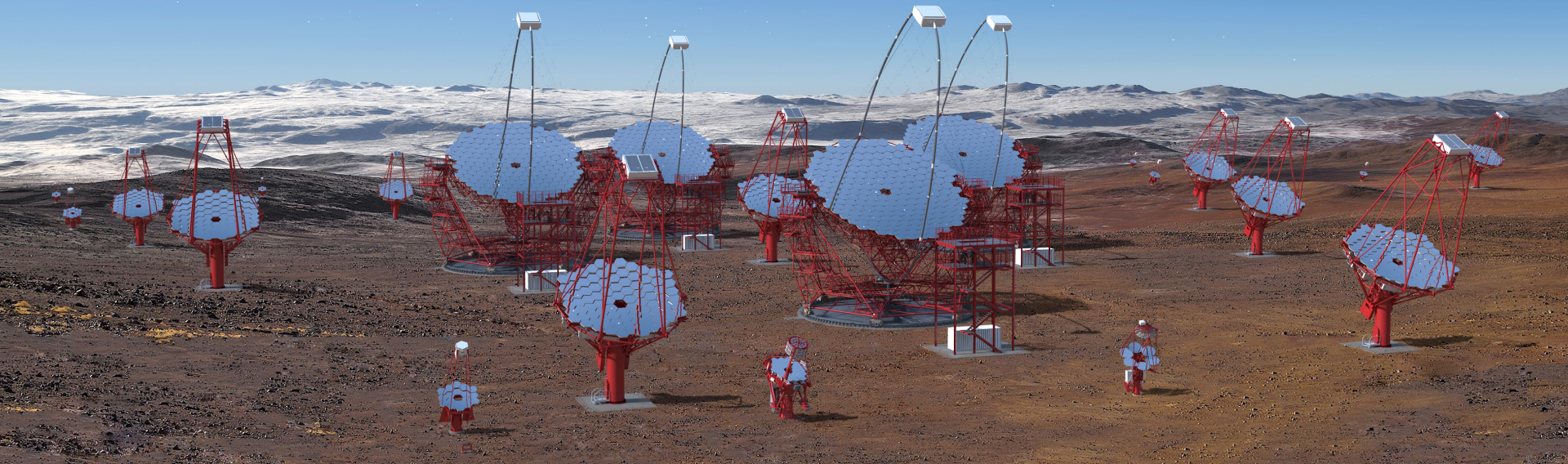




cherenkov
telescope
array



Da ASTRI a CTA: osservare il cielo nei raggi gamma



Stefano Vercellone (INAF – OA Brera)

stefano.vercellone@inaf.it

Mi presento



- Laurea in Astronomia presso l'Università di Padova
- Specializzazione in Sistemi Spaziali presso il CISAS di Padova
- Ricercatore presso l'Osservatorio Astronomico di Brera, sede di Merate
- 1998 – oggi : membro del team del satellite gamma AGILE.
 - Studio dei nuclei galattici attivi, pianificazione e coordinamento di osservazioni multifrequenza
- 2012 – oggi : Science manager del Progetto ASTRI
 - Coordinamento del gruppo di lavoro per lo sfruttamento scientifico del prototipo ASTRI e del futuro ASTRI mini-array.
- 2016 – 2017 : Science Coordinator del Consorzio che pianifica e costruisce il Cherenkov Telescope Array
 - Coordinamento dei vari gruppi scientifici che devono ottimizzare il ritorno scientifico di CTA.

Outline



Le altissime energie
I telescopi Cherenkov
Il Progetto ASTRI
Il futuro Cherenkov Telescope Array
Scienza per tutti !



Outline



Le altissime energie

I telescopi Cherenkov

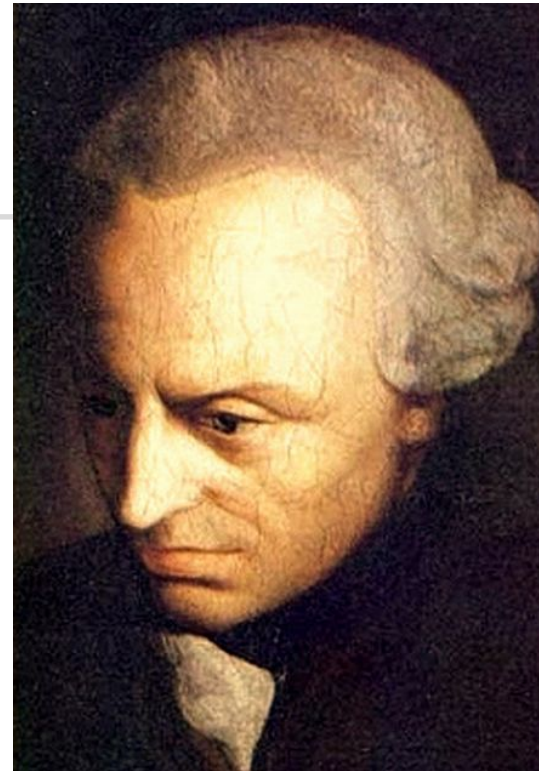
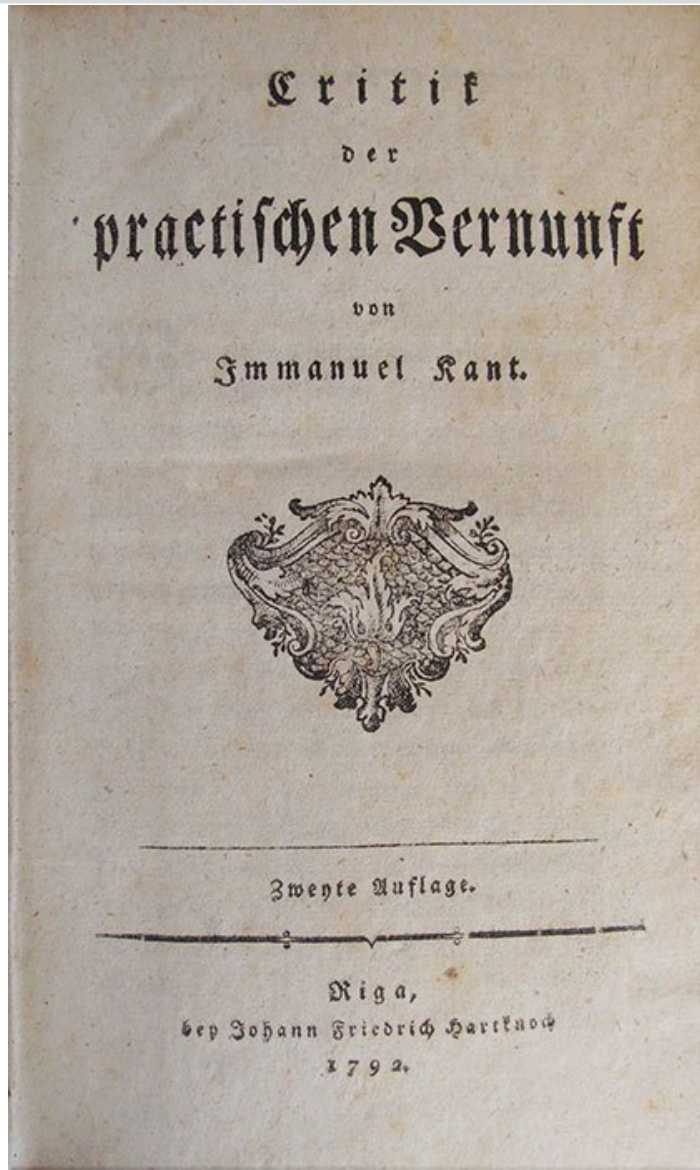
Il Progetto ASTRI

Il futuro Cherenkov Telescope Array

Scienza per tutti !



Immanuel Kant

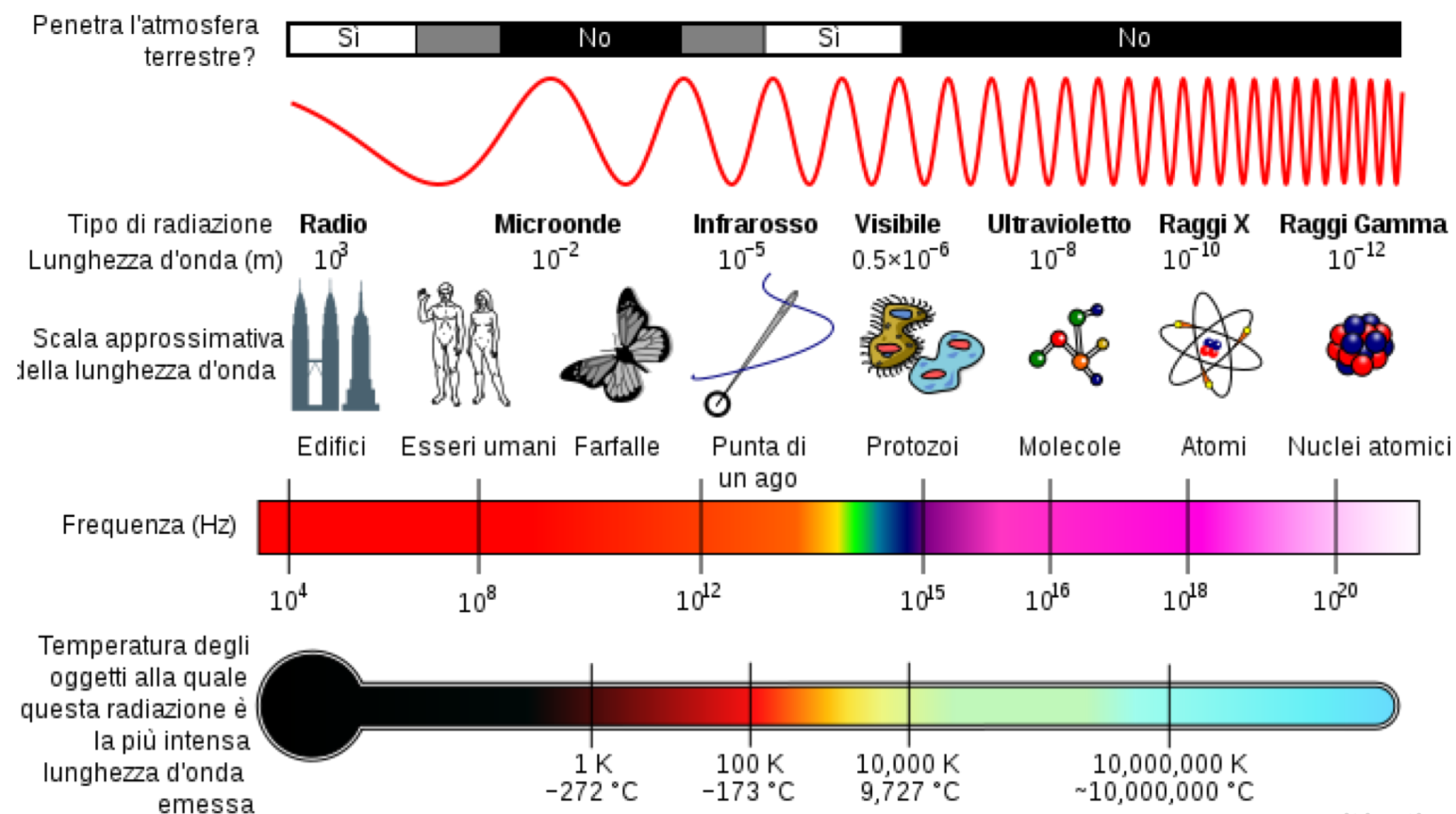


«Due cose riempiono l'animo di **ammirazione e venerazione sempre nuova e crescente**, quanto più spesso e più a lungo la riflessione si occupa di esse: **il cielo stellato sopra di me**, e la legge morale dentro di me.»

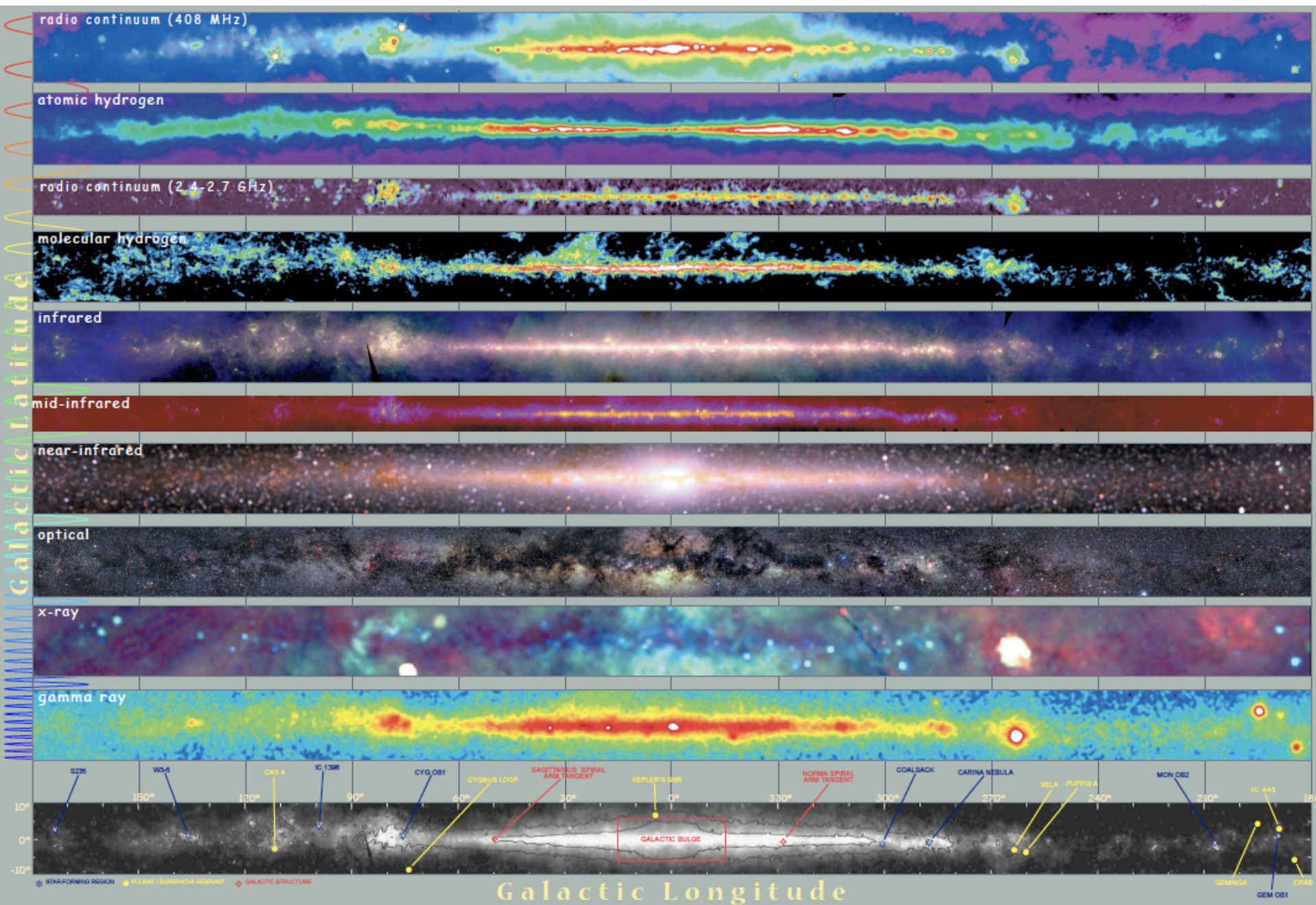
(Epitaffio di I. Kant, estratto dalla *Critica della ragion pratica*)



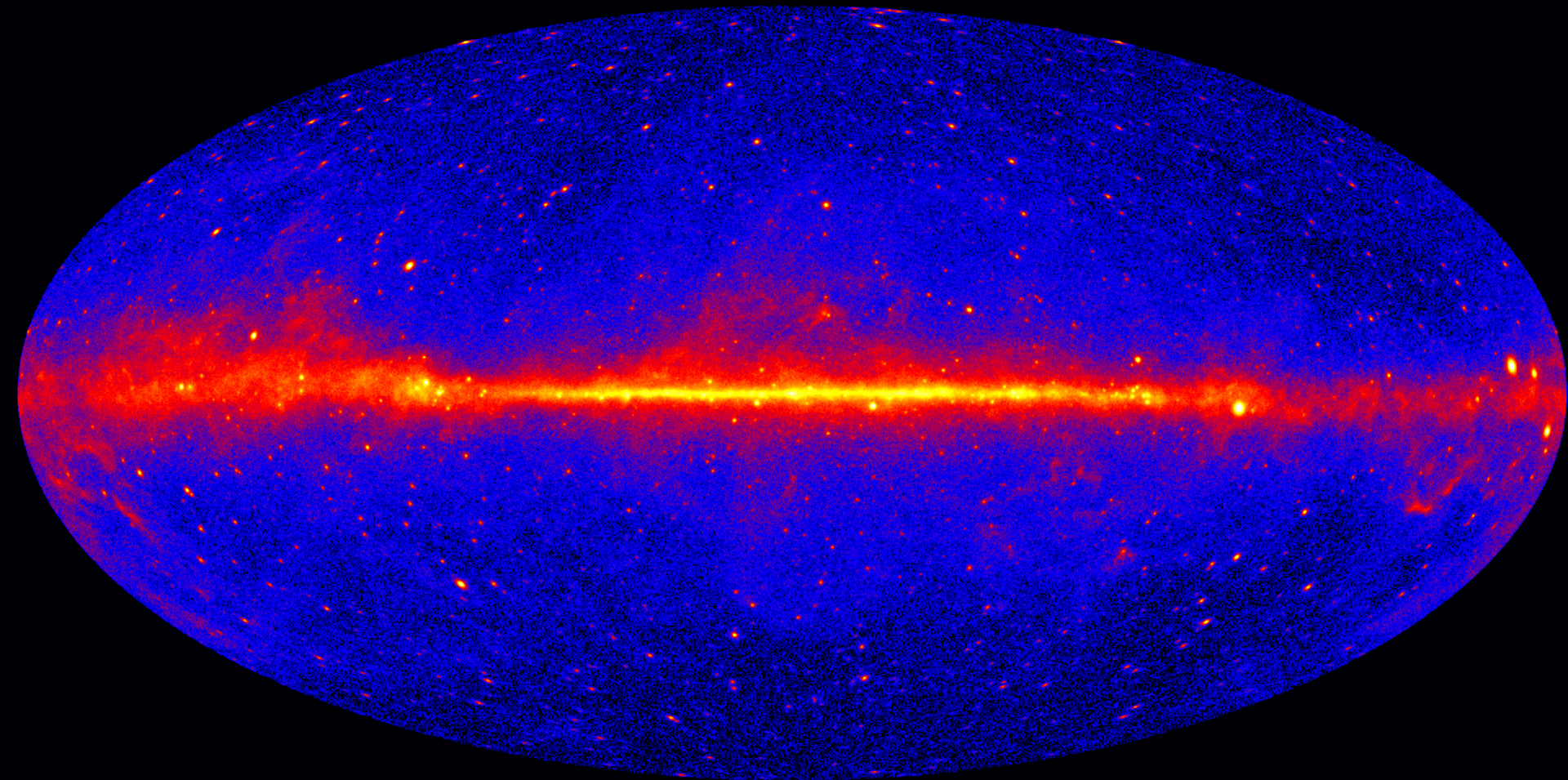
Lo spettro elettromagnetico



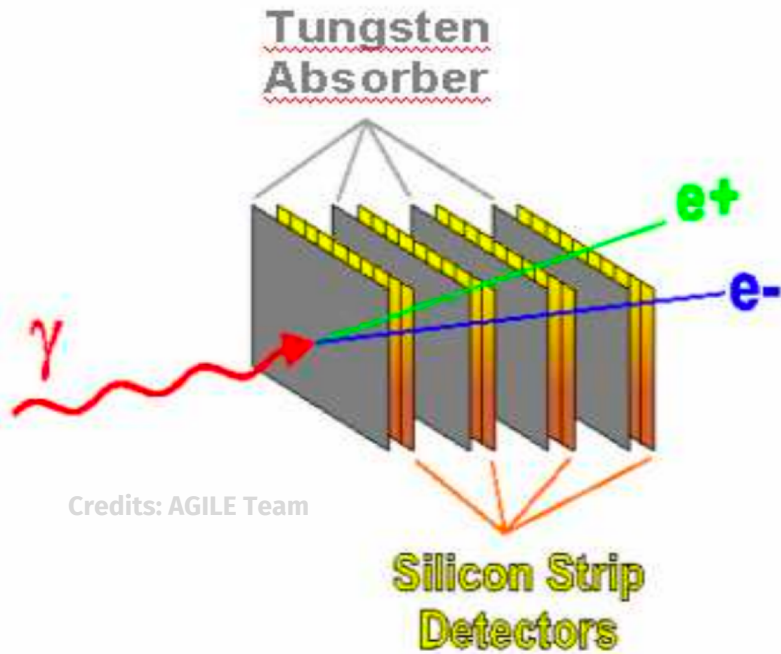
Fonte: Wikipedia



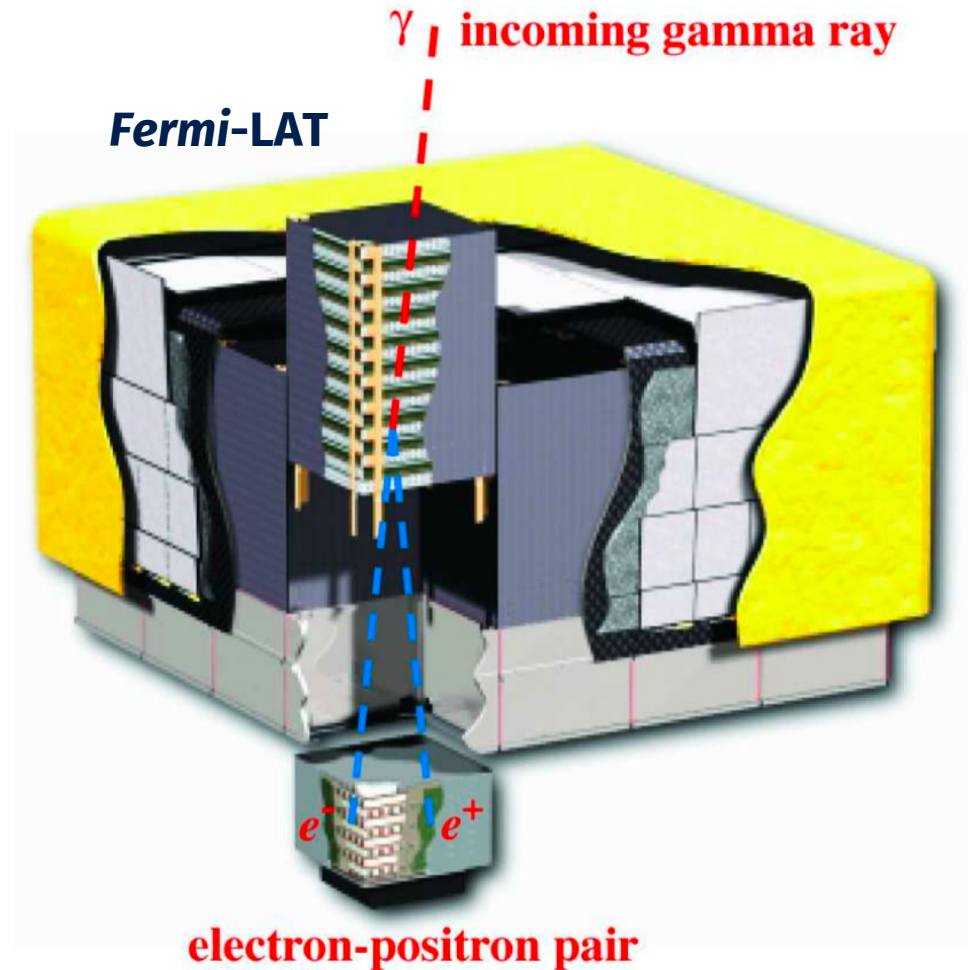
Il cielo nei raggi γ (secondo il telescopio *Fermi*)



Imaging dei raggi γ ($30 \text{ MeV} < 100 \text{ GeV}$)



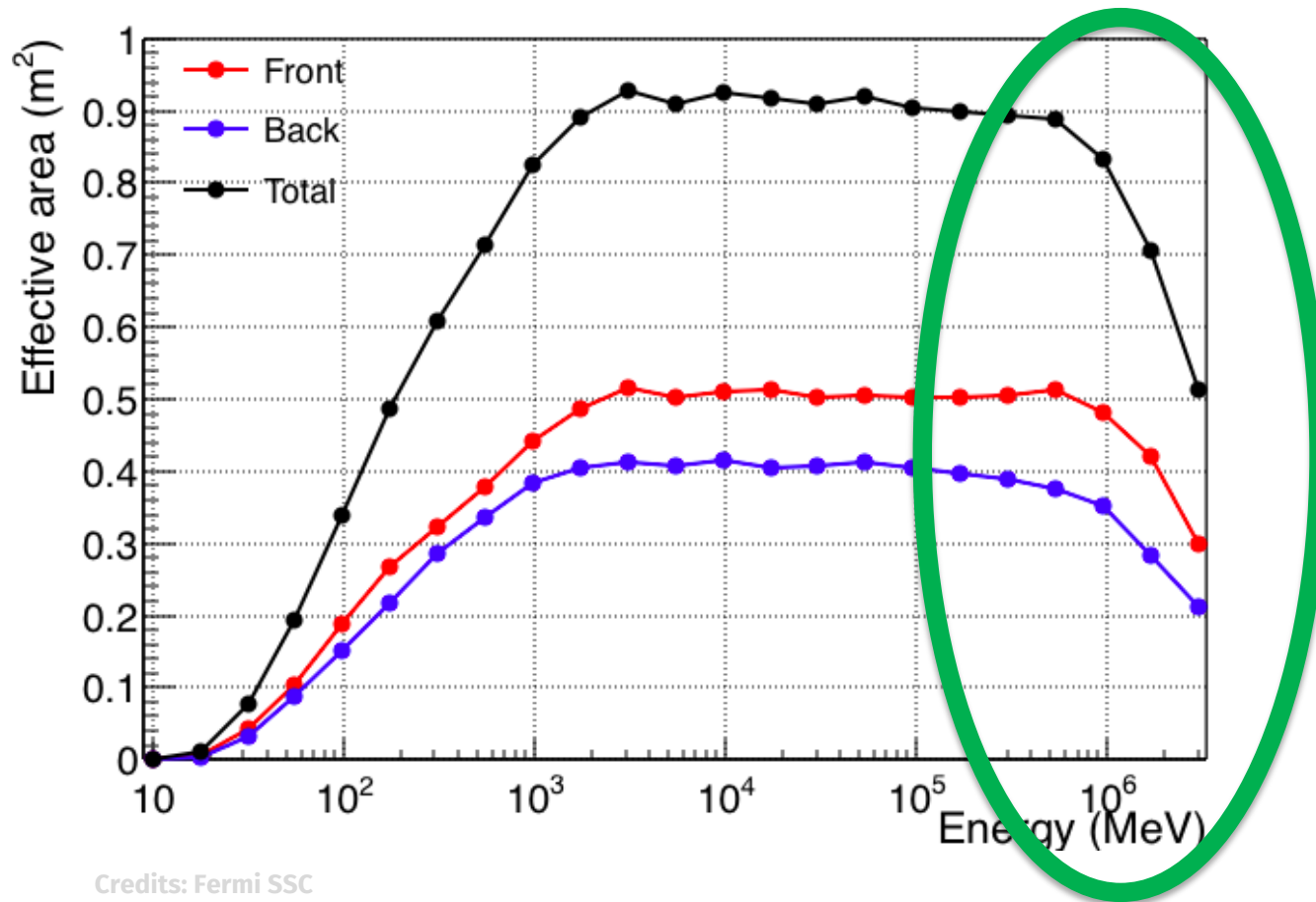
Osservare i raggi gamma in questo range di energia e' possibile solo dallo spazio, quindi i telescopi sono molto costosi: **Fermi ~ 700 milioni di USD.**



Cosa accade ad energie molto elevate?



Area efficace in asse del Large Area Telescope a bordo di Fermi-LAT



Area efficace = Area geometrica * Efficienza di rivelazione

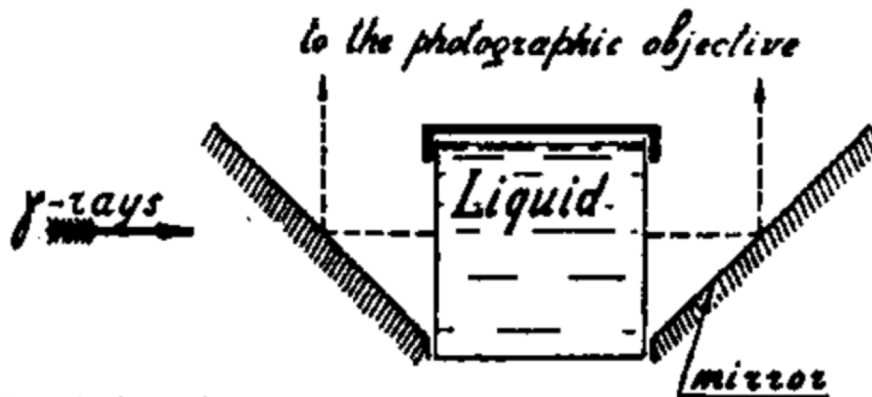
Una luce azzurrina...



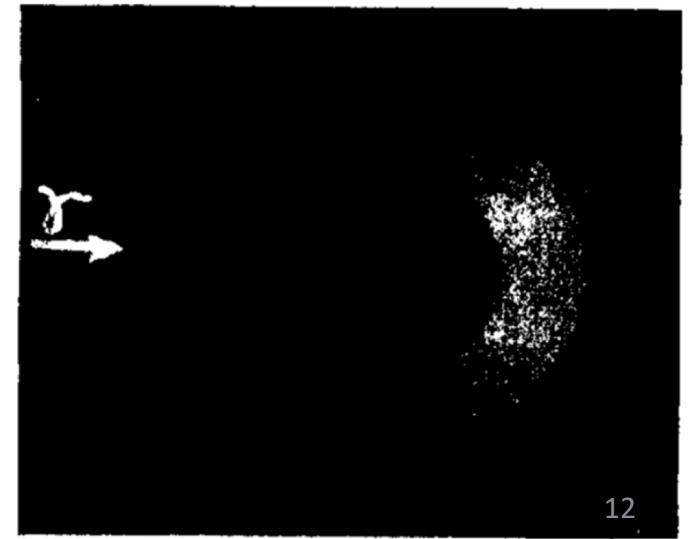
Pavel Alekseevič Čerenkov
1904 – 1990
Nobel per la Fisica nel 1958

P.A. Cerenkov
The Physical Institute of the Academy of Sciences U.S.S.R., Moscow
Received June 15, 1937

Visible Radiation Produced by Electrons Moving in a Medium
with Velocities Exceeding that of Light



Čerenkov, Physics Review. 52, 378, 1937



Effetto Čerenkov



Emissione di radiazione elettromagnetica da parte di un materiale le cui molecole sono polarizzate da una **particella carica in moto** che lo attraversa.

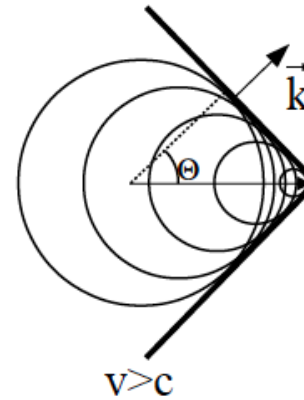
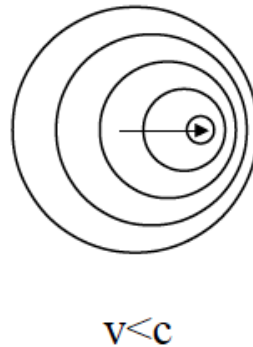
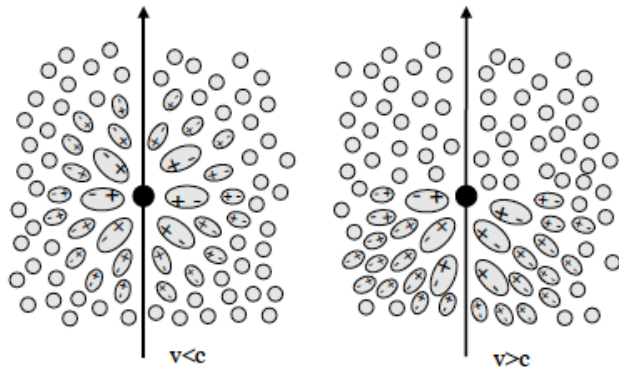
L'effetto Čerenkov si manifesta solo quando la **velocità della** particella nel mezzo attraversato risulta **superiore alla velocità della luce nello stesso mezzo**.

Analogo elettromagnetico
del boom sonico dei jet militari.



Effetto Čerenkov

de Naurois & Mazin, Comptes Rendue Physique, 16, 610, 2015



v : velocità
della particella
carica

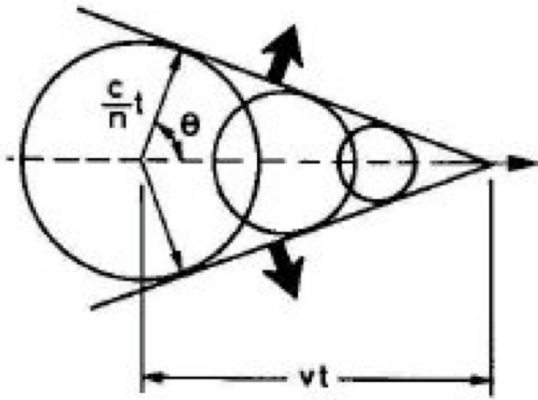
c : velocità della
luce *nel mezzo*

Se $v < c \rightarrow$ i dipoli sono disposti in maniera simmetrica $\rightarrow$ nessuna emissione.

Se $v > c \rightarrow$ rottura della simmetria $\rightarrow$ momento di dipolo diverso da zero, $\rightarrow$ emissione di radiazione.

L'energia spesa dalla particella nel polarizzare gli atomi del mezzo viene restituita dal mezzo nel processo di diseccitazione sotto forma di radiazione.

Effetto Čerenkov



n è l'indice di rifrazione del **mezzo**

c/n è la velocità della luce nel **mezzo**

$\beta = v/c$ è il rapporto tra la velocità della particella e la velocità della luce

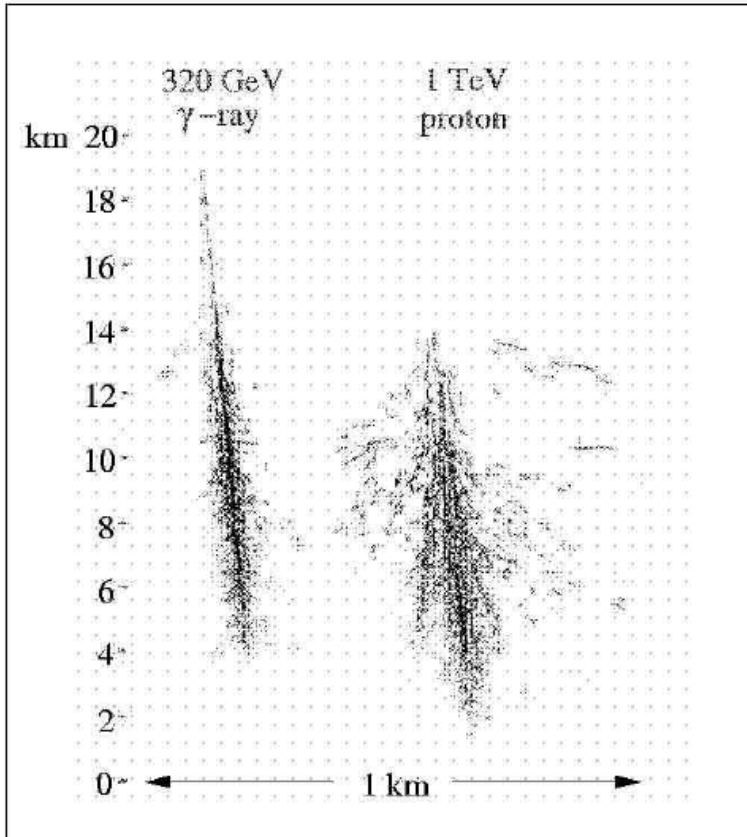
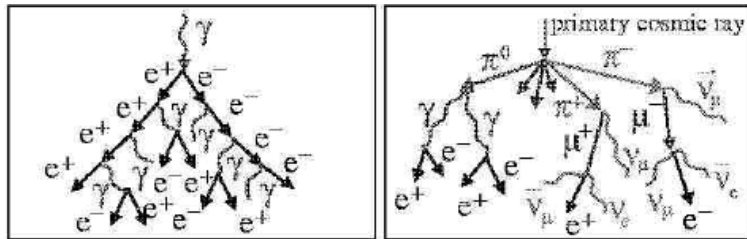
$$\text{Quindi } \cos \theta = (1/n) * (c/v) = 1/n\beta$$

Se la particella è relativistica, allora $\cos \theta \propto 1/n$

Nell'atmosfera $n \cong 1.00029 \rightarrow \theta \cong 1.3^\circ$

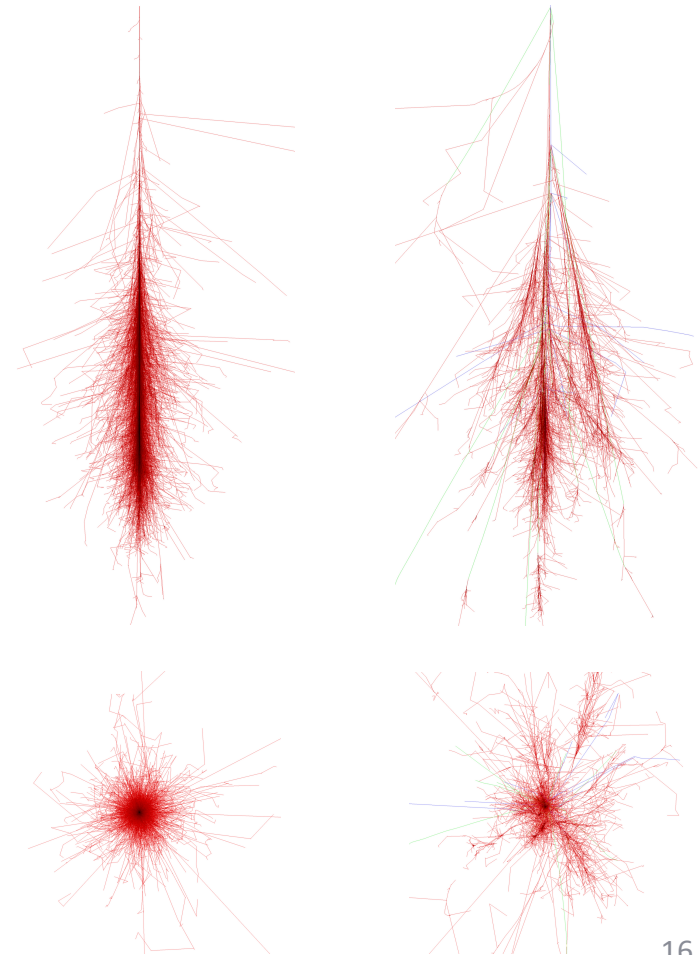
Nell'acqua $n \cong 1.335 \rightarrow \theta \cong 42^\circ$

Effetto Čerenkov

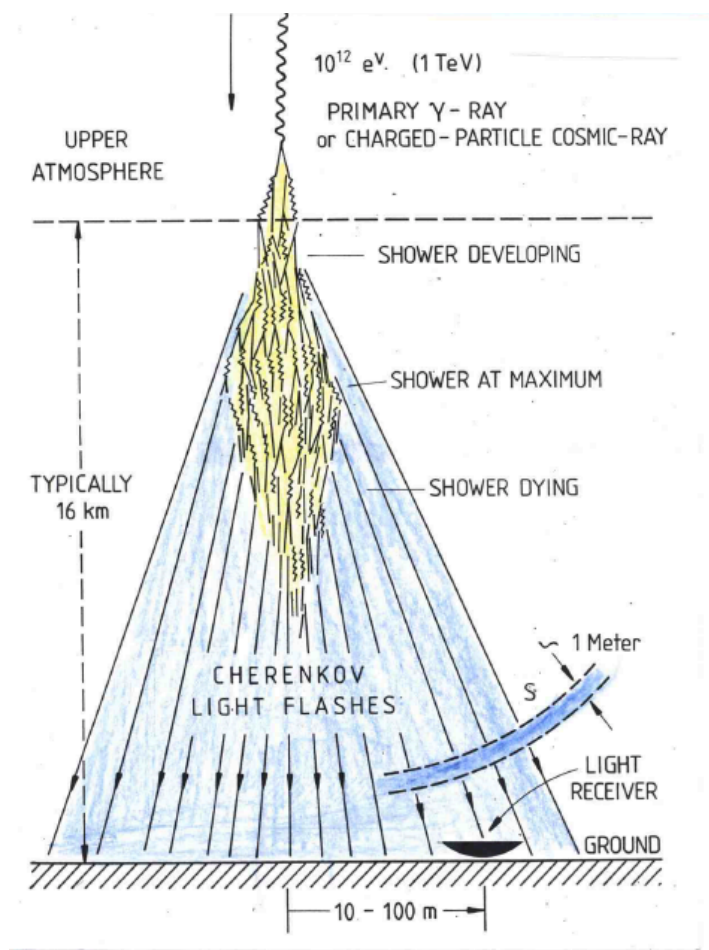


100 GeV photon

100 GeV proton



Effetto Čerenkov

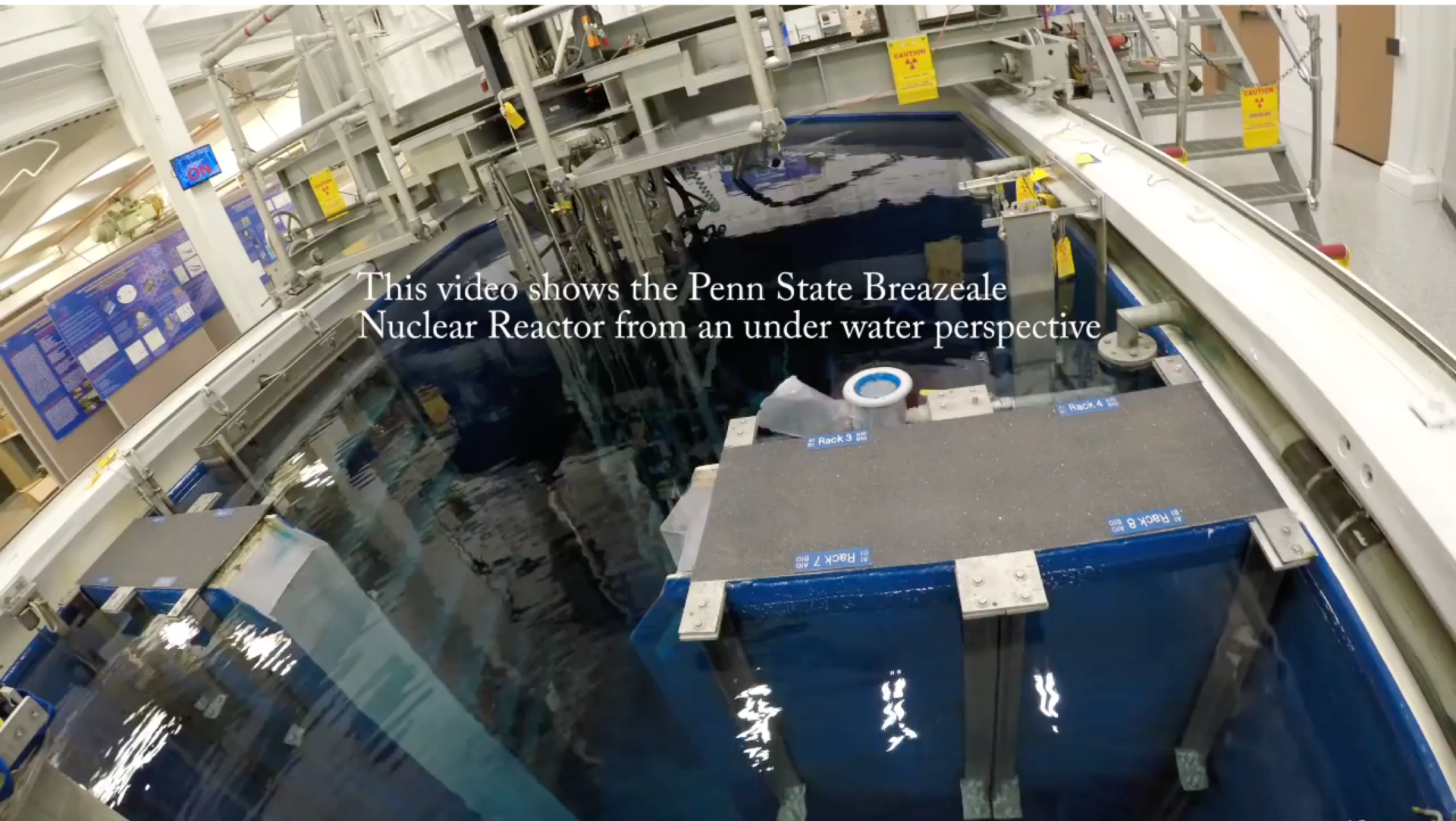


Il massimo sviluppo dello sciame (max luce Cherenkov) si ha a ~ 10 km di altezza.

L'area illuminata al suolo ha forma circolare/ellittica (dipende dall'inclinazione del primario) ed ha raggio $\sim 10000 \cdot (1.3^\circ \approx 0.023 \text{ mrad}) \approx 230 \text{ m}$.

Il numero di fotoni nella tipica banda di rivelazione ($300 \text{ nm} < \lambda < 550 \text{ nm}$) è di $5\text{-}20 \text{ } \gamma/\text{m}^2$.

... e l'acqua cosa c'entra ?



This video shows the Penn State Breazeale Nuclear Reactor from an under water perspective

Outline



Le altissime energie

I telescopi Cherenkov

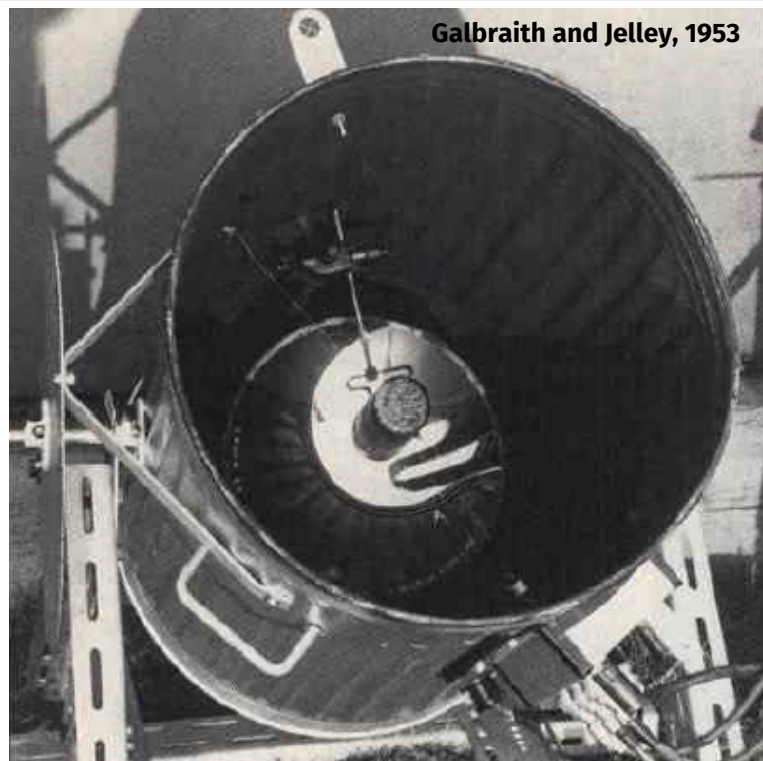
Il Progetto ASTRI

Il futuro Cherenkov Telescope Array

Scienza per tutti !



All'inizio erano semplici...



Bidone dell'immondizia, specchio,
fotomoltiplicatore.

Resti della Seconda Guerra Mondiale:
montature per cannoni e specchi per
illuminare il cielo.



Le prime luci



Credits: W. Benbow



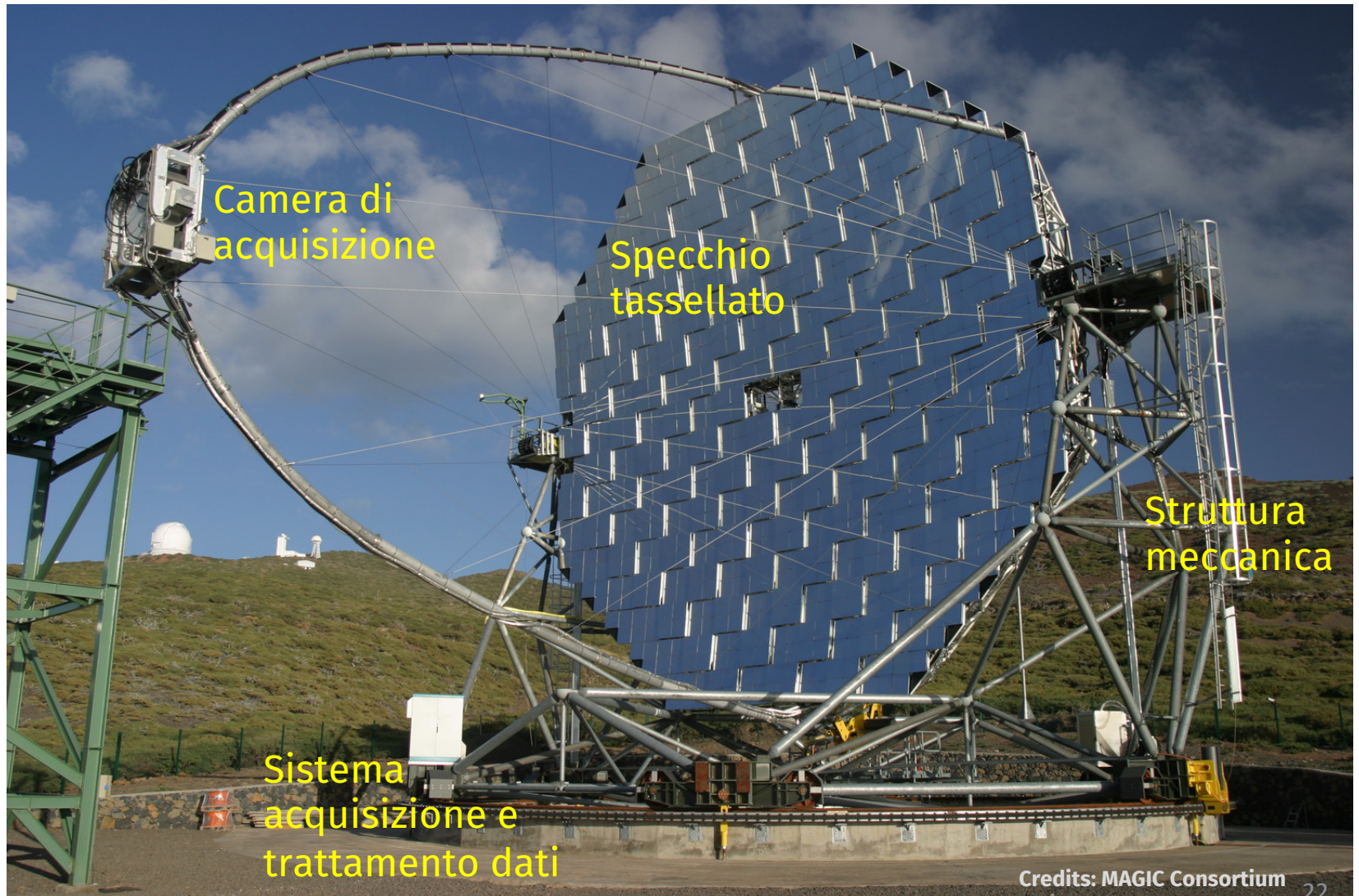
Buon compleanno Whipple !

Il 23 Ottobre 1968 veniva inaugurato il telescopio Whipple posto in Arizona (Mt. Hopkins).

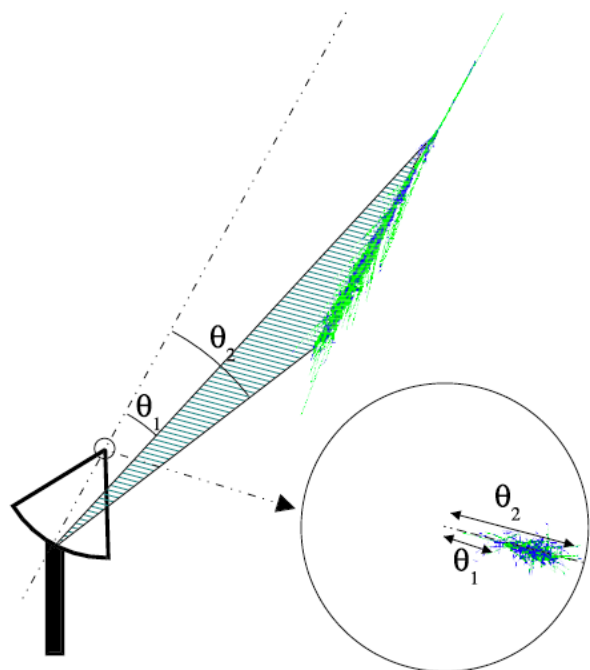
Il telescopio Whipple rivelò la prima sorgente VHE Galattica (la pulsar del Granchio, 1989) e la prima sorgente VHE extra-galattica (MRK 421, 1992).

Ci vollero 20 anni di test per ottenere questi primi successi !

Oggi questo è un tipico telescopio Čerenkov



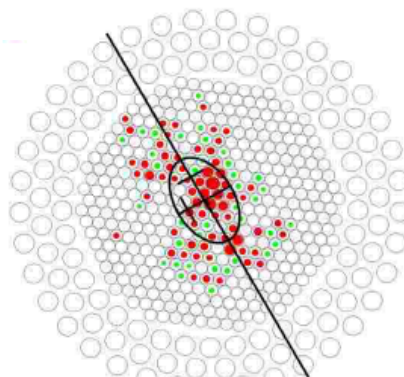
La luce Čerenkov sulla camera



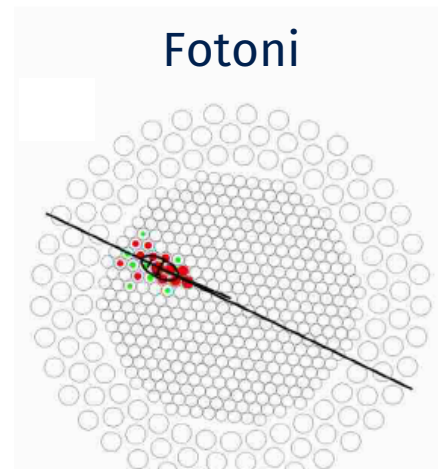
de Naurois & Mazin, Comptes Rendue Physique, 16, 610, 2015

La durata del flash Čerenkov è di circa **5-20 nano-secondi**, viene richiesta un'elettronica molto veloce.

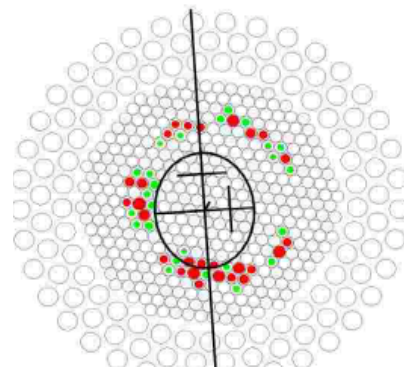
Particelle



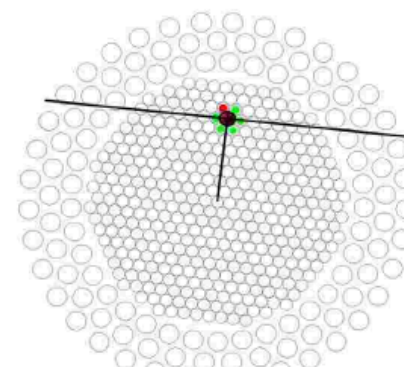
Fotoni



Muoni



Rumore fondo cielo

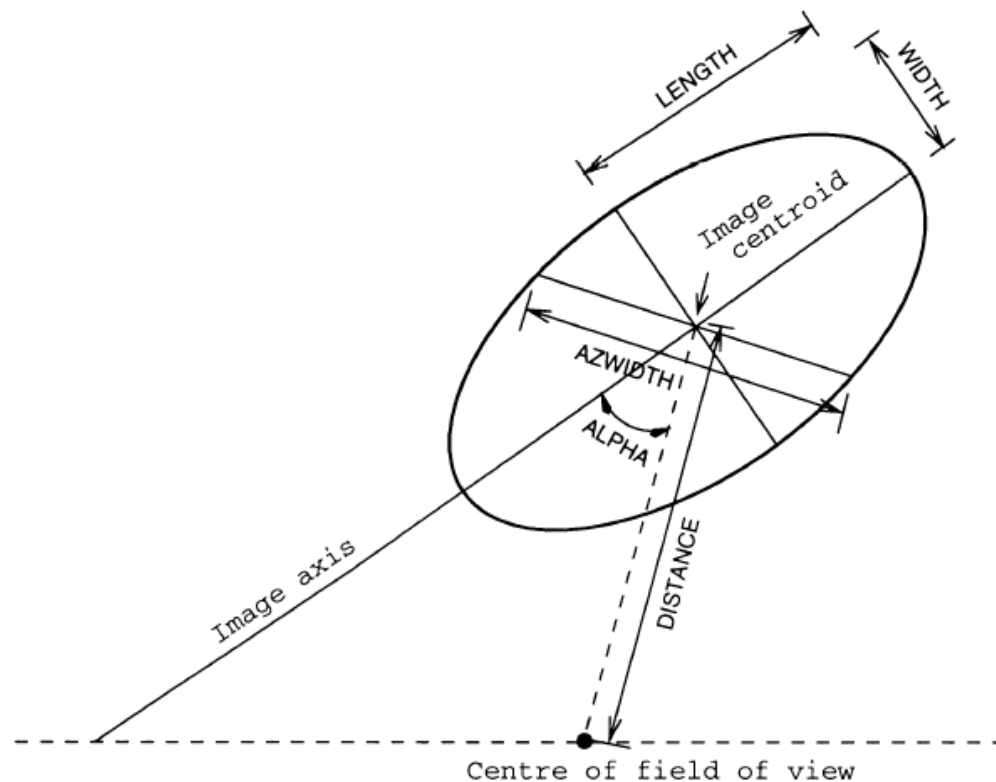


La luce Čerenkov sulla camera

Le **quantita' fisiche** legate all'evento che viene rivelato dalla camera Čerenkov sono derivate **dall'analisi morfologica dell'ellisse** attraverso i **parametri di Hillas**.

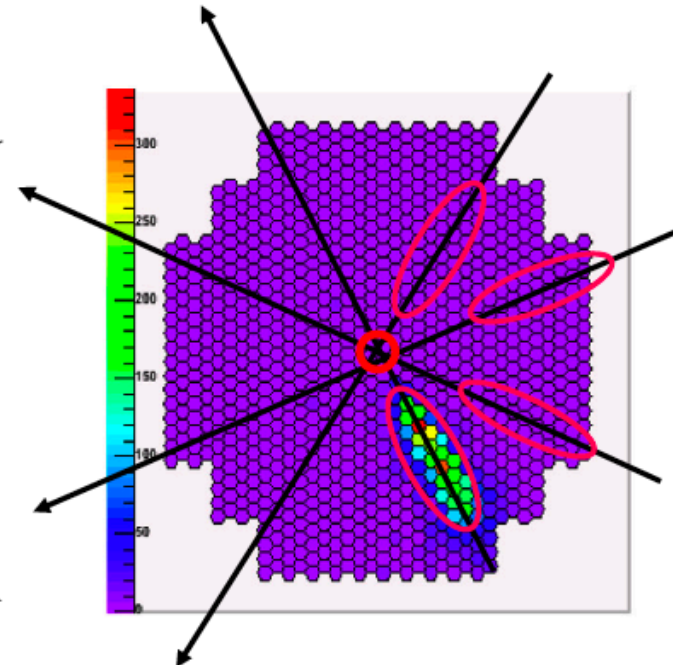
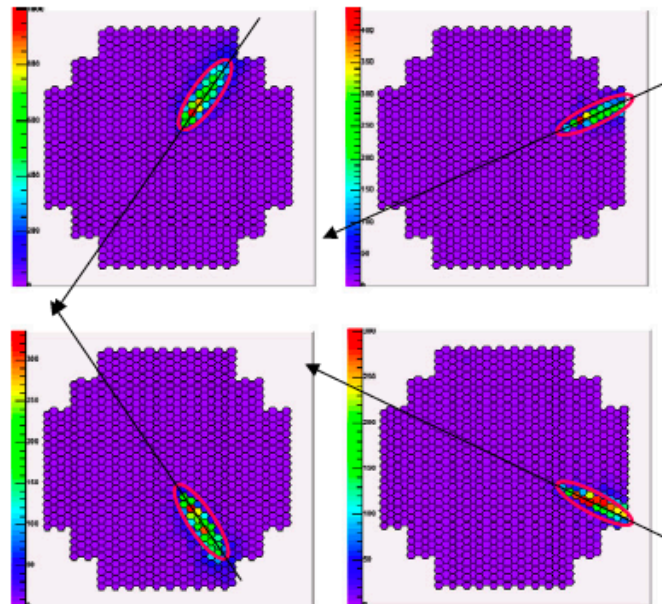
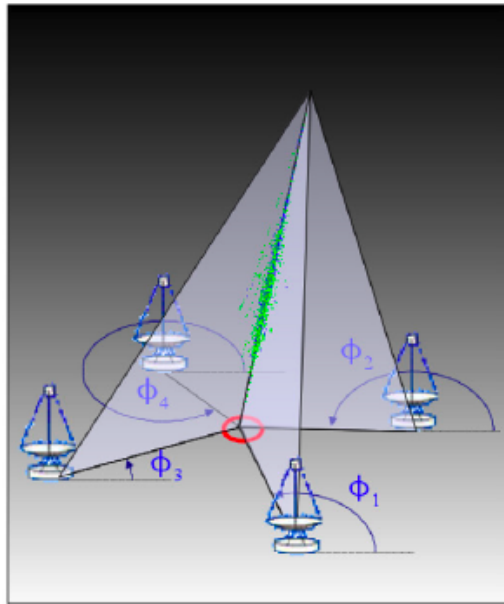
Per esempio, tipicamente gli eventi gamma hanno un piccolo valore del parametro **alpha**.

I parametri ottimali per separare il segnale dal fondo sono determinati per mezzo di **simulazioni Monte Carlo**.



Ong, 1998, Physics Reports, 305 , 93

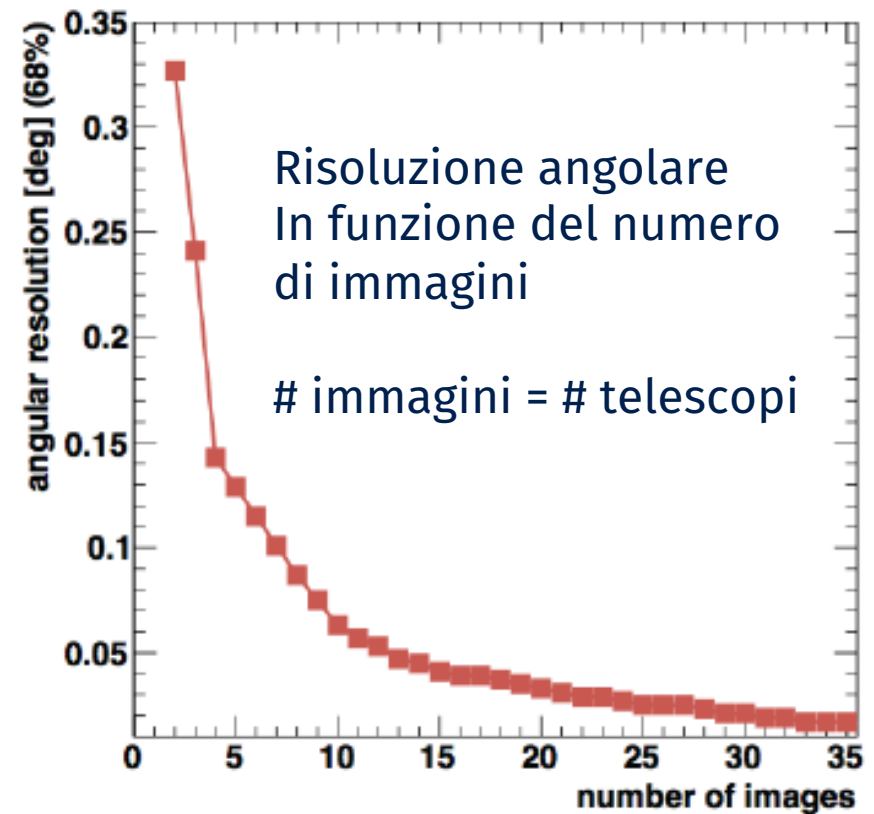
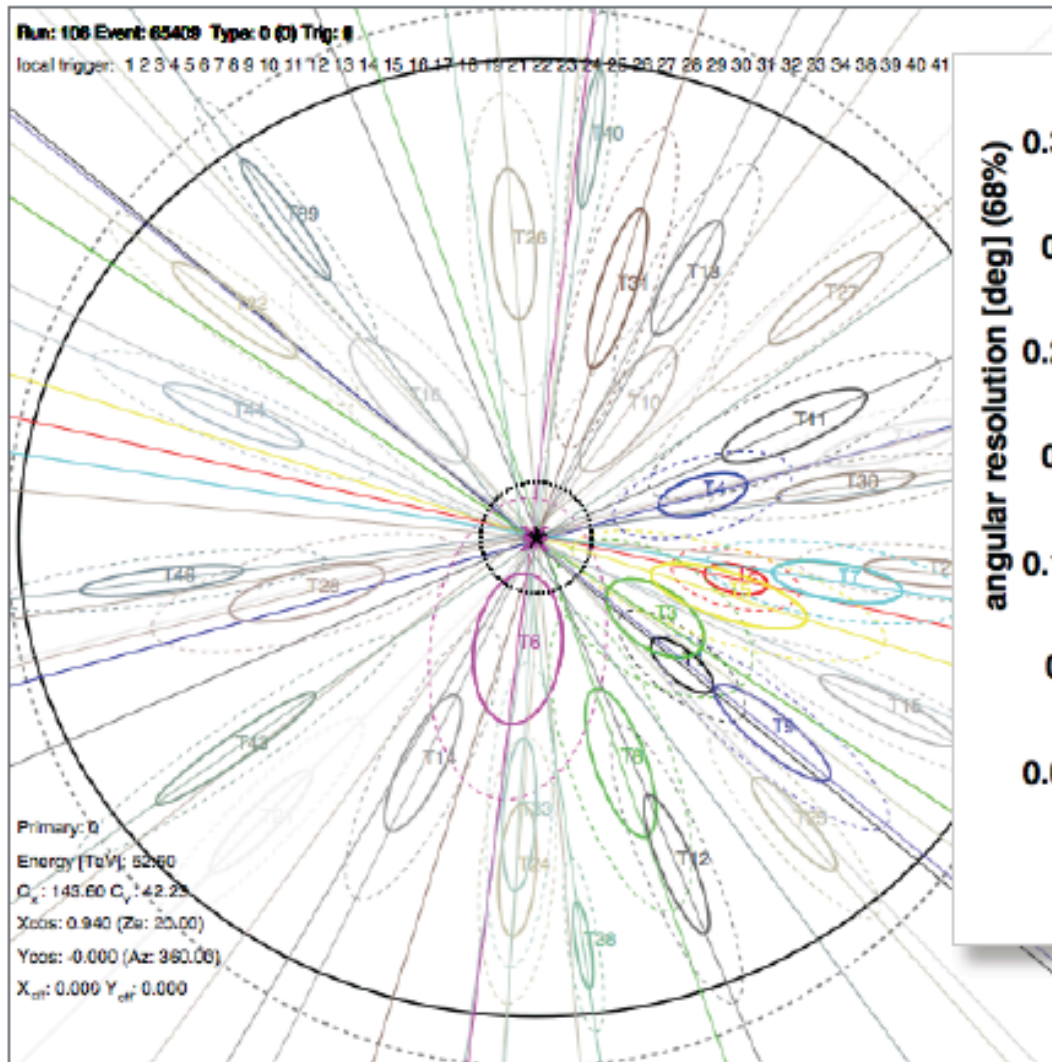
Un salto in avanti: la stereoscopia



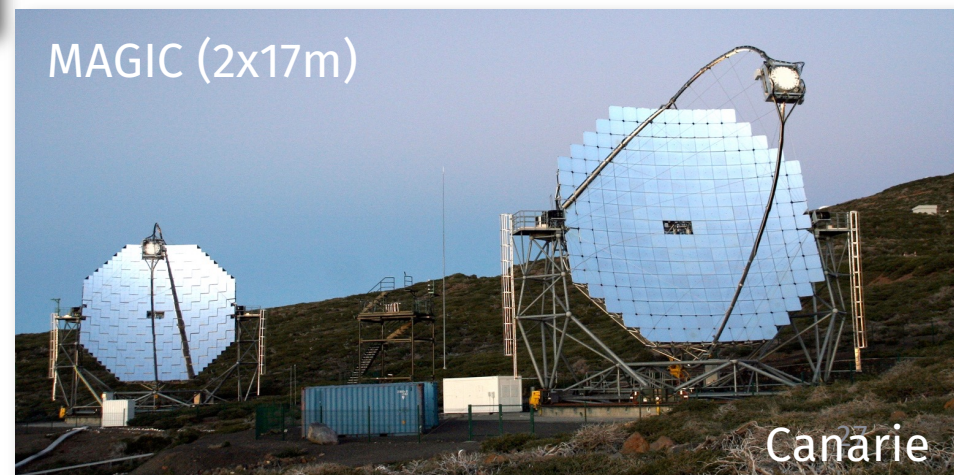
de Naurois & Mazin, Comptes Rendue Physique, 16, 610, 2015

L'utilizzo di un **array di telescopi** permette di ottenere una miglior **reiezione del fondo** di particelle e di migliorare sia la **risoluzione angolare**, sia la **risoluzione energetica**.

Vantaggi della stereoscopia



Gli array attuali



Una scienza abbastanza giovane



Hillas, 1985

CERENKOV LIGHT IMAGES OF EAS PRODUCED BY
PRIMARY GAMMA RAYS AND BY NUCLEI

A. M. Hillas
Physics Department
University of Leeds, Leeds LS2 9JT, UK.

ABSTRACT

It is shown that it should be possible to distinguish effectively between background hadronic showers and TeV showers from a point source on the basis of the width, orientation of the Cerenkov light images of the shower, the focal plane of a focusing mirror, even with a relatively coarse pixel size such as employed in the Mt. Hopkins d

1. Detection of point sources of cosmic rays

Certain X-ray binaries, pulsars and active galaxies appear to be sources of TeV cosmic rays — presumed to be gamma-rays — have been detected by observing flashes of Cerenkov radiation from the upper atmosphere, but these do not stand out against the intense isotropic background of ordinary proton showers. If the appearance of the Cerenkov flashes differs in classes of shower, much of the background might be rejected. paper, Dawley et al. (2) describe the modification of the 10m the Whipple Observatory (Mt. Hopkins, Arizona) to record data Cerenkov image on a 0.5° grid, using 37 photomultipliers in the plane of the focusing mirror. (A central photomultiplier is a ring of 6 others, then by a further ring of 12, and another whole forming a hexagonal grid pattern.) Predictions of the this system to air showers will be presented. Even though the widths of shower images are less than 0.5°, the image dimensions measured well enough to provide discrimination between types though the alignment of the short image with the source will be clear than with finer angular resolution.

2. Simulation of Cerenkov image patterns

A 3-dimensional Monte-Carlo calculation is used to aid development. The computer program has been used previously investigations (2) and is much more detailed than is necessary ting Cerenkov processes, following particles down to an ether (far below the Cerenkov threshold), although "thin sampling" to follow particles below 1/1000 of the primary energy to re-time. The model atmosphere is not isothermal. Hadronic collisions simulated both by a radial scaling model with rising cross and by a model with increased production of low-energy secondary to scaling) at high primary energies (though a less dramatic proposed by Mészáros and Wolfendale, for example, as the particles in the fragmentation region — high x — are larger. However, at TeV energies, there is little difference between the constrained by accelerator data, so the simulation results are used together in the presentation below. Although some loss of Cerenkov light by Rayleigh and scattering is allowed for (2), scattered light is assumed not to be spread of the image (size $\sim 1^\circ$) in a clear mountain atmosphere.

Le basi

445
00 9.5-3

The Astrophysical Journal, 342:379-385, 1989 July 1
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OBSERVATION OF TeV GAMMA RAYS FROM THE CRAB NEBULA USING THE ATMOSPHERIC CERENKOV IMAGING TECHNIQUE

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D. A. LEWIS,⁴ D. MACOM,⁵ N. A. PORTER,² P. T. REYNOLDS,^{1,2} AND G. VACANTI¹

Received 1987 August 1; accepted 1988 December 9

ABSTRACT

The Whipple Observatory 10 m reflector, operating as a 37 pixel camera, has been used to observe the Crab Nebula in TeV gamma rays. By selecting gamma-ray images based on their predicted properties, more than 98% of the background is rejected; a detection is reported at the 9.0 σ level, corresponding to a flux of 1.8×10^{-11} photons $\text{cm}^{-2} \text{s}^{-1}$ above 0.7 TeV (with a factor of 1.5 uncertainty in both flux and energy). Less than 25% of the observed flux is pulsed at the period of PSR 0531. There is no evidence for variability on time scales from months to years. Although continuous emission from the pulsar cannot be ruled out, it seems most likely that the observed flux comes from the hard Compton synchrotron spectrum of the nebula.

Subject headings: gamma rays: general — nebulae: Crab Nebula — pulsars — radiation mechanisms

1. INTRODUCTION

The observation of polarization in the radio, optical, and X-ray emission from the Crab Nebula is usually taken as confirmation of the synchrotron origin of the radiation and is a strong indication of the presence in the nebula of a reservoir of relativistic electrons with energies up to 1 TeV. The presence of the radio pulsar, PSR 0531, near the center of the nebula provides a source for the on-going injection of relativistic electrons into this reservoir. The collision of the synchrotron-radiating electrons with synchrotron-radiated photons within the nebula inevitably results in a hard photon spectrum (at some level) that extends from the X-ray into the gamma-ray energy range; the shape of the spectrum mirrors that of the soft photon spectrum but with greatly reduced intensity. The Compton synchrotron model of the nebula was first developed by Gould (1965) and was refined by Rieke and Weekes (1969) and by Grindlay and Hoffmann (1971). A strong flux of gamma rays was predicted with maximum luminosity in the 0.1–1.0 TeV energy range. The gamma-ray flux level depends on the strength of the nebular magnetic field, which is a free parameter in the model and is little constrained by observations at other wavelengths. However, based on equipartition arguments, it is estimated to be $\sim 10^{-5}$ G.

The observation of a flux of 0.14 TeV gamma rays from the Crab Nebula was reported by the Parisian group using the atmospheric Cerenkov imaging technique (Croci et al. 1972); based on observations that spanned 3 years, their detection was still only at the 3 σ level. This demonstrates the extreme weakness of the source and the lack of sensitivity of this technique. The detection of TeV gamma rays from the Crab Nebula is a confirmation of the Compton synchrotron model and provides a direct measure of the magnetic field. This measurement, which was conservatively interpreted as an upper limit, places an average magnetic field of 3×10^{-5} G, or a radially symmetric field of 1.5×10^{-5} G with $B_z = 1 \times 10^{-5}$ G at a distance of 0.1 pc from the pulsar (Grindlay 1976).

Subsequent to the discovery of PSR 0531 in the nebula, gamma-ray observations concentrated on the pulsar because greater sensitivity could be achieved by the assumption of a concentration of the gamma-ray emission with the periodic radio emission. Several detections were reported at very low energies (Grindlay 1972; Jennings et al. 1974; Grindlay, Heinen, and Weekes 1978; Porter et al. 1976; Escoffier, Lumb, and Lamb 1976; Vishwamath 1982; Vishwamath et al. 1983; Gupta et al. 1977; Gibson et al. 1982b; Downhale et al. 1984; Tanar et al. 1985; Bhat et al. 1986), but the statistical significance was not high, and upper limits were also produced which appeared to be in conflict with the reported flux (Heinen et al. 1973; Vishwamath et al. 1986; Bhat et al. 1987). At energies above 1 TeV there were also reports of emission from the direction of the Crab (Mukasey 1983; Beere et al. 1984; Dzikowski et al. 1981; Kirov et al. 1985), but, because the limited angular resolution and the absence of anticoincidence, it was not possible to identify the source or observed signal with the nebula or the pulsar. Again there were conflicting upper limits (Craig et al. 1981; Watson 1981; 100 MeV energies (which are accessible to study by π chambers on satellites), both a pulsed and steady component were detected (Kusler et al. 1977; Horrocks et al. 1977; Cl. et al. 1987); at 1 GeV the strength of the unpulsed component (which might originate in the nebula or near the pulsar) is 6 times that of the pulsed flux.

Using a refined version of the atmospheric Cerenkov technique, we here report the detection of gamma rays above 0.7 TeV from the Crab Nebula at a high level of statistical significance; over the epoch 1966–1988 we find no evidence for variability, and the observed flux is in agreement with that reported previously in 1969–1972 and in an earlier observation using this same technique in 1983–5 (Cawley et al. 1987; Gibbs 1987). The observed gamma-ray flux is only 0.2% of cosmic-ray background. A periodic analysis using the 3.3 yr time period of the pulsar indicates that less than 25% of observed signal is pulsed. The detection of such a weak but a steady (non-pulsed) source with a significance of 9 σ demonstrates the development of the atmospheric Cerenkov ground-based gamma-ray astronomy. It demonstrates the power of using atmospheric Cerenkov imaging to detect gamma-ray-initiated air showers from those gamma rays

1 sorgente

>150 sorgenti

Hinton & Hoffmann, 2009

Teraelectronvolt Astronomy

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²Departments of Physics and Astronomy, Max Planck Institute für Kernphysik, Heidelberg D-69029, Germany; email: werner.hofmann@mpi-kp.de



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0068-4169/09/07-0523\$20.00

Key Words

gamma-ray astronomy, high-energy astrophysics

Abstract

Ground-based γ -ray astronomy, which provides access to the TeV energy range, is a young and rapidly developing discipline. Recent discoveries in this wavelength have important consequences for a wide range of topics in astrophysics and astroparticle physics. This article is an attempt to review the experimental status of this field and to provide the basic formulas and concepts required to begin the interpretation of TeV observations.

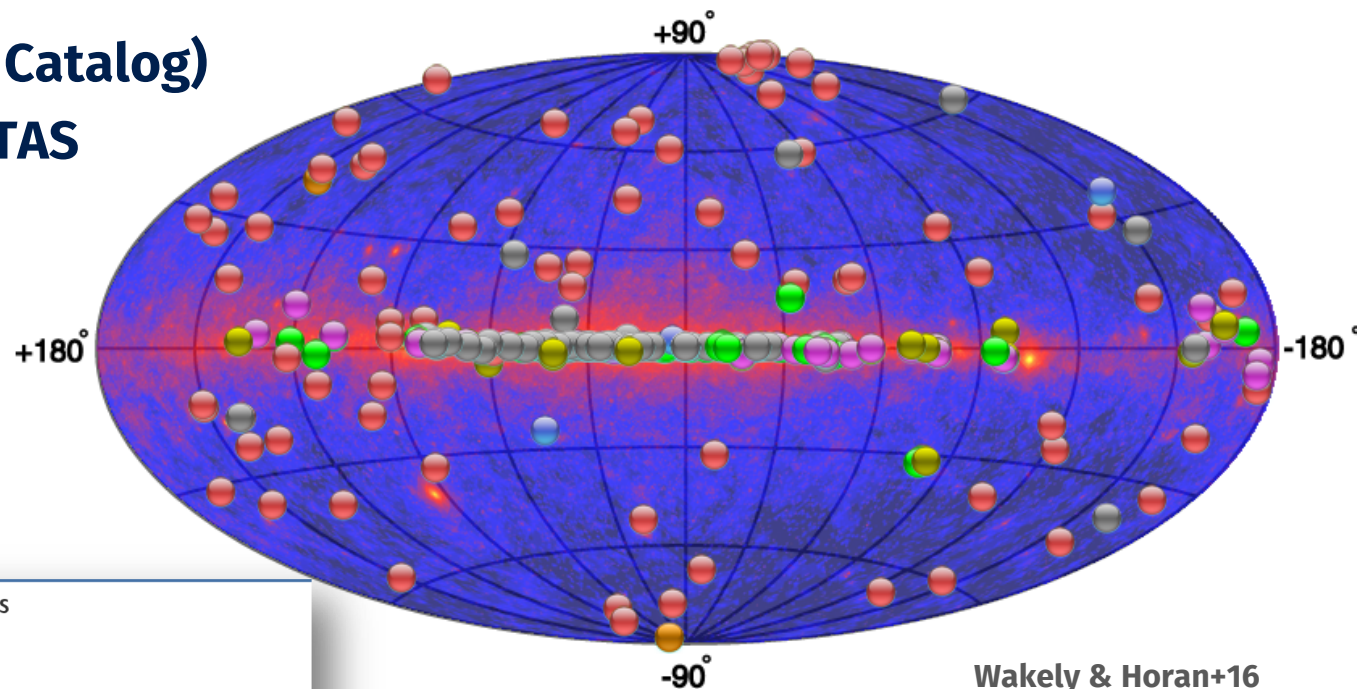
Il cielo sopra i 100 GeV

TeVCat (TeV sources Catalog)

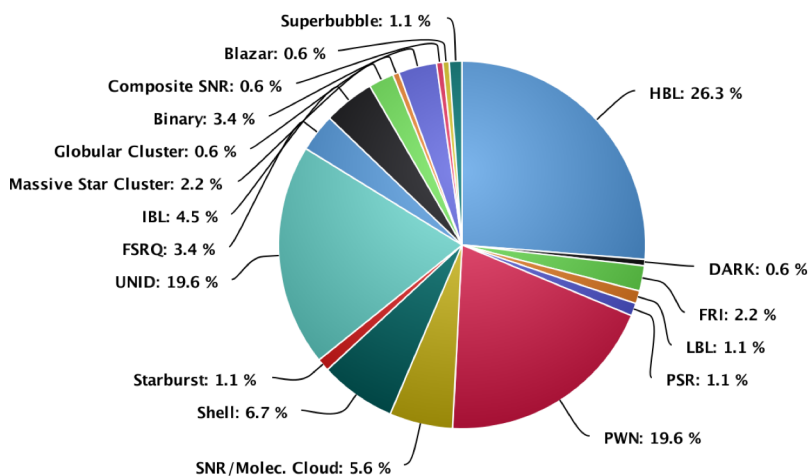
H.E.S.S., MAGIC, VERITAS

~220 sorgenti

$E > 100 \text{ GeV}$



TeVCat Source Types



Cielo al TeV (pallini) sovrapposto al cielo visto da *Fermi*-LAT (mappa).

Spesso sono simili, ma vi possono essere importanti **differenze...**

Come migliorare rispetto agli array attuali?



Come migliorare rispetto agli array attuali?

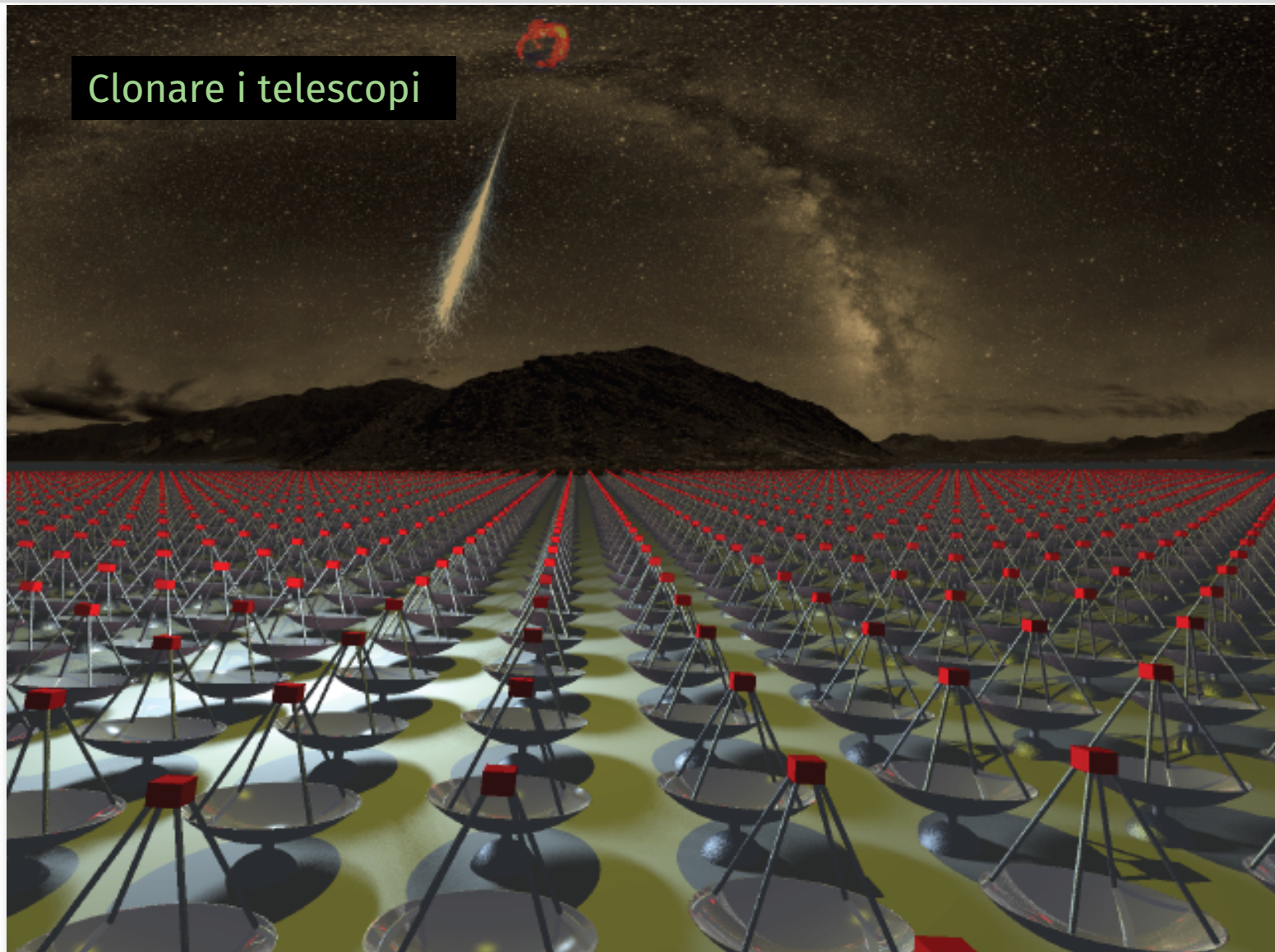


A long time ago in a galaxy far,
far away....

"L'attacco dei cloni"



La soluzione ottimale per i telescopi Čerenkov

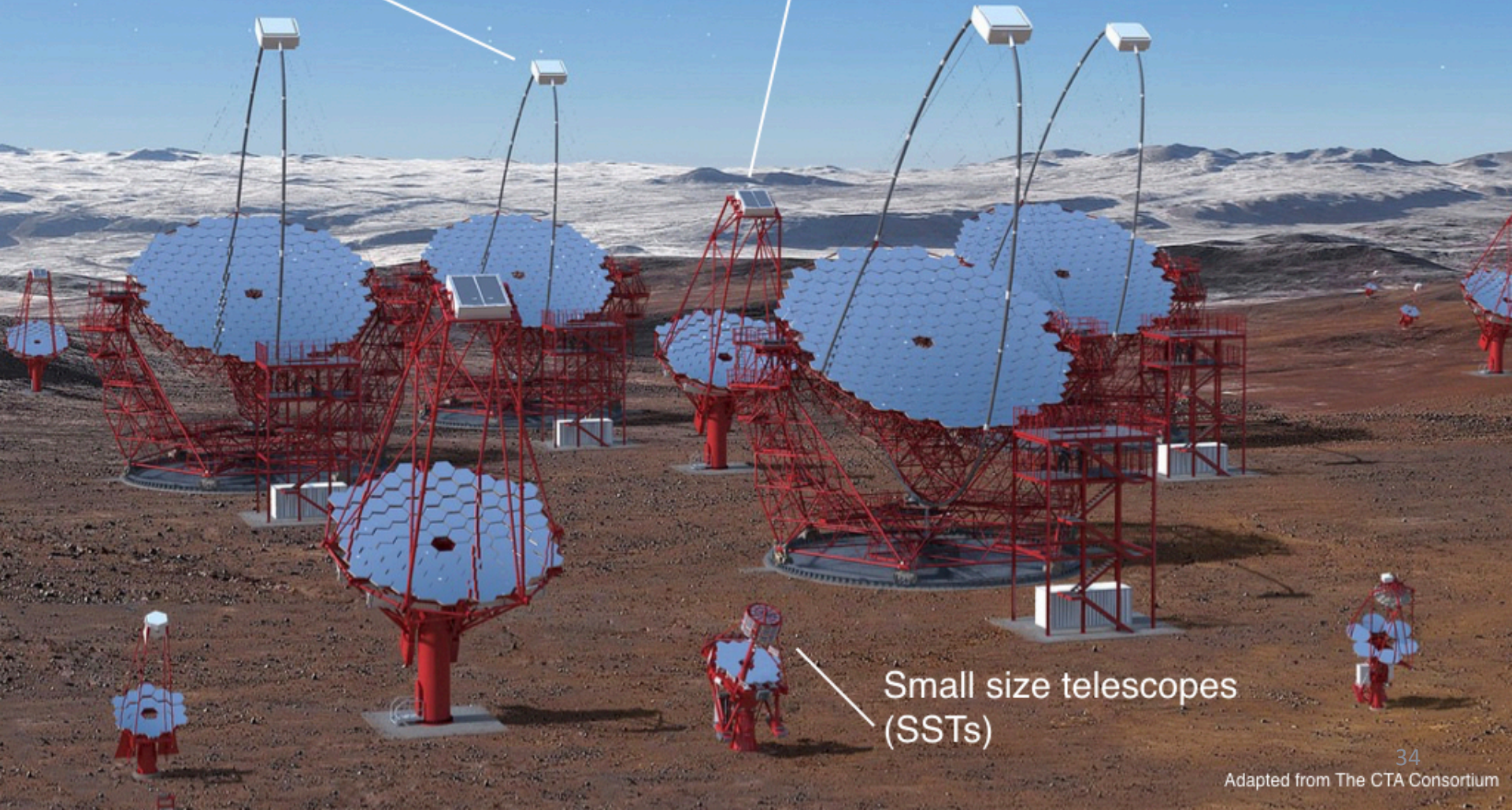


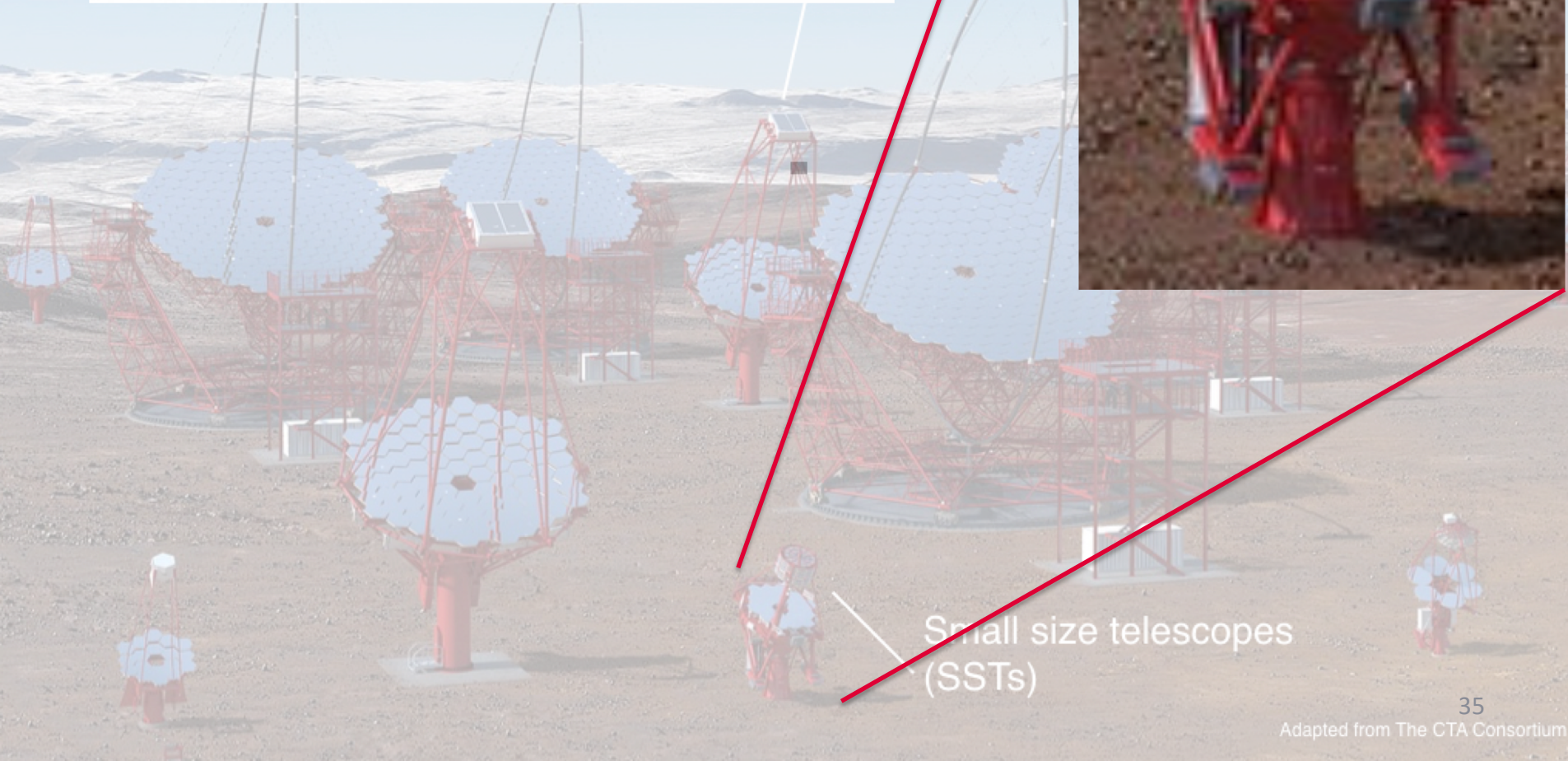
Una soluzione piu' ragionevole...

Large size telescopes
(LSTs)

Medium size telescopes
(MSTs)

Small size telescopes
(SSTs)





Small size telescopes
(SSTs)

Outline



Le altissime energie

I telescopi Cherenkov

Il Progetto ASTRI

Il futuro Cherenkov Telescope Array

Scienza per tutti !



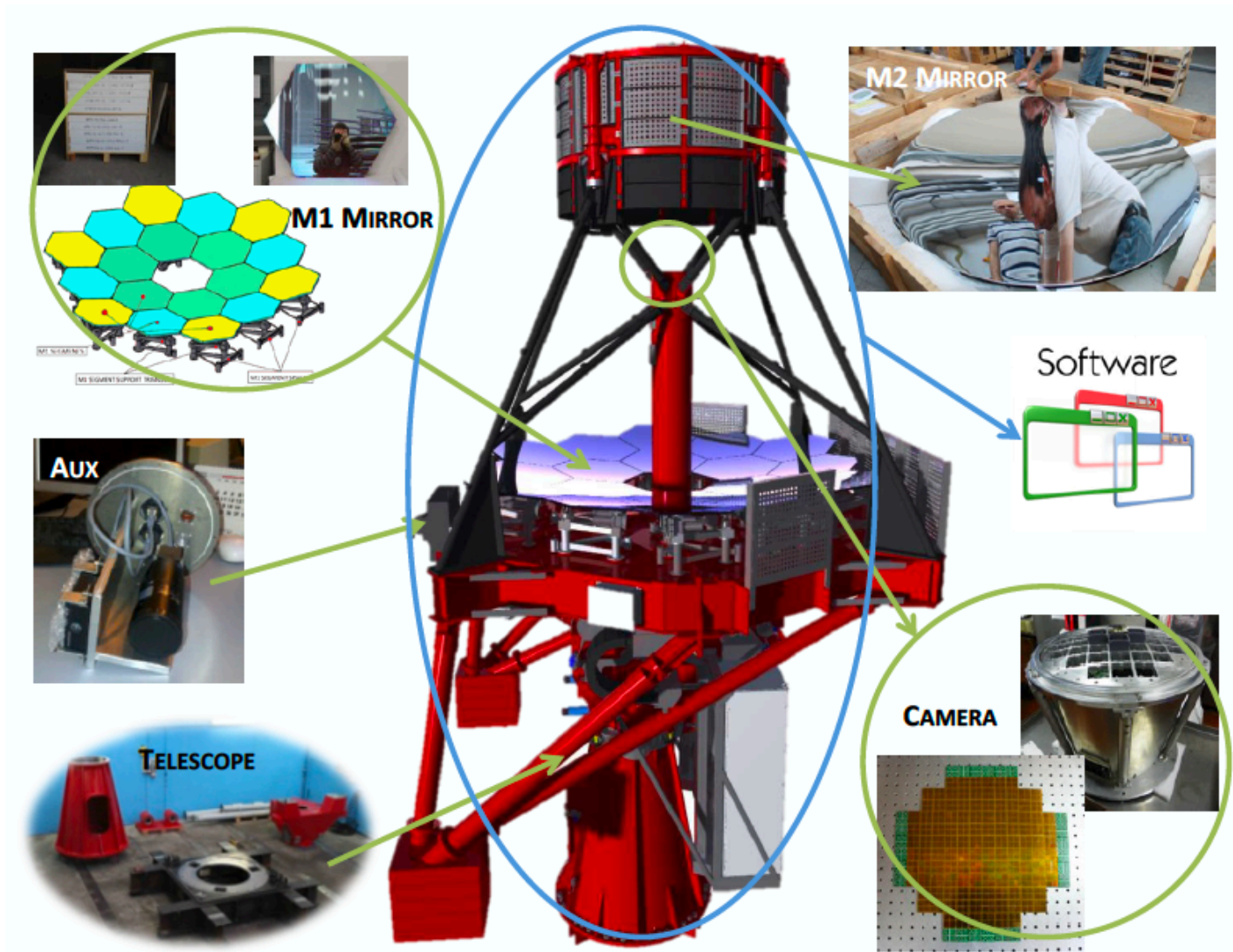
Astrofisica con **S**pecchi a **T**ecnologia **R**eplicante **I**taliana

Goal #1: progettare e costruire un ***prototipo end-to-end*** da proporre come SST a due specchi per CTA.

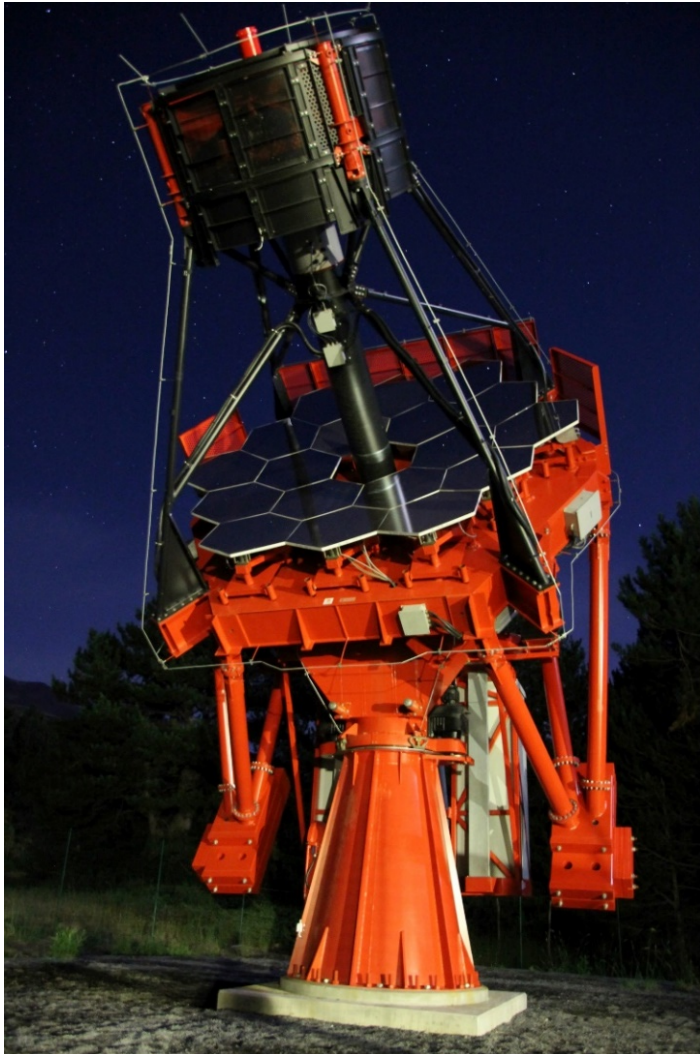
Goal #2: costruire un ***mini-array di 9 telescopi*** per CTA.

Goal #3: contribuire all'intero ***array di SST per CTA***.

Cosa significa *end-to-end* ?



Il Progetto ASTRI



Inaugurazione prototipo (24/09/2014)



Stazione osservativa INAF di Serra La Nave (CT)

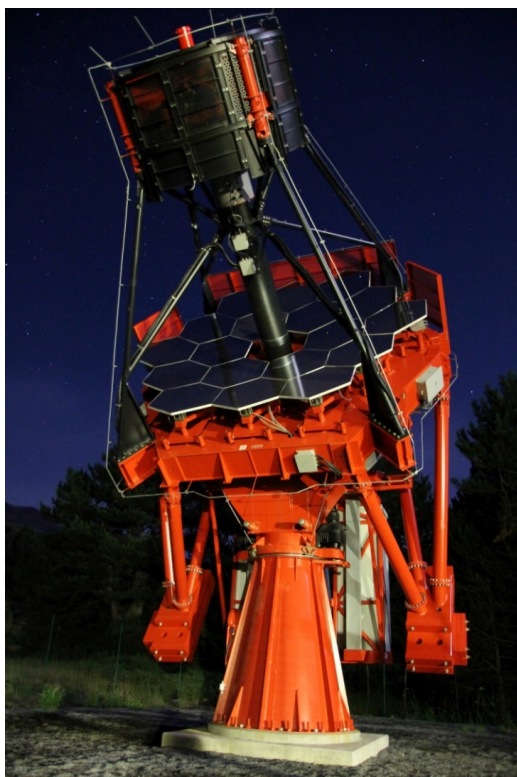


Credits: T. Abegg

Il prototipo ASTRI



Le soluzioni innovative del prototipo ASTRI



Disegno ottico a 2 specchi (ASTRI SST-2M)

Prima volta per telescopi Čerenkov
Configurazione ottica Schwarzschild-Couder
Miglior PSF lungo tutto il campo di vista

Foto-rivelatori al silicio

Pixel di piccole dimensioni
Possono lavorare anche con la luce della Luna

Ampio campo di vista ($\sim 10^\circ$ di $\varnothing$)

Importante per le survey e le sorgenti estese
Permette di rivelare eventi a 100 TeV

Sito osservativo operativo INAF

Installato a Serra La Nave sul Monte Etna (CT)

L'Etna e' un vero sito astronomico...



Credits: Pareschi

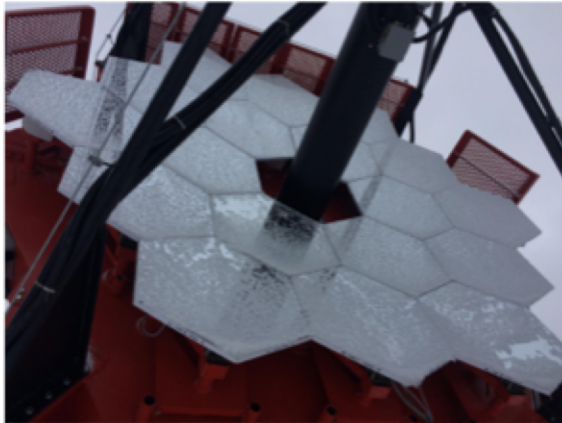
...anche se e' un po' peculiare...



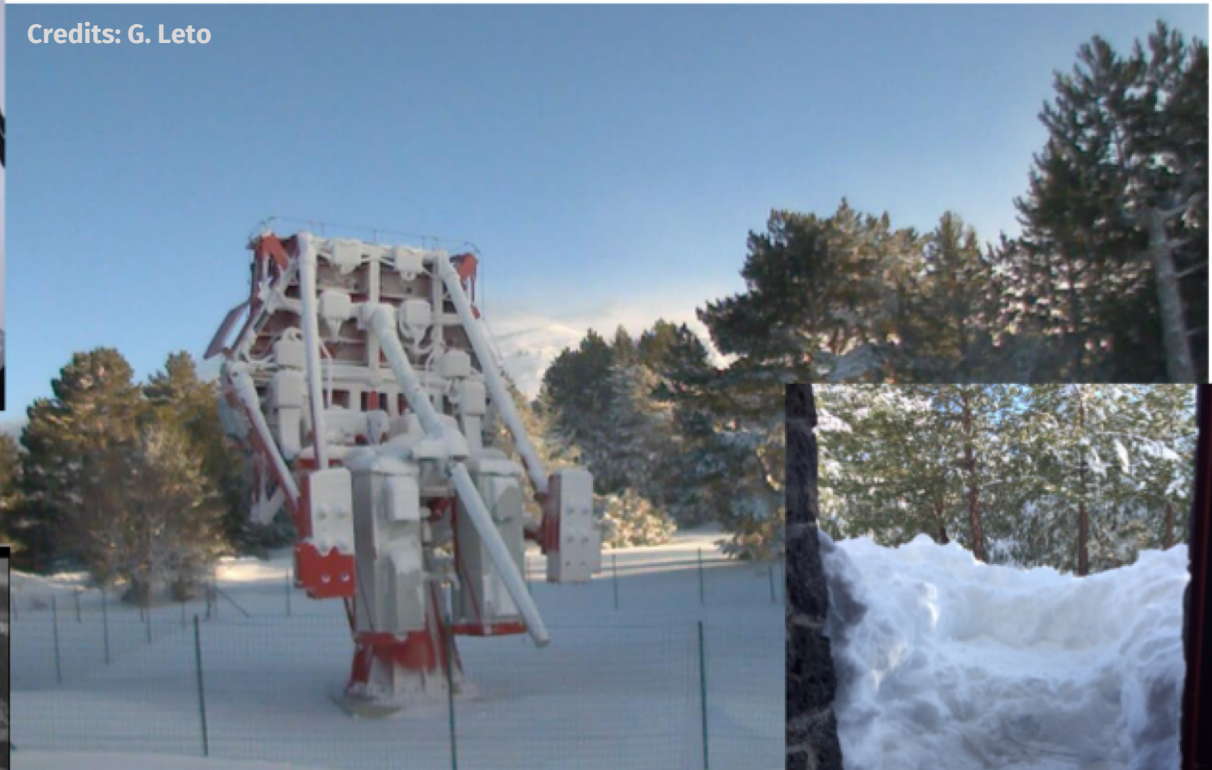
Credits: ASTRI Team



...gli inverni possono essere severi !



Credits: G. Leto

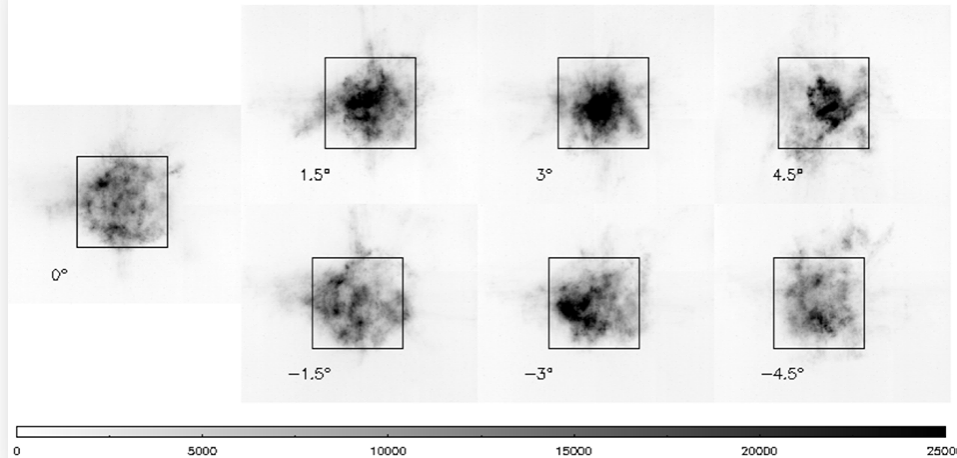


Inverno 2014- 2015

Il prototipo ASTRI funziona !

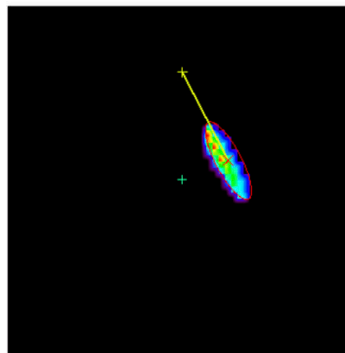


Giro, Canestrari, Sironi et al. 2017, A&A 608, A86

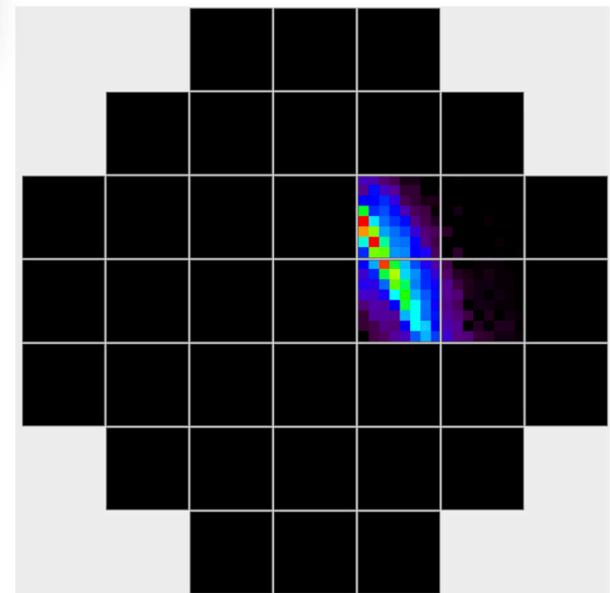


Prima caratterizzazione ottica di un telescopio Schwarzschild-Couder sino a 4.5° di off-axis.

Prima luce Cerenkov acquisita dalla camera di ASTRI di una shower generata da raggi cosmici nell'atmosfera terrestre.



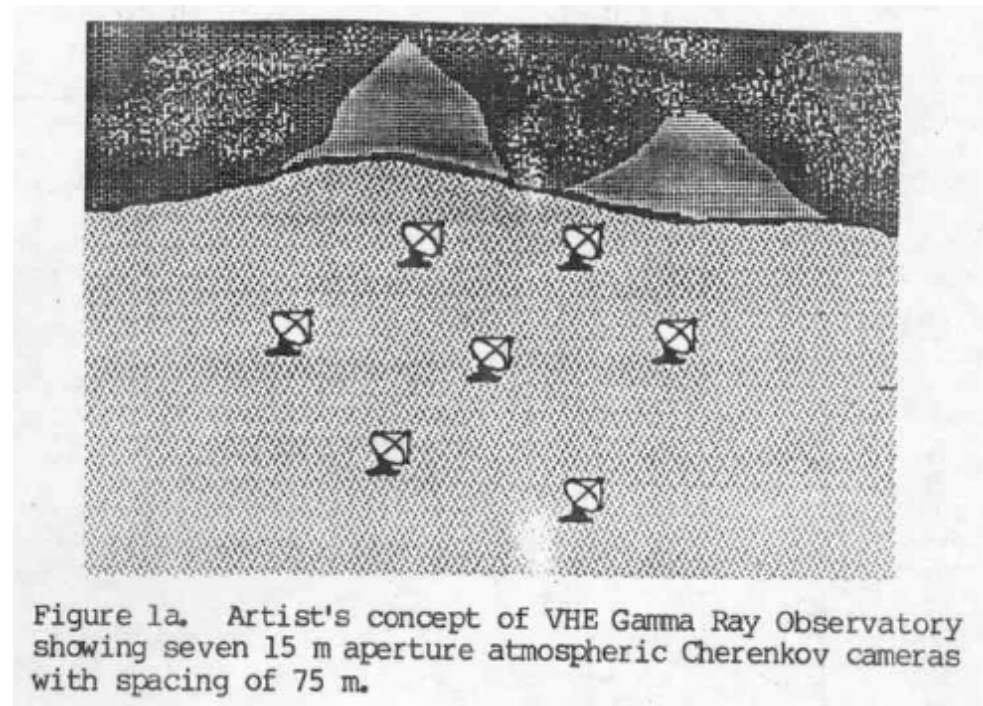
Credits: ASTRI Team, May 2017



Il concetto di mini-array...

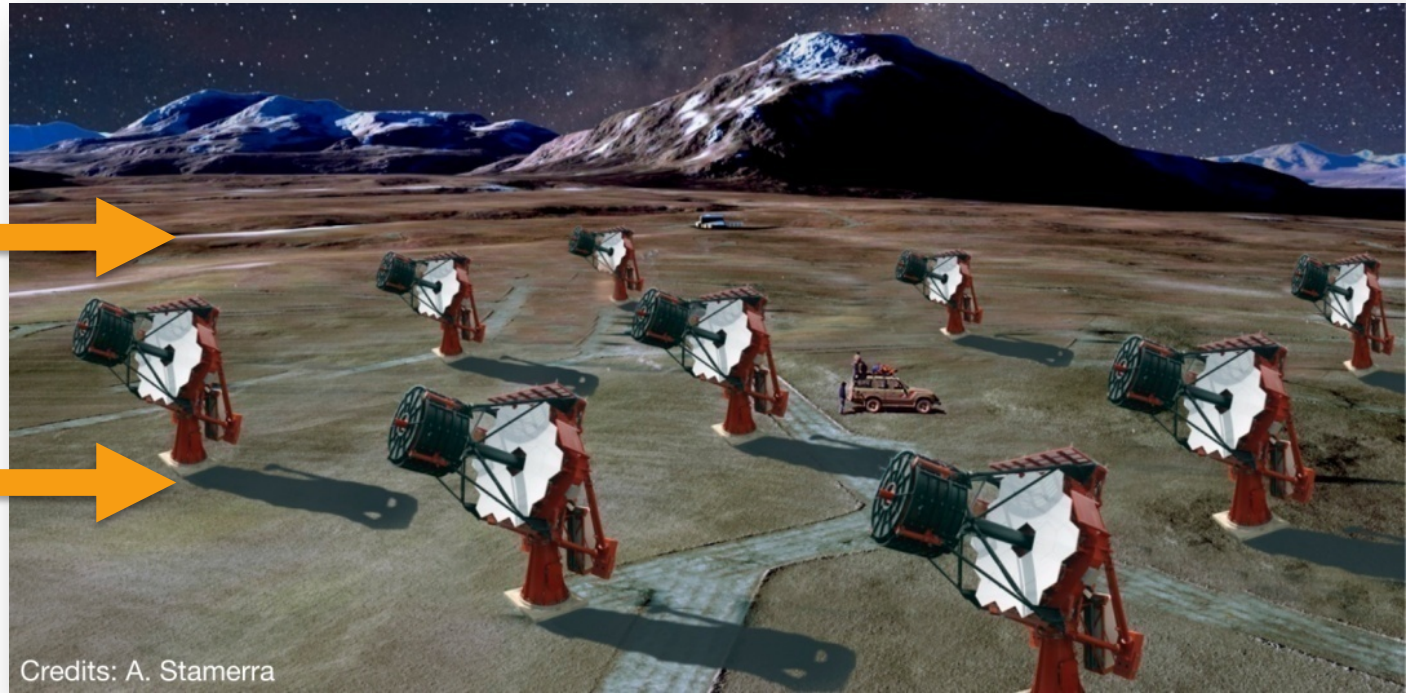


Stonehenge, tra il 3100 a.C. e il 1600 a.C



NASA Workshop, Space Lab. Science, Baton Rouge, 1984

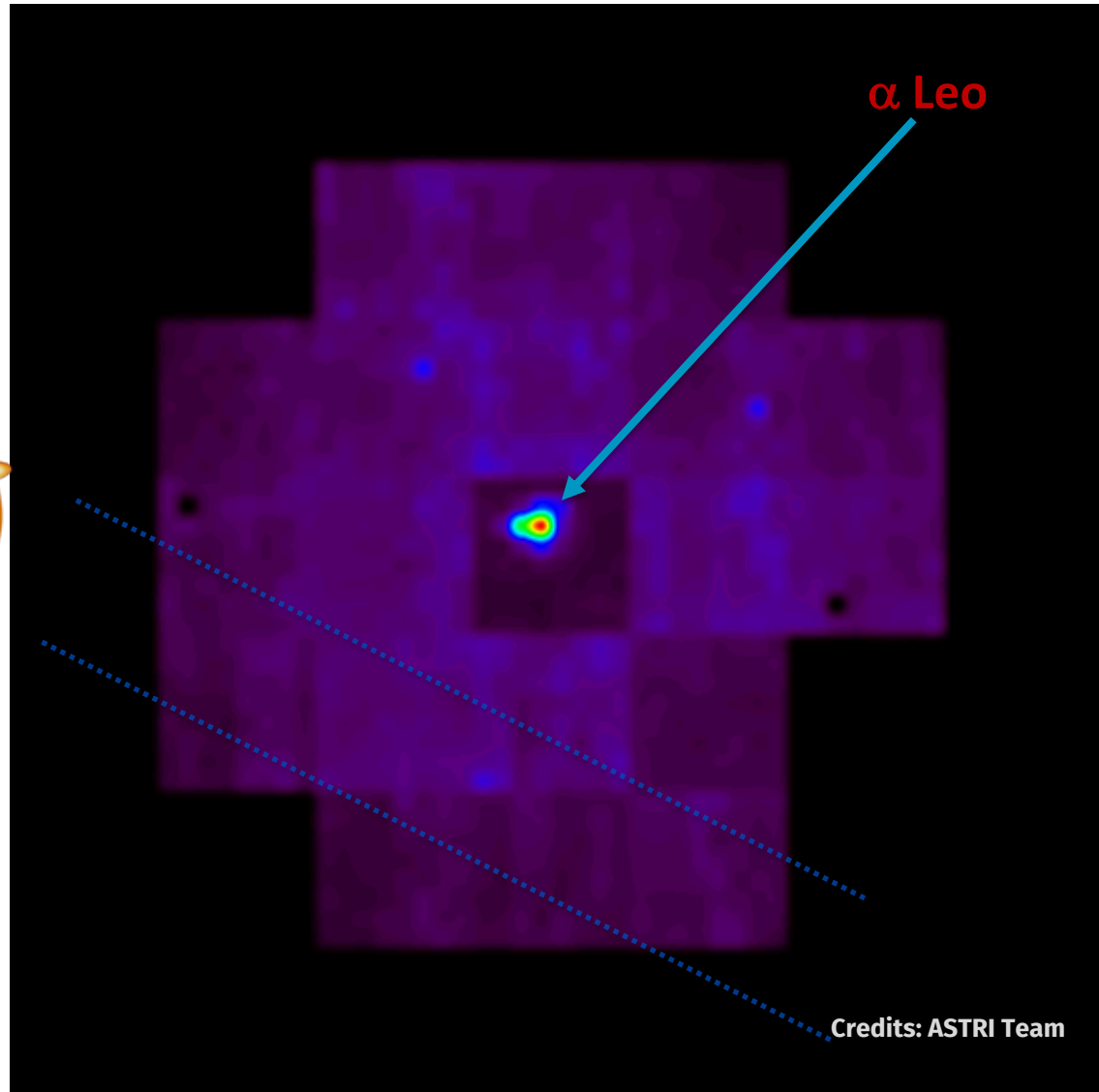
Dal prototipo al mini-array



Mini-array di 9 ASTRI SST-2M

- 9 telescopi e camere ASTRI.
- End to end: validazione e commissioning dell'array (inclusi trigger e Software di analisi) per mezzo di osservazioni di sorgenti astrofisiche.

Esprimete un desiderio !



Outline



Le altissime energie

I telescopi Cherenkov

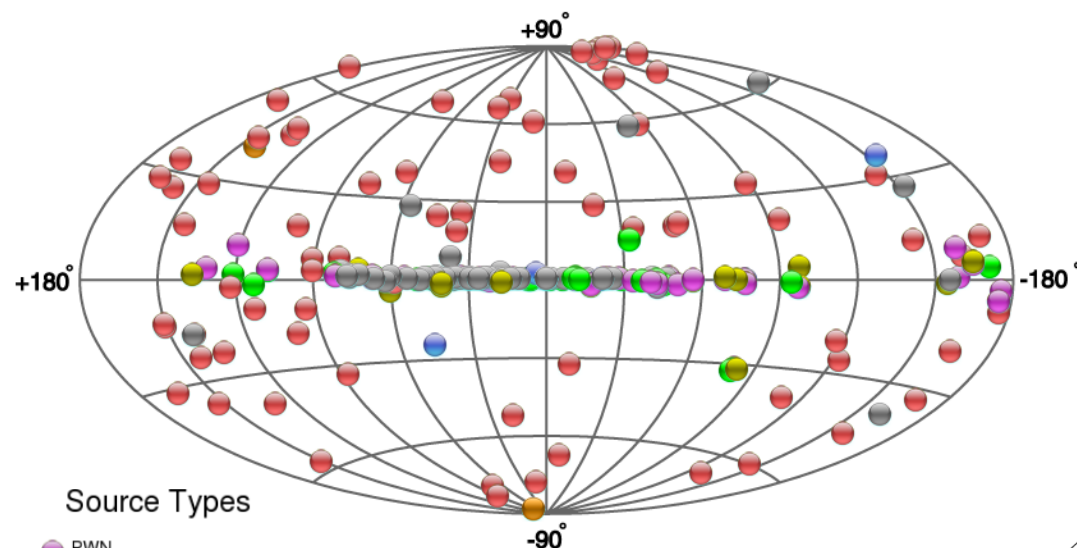
Il Progetto ASTRI

Il futuro Cherenkov Telescope Array

Scienza per tutti !



Il cielo ad $E > 50$ GeV

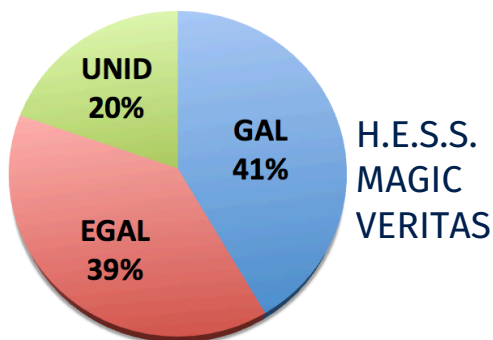


Source Types

- PWN
- Binary XRB PSR Gamma BIN
- HBL IBL FRI FSRQ Blazar LBL AGN (unknown type)
- Shell SNR/Molec. Cloud Composite SNR Superbubble
- Starburst
- DARK UNID Other
- uQuasar Star Forming Region Globular Cluster Cat. Var. Massive Star Cluster BIN BL Lac (class unclear) WR

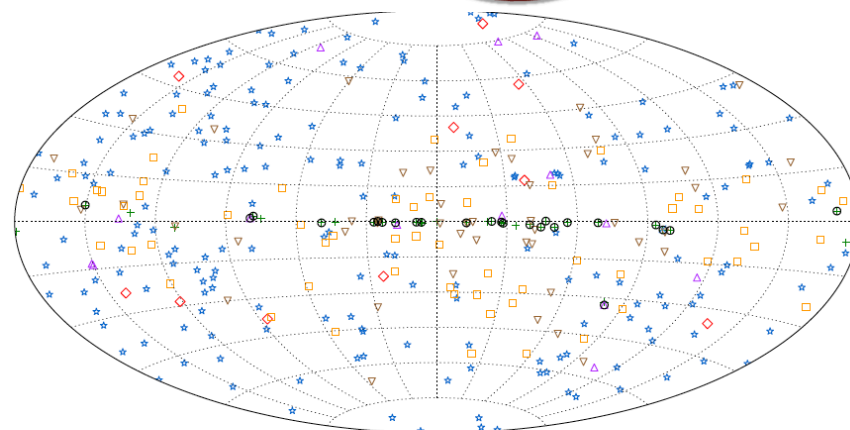
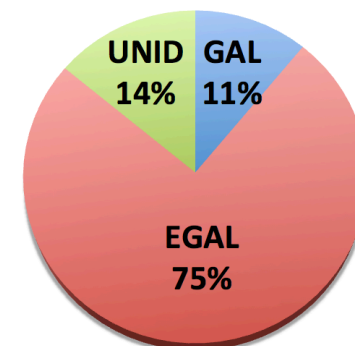
Wakely & Horan <http://tevcat.uchicago.edu/>

~220 sorgenti TeVCat



H.E.S.S.
MAGIC
VERITAS

360 sorgenti *Fermi*-LAT $E > 50$ GeV



+	SNRs and PWNe	★	BL Lacs	□	Unc. Blazars	▽	Unassociated
×	Pulsars	◇	FSRQs	△	Others	○	Extended

2FHL Ackermann+16

Solo il ~25% delle sorgenti 2FHL sono state rivelate in precedenza dagli attuali array di telescopi Čerenkov.

Il catalogo di *Fermi*-LAT e' una riserva di possibili candidate per il futuro CTA.

Two sites (North and South) for a whole-sky coverage

Operated as an open Observatory

A factor of 5-20 more sensitive w.r.t. the current IACTs depending on the energy band

A few large size telescopes to cover the range 20 - 150 GeV

~km² array of medium size telescopes for the 0.15 - 5 TeV domain

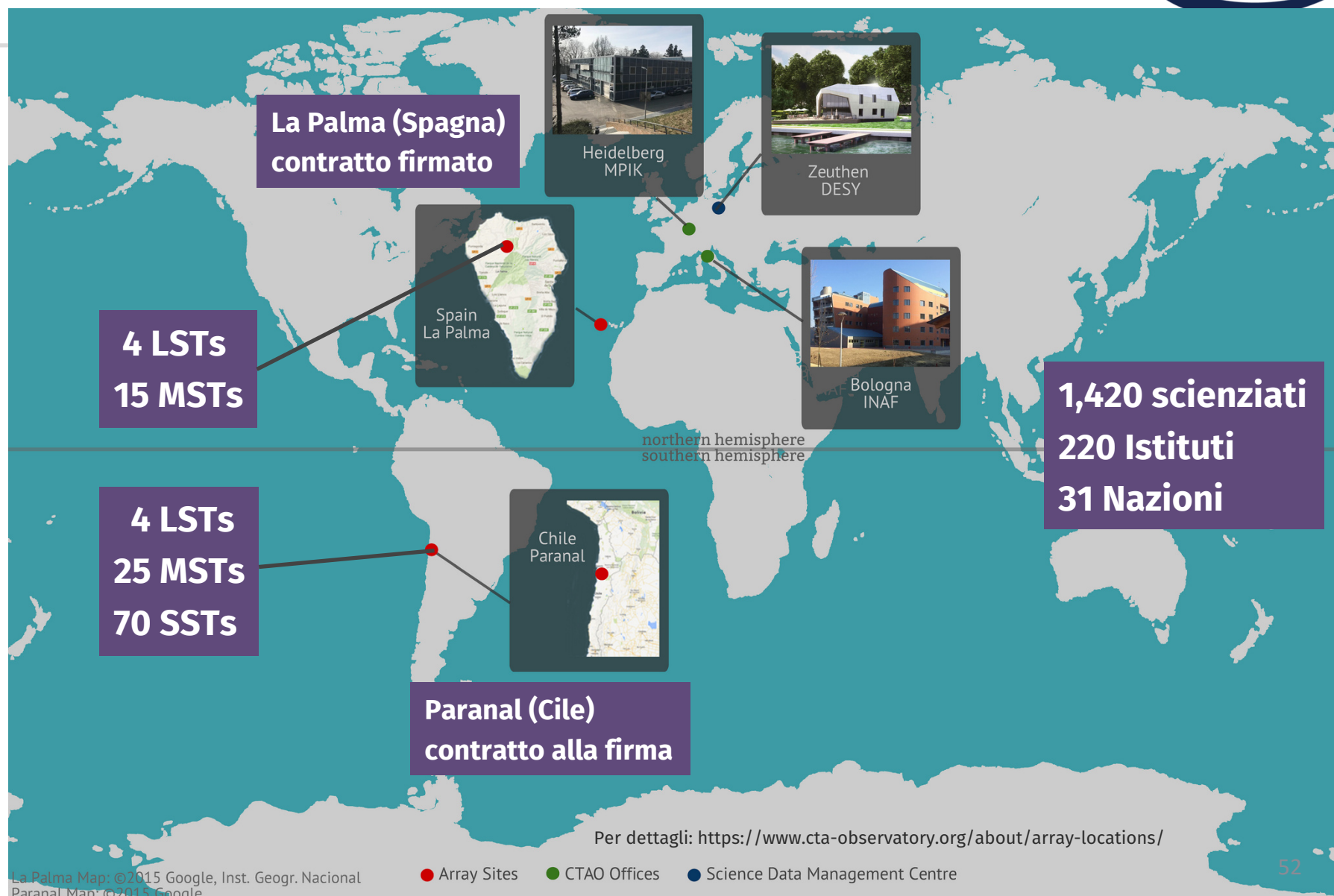
~4km² array of small size telescopes, sensitive above 5 TeV up to 300 TeV

4 LSTs [N & S]

15 MSTs [N]
25 MSTs [S]
(24 SCTs [S])

70 SSTs [S]

Dove si trovera' CTA



Il sito Nord di CTA (La Palma)



Il sito Sud di CTA (Paranal)



Vulcano Llullaillaco
6739 m, 190 km east

Cerro Armazones
E-ELT

Cerro Paranal
Very Large Telescope

Cherenkov Telescope Array Site

Crono-programma e disposizione dei telescopi



Project Phases

Pre-Construction

Current Phase

Pre-Production

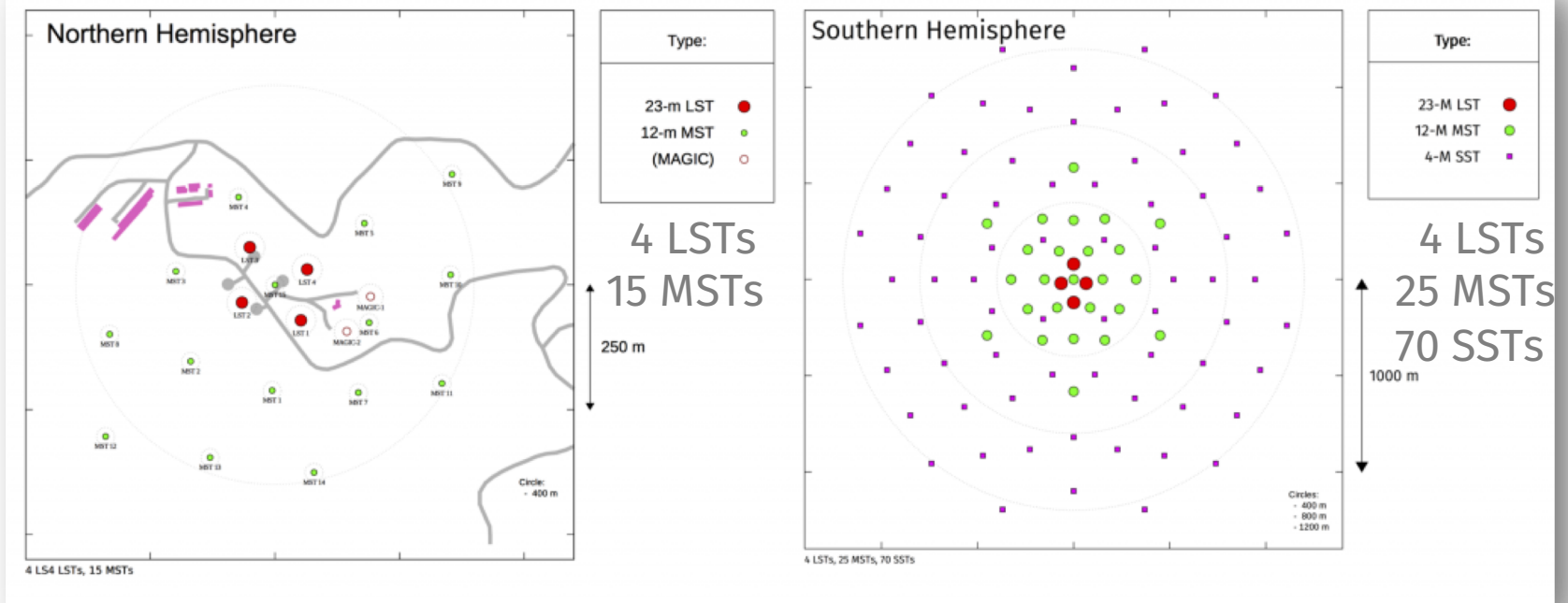
2019-2021

Production

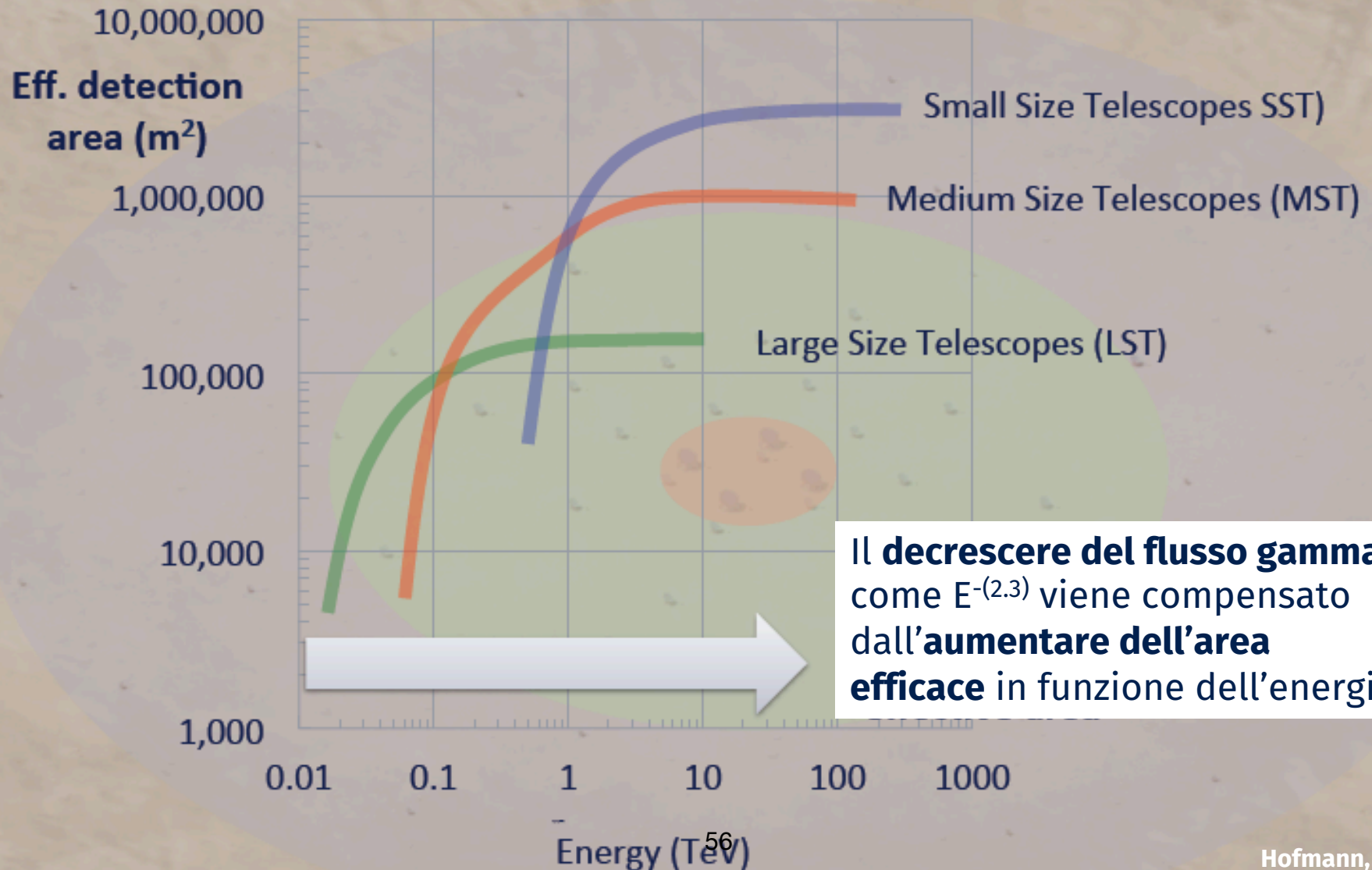
2021-2025



First Pre-Production
Telescopes on Site



Area efficace dell'array



Large Size Telescope

<http://www.lst1.iac.es/webcams/>



Medium Size Telescope Prototype



https://www-zeuthen.desy.de/cta_cam/photogallery/content/index.html

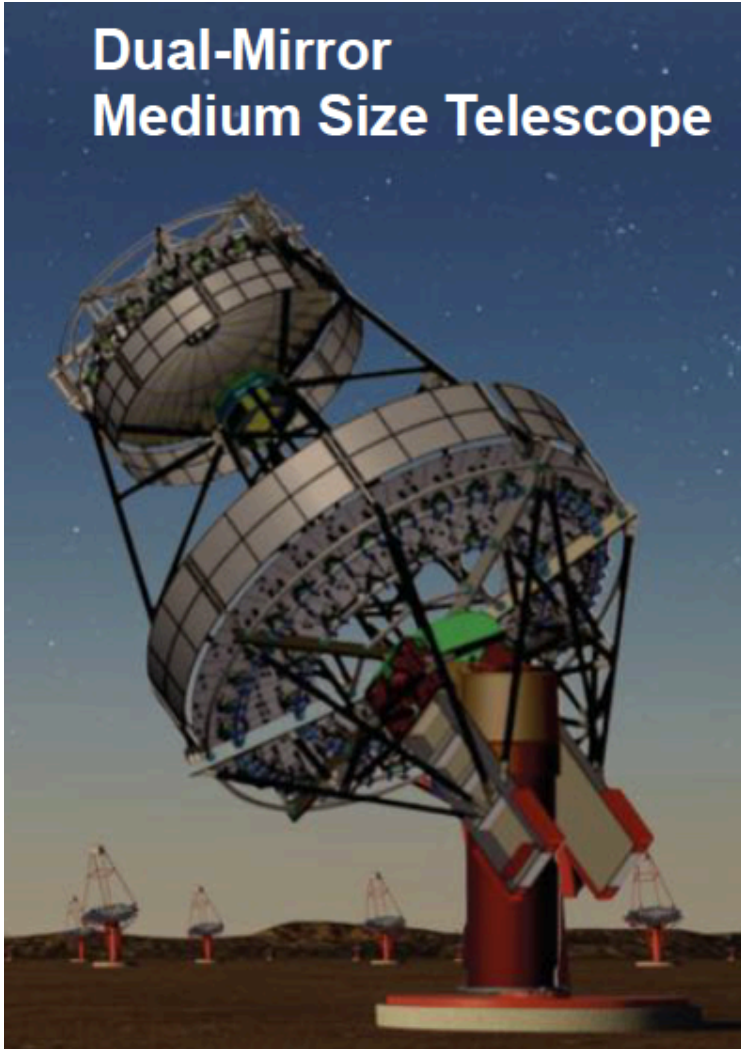


Credits: The CTA Consortium

Dual-mirror MST prototype



Dual-Mirror Medium Size Telescope



Small size telescope prototypes



SST-2M GCT prototype in Paris

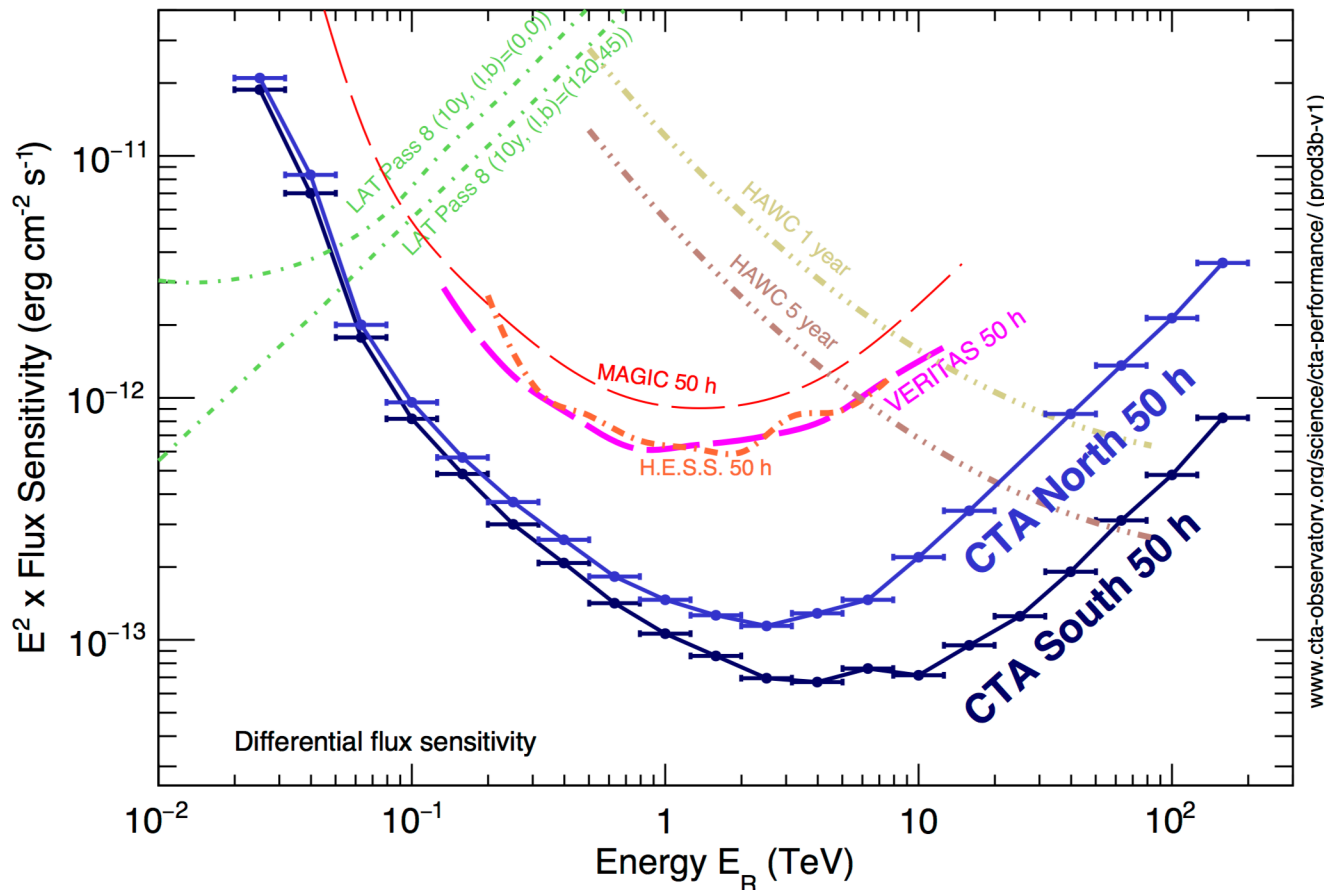


SST-1M prototype in Krakow



SST-2M ASTRI prototype on Mt. Etna (Sicily)

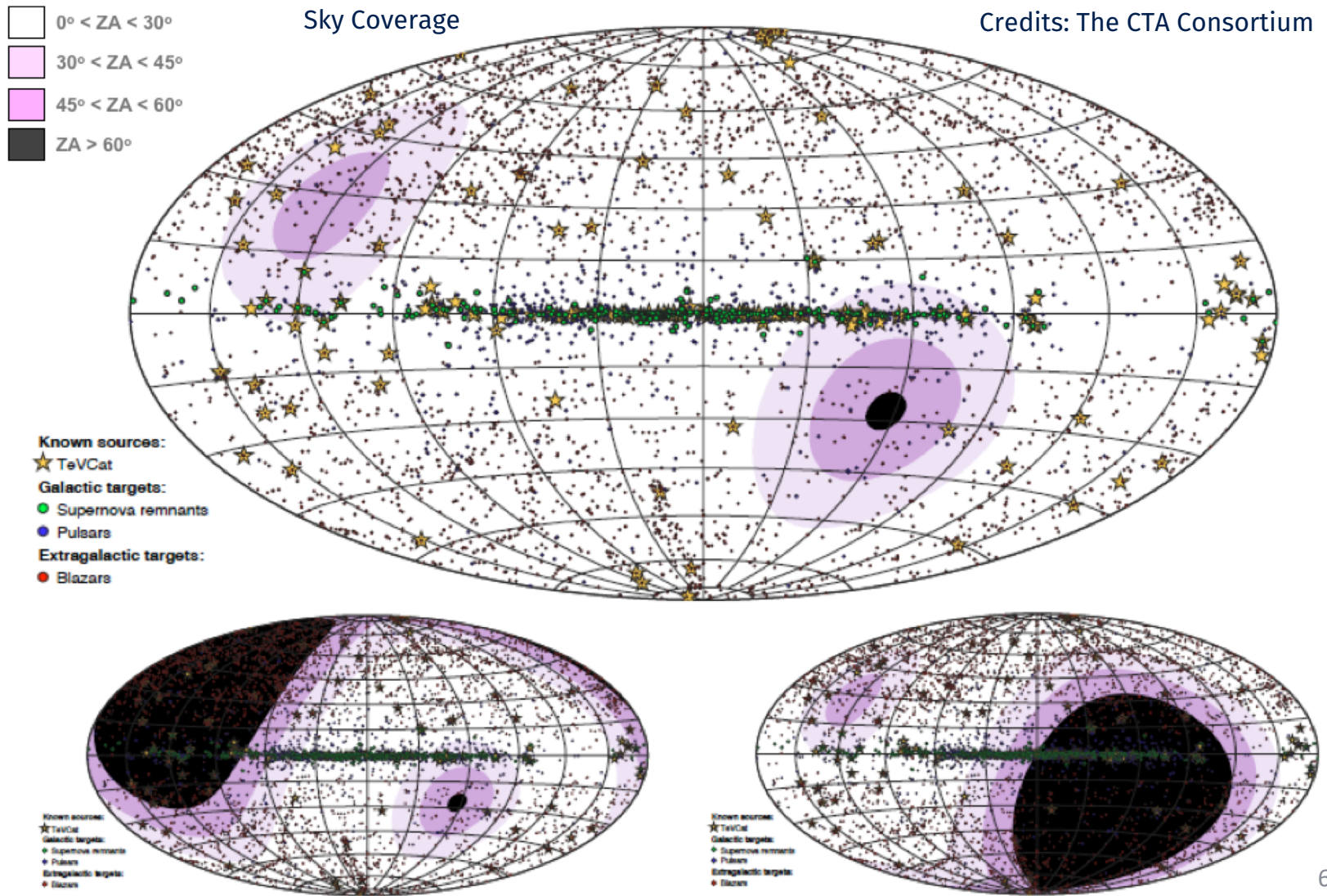
Sensibilit  differenziale



Un **miglioramento** di un **fattore tra 5-20** nella sensibilit  rispetto agli array attuali.

Estensione del range di energia accessibile sia **sotto 100 GeV**, sia **sopra 100 TeV**.

CTA come Osservatorio *all-sky*



CTA come *transient factory*

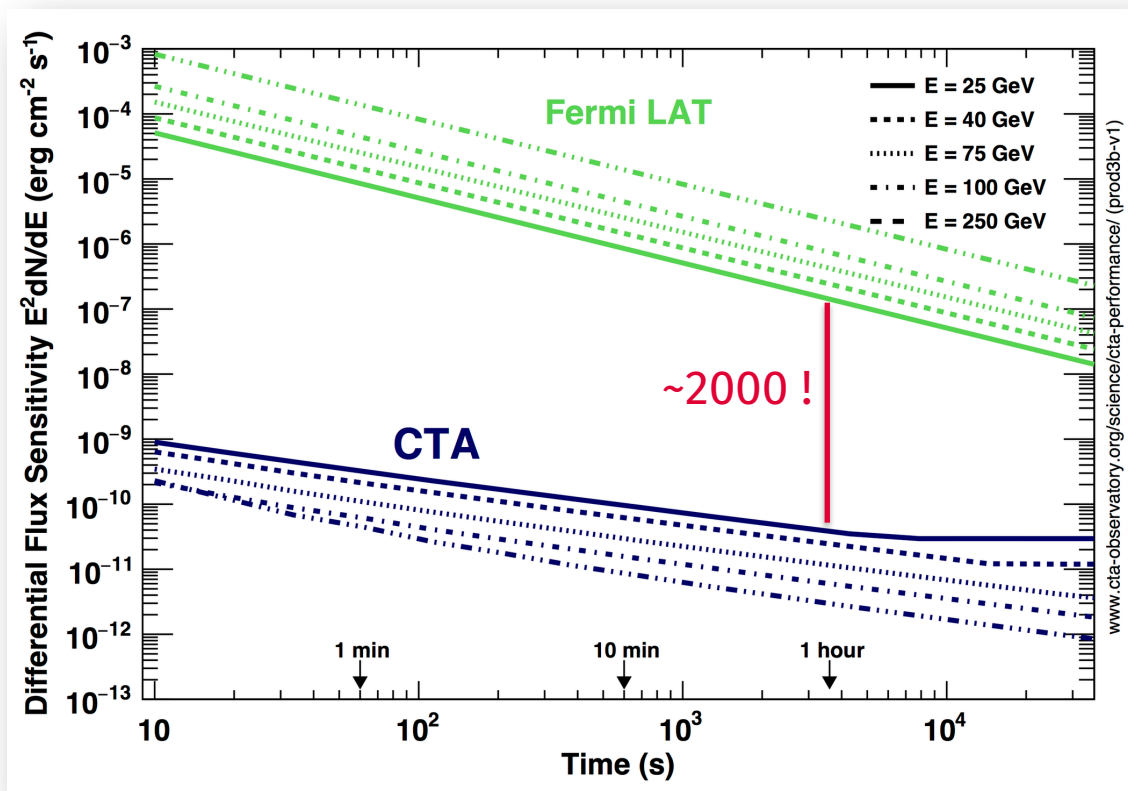


Enorme vantaggio rispetto a Fermi nello stesso range energetico per fenomeni transienti su tempo-scala dal minuto al giorno:

- Flare da AGN
- Binarie gamma
- Gamma-ray bursts

Svantaggi rispetto a Fermi

- Campo di vista meno ampio
- CTA richiede un trigger esterno per poter ripuntare il transiente



Outline



Le altissime energie
I telescopi Cherenkov
Il Progetto ASTRI
Il futuro Cherenkov Telescope Array
Scienza per tutti !



Tematiche Scientifiche di CTA

Tematica 1: Accelerazione delle particelle cosmiche

- Come e dove le particelle sono accelerate?
- Come si propagano?
- Qual e' il loro impatto sull'ambiente attorno ai siti di accelerazione?

Tematica 2: Lo studio degli ambienti estremi

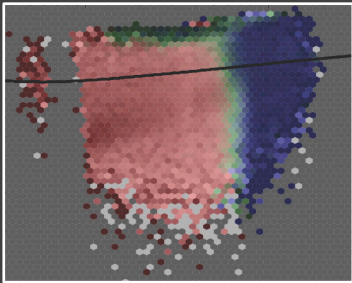
- Quali sono i processi nelle stelle di neutroni e nei buchi neri?
- Quali sono i processi nei getti e nei venti in AGN?

Tematica 3: La frontiera della Fisica

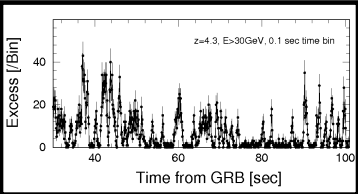
- Qual e' la natura della materia oscura? Come e' distribuita?
- La velocita' della luce e' costante alle altissime energie?
- Esistono particelle come gli assioni?

Il programma osservativo di CTA

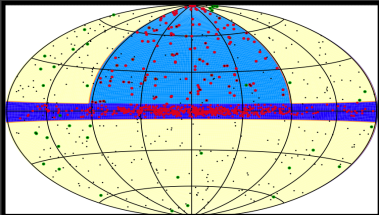
- **9 Key Science Projects (KSPs) e 1 Dark Matter Program**
 - I KSPs sono un set di osservazioni che devono rispondere a diverse domande scientifiche
- Sono focalizzati su **grandi progetti**:
 - Survey & studi di popolazione (generazione di cataloghi e grande mole di dati)
 - Classi di sorgenti molto numerose (AGN, SNRs, PWNe...)
 - Alcuni oggetti peculiari



Dark Matter Programme

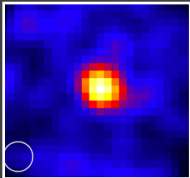


Transienti



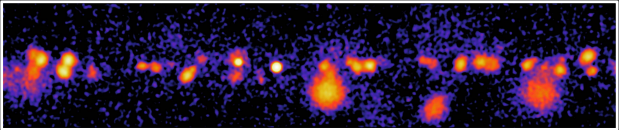
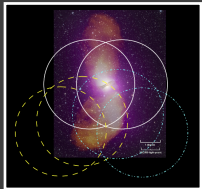
Survey Extra-galat.

Cluster di galassie



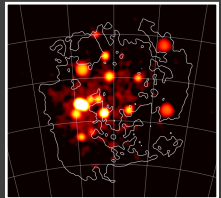
Sistemi di formazione stellare

AGN



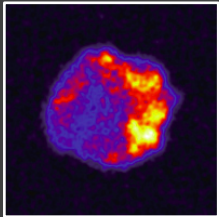
Survey del Piano Galat.

Survey della LMC

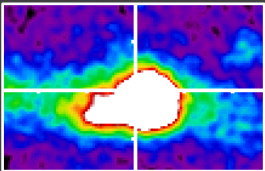


Galattico

PeVatroni



Survey del Centro Galat.





cherenkov
telescope
array

Science with the Cherenkov Telescope Array



Science with CTA

340 pagine che
descrivono gli obiettivi
scientifici di CTA

<https://arxiv.org/abs/1709.07997>

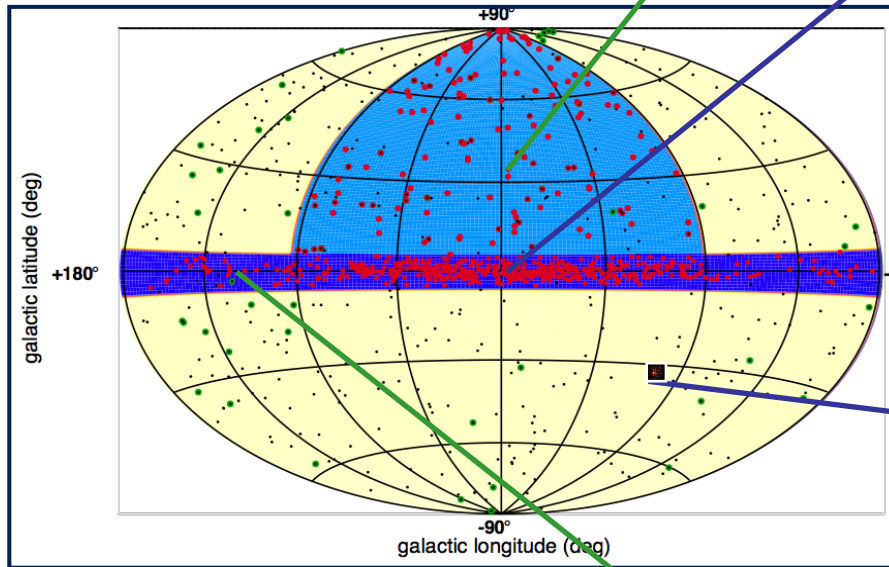
Sara' pubblicato in un
libro ed anche free on-
line da World Scientific
nel Gennaio 2019

<https://www.worldscientific.com/worldscibooks/10.1142/10986>

Le survey di CTA

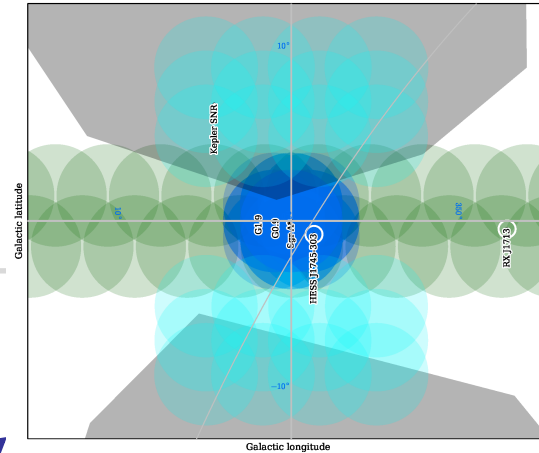
Survey Extra-galattica :

Survey di $\frac{1}{4}$ del cielo fino a $F_{\text{lim}} \sim 6$ mCrab
Studio della popolazione di AGN alle VHE,
Studio del duty cycle e di nuove sorgenti.
Esposizione $O(1000)$ h



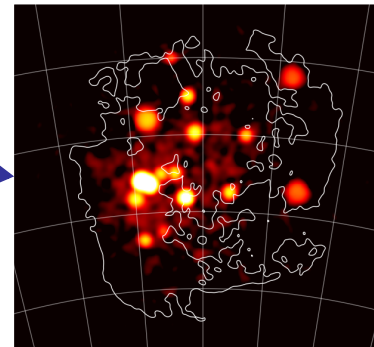
Survey del Piano Galattico:

Survey dell'intero piano fino a $F_{\text{lim}} \sim 2$ mCrab
Studio di popolazione per: SNRs, PWNe, etc.
Ricerca di candidate PeVatroni
Esposizione: $O(1620)$ h



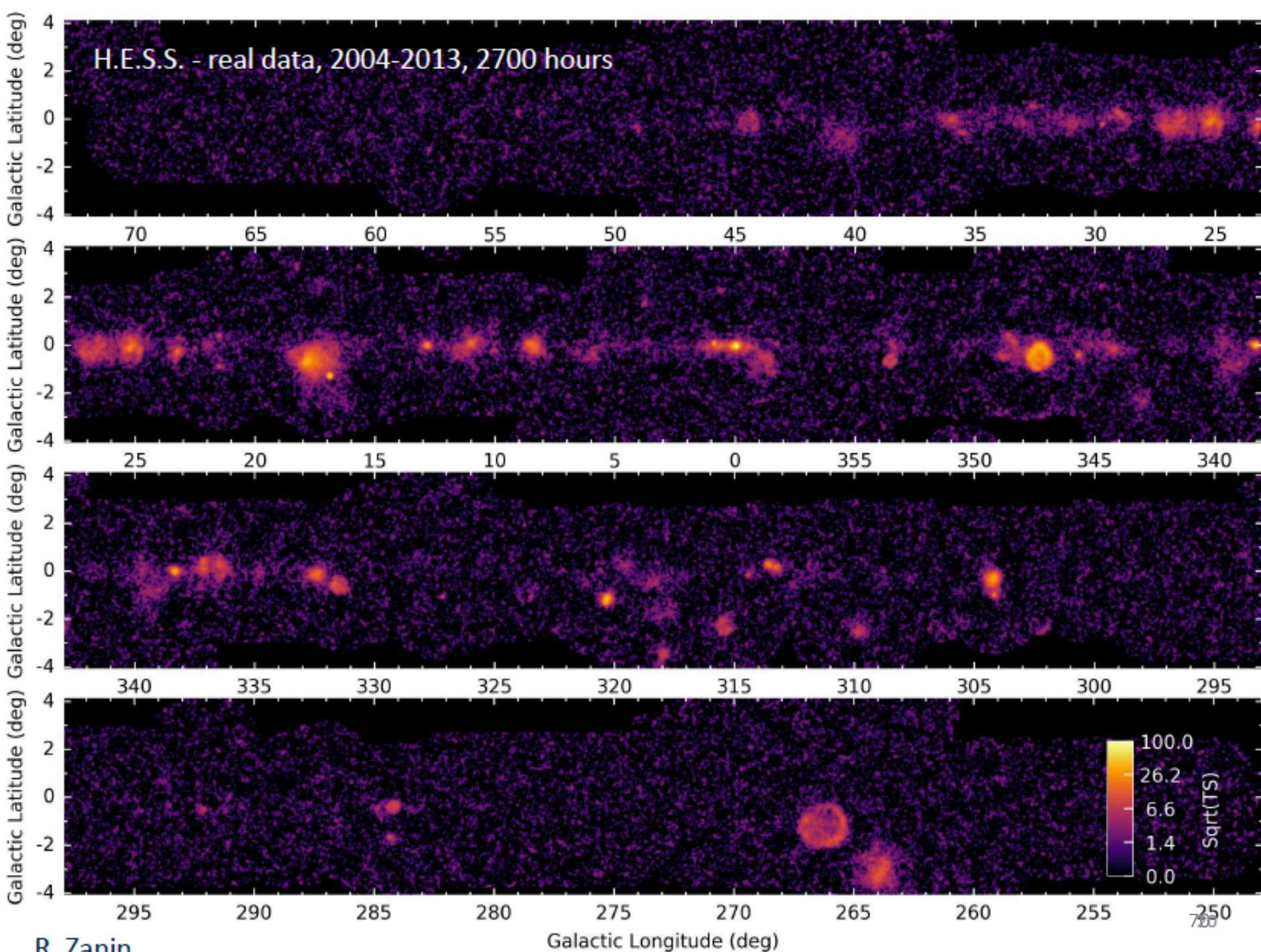
Survey del Centro Galattico:

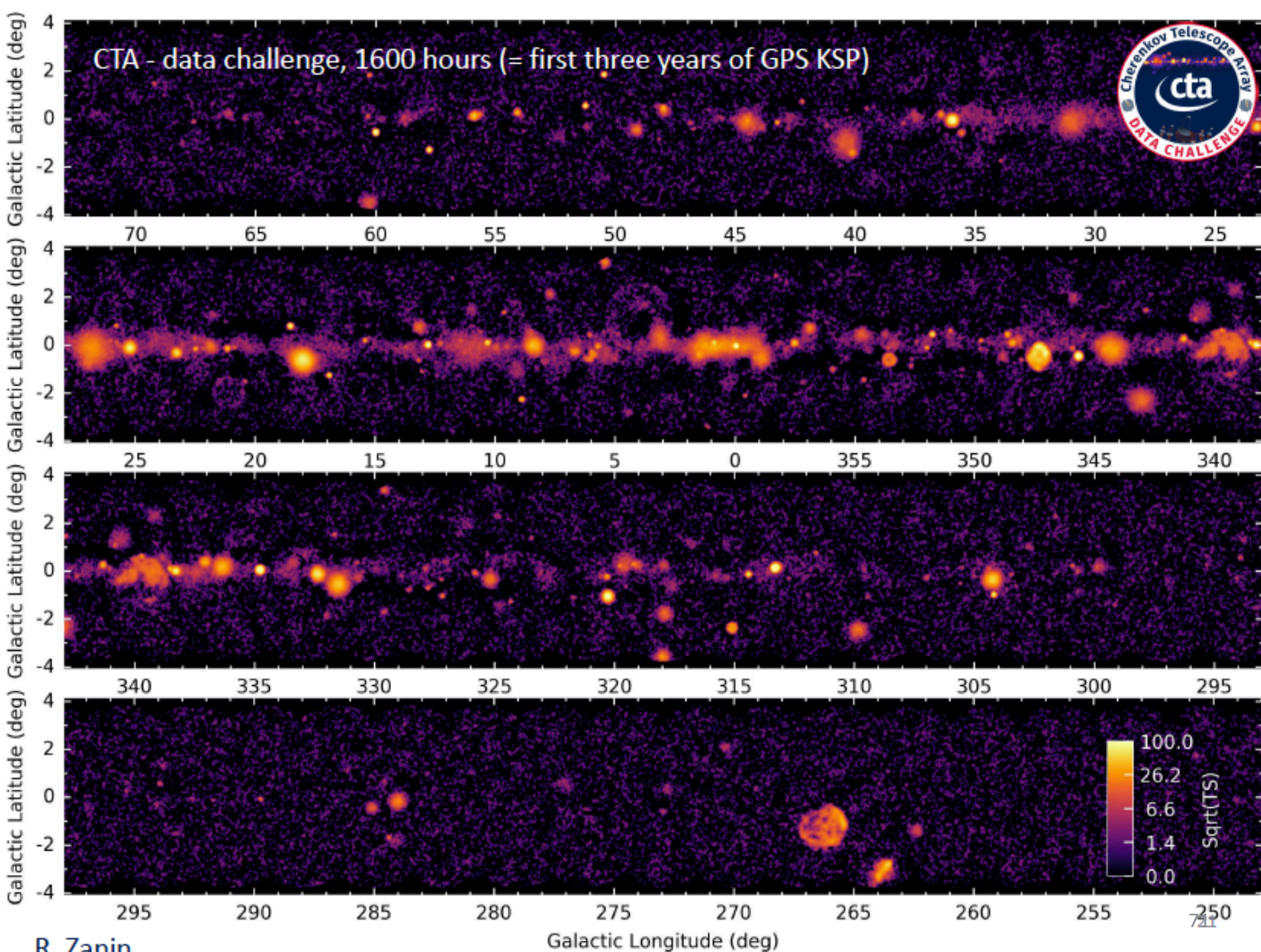
Identificazione della sorgente centrale;
Spettro e morfologia dell'emissione diffusa.
Ricerca della DM; studio delle Fermi Bubbles.
Esposizione: $O(525)$ h, $10^\circ \times 10^\circ$: $O(300)$ h

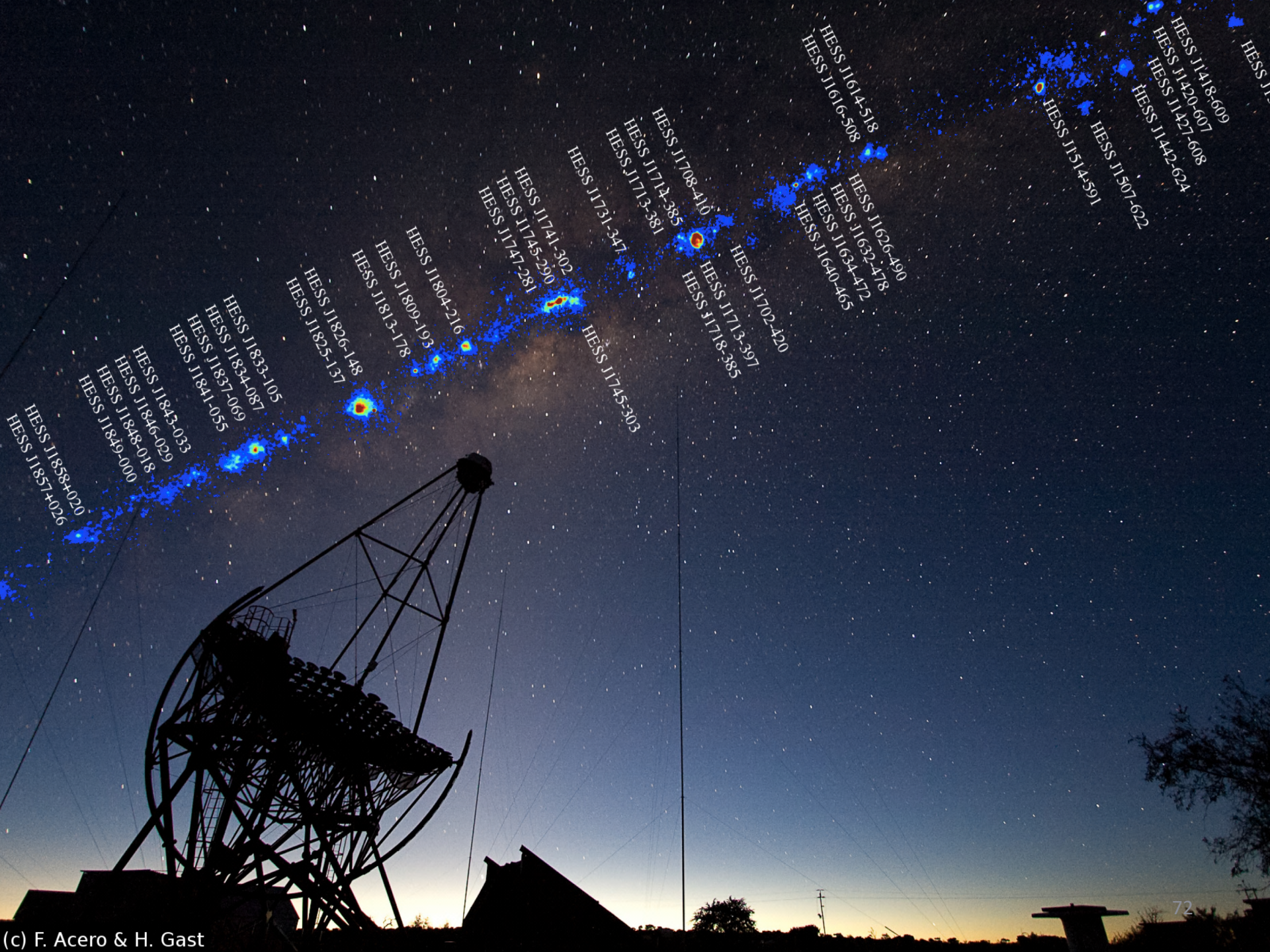


Survey della Large Magellanic Cloud :

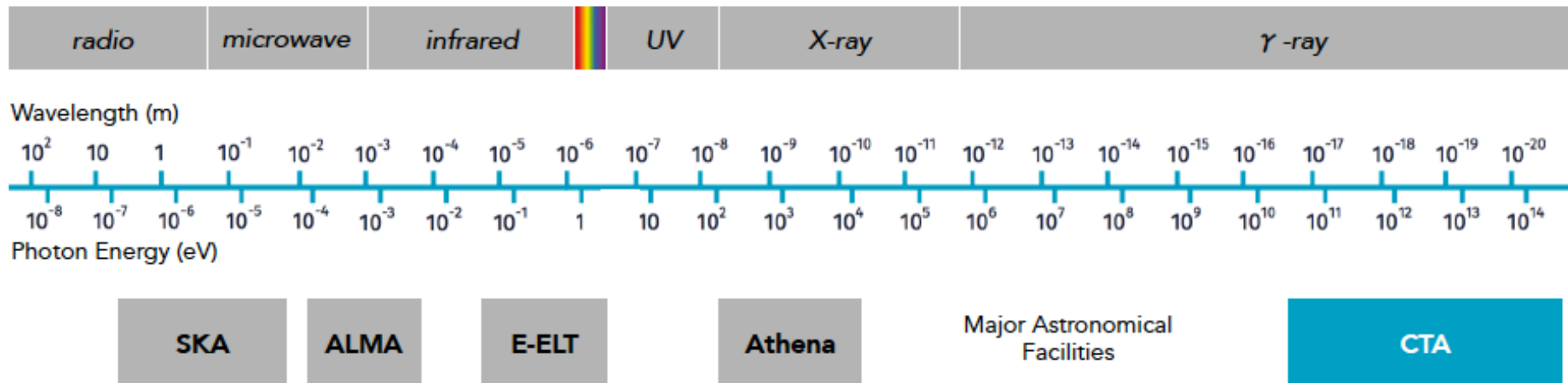
Nostra galassia satellite con alta SFR
Importante per lo studio dell'emissione diffusa
Esposizione: $O(340)$ h in sei puntamenti.







Sinergie scientifiche con CTA



Queste sono solo alcune delle principali facilities astronomiche che saranno disponibili simultaneamente a CTA.

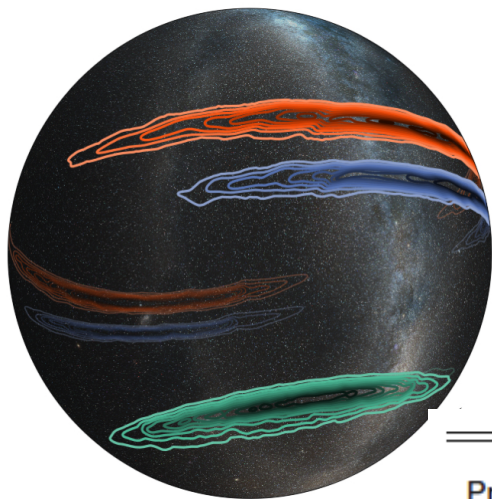
Occorre aggiungere **LIGO + VIRGO + LISA*** (onde gravitazionali) ed **IceCube + KM3NeT*** (neutrini) per l'astronomia multi-messaggera.

*) ancora da costruire

L'Astrofisica multi-messaggera e' realta' !



Studio dei transienti



I **transienti** comprendono un'ampia varietà di sorgenti astrofisiche. Alcuni sono ben noti **emittitori di radiazione in banda gamma**, mentre altri sono sorgenti di segnali non fotonici come i raggi cosmici, i **neutrini e le onde gravitazionali**

Credits: The LIGO Scientific Collaboration

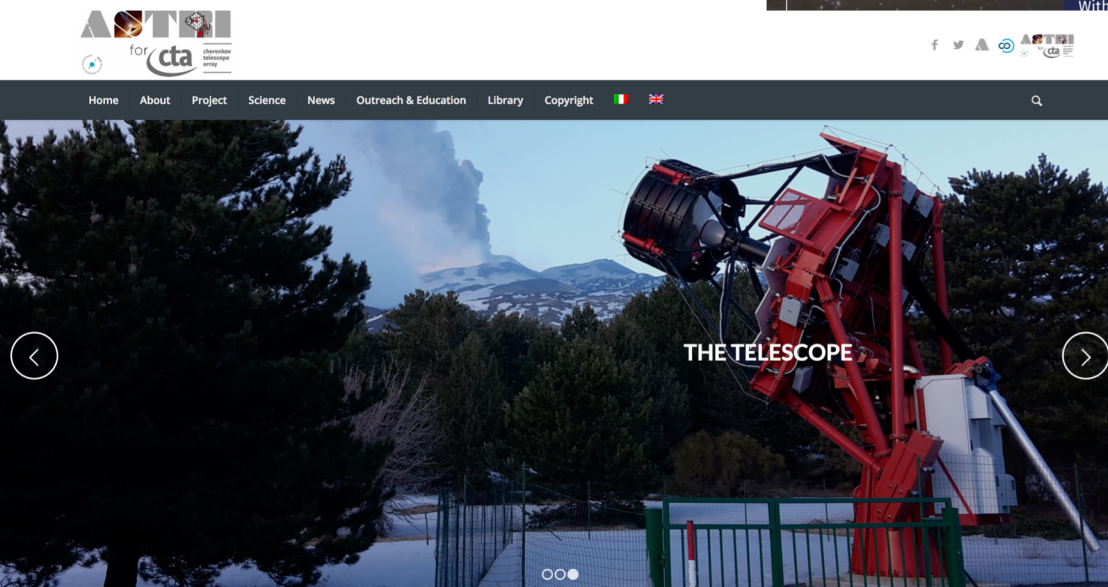
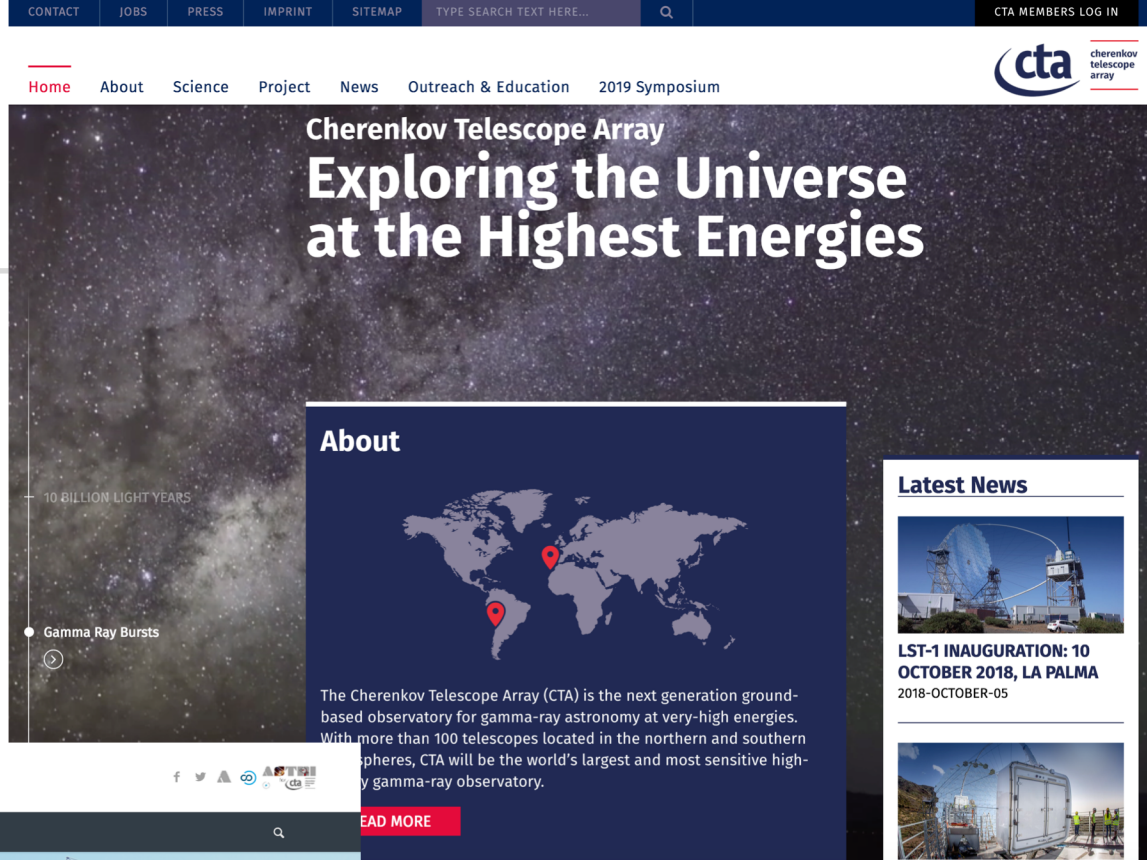
Priority	Target class	Observation times (h yr ⁻¹ site ⁻¹)			
		Early phase	Years 1–2	Years 3–10	Years 1–10
1	GW transients	20	5	5	
2	HE neutrino transients	20	5	5	
3	Serendipitous VHE transients	100	25	25	
4	GRBs	50	50	50	
5	X-ray/optical/radio transients	50	10	10	
6	Galactic transients	150	30	0(?)	

Follow-up priority	Target class	Detected @ HE	Trigger	Rate (yr ⁻¹)	Urgency	Activity duration	Obs. time (h) /night	Total time (h)	Site
1	Magnetar giant flares	–	MeV	0.1	1 min	1–2 d	Max. 1	10	A/B
2	PWN flares: Crab nebula	Y	HE	1	1 d	5–20 d (HE)	4	50	S&N
3	HMXB microquasars: Cyg X-3	Y	HE/X-ray	0.5	1 d	50–70 d (HE)	Max. 1	50	N
	Cyg X-1	Y	HE/X-ray	0.2	1 d	1–10 d ?	Max. 1	30	N
4	Unidentified HE transients	Y	HE	1	1 d	?	2	20	A/B
5	LMXB microquasars	?	X-ray/radio	1	1 d	Weeks	2	20	A/B
6	Novae	Y	HE/opt.	2	1 d	Weeks	2	20	A/B
7	Transitional pulsars	Y	Radio/opt.	0.5	1 d	Weeks	2	20	A/B
8	Be/X-ray binary pulsars	N	X-ray	1	1 d	Weeks	2	20	A/B

Info

Sito del progetto CTA

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



Sito del progetto ASTRI

<http://www.brera.inaf.it/astri/>

- ***Tera-electronVolt Astronomy***
 - Hinton and Hofmann, Annual Review of Astronomy and Astrophysics, 47, 523 (2009)
- ***Science with the Cherenkov Telescope Array***
 - Edited by Hinton, Ong and Torres, arXiv:1709.07997
- ***From the Etna volcano to the Chilean Andes: ASTRI end-to-end telescopes for the Cherenkov Telescope Array***
 - Scuderi, SPIE 2018, Paper No. 10700-223
- ***Small-size telescope array for gamma-ray astronomy***
 - Vercellone, 2014, SPIE Newsroom. DOI: 10.1117/2.1201405.005488

