



MAX-PLANCK-GESELLSCHAFT

THE CHERENKOV TELESCOPE ARRAY PROJECT: OVERVIEW AND THE GALACTIC SCIENCE PROGRAM

CTA consortium represented by R. Zanin (MPIK, Heidelberg)

CRIS 2018, Portopalo di Capo Passero June 18 2018

STATUS OF γ -RAY ASTRONOMY



1

Fermi LAT



HAWC



MAGIC



VERITAS



HESS



FACT

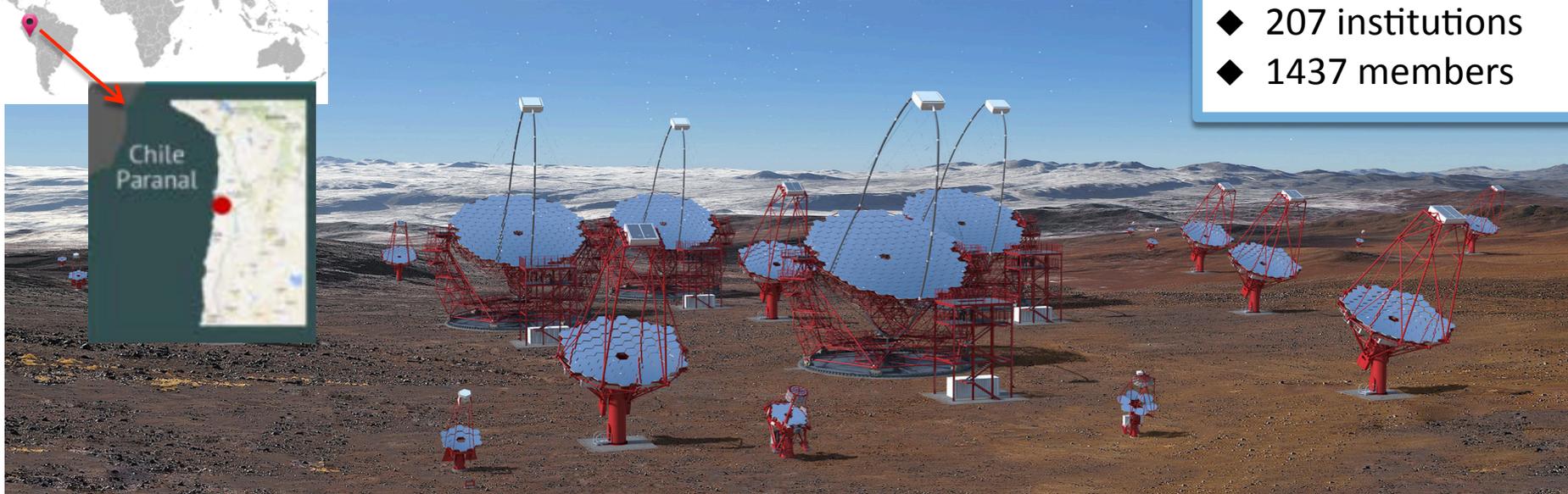


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THE CHERENKOV TELESCOPE ARRAY



2



- ◆ 32 countries
- ◆ 207 institutions
- ◆ 1437 members



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CTA: SOUTHERN SITE

3

25 MST

medium sized telescopes

12 m \odot

> 7° FoV

1 km²

4 LST

large sized telescopes

23 m \odot

4.5° FoV

400 m²

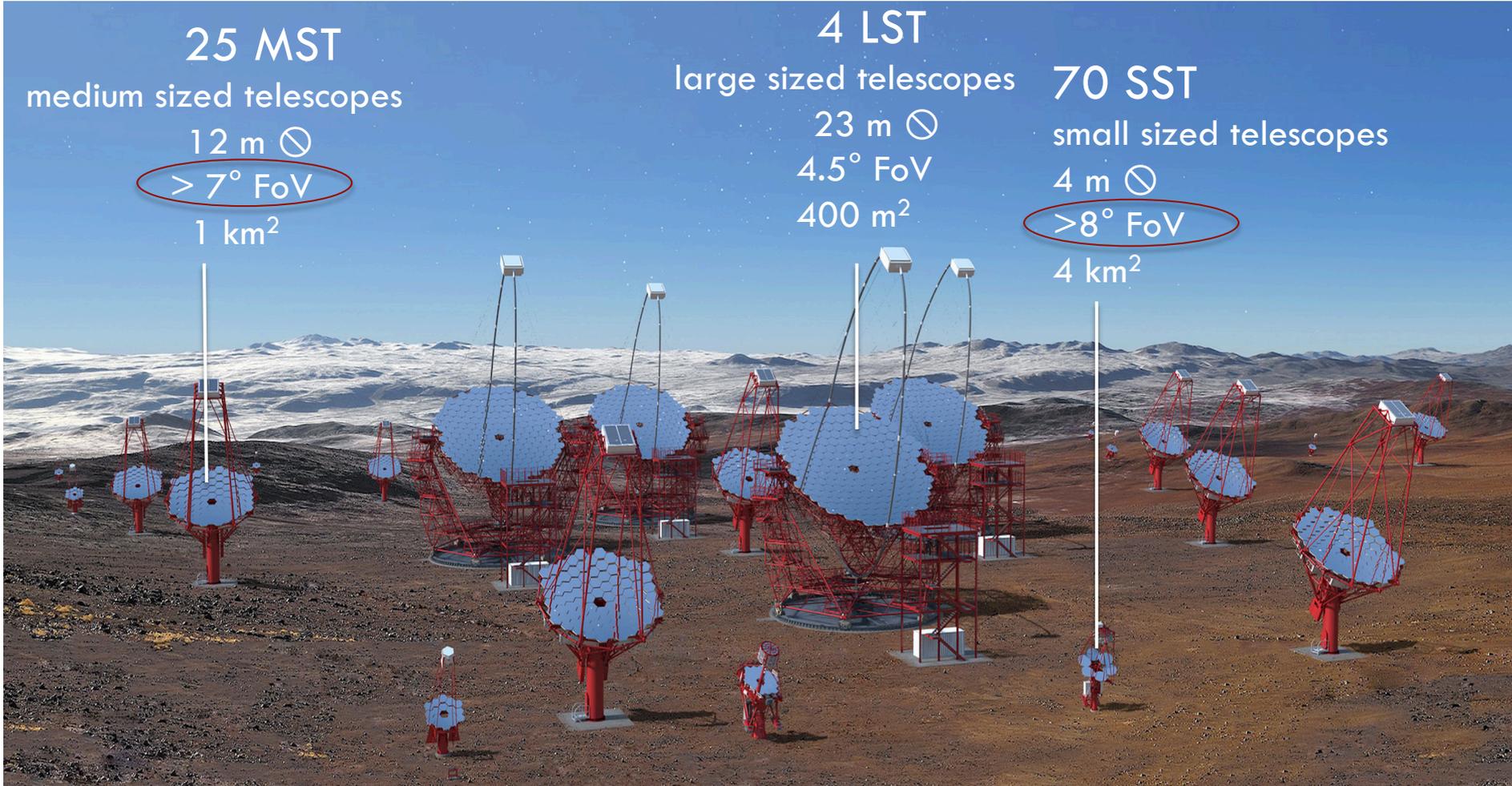
70 SST

small sized telescopes

4 m \odot

> 8° FoV

4 km²



CTA: SOUTHERN SITE

3



CTA: SOUTHERN SITE

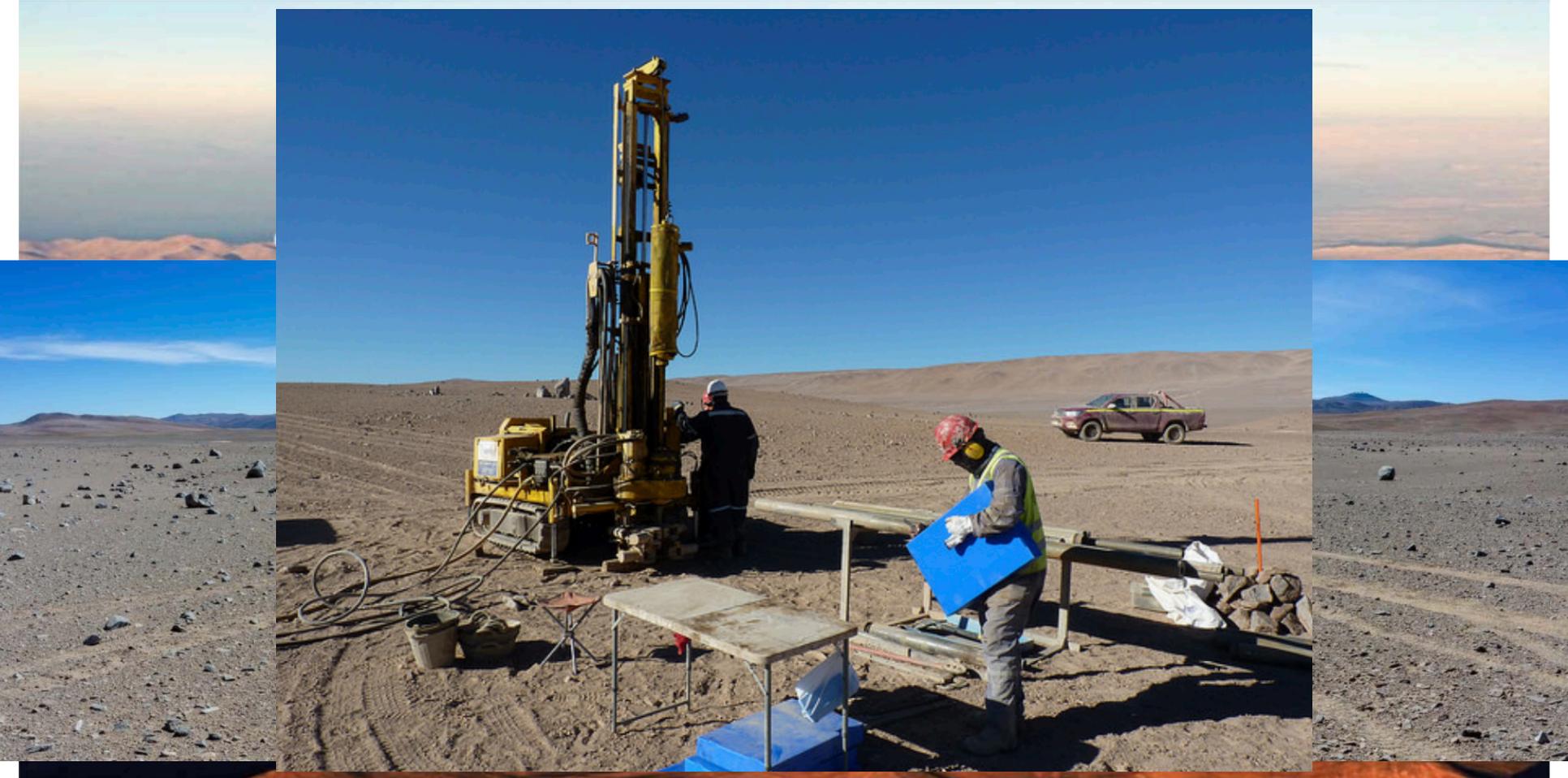
3



CTA: SOUTHERN SITE



3



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CTA: NORTHERN SITE

4



CTA: NORTHERN SITE

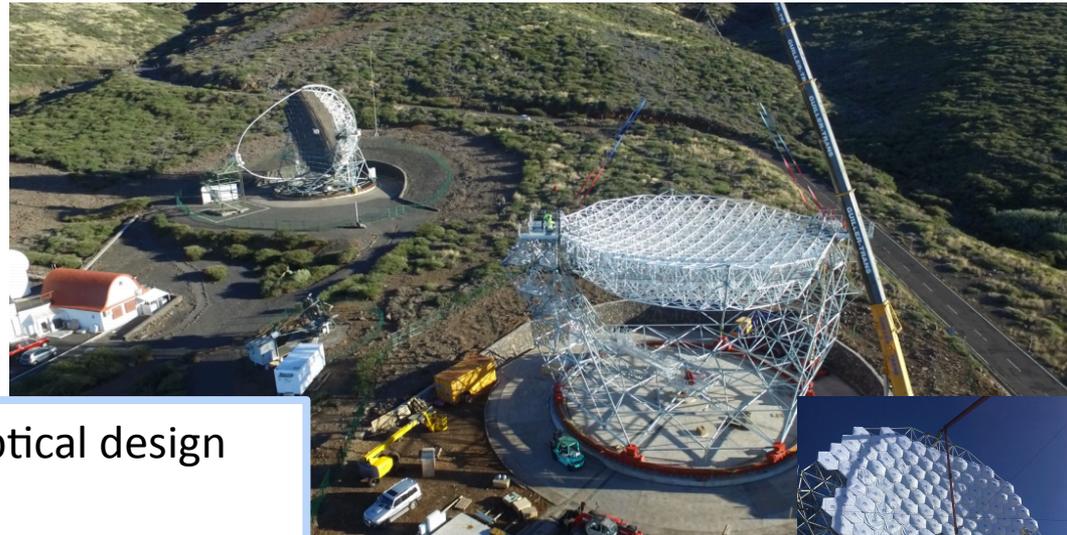
4



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THE TELESCOPES: LSTs & MSTs

5



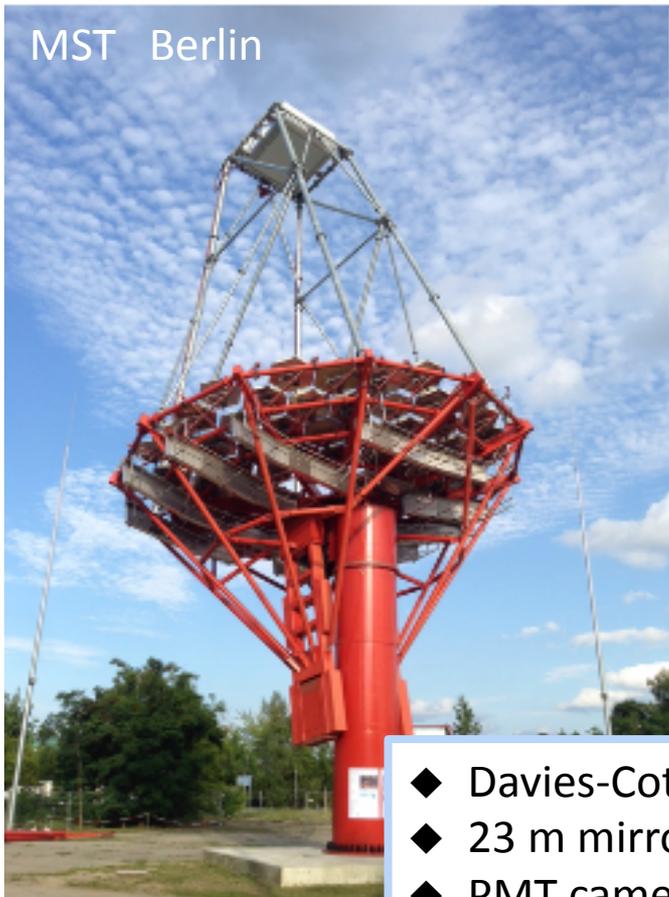
- ◆ Davies-Cotton optical design
- ◆ 23 m mirror
- ◆ PMT camera: analog memories



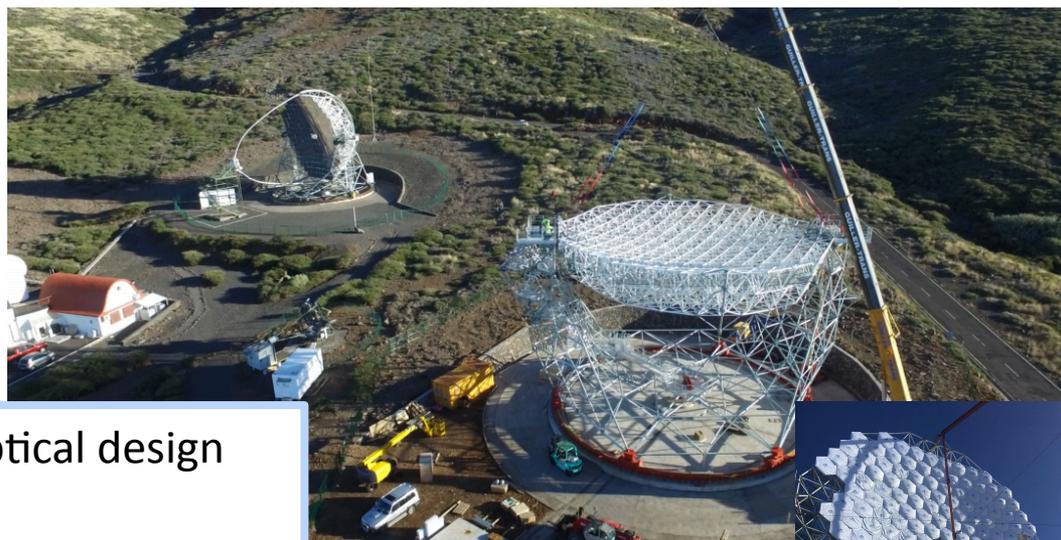
THE TELESCOPES: LSTs & MSTs

5

MST Berlin



- ◆ Davies-Cotton optical design
- ◆ 12m mirror
- ◆ 2-types of PMTs cameras:
 - ◆ FlashCam: FlashADC @ 200 MHz
 - ◆ NectarCam: analog memories @ 1GHz



- ◆ Davies-Cotton optical design
- ◆ 23 m mirror
- ◆ PMT camera: analog memories



THE TELESCOPES: LSTs & MSTs

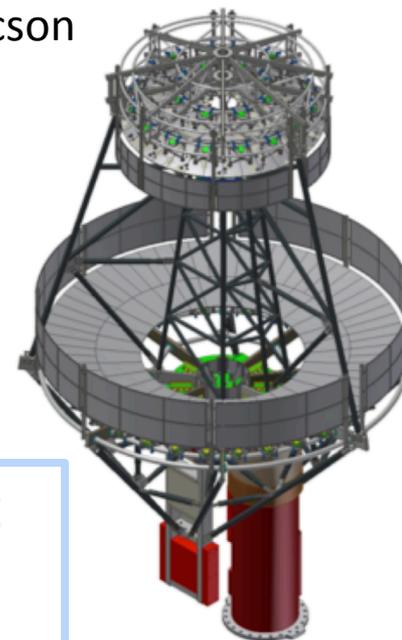
5

MST Berlin



- ◆ Davies-Cotton optical design
- ◆ 12m mirror
- ◆ 2-types of cameras:
 - ◆ FlashCam: FlashADC @ 200 MHz
 - ◆ NectarCam: analog memories @ 1GHz

SCT Tucson



- ◆ 10-5 m dual mirror Schwarzschild-Couder optical design
- ◆ > 11000 SiPMs camera → GCT like

THE TELESCOPES: SSTs

6

- ◆ SiPMs cameras
 - ◆ Light-weight, mechanically robust, slow aging
 - ◆ full moon observations

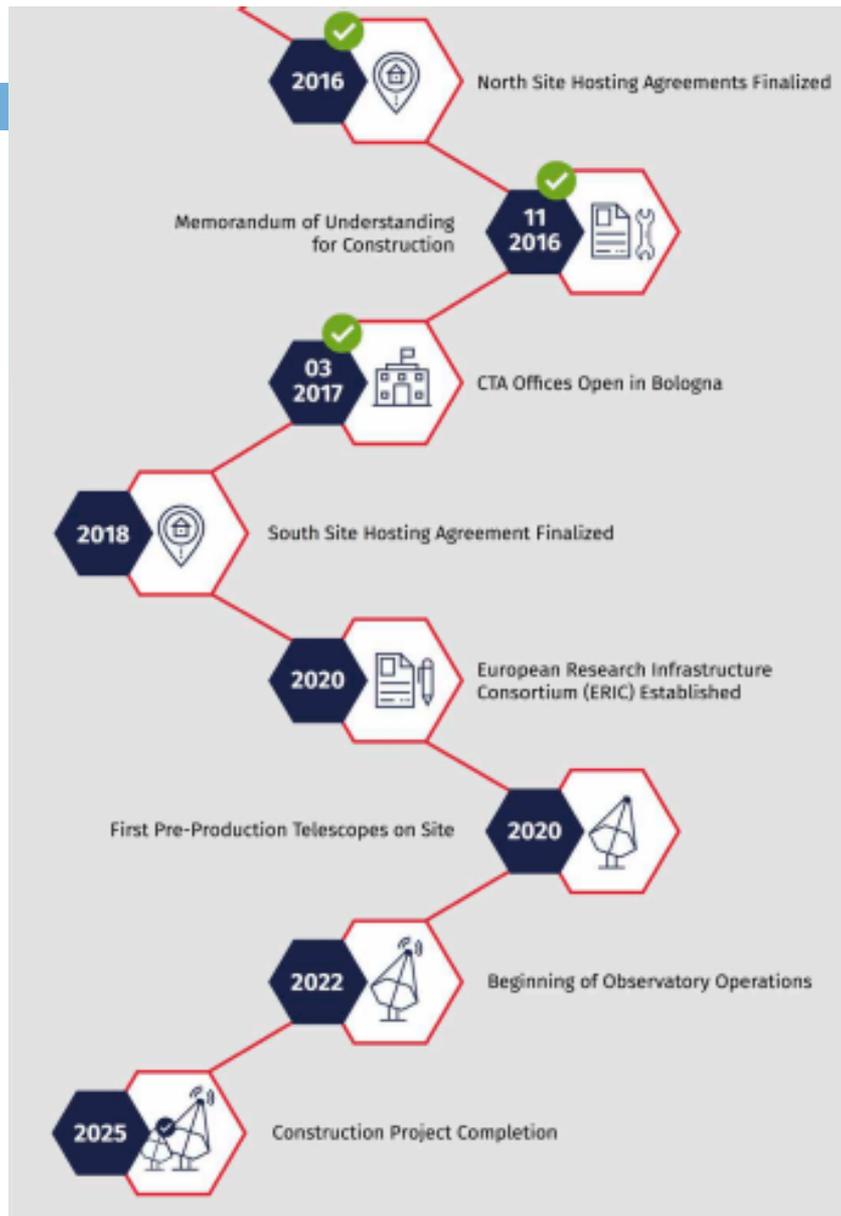


4m dual-mirror based on Schwarzschild-Couder optical design



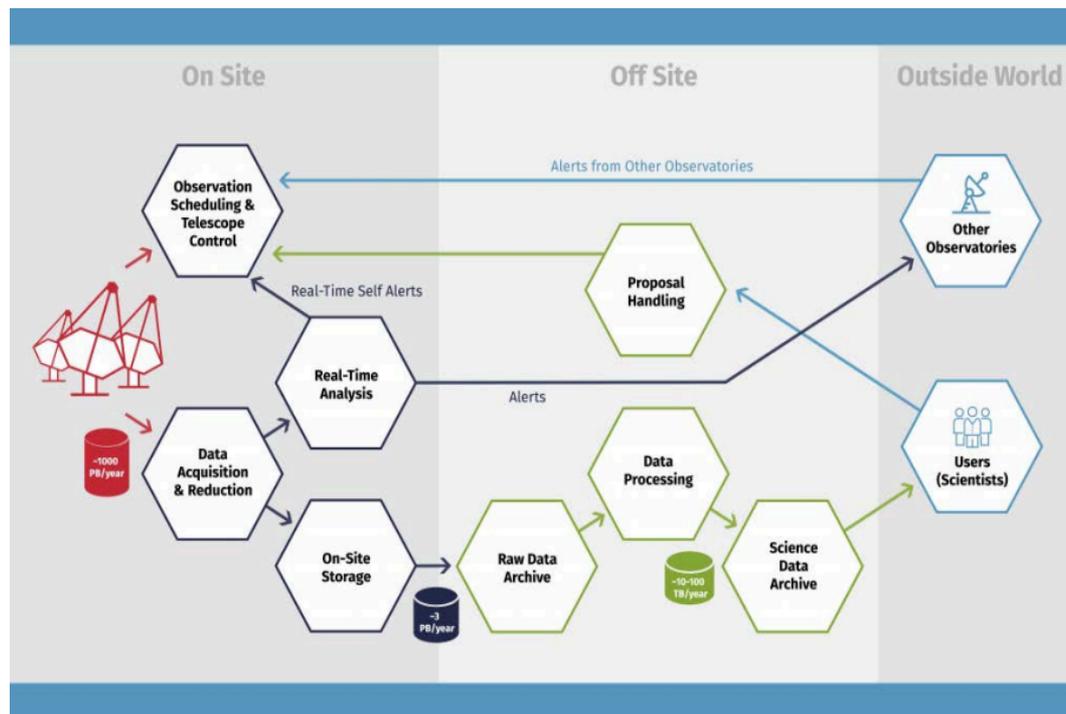
Davies-Cotton optical design
R. Zanin

THE TIMELINE



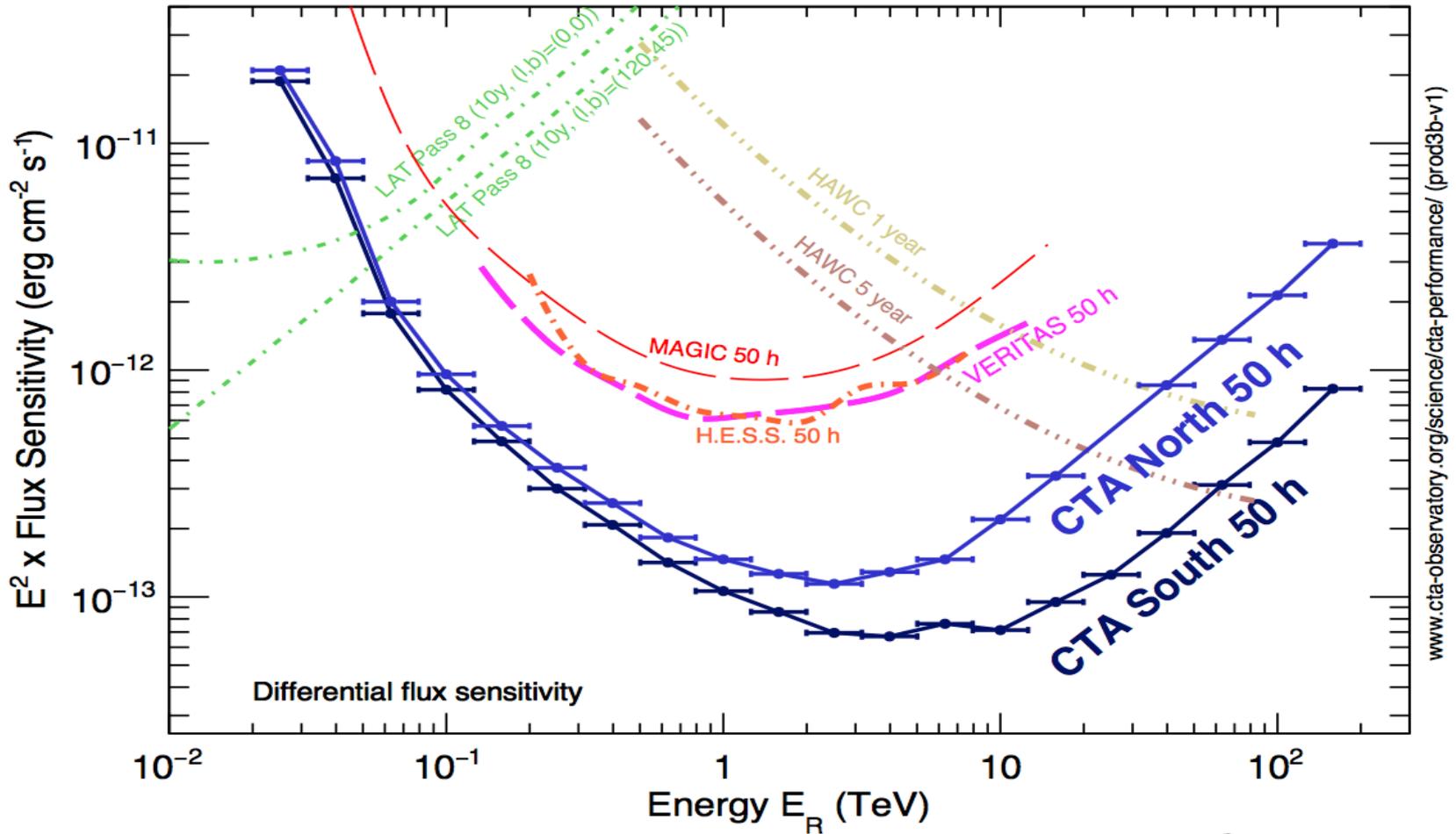
CTA – AN OPEN OBSERVATORY

8

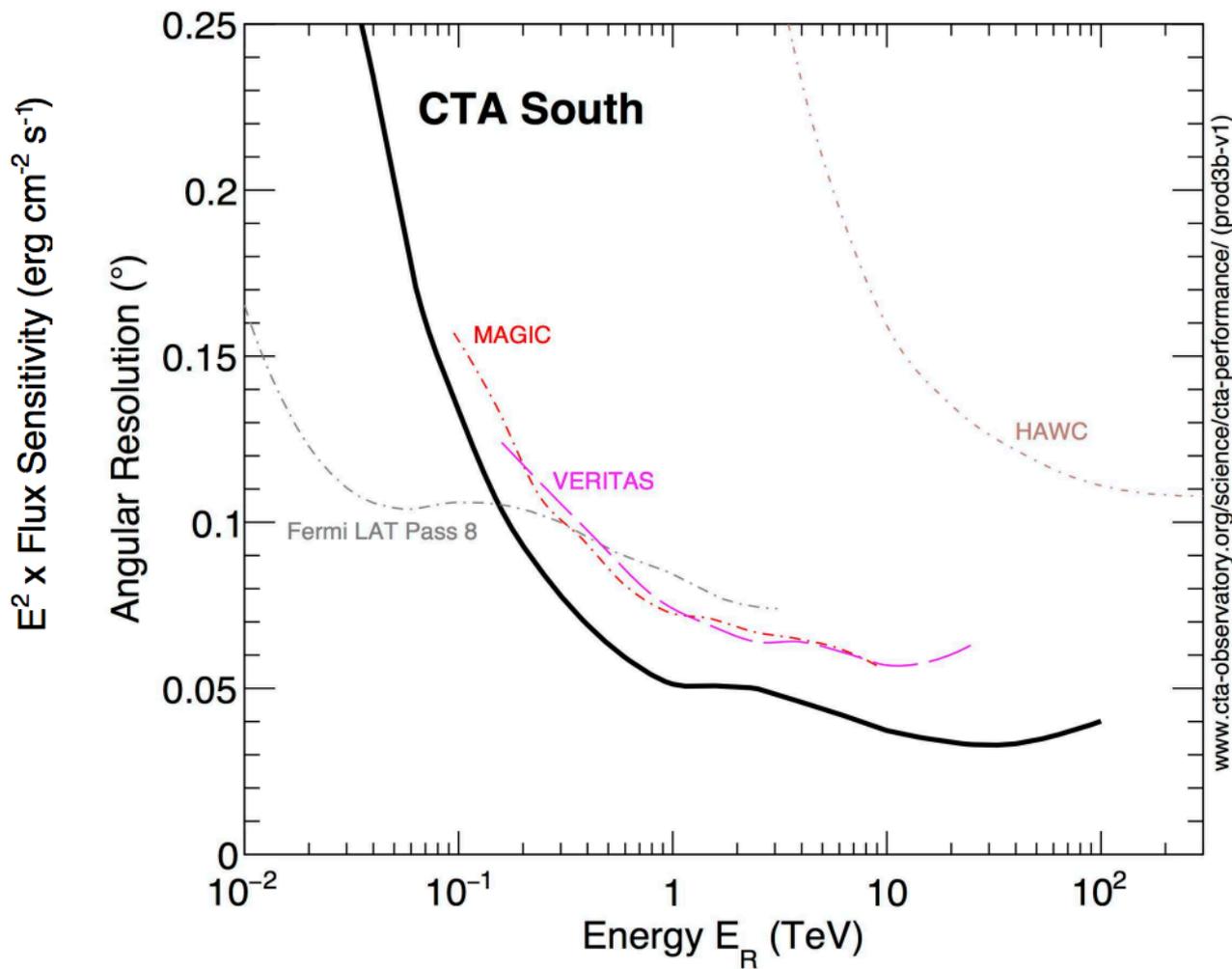


- ◆ Strict separation between CTA-Consortium (CTAC) and CTA-Observatory (CTAO)
 - ◆ **CTAC:** Science case definition, specifications, requirements, telescope design
 - ◆ **CTAO:** construction and running of observatory (including time allocation)
- ◆ for first 10 yr 40% time is blocked for CTAC

CTA PERFORMANCE

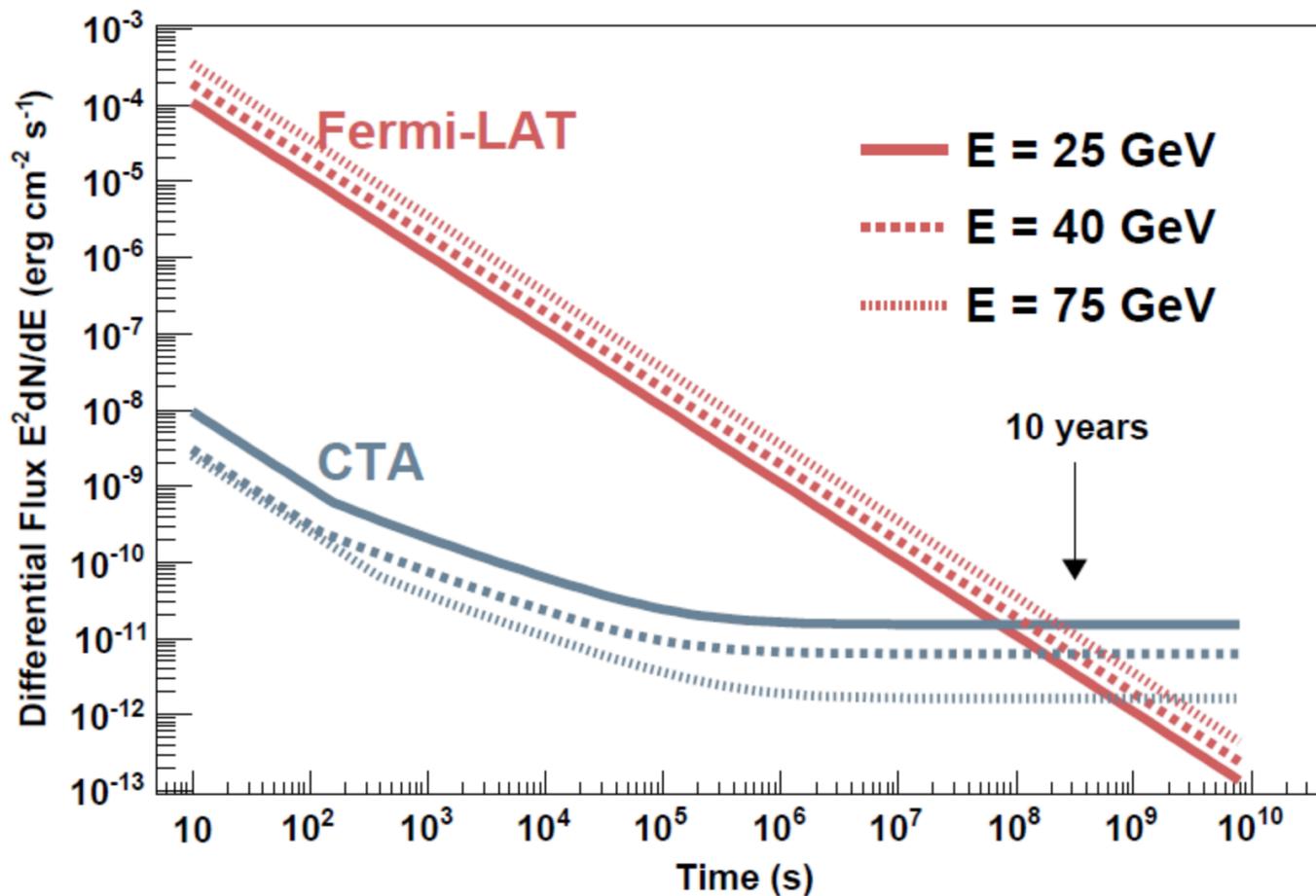


CTA PERFORMANCE



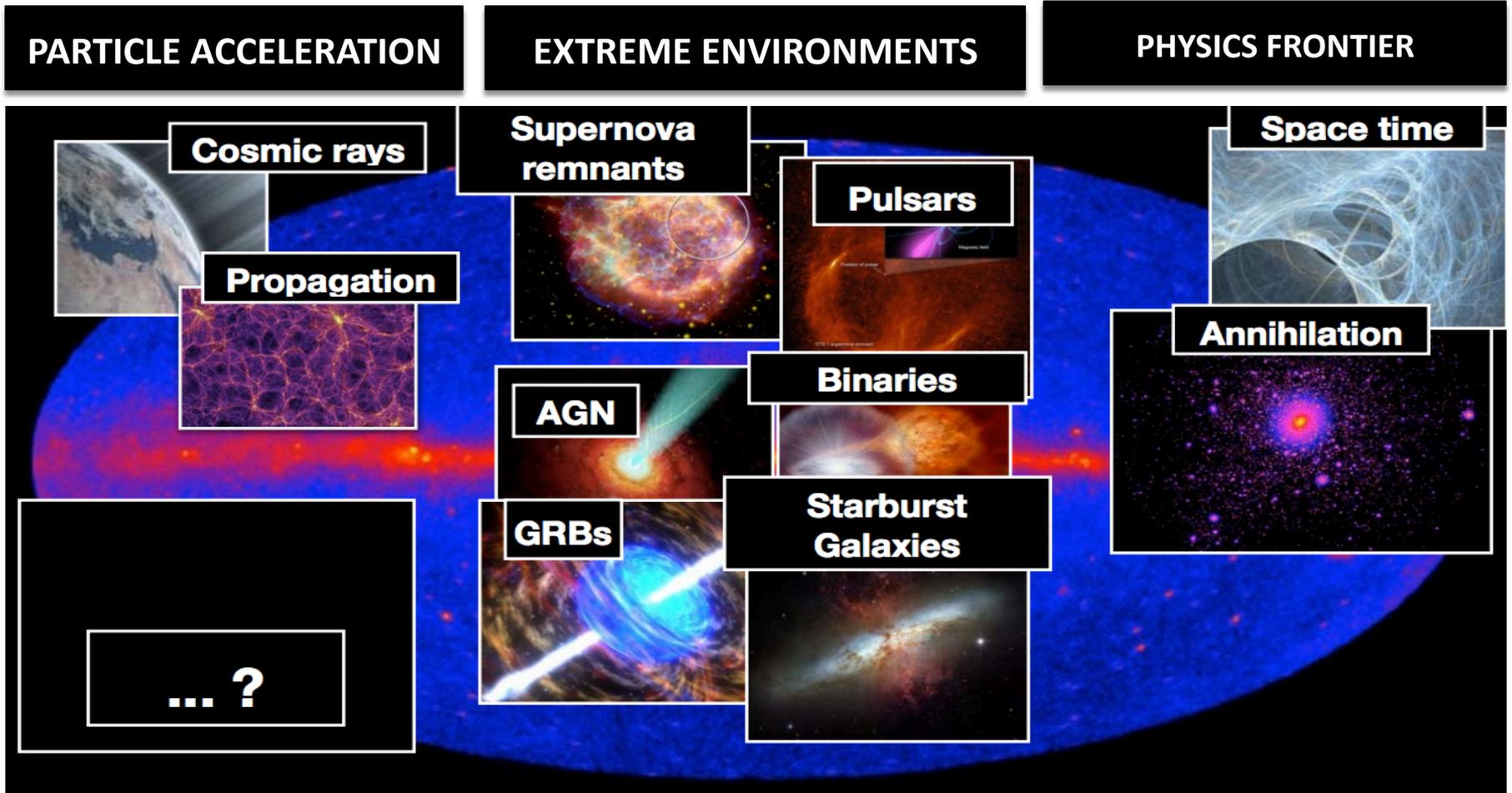
CTA PERFORMANCE

11



THE SCIENCE CASE

11



KEY SCIENCE PROJECTS

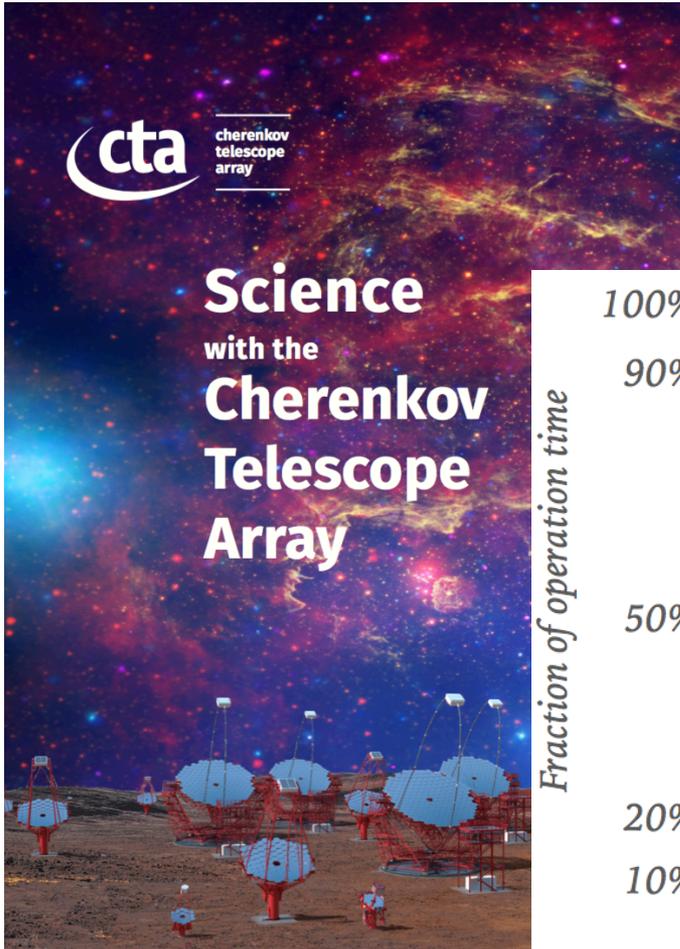
11



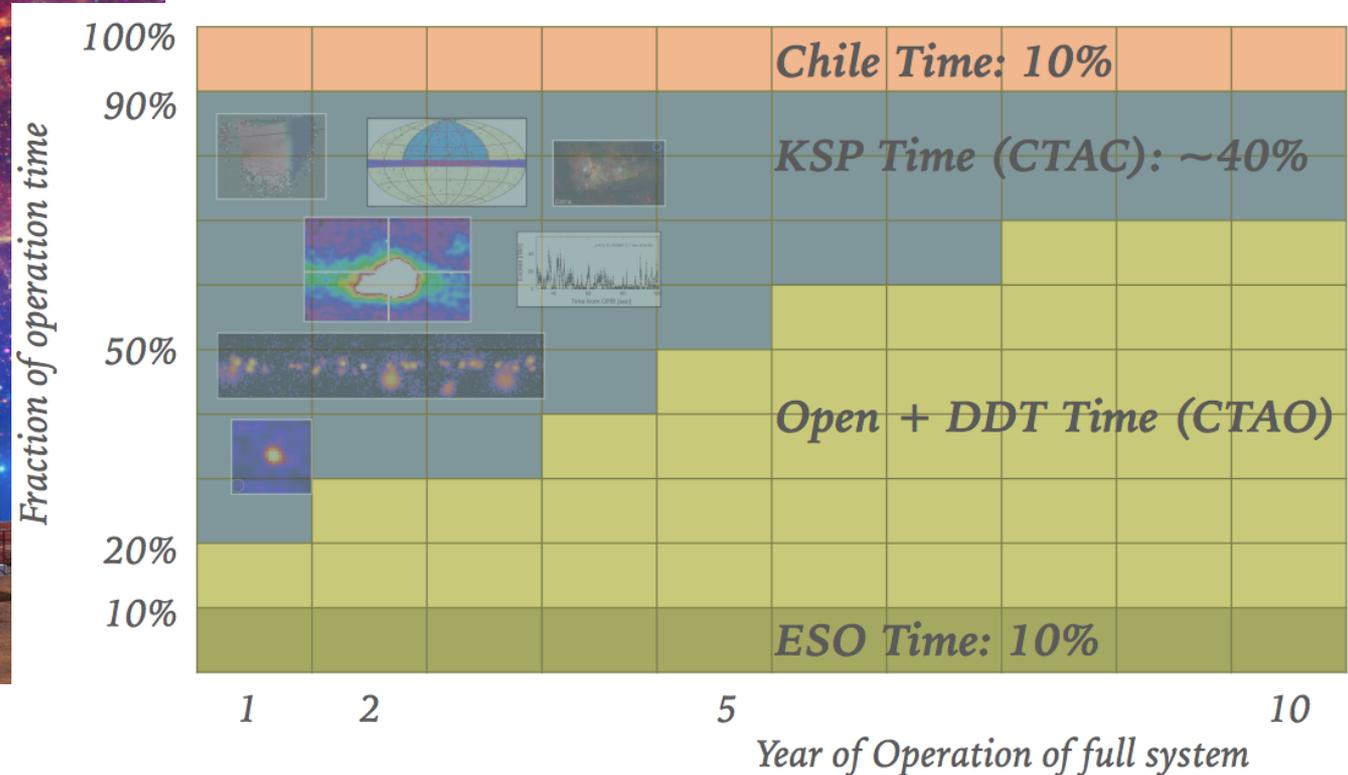
- ◆ Time allocated for CTAC is devoted to the KSPs
- ◆ 200-page document in <https://arxiv.org/abs/1709.07997>

KEY SCIENCE PROJECTS

11

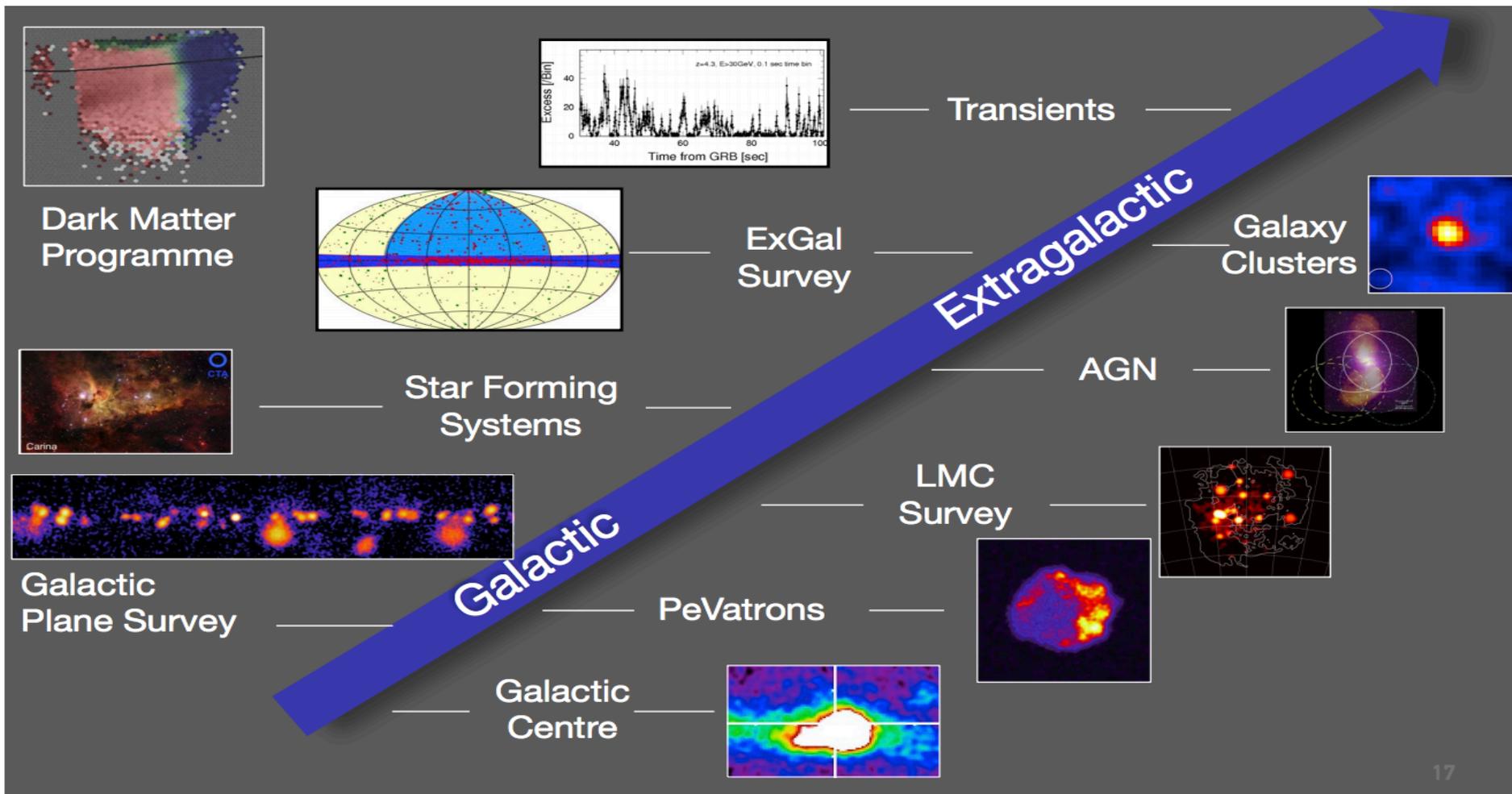


- ◆ Time allocated for CTAC is devoted to the KSPs
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KEY SCIENCE PROJECTS

12



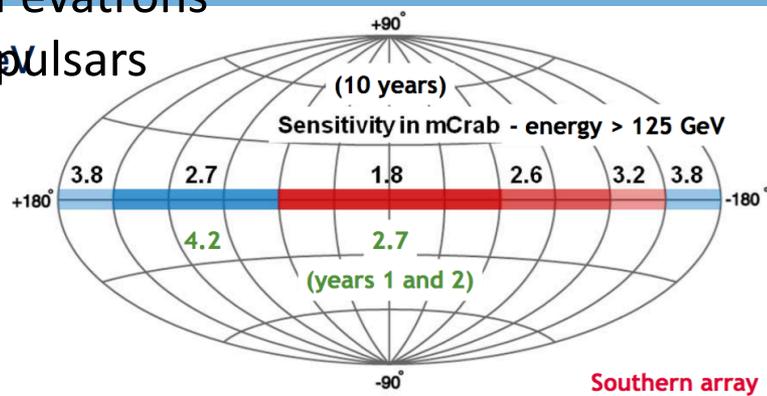
THE SURVEYS

13

GALACTIC PLANE SURVEY (1650 hr)

survey of Galactic plane to 2-4 mCrab

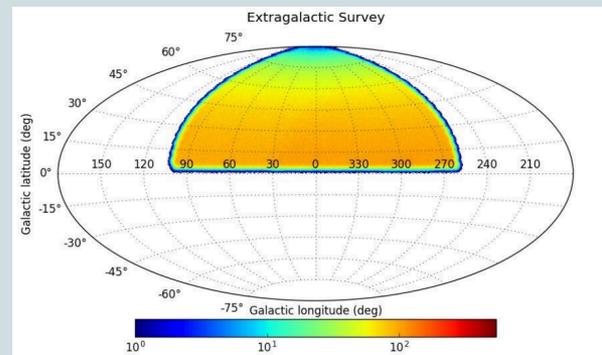
- ◆ VHE PWN & SNR population study
- ◆ Pevatrons
- ◆ pulsars



EXTRAGALACTIC SURVEY (1000 hr)

Unbiased survey of ¼ sky to ~6 mCrab

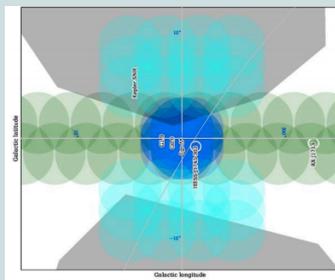
- ◆ VHE population study
- ◆ New, unknown source classes?



GALACTIC CENTER SURVEY

(525 hr + 300 hr)

- ◆ ID central source
- ◆ diffuse emission
- ◆ base of Fermi bubbles
- ◆ deep DM search



LARGE MAGELLANIC CLOUD SURVEY

(350 hr)

face-on satellite galaxy with high SFR

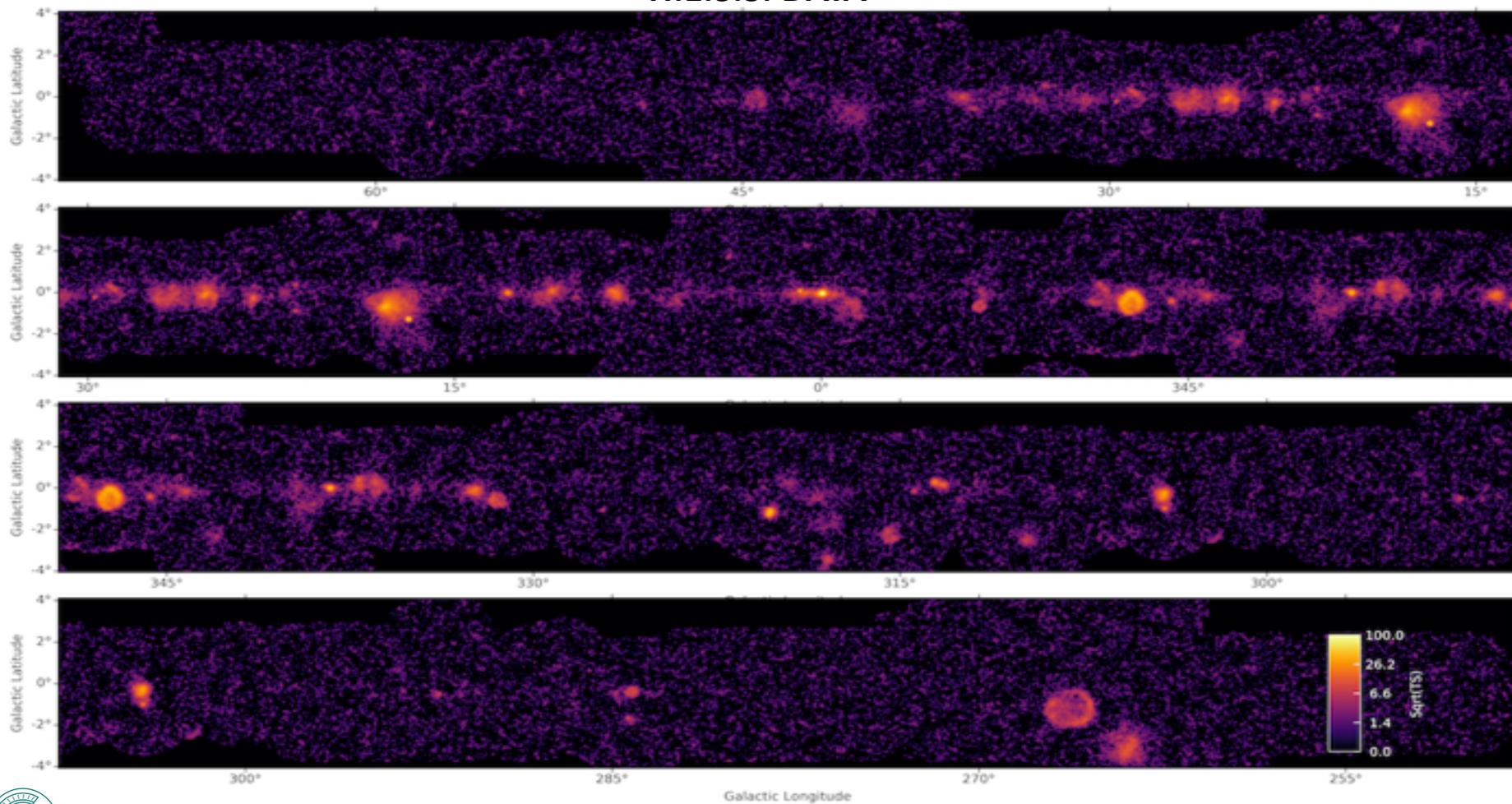
- ◆ extreme Galactic sources
- ◆ DM search
- ◆ diffuse emission

THE GALACTIC PLANE SURVEY

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H.E.S.S. collaboration 2018

H.E.S.S. DATA

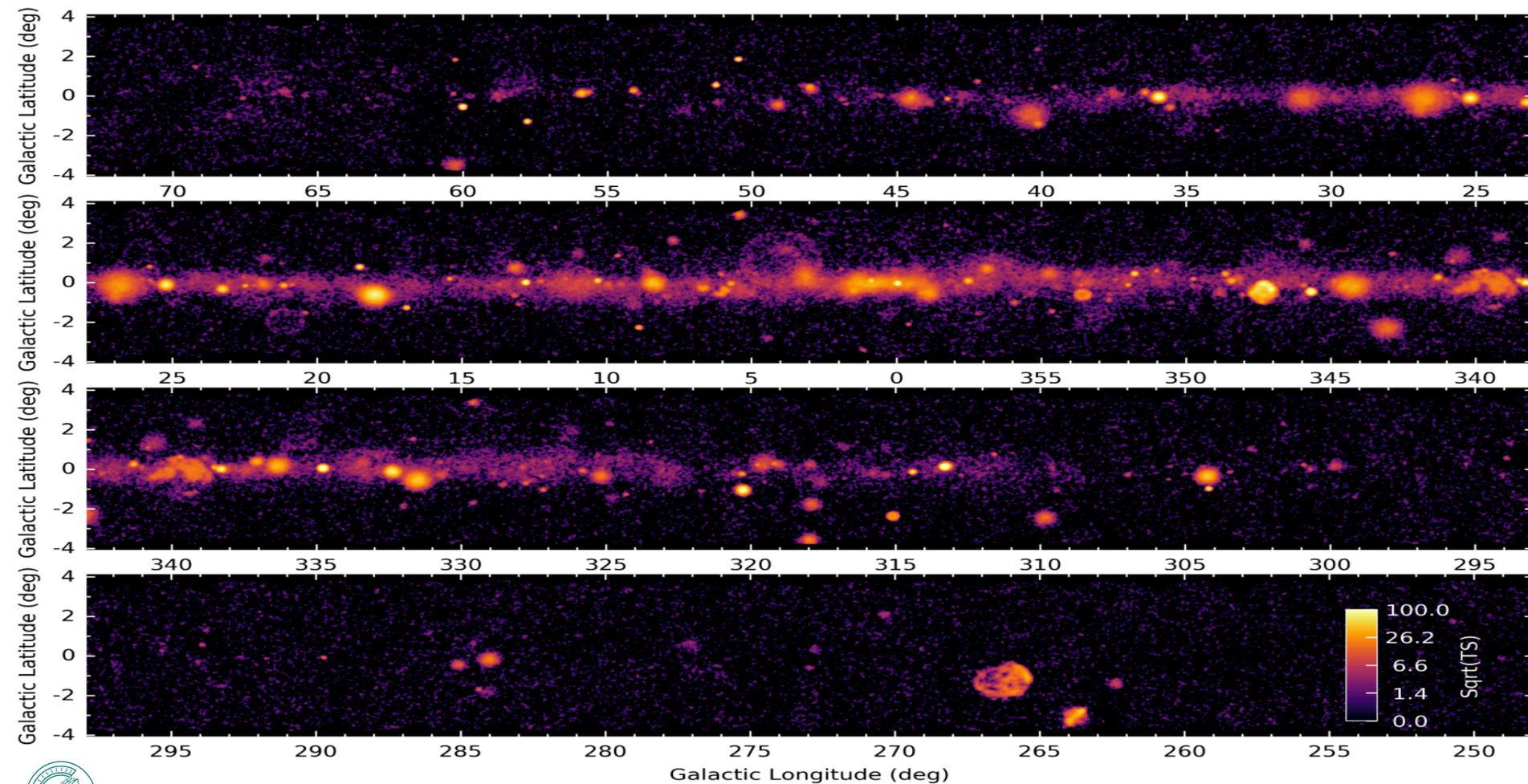


THE GALACTIC PLANE SURVEY

14

H.E.S.S. collaboration 2018

H.E.S.S. DATA

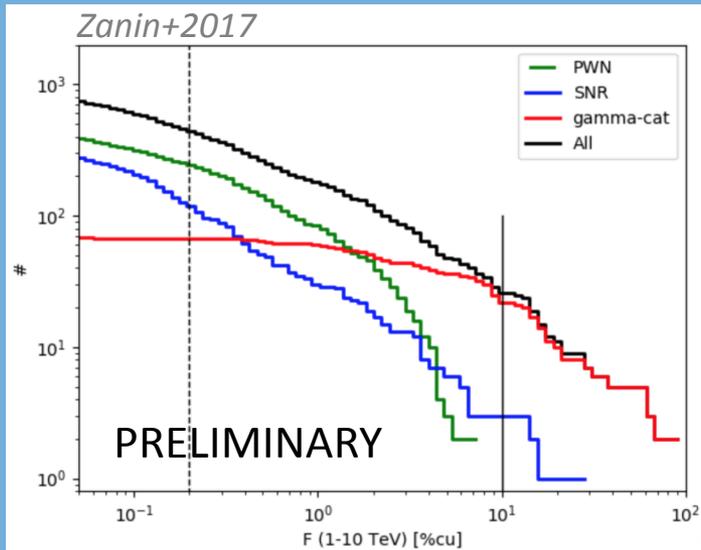


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THE GALACTIC PLANE SURVEY

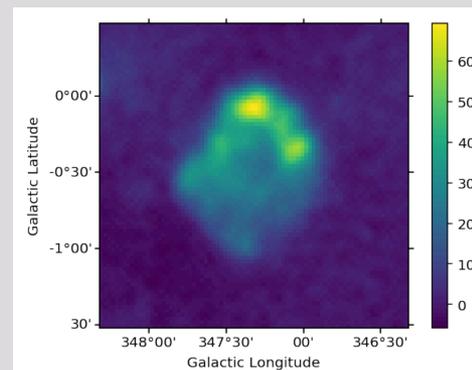
14

POPULATION STUDIES



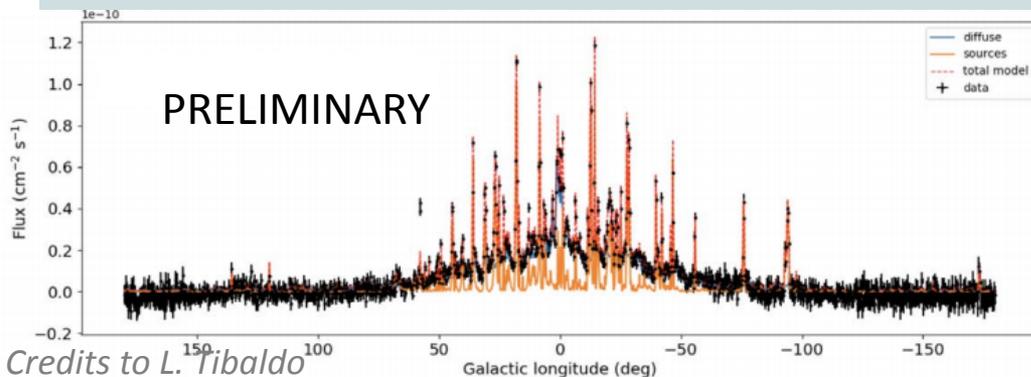
- ◆ optimistic numbers: source confusion & extension not properly accounted

EXTENDED SOURCES



Credits to F. Acero

DIFFUSE EMISSION



Credits to L. Tibaldo

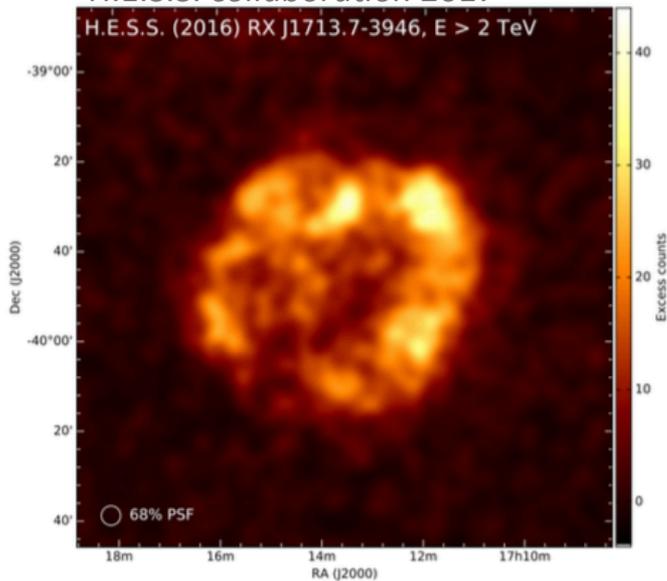
HIGH-PRECISION MORPHOLOGICAL STUDIES



15

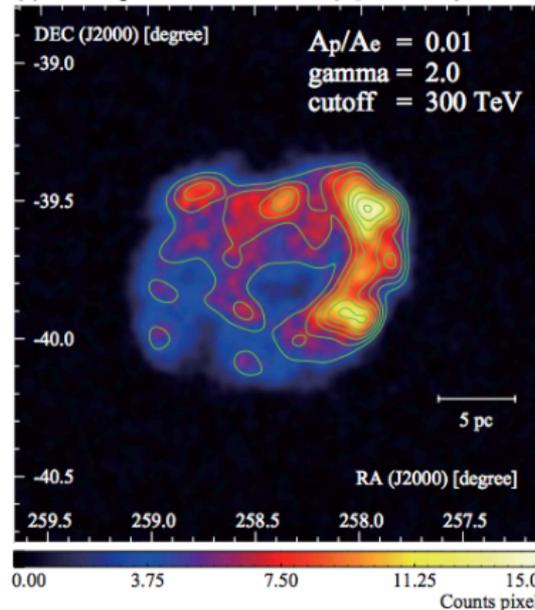
RX J1713

H.E.S.S. collaboration 2017

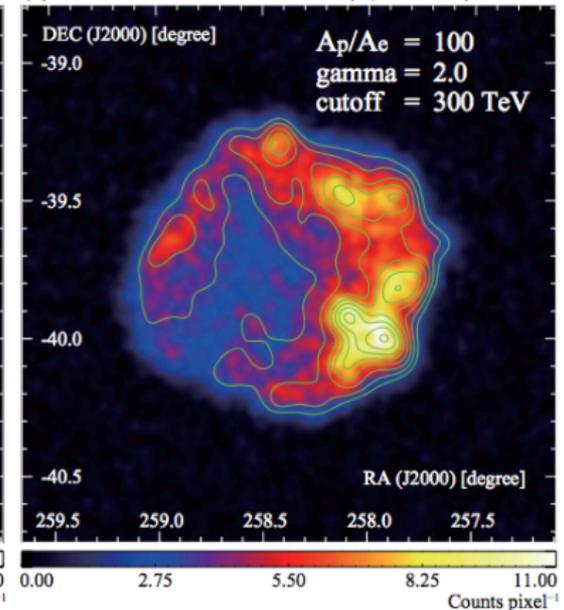


CTA consortium 2017

(a) CTA lepton-dominated case ($A_p/A_e=0.01$)



(b) CTA hadron-dominated case ($A_p/A_e=100$)



- ◆ in 50 h, CTA will be able to discriminate between the two extreme cases of fully leptonic and fully hadronic dominant gamma-ray emission
- ◆ sub-structures on arc-minute scales

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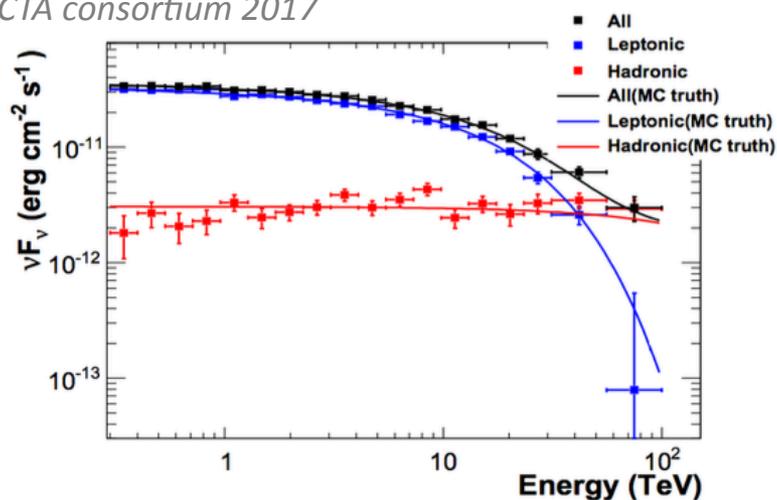


HIGH-PRECISION SPECTRAL STUDIES

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RX J1713

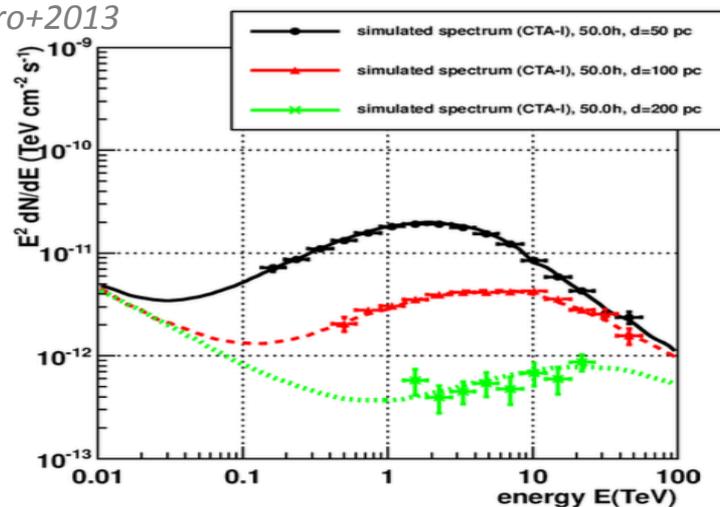
CTA consortium 2017



- ◆ 50 h to detect at 3s the flatter hadronic component emerging above the leptonic one with a cutoff at $\sim 10\text{-}20$ TeV

The V-shape of a MC illuminated by CR

Acero+2013



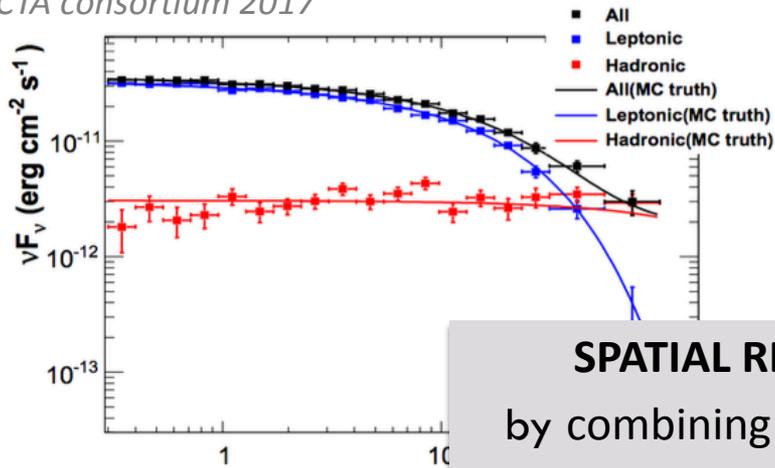
- ◆ in 50 h for $d < 100$ pc the V-shape is detectable

HIGH-PRECISION SPECTRAL STUDIES

16

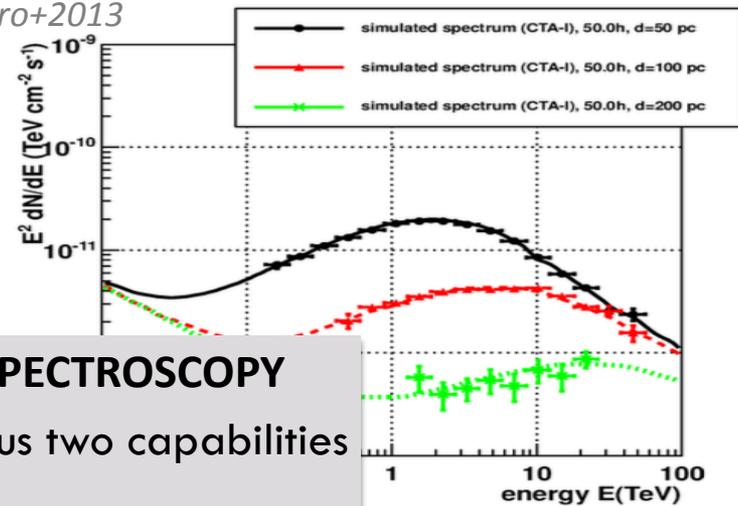
RX J1713

CTA consortium 2017



The V-shape of a MC illuminated by CR

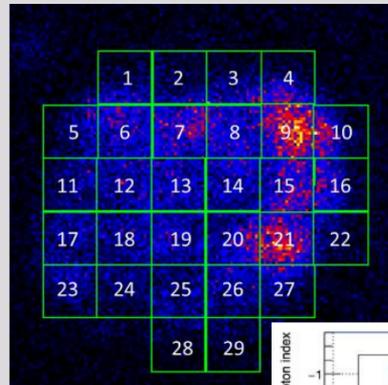
Acero+2013



SPATIAL RESOLVED SPECTROSCOPY

by combining the previous two capabilities

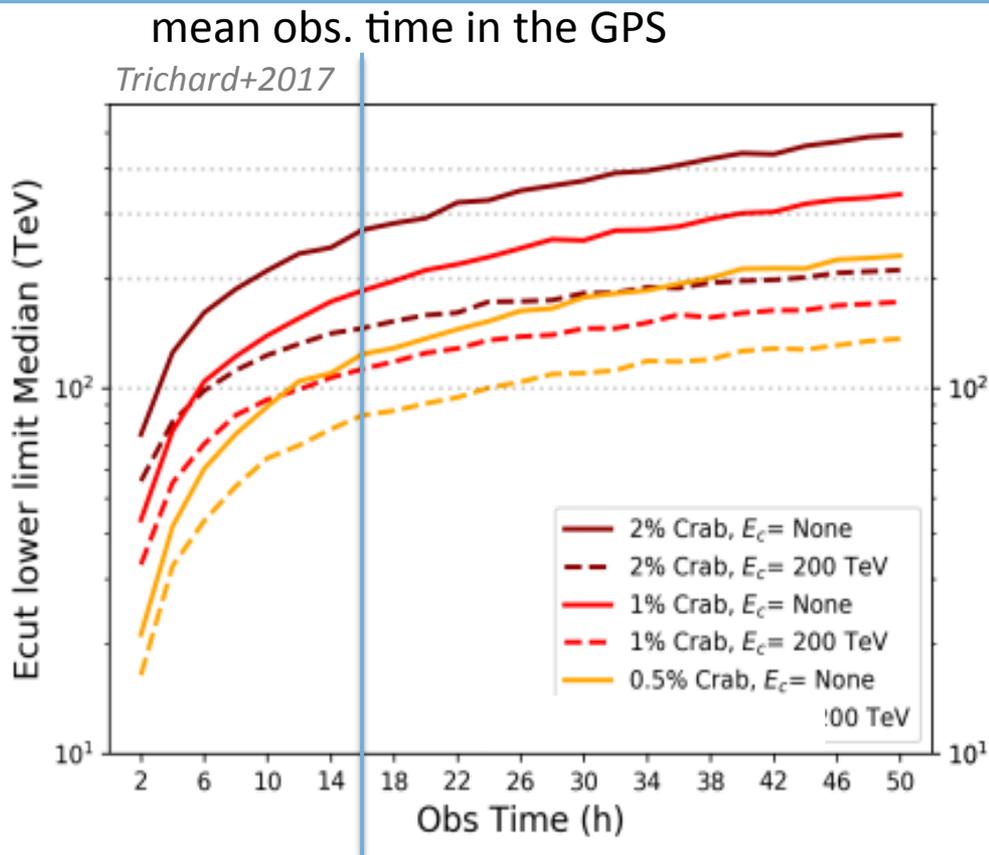
- ◆ 50 h to detect at 3s t hadronic component above the leptonic o at ~10-20 TeV



pc the V-shape is

PEVATRONS

17



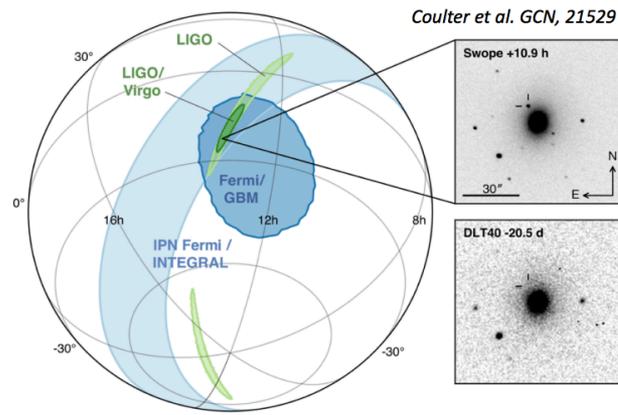
- ◆ A lower limits on the cutoff energy at 200 TeV can be set in ~ 15 hr for sources with a flux up to 1% Crab at 1 TeV
 → huge potential to select the PeVatrons candidates

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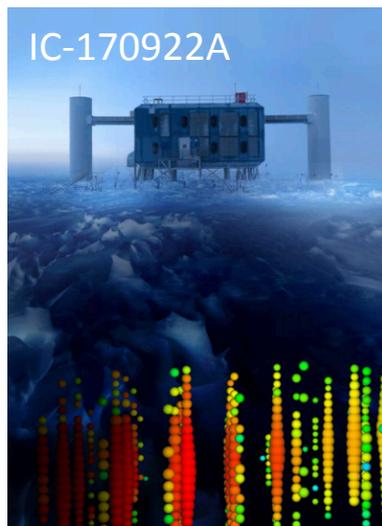
TRANSIENTS

18

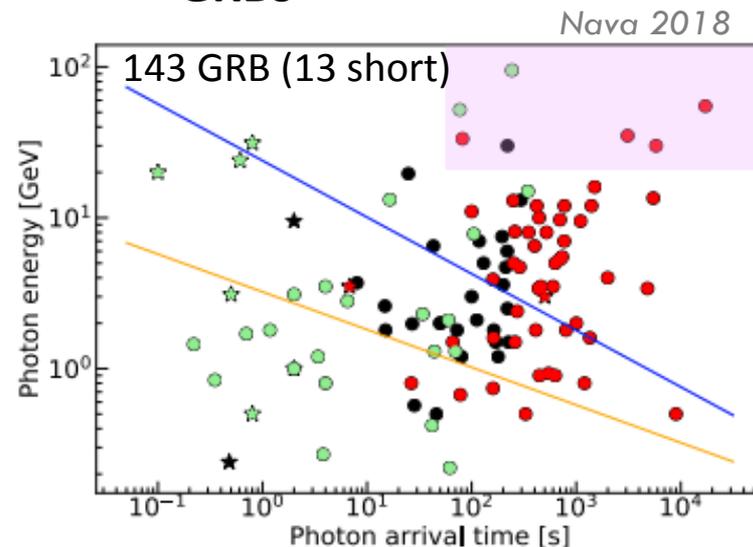
GRAVITATIONAL WAVES



NEUTRINOS



GRBs



- ◆ 11 between 20 and 95 GeV
- ◆ up to 10^4 s after the explosion
- ◆ SSC? hadronic component?

- ◆ Triggers from CTA: serendipitous discoveries
 - ◆ expected rate low, but identified events with high impact

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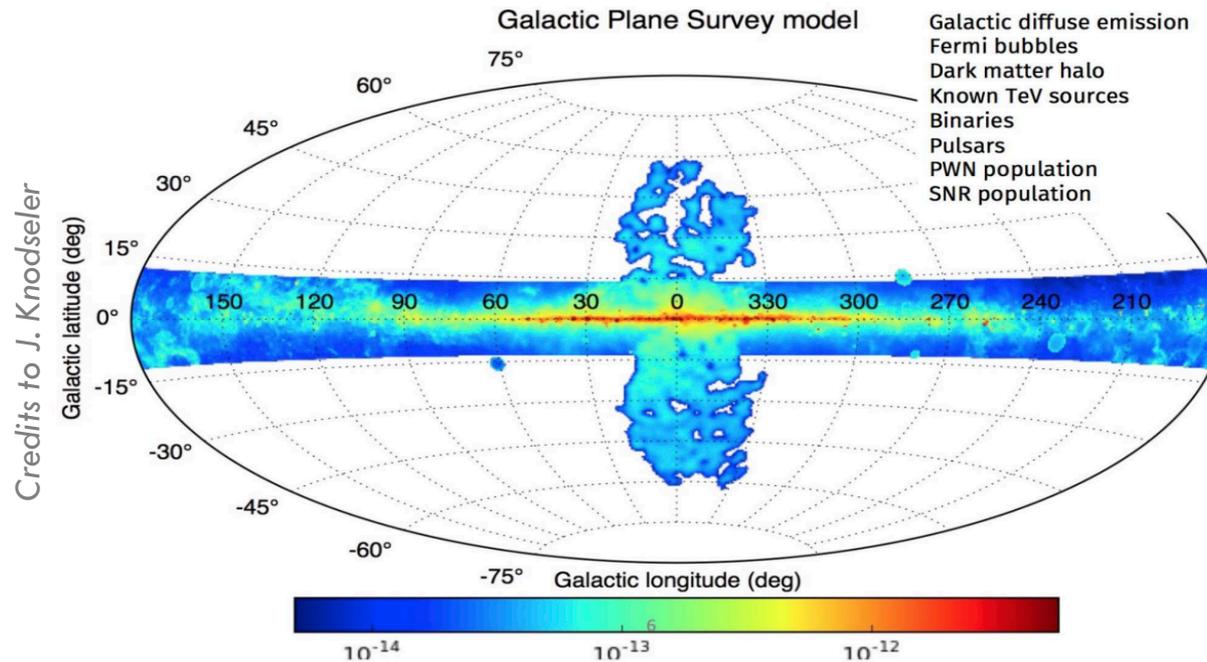
FIRST CTA DATA CHALLENGE

19

- ◆ Goals:
 - ◆ familiarize with CTA data analysis
 - ◆ development of high-level analysis software
 - ◆ software capabilities assessment
- ◆ Simulated sky model uses inputs from MAGIC/VERITAS/H.E.S.S./HAWC + Fermi-LAT

$\gamma\pi$ A Python package for gamma-ray astronomy

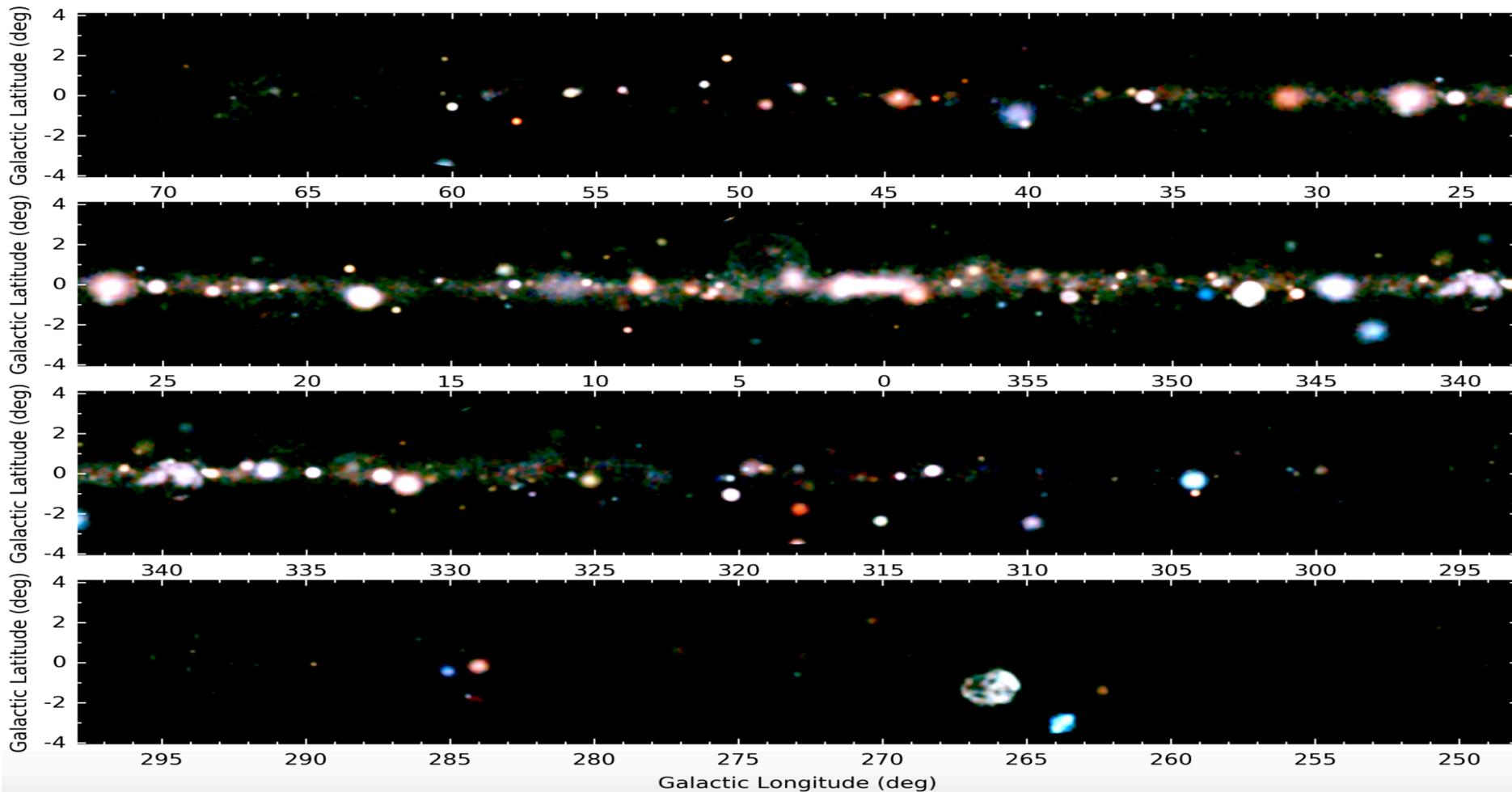
ctools
cherenkov telescope array



FIRST CTA DATA CHALLENGE

20

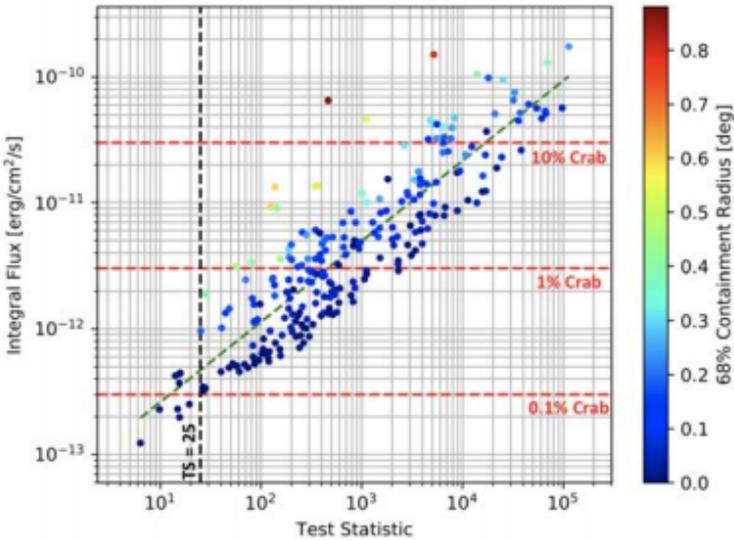
R: 0.3-1 TeV, G: 1-10 TeV, B: 10-300 TeV



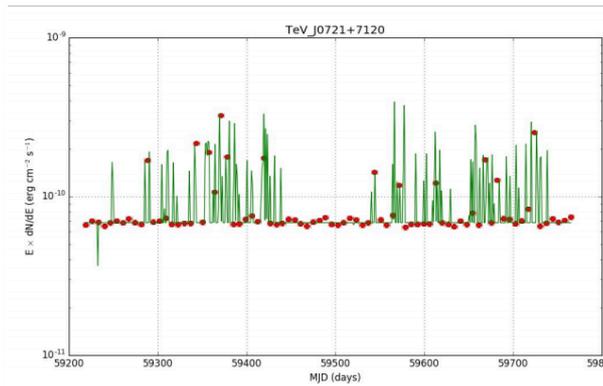
FIRST CTA DATA CHALLENGE

21

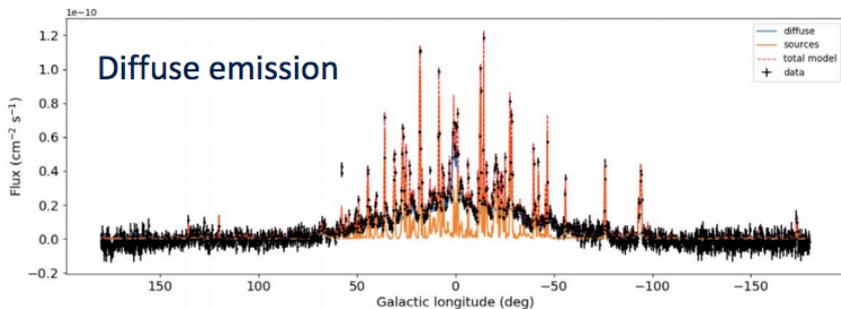
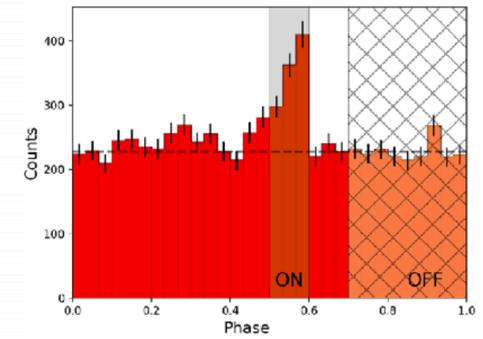
Galactic plane survey: catalogs



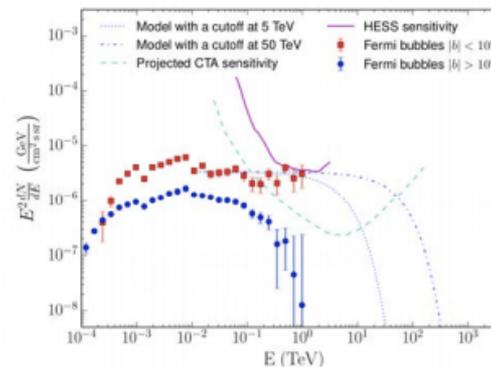
AGN lightcurves



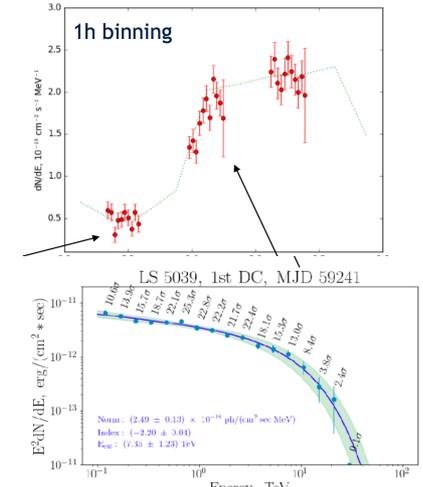
Vela pulsar



Fermi bubbles



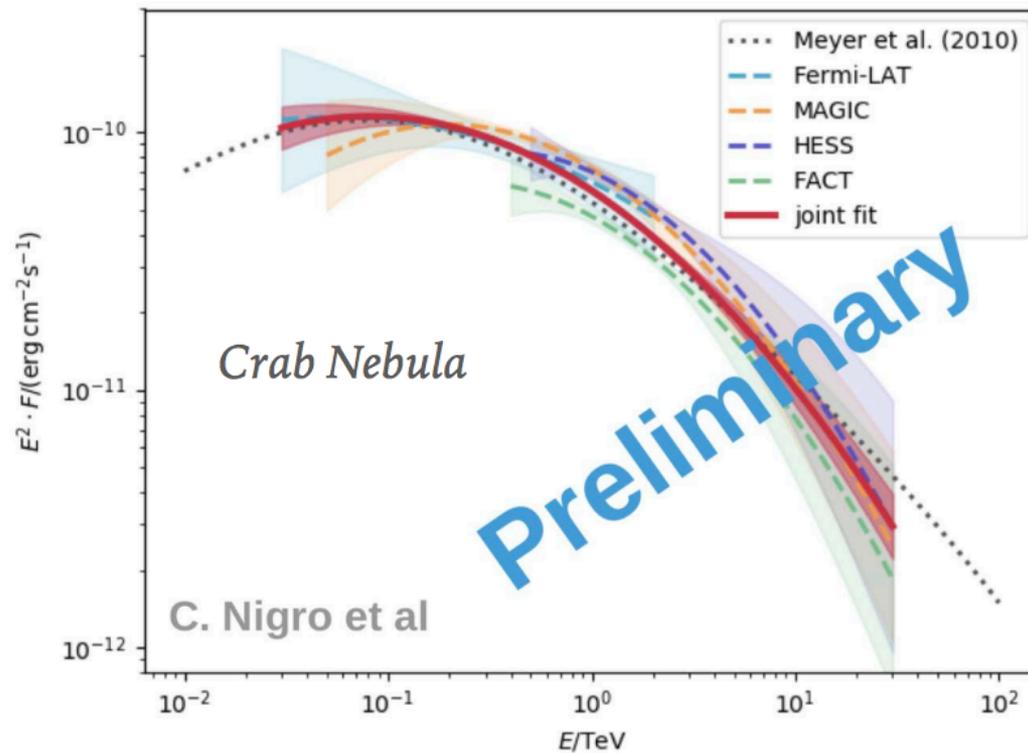
γ-ray binaries



NEW ERA: VHE JOINS THE MWL ASTRONOMICAL COMMUNITY

22

- ◆ definition of common data formats
- ◆ high-level analysis software under validation with real data





SUMMARY

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- ◆ CTA on track for construction.
- ◆ CTA Key Science Program will serve as legacy data sets
- ◆ The data & software preparation phase has posed solid milestones to allow the VHE astronomy to join the MWL community

- ◆ In the Galactic plane
 - ◆ Revealing a factor 3-9 more sources
 - ◆ First full plane studies of diffuse emission
 - ◆ CTA can resolve spatial substructures on arc-minute scales
 - ◆ CTA can reconstruct previously immeasurable spectral features
 - ◆ CTA can deeply explore the spatial resolved spectroscopy
 - ◆ Pevatrons with a cutoff lower limits can be detected in ~ 15 hours for a flux(@1TeV) = $3e-13 \text{ cm}^{-2}\text{s}^{-1}\text{TeV}^{-1}$



THE CHERENKOV TELESCOPE ARRAY



1



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THE TELESCOPES: SSTs

7

1M-SST Krakow



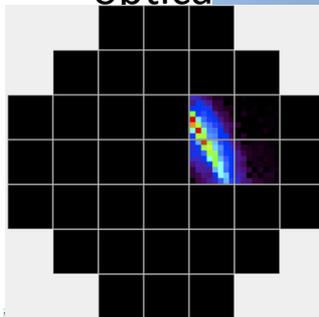
2M-SST GCT Paris



2M-SST ASTRI
Serra la Nave,
Italy



◆ Davies optical



- ◆ 4m dual-mirror based on Schwarzschild-Couder optical design
- ◆ Cherenkov camera: SiPMs
- ◆ Low cost