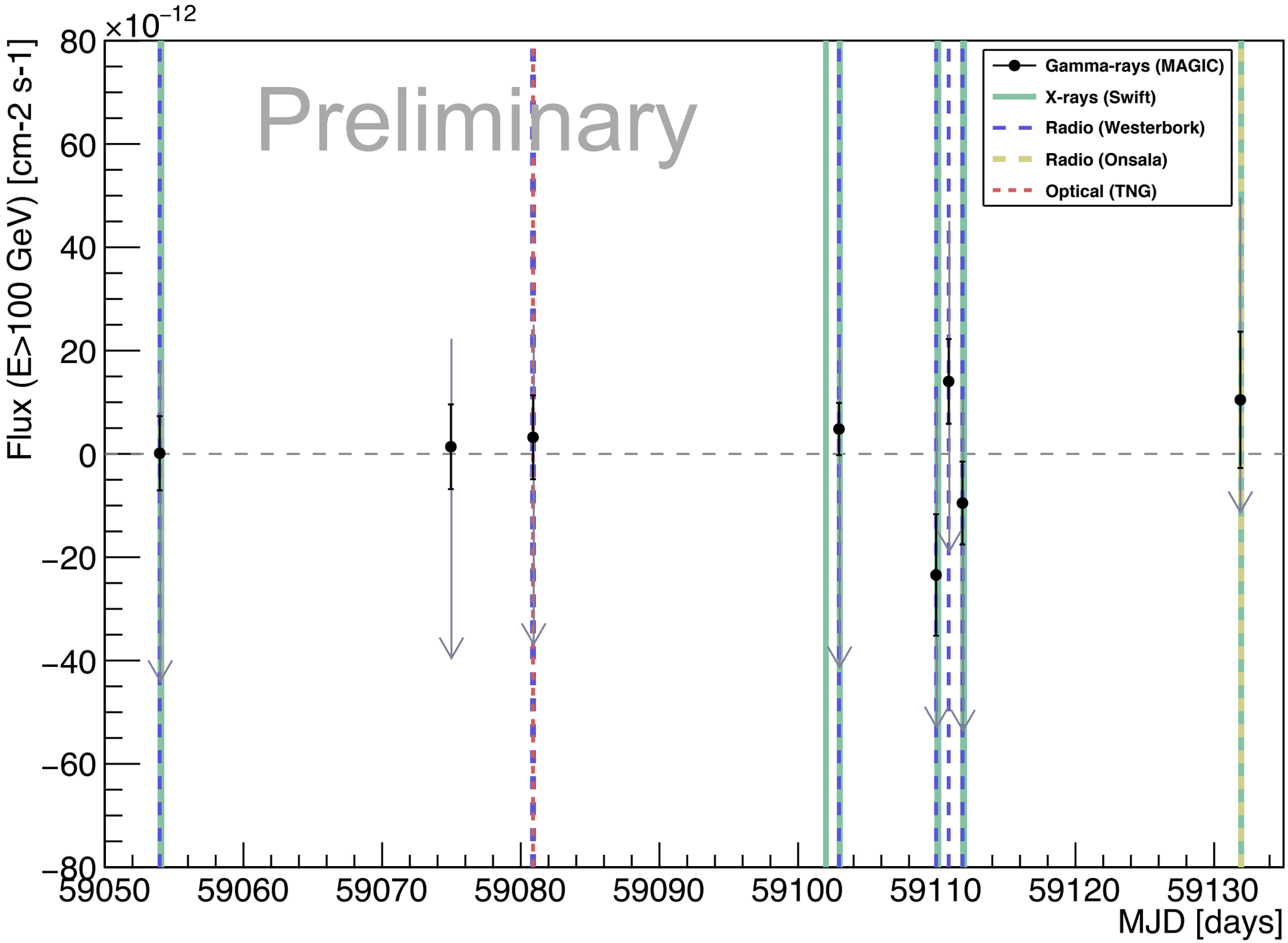
Radio

Optical



- **MAGIC observations in a MWL context :** Multiwavelenght collaboration to **monitor this magnetar**
  - **VHE gamma-rays/ fast optical: MAGIC**
  - **X-rays: Swift**
  - **Radio: Westerbork** and **Onsala**
  - **Optical: TNG/SiFAP2**
- **Simultaneous** observations
  - Once/twice per month
  - Increased cadence in case of outburst

MWL lightcurve



MWL collaboration

- Coordinated observations from July to October 2020

Date (MJD)	MAGIC (gamma/optical cpix)	Swift (X-rays)	TNG/SiFAP2 (optical)	Westerbork/Onsala (radio)
59053.96-59054.04	yes/no	yes	no	yes/no
59080.88-59080.97	yes/no	no	no	no/no
59102.95-59103.03	yes/no	no	yes	yes/no
59109.95-59110.03	yes/no	yes	no	yes/no
59110.86-59110.94	yes/no	yes	no	yes/no
59111.85-59111.93	yes/no	yes	no	yes/no
59131.89-59131.98	yes/yes	yes	no	no/yes

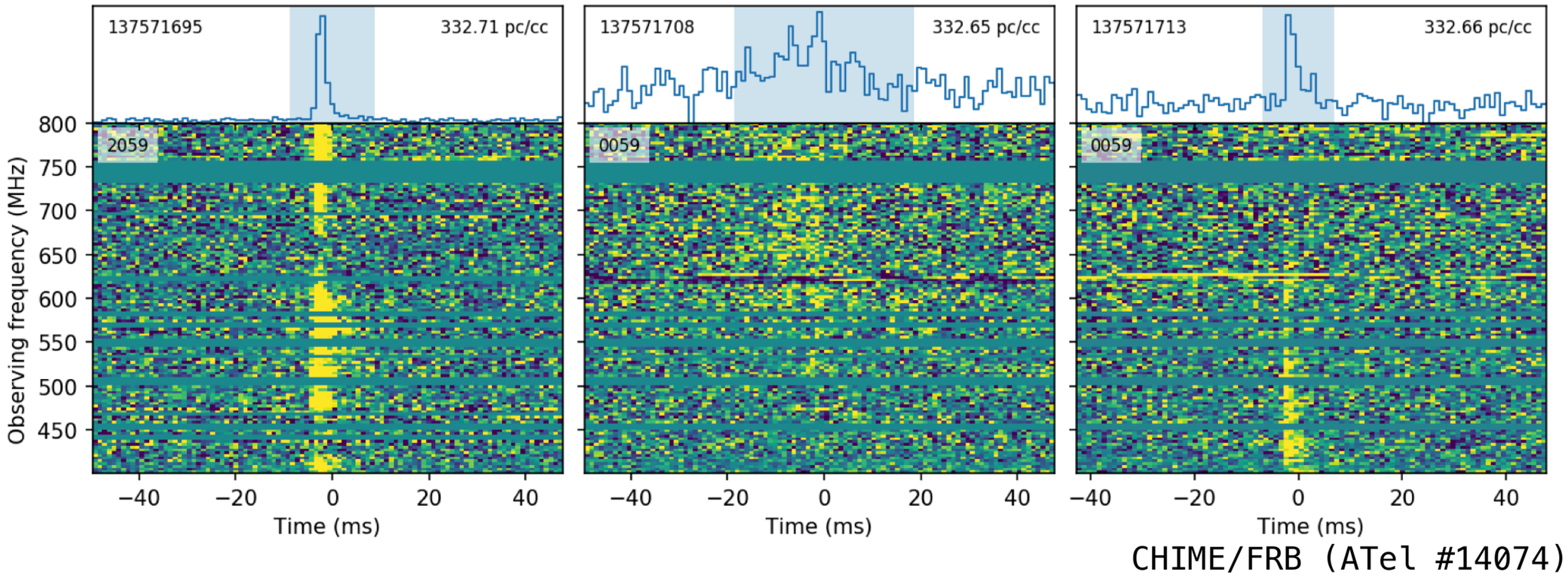
- No detections by Westerbork/Onsala (radio), TNG (optical), MAGIC(gamma)
- Bursts detected/reported on different days by Swift (X-rays)

September: bursting activity

- **Bursts reported by Swift/XRT on different days in September 2020** (Borghese et al. in prep)
  - triggered an increased of cadence
- Contemporaneous observations:
  - **No radio bursts** seen in radio by Westerbork
  - **No VHE emission** detected by MAGIC

Example of bursts detected by **Swift/XRT on September 10**

October 8, 2020: more **radio bursts**

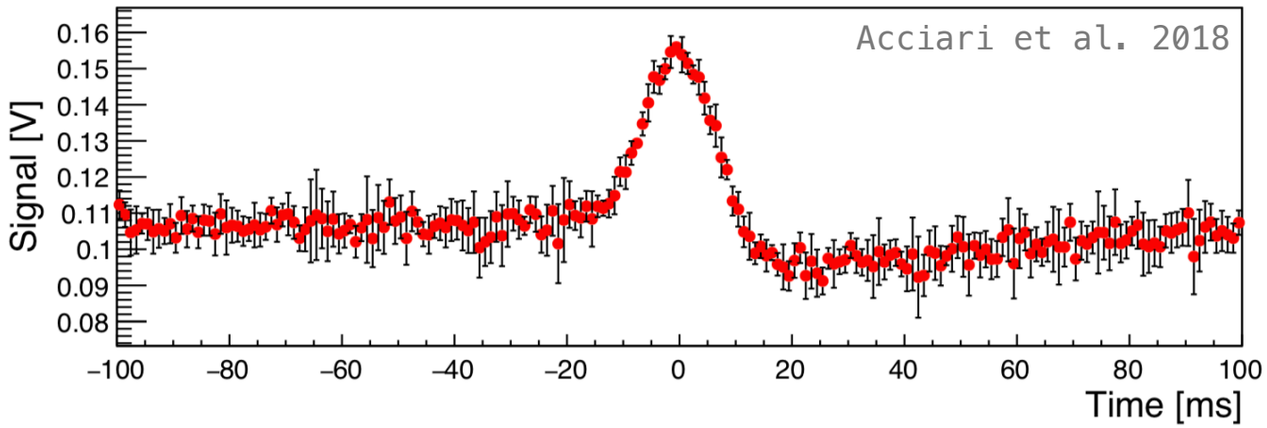


- **Three radio bursts** detected on October 8 by CHIME/FRB (ATel #14074)
  - Confirmed by FAST on October 9 (ATel #14084)
- **No X-ray counterpart**
  - No signal in Swift (ATel #14076)
  - No detection in INTEGRAL (ATel #14087)
- **Radio fluence lower than April 28 burst**

October **radio bursts**

- MWL observations triggered on **October 9** (one day after CHIME/FRB detection)
  - **Swift** ToO approved:
    - Period of **bursting activity**: about **25 bursts detected** (Borghese et al. in prep)
  - **MAGIC** observed during the Swift burst window:
    - **Simultaneous gamma+optical observations**
    - **No VHE signal detected**
    - **Optical** data with cpix:
      - **ongoing analysis** for the identification of burst-like signals
      - cleaning of background events
  - **Radio** data:
    - No observations scheduled with Westerbork
    - **Onsala** observations did **not reported bursting activity**

Example of a background-like event in MAGIC cpix



- **FAST** performed 1-h observations on October 9 (ATel #14084): **pulsed emission and radio bursts**

Summary

- **MWL monitoring** of the magnetar SGR 1935+2154 (**gamma rays, X-rays, optical and radio**) on-going:
  - Monthly monitoring and ToO observations during flaring states
  - **MAGIC:**
    - **Gamma-ray and fast optical observations**
    - **No VHE emission detected and no FOBs confirmed** (on-going analyis for the search of burst-like signals)
  - **Swift: several bursts detected** in different periods
  - **Westerbork/Onsala: no radio emission**
  - **TNG/SiFAP2: no optical bursts reported**
- SGR 1935+2154 has proven the **SGR-FRB connection** (see review by Zhan, Nature 2020). **This magnetar is the first FRB located in the Galaxy and the first known FRB source**

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