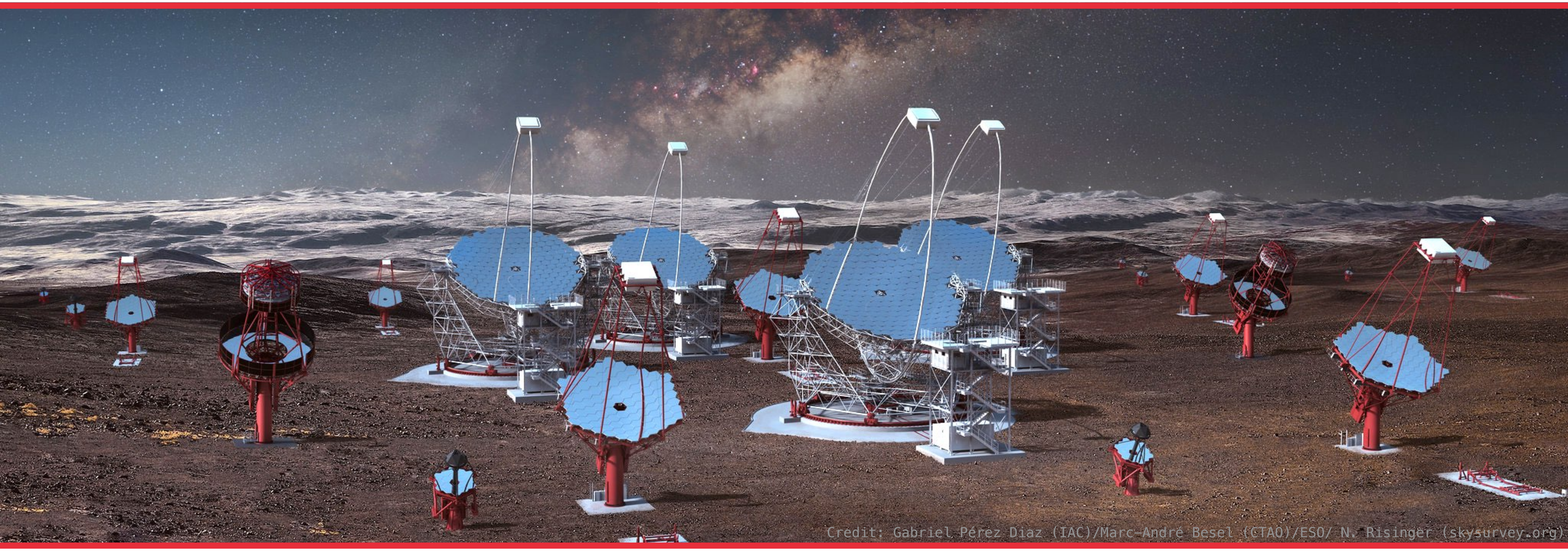
Prospects for **Galactic transient sources** detection with the **Cherenkov Telescope Array**



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for the CTA Consortium

cherenkov telescope array

Galactic transients

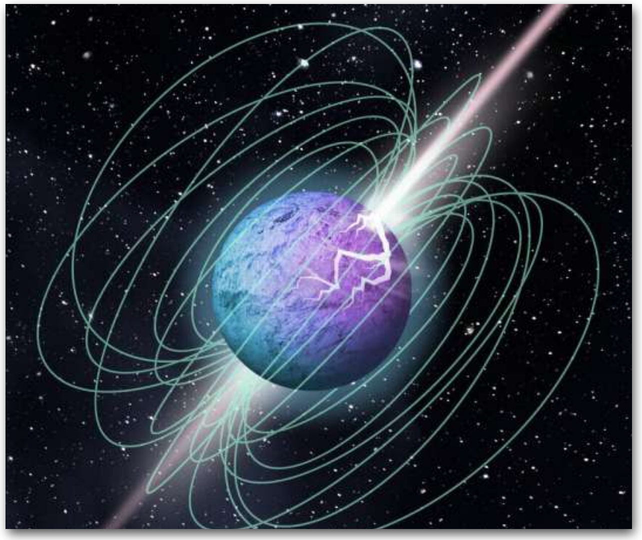
- A wide range of sources in our Galaxy exhibit transient emission via **accretion/ejection processes** and interactions between e.g. jets, **outflows and/or strong winds**

- These events can accelerate particles up to relativistic energies, leading to the **production of high-energy (HE, E>100 MeV) radiation**

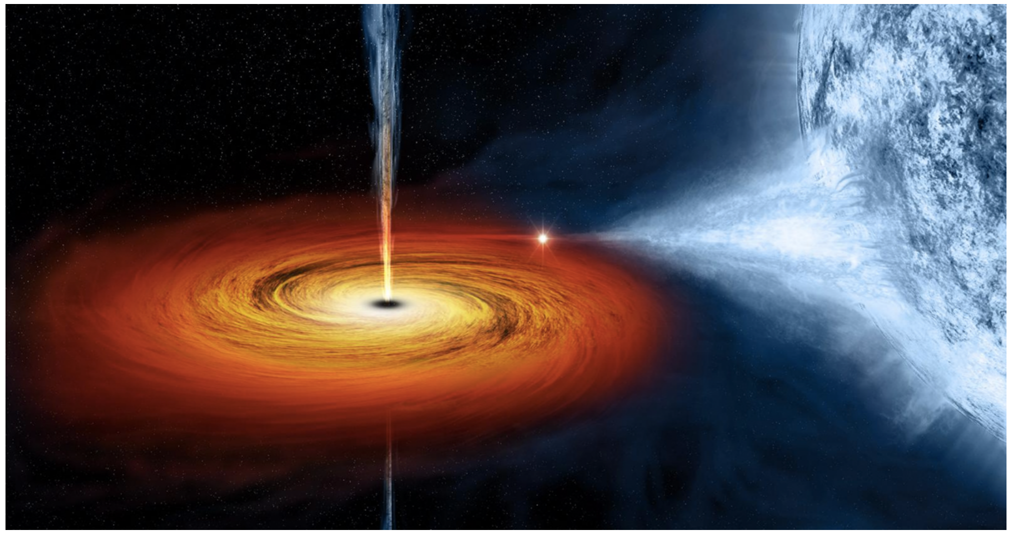
- **Some objects** such as microquasars, magnetars (giant flares), novae or flares from pulsar wind nebulae (PWNe) **have already been detected in the MeV- (few) GeV regime** (see e.g. Fermi collaboration 2010, Fermi collaboration 2012)

novae

magnetars

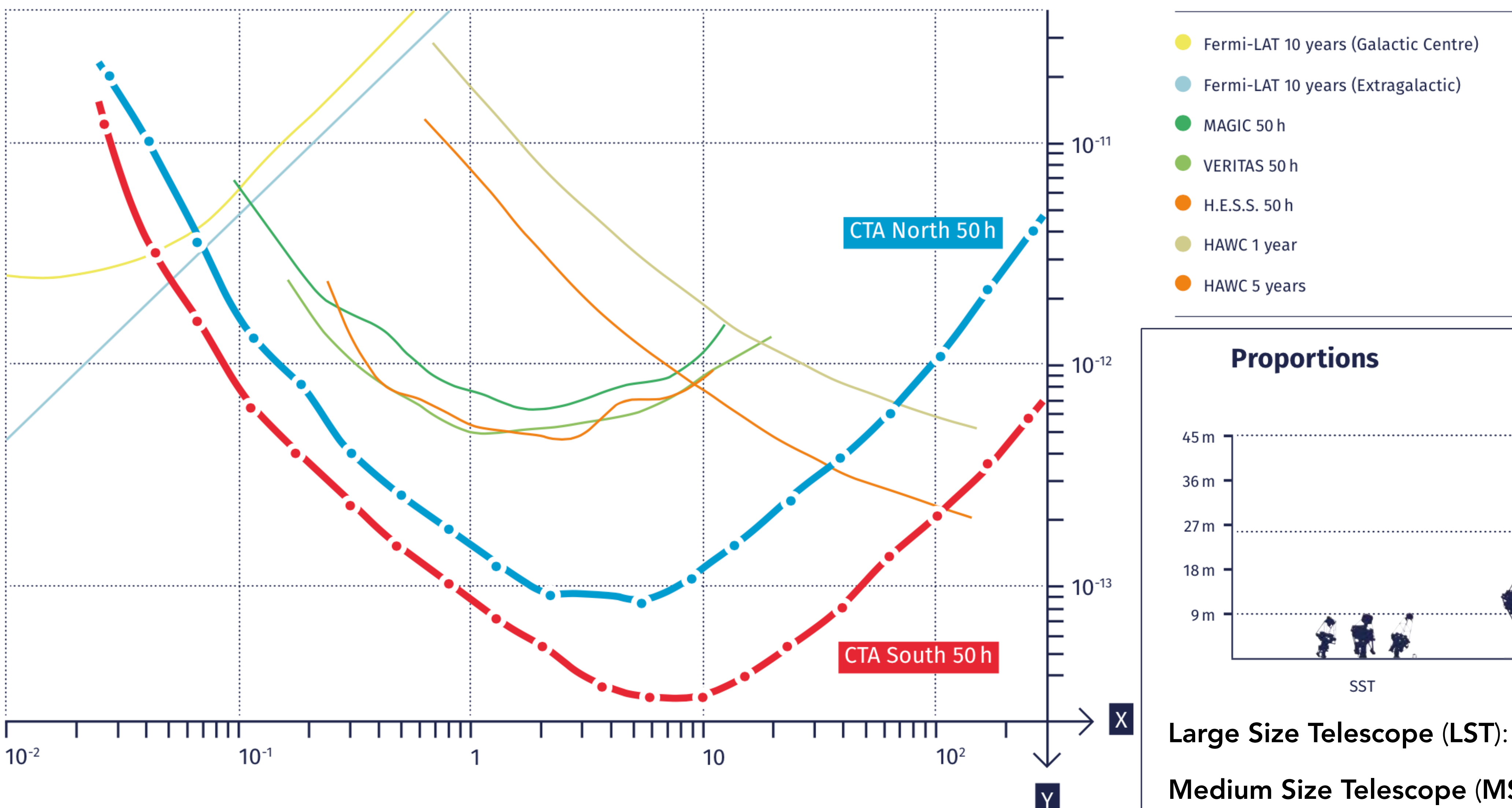


microquasars



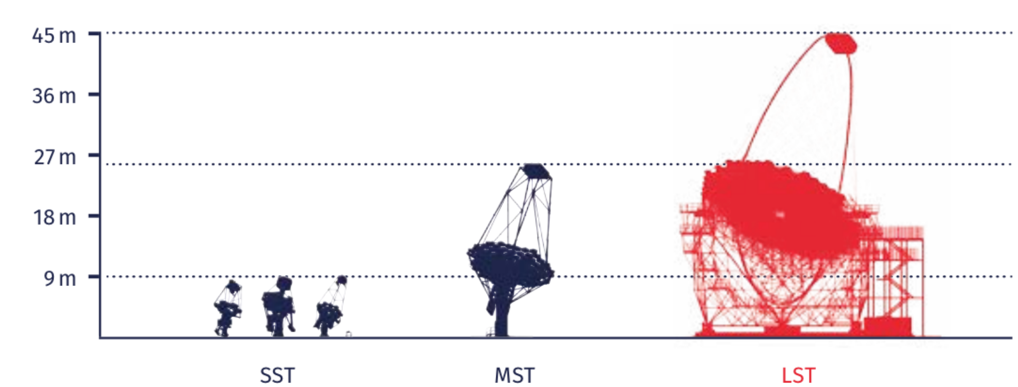
Cherenkov Telescope Array (CTA)

- Future ground-based gamma-ray observatory
  - **Improve current sensitivity** of instruments**:** by **an order of magnitude**
  - **Enlarge the energy range** : almost **four decades** in energy.
  - **Improve energy and angular resolution**
- Two array sites: **CTA-North** (La Palma, Spain) **& CTA-South** (Paranal, Chile)
- **Three clases of telescopes** sensitive to different energies



X = Energy E_R (TeV) Y = E^2 x Flux Sensitivity (erg cm^{-2} s^{-1}) (Differential Flux Sensitivity)

Proportions

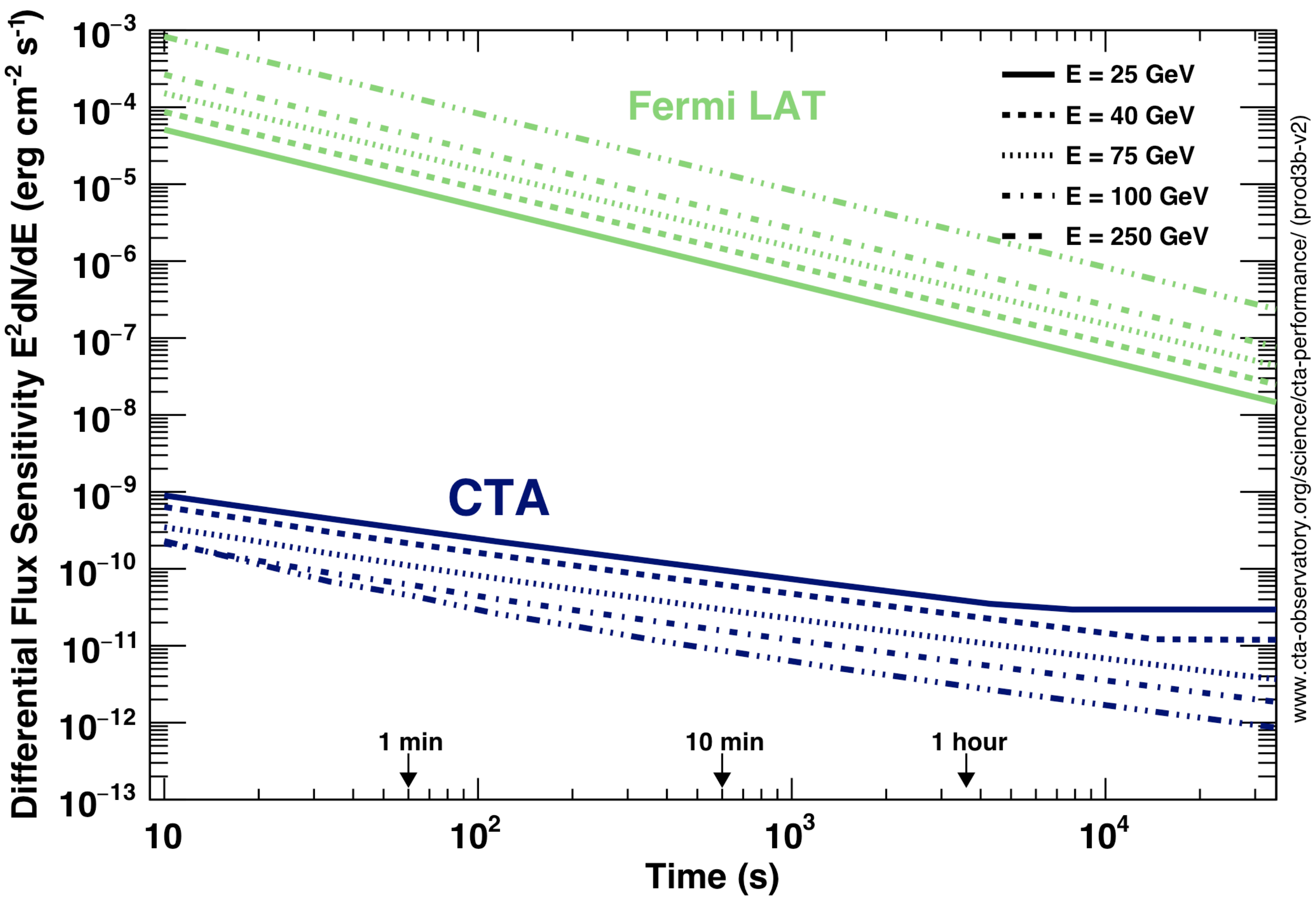


Large Size Telescope (LST):	Φ:23m, E: 20 - 150 GeV
Medium Size Telescope (MST):	Φ:12m, E: 150 GeV - 5 TeV
Small Size Telescope (SST):	Φ:4m, E: 5 TeV -300 TeV

https://www.cta-observatory.org/

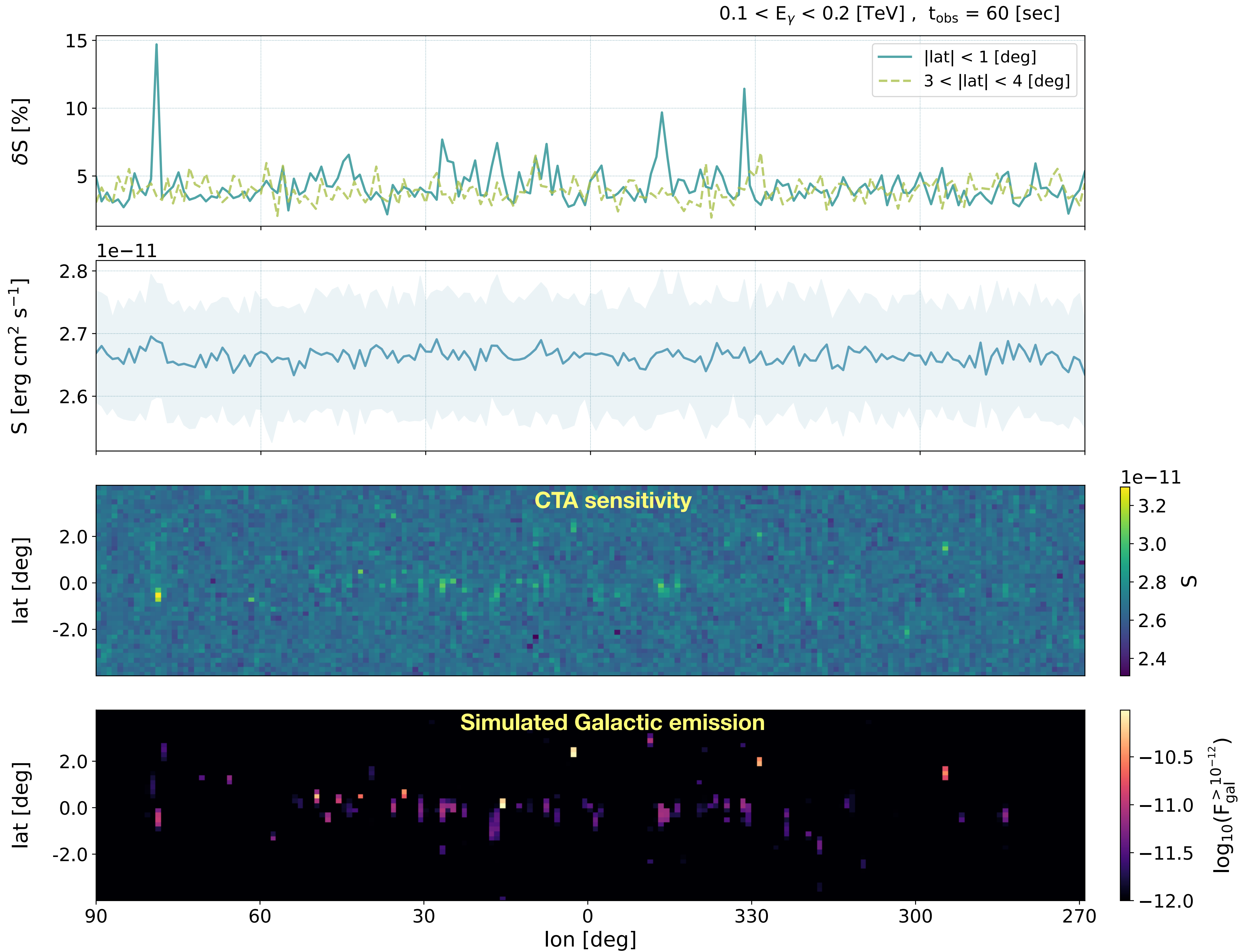
Galactic transients task force

- Sub-group inside the Transients/MWL working group of CTA consortium
- Study the **capabilities of CTA to detect Galactic transient events**
- Working on a CTA consortium publication "Galactic Transient Sources with the Cherenkov Telescope Array"
  - The results shown in this presentation are part of the **paper in preparation**
- **Short-time sensitivity of CTA will allow unprecedent transient detection**

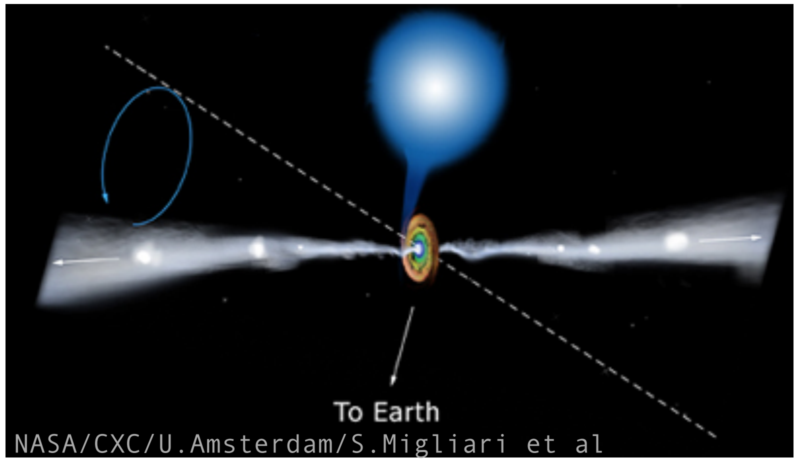


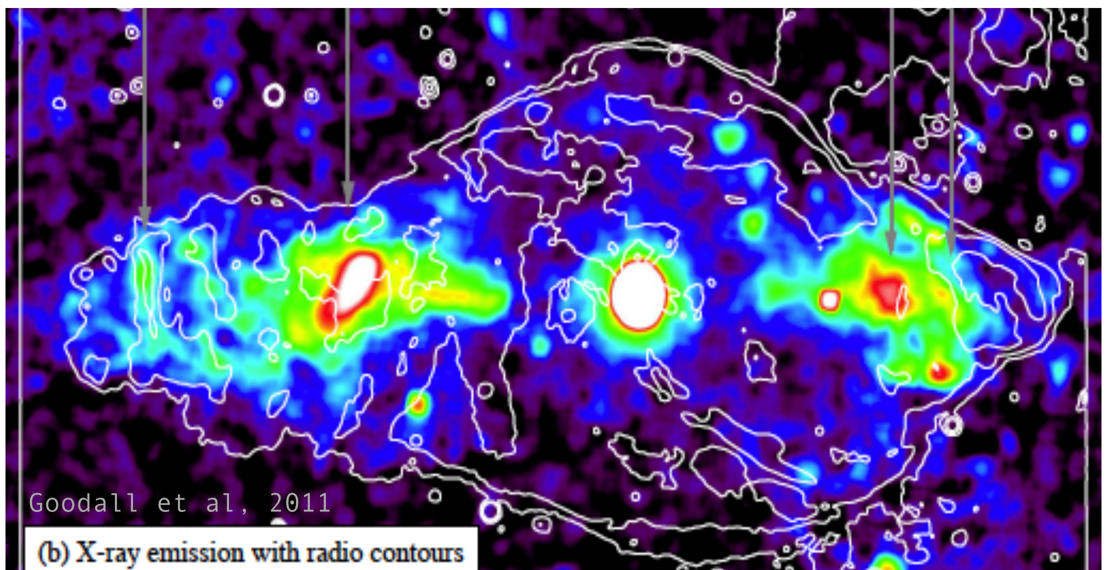
Sensitivity studies

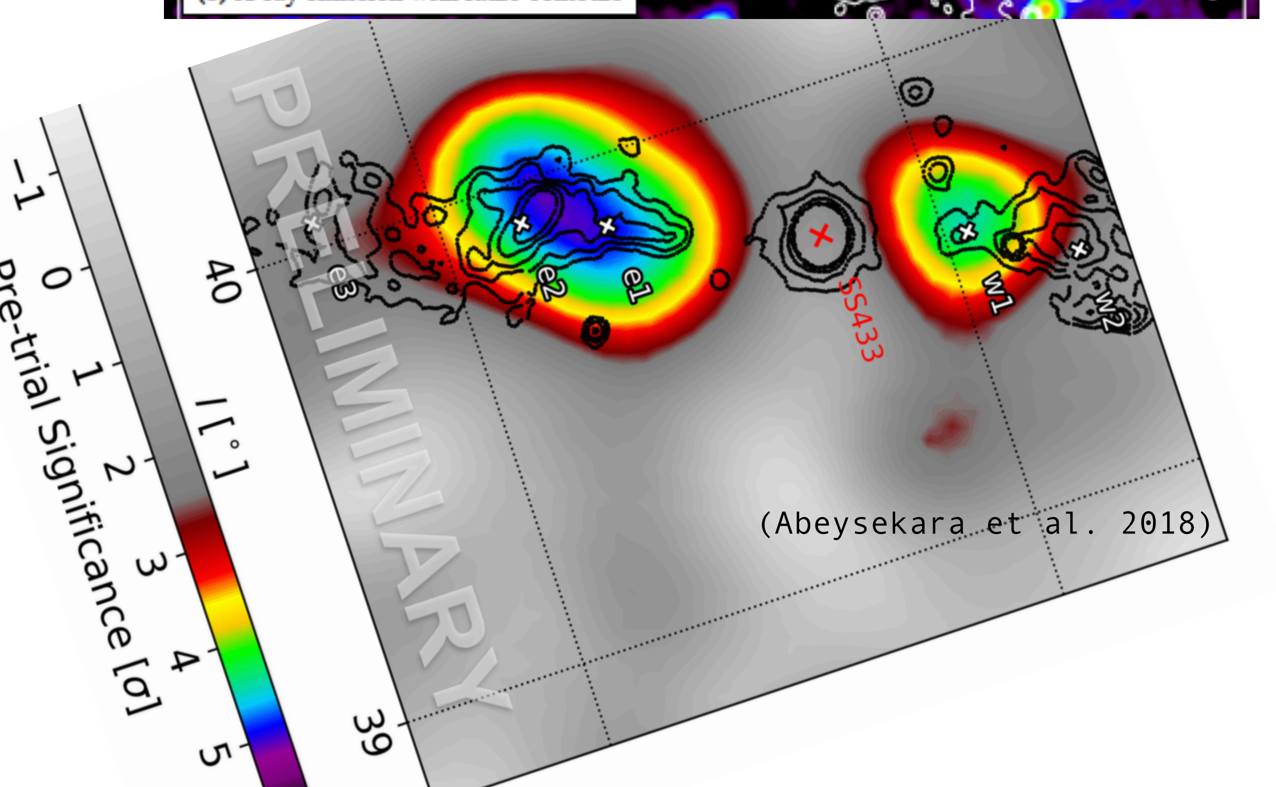
- CTA-S sensitivity in the Galactic Plane (100-200 GeV)
- **No significant degradation in sensitivity** for detection of new sources
  - Only relative increase of the flux threshold of 5–10%, when coinciding with strong Galactic emitters.



The microquasar SS433



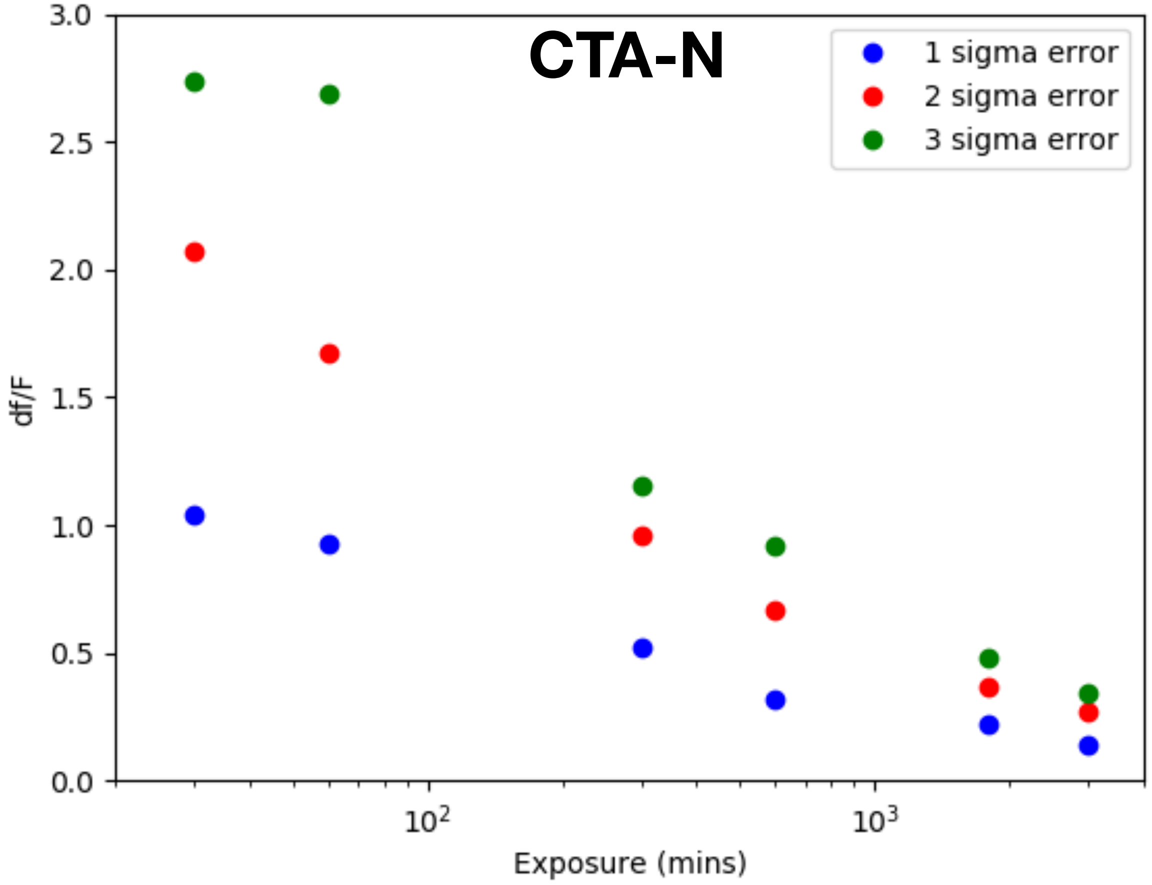


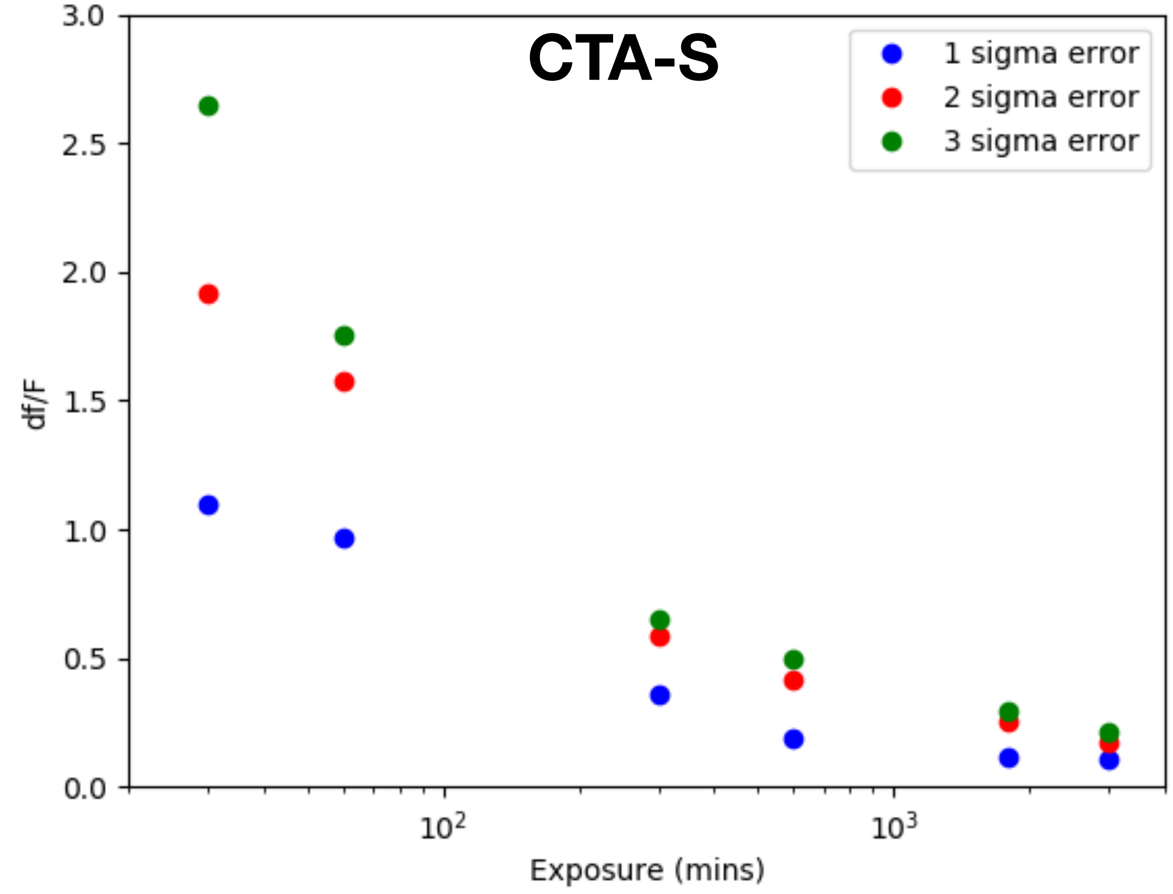


- **VHE emission reported by HAWC: 5.4σ (combined) detection in eastern (e1) and western (w1) lobes**
  - 2.7 years of data (Abeysekara et al. 2018)
  - Spectral point at 20 TeV
  - ULs on the angular size of the emission regions
- **HE emission reported with *Fermi*-LAT** by several authors (Bordas et al. 2015, 2016, Xing et al. 2019, Sun et al. 2019, Fang et al. 2020, Li et al. 2020)
- IACTs have not detected the central binary nor lobes (Ahnen et al. 2018)
- Our goal: test the **capability of CTA** to detect emission from SS 433, simulating the **central source** with both the **east and west lobes as extended sources**
  - Energy range = 0.1 -100 TeV
  - Lobes: input fluxes from HAWC at 20 TeV: 2.4e-16 TeVcm^{-2}s^{-1} (east) and 2.1e-16 TeVcm^{-2}s^{-1} (west)
  - Central source: input flux : 0.5 x flux of west lobe
- Short-term variability tests

Central source and lobes

Central source





Lobes

CTA-N

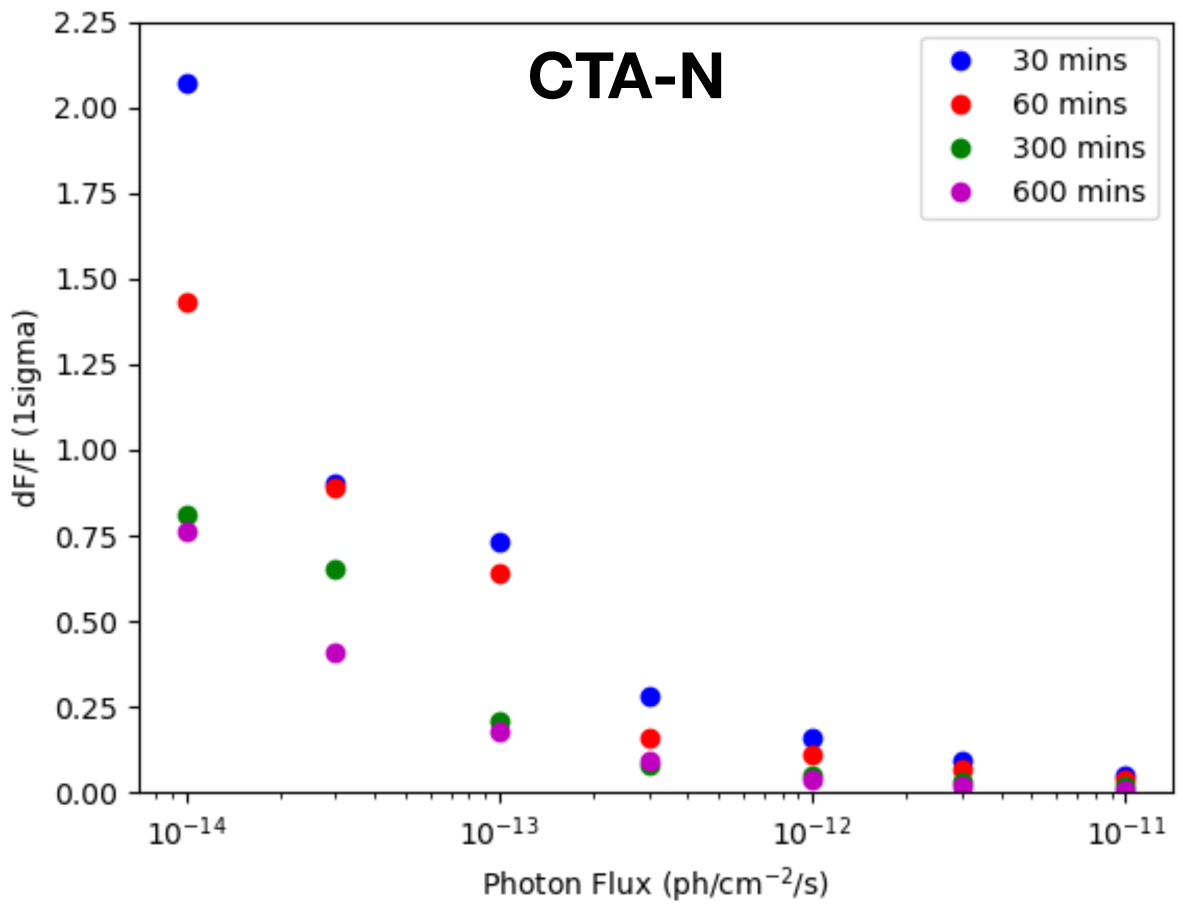
West lobe σ_w	East lobe σ_e	TS^{West}_{10hrs}	TS^{East}_{10hrs}	TS^{West}_{30hrs}	TS^{East}_{30hrs}	TS^{West}_{50hrs}	TS^{East}_{50hrs}
0.001	0.001	52.0	76.8	229.1	303.7	354.3	477.2
0.0625	0.0875	38.9	10.9	121.9	105.2	152.0	114.5
0.175	0.125	7.9	9.4	23.7	57.6	57.1	100.2
0.26	0.1875	2.4	8.2	6.3	20.1	9.4	37.5

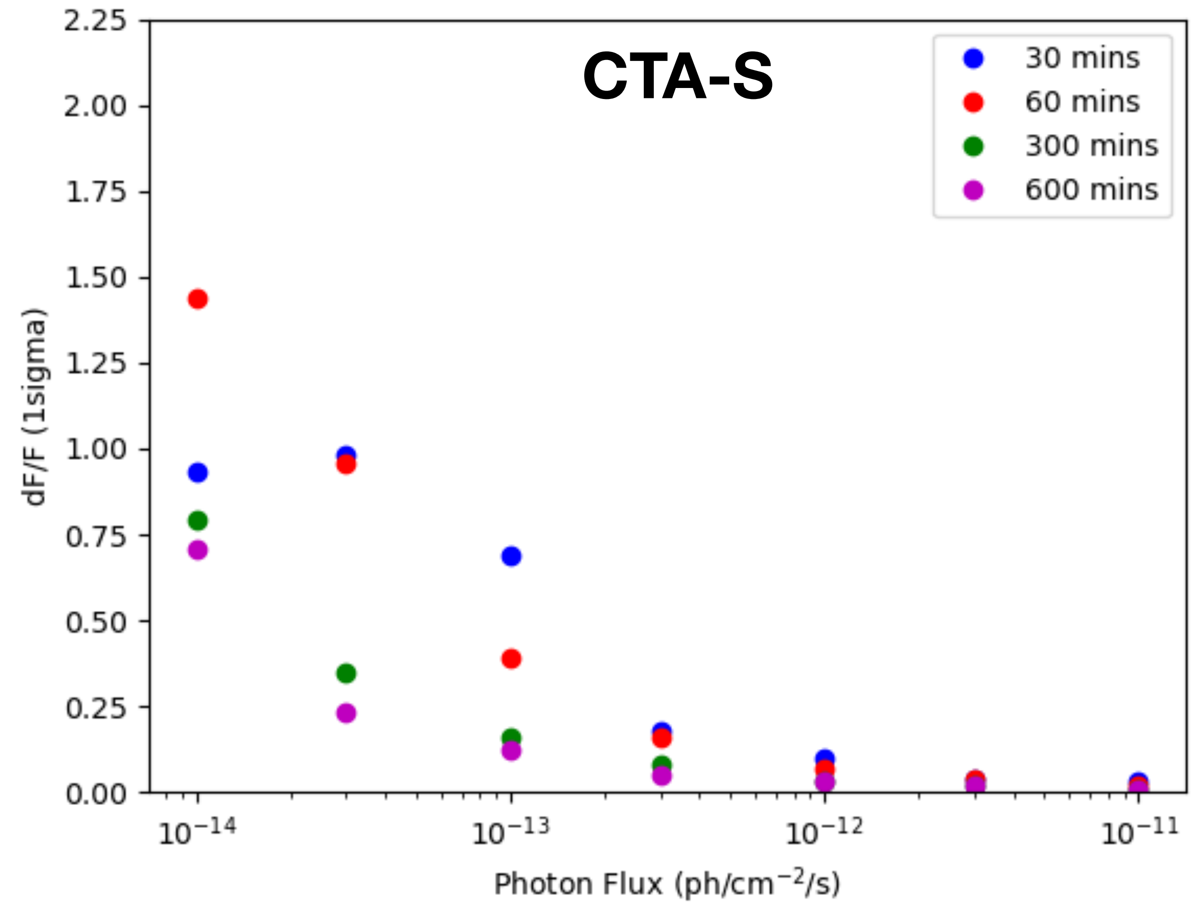
CTA-S

σ_w	σ_e	TS^{West}_{10hrs}	TS^{East}_{10hrs}	TS^{West}_{50hrs}	TS^{East}_{30hrs}	TS^{West}_{50hrs}	TS^{East}_{50hrs}
0.001	0.001	137.4	184.6	738.8	821.9	886.3	1261.4
0.0625	0.0875	59.2	73.6	178.4	384.2	273.1	401.0
0.175	0.125	11.1	31.3	76.3	104.3	79.5	226.7
0.26	0.1875	2.6	7.2	44.4	60.3	34.7	115.9

- CTA-N and CTA-S will **detect the central source and its lobes**

Testing short-term variability with SS433

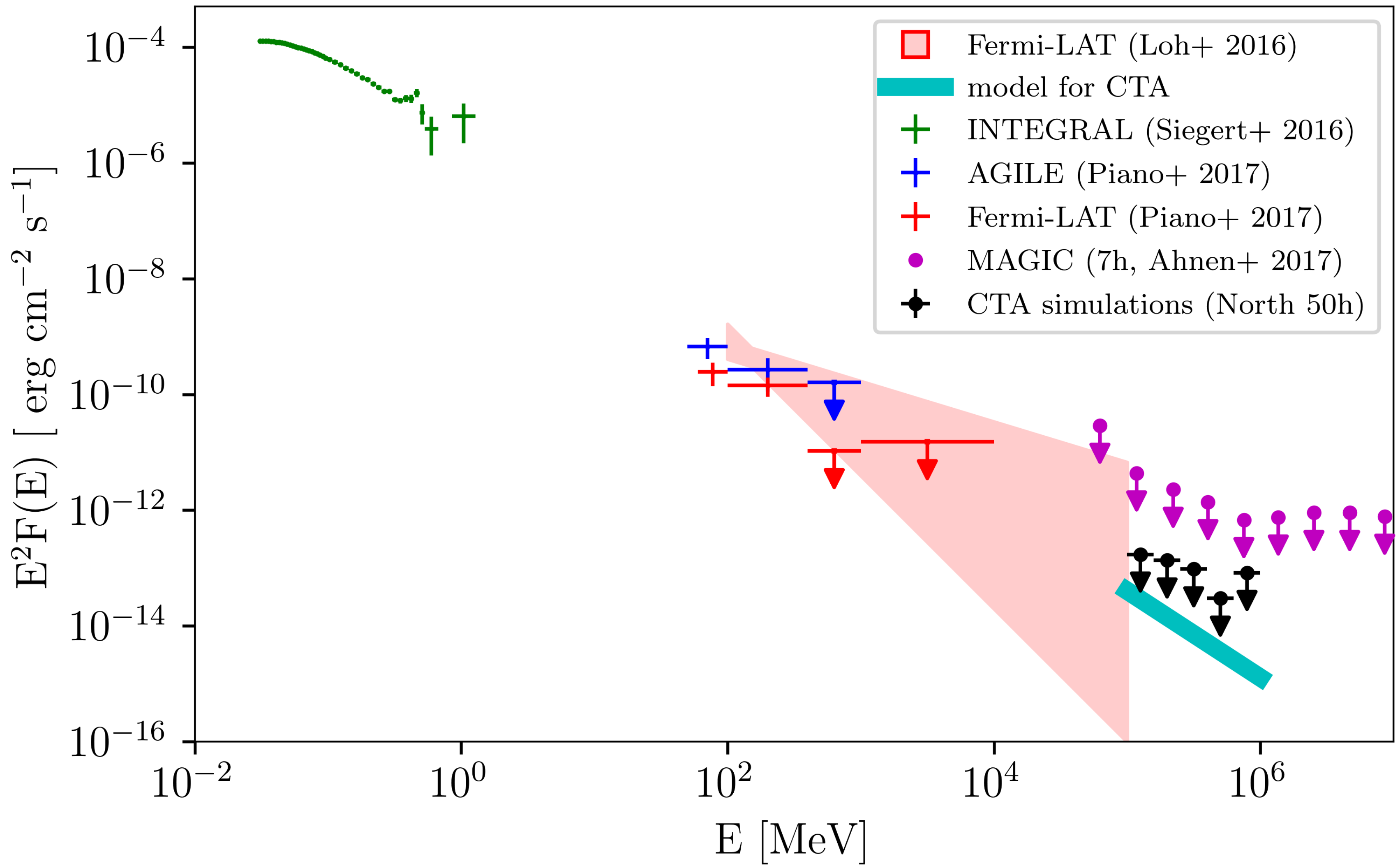




- Test the **effectiveness of CTA on dim transient sources** and determine what **level of variability can be observed** at shorter exposures
  - If photon flux < 1×10^{-13} ph/cm2/s : > 10 hours observations to detect any variability
  - If photon flux >= 1×10^{-13} ph/cm2/s: CTA could detect ~ 10% variability in 5 -10 hours
  - If photon flux >= 3×10^{-12} ph/cm2/s : ~ 5% variability with observations 0.5 -1.0 hour

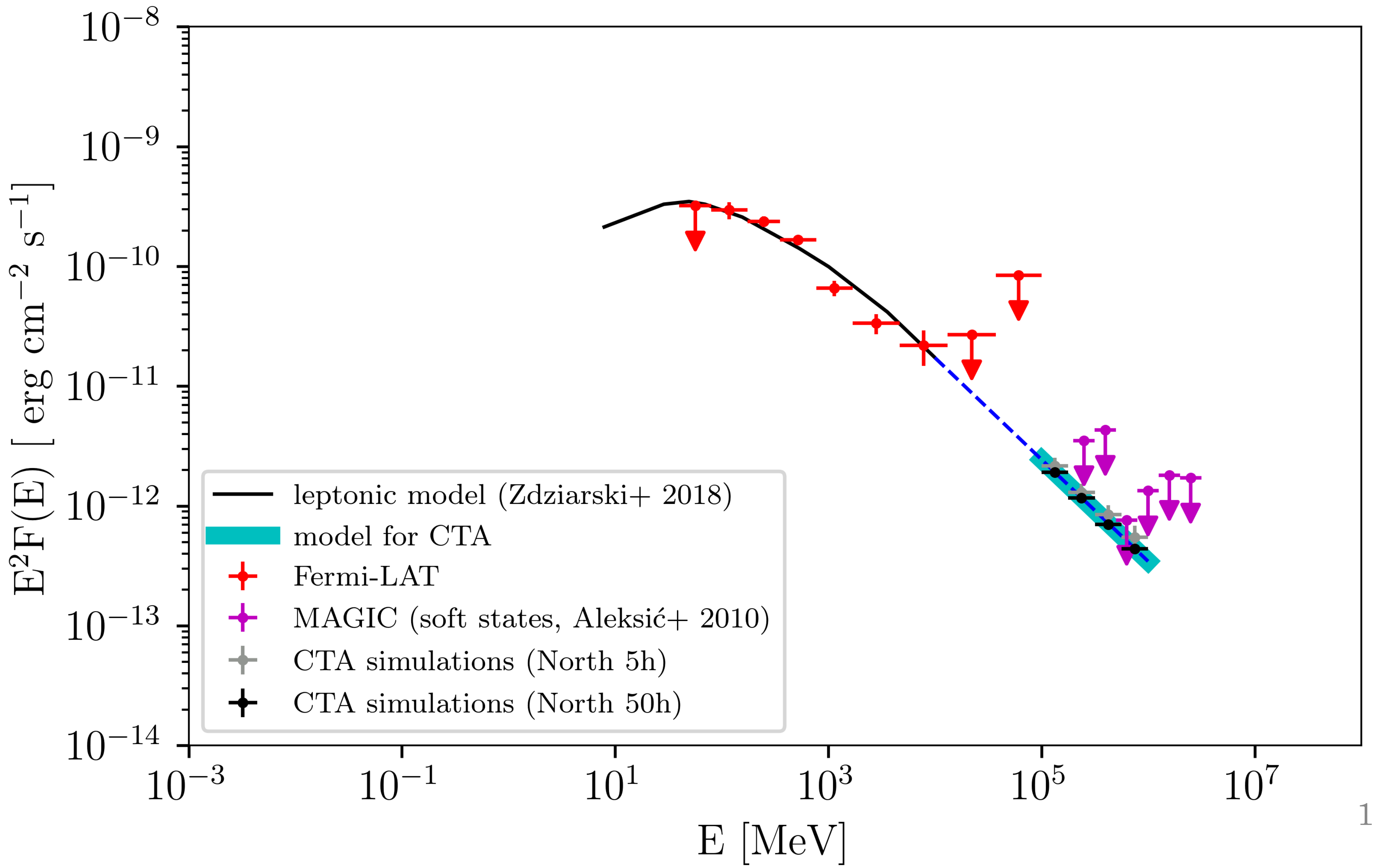
V404 Cygni

- **LMXB:** low mass star + BH
- **Major outburst in June 2015** after 26 years in quiescence
  - **Hint of transient detection (~4σ) in *Fermi*-LAT data** (Loh et al. 2016) coincident with the brightest peak of luminosity observed in radio, hard X-ray and soft γ-ray bands (Loh et al. 2016; Siegert et al. 2016, Piano et al. 2017)
  - No VHE emission detected by MAGIC (Ahnen et al.2017)
- CTA simulations (100 GeV-1 TeV): extension of the PWL spectrum observed by *Fermi*-LAT (Loh et al. 2016)
- **No detection with CTA in a 50-hour observation**



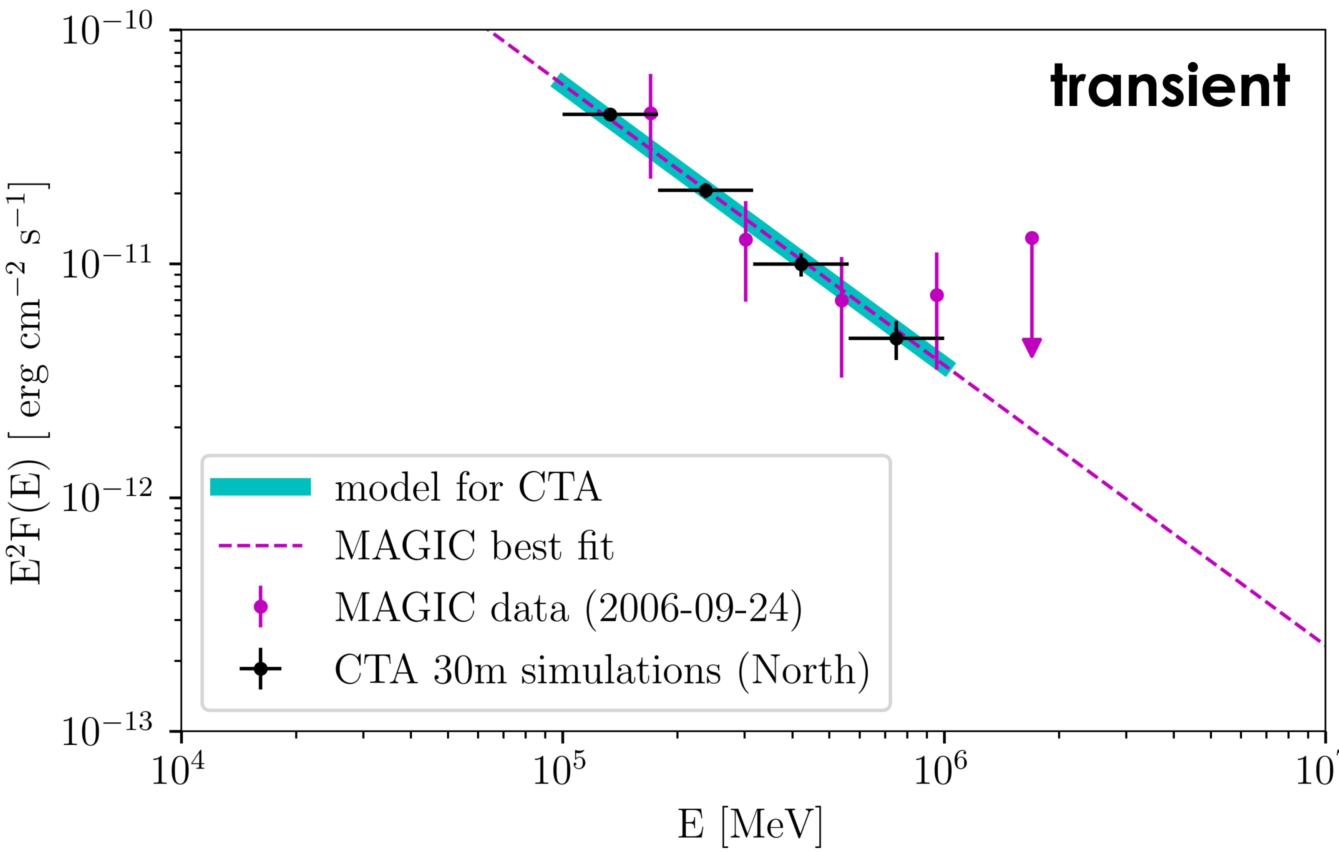
Cygnus X-3

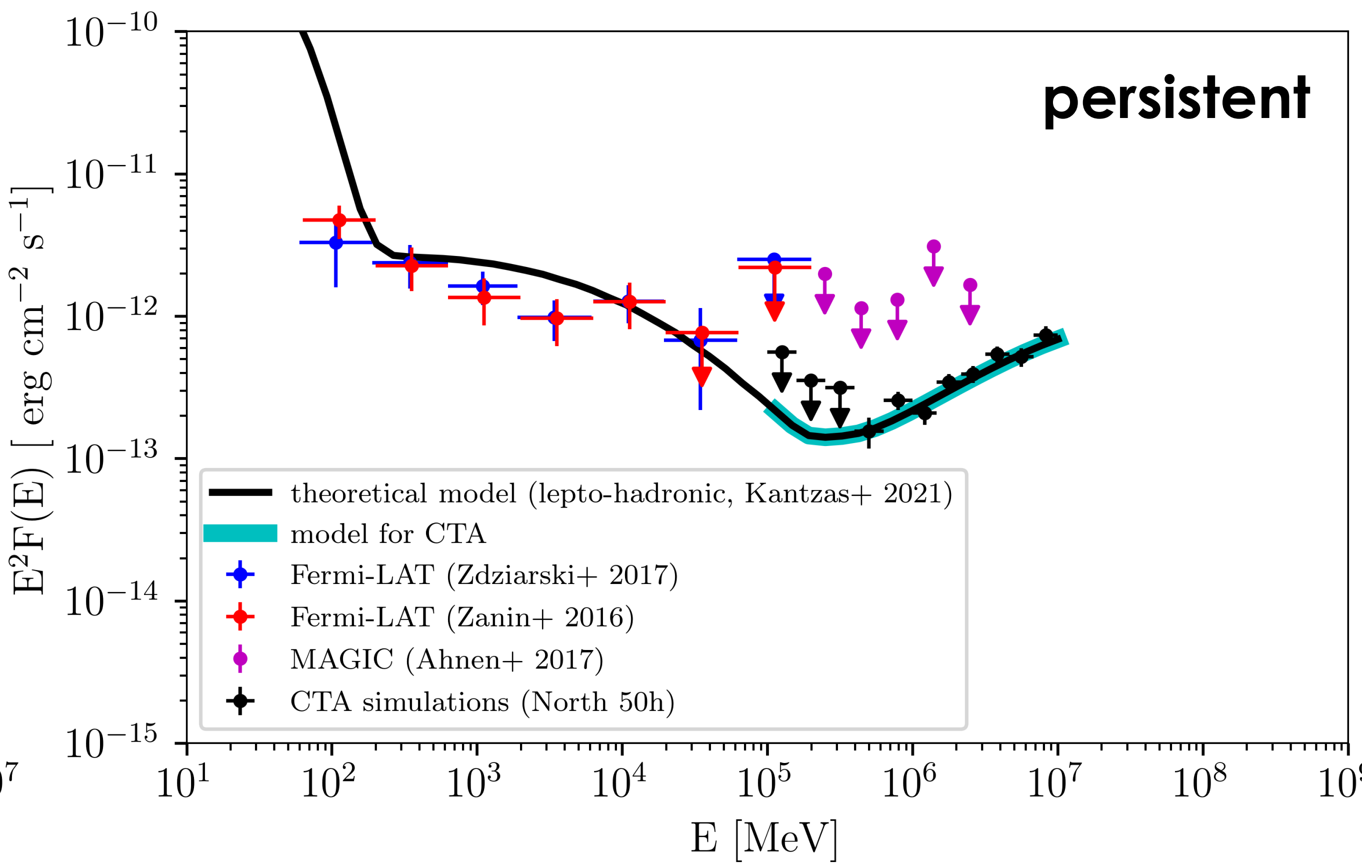
- **HMXB**: WR+compact object (likely BH) in a close orbit: 4.8 h
- Major **radio flares during soft state** (Szostek et al. 2008)
- **Transient HE emission detected:** AGILE (Tavani et al. 2009) and *Fermi*-LAT (Abdo et al. 2009)
- No VHE reported by MAGIC (ICRC 2017, id.734)
- CTA simulations (100 GeV – 1 TeV): extension of the GeV model by Zdziarski et al. 2018
- **CTA-N will detect Cygnus X-3 with high significance:**
  - **5h : 13σ** (TS=160)
  - **50h: 35σ** (TS= 1249)



Cygnus X-1

- **HMXB:** O9.7 Iab supergiantstar + BH
- **Transient episodes** with AGILE (Bulgarelli et al. 2008, Sabatini et al. 2010, 2013)
- **Persistent HE emission during hard state** seen by *Fermi*-LAT (Zanin et al. 2016, Zdziarski et al. 2017)
- **VHE: hint of transient emission with MAGIC**: 4σ in 80 min (Albert et al. 2006), **no persistent** signal detected (Ahnen et al. 2017)
- CTA simulations (100 GeV – 1 TeV) to search for:
  - transient emission: 30-minute observation with MAGIC hint SED as input
  - persistent emission: lepto-hadronic model by Kantzas et al. 2021, assuming 50 h of observations



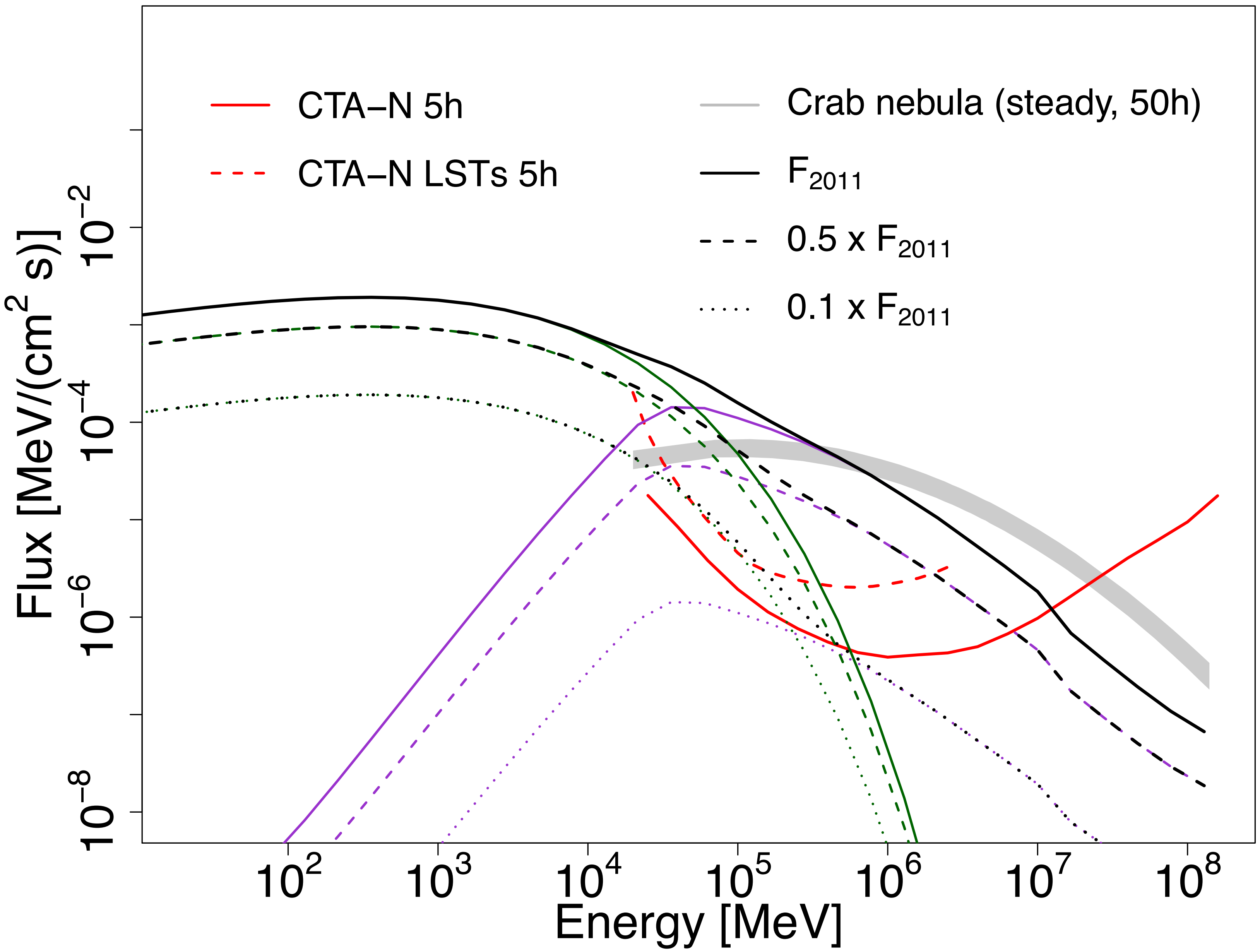


- **Detection of transient (44σ, TS=1907) and persistent emission (39σ, TS= 1537) with CTA-N**

Crab Nebula flares

- Studying the capabilities of CTA to detect the **rapid and bright MeV flares observed in Crab** (Tavani et al. 2011, Abdo et al. 2011) with **timescales of hours**

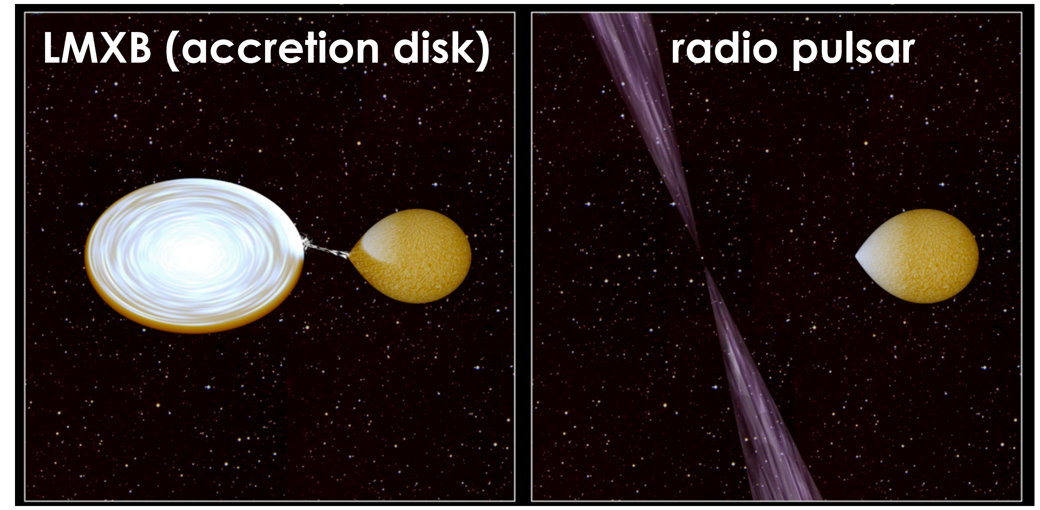
- **Crab nebula SED in flaring state,** for different parameters related to the physical properties of the nebula, taking April 2011 flare as reference



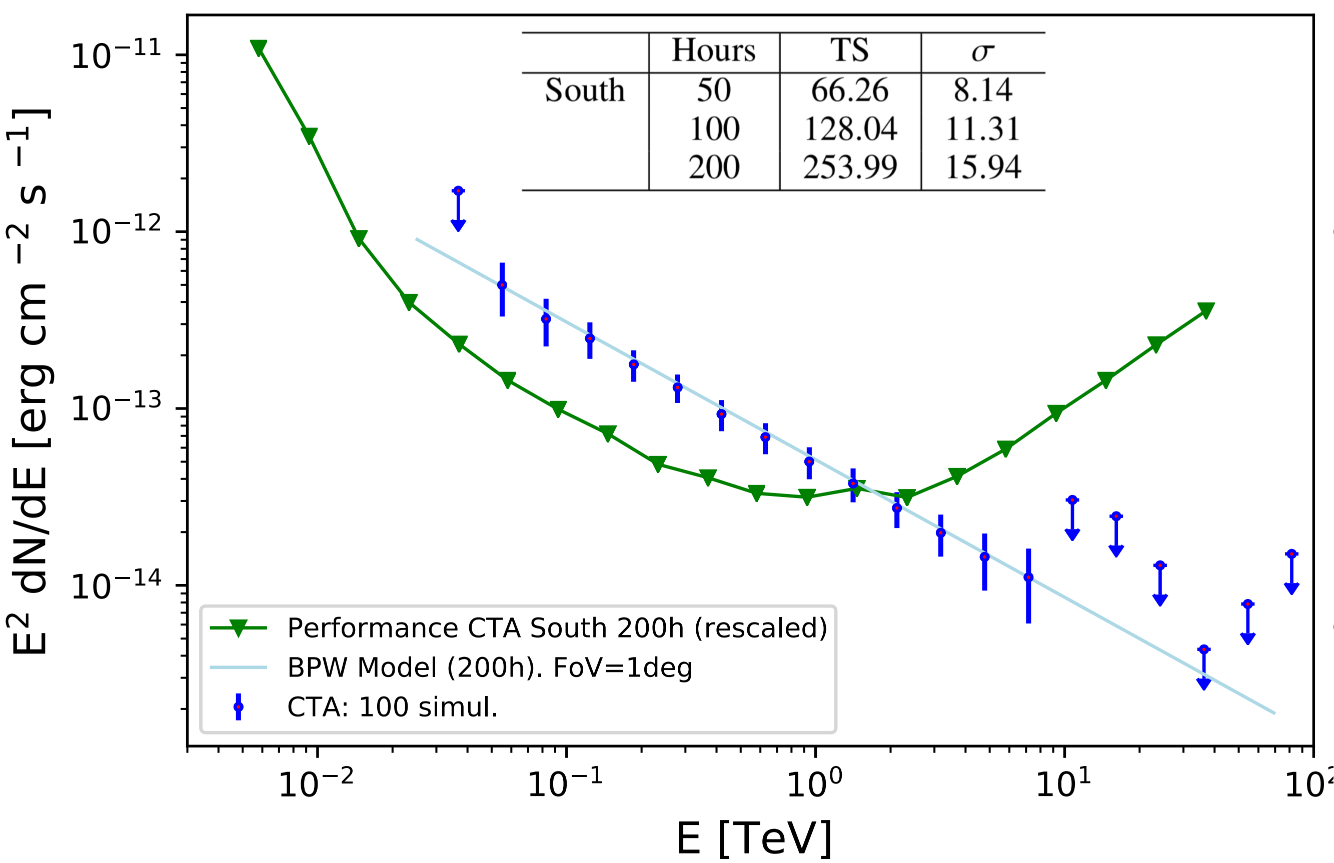
- Flares dimmer than April-2011-flare (e.g. by a factor 0.5 at hundreds of MeV) **could be detected in < 5h**
- **Good prospects for CTA and specially LSTs**

Transitional millisecond pulsars (tMSPs)

- Composed of a low-mass star and a millisecond-rotation pulsar
- **Switch between LMXB (accretion phase) and radio pulsar**
  - *Fermi*-LAT has detected these systems during the accretion phase (Ray et al. 2012)
- Can CTA detect tMSPs?
  - **PSRJ1023+0038 and XSS1227-4859 during the accretion phase**
  - ***Fermi*-LAT analysis**-> **spectral parameters**-> simulations in the **CTA band** (E: 0.03-100 TeV) assuming a broken power-law (BPWL) model

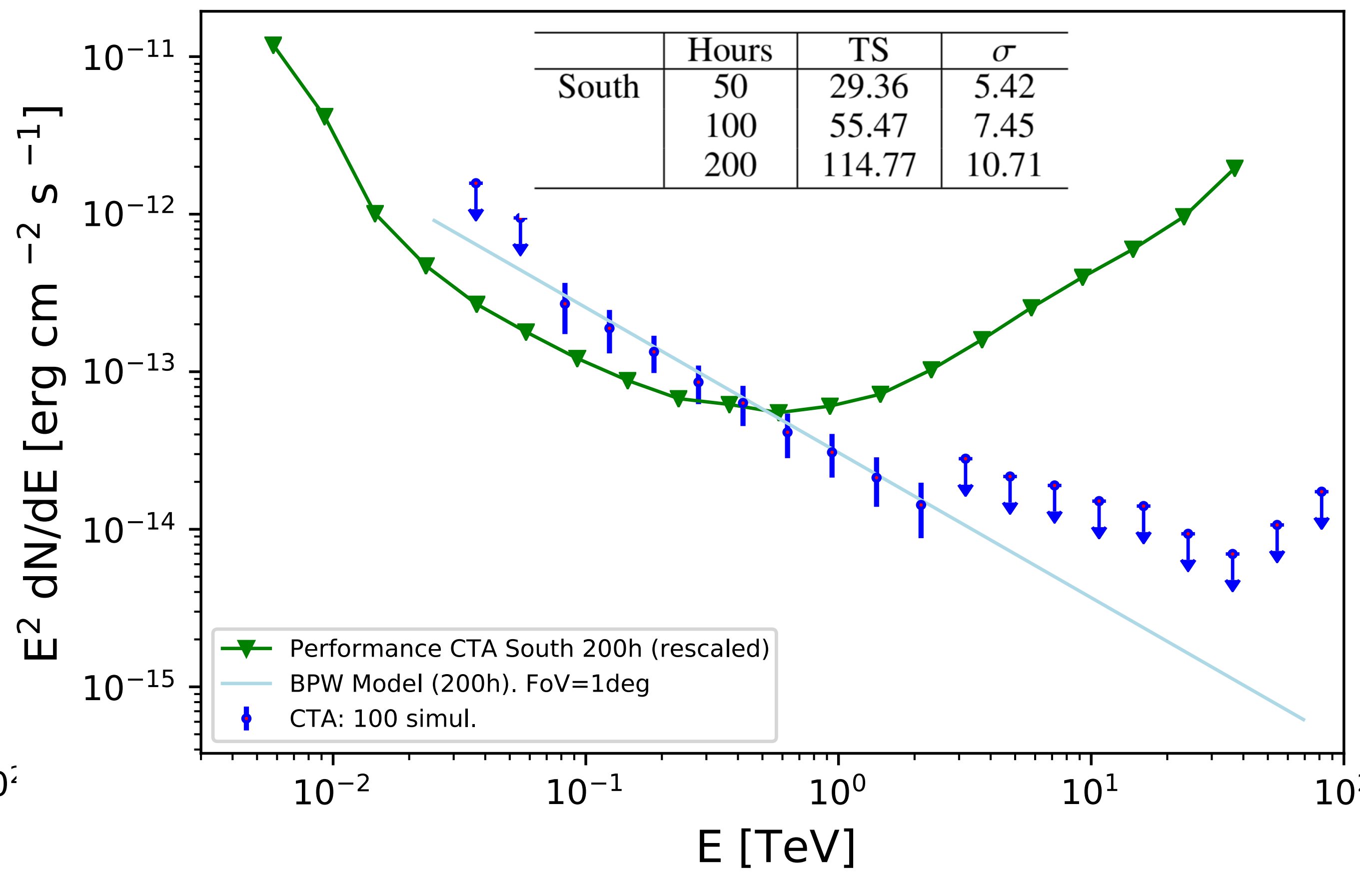


XSS1227-4859



	Hours	TS	σ
South	50	66.26	8.14
	100	128.04	11.31
	200	253.99	15.94

PSRJ1023+0038



	Hours	TS	σ
South	50	29.36	5.42
	100	55.47	7.45
	200	114.77	10.71

- **Long observation times (>50h) needed** to detect tMSPs

Summary

- CTA will perform **detections of Galactic transients** with unprecedent sensitivity
- **Sensitivity studies in the Galactic Plane**
  - No degratation for the detection of new sources
- **Microquasars**:
  - **SS433**:
    - CTA will **detect the central source and both lobes**
    - Tests on short-time variability
  - **Cygnus region**: depending on the spectral model:
    - **Cygnus X-3: detected emission in 5h and 50h with high significance**
    - **Cygnus X-1: transient and persistent emission also with high significance**
    - No expected emission from the LMXB V404 Cyg
- **Flares from the Crab Nebula**:
  - **Detection both with CTA-N and with LSTs subarray** in **<5 h**
- **Transitional millisecond pulsars:**
  - **Long observation times (>50h) required** to detect tMSPs

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Thank you

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