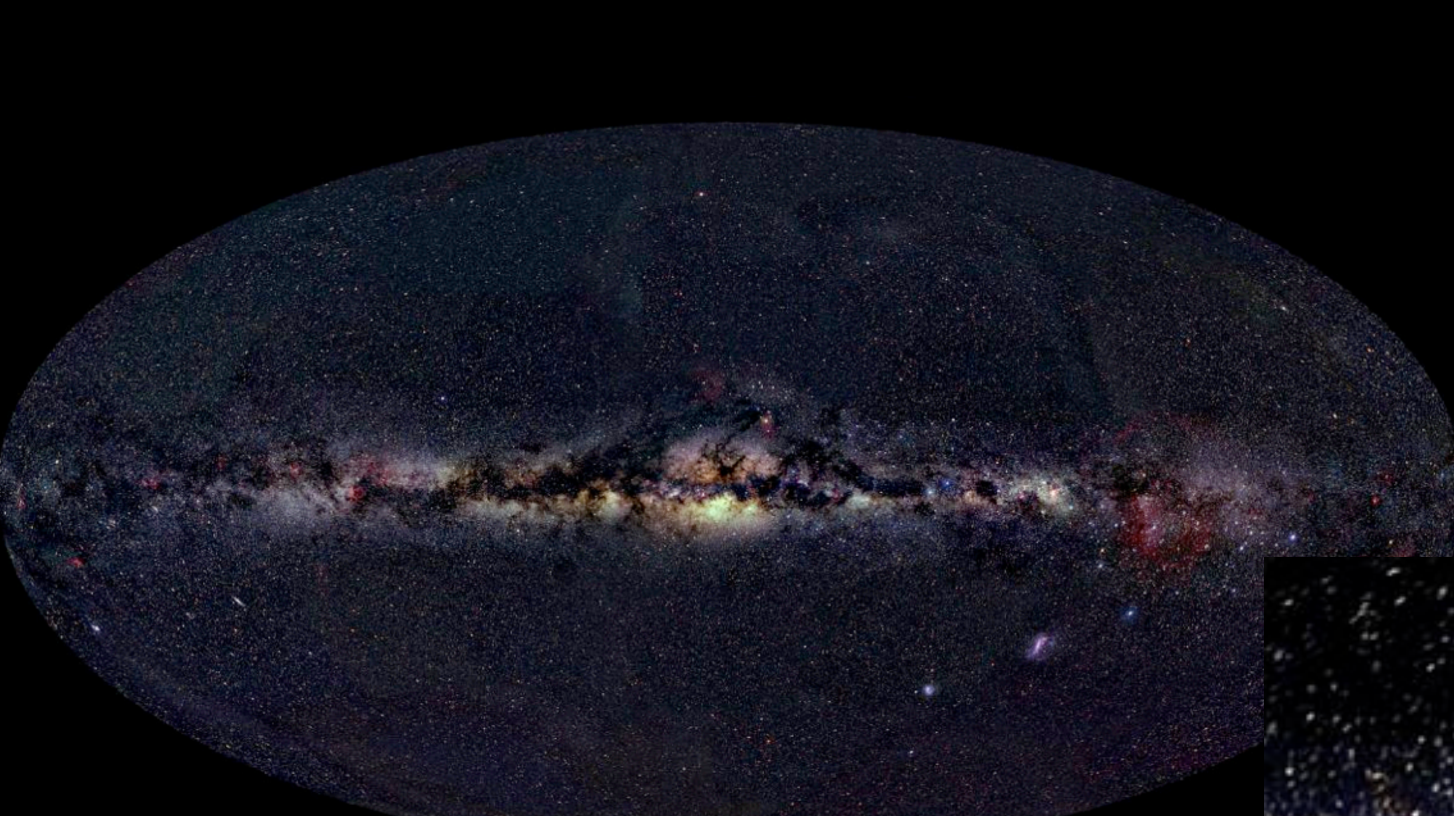
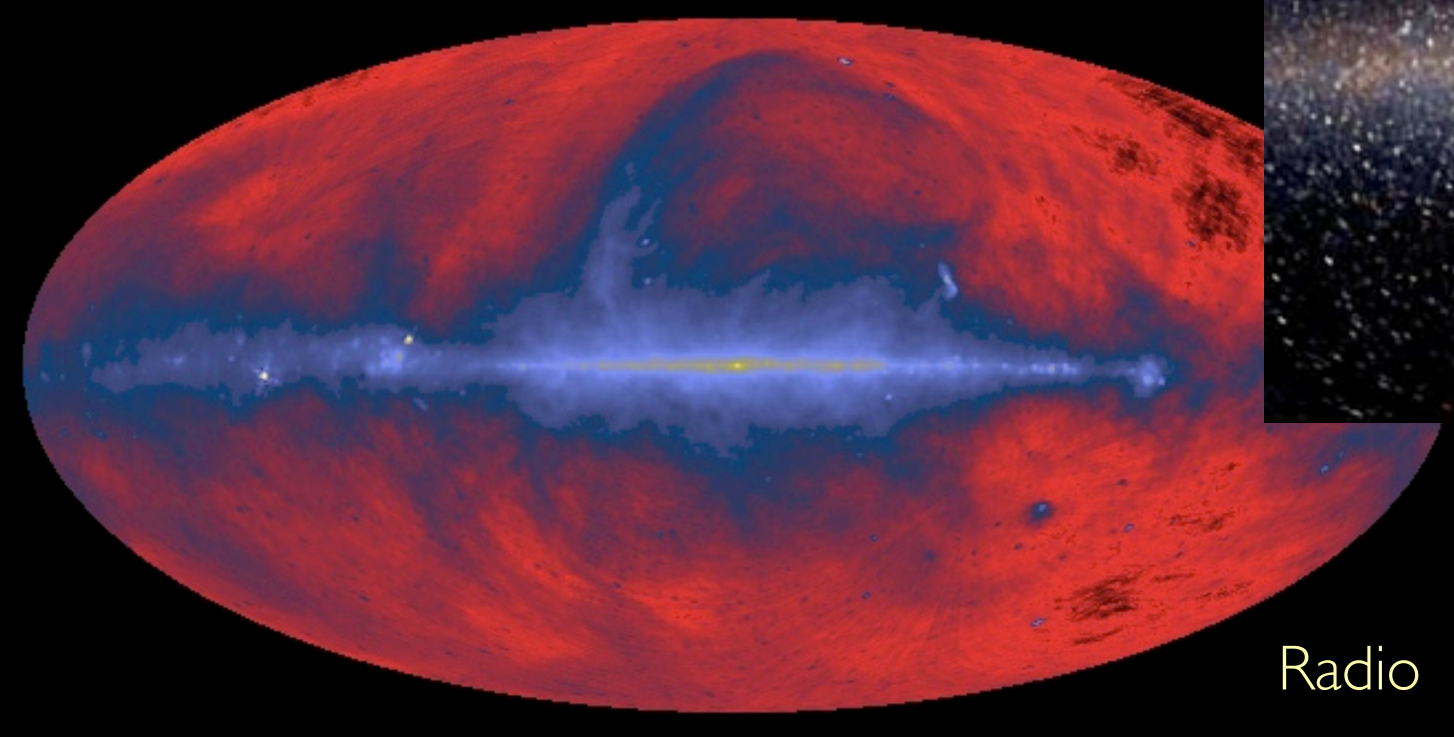
THE CHERENKOV TELESCOPE ARRAY CTA

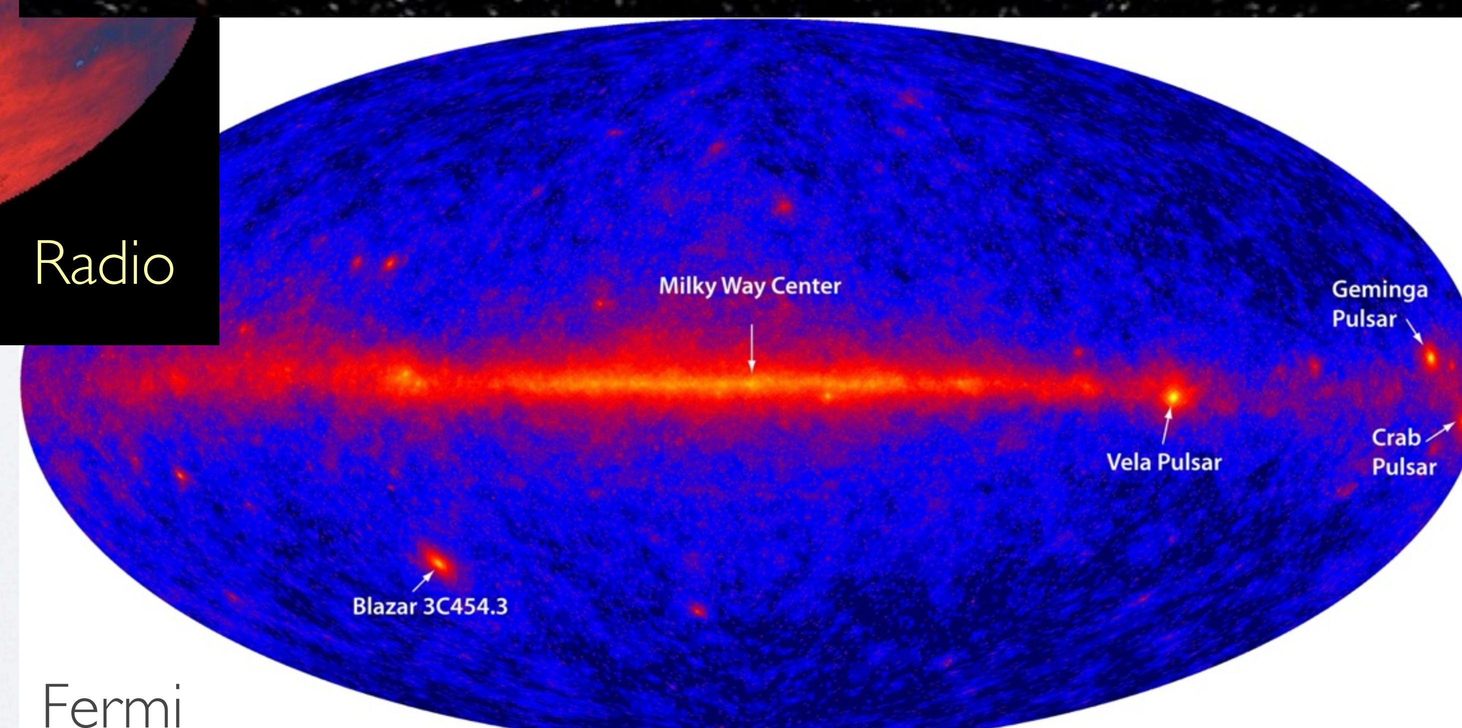
Stefan Schlenstedt, DESY

Marseille, December 14th, 2009



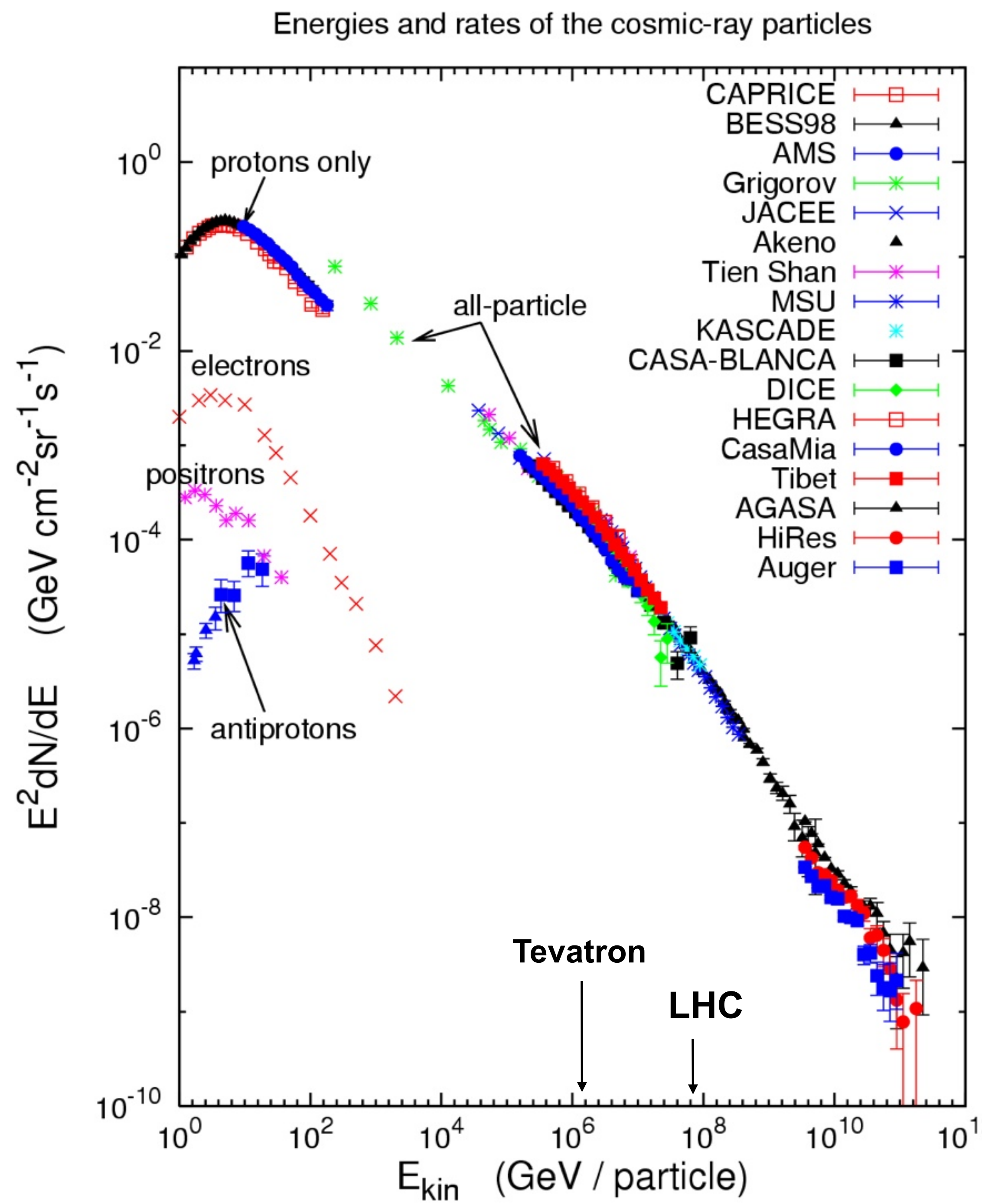

Radio


COBE


Milky Way Center
Geminga Pulsar
Crab Pulsar
Vela Pulsar
Blazar 3C454.3
Fermi

COSMIC RAYS

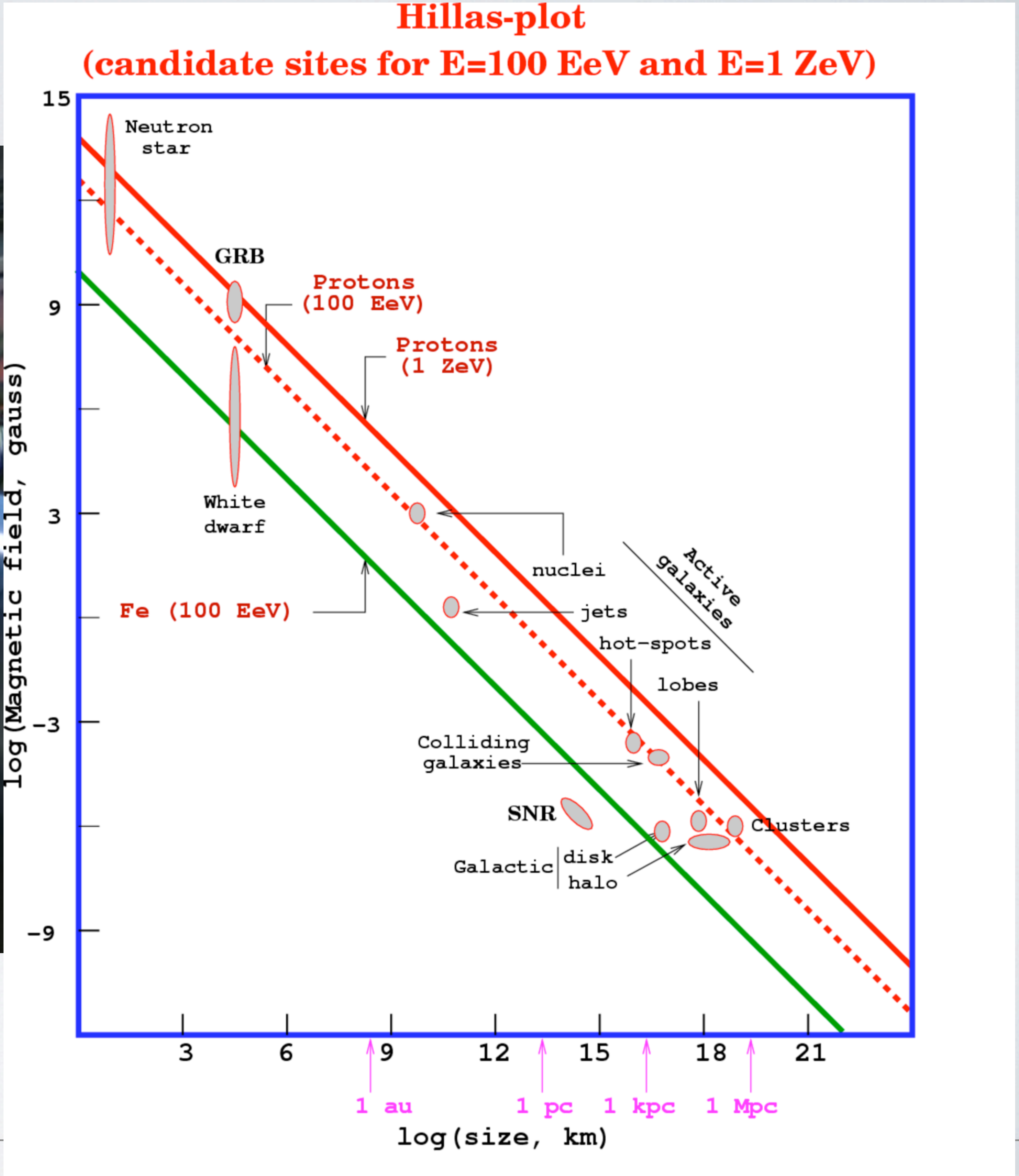
Victor F. Hess
1912



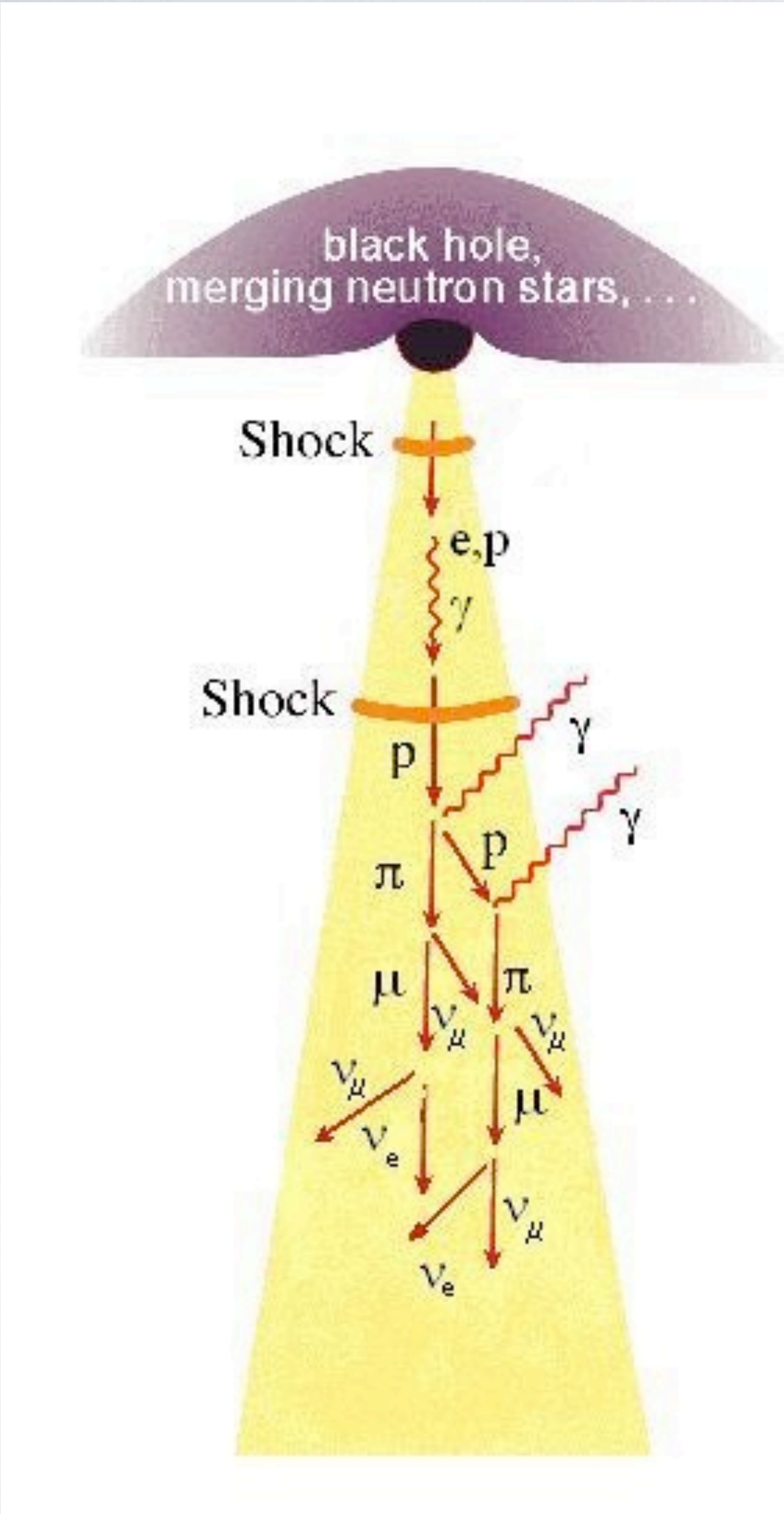
ACCELERATORS IN COSMOS

large fields

large radius



COSMIC ACCELERATORS

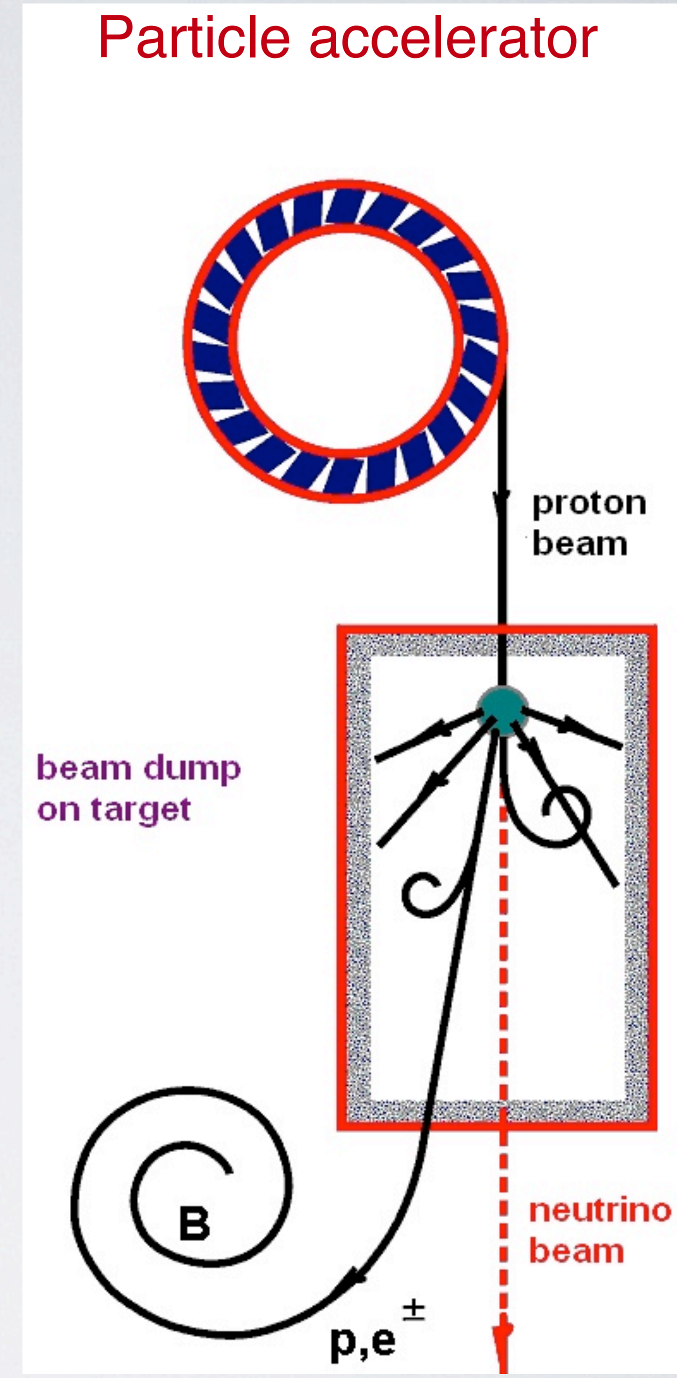


proton acceleration in shock waves (Fermi)

neutrino production

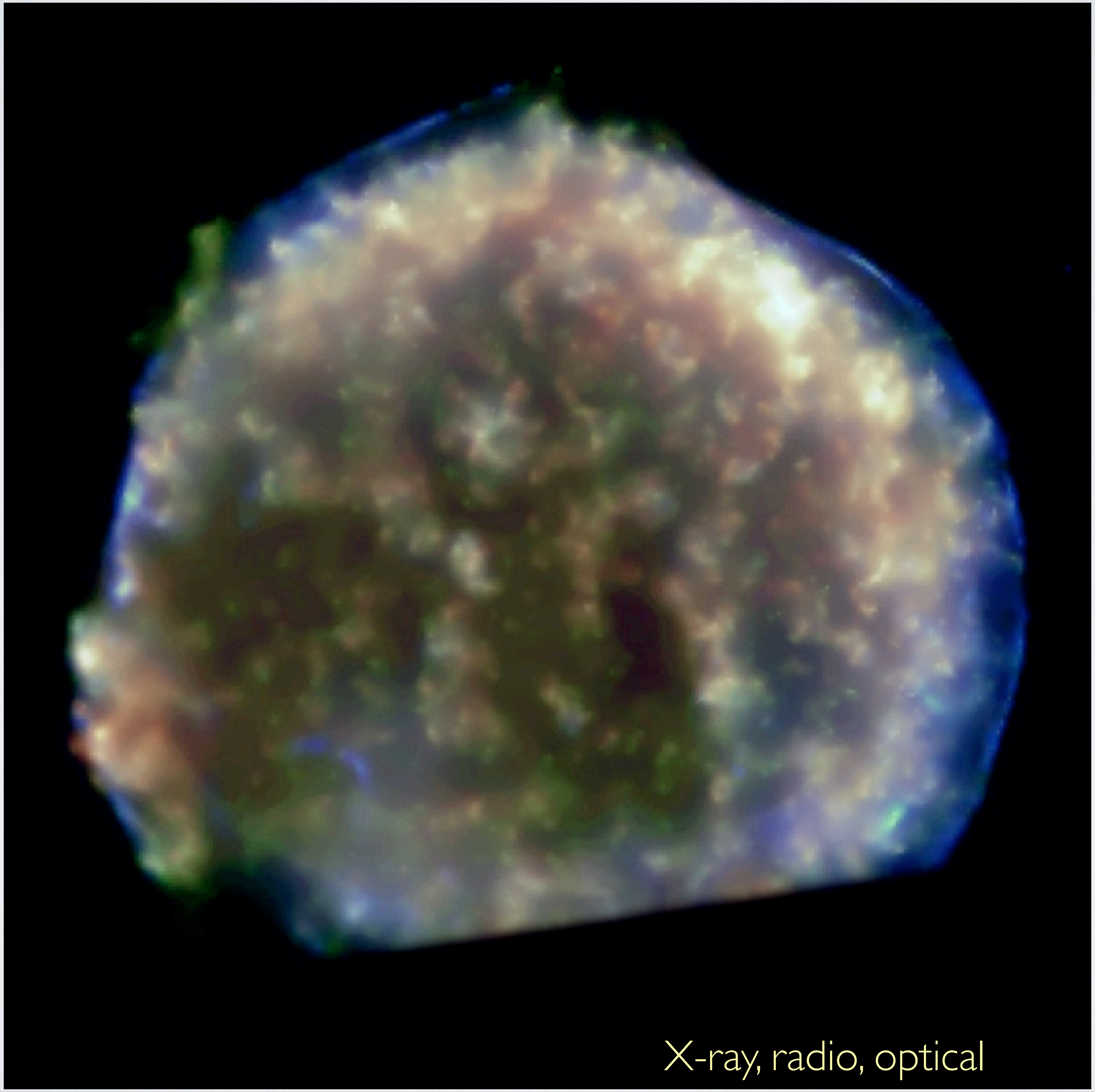
- proton interactions with baryons and photons
- decay of pions and muons

simultaneous gamma production in π^0 decays



F. Halzen

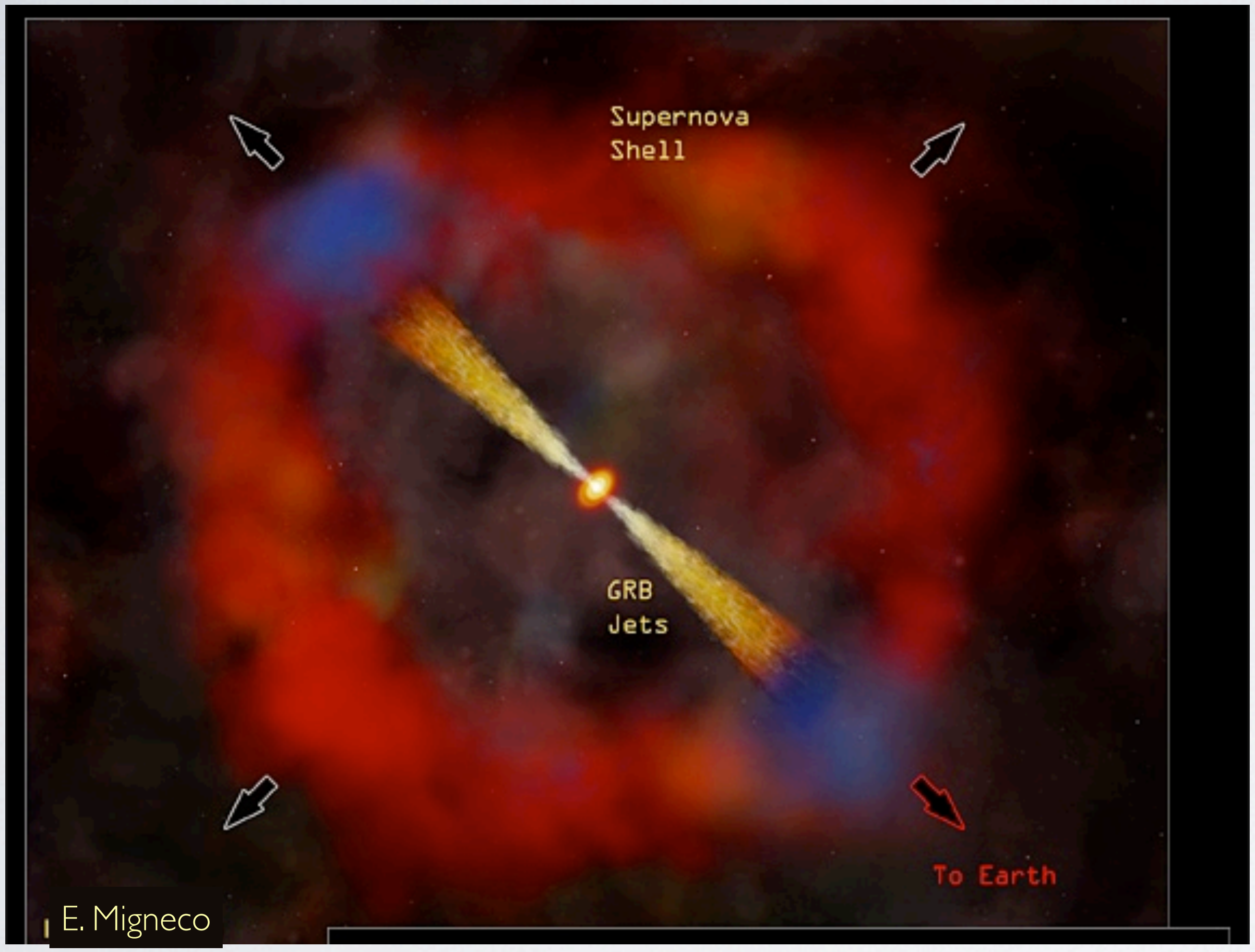
POSSIBLE SOURCE OF COSMIC RAYS : SUPERNOVAE AND SUPERNOVA REMNANTS



Tycho Brahe, 1572

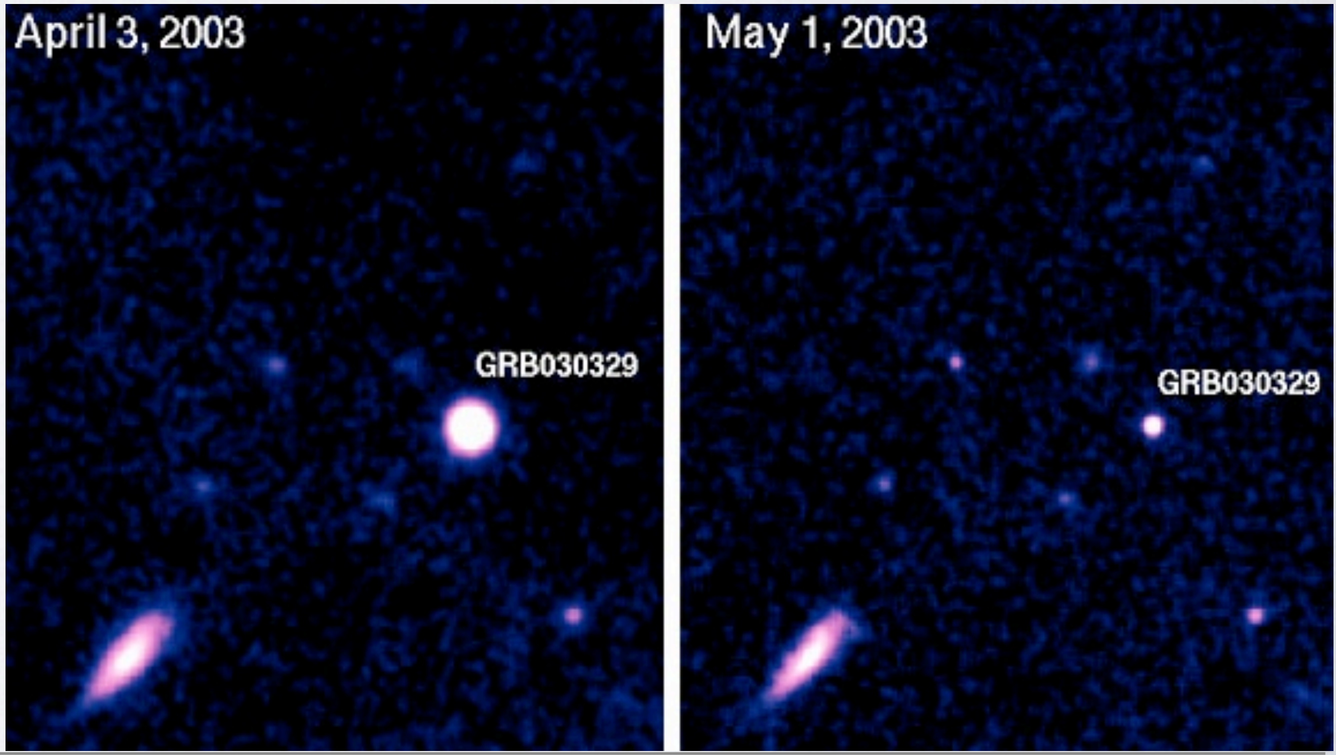
Association with Gamma Ray Bursts

POSSIBLE EXTRA-GALACTIC SOURCE OF COSMIC RAYS: GAMMA-RAY BURSTS



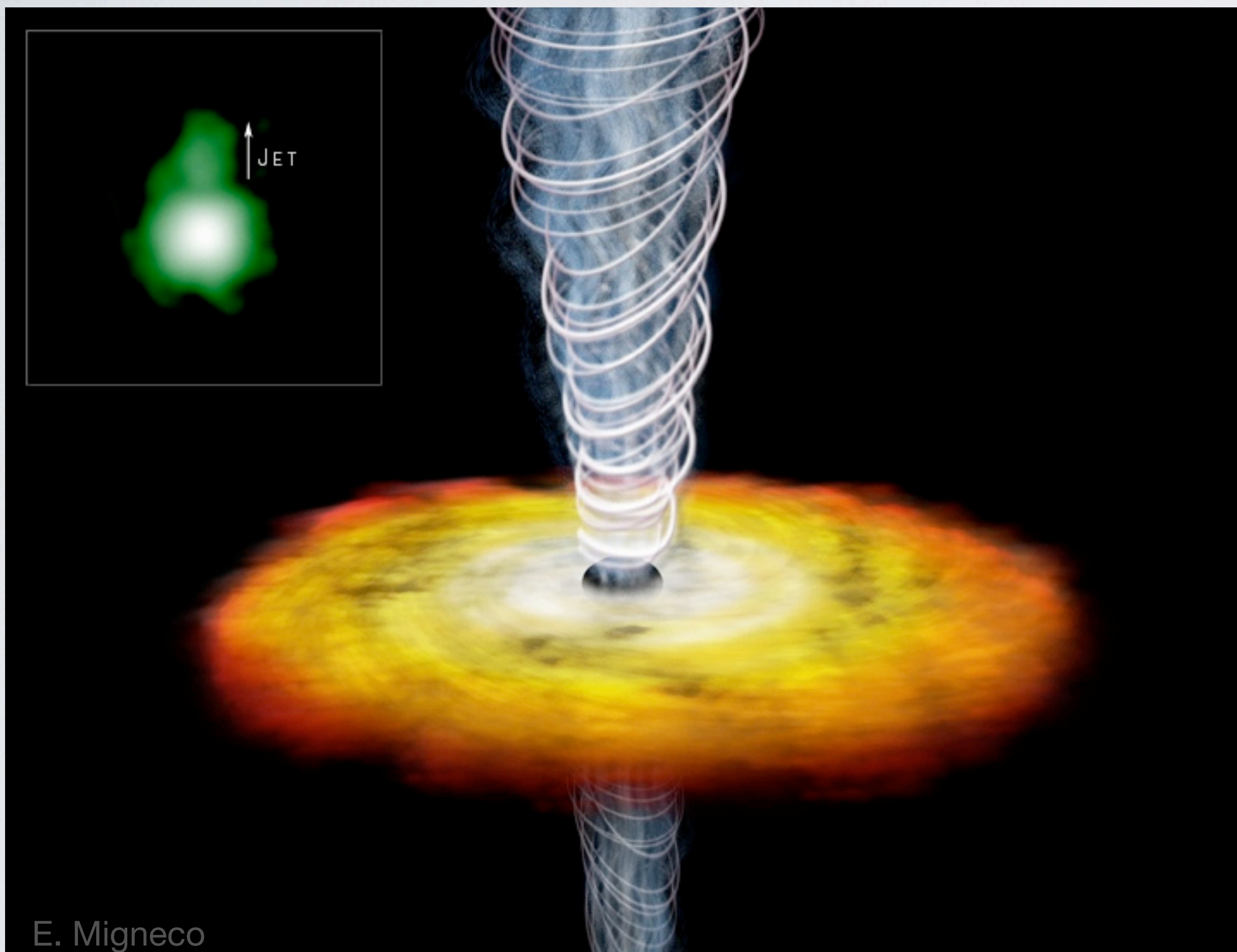
Most powerful emissions of γ rays

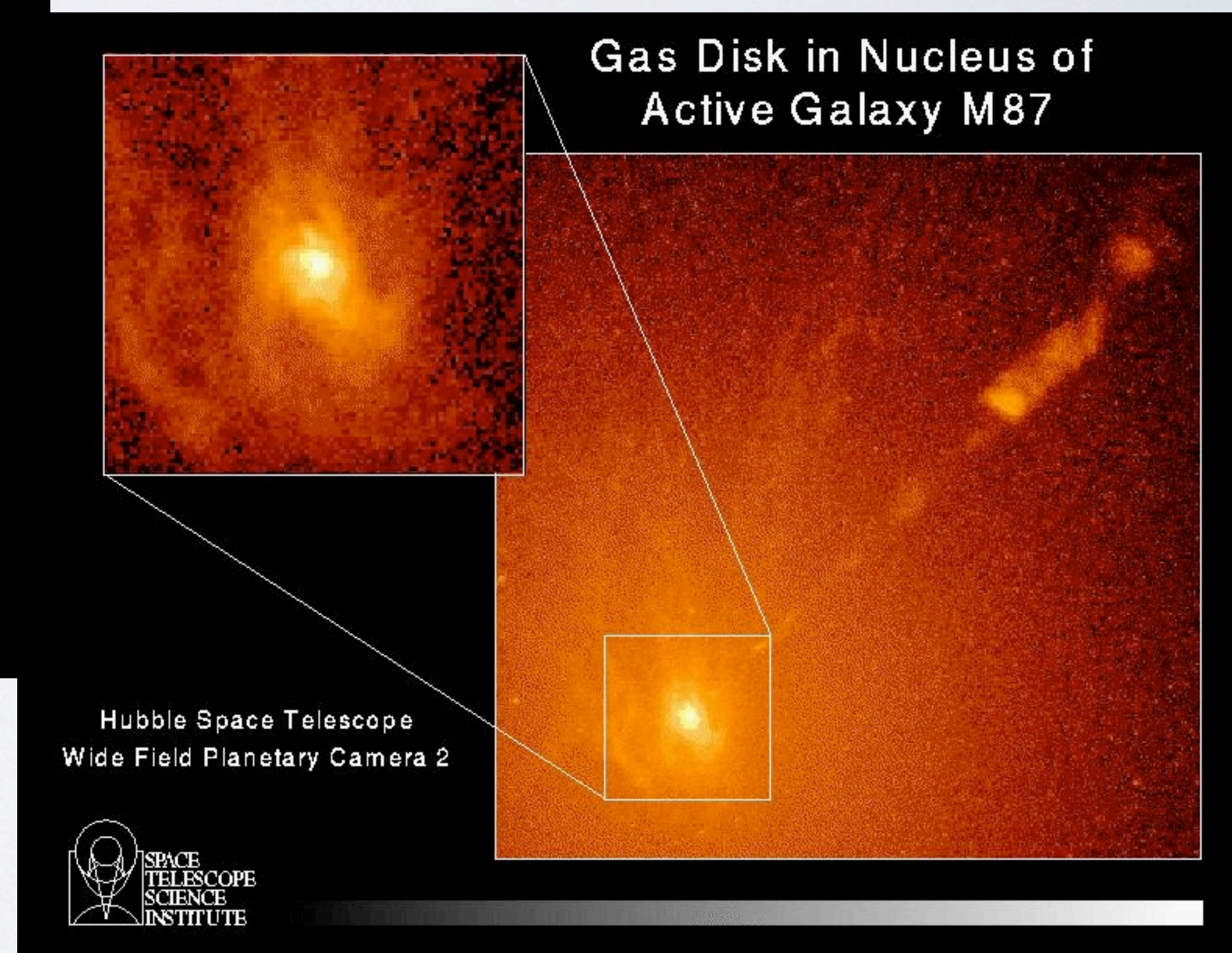
$L_\gamma = 10^{51...53}$ erg/s (sun 10^{41} erg/y)



POSSIBLE EXTRA-GALACTIC SOURCES OF COSMIC RAYS: ACTIVE GALACTIC NUCLEI

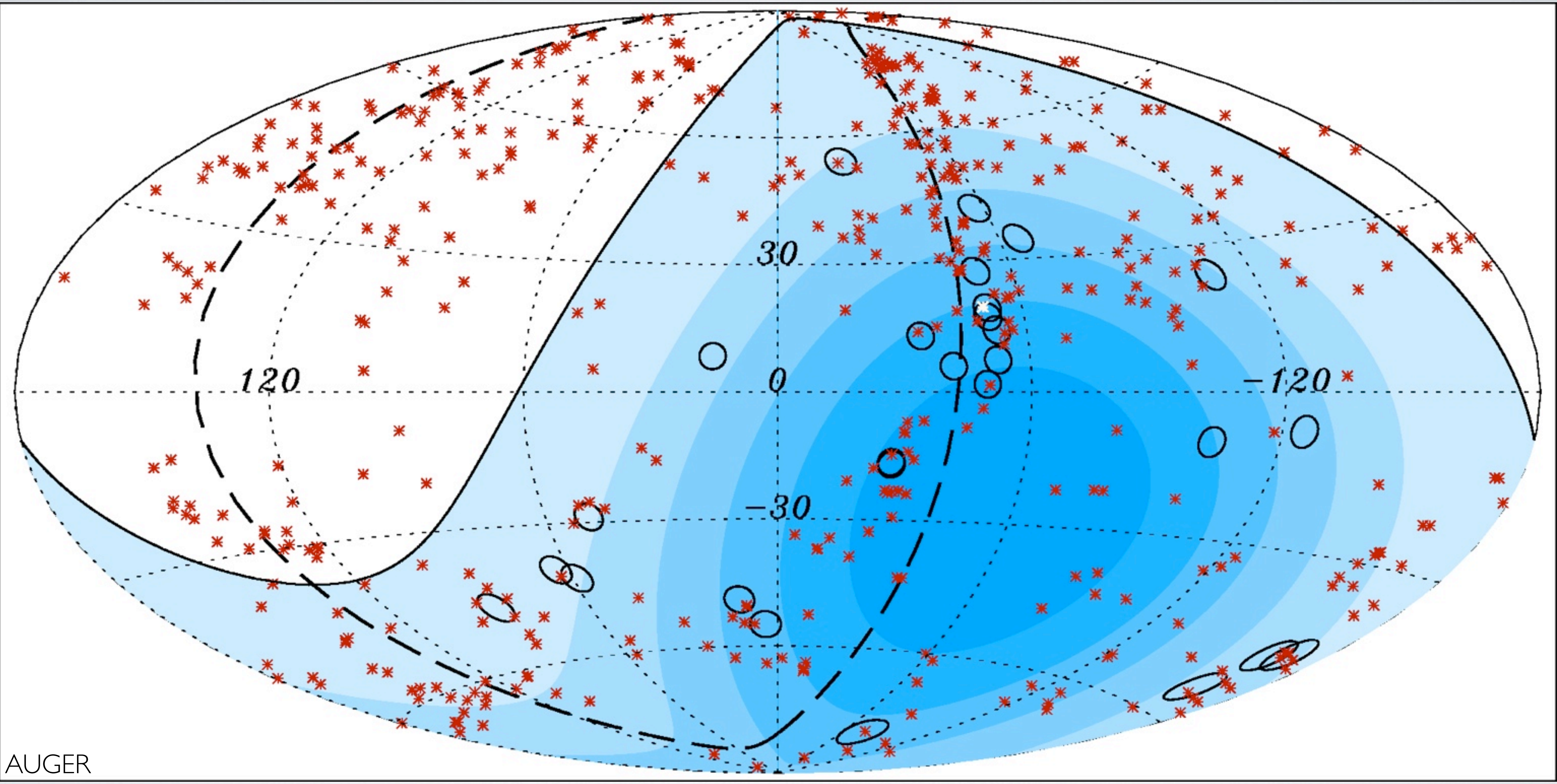
Massive black hole $10^{6...9}$ $M_\odot$ with collimated jets





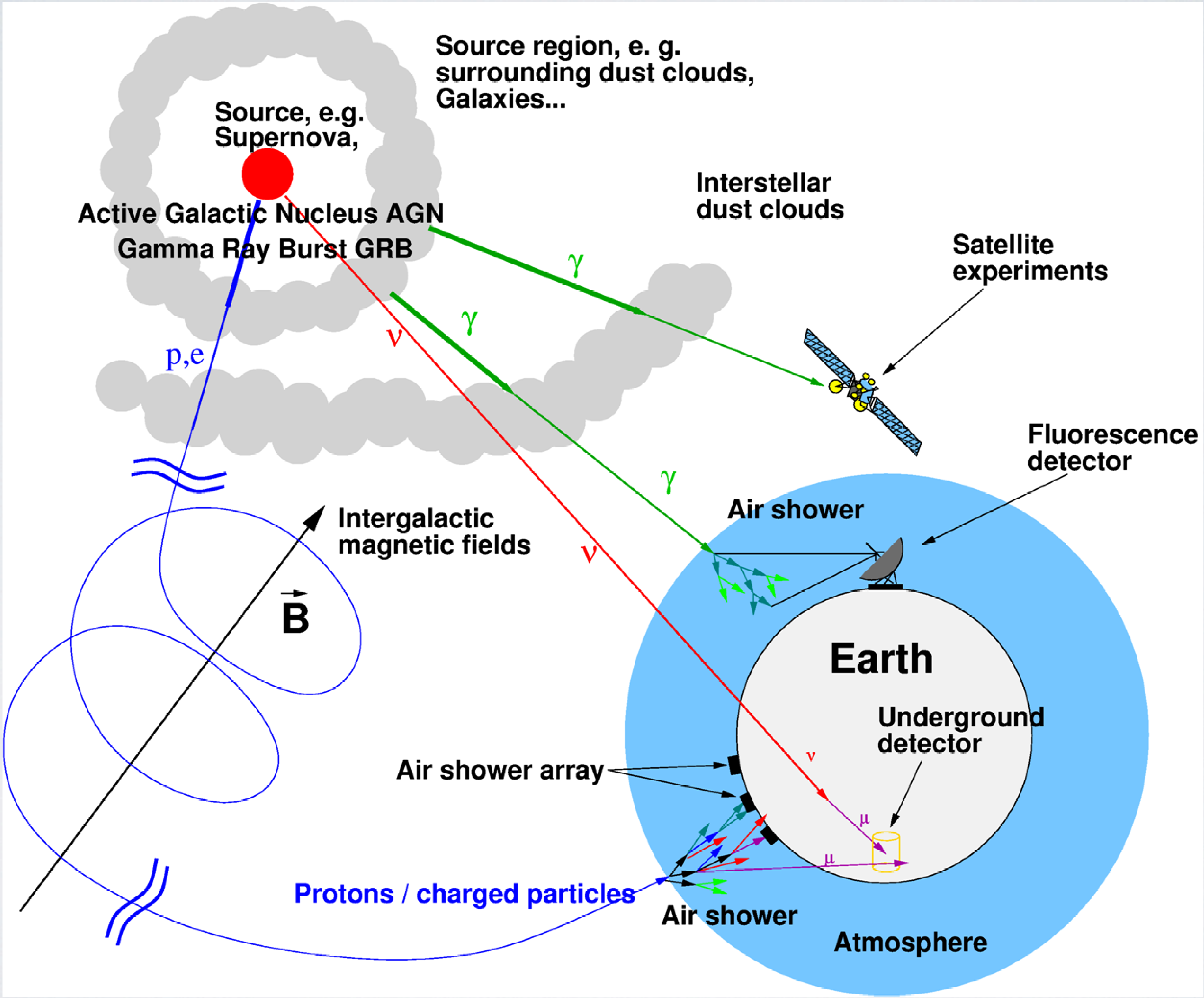
Brightest observed steady sources: $L_\gamma = 10^{42} \div 10^{47}$ erg/s

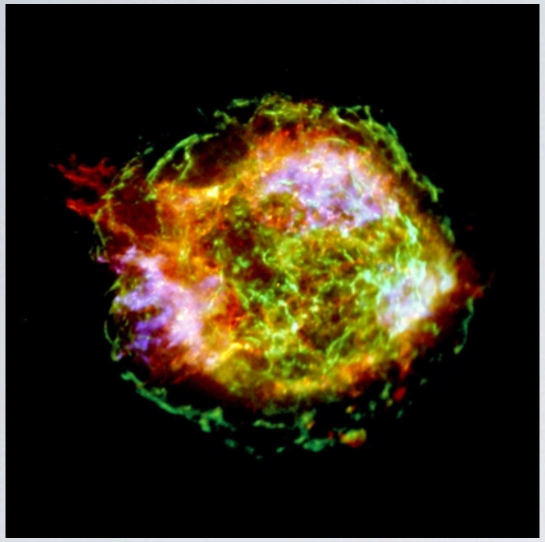
HIGHEST ENERGY COSMIC RAYS



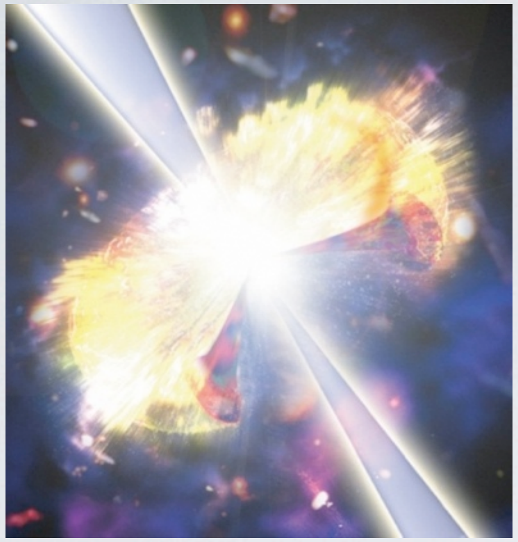
from Active Galactic Nuclei?

PARTICLE PROPAGATION

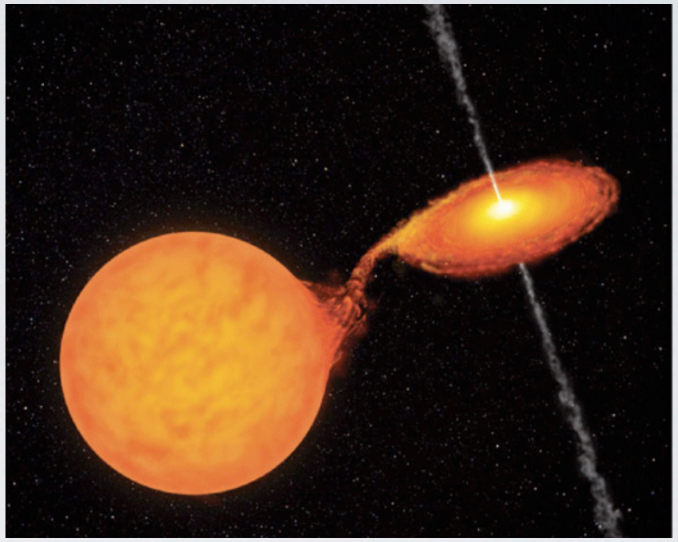




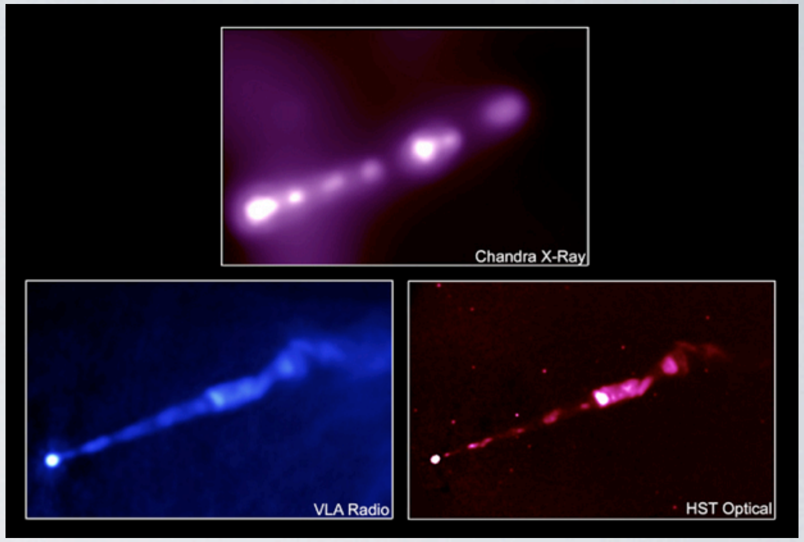
SNR



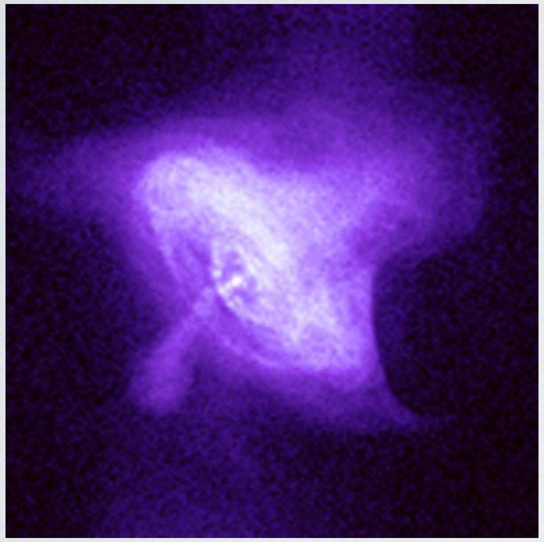
GRB



Micro quasars



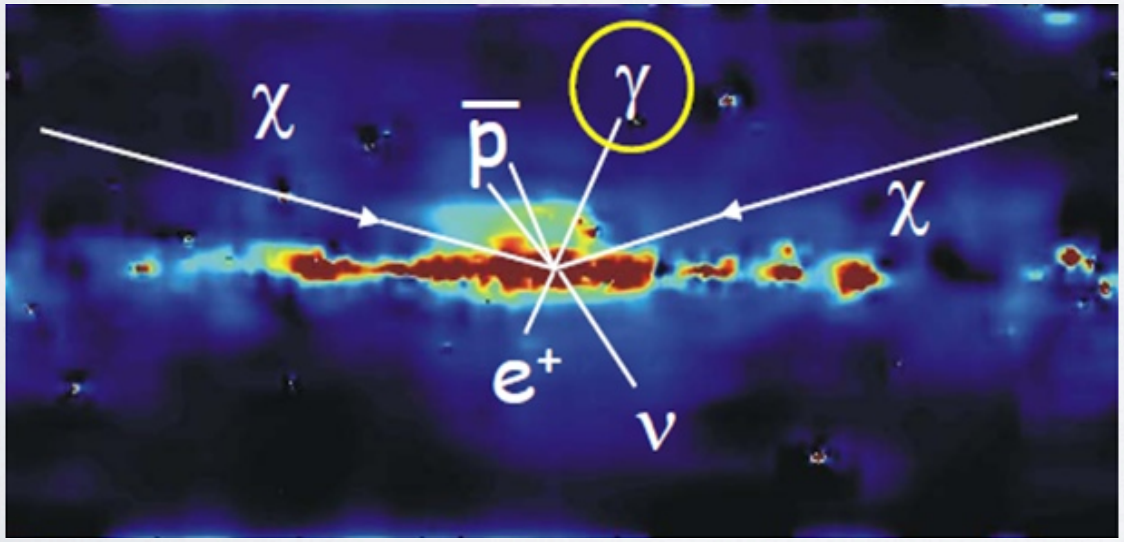
Active galactic nuclei



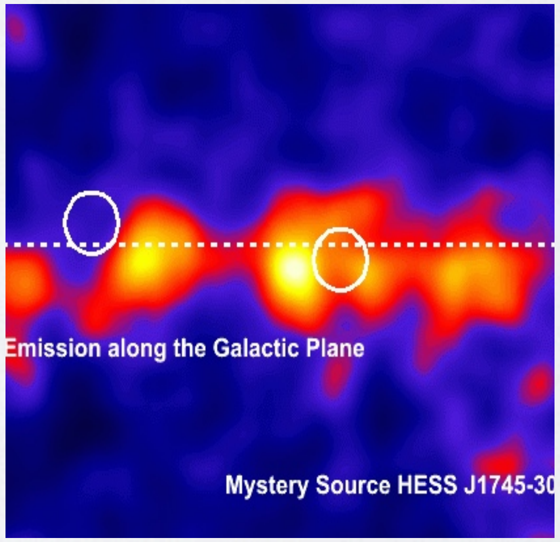
Pulsar, PWN

- Sources of cosmic rays
- Astrophysics of sources
- Acceleration and propagation

Starburst galaxies

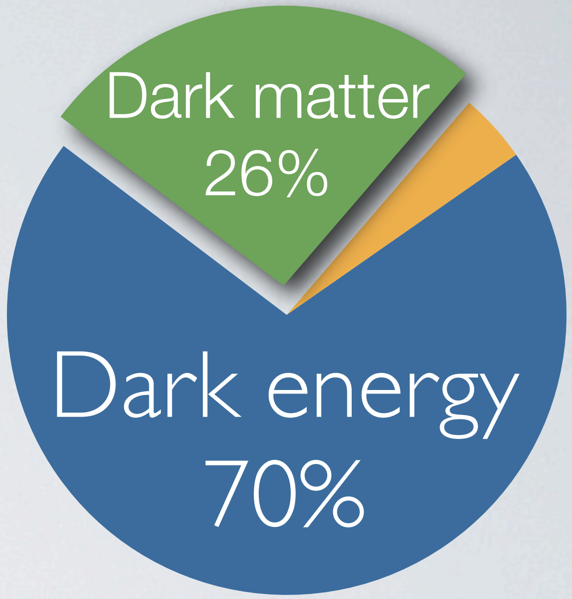


Dark matter

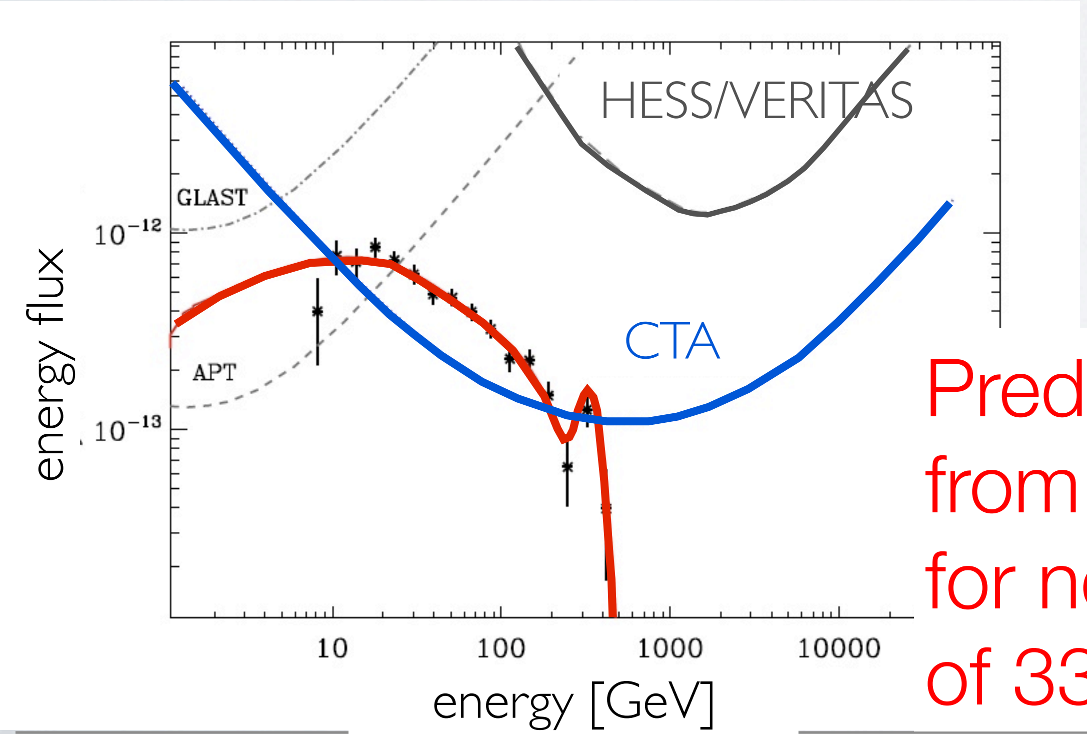


Unknown sources

NATURE OF DARK MATTER PARTICLES?



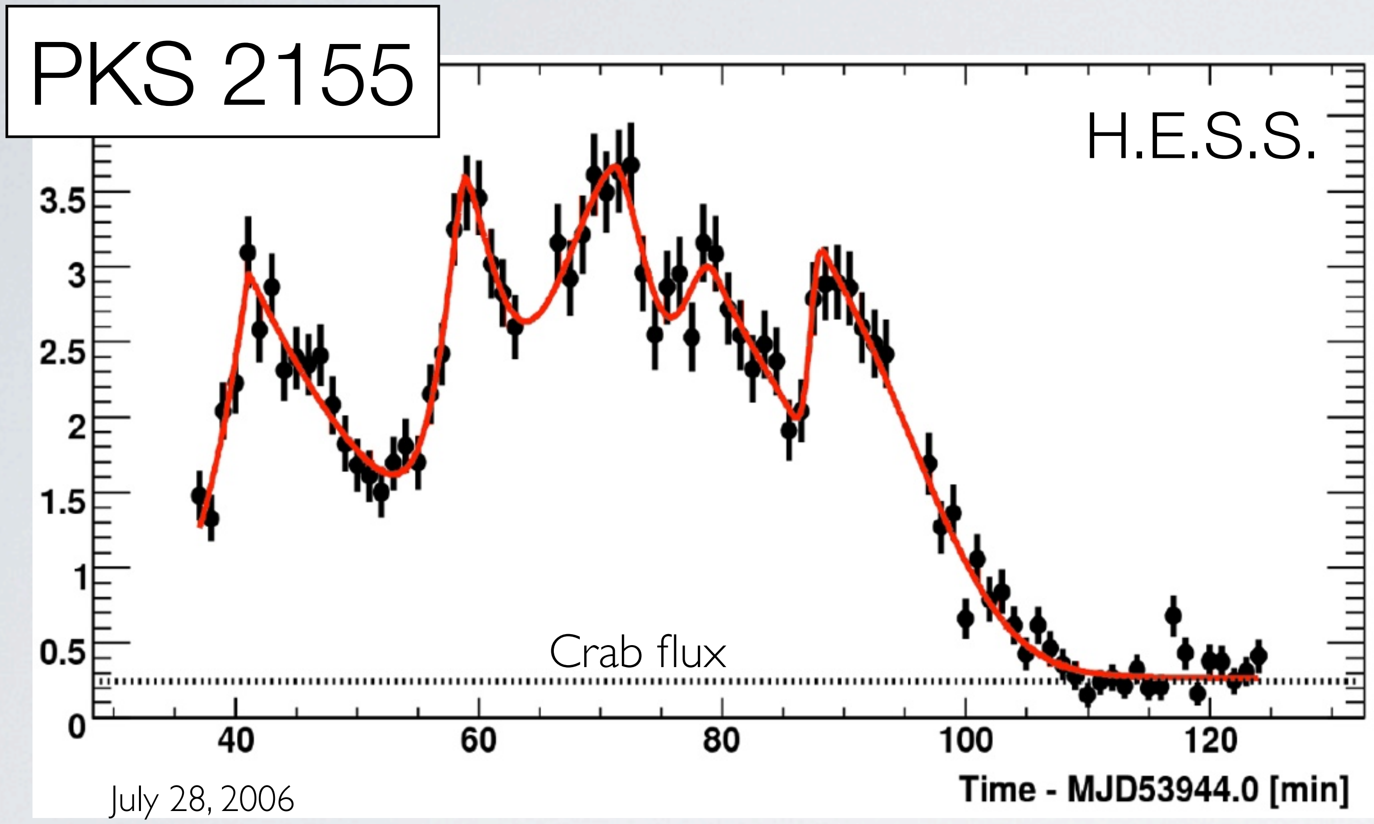
- Presence inferred from gravitational effects on visible matter
- Search for annihilation signal of dark-matter particles
- Challenge: distinguish this signal from astrophysical gamma rays

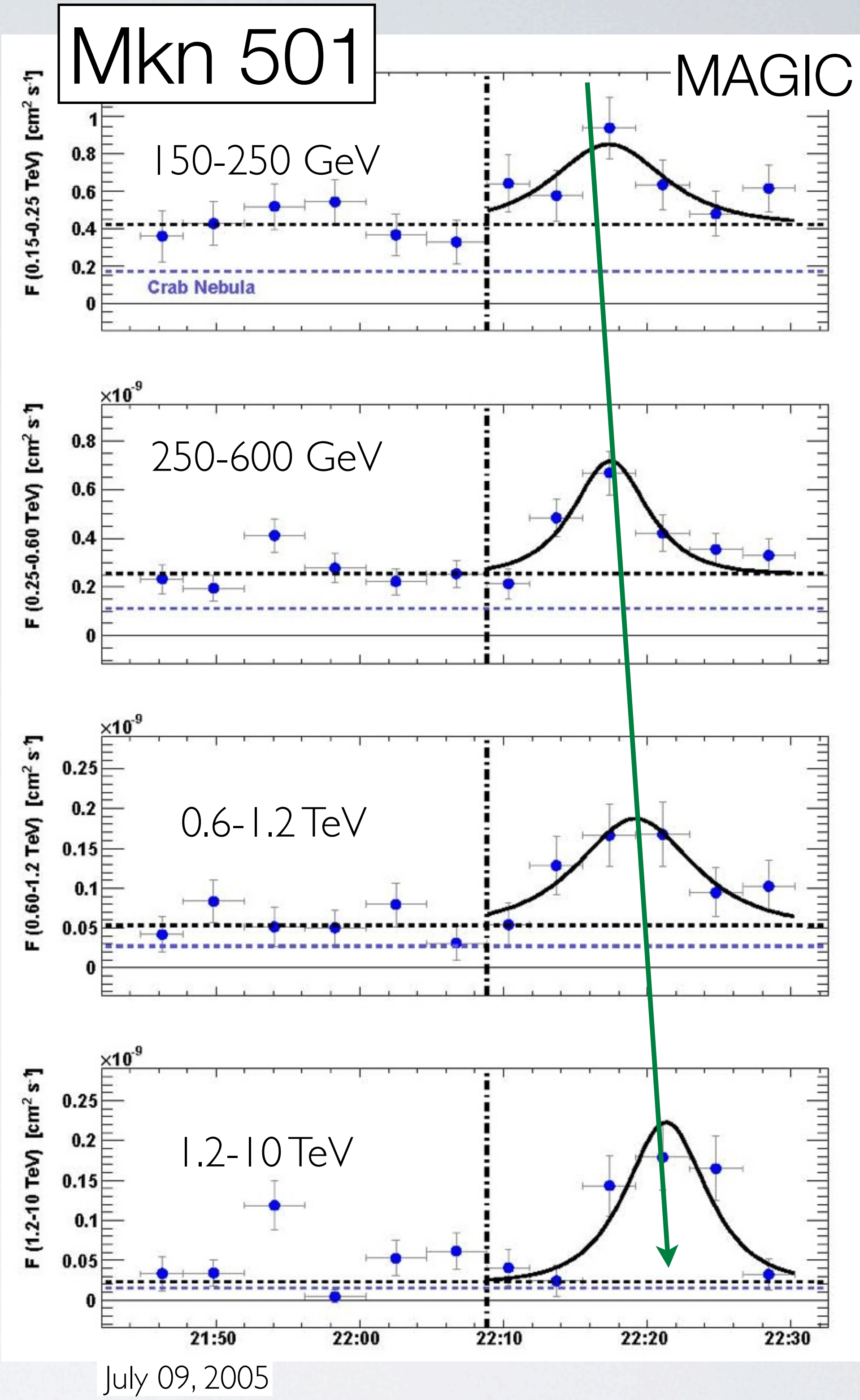


Predicted signal from a dwarf galaxy for neutralino mass of 330 GeV

Parallel with other searches (e.g. Edelweiss, IceCube) and production (LHC)

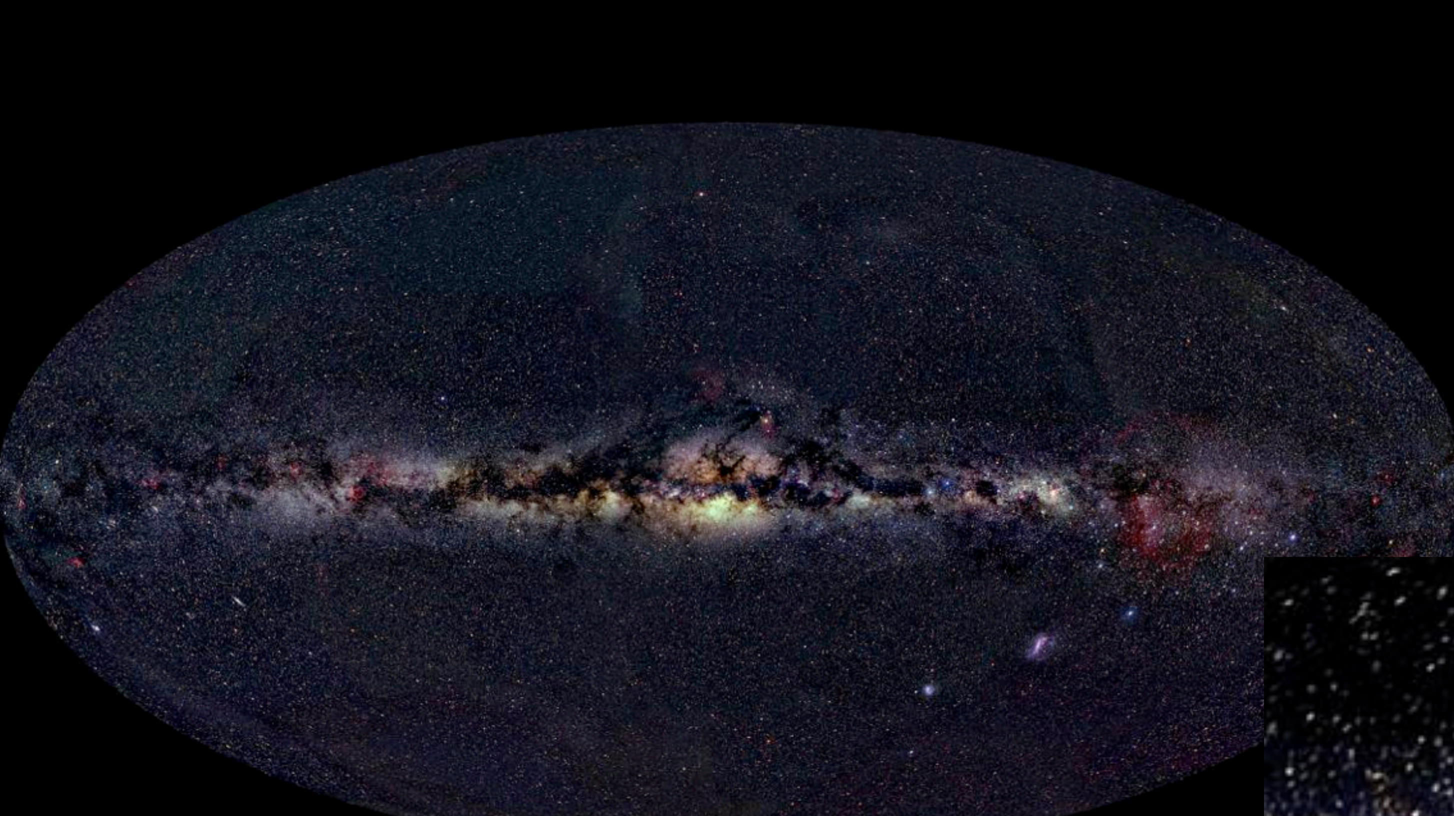
BLAZARS: EXCEPTIONAL FLARES

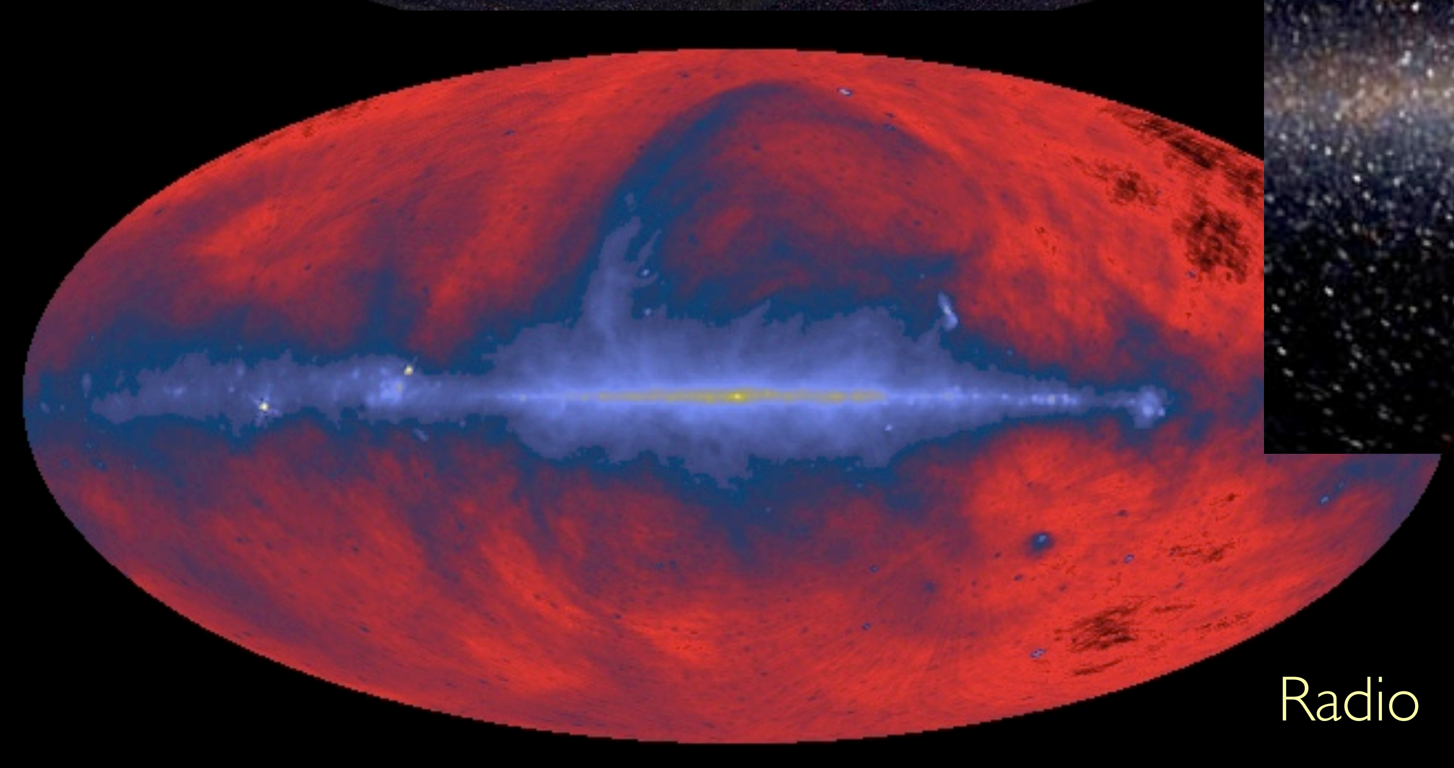




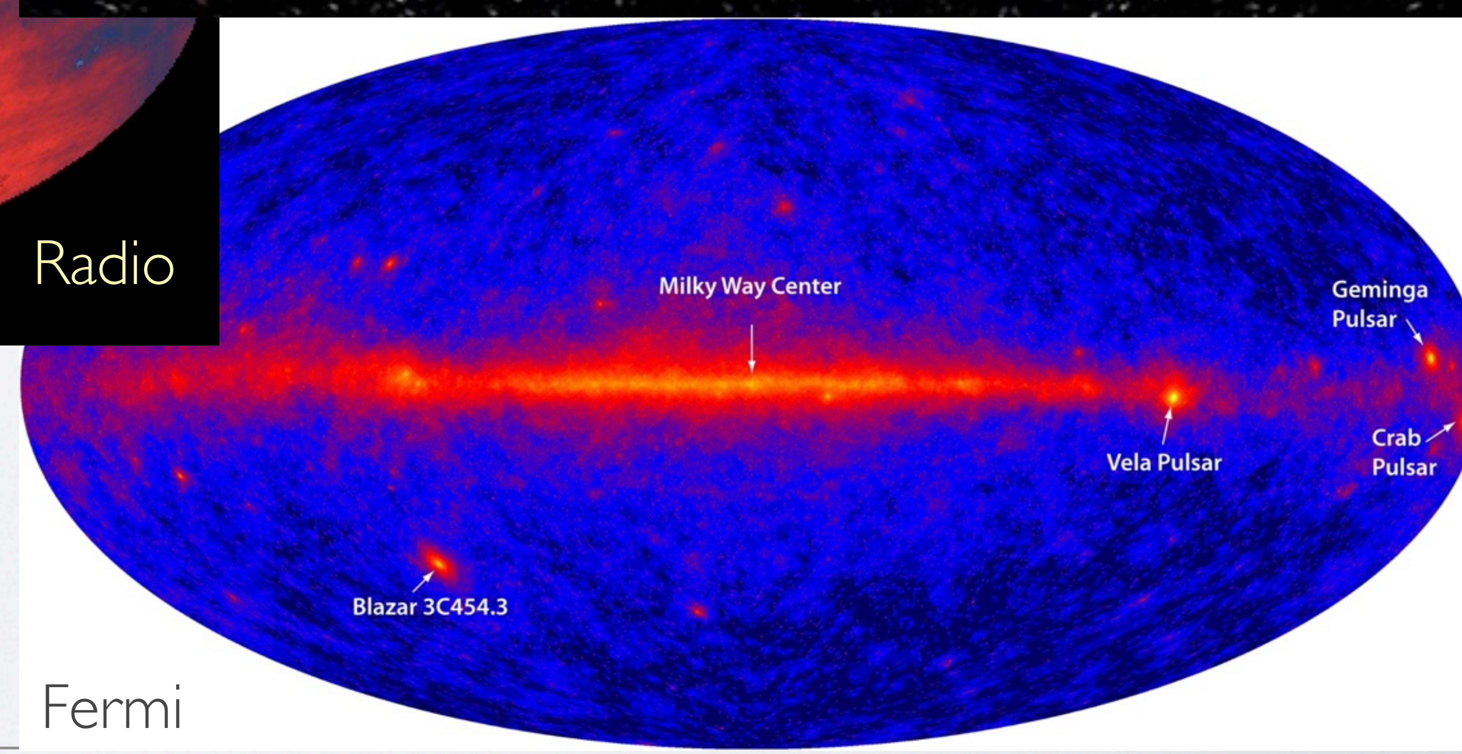
peak flux ≈ 50 times average
doubling times < 3 min

- Dynamics of acceleration?
- Vacuum dispersion from quantum gravity?

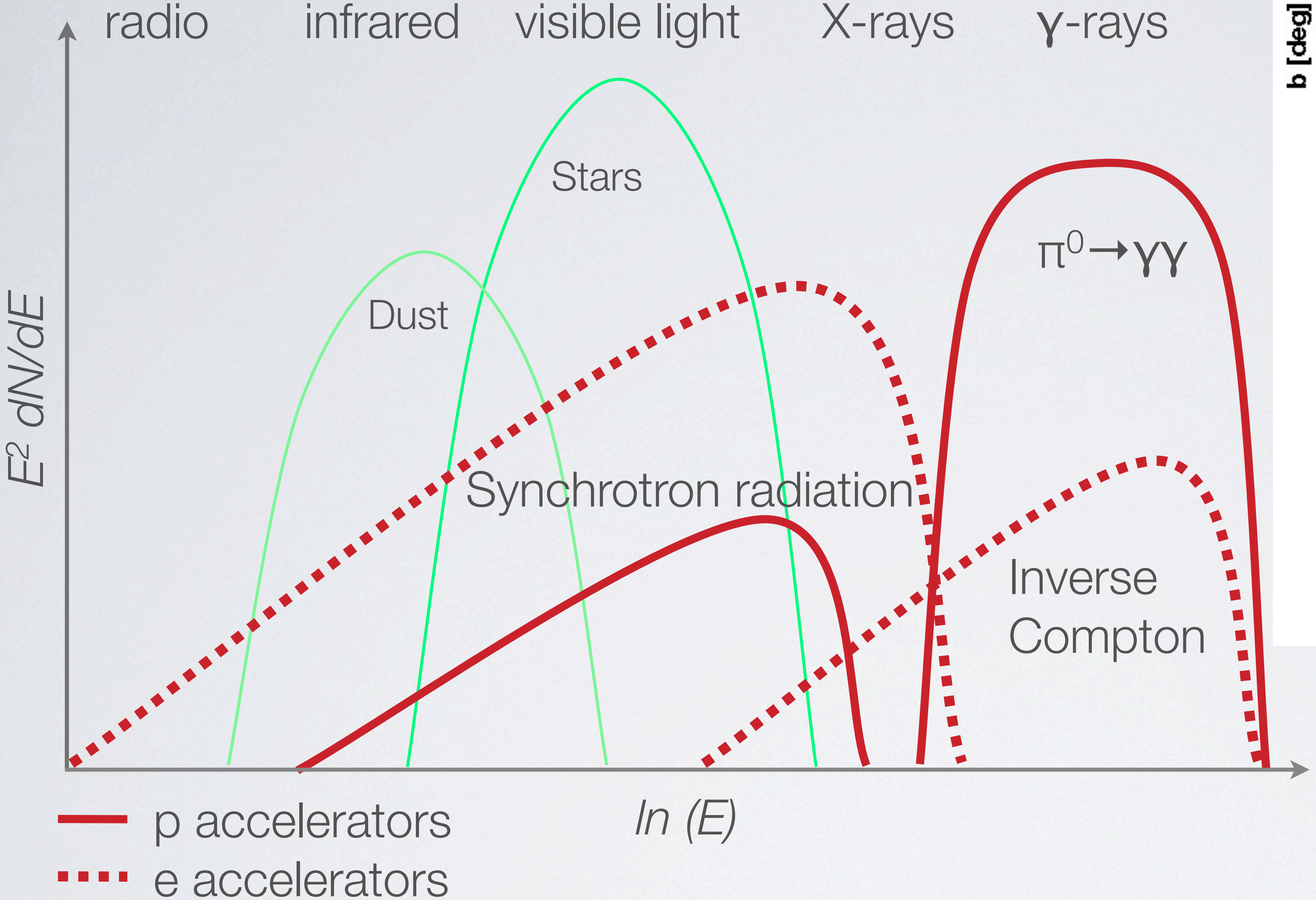


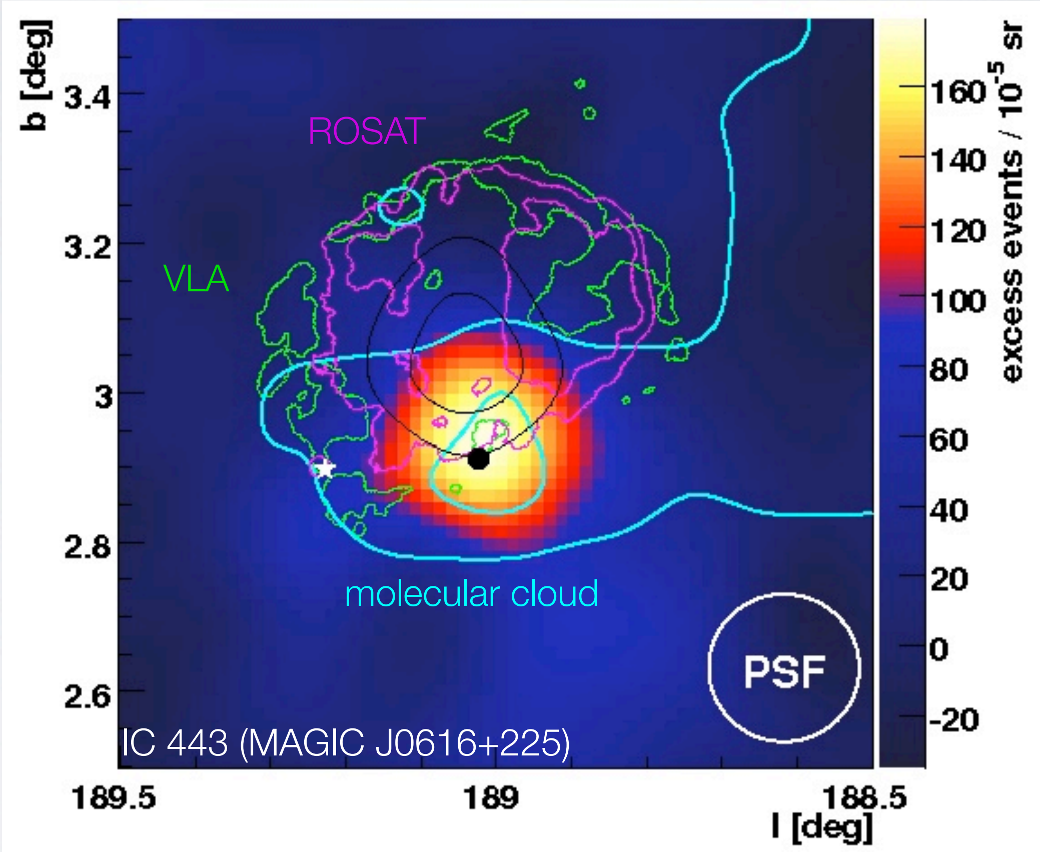

Radio


COBE


Milky Way Center
Geminga Pulsar
Crab Pulsar
Vela Pulsar
Blazar 3C454.3
Fermi

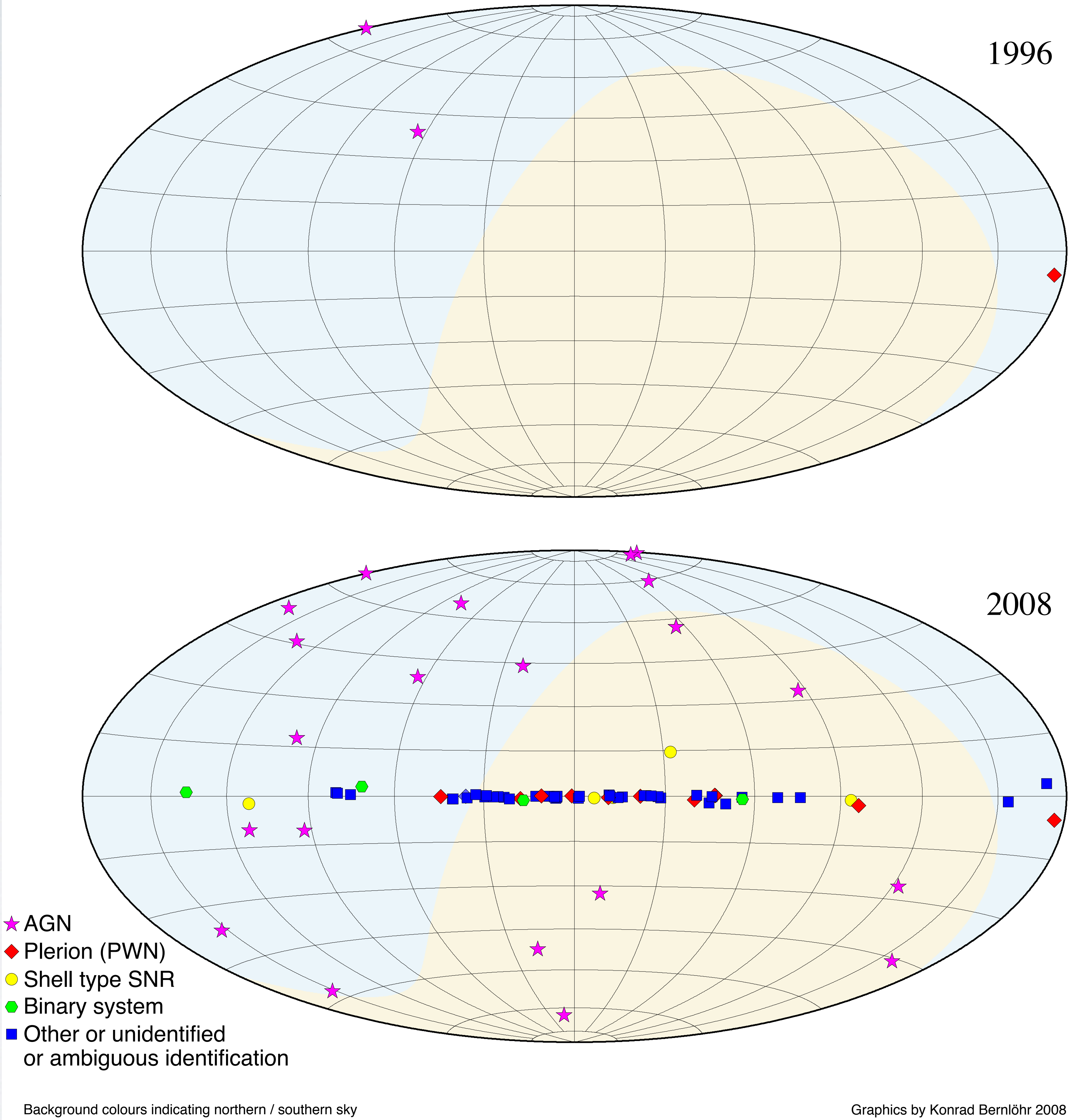
MULTI-WAVELENGTH ASTRONOMY

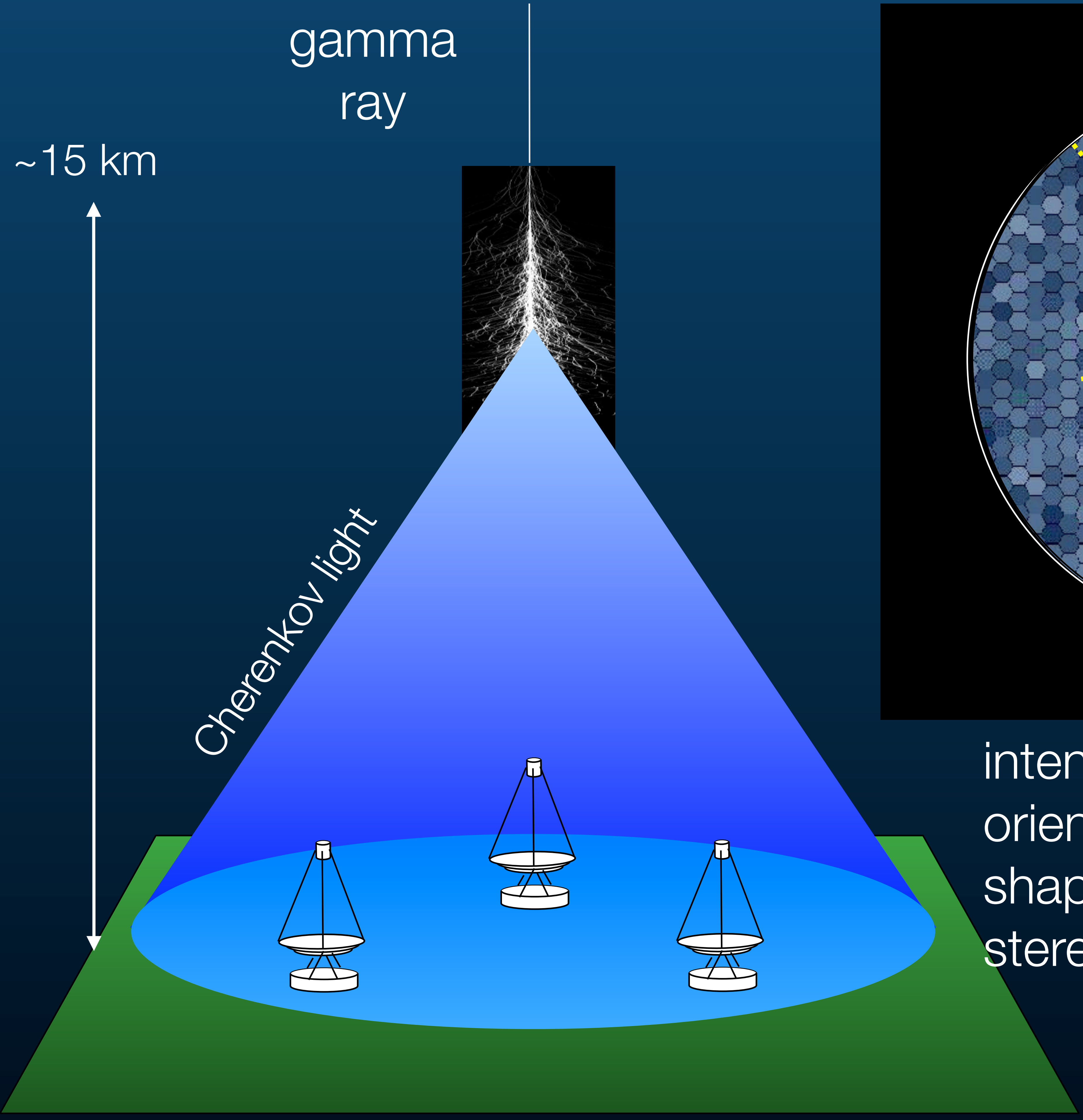


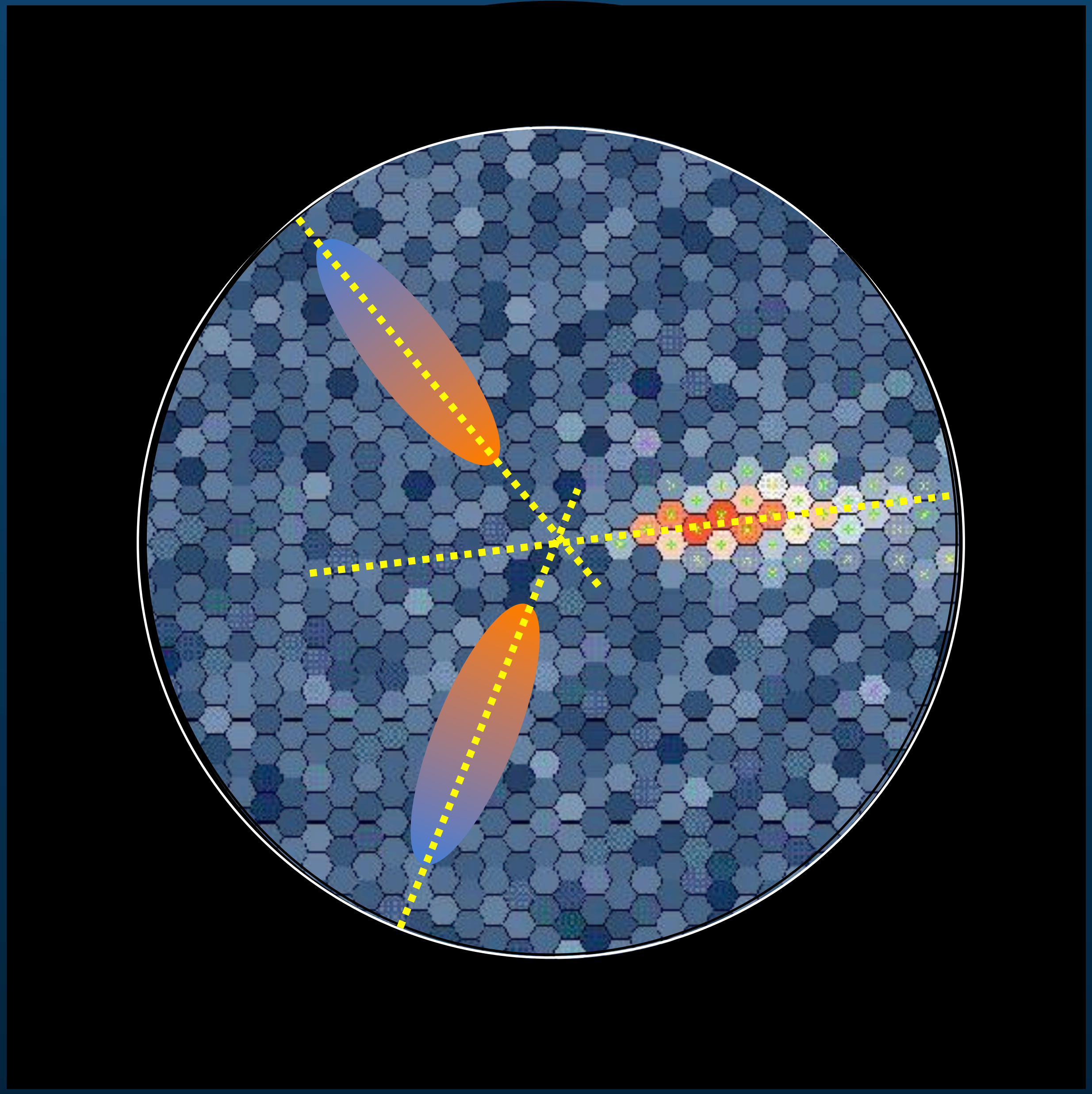


peaks reflect primary spectrum and depend on magnetic fields and matter density

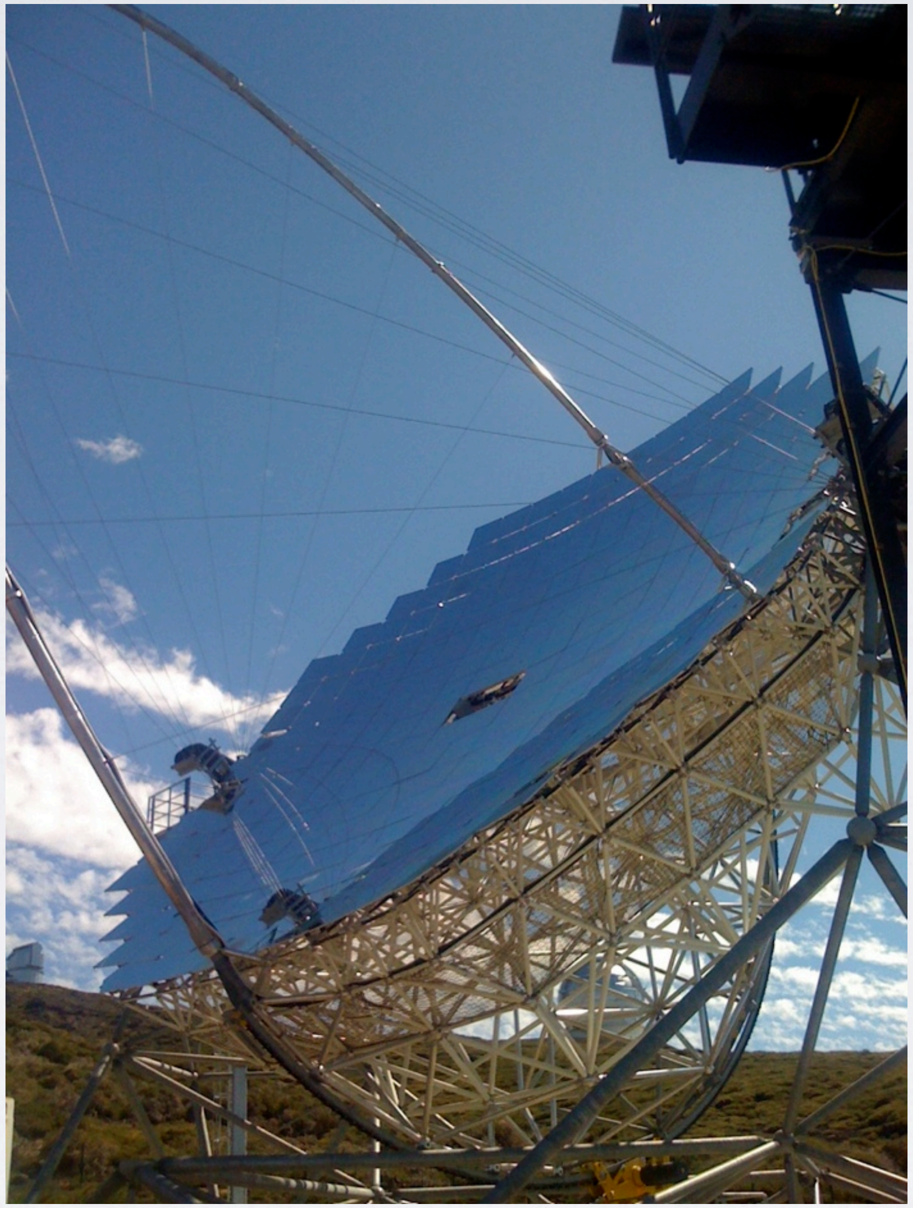
HIGH-ENERGY GAMMA-RAY SKY







intensity → energy
orientation → direction
shape → primary
stereo → source position

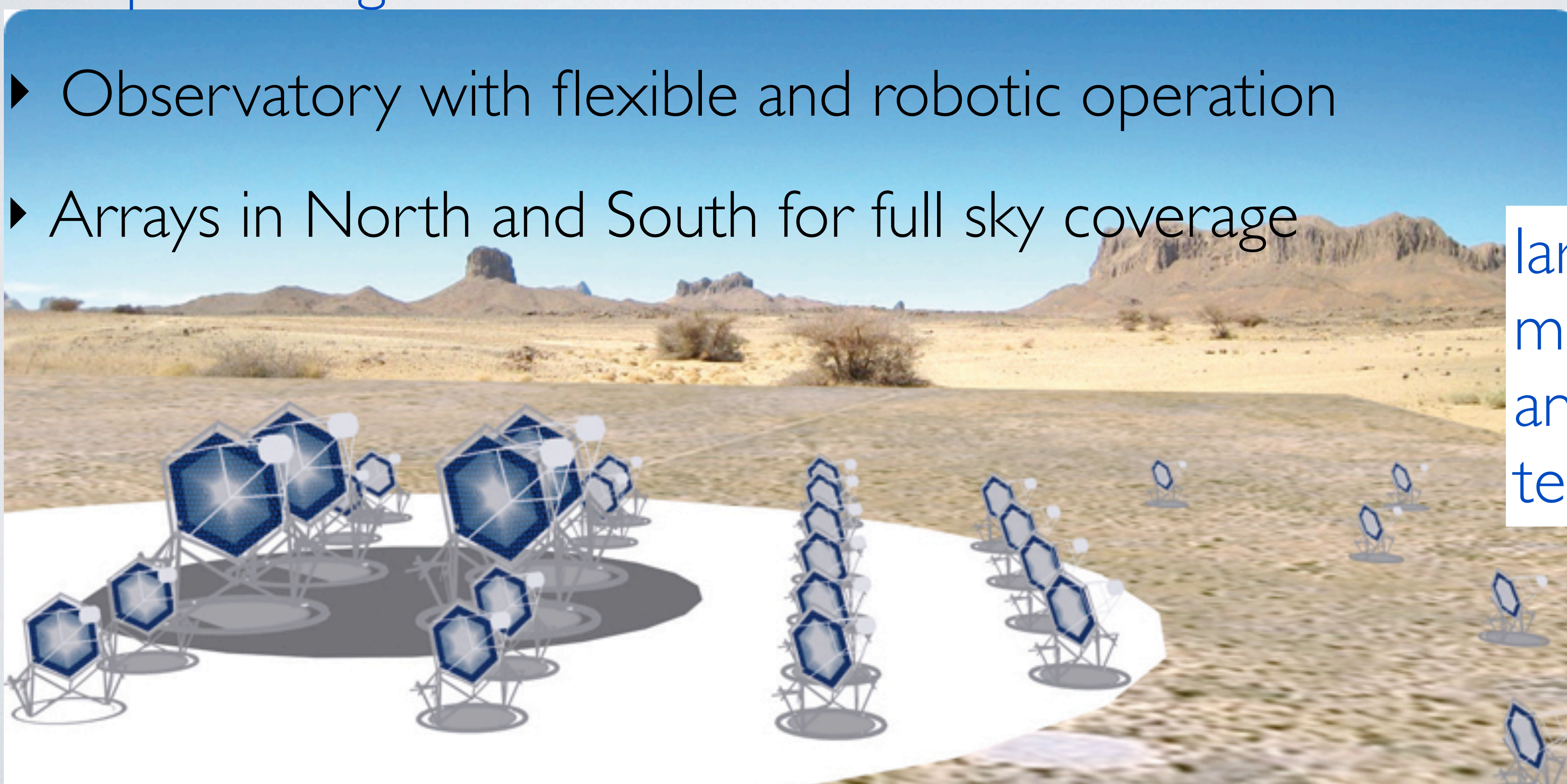




THE NEXT GENERATION

THE CHERENKOV TELESCOPE ARRAY

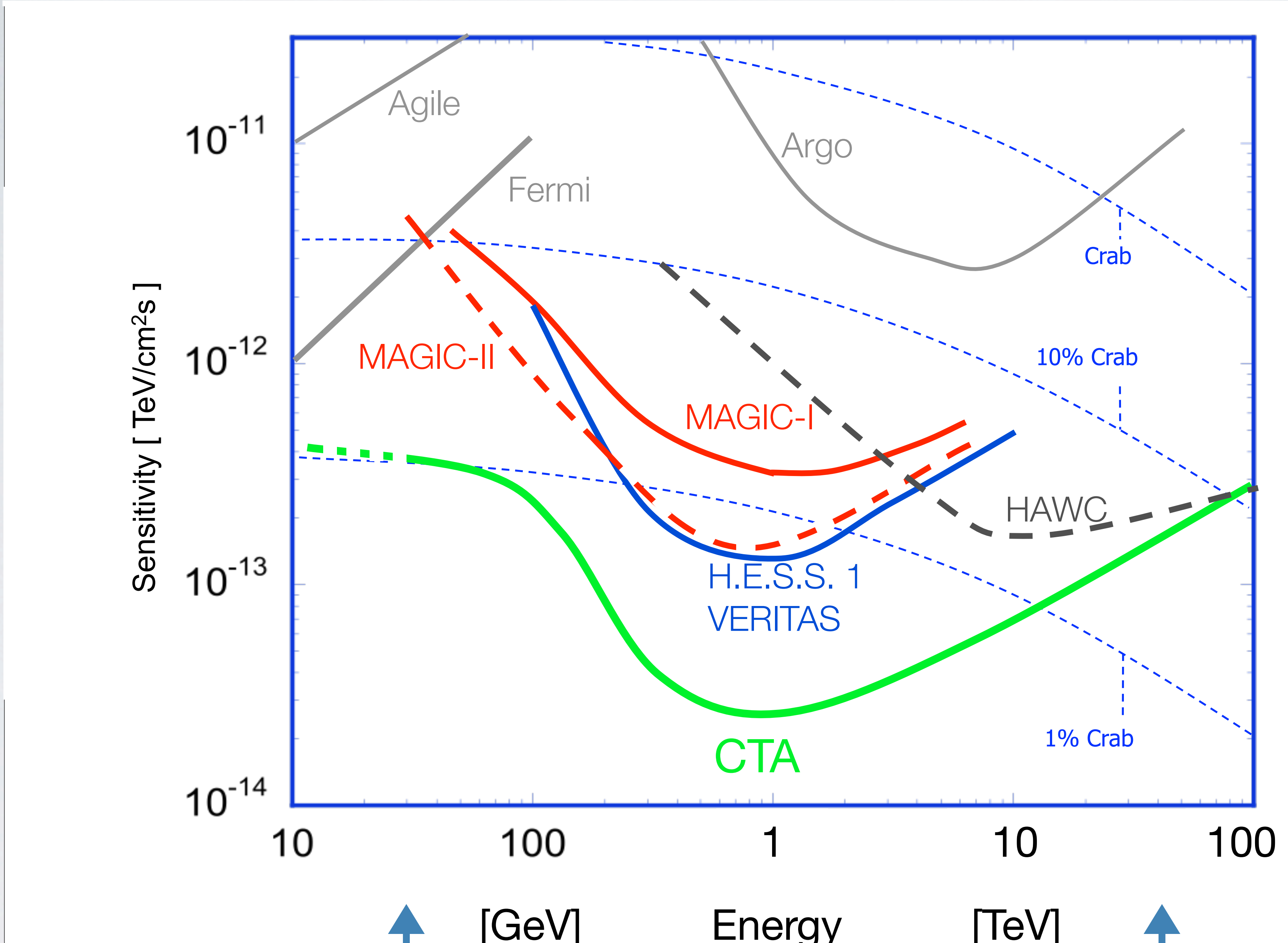
CTA: An advanced facility for ground-based γ-ray astronomy and astro-particle physics

- Increase sensitivity
- Extend energy range
- Improve angular resolution
- Observatory with flexible and robotic operation
- Arrays in North and South for full sky coverage



large, medium and small telescopes

SENSITIVITY

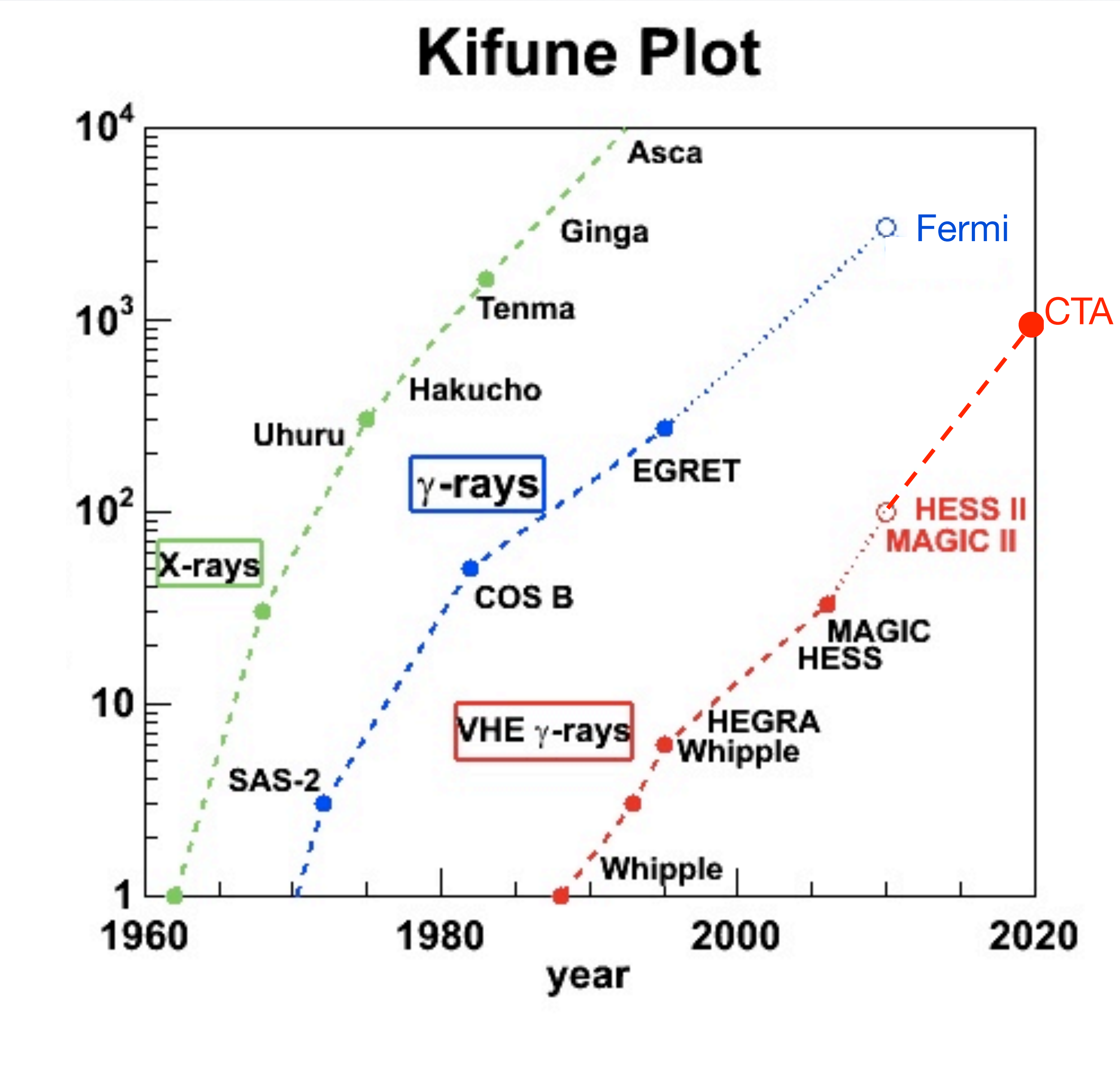


AGN
pulsars
GRB

Deep look
at the TeV
sky

Galactic
sources
(knee)

NUMBER OF SOURCES



THE PROJECT

- CTA consortium – extended H.E.S.S. + MAGIC community from 20 countries in Europe, Americas, Japan
- Priority project by European funding agencies ASPERA and ASTRONET → ASPERA call
- European Strategy Forum on Research Infrastructures (ESFRI) Roadmap 2008
- EU calls for ESFRI projects for preparatory phase, and for e-Infrastructure

WORK PACKAGE STRUCTURE

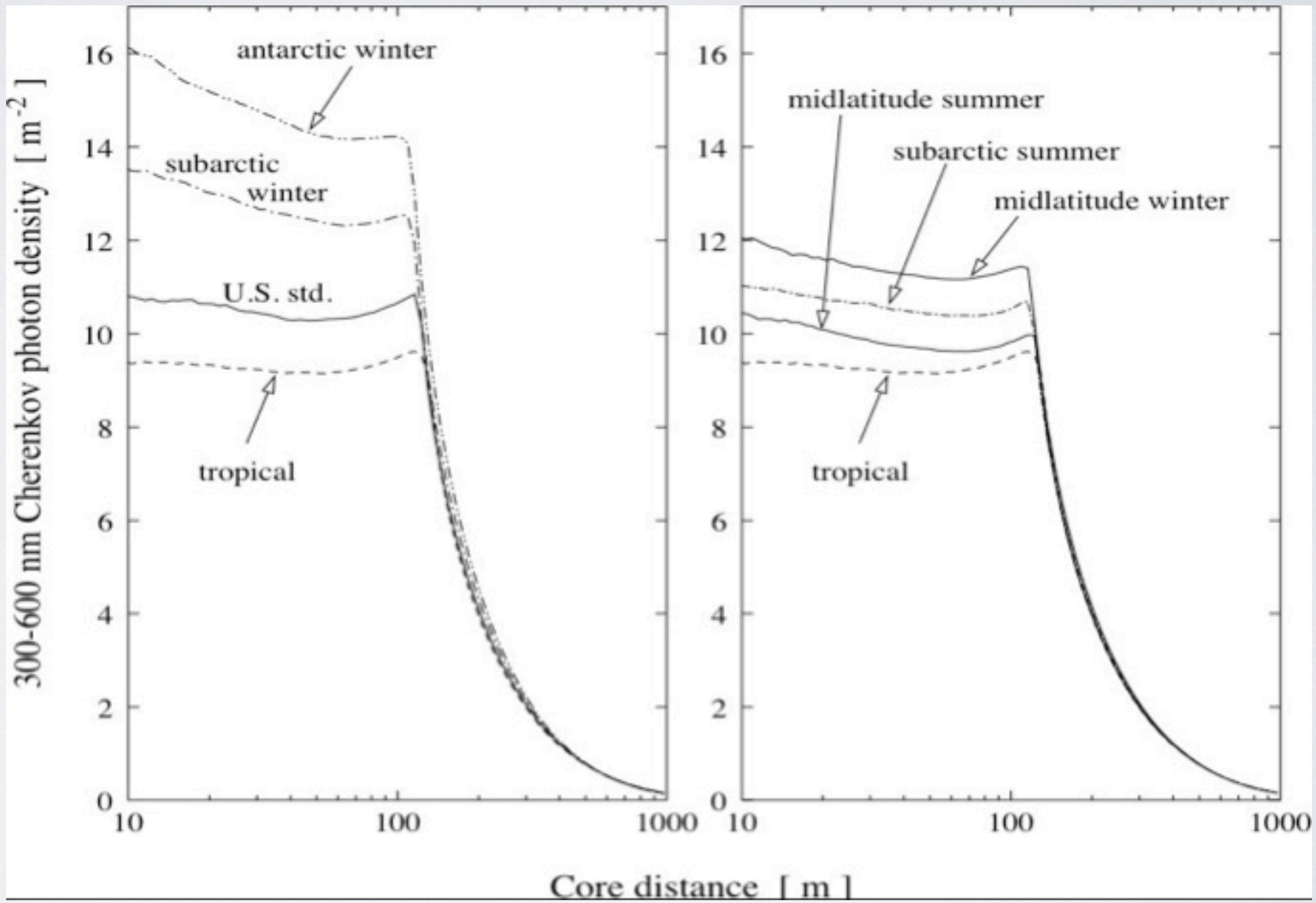
- Management, governance, legal aspects and financial model
- Preparing construction
  - project office with system engineering and integration, and contacts to industry
  - for different telescope types
    - keep structure for common aspects
    - transition from vertical to horizontal structure for specifics
- Preparing operation
  - data and user tools, computing, outreach...

CTA IN EU SEVENTH FRAMEWORK (FP7) FUNDING APPLICATIONS

- INFRA-2010-2.2.10: Construction of new infrastructures - preparatory phase
  - bring the project to the level of legal and financial maturity required to implement the project (governance, logistical, also technical work for prototypes and efficient start-up)
- INFRA-2010-1.2.3: Observatory Research e-Infrastructure
  - coordination, deployment and further evolution of structured information systems (Grid) – and development of user-configured tools and virtual research facilities

ATMOSPHERIC MONITORING AND INSTRUMENT CALIBRATION

- Temperature – density, thickness, refractive index
- Aerosols



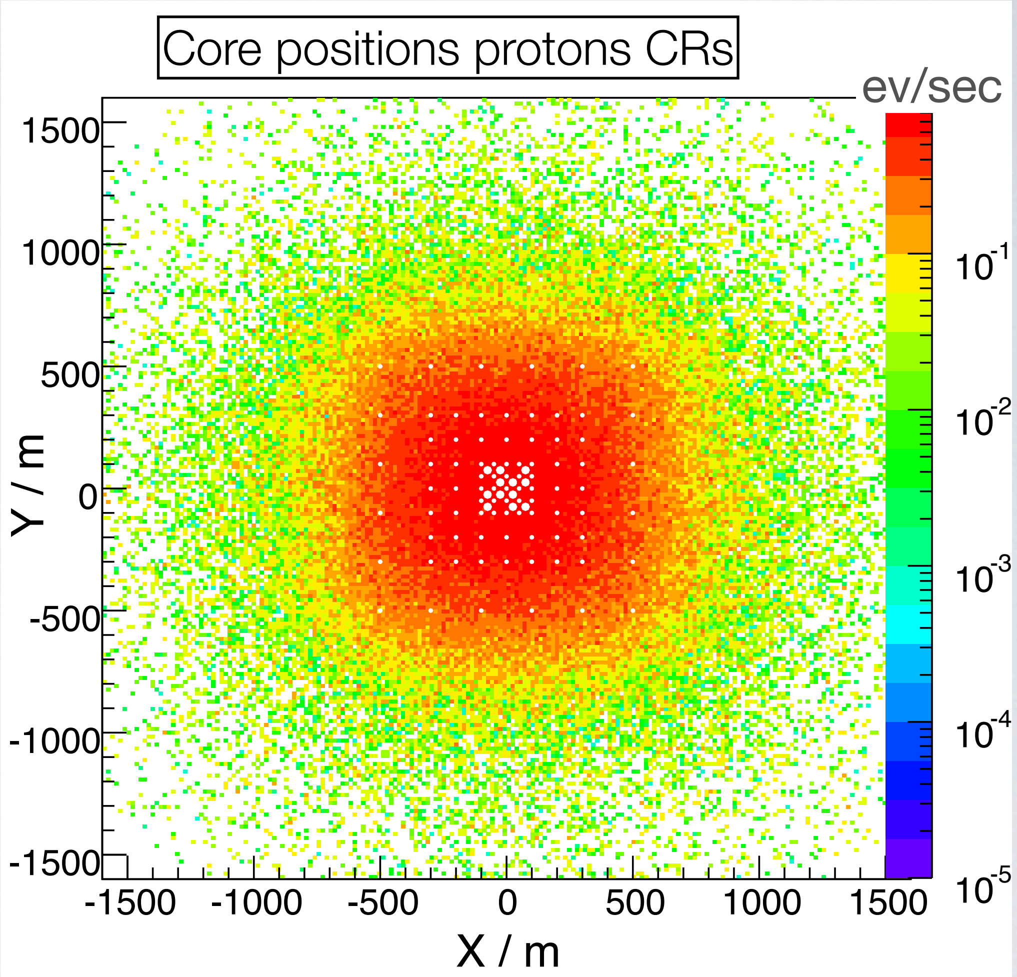
WHERE?

- Establish a list of candidate site possible CTA – for both North and South Hemisphere
  - Flat Area: 3 x 3km^2 (SH), 1 x 1km^2 (NH)
  - Cloud Coverage: > 70% of clear nights
  - Altitude 1500–4000m
  - Latitude +30° N ... -30° S
  - Atmosphere: transparent, dry and quite in general (low aerosol content, reasonable relative humidity and wind speed)
  - Infrastructure

ARRAY LAYOUT

- Explore parameter space
  - telescope diameter and focal length
  - telescope spacing
  - camera size and pixel size
  - read-out speed
  - off-axis performance
  - array height

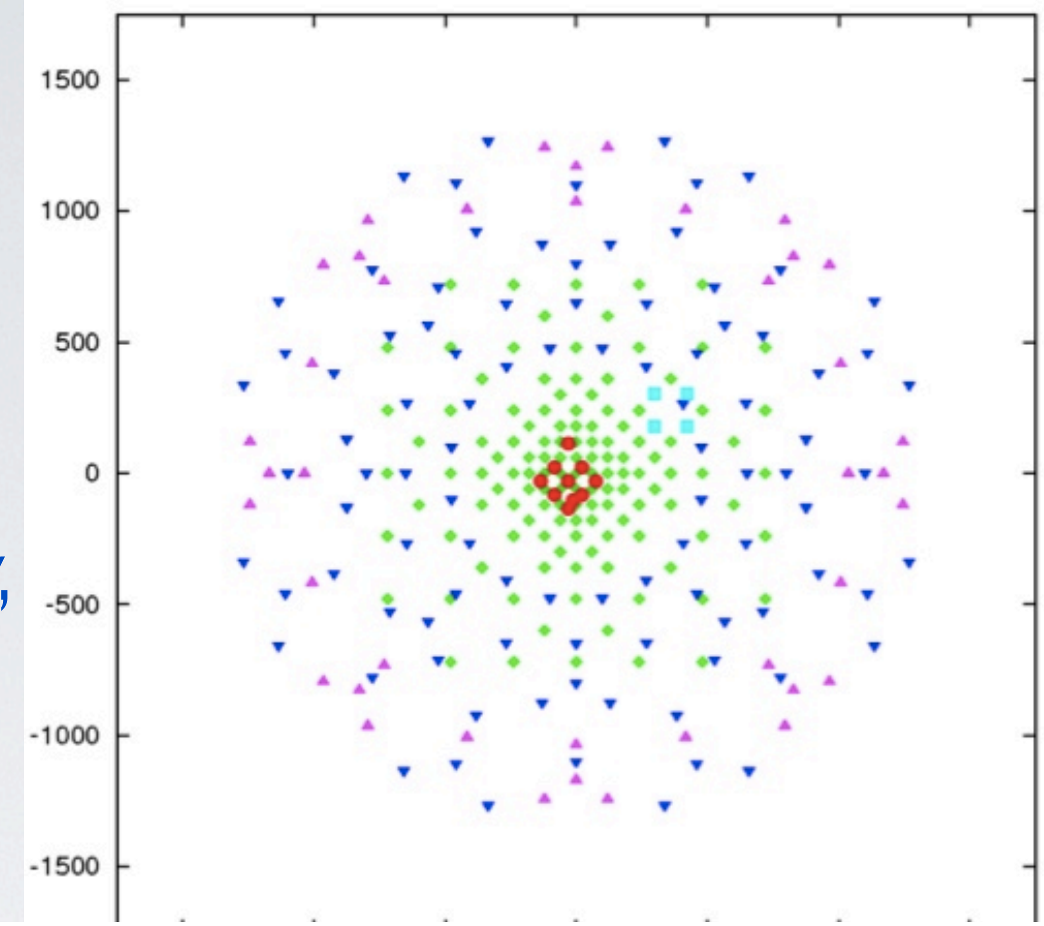
→ Performance in a given budget

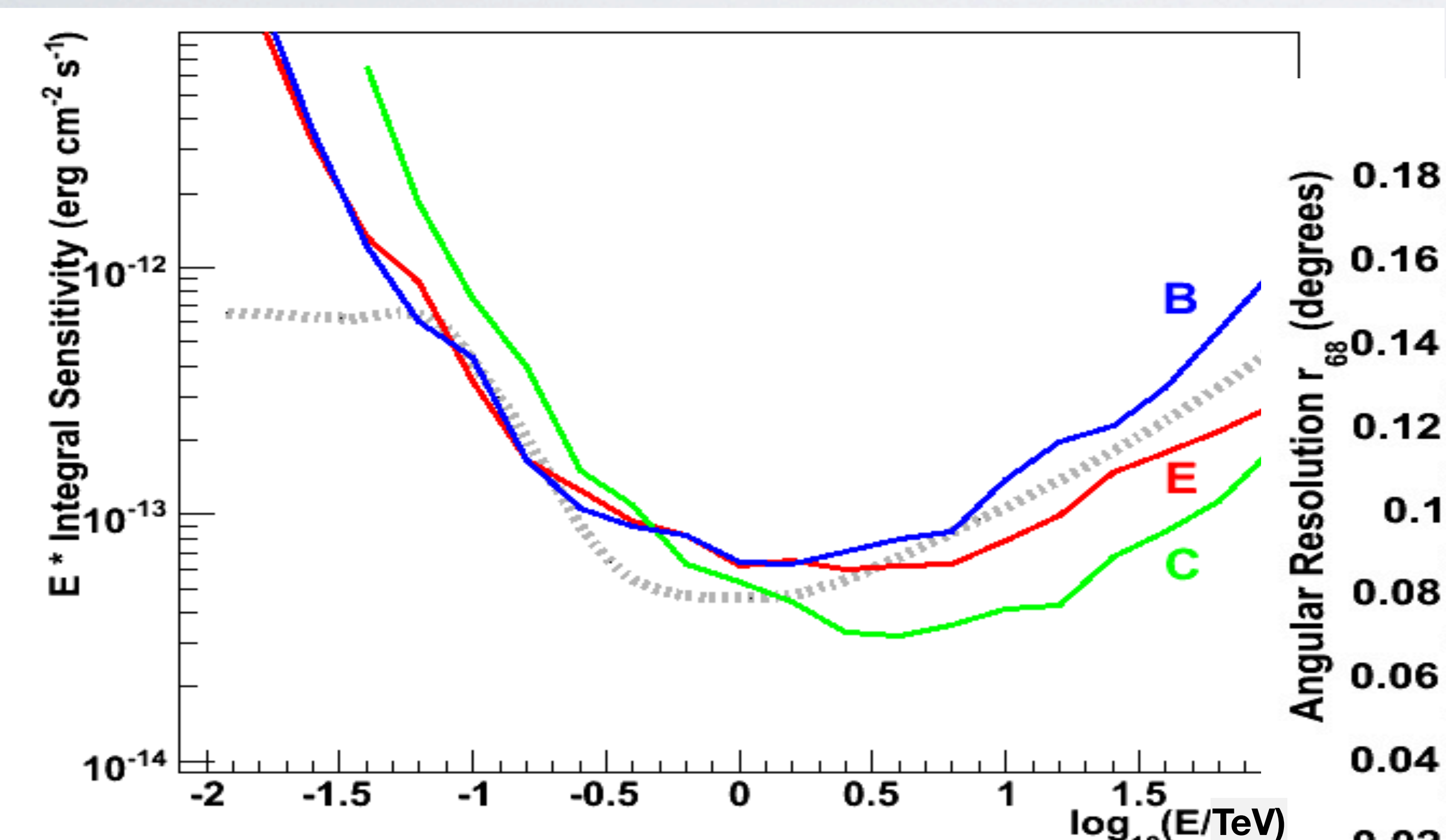


- 10^{11} showers with grid and batch cluster

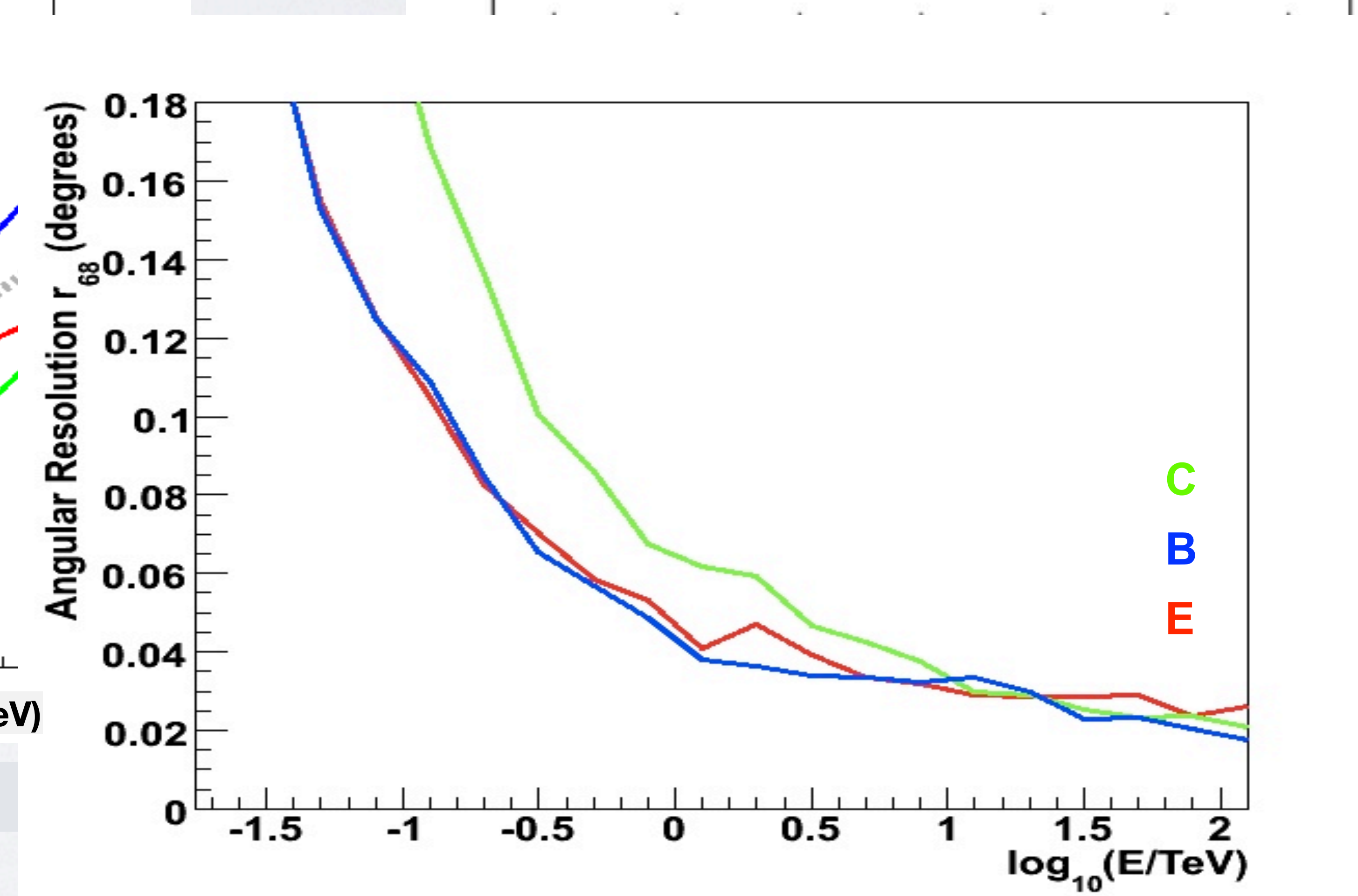
OPTIMIZATION WITHIN A FIXED BUDGET

- Investigate > 45 array configurations from a pool of 275 telescopes: sensitivity, resolution, trigger, E_{thr}





Likely ~30% better with optimized analysis



- Data rate South 400 MB/s → 1.8 PB/ year → trigger farm

PRELIMINARY RECOMMENDATION FROM MC WORK PACKAGE

- Mix of three telescopes types (or two with different PMTs for HE component)
- Regular grids used to explore field of view and telescope separation phase space
  - 60, 85, 120, 170 and 240 m spacing for all FoVs
  - 37 telescopes with 5° ≅ 24 telescopes with 8°

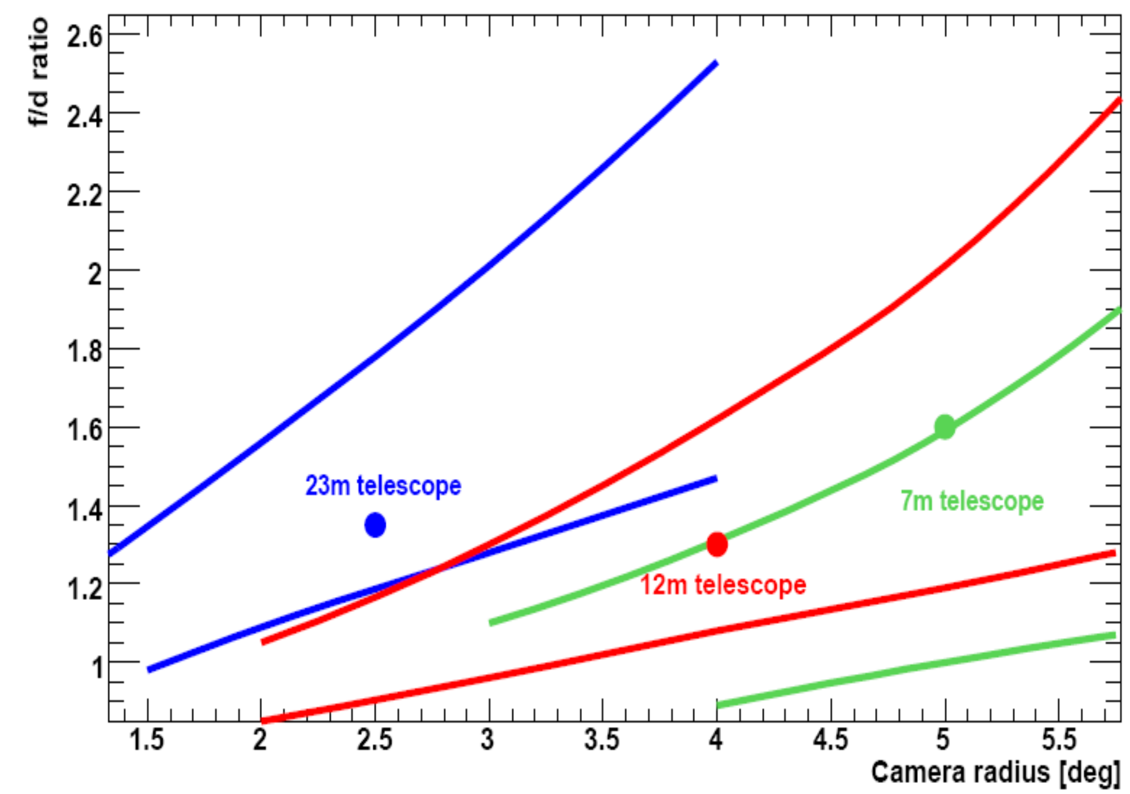


Figure 7: Range of reasonable f/d ratio for a given FOV for 23 m parabolic telescopes (blue), 12 m Davies-Cotton telescopes (red) and 7 m Davies-Cotton telescopes (green). The telescopes used in the MC productions are shown with circles.

PRELIMINARY RECOMMENDATION CONT

- 12 m class telescope
  - field of view 6-8°
  - f/D of 1.3...1.4 and Davies-Cotton optics
  - pixel size 0.15-0.2°
- 24 m class telescope
  - field of view 5-6°
  - f/D of 1.3...1.4 and parabolic optics
  - pixel size 0.08-0.1°
- No recommendation yet for HE part but FoV >7°

TELESCOPE CONSTRUCTION

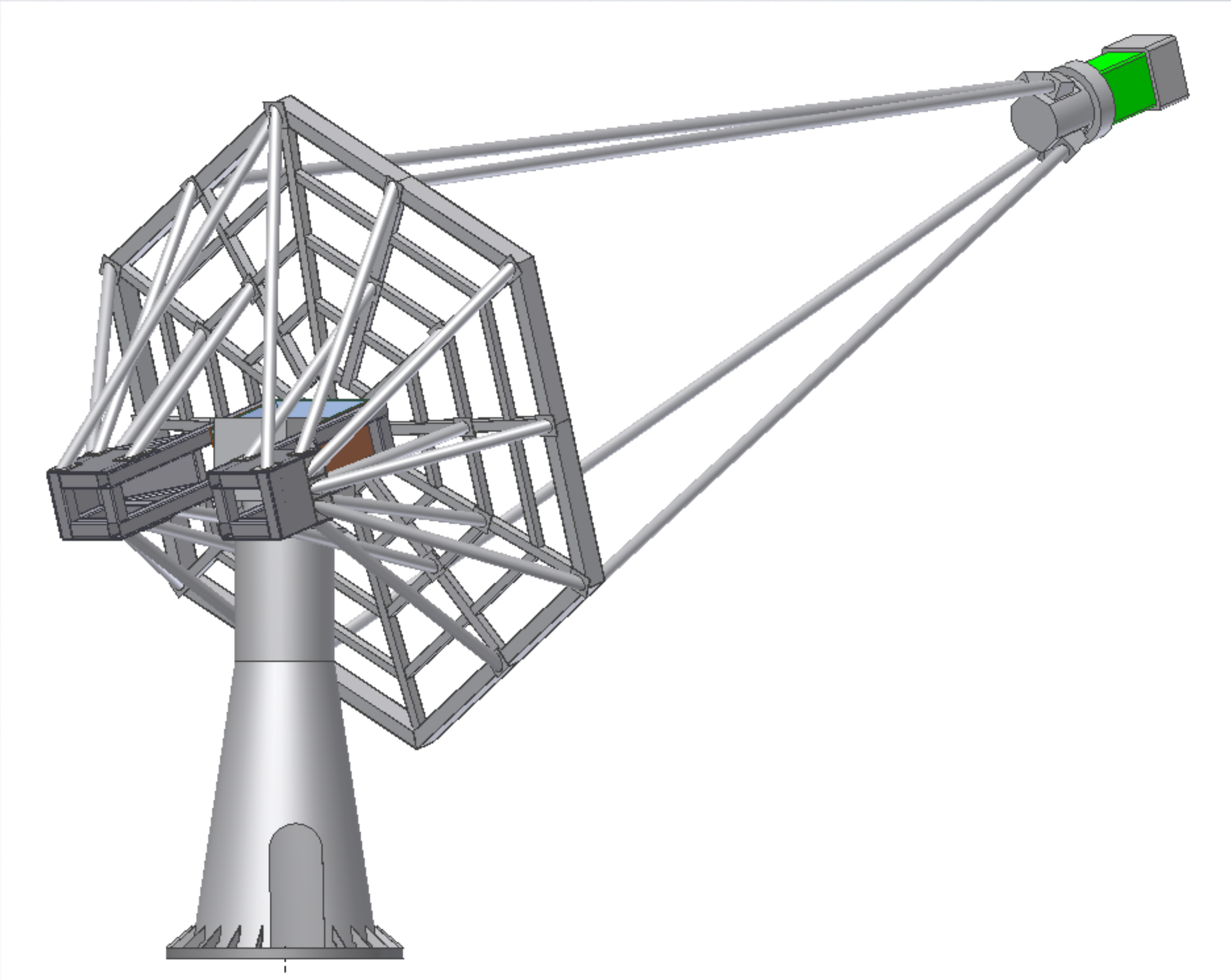
- Baseline designs for different
  - diameter
  - focal length
  - field of view
  - mirror arrangement
  - alternatives

→ Prediction of performance parameters and costs

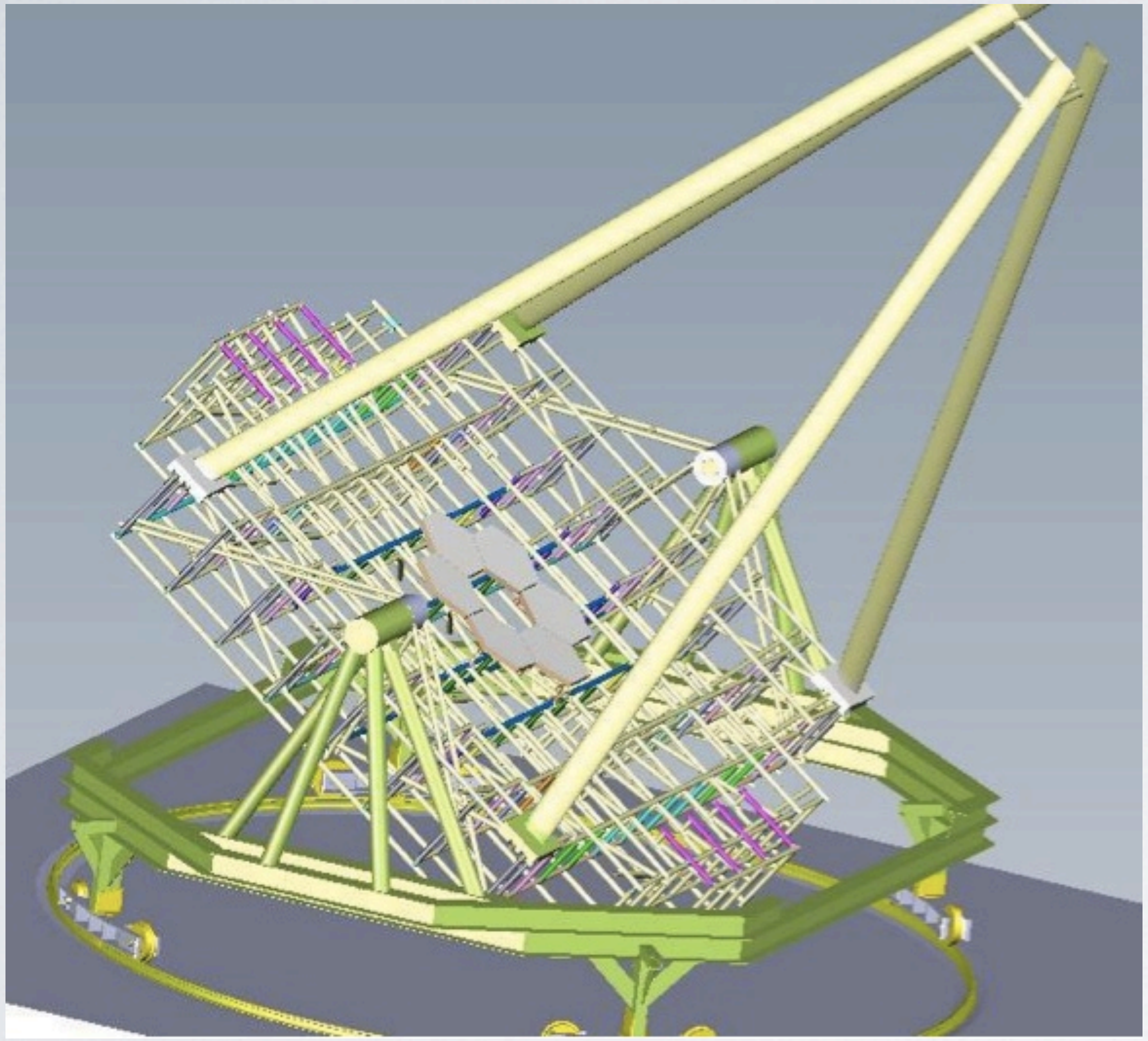
- large-size telescope
- small-size telescope
- medium-size telescope
- drive and control system
- energy management

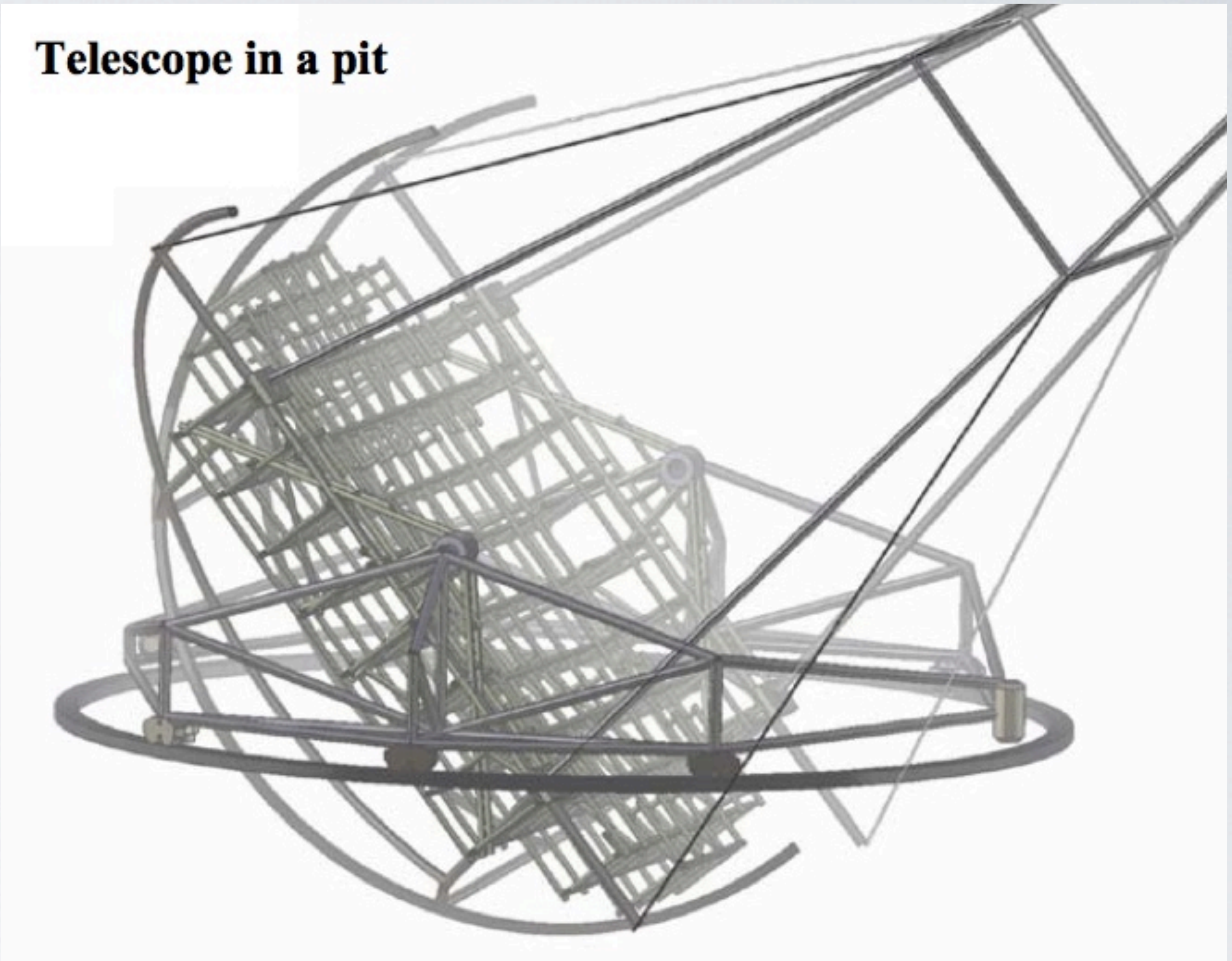
TOWARDS A MEDIUM-SIZE TELESCOPE

- Diameter 12 m
- Focal length 16 m
- Field of view 8°
- Price and ease of construction
- Small deformations → small point spread function



MEDIUM-SIZE TELESCOPES CONT





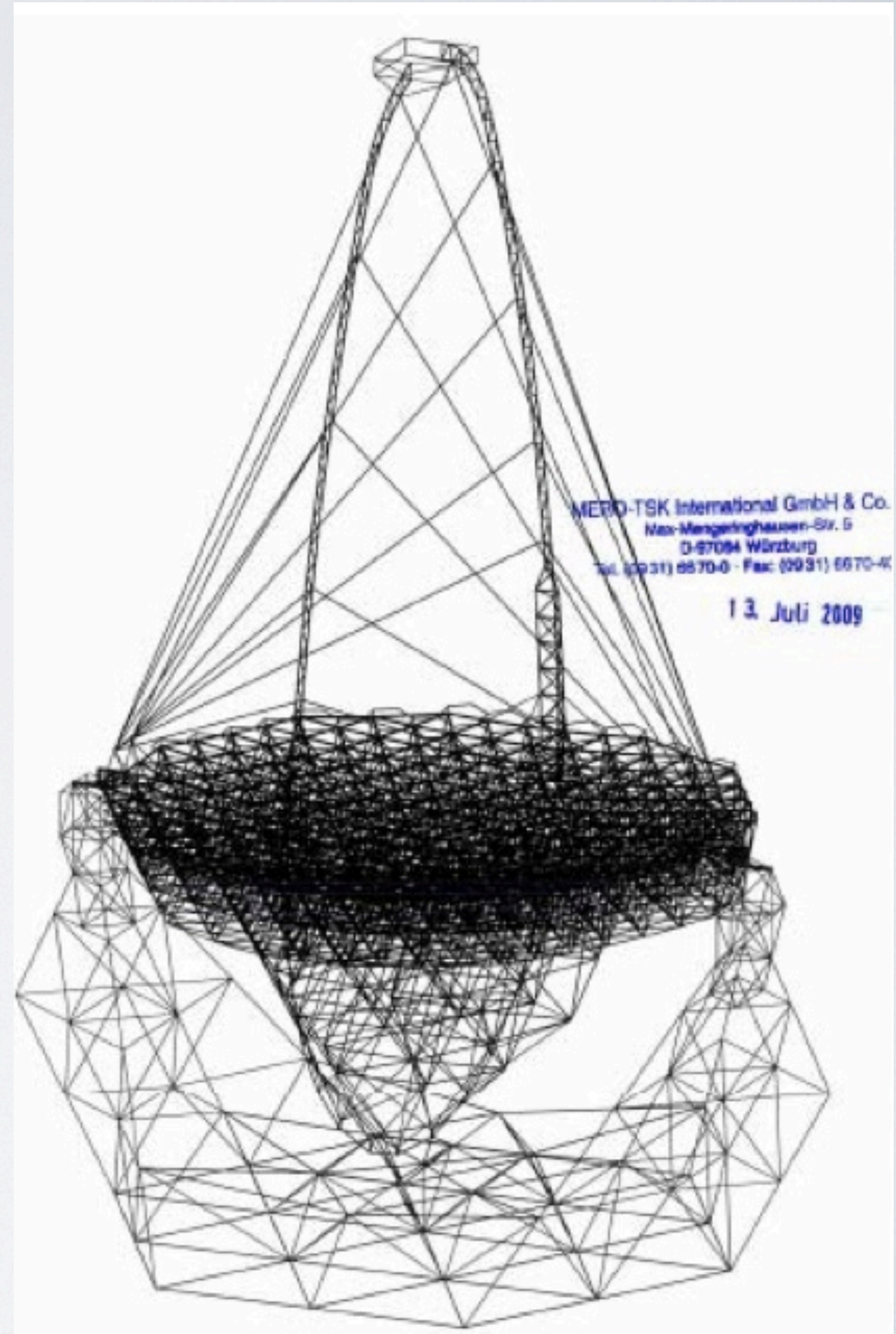
- Price and performance reviews
- Collaboration between designers

AGIS

- Schwarzschild-Couder design
- Field of view
- Angular resolution
- Prototype

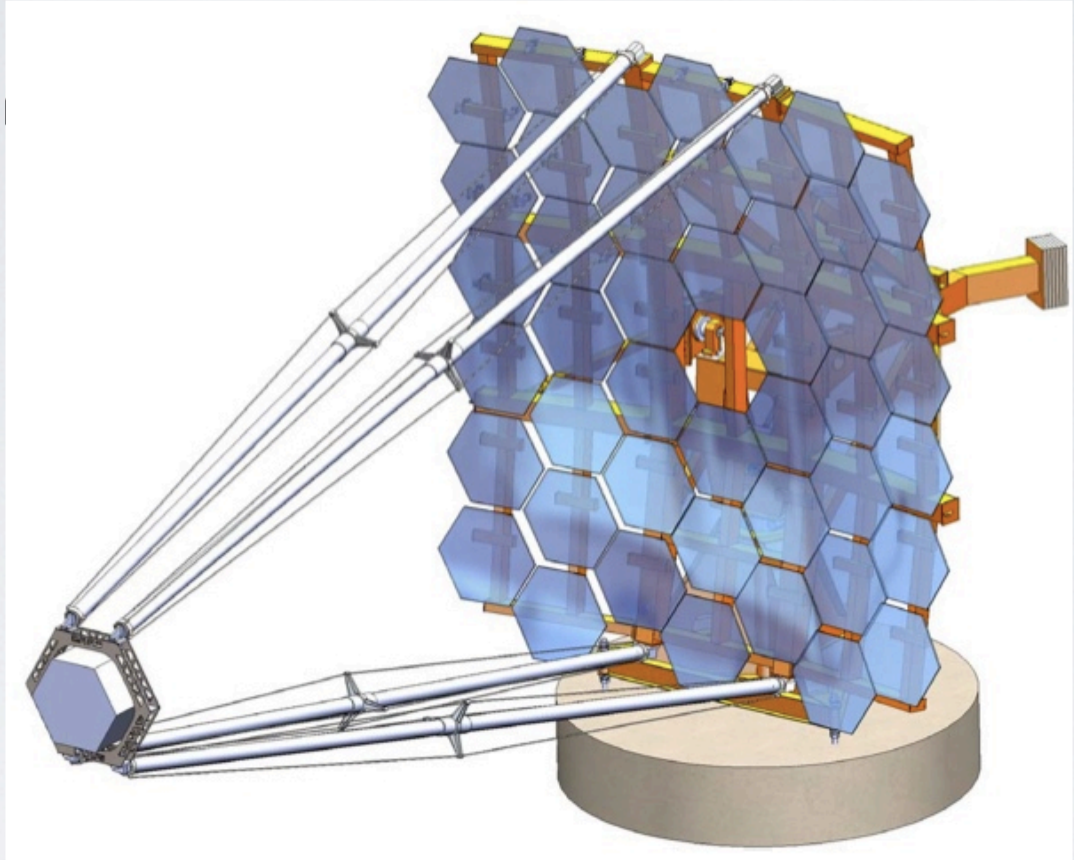
LARGE-SIZE TELESCOPE

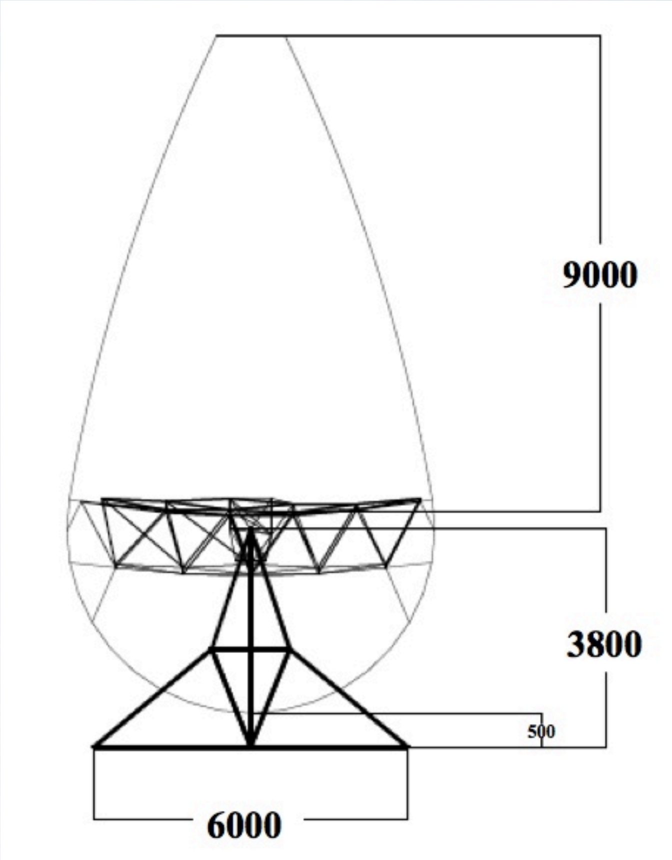
- Dish diameter 23 m
- Sensitivity down to 20 GeV
- Light weight for GRBs
- Fibre carbon structure
- Light camera
- Active camera damping system

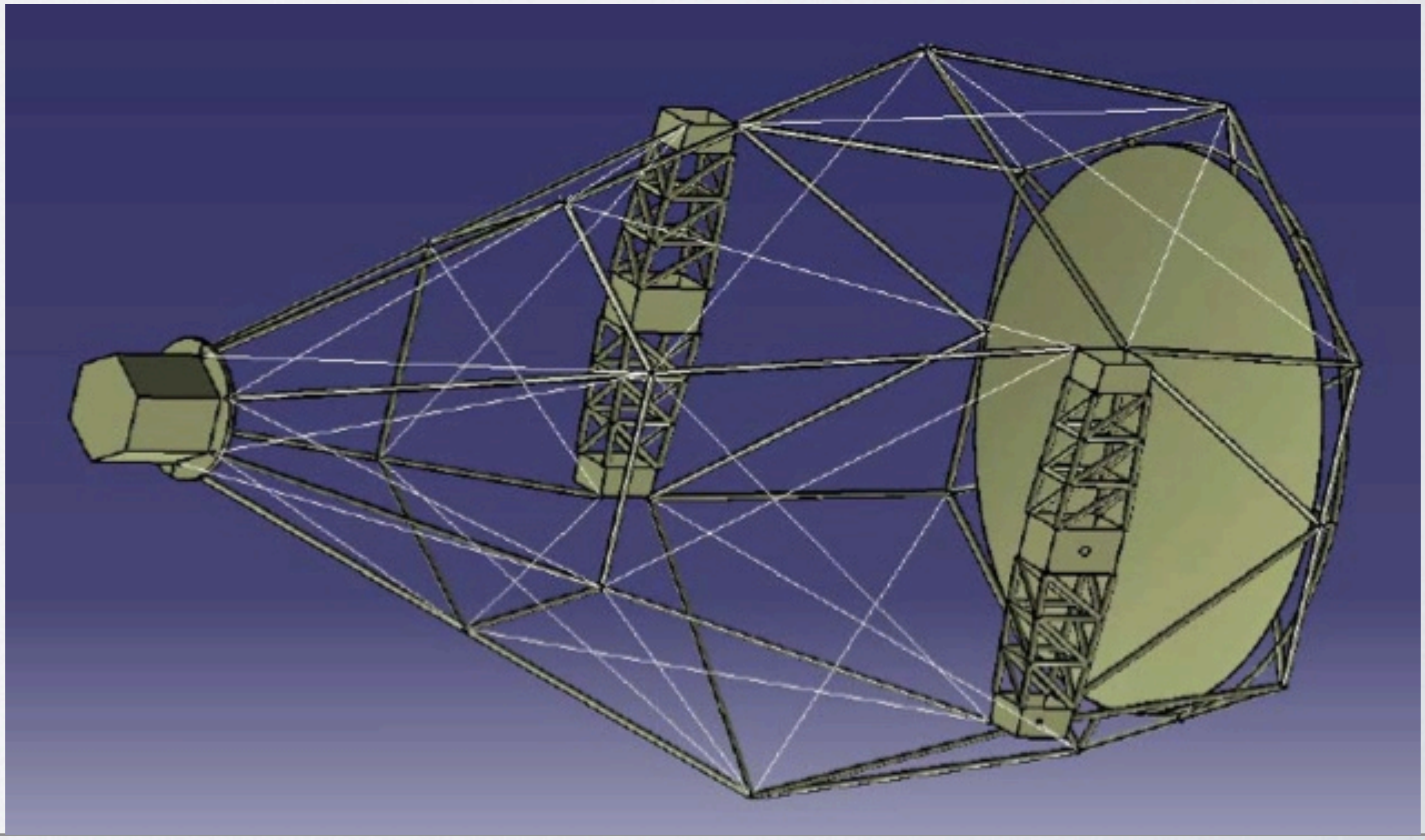


SMALL-SIZE TELESCOPES

- Different ideas at various stages







DRIVE AND SAFETY SYSTEM

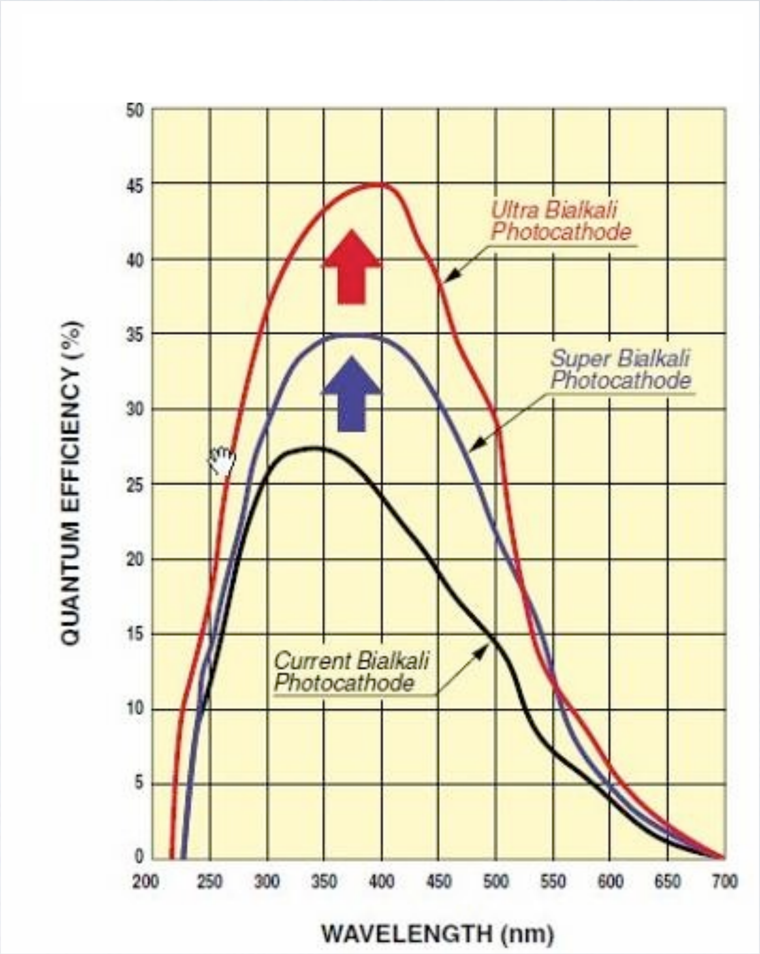
- Motors
- Feedbacks
- Gears
- End switches
- Emergency system

MIRROR DEVELOPMENT

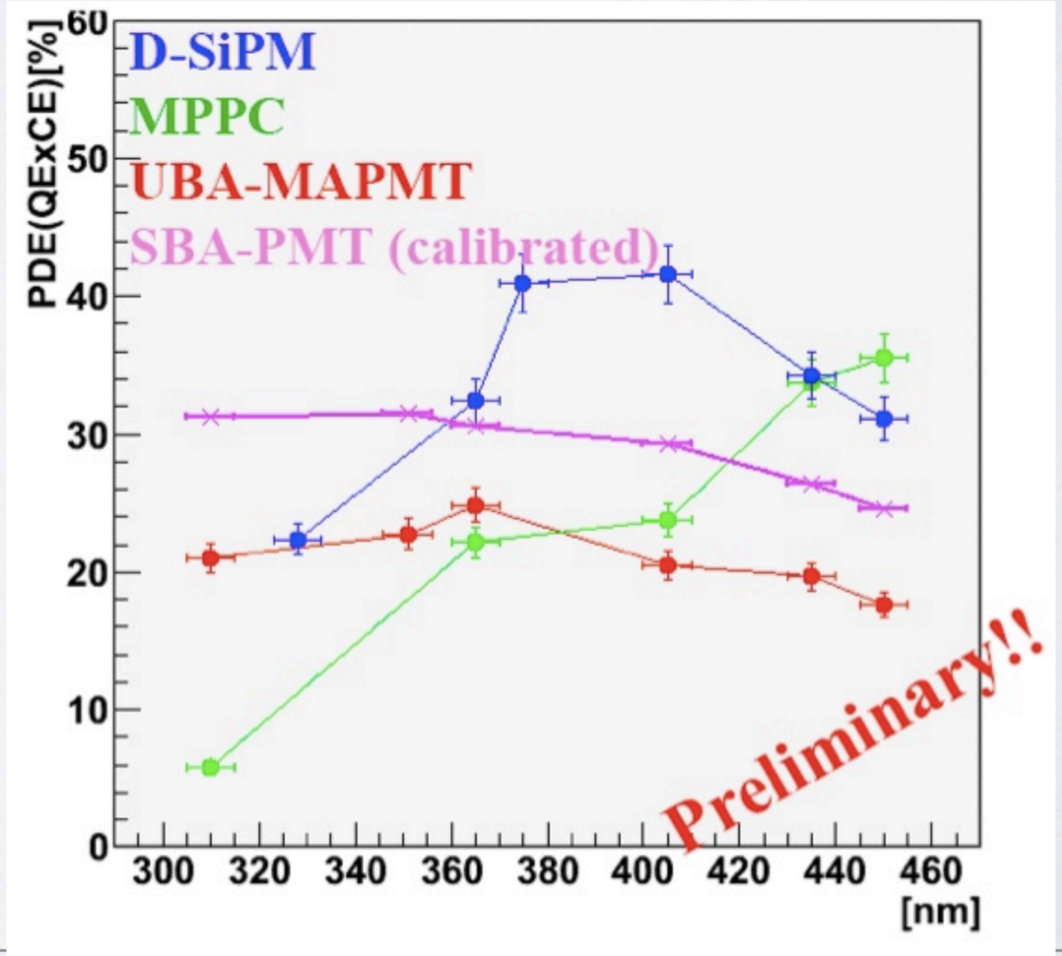
- Hexagonal 1.2 m w/ reflectance > 80% (300-600 nm)
- Technologies investigated looking at cost reduction
  - all aluminum mirrors
  - cold slumped glass mirrors
  - carbon/glass fiber composite mirrors
- Coating (SiO_2 w/ and w/o carbon admixtures, Al_2O_3), single- and multi-layer
- Mirror testing group
- Active mirror control designs tested

CAMERA

- Improvements of classical PMTs
  - super-bialkali and ultra-bialkali cathode

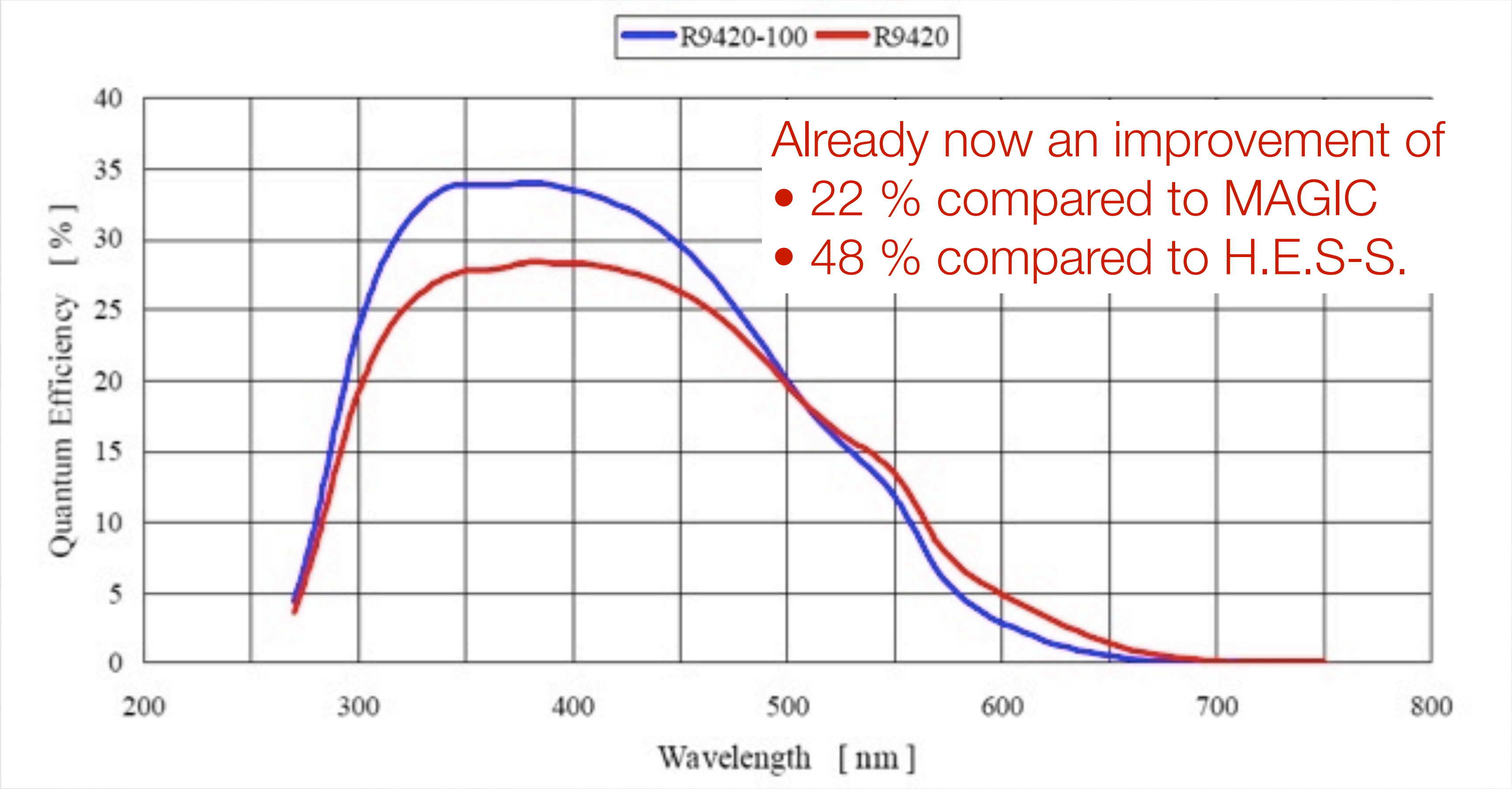


- Alternative light sensors
  - HPDs, SiPMs
  - performance, costs, ...



PHOTOTUBES

- Electron Tubes Enterprises
- Hamamatsu



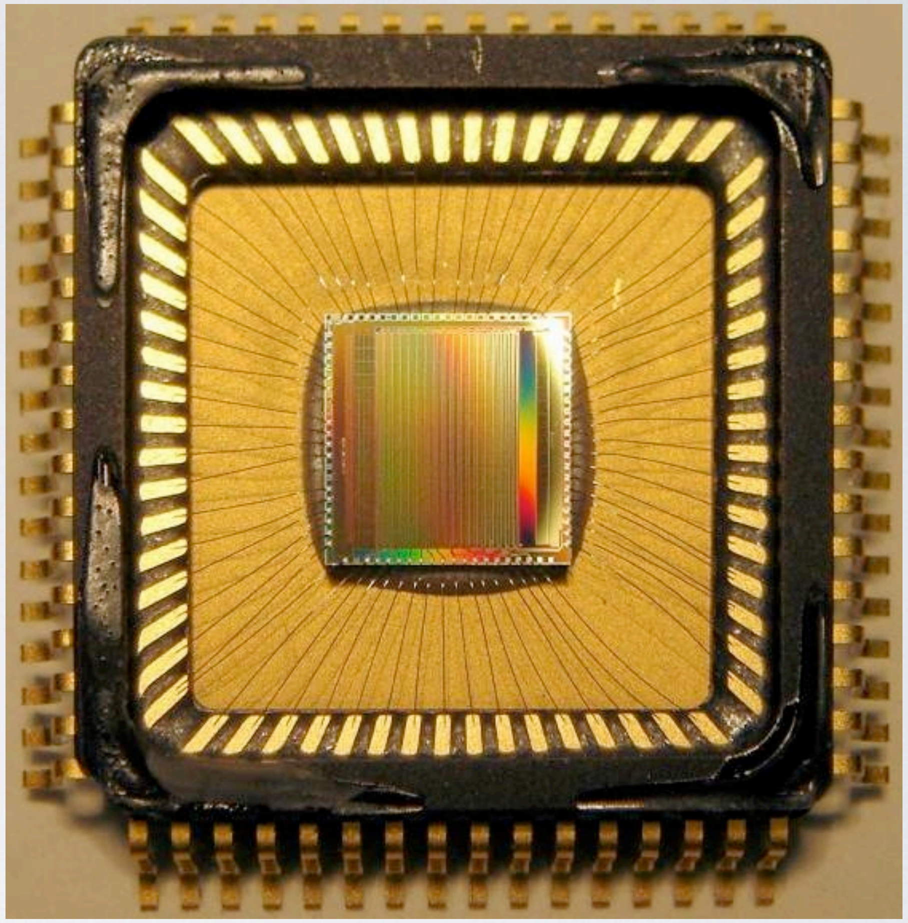
- accelerated aging tests
- after-pulsing

- 1.5 inch for all telescopes ?!
- build test-cluster

FAST READ-OUT ELECTRONICS

- Different techniques
  - memory depth
  - speed
  - effective range
  - bandwidth

→ Prediction of performance parameters and costs

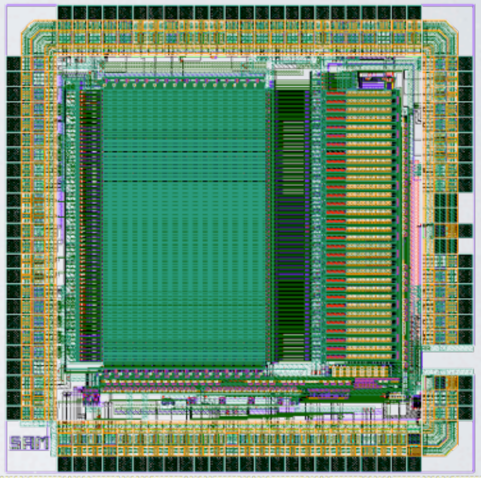


Example

FADC system based on domino ring sampler

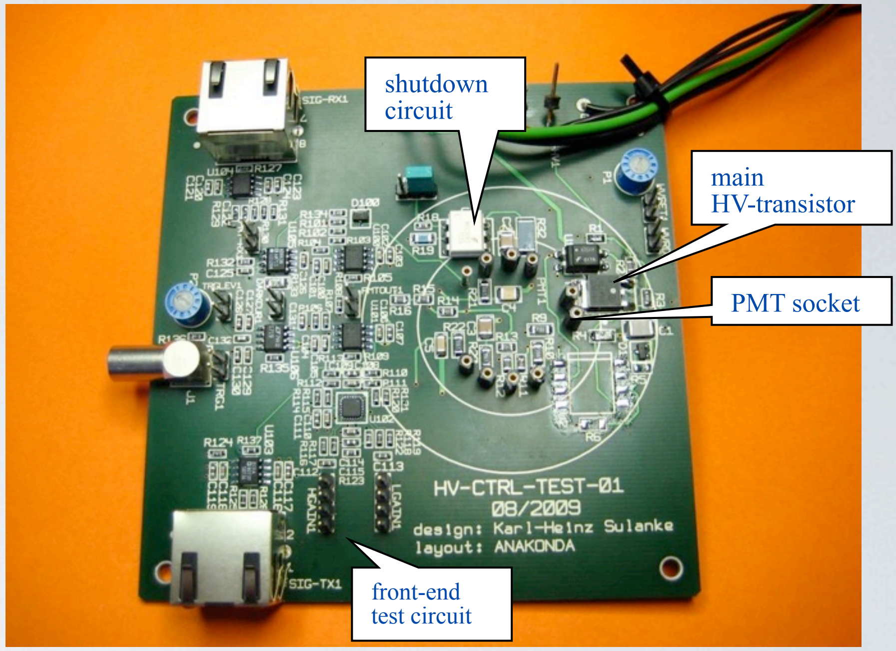
FRONT-END ELECTRONICS

- DRAGON
    - low noise, fast amplifier input w/ 1.9 GHz BW (downgraded), DRS4 sampling chip (11.5 bit dynamic range), differential ADC, 5 Gsamples/s, 450 MHz
- NECTAR
    - two gain amplifier input, SAM (analog memory w/ 17 bit dynamic range), low power ADC, 300 MB/s serializer



- Fully digital camera
    - lo/hi gain FADCs, FPGA ring buffer → dead-time free operation

ELECTRONICS

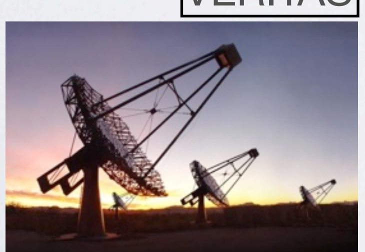


- High voltage system for camera PMTs
  - special on control, safety, power
- Camera trigger
  - different analog solutions (comparators, clipper) with sectorization/ clustering
  - FPGA based digital camera trigger in a three-stage trigger structure
- Array trigger and clock distribution

ARRAY OPERATION CENTER

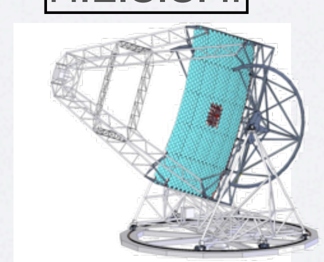
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	★ Startup meeting											
		★ FP7 proposal										
		Array layout										
				★ Consortium								
				★ FP7 proposal								
Design and Prototype Phase			Components									
					Telescopes							
								Array construction				
									Science operation			

VERITAS



Fermi

H.E.S.S. II



MAGIC II

- CTA consortium
  - in European process
  - collaboration building
  - work packages cover all topics
- CTA funding for design, R&D and prototype phase
- First decisions – first prototypes
- Pushing for start of construction in 2013