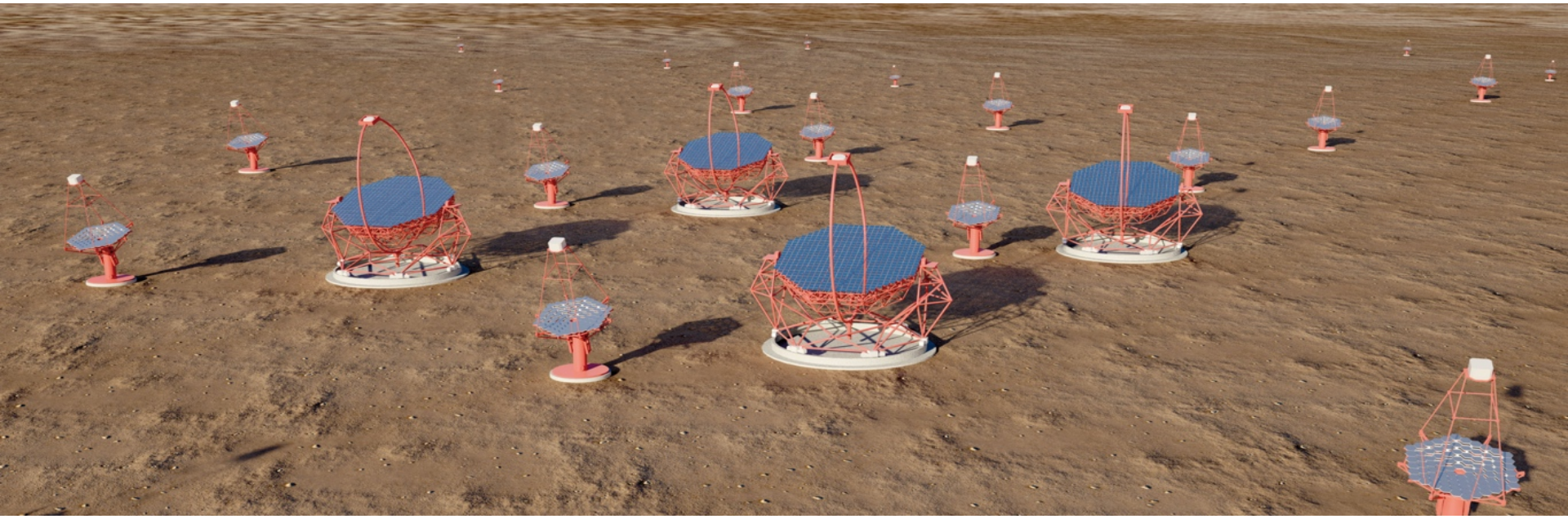
γ-ray astronomy at DESY



Stefan Ohm for the γ-ray groups

79th PRC Meeting
Hamburg, May 11th

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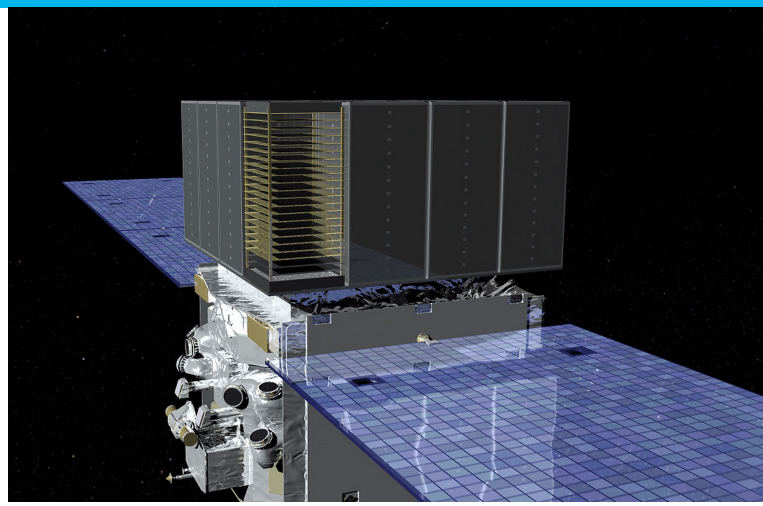
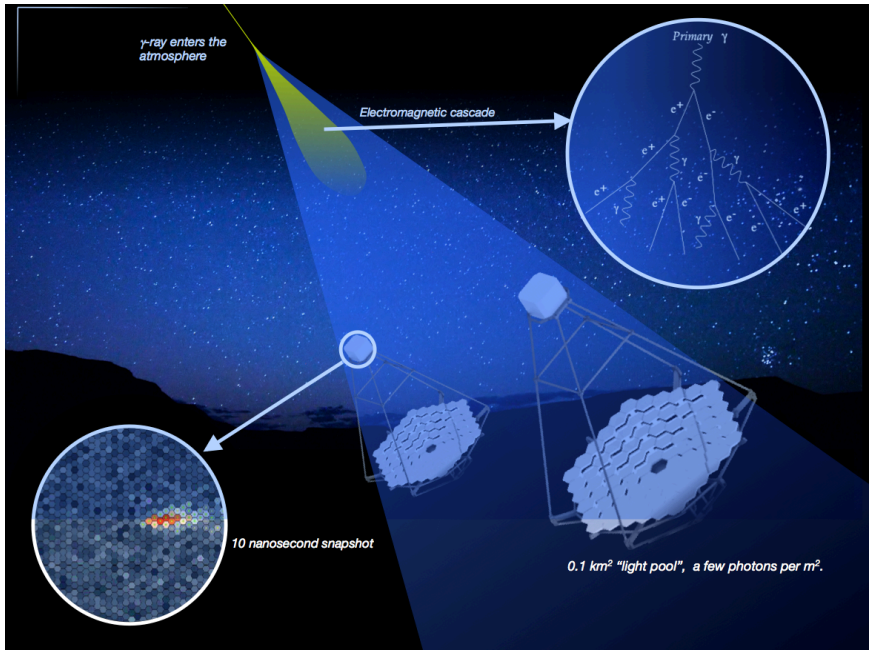
DESY

How to detect γ rays?

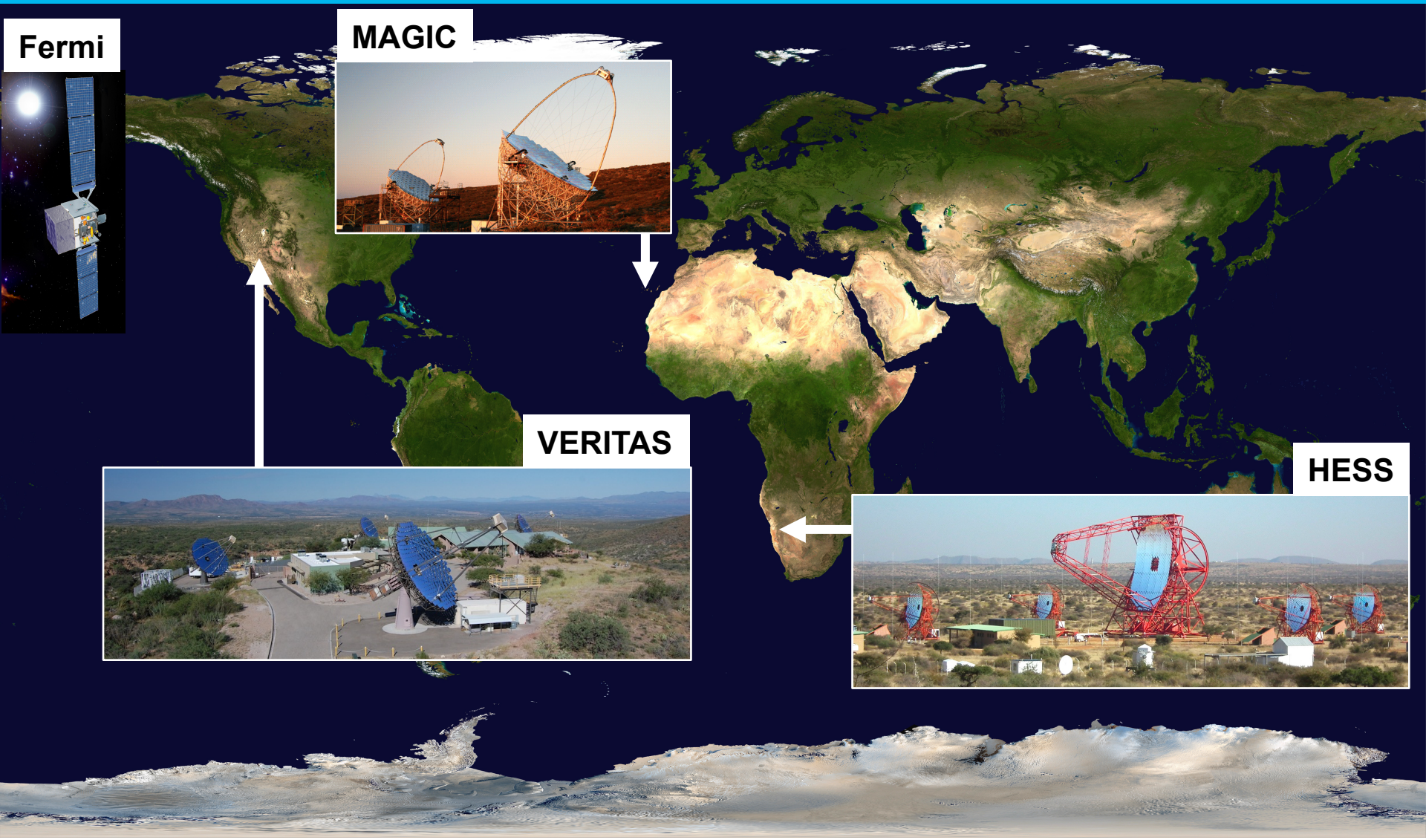
- From space: *Fermi*-LAT
  - Imaging, wide field-of-view
  - Covers energy range from ~20 MeV – 300 GeV
  - Pair-conversion telescope, with a precision tracker and calorimeter
  - Limited detection area



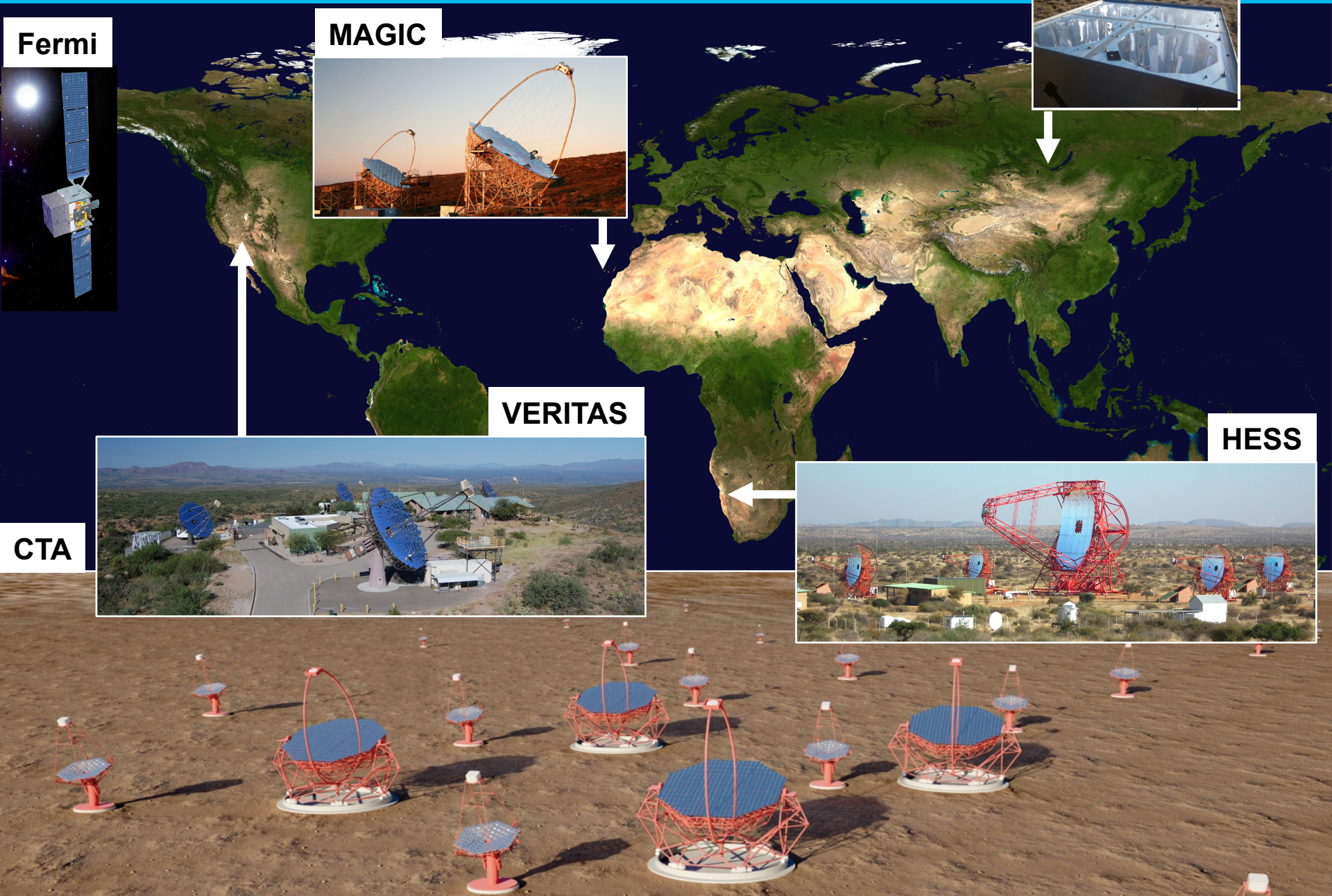


- From ground: Imaging Atmospheric Cherenkov Telescopes (IACTs)
  - Imaging, smallish field-of-view
  - Covers energy range from 30 GeV – 100 TeV
  - Collect Cherenkov radiation produced by charged particles in shower and focus on fast camera
  - Large collection area

Instruments currently in operation

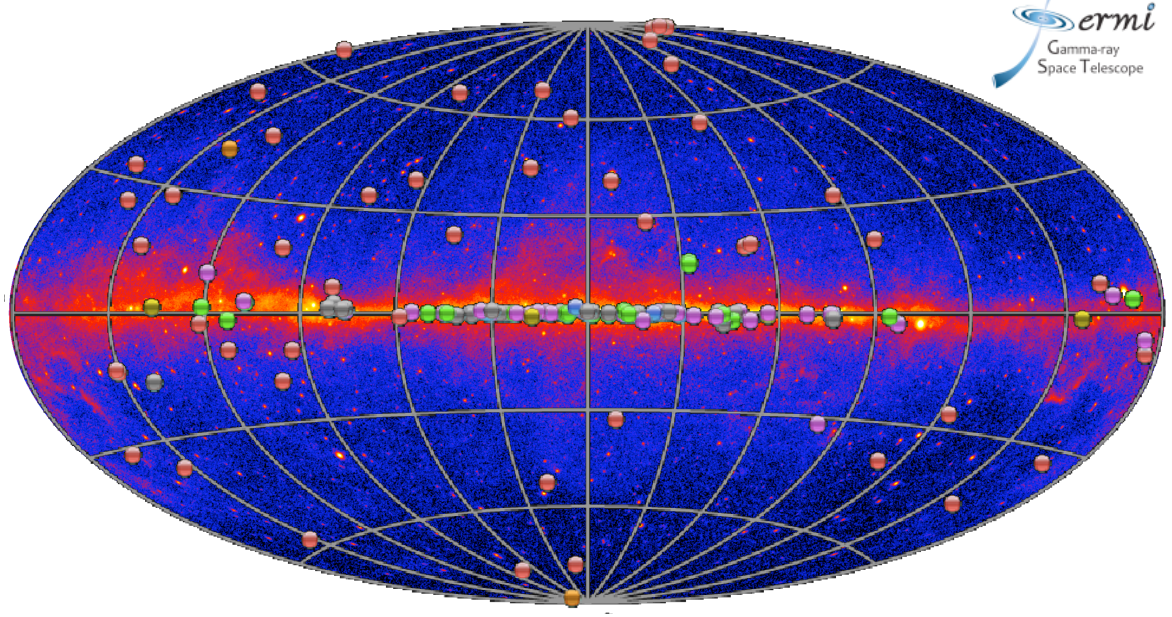


+ future instruments

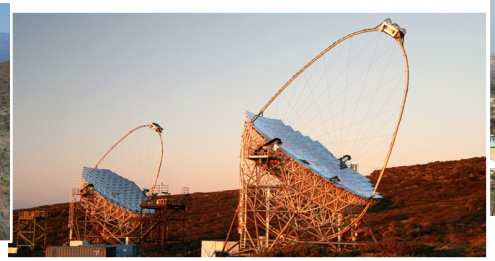


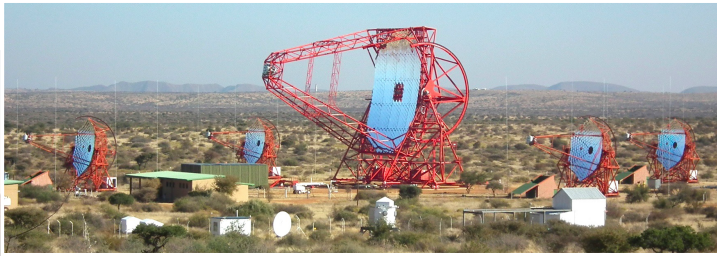
The γ-ray sky in 2015

- GeV γ-rays
  - ~3000 sources
  - ½ extragalactic
  - ~1000 unassociated
  - 25 extended sources



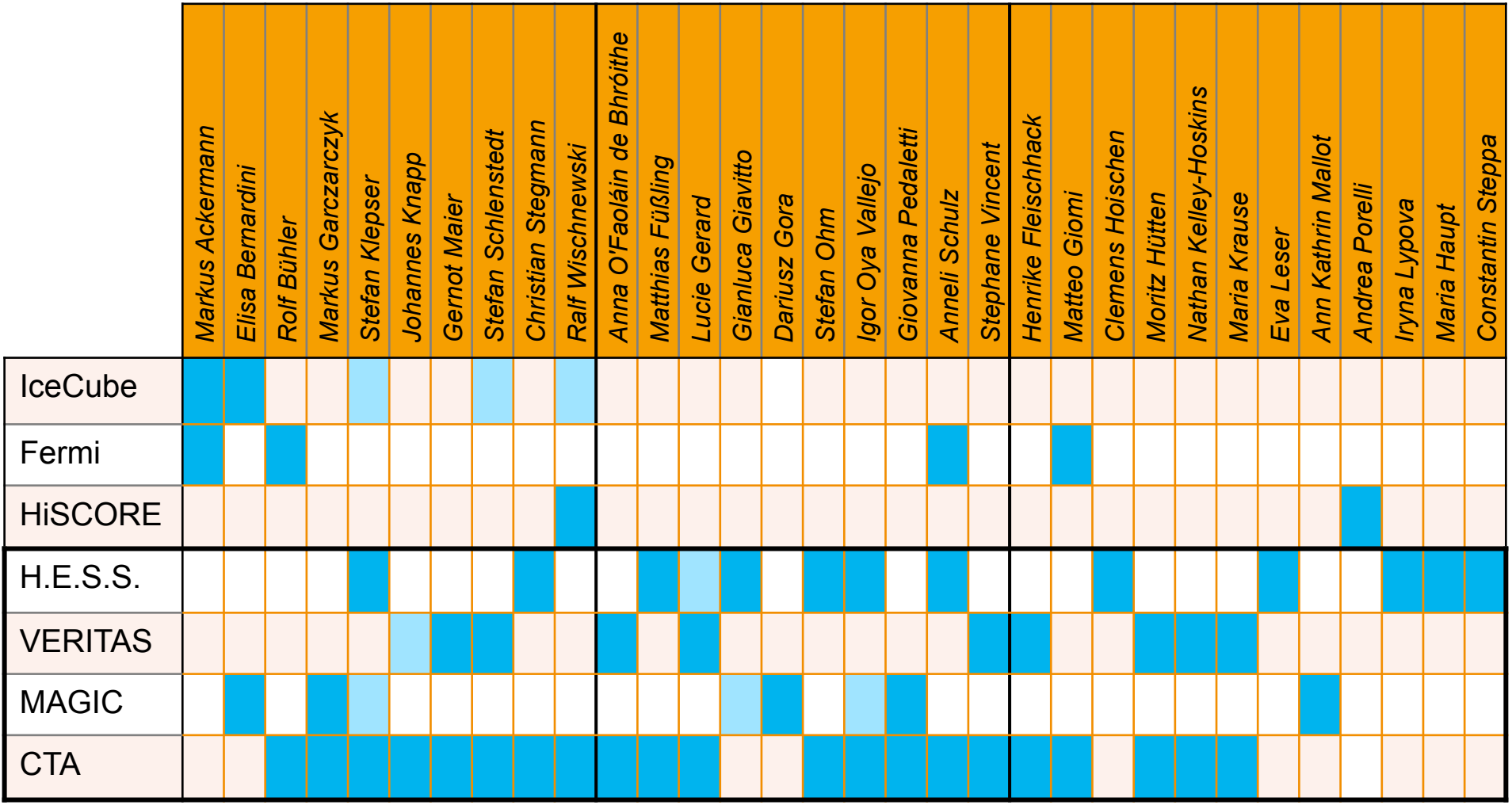
- TeV γ-rays
  - >150 sources in total
  - ~50 of extragalactic origin
  - ~100 Galactic sources





DESY

Who we are



Collaboration member

Former collaboration member

Recent highlights from current instruments

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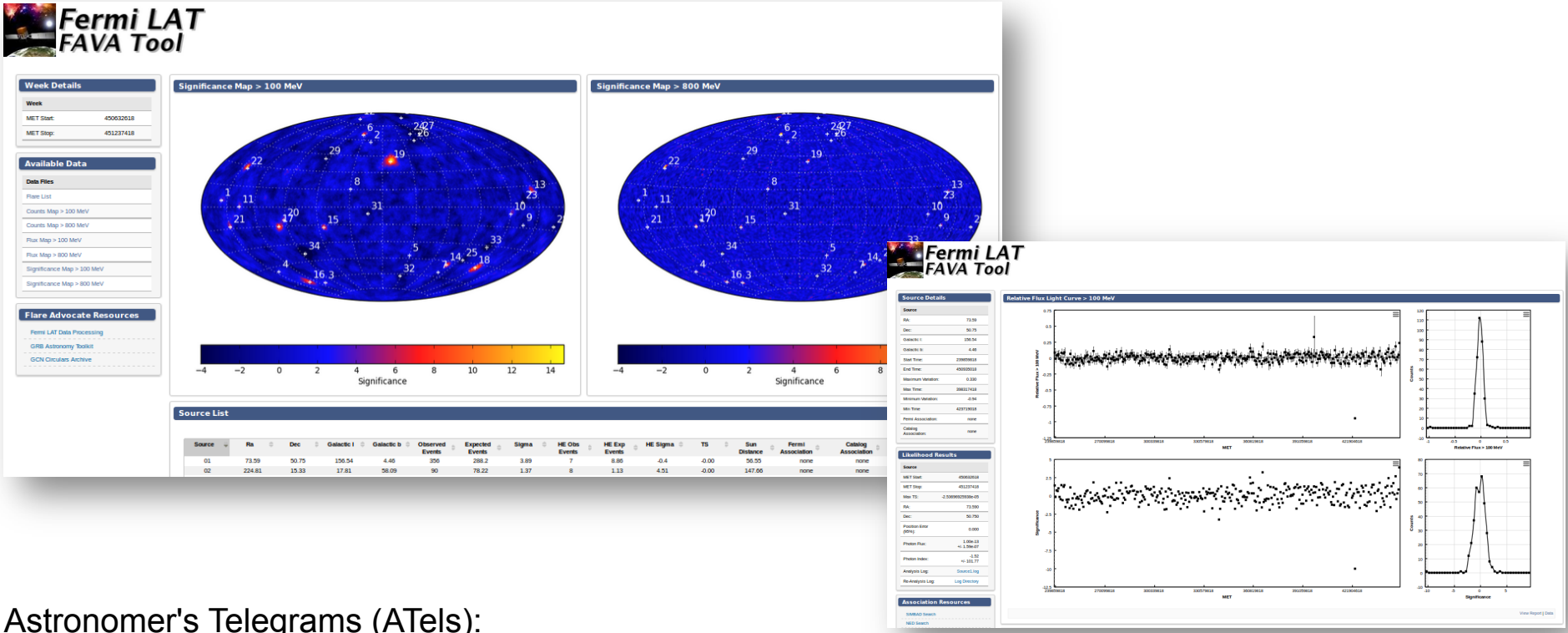
DESY

Fermi-LAT all-sky monitor

- *Fermi* All-sky Variability Analysis (FAVA) is an all-sky γ-ray monitor
- Running as real time flare monitor since ½ year within LAT collaboration
- Already discovered and announced 5 new flaring γ-ray sources



Astronomer's Telegrams (ATels):
6553, 6529, 6101, 6100, 6098, 6020

Method paper: Ackermann et al., ApJ 771 1, 2013

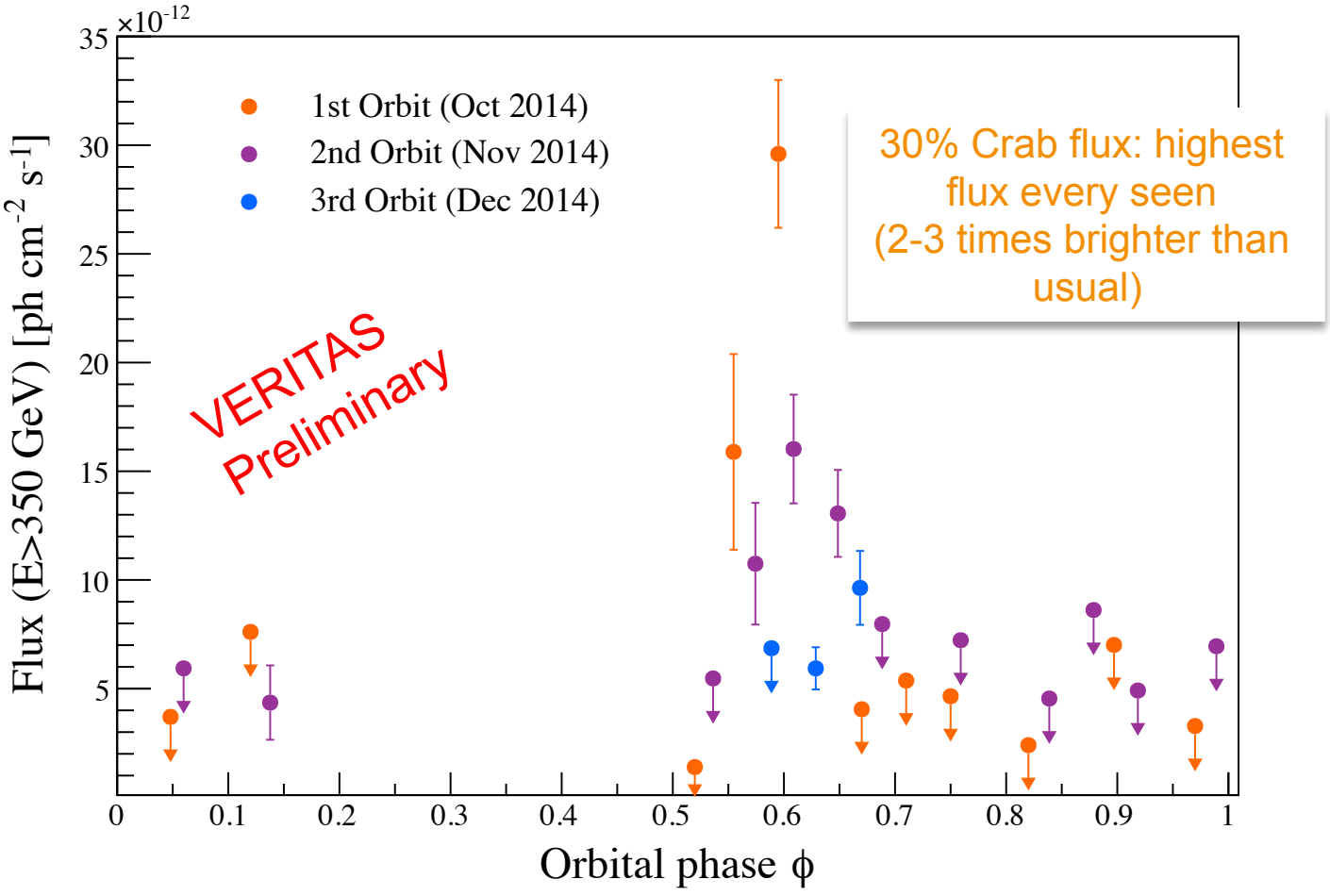
The VERITAS long-term observing plan

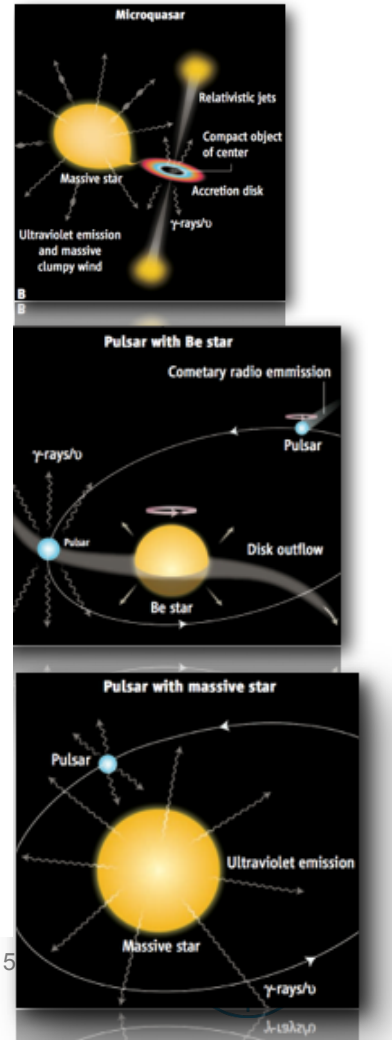
- Full operations of VERITAS started 2007 – no ‘low-hanging-fruits’ left
- Almost any science question requires deep exposure of 50 → 100 hours
- VERITAS developed a long-term observing plan, which covers ~70% of the available observing time for the next five years
  - Focus on a few high-impact science questions
  - Take into account the impact of the new HAWC observatory and the schedule of CTA
  - Galactic long-term plan coordinated by DESY scientists

Historically bright flares of the γ-ray binary LS I +61 303

- VERITAS observed an unexpected bright and fast flare from the binary system LS I +61 303 in October 2014 (ATel: 6785)
- Publication with DESY lead author in preparation

Binaries are among the most efficient particle accelerators known. How do they work?



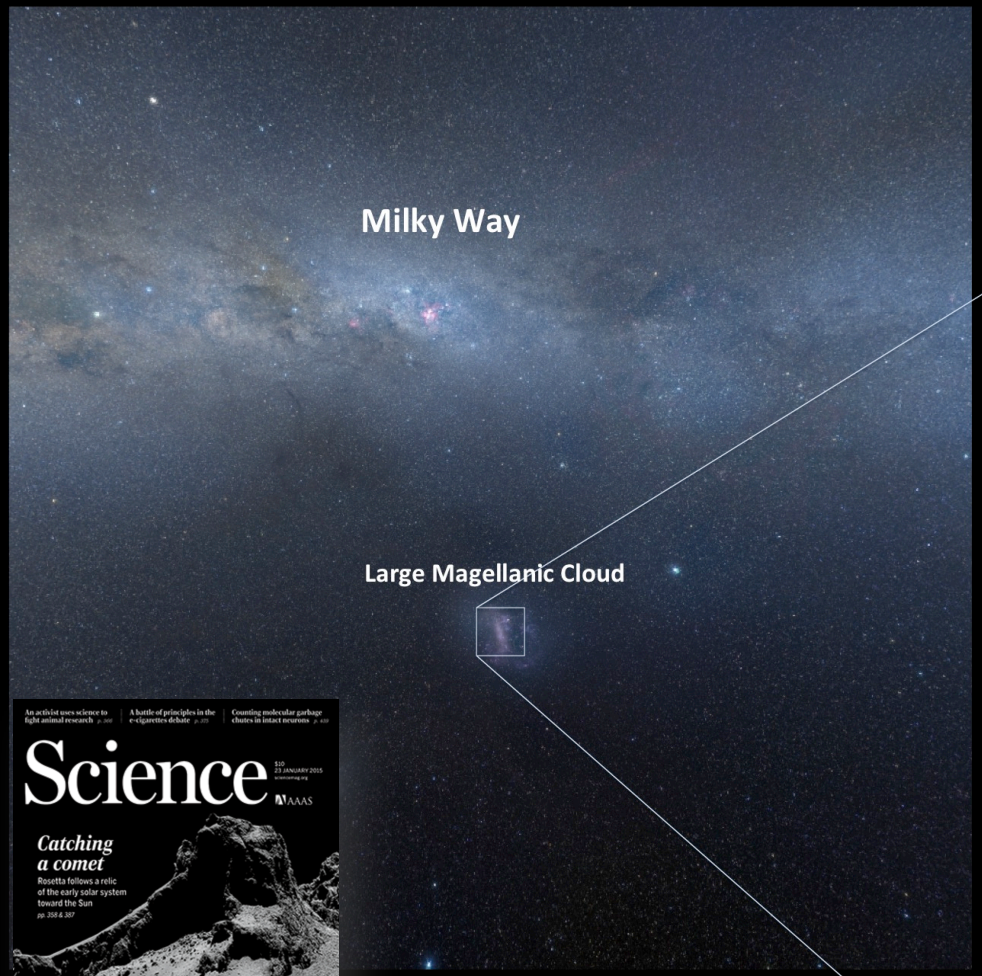


MAGIC: AGN program and multi-wavelength synergies

- Strong AGN program
  - 2015 already started as successful flare-catching year (3 ATels on AGN)
  - DESY scientists regularly serve as flare advocates
- Large Target-of-Opportunity program
  - With alerts from optical, X-ray, and γ-ray instruments (Fermi-LAT, HESS, VERITAS, HAWC)
  - Agreements with multi-messenger instruments (gravitational waves, neutrinos)

  → Ligo-Virgo, IceCube (DESY-lead)
- Cosmic-ray diffusion in the W44 region
  - Cooperation with *Fermi*-LAT and NANTEN
  - ICRC contribution, project is DESY-lead

H.E.S.S. observations of the Large Magellanic Cloud

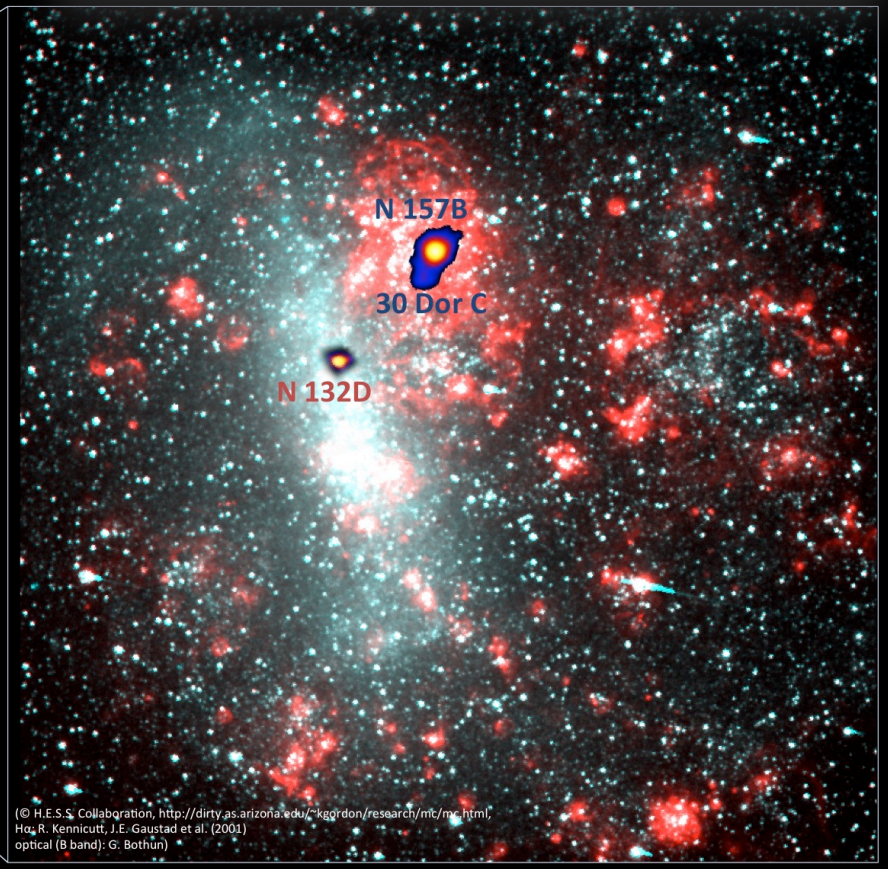


REPORTS

ASTROPHYSICS

The exceptionally powerful TeV γ-ray emitters in the Large Magellanic Cloud

The H.E.S.S. Collaboration*†

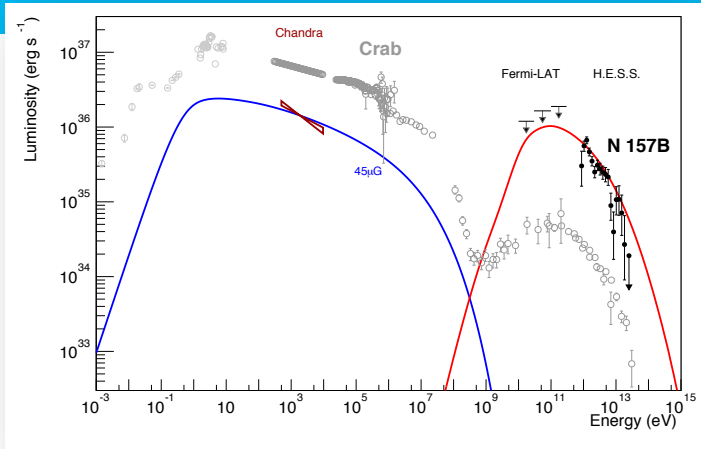


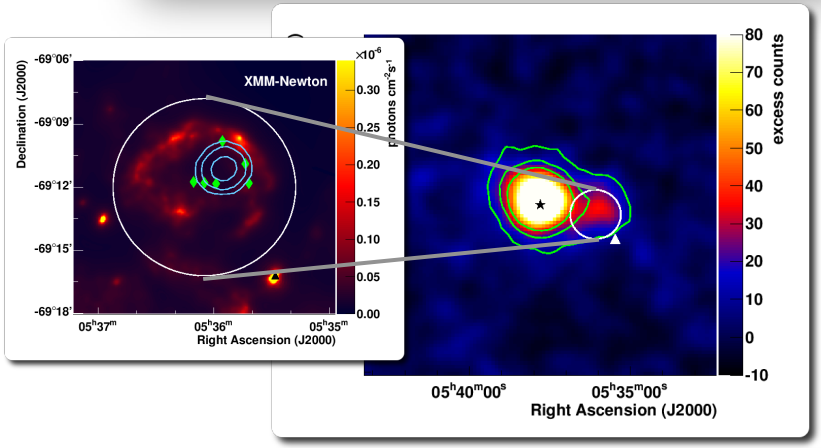
(© H.E.S.S. Collaboration, http://dirty.as.arizona.edu/~kgordon/research/mc/mc.html,
Hα: R. Kennicutt, J.E. Gaustad et al. (2001)
optical (B band): G. Bothun)

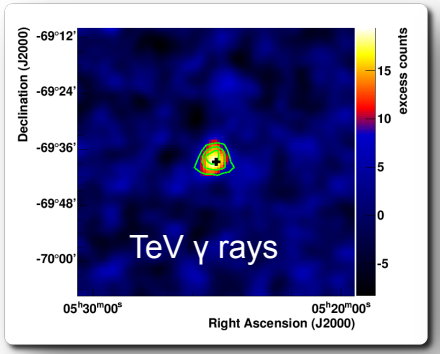
H.E.S.S. observations of the Large Magellanic Cloud

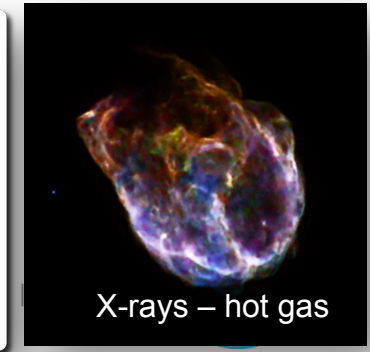
- Results
  - Discovery of three luminous TeV sources, equally or more powerful than Galactic counterparts
- N 157B
  - Environment very important for production of γ rays
- 30 Dor C
  - First superbubble detected at TeV energies
  - Superbubbles are blown by stellar winds and SN explosions
  - Superbubbles are suspected to be main CR accelerators
- SNR N132D
  - Particle acceleration in SNR shells is more efficient than we thought

→ Observationally a major step forward









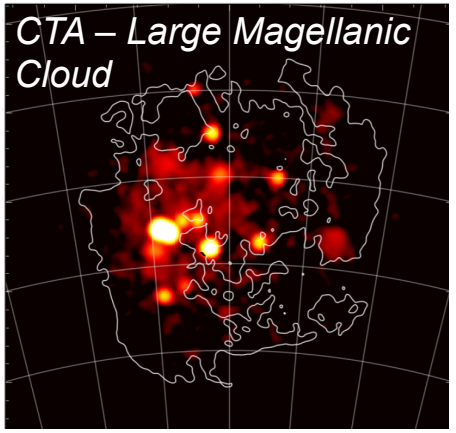
Towards science with CTA

HELMHOLTZ ASSOCIATION

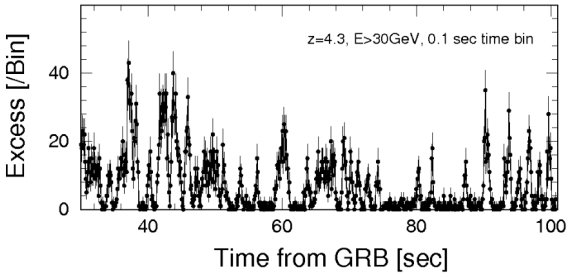
DESY

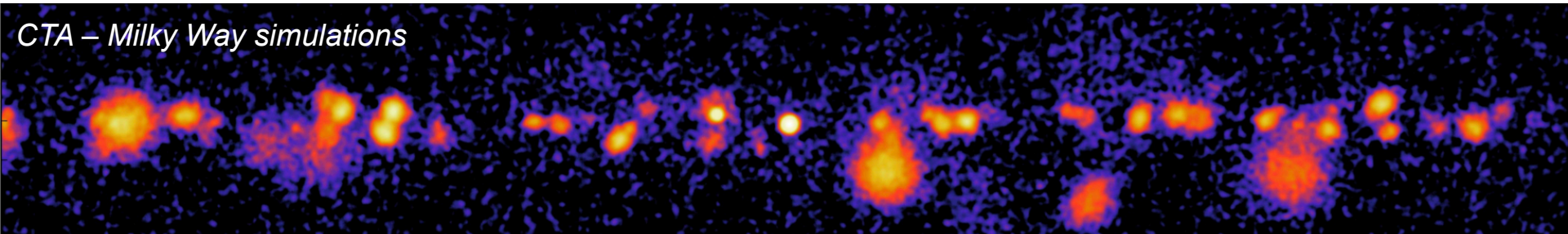
The Cherenkov Telescope Array – Key Science Projects

- Planning the observation using CTA-Consortium's proprietary time
- Legacy data sets, address major science questions
  - What could not be obtained by an individual users proposal
- **K**ey **S**cience **P**rojects (part of **T**echnical **D**esign **R**eport)
- DESY involved in several Key Science Projects (KSPs)
  - Significant contribution to Galactic and Extragalactic surveys
  - Leading in Star-forming systems KSP
  - Close relation to science topics with current instruments



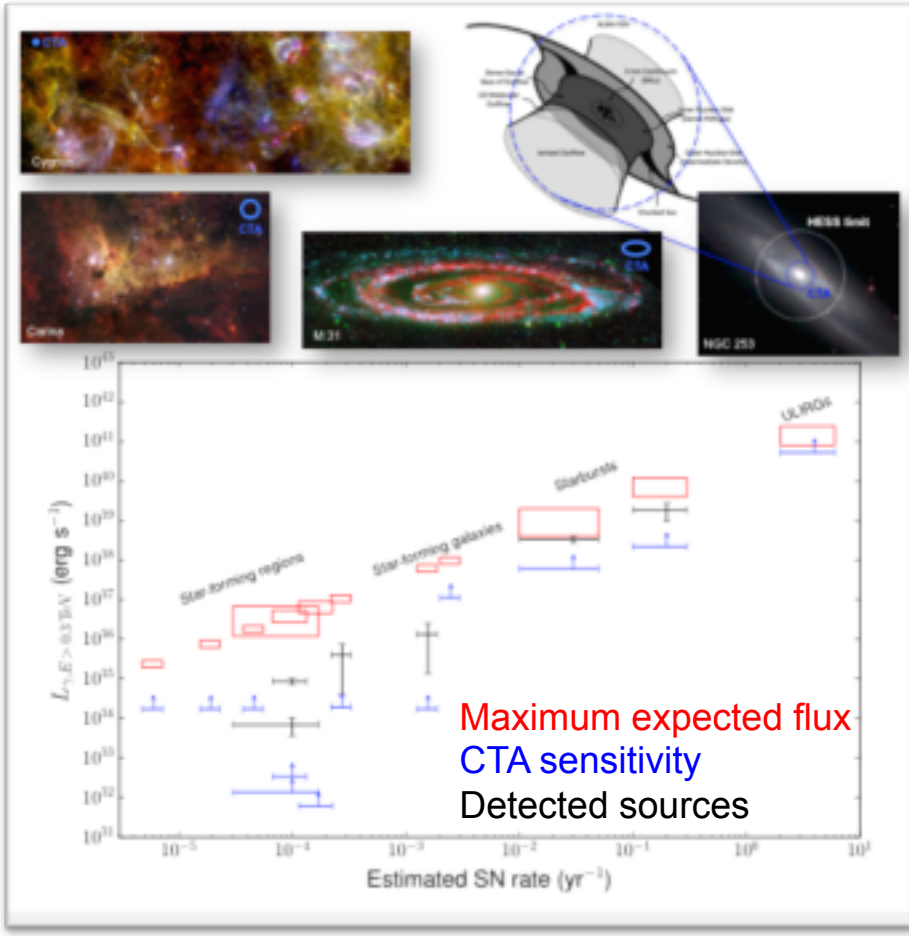
Simulated GRB lightcurve





The Cherenkov Telescope Array – Star-forming systems

- **CTA Science Theme 1:**
  "*Understanding the Origin and Role of Relativistic Cosmic Particles*"
- Cosmic rays
  - are a major ingredient of the interstellar medium
  - are a major source of ionisation
  - regulate astro-chemistry in space
  - are dynamically important in galaxy formation and evolution
- Probe star-forming systems on all scales
- Probe feedback of Cosmic rays with interstellar medium

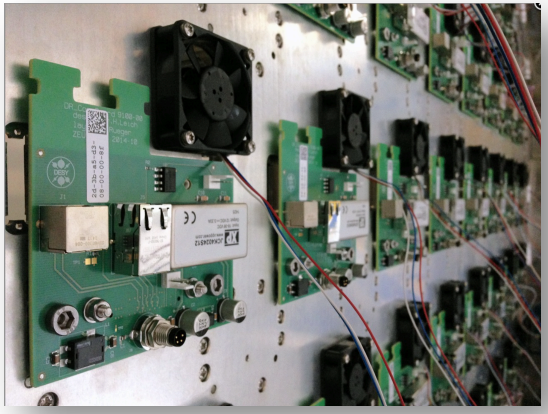


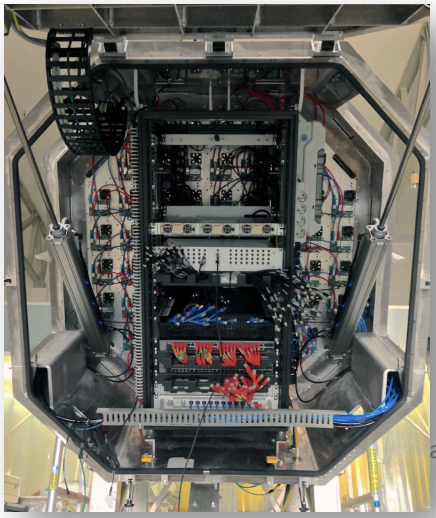
- Measure fraction of CRs that are channeled into γ rays as a function of star-formation rate

Upgrading current instruments

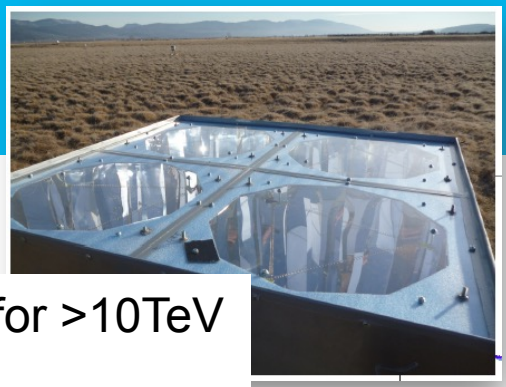
H.E.S.S.-I upgrade

- Goal
  - Reduction of dead time and down time
  - Replacing all electronics of the old H.E.S.S.-I cameras
- Huge progress in past 6 months
  - Ventilation, pneumatics, power supply
  - Drawer interface box
  - Testing, testing, testing
- Green light for upgrade of first camera in July
- Cameras 2 – 4: mid-2016





TeV/PeV Astronomy: HiSCORE – R&D

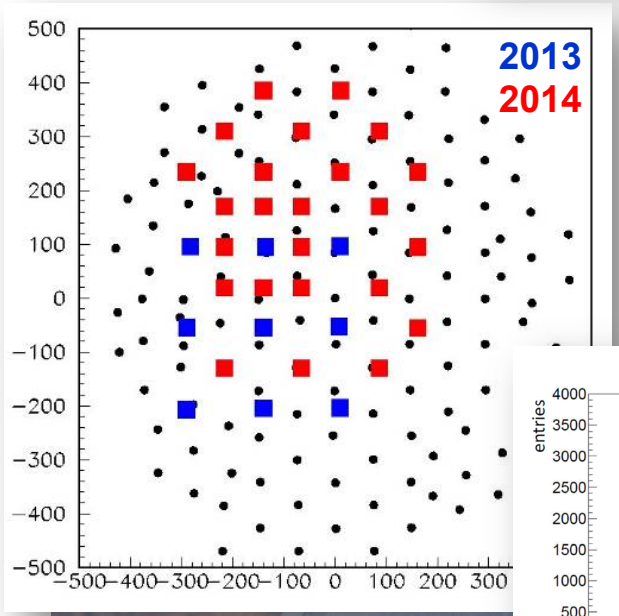


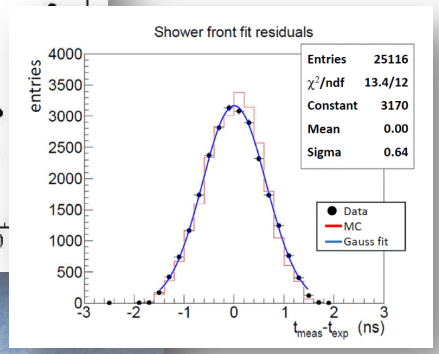
- **HiSCORE**: 1 km^2 array of wide-angle, non-imaging Cherenkov detectors
- **Taiga:** IACTs with 8^o FoV and 4m^2 mirrors

Hybrid technology for >10TeV
Proof of principle

HiSCORE

- Installation of 28 stations finished
  - 0.25 km^2
  - E_{th} < 30TeV
  - 1 km^2 in 2015/16
  - Russian MEGA-grant: major source
- DESY contribution
  - Helmholtz-Russian-Joint-Research-Groups-303 (2012-2015): 1 PhD, Project-PI Shower reconstruction, based on sub-nsec array time synchronization working
  - ***White-Rabbit (used in CTA)***





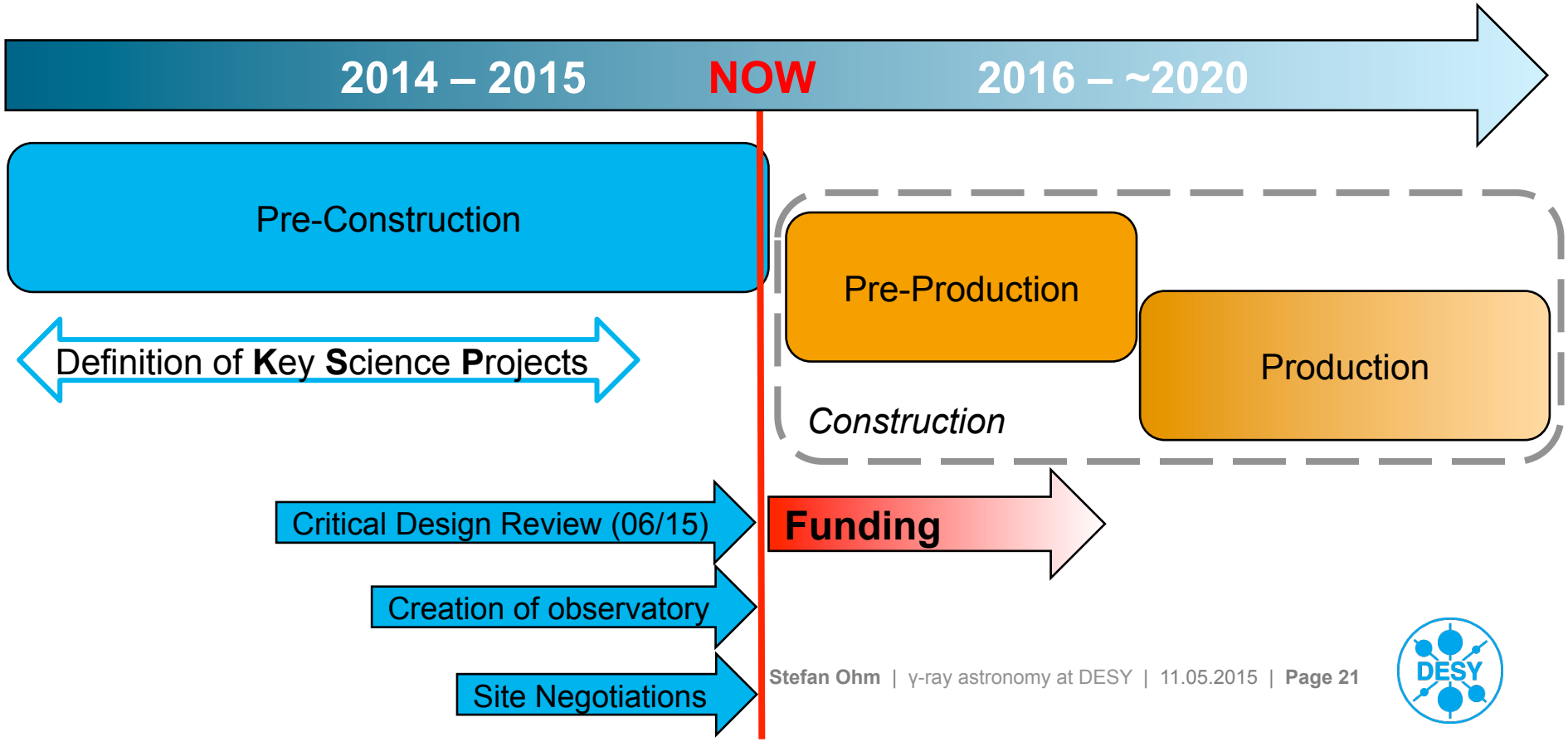
Towards construction of CTA

HELMHOLTZ ASSOCIATION

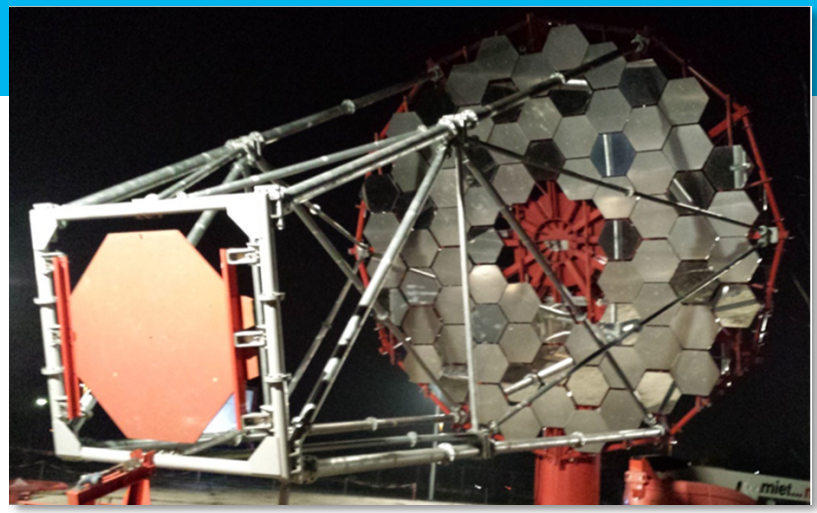
DESY

The Cherenkov Telescope Array

- Next-generation Imaging Atmospheric Cherenkov Telescope
  - Critical design review in June, then entering pre-production phase
  - First telescopes on southern site in 2016
  - First science ~2017



DESY involvement in CTA



- Leader of Medium Size Telescope project
  - New camera support structure mounted
  - Design improvement of dish
  - Pre-production phase imminent → start building
- Leader of Array control and data acquisition
  - Driving the definition of ACTL products to be delivered to CTA
  - Design of network architecture
  - Timing distribution system (White Rabbit)
  - Test cluster installation and synergies with MST activities
- Monte Carlo production
- Production of Instrument Response Functions
- CTA science tools
- Key Science Projects
- Application to host CTA headquarter

DESY involvement in CTA

- L
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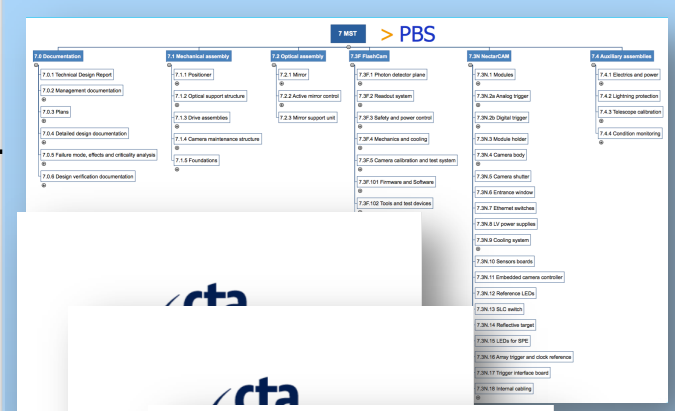
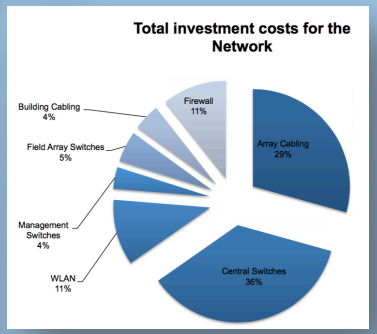
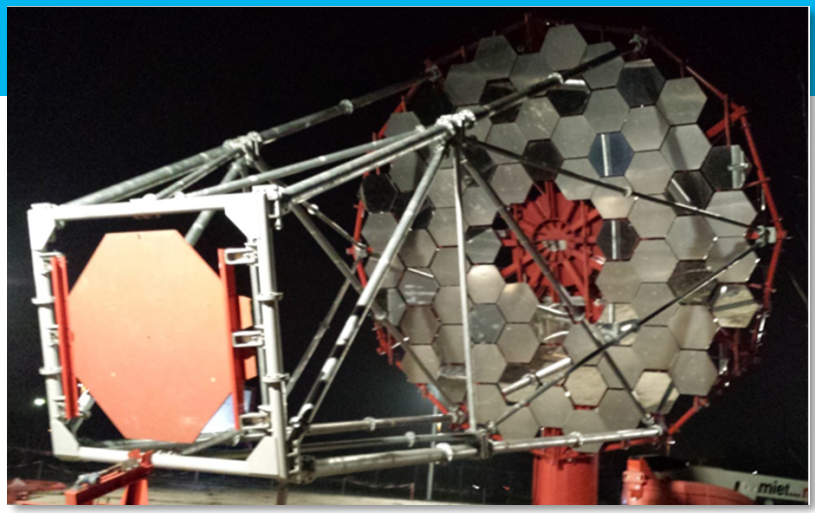
- A

MST & ACTL: *hundreds of pages written for the Technical Design Review*







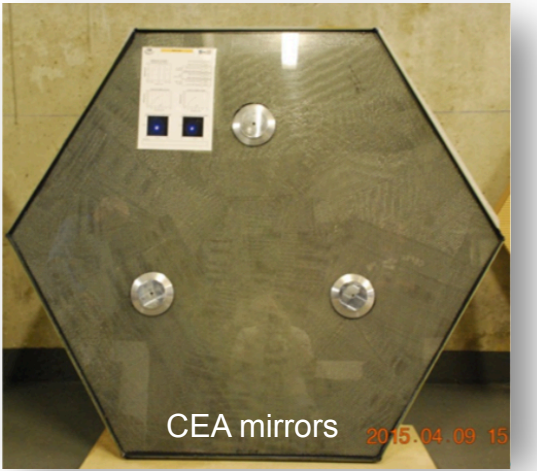
vered to CTA

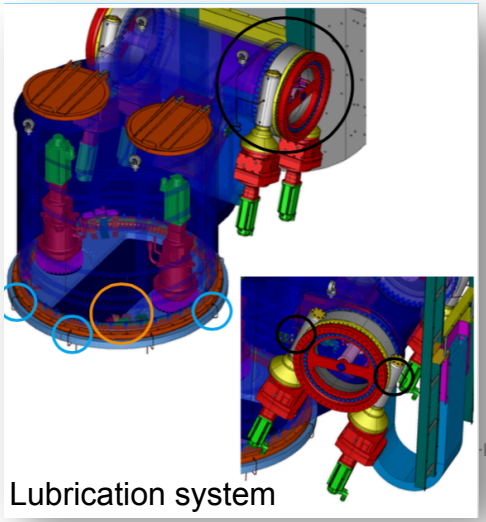
activities

ons

The Cherenkov Telescope Array – MST

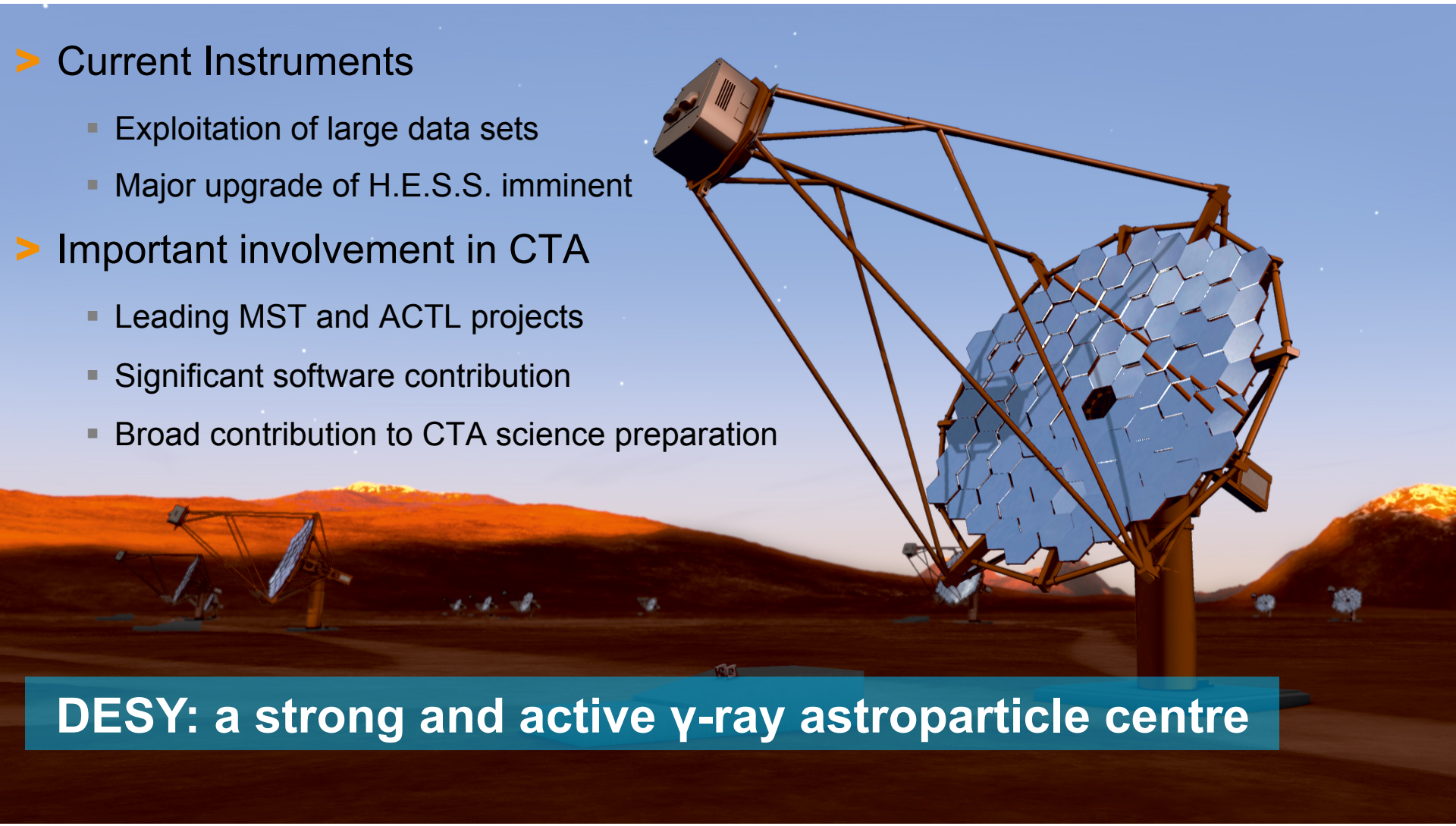
- New camera support structure
  - installed within 3 days
  - much stiffer, oscillations at camera frame down by factor 10
- Three different mirror types currently under testing
- Drive assembly (implementation, optimization and testing of PLC code)
- Drive health monitoring → develop automatic monitoring system
- Measurement of bending/hysteresis, pointing studies




Lubrication system

Summary

- Current Instruments
  - Exploitation of large data sets
  - Major upgrade of H.E.S.S. imminent
- Important involvement in CTA
  - Leading MST and ACTL projects
  - Significant software contribution
  - Broad contribution to CTA science preparation



DESY: a strong and active γ-ray astroparticle centre

Summary

Catania, Sept. 2014:
overwhelmed by the amount of work ahead of us…

Summary

Catania, Sept. 2014:
overwhelmed by the amount of work ahead of us…

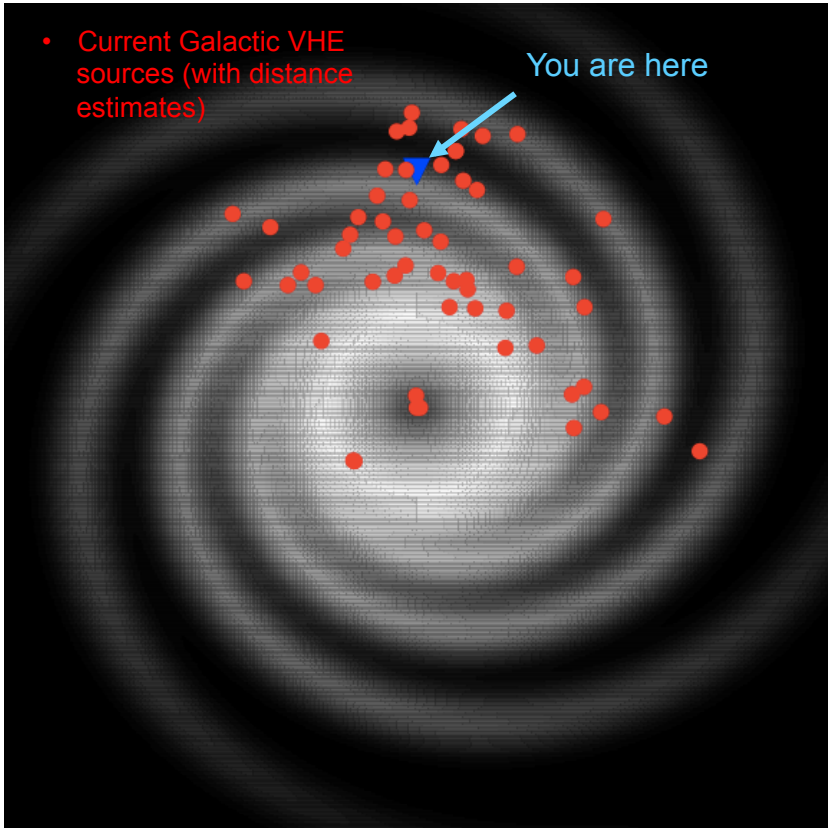
Turku, last week:
People are smiling again, now that TDR is submitted!

Backup

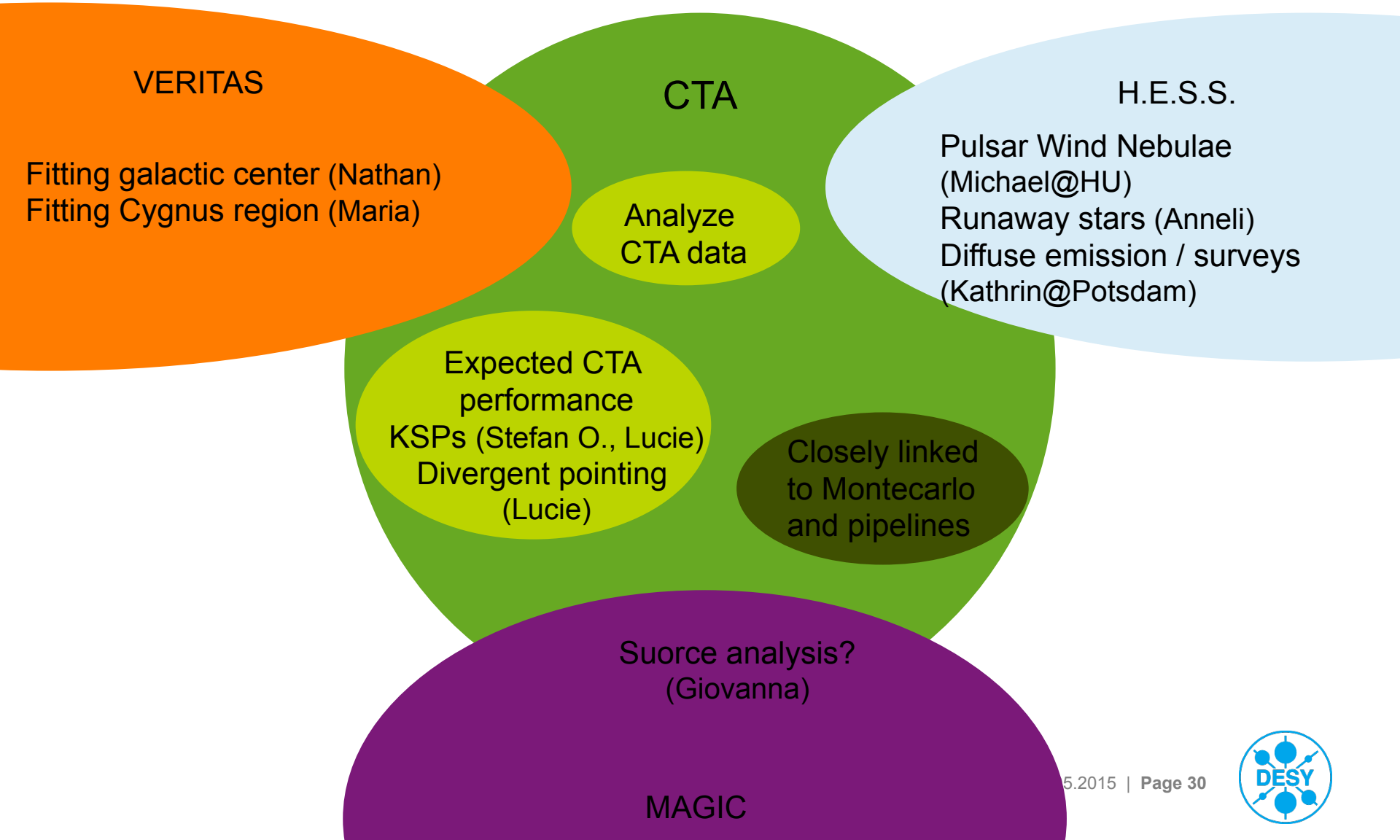
H.E.S.S. Galactic γ-ray sources

- Zoo of different particle accelerators
  - Particle acceleration very common in Galaxy
  - Study particle acceleration and γ-ray production
  - Population studies
- Impact
  - Feedback of non-thermal particles?
  - Environmental effects? (e.g. magnetic fields)
  - Cosmic-ray propagation
- Connection to other galaxies?
  - Importance of non-thermal particles for galaxy evolution and dynamics, for cosmology?

→ Observe Milky Way neighbour galaxy



CTA science tools @ Zeuthen



What we have done

- Mainly developed at IRAP, but DESY is involved since >2 years as the largest outside contributer. We have participated in:
  - Adding instrument background
  - Applying ctools to VERITAS and H.E.S.S.

  → Considered as standard tools in H.E.S.S. and VERITAS
- Validated on Fermi-LAT data
- Developed high level analysis scripts
- Implementation of IACT background methods
- Participated in two and organized one coding sprint
- Define high level interfaces/structure
- Currently writing the journal paper