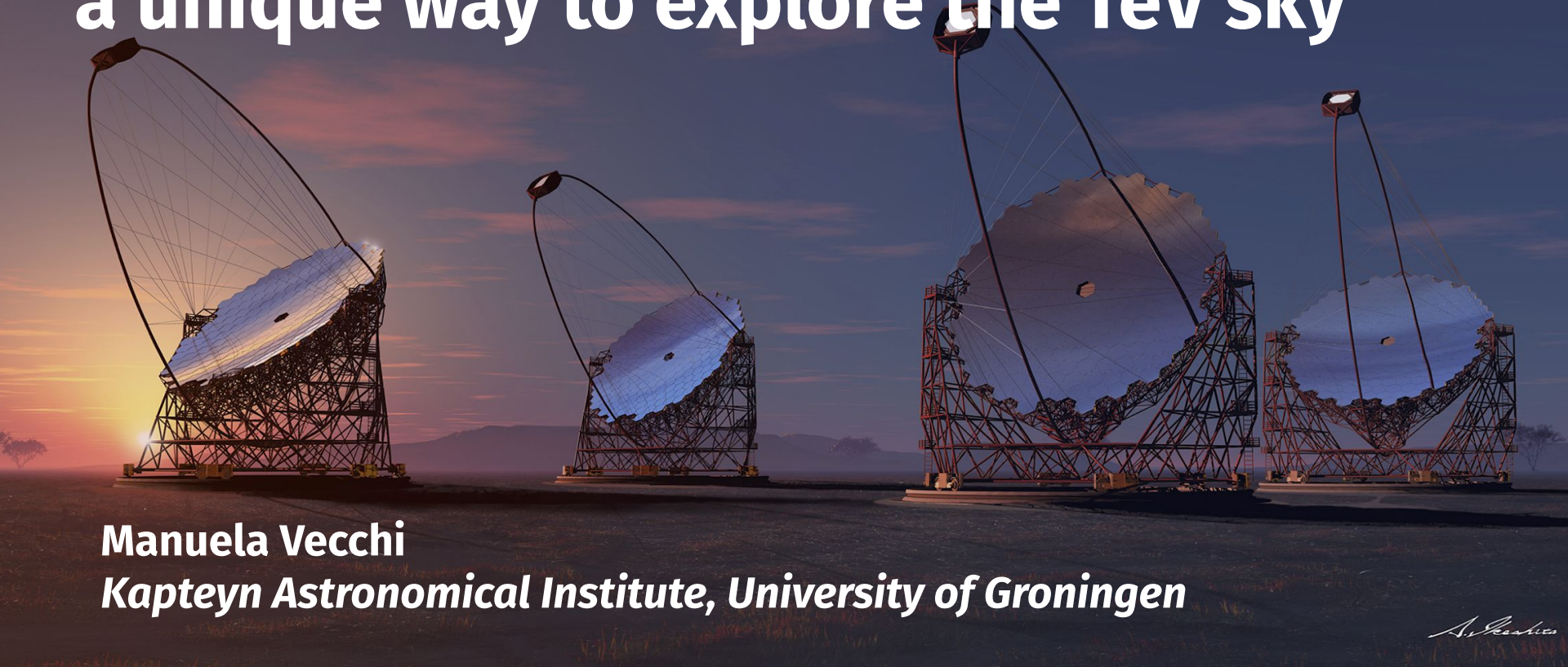
Gamma-ray astronomy in the Netherlands: a unique way to explore the TeV sky

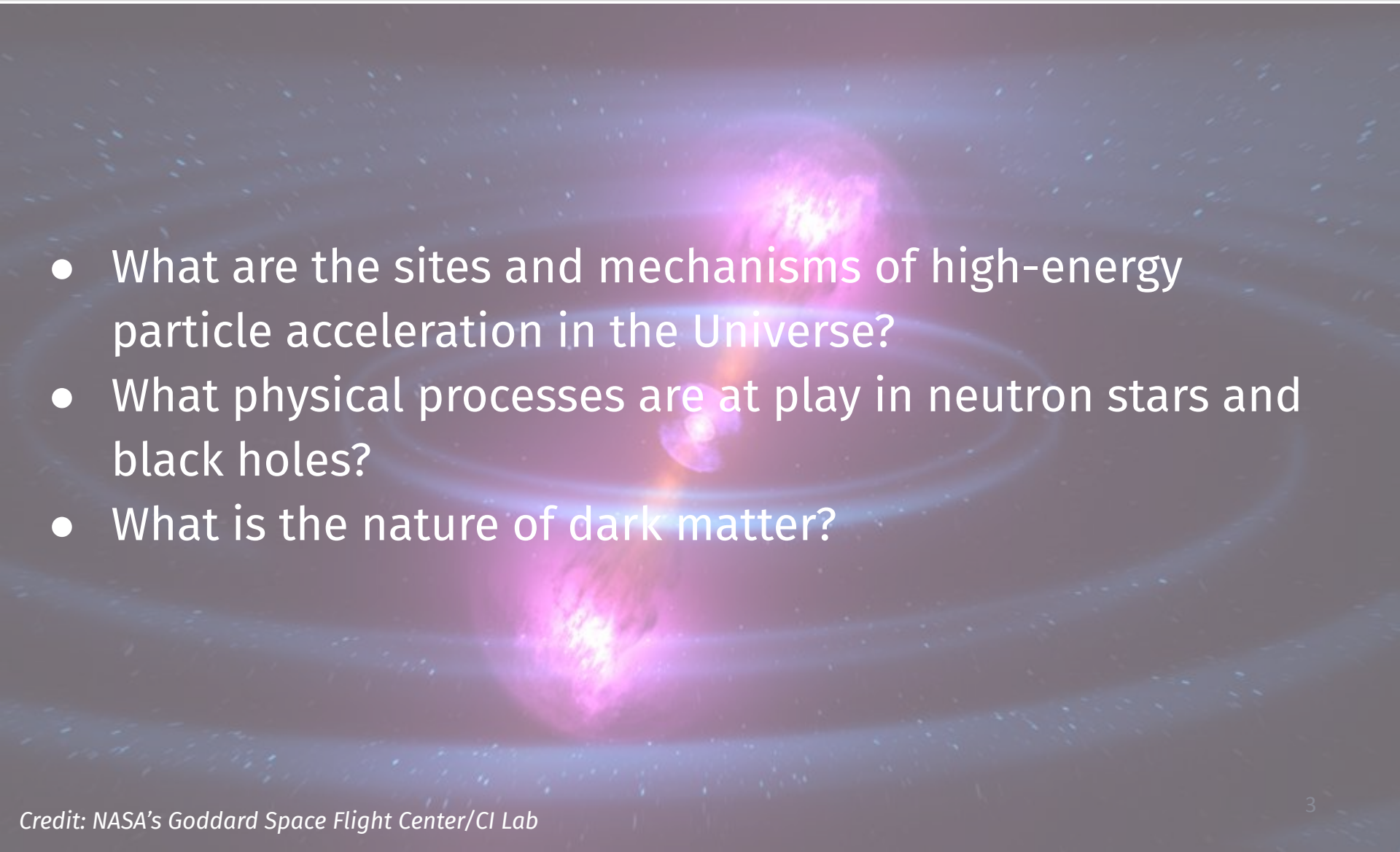


Manuela Vecchi
Kapteyn Astronomical Institute, University of Groningen

Outline

- Gamma-ray astronomy: what, why, and how ?
- The Dutch contribution to gamma-ray astronomy
  - The HESS experiment: a success story and more ahead
  - Cherenkov Telescope Array Observatory: bigger, better and faster
  - SWGO: the future in the PeV sky
- Conclusions

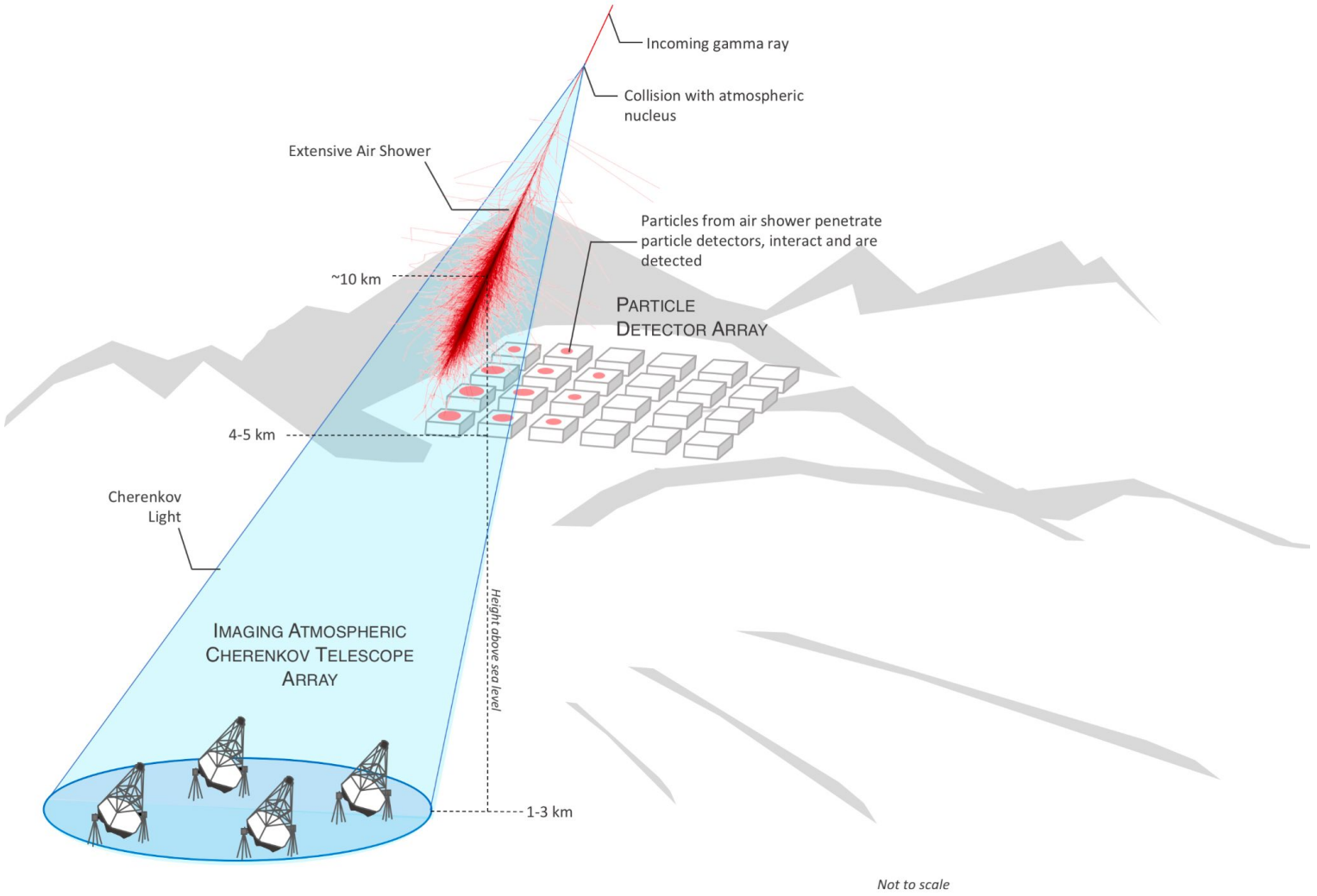
Gamma-ray astronomy addresses several scientific questions



- What are the sites and mechanisms of high-energy particle acceleration in the Universe?
- What physical processes are at play in neutron stars and black holes?
- What is the nature of dark matter?

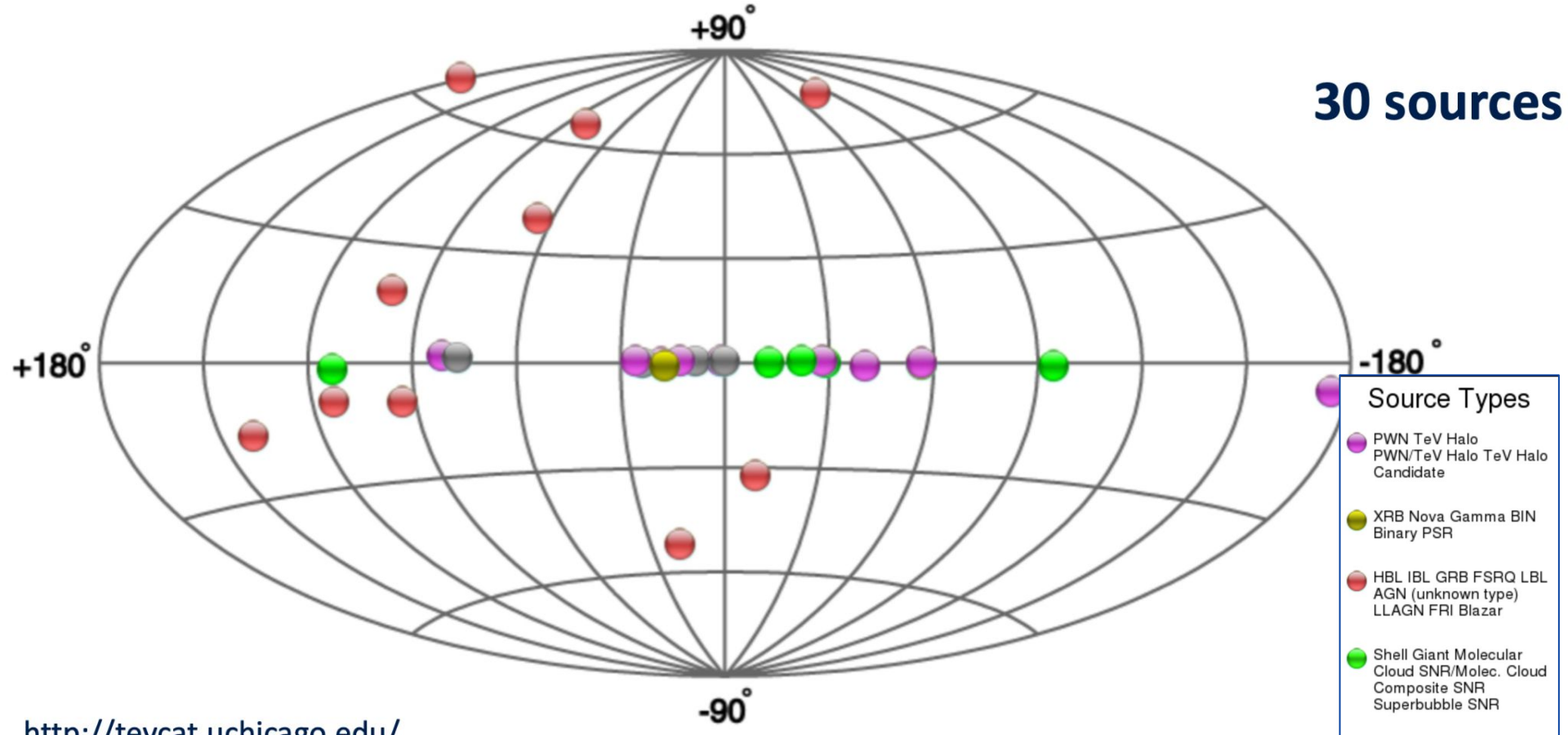
Credit: NASA's Goddard Space Flight Center/CI Lab

Ground-based gamma-ray detection



Credits: Richard White, MPIK

The gamma-ray sky in 2005



http://tevcat.uchicago.edu/

Slide from W. Hoffman

The gamma-ray sky in 2024

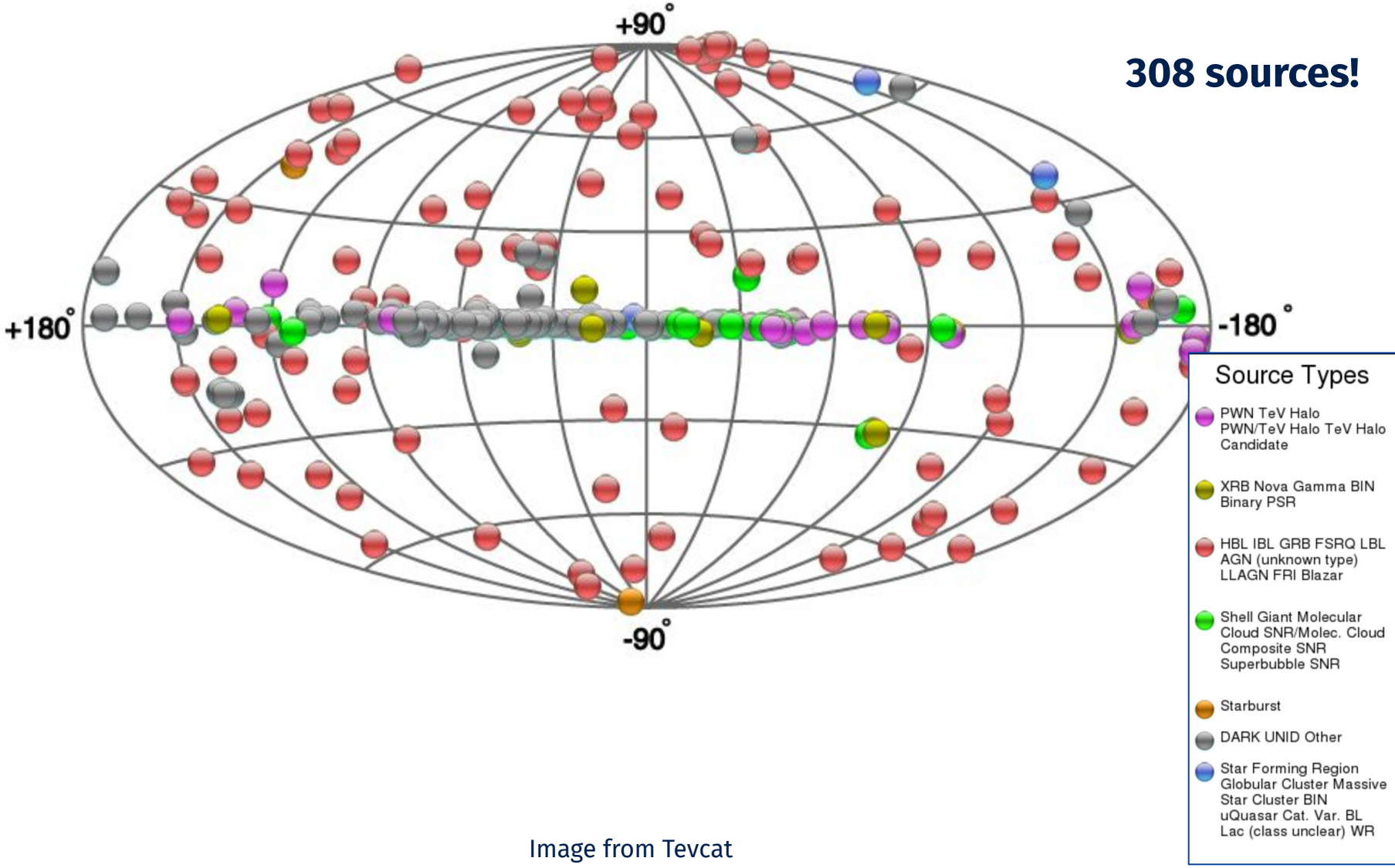


Image from Tevcat

The H.E.S.S. observatory

- Located in the Khomas Highland of Namibia at 1800m asl
- H.E.S.S. phase I: four 12m IACTs
  - FoV 5°
  - first light 2002

- H.E.S.S. phase II: 28m telescope; FoV 3.5°; first light 2012

  - Energy range: 30 GeV to 100 TeV
  - Energy resolution ~10% (68% cont.)
  - Angular resolution ~0.06° (68% cont.)

- H.E.S.S. collaboration: ~250 members, at 38 institutes, in 13 countries

Dutch members: Jacco Vink, Manuela Vecchi, Jann Aschersleben

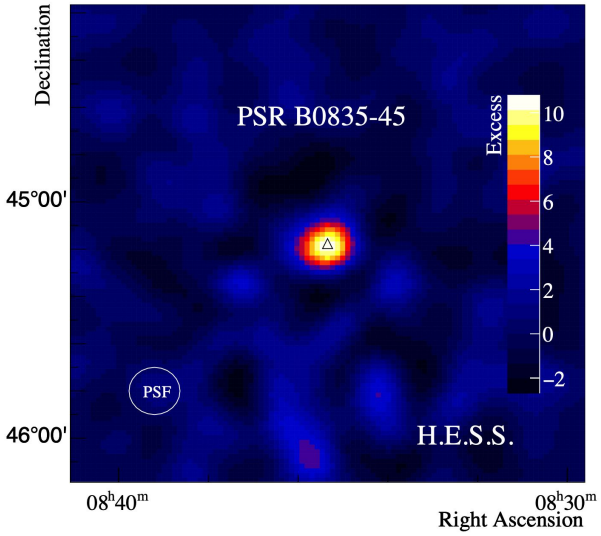
H.E.S.S.

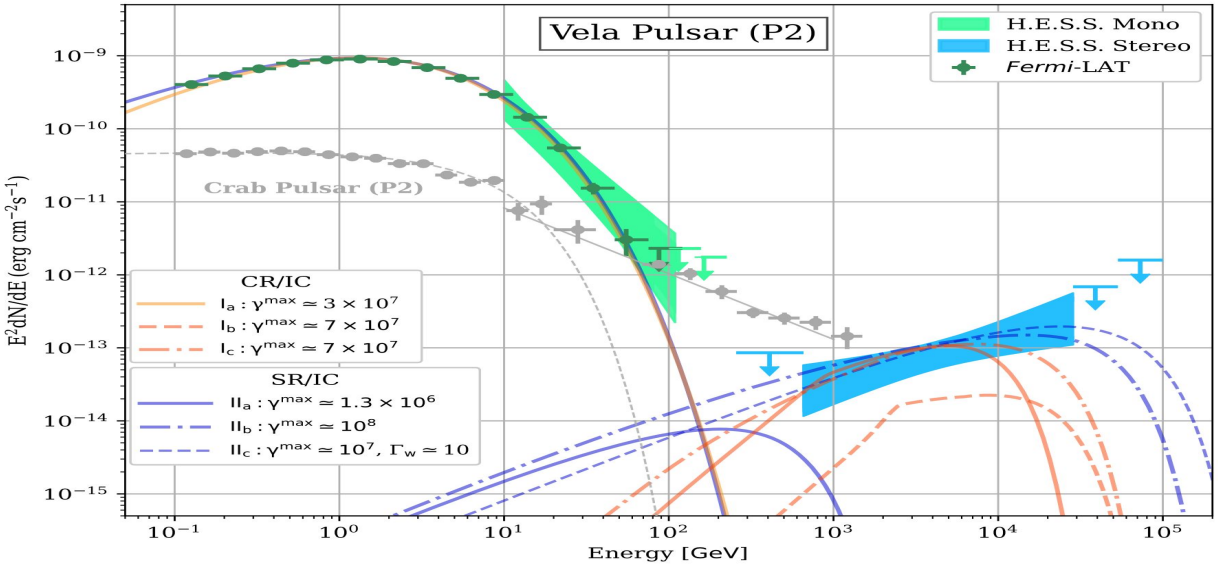
Most notable HESS scientific discoveries

- Identification of galactic sources *Astron.Astrophys.* 672 (2023) and many others
- Identification of extragalactic sources A&A, 430 3 (2005) and many others
- Cosmic-ray acceleration A&A, 653, A152 (2021) and many others
- Indirect Dark Matter searches *JCAP* 04 (2023) 040 and many others
- Transient sources *Astrophys.J.Lett.* 946 (2023) and many others

Vela Pulsar: a new TeV gamma-ray emitter

Discovery of a novel radiation component beyond the GeV cutoff of the Vela pulsar spectrum, extending for the first time up to 20 TeV.





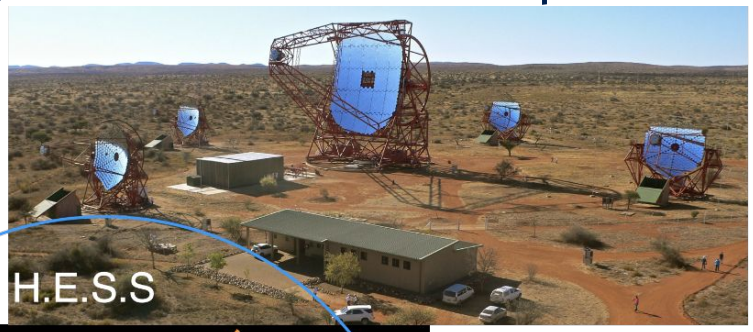
Aharonian et al, Nature Astron. (2024)

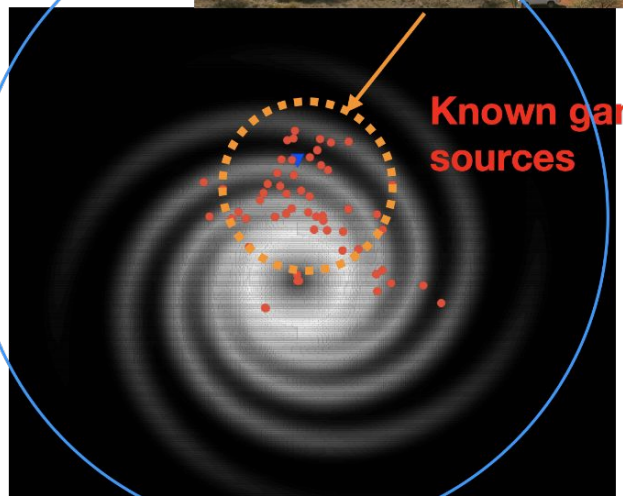
How can we make it even better ?

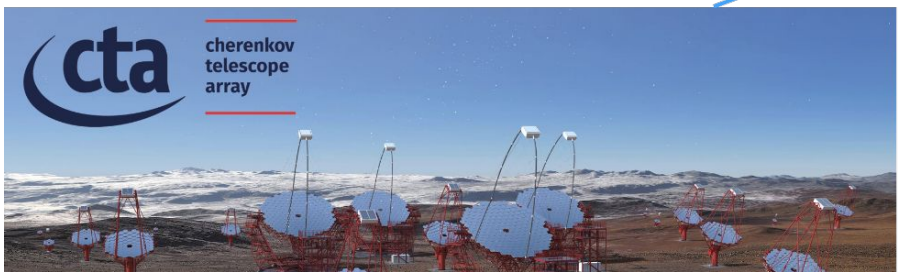
The **Cherenkov Telescope Array Observatory** is the future project for TeV gamma-ray astronomy.

CTAO compared to current generation Imaging Air Cherenkov telescopes:

- 5-10 x more sensitive
- 5 x better angular resolution
- 2.5 x larger field of view

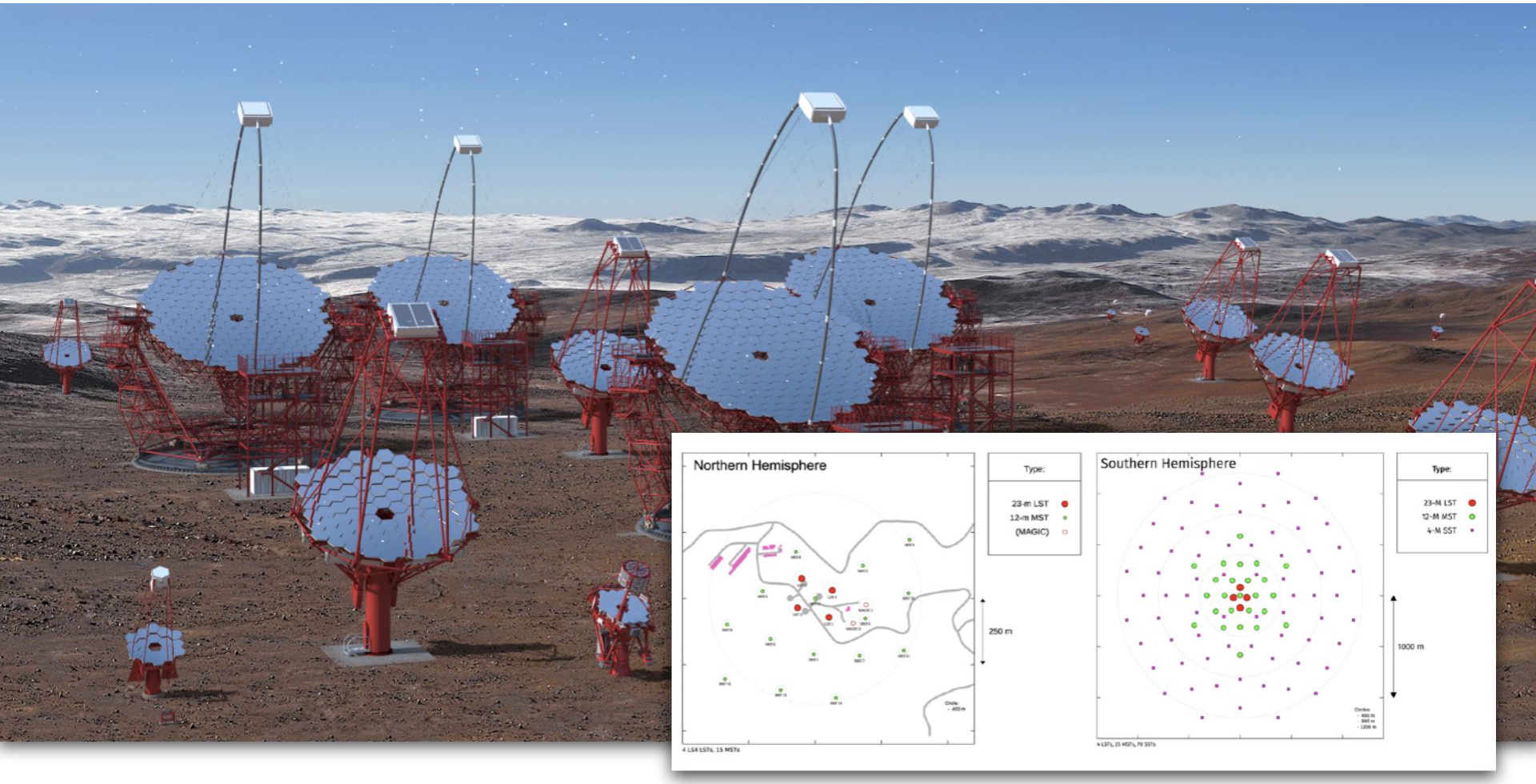






slide credit: Jacco Vink

Two arrays to cover the whole sky

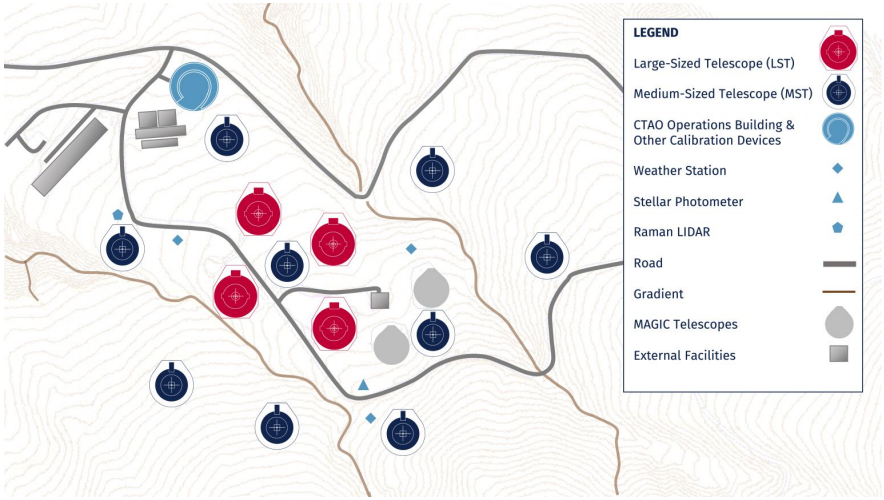


- **Two arrays** for observations of northern and southern sky (La Palma & Paranal)
- **Three telescope sizes** for broad energy coverage
  - LSTs (23 m diameter dish), MSTs (12 m), SSTs (4 m)

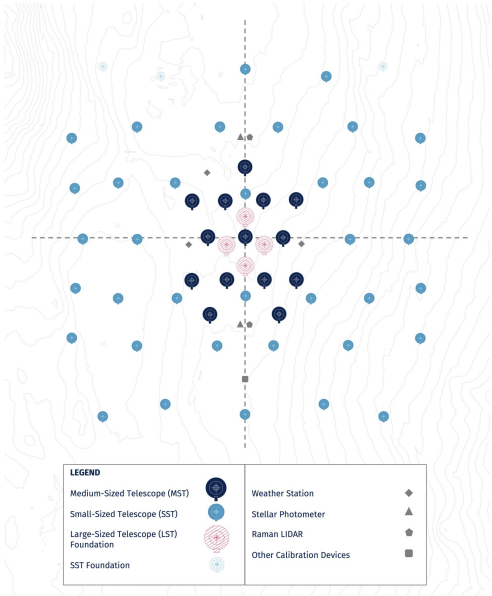
The project status

Construction phase (ongoing, until 2028):

- significant improvement wrt current running facilities
- significant increase of the discovery space and high-impact science



Northern Array: 4 LSTs and 9 MSTs

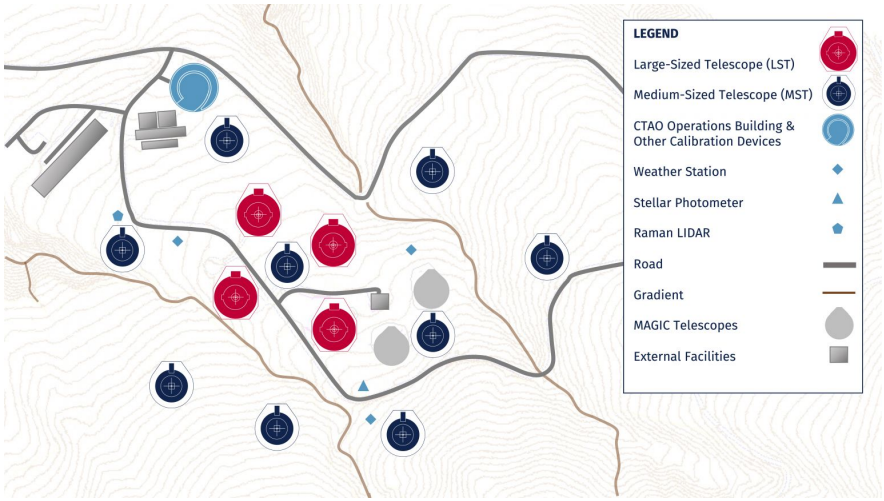


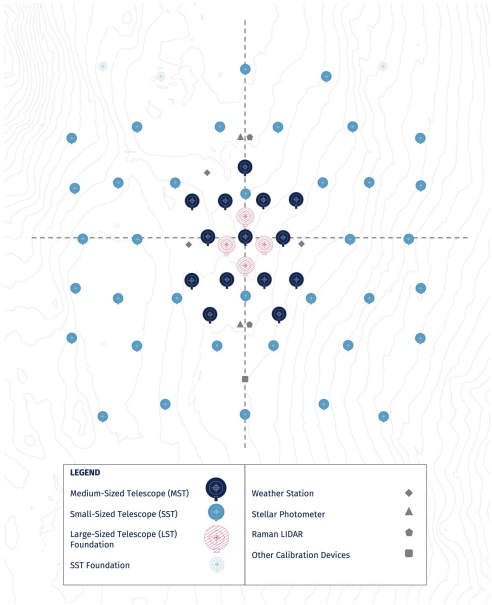
Southern Array: 14 MSTs and 37 SSTs+

The project status

Construction phase (ongoing, until 2028):

- significant improvement wrt current running facilities
- significant increase of the discovery space and high-impact science





Operations and enhancement phase:

- operations of the observatory and construction towards the full scope configuration

LST-1: The first LST and its first discovery

- LST-1 has been operating since 2018
- The LST-1 has discovered the most distant AGN (z=0.997) at very high energies (>100 GeV) !

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26 Jun 2024; 13:34 UT

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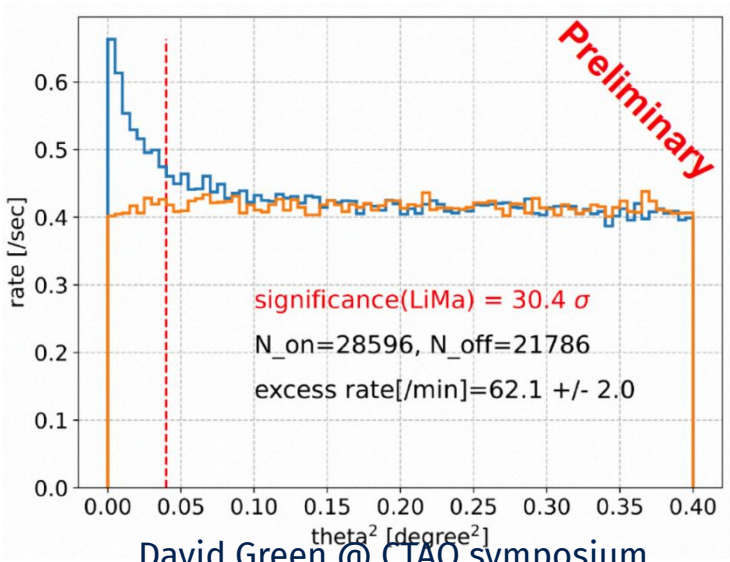
First detection of VHE gamma-ray emission from FSRQ OP 313 with LST-1

ATel #16381; *Juan Cortina (CIEMAT) for the CTAO LST collaboration*
on 15 Dec 2023; 14:31 UT
Credential Certification: Juan Cortina (Juan.Cortina@ciemat.es)

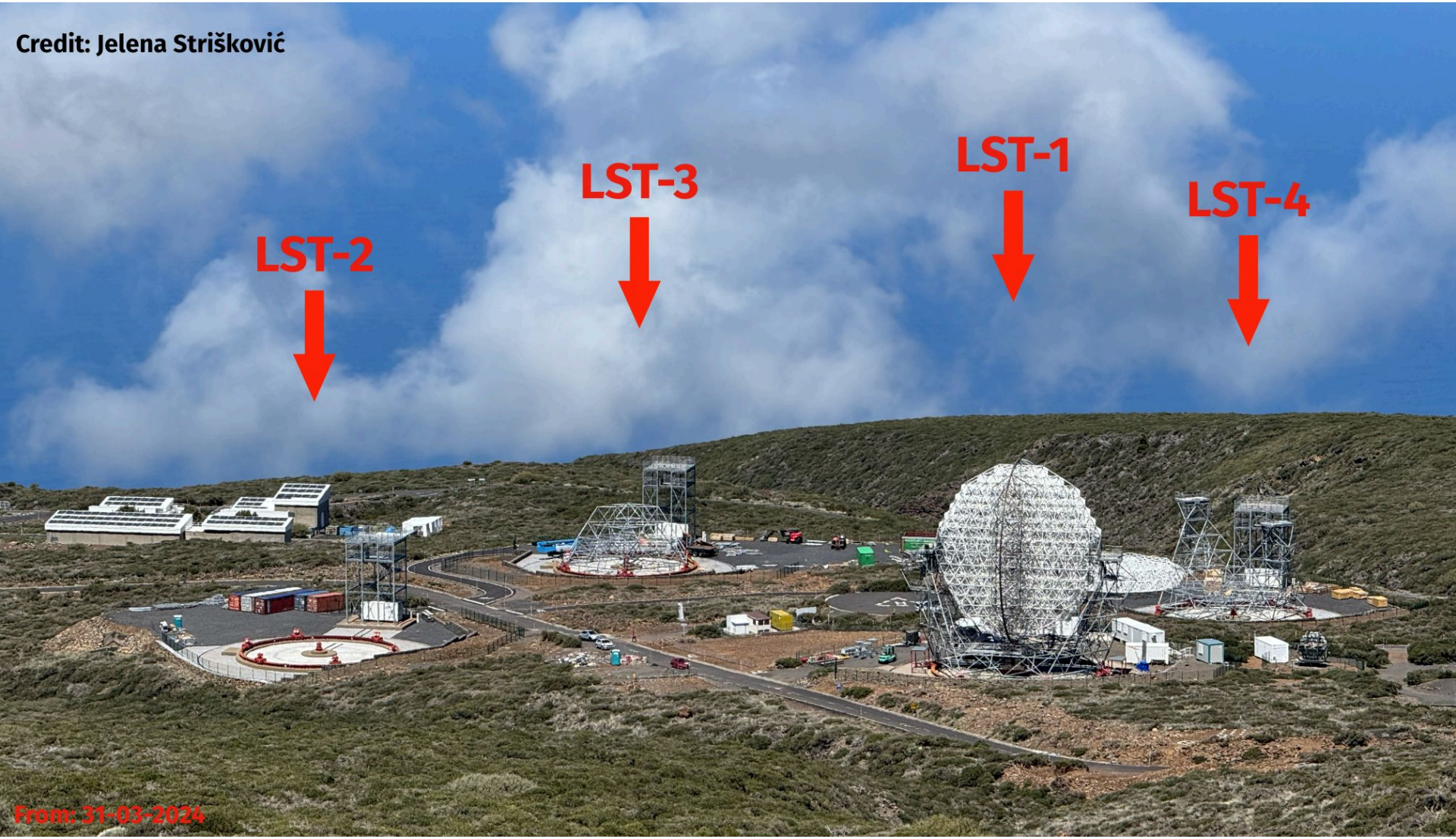
Subjects: Gamma Ray, >GeV, TeV, VHE, Request for Observations, AGN, Blazar, Quasar

Related
16614 Optical follow-up of FSRQ OP313 using 1.3 m Devasthal Fast Optical Telescope (DFOT)
16515 The FSRQ B2 1308+326: the activity phase at epoch of high-energy flare in 2024 February
16504 Swift-XRT follow-up confirms the high activity state of the FSRQ OP 313
16497 Fermi-LAT detection of renewed gamma-ray activity from the FSRQ OP 313
16381 First detection of VHE gamma-ray emission from FSRQ OP 313 with LST-1



David Green @ CTAO symposium

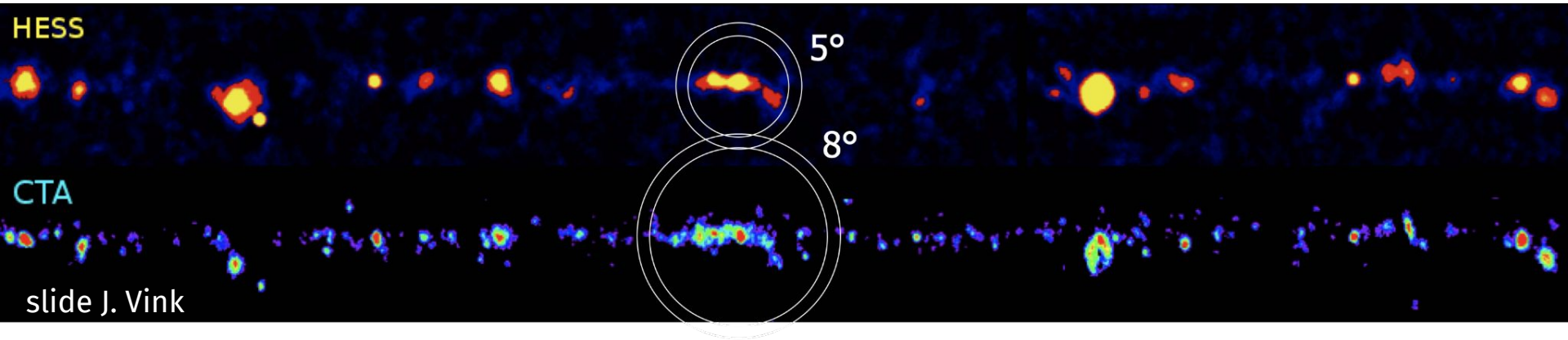
CTAO Northern array: construction is ongoing



(Selected) scientific goals

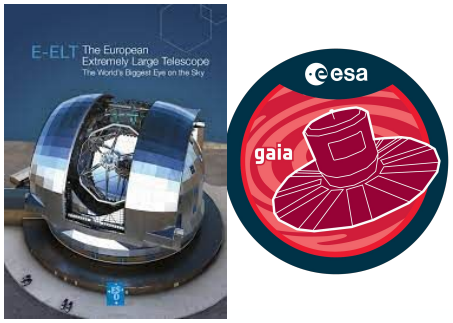
CTAO Galactic plane survey

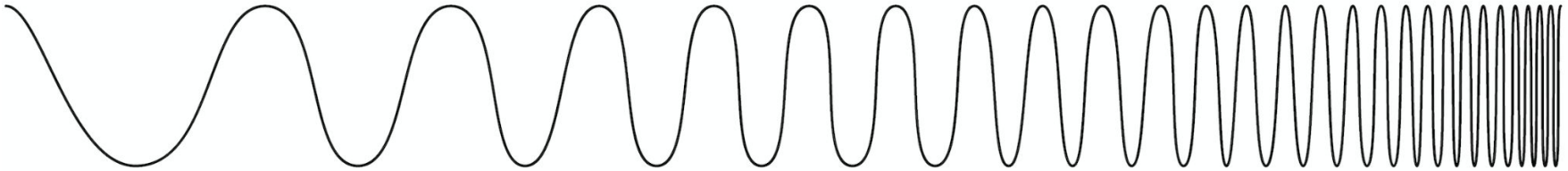
- Number of TeV sources will increase by a factor of about 5
- Much deeper than any previous gamma-ray survey.



arxiv: 2310.02828

Synergies with the Dutch MWL community

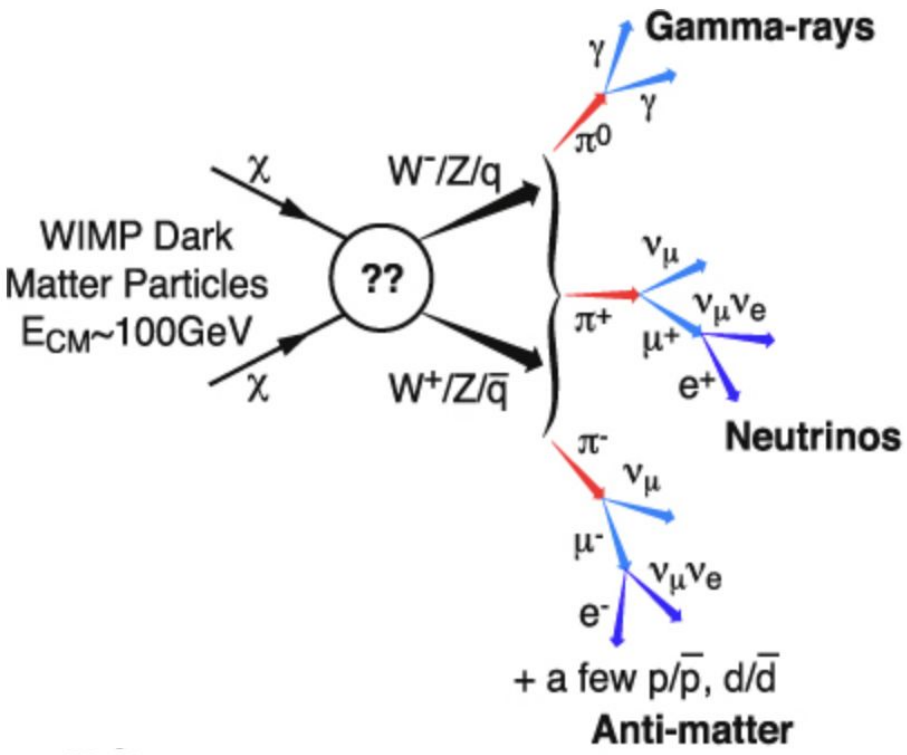




Radio Microwave Infrared Visible Ultraviolet X-ray Gamma ray

Indirect dark matter searches

Weakly interacting massive particles (WIMPs) were created in the early universe and they are predicted in supersymmetric extensions of the Standard Model.



Adapted from E. A. Baltz et al, J. Cosmol. Astropart. Phys. JCAP07 (2008) 013

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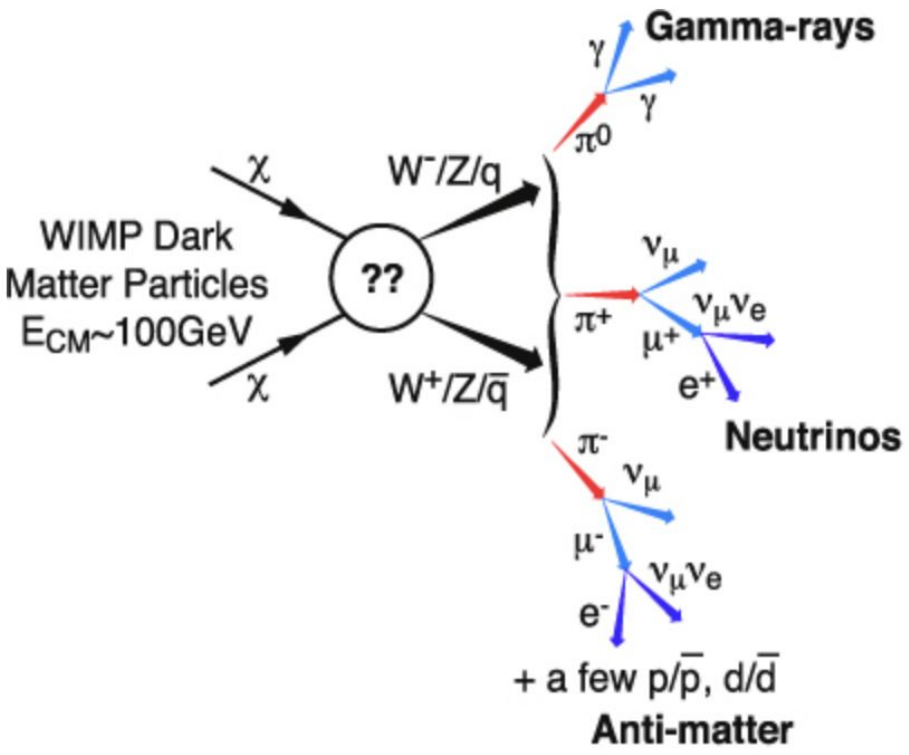
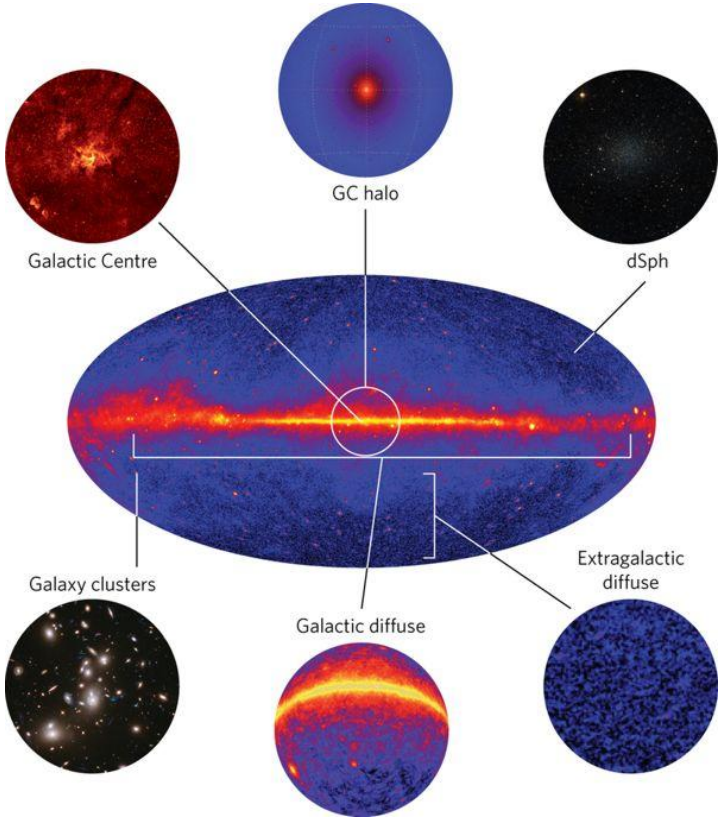
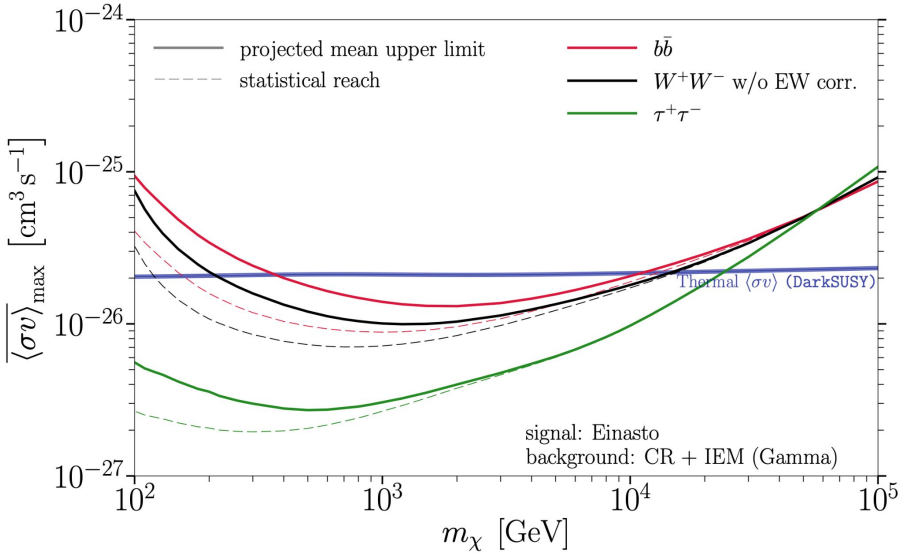


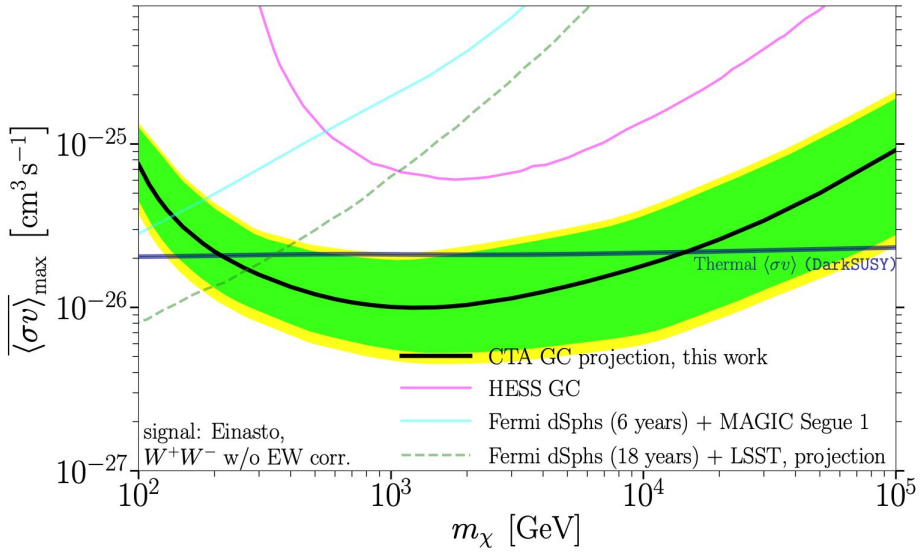


J. Conrad and O. Reimer Nature Physics 13, 224–231 (2017)

DM searches in the Galactic Centre

- Distance: 8.5 kpc
- DM content: $\log_{10}J$ [GeV^{2}cm^{-5}]=22.85
- Observation time: 525 h
- Astrophysical gamma-ray sources:
  - Fermi bubbles
  - diffuse emission (CR interactions)
  - point-like sources (unresolved?)





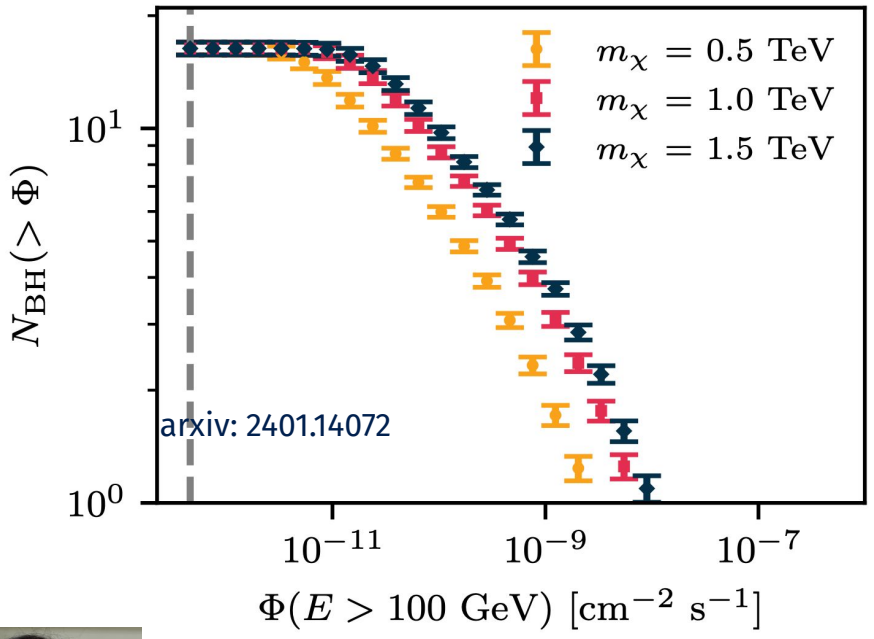
The CTA Consortium, JCAP 01 (2021) 057

Intermediate Mass Black holes: an alternative target to search for Dark Matter

Intermediate Mass Black Holes are expected to be surrounded by high DM densities (spikes) which may cause gamma-ray emission.

HESS and Fermi-LAT would be sensitive enough to probe DM annihilation cross section even below the thermal relics for DM masses in the GeV-TeV range.

arxiv: 2401.14072






Jann Aschersleben, Natacha Barrow, Mathilde Croisonnier, Manuela Vecchi

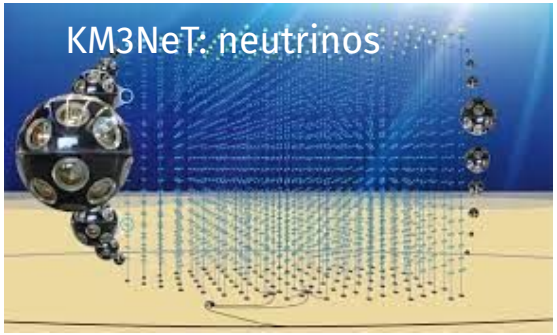
See Jann Aschersleben's talk

Dark matter: Synergies with Dutch science

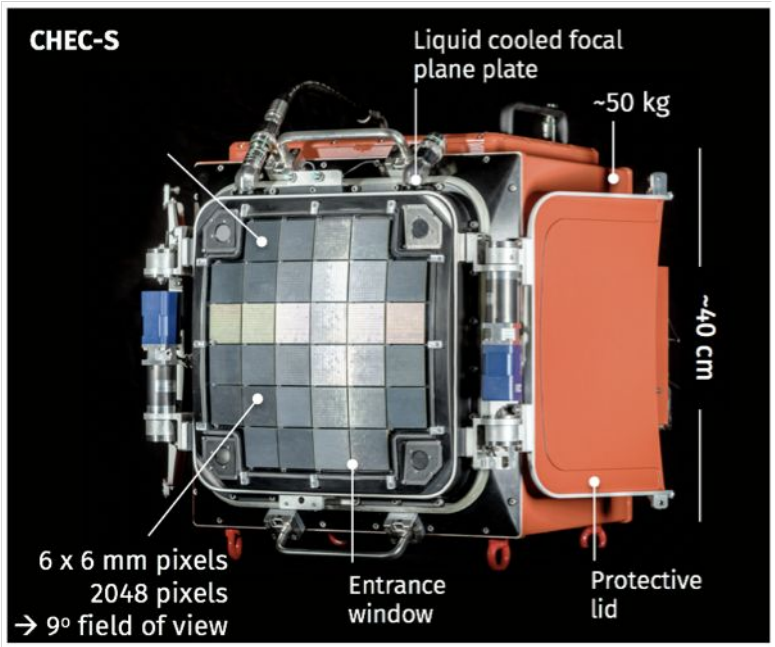
LOFAR

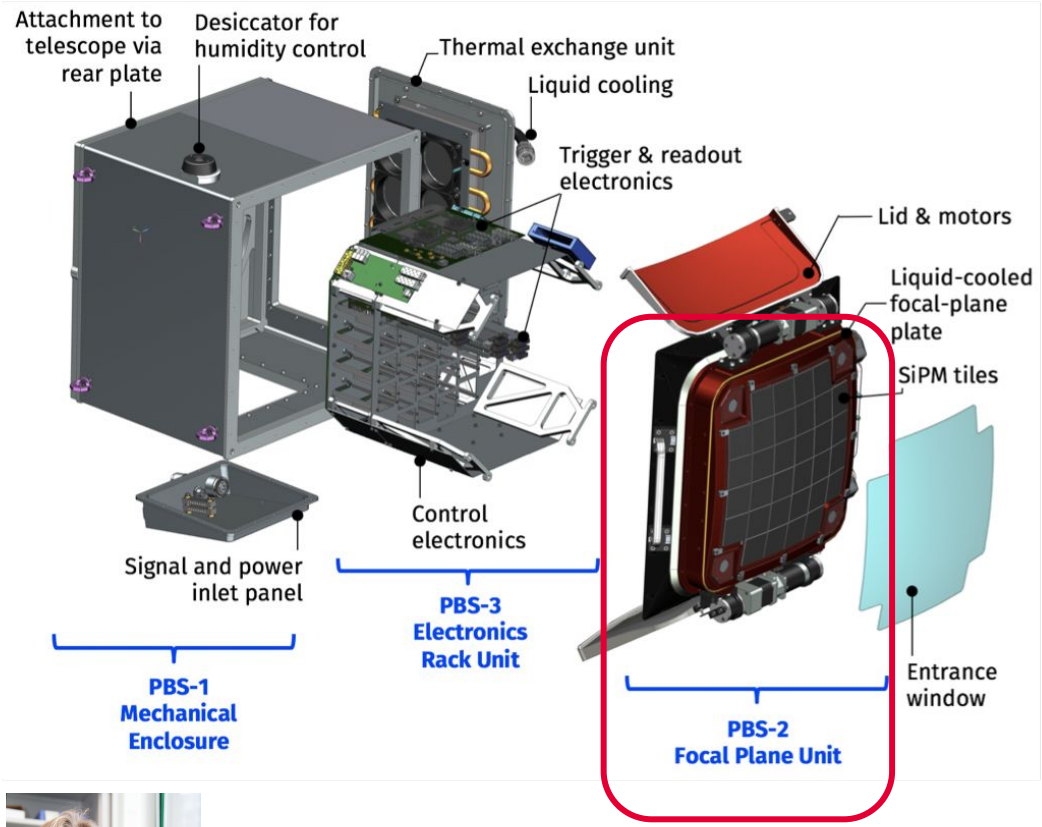
NEAT

esa gaia



Instrumentation: the Focal Plane Unit of SST cameras





Andrey Baryshev, Marielle Bekema

Our team

GRAPPA
GRavitation AstroParticle Physics Amsterdam




Jacco Vink, Sera Markoff, Christoph Weniger, Evert Rol

rijksuniversiteit groningen

NOVA






Manuela Vecchi, Andrey Baryshev, Marielle Bekema, Jann Aschersleben, Natacha Barrow, Dagmar Rozendal, Mathilde Croisonnier

Vision for HESS-CTAO in the Netherlands

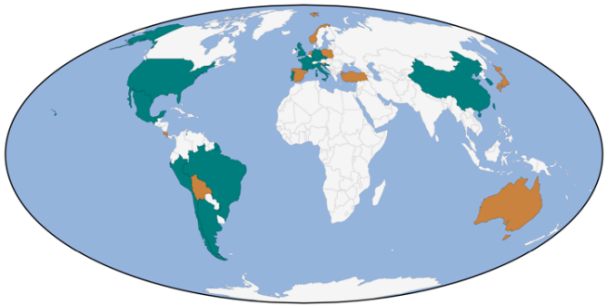
- HESS operations will continue until 2025, with a likely extension to 2028.
- The legal entity (ERIC) to operate the CTA Observatory is taking off: the NL will soon discuss membership options.
- The CTAO early science is expected around 2027: the observatory can operate even in a reduced configuration well before completion.
- The CTAO construction phase con is expected to be completed around 2028 and will operate for at least a decade.

SWGO

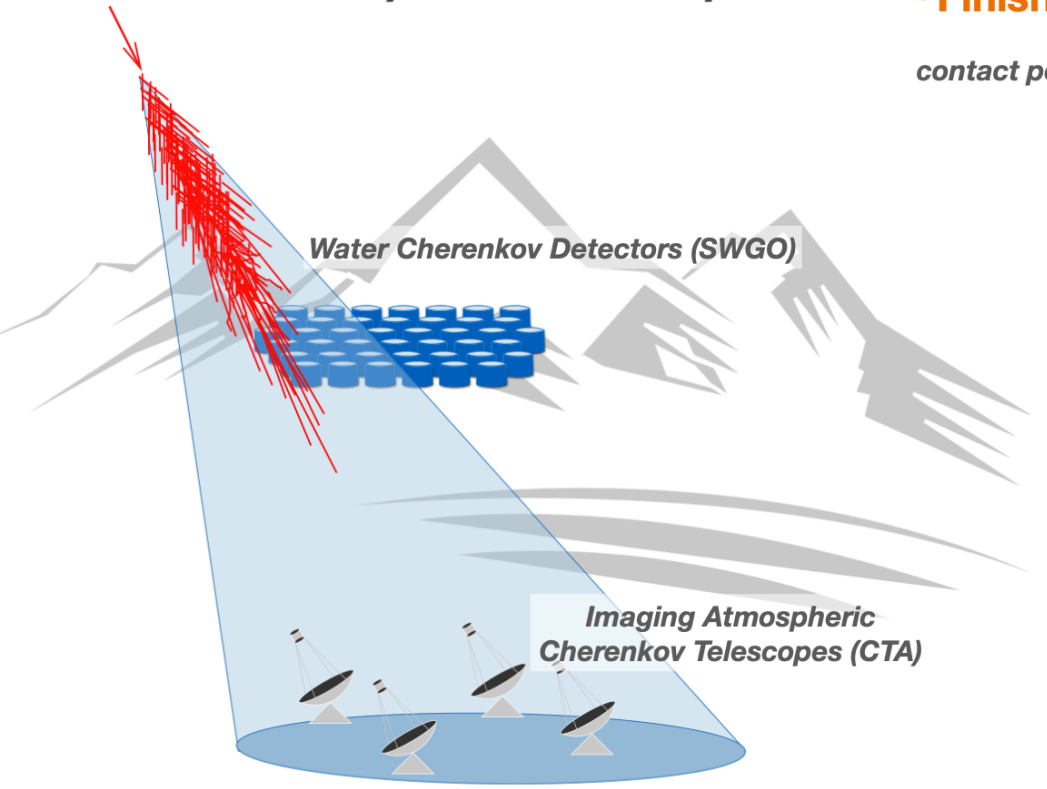
The Southern Wide-field Gamma-ray Observatory

SWGO in a nutshell

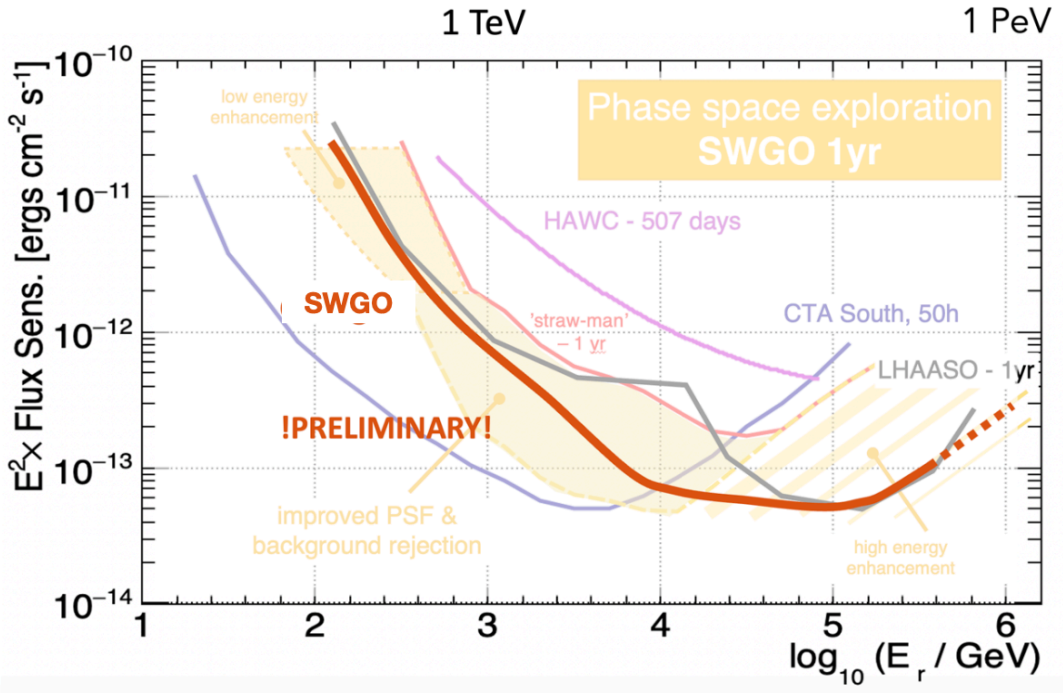
- high altitude water-Cherenkov detector observatory to measure **gamma rays** and **cosmic rays**
- International collaboration.
- Will be located in South-America
- Complementary observations to CTA
- **Finishing its R&D phase by 2025.**



contact person in the Netherlands. Harm Schoorlemmer



Comparison of differential point-source sensitivity



Conclusions

The gamma-ray community in the Netherlands is growing and participating in HESS, CTAO and SWGO projects.

- HESS has provided very high-impact results and will continue to do so for the next years.
- CTAO is the future project for ground-based gamma-ray astronomy with the IACT technique with superior performance wrt current generation observatories.
- SWGO is the future project for PeV gamma-rays and will be able to achieve the highest energy gamma rays with a large field of view.

Job Advertisements

Postdoc at RUG

- goal: developing a software framework for calibrating the cameras of the Small-Sized Telescopes for CTAO.
- duration: 2+1 years
- starting date: negotiable, from the 1st of September 2024
- contact: Manuela Vecchi

Postdoc at UvA

- goal: developing a software framework for Small-Sized Telescopes for CTAO.
- duration: 2+1 years
- starting date: negotiable, from the 1st of September 2024
- contact: Jacco Vink

cherenkov telescope array

Thank you for your attention