Visokoenergijska gama-astronomija teleskopima MAGIC

Dario Hrupec

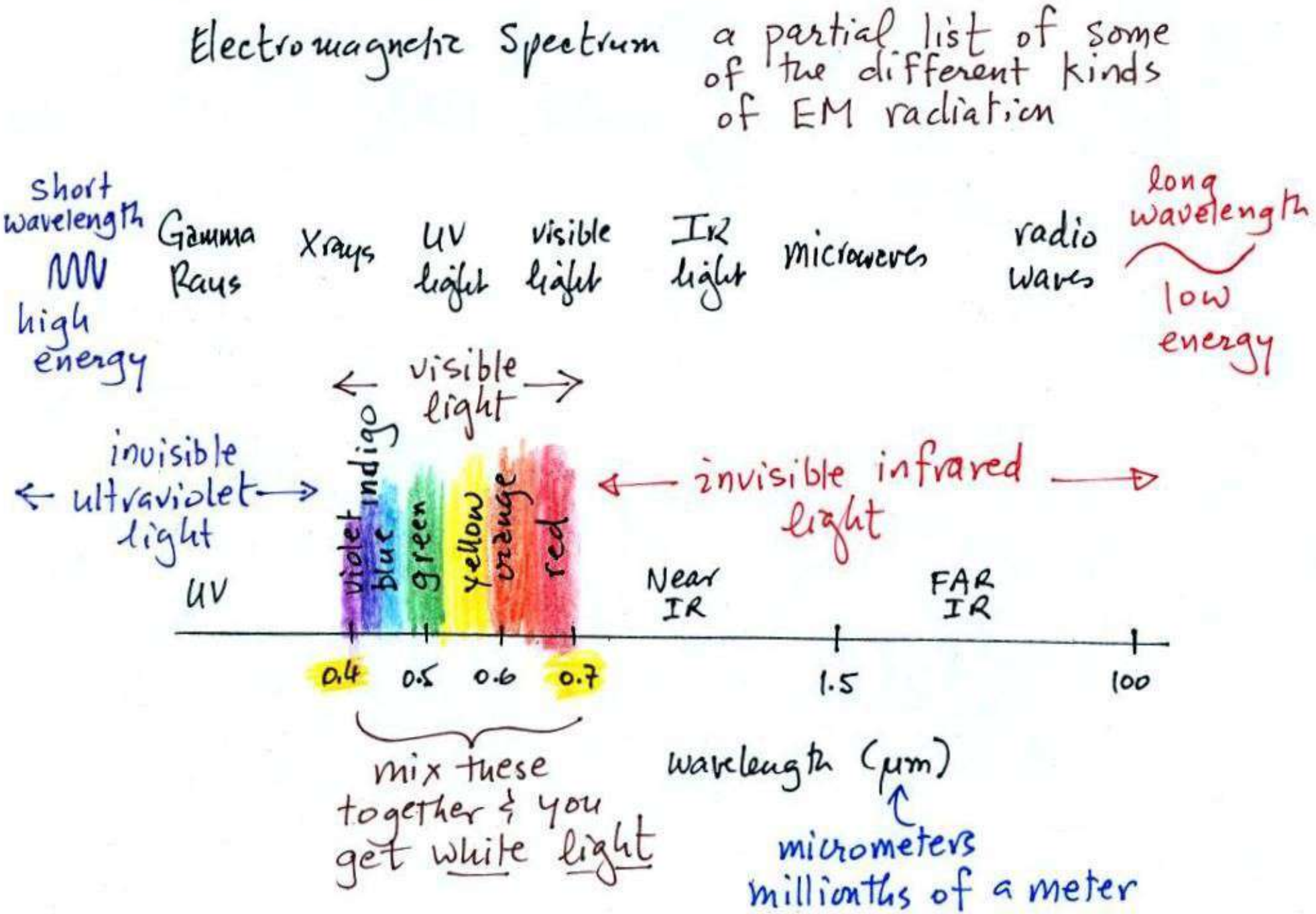
Sljeme Star Party, 11. travnja 2015.

od astronomije
do gama-astronomije

noćno nebo golim okom: vidljiva svjetlost


djelić noćnog neba teleskopom Hubble:
više-manje vidljiva svjetlost

vidljiva svjetlost vs. nevidljiva svjetlost



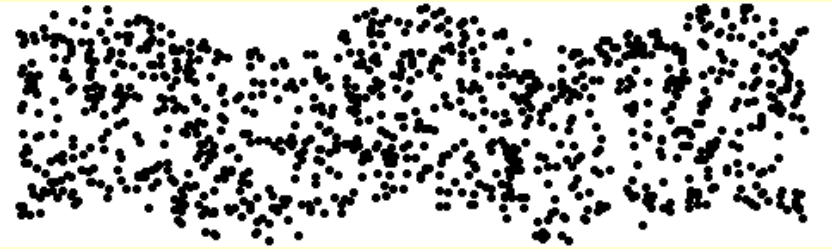
“knjigovodstvo” elektromagnetskih valova

Region	Energy	Wavelength
γ-ray	$E > 100$ keV Precisely, $E > m_e c^2 = 511$ keV	$\lambda < 1$ pm Precisely, $\lambda < \lambda^e_{\text{COMPTON}} = 2.43$ pm
X-ray	100 eV $< E <$ 100 keV	1 pm $< \lambda <$ 10 nm
ultraviolet	10 eV $< E <$ 100 eV	10 nm $< \lambda <$ 100 nm
visible	1 eV$< E <$ 10 eV Precisely, 1.7 eV $< E <$ 3.2 eV	100 nm $< \lambda <$ 1 μm Precisely, 380 nm $< \lambda <$ 750 nm
infrared	1 meV $< E <$ 1 eV	1 μm $< \lambda <$ 1 mm
microwave	0.1 μeV $< E <$ 1 meV	1 mm $< \lambda <$ 10 cm
radio	$E <$ 0.1 μeV	$\lambda >$ 10 cm

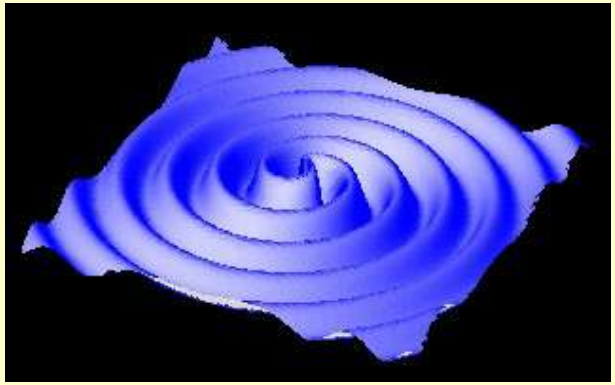
što je uopće val?

poremećaj koji se širi kroz prostor (i prenosi energiju)

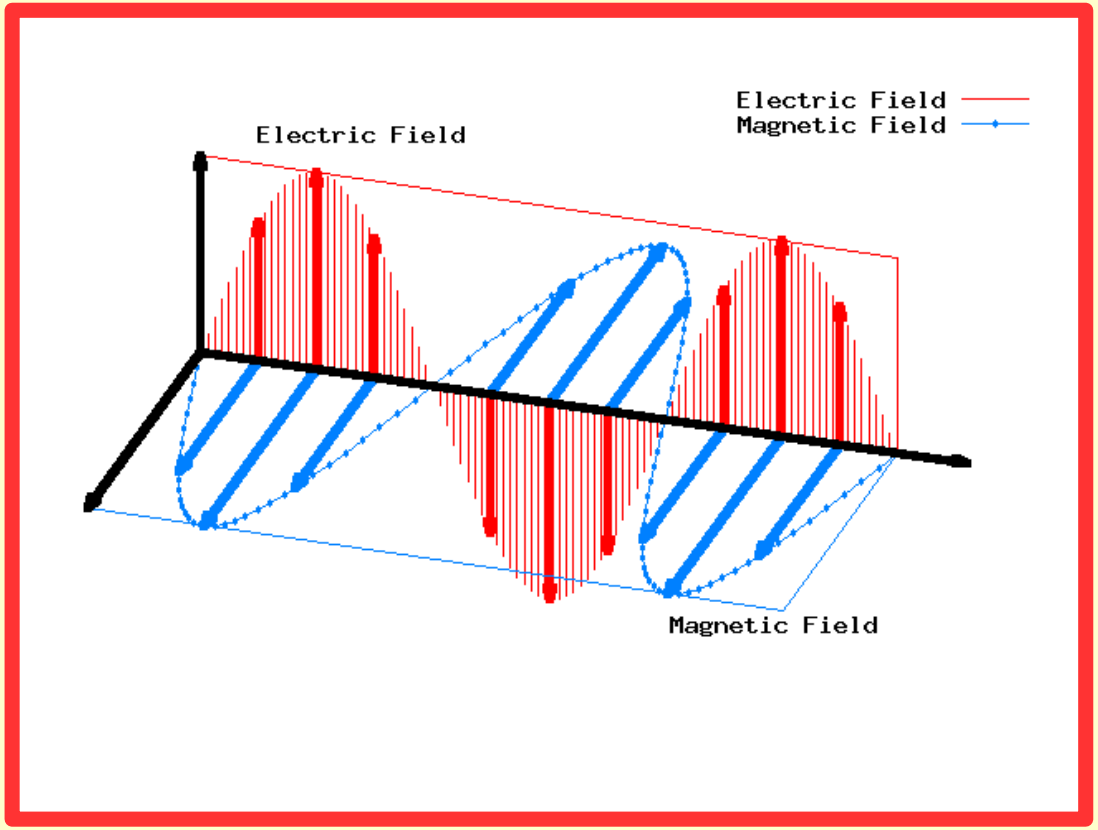
mehanički val



gravitacijski val



elektromagnetski val



što je elektromagnetski val?

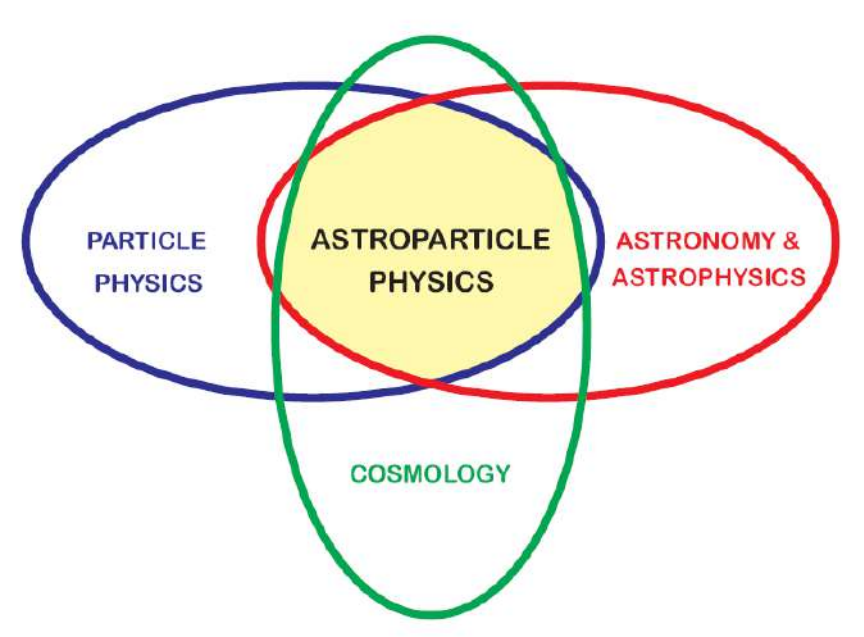
[1]Objašnjenje elektromagnetskog zračenja izlazi izvan okvira ovog teksta. Recimo samo da se radi o prirodnoj pojavi koja, između ostalog, ima svojstva vala (širi se kroz prostor i prenosi energiju), ali i svojstva čestice (ima količinu gibanja premda nema masu).

D. Hrupec, Nevidljiva svjetlost iz svemira, Priroda 1043, 03/15

$$E = h\nu = \frac{hc}{\lambda}$$

gama astronomija – dio astročestične fizike

the study of particles of astronomical origin



- gamma-ray astronomy
- study of cosmic neutrino
- study of cosmic rays
- gravitational wave searches
- dark matter searches
- nuclear astrophysics

kako dobivamo informacije iz svemira?

mikroskopske materijalne čestice i veća tijela:
mikrometeoriti, meteoriti, uzorci koje su donijele letjelice

astročestice:

elektromagnetsko zračenje
(vidljiva svjetlost, radiovalovi, IC, UV, X-zrake, gama-zrake)

subatomske materijalne čestice: kozmičke zrake

astrofizički neutrini

gravitacijski valovi

gama-područje među astronomijama

opažačka astronomija

* područja unutar elektromagnetskog spektra
    - radioastronomija
    - infracrvena astronomija
    - optička astronomija
    - ultraljubičasta astronomija
    - rendgenska astronomija
    - gama-astronomija
* područja izvan elektromagnetskog spektra
* astrometrija i nebeska mehanika

teorijska astronomija

posebna potpodručja

- astronomija Sunca
- znanost o planetima
- astronomija zvijezda
- galaktička astronomija
- izvangalaktička astronomija
- kozmologija

nove astronomije & astronomije u nastanku

područja unutar elektromagnetskog spektra:

rendgenska astronomija ✓✓

gama-astronomija ✓

područja izvan elektromagnetskog spektra:

astronomija kozmičkih zraka

astronomija astrofizičkih neutrina

astronomija gravitacijskih valova

gama-zrake: od niskih do vrlo visokih energija

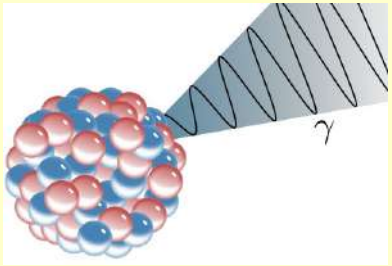
zumiranje gama-područja

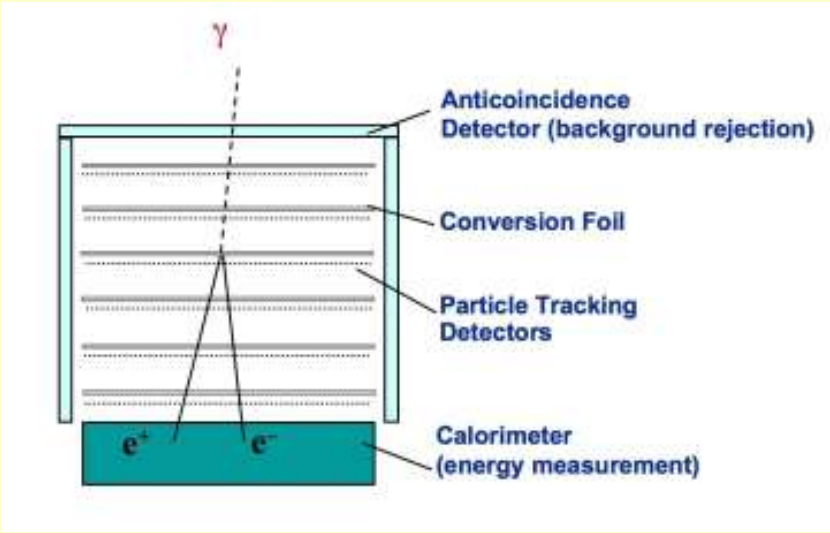
Region	Energy	Wavelength
γ-ray	**$E > 100$ keV** Precisely, $E > m_e c^2 = 511$ keV	**$\lambda < 1$ pm** Precisely, $\lambda < \lambda^e_{COMPTON} = 2.43$ pm
X-ray	100 eV $< E <$ 100 keV	1 pm $< \lambda <$ 10 nm
ultraviolet	10 eV $< E <$ 100 eV	10 nm $< \lambda <$ 100 nm
visible	1 eV $< E <$ 10 eV Precisely, 1.7 eV $< E <$ 3.2 eV	100 nm $< \lambda <$ 1 μm Precisely, 380 nm $< \lambda <$ 750 nm
infrared	1 meV $< E <$ 1 eV	1 μm $< \lambda <$ 1 mm
microwave	0.1 μeV $< E <$ 1 meV	1 mm $< \lambda <$ 10 cm
radio	$E <$ 0.1 μeV	$\lambda >$ 10 cm

Region	Energy
LE/ME	100 keV $< E <$ 100 MeV
HE	100 MeV $< E <$ 100 GeV
VHE	**100 GeV $< E <$ 100 TeV**
UHE	100 TeV $< E <$ 100 PeV
EHE	$E >$ 100 PeV

gama-zrake niskih energija

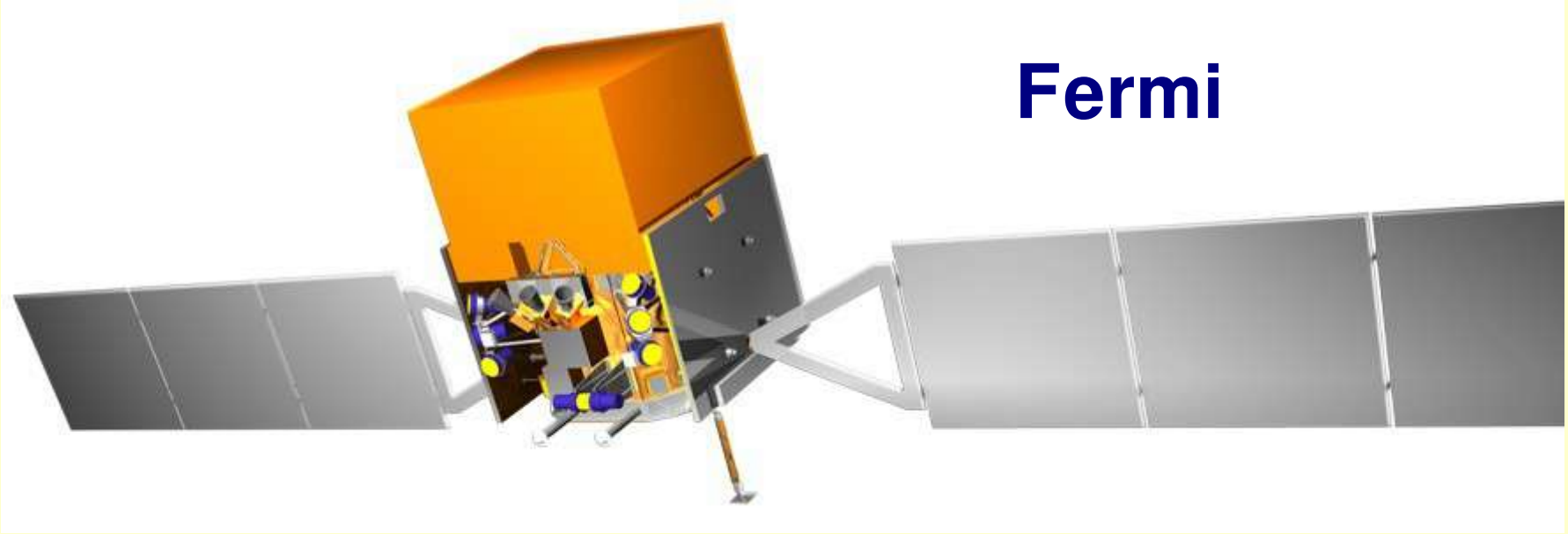
- od 100 keV do 100 MeV
- **zemaljski izvori**
- laboratorijski detektori





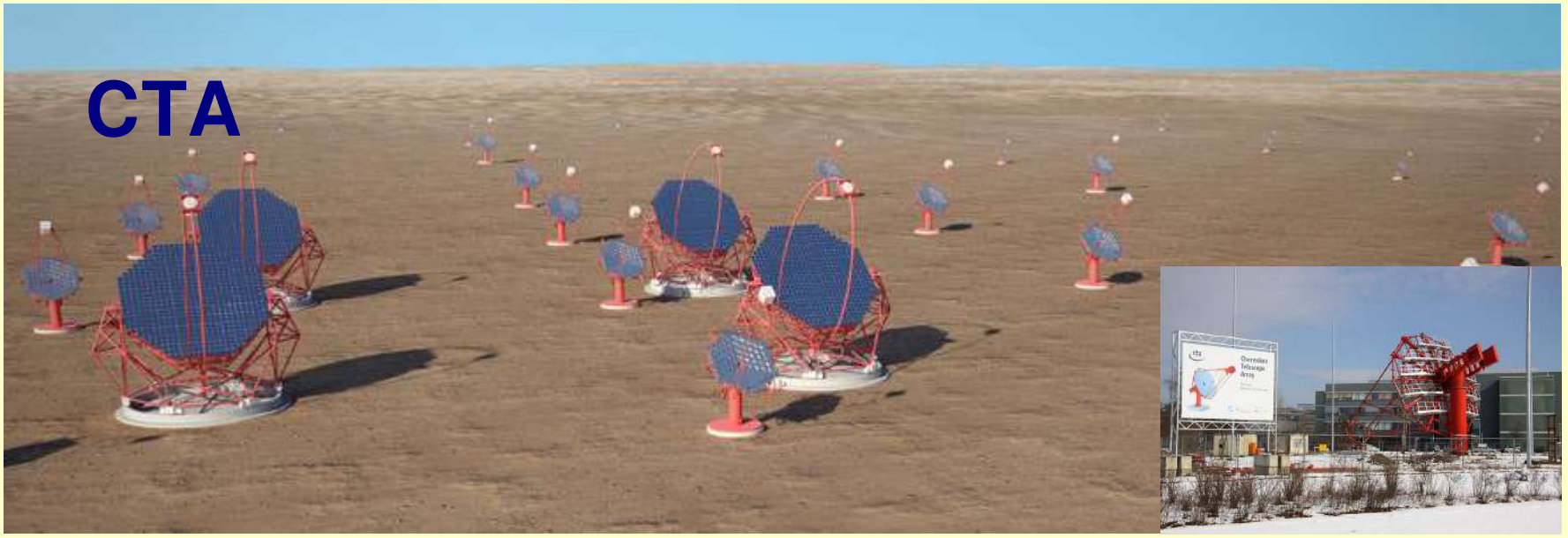
gama-zrake visokih energija

- od 100 MeV do 100 GeV
- **kozmički izvori**
- satelitski detektori



gama-zrake vrlo visokih energija

- od 100 GeV do 100 TeV
- **kozmički izvori**
- zemaljski teleskopi

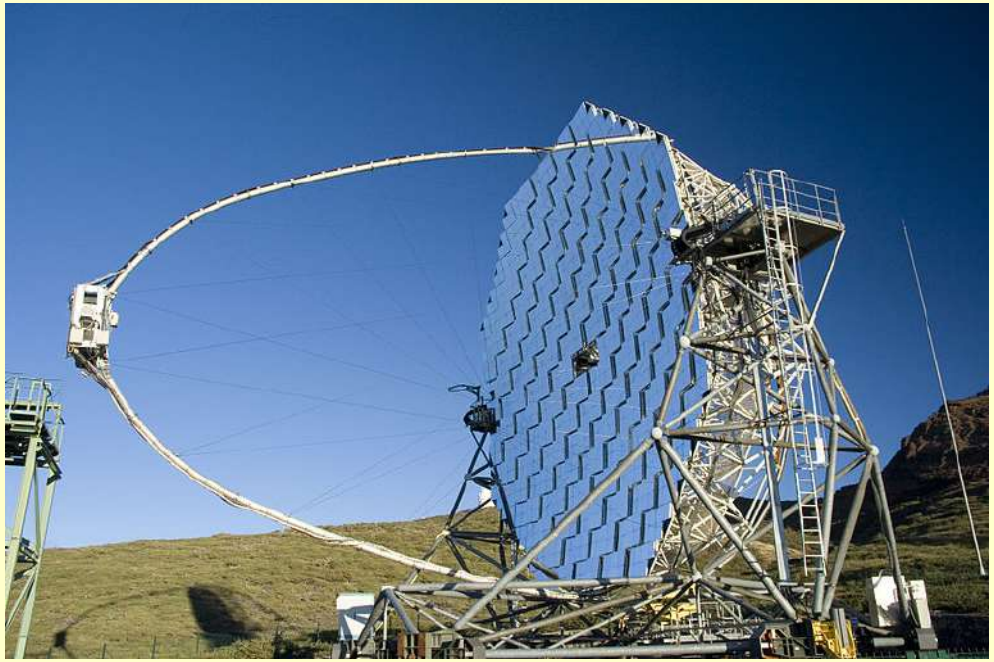


teleskopi MAGIC

Čerenkovljevi teleskopi

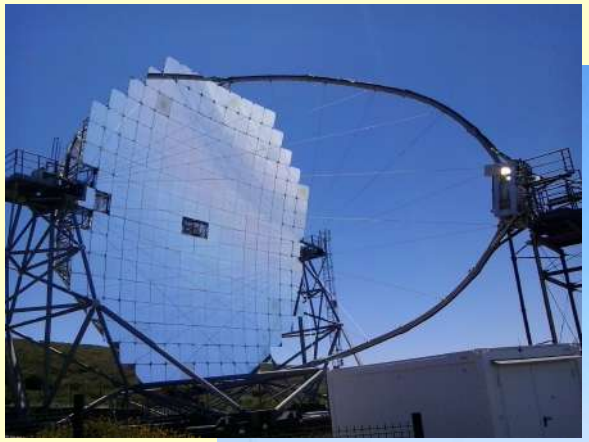
teleskopi MAGIC: opći podaci

organizacija	kolaboracija MAGIC
mjesto	La Palma, Kanari
visina	2200 m
područje spektra	VHE gama-zrake (indirektno)
početak rada	2004
vrsta teleskopa	reflektor
promjer	17 m
površina zrcala	240 m^2
broj teleskopa	2



Major Atmospheric Gamma-ray Imaging Cherenkov Telescopes

kanarski otok La Palma, Španjolska



kolaboracija MAGIC

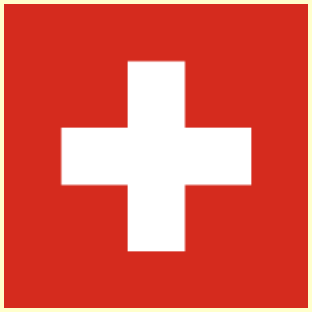
52

48

39

12

10



8

6

4

4

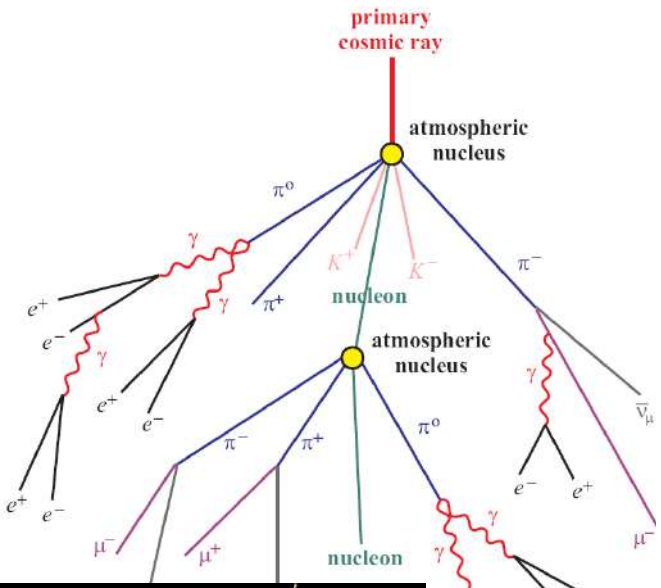
3

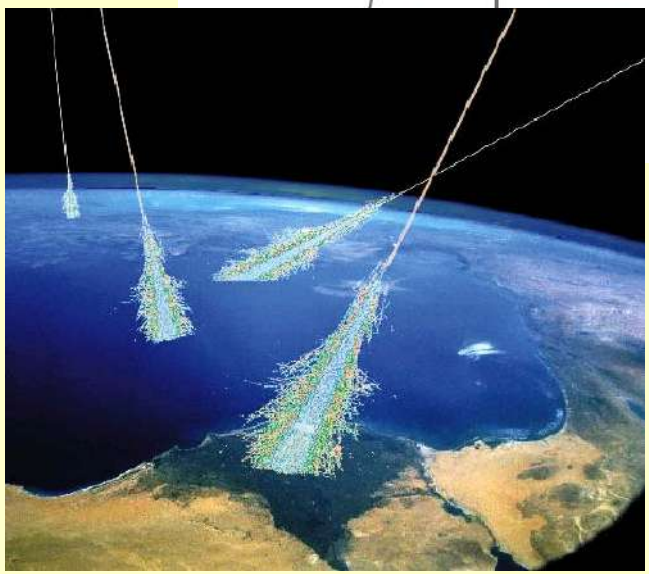
kako opažamo gama-zrake vrlo visokih energija

selektivna transparentnost atmosfere

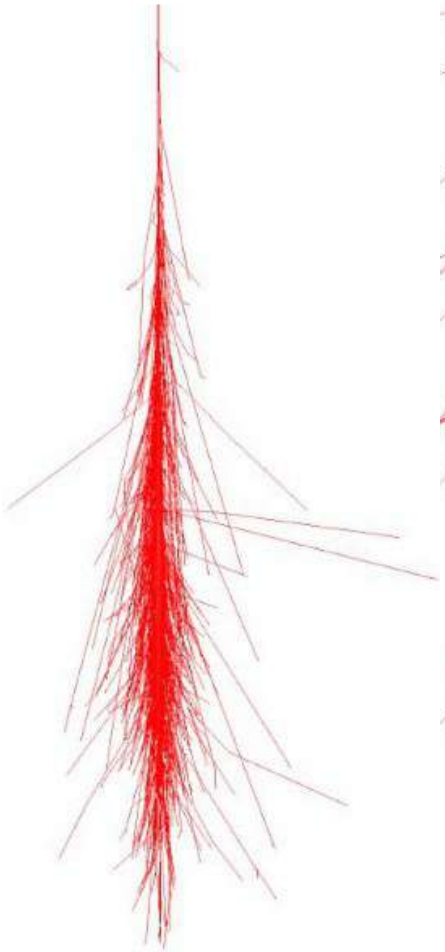
γ X UV

IACT:
EAS - Extensive Air Shower

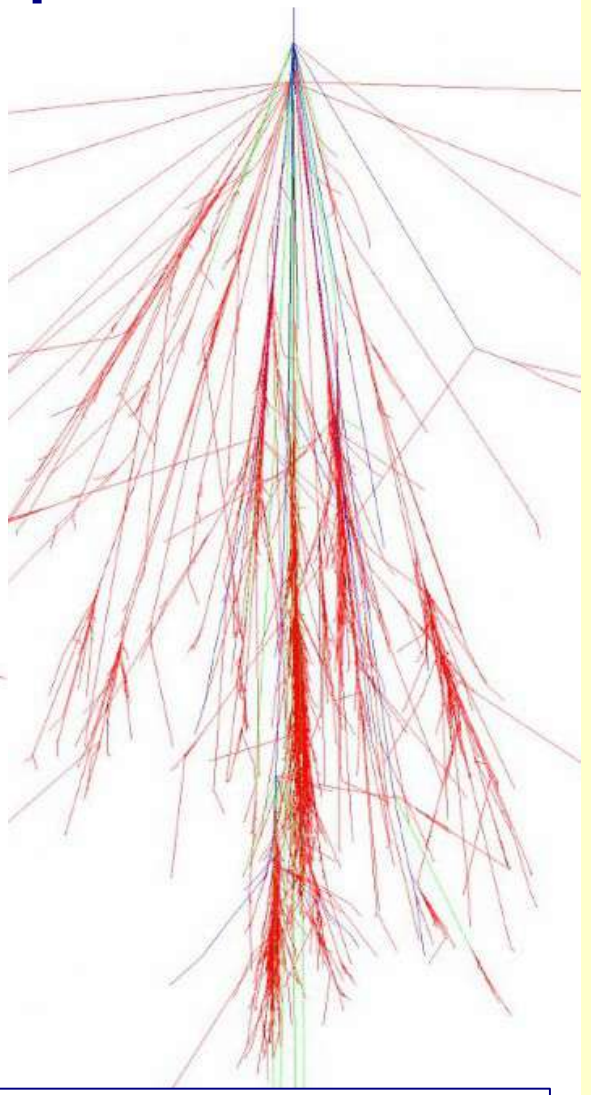




gamma 50 GeV



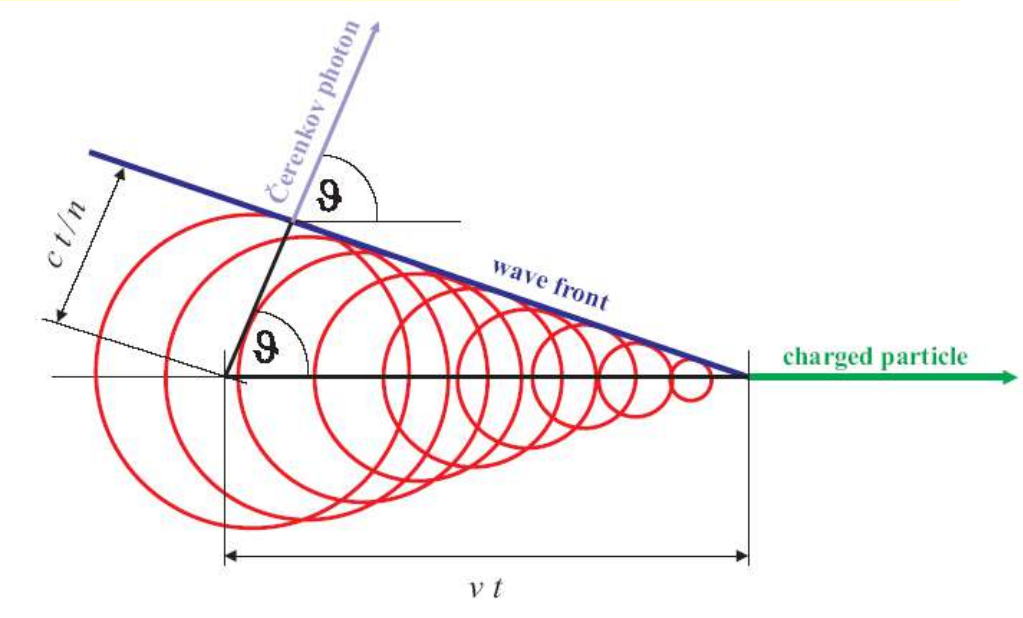
proton 200 GeV

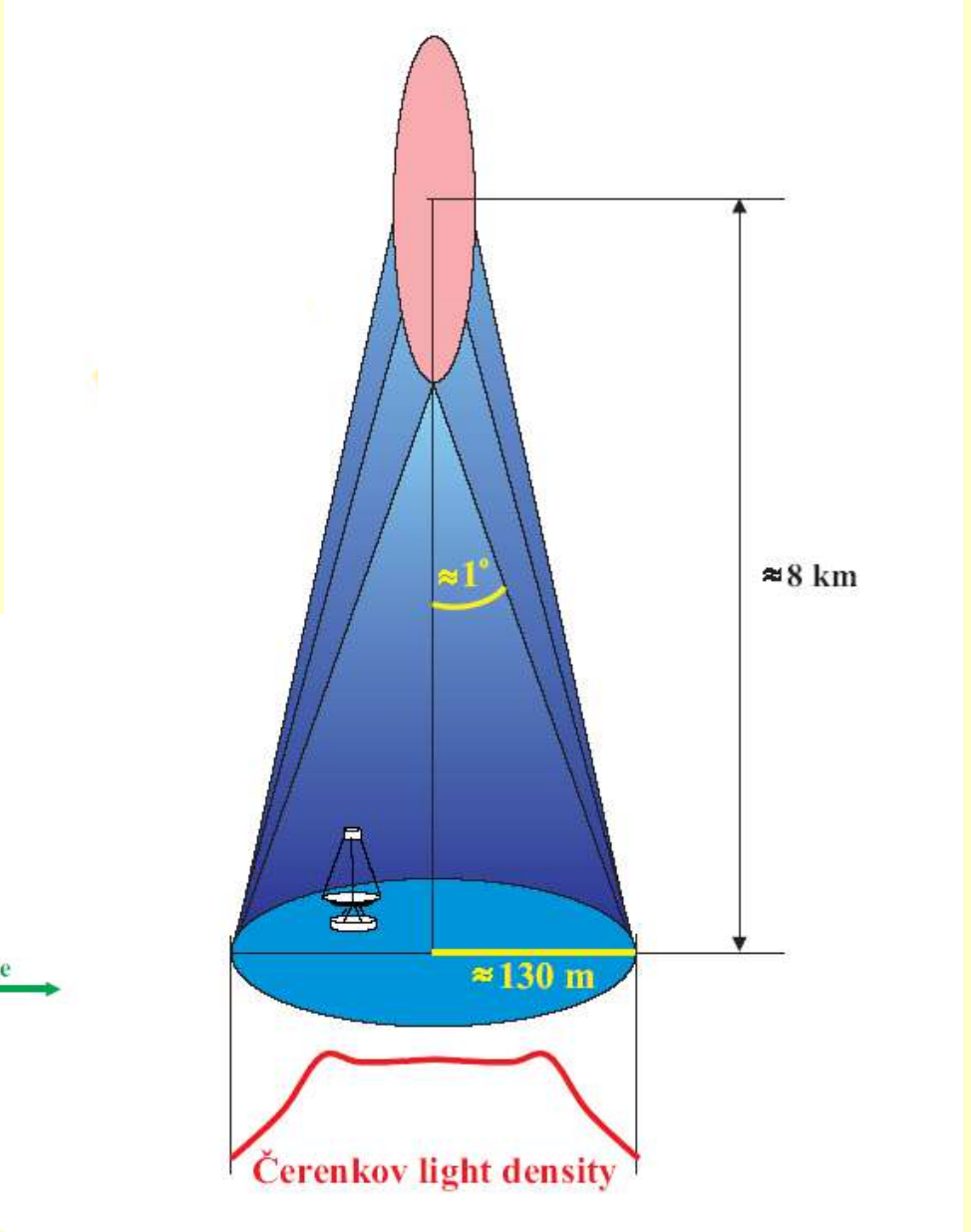


IACT (Imaging Atmospheric Cherenkov Technique)

IACT:
Cherenkov light from EAS

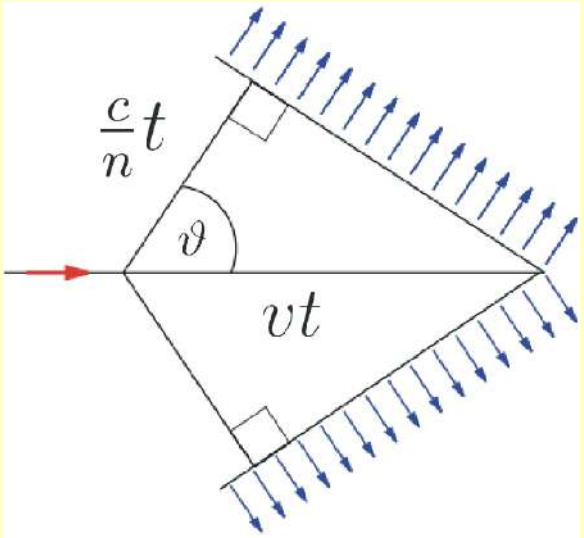
The essential mechanism for the detection of VHE γ-rays at ground





IACT:
Cherenkov radiation

EM radiation *produced by medium* when a relativistic charged particle travels through it with a velocity that **exceeds the velocity of light** in that medium.



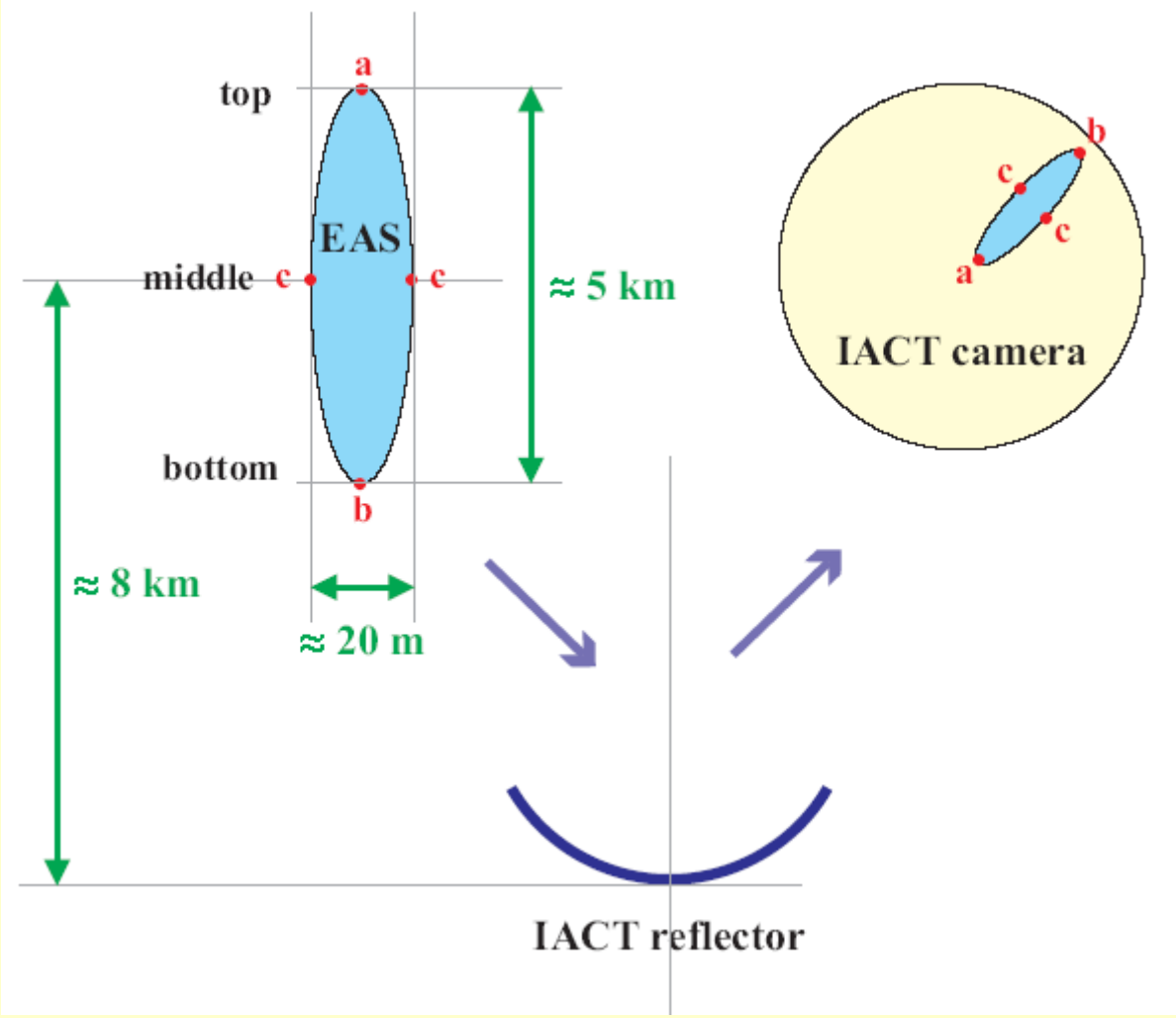
- continuous spectrum (visible & **UV**)
- applications in particle physics (RICH) and astroparticle physics (Čerenkov telescopes and neutrino telescopes)

$$\cos\vartheta = \frac{\frac{c}{n}t}{vt} = \frac{1}{n\beta}$$

In the atmosphere at ground level:

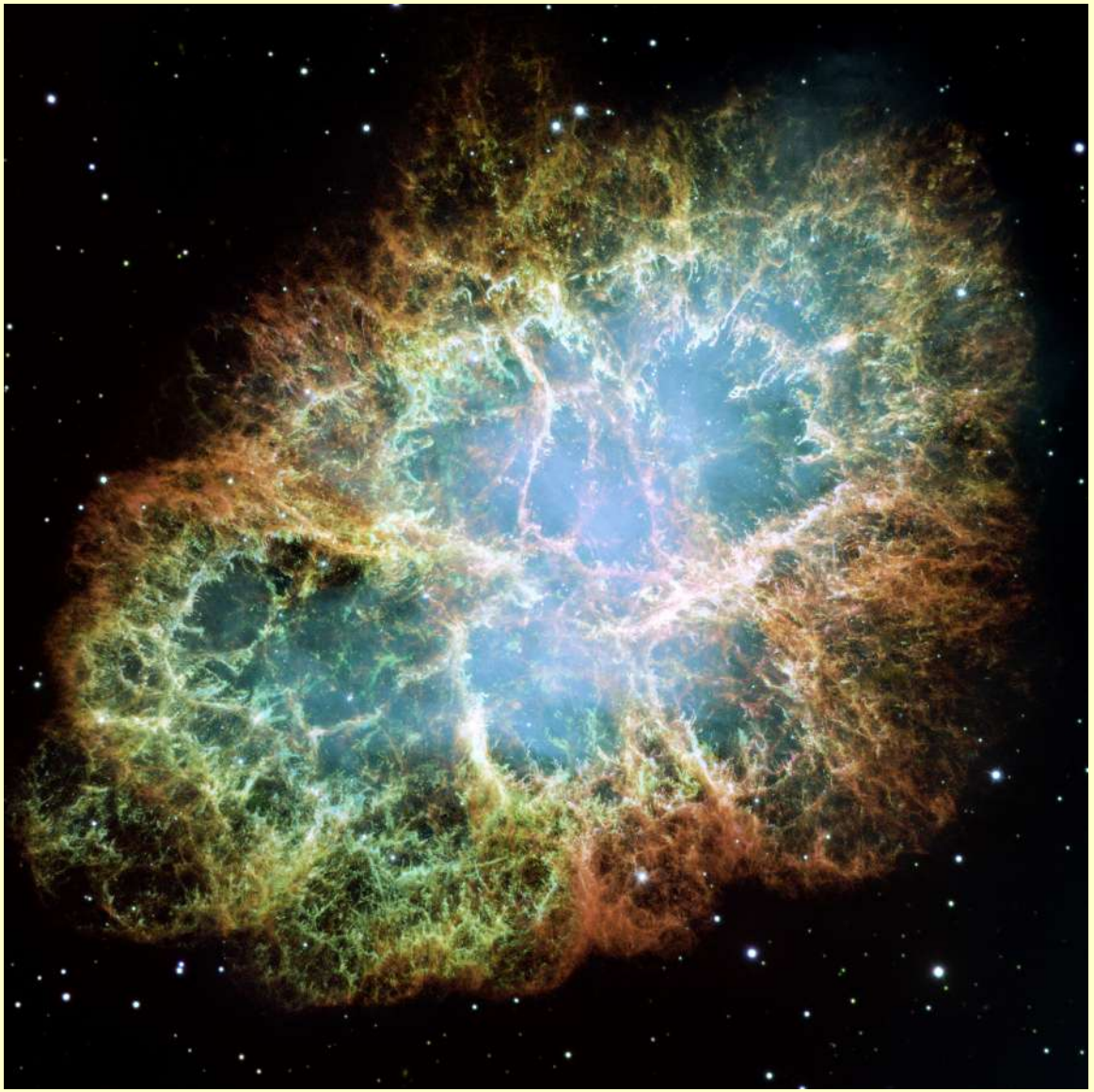
- $n = 1.00029$
- $\theta_{max} = 1.3^{o}$
- $E_{th}(e) = 21$ MeV, $E_{th}(\mu) = 4.4$ GeV, $E_{th}(p) = 39$ GeV,
- light yield (visible) = 30 photons/m (or 10^4 photons/RL)

IACT:
From an EAS to a camera image

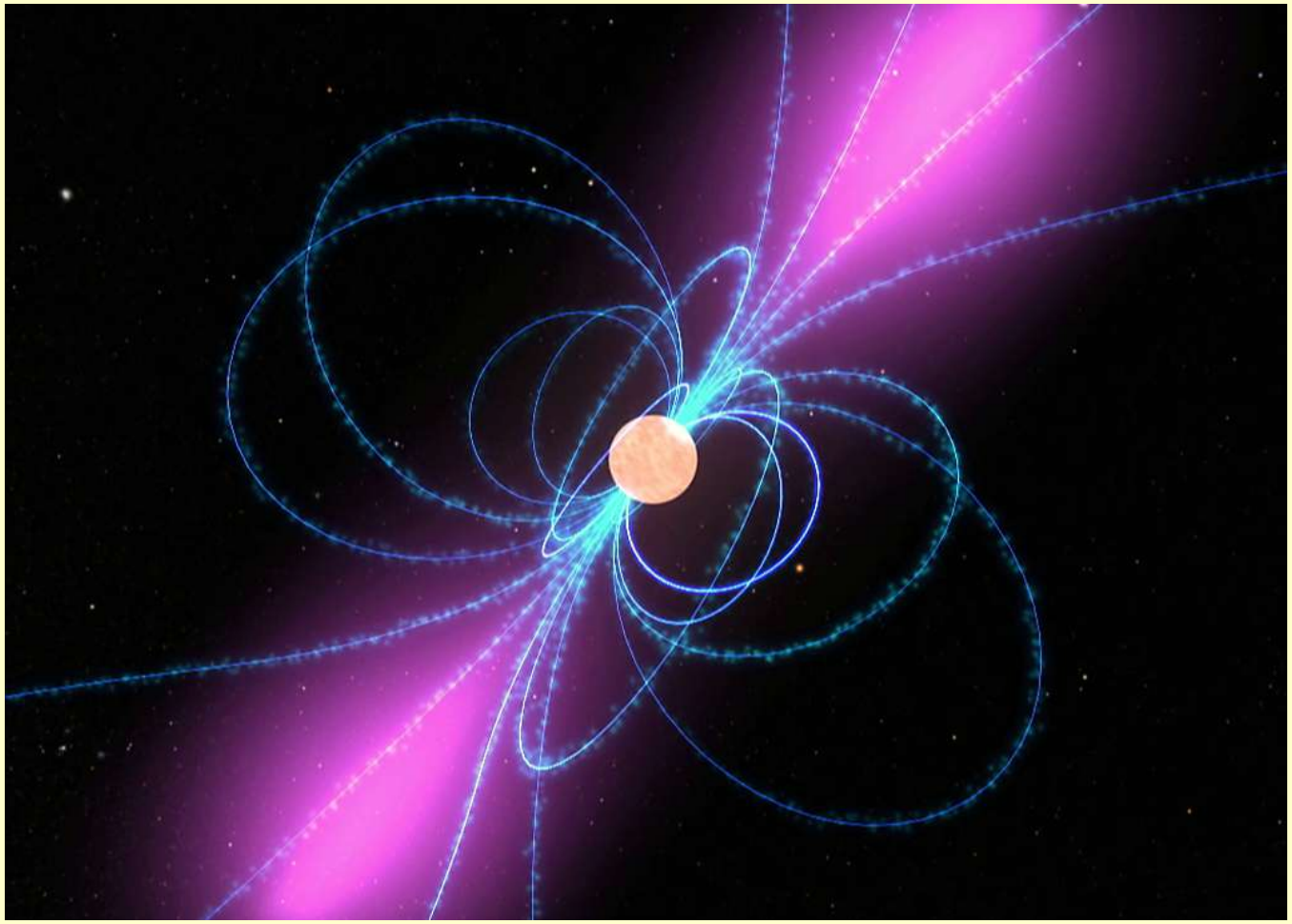


odakle dolaze gama-zrake vrlo visokih energija

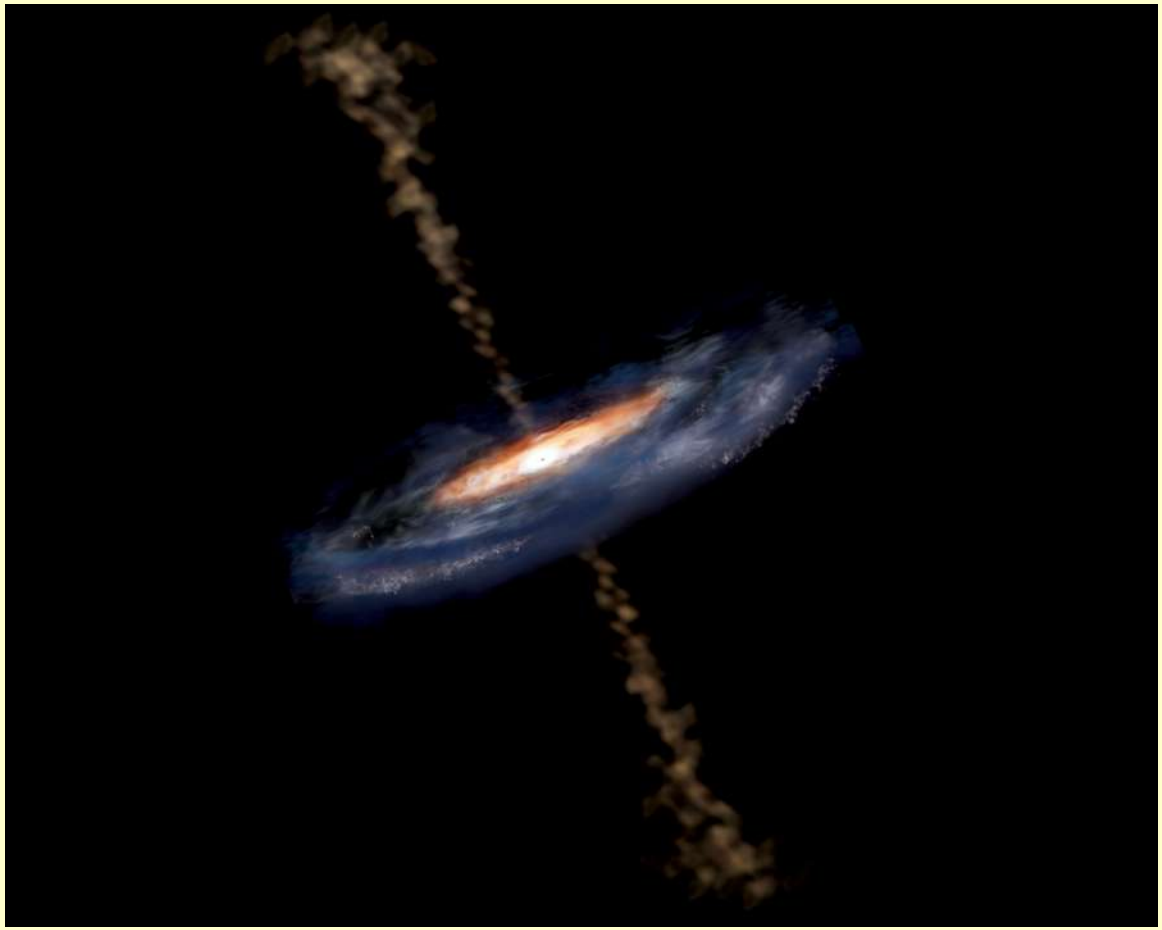
Izvori VHE γ-zraka:
SNR – Supernova remnant



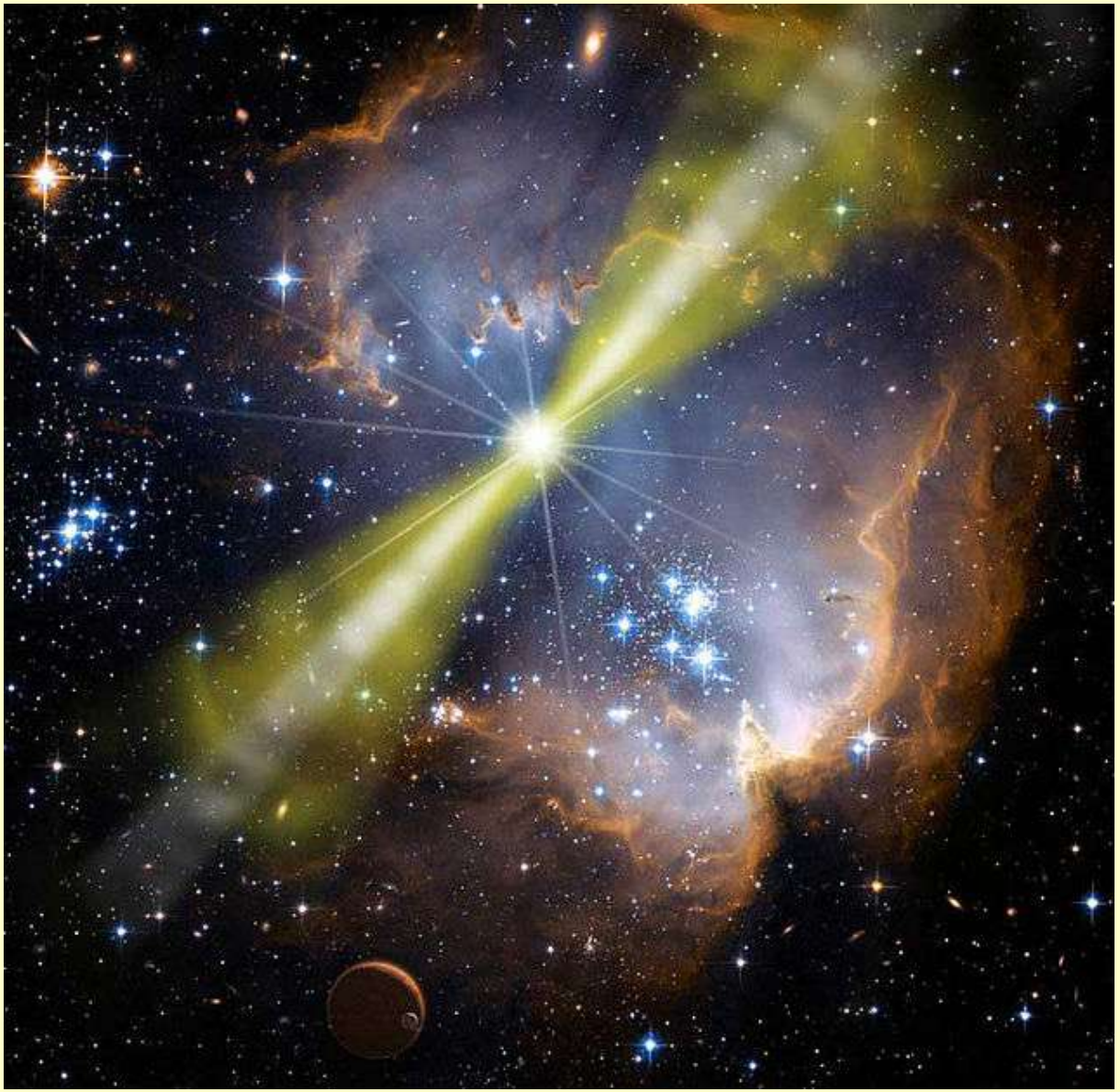
Izvori VHE γ-zraka:
Pulsar – fast rotating neutron star



Izvori VHE γ-zraka:
AGN – Active galactic nucleus



Izvori VHE γ-zraka:
GRB - Gamma-ray burst



što dalje?
(umjesto zaključka)

Što nakon MAGIC-a:
Cherenkov Telescope Array

the Cherenkov Telescope Array[1] is a new observatory for *very high-energy* (VHE[2]) **gamma rays**

[1] 50–100 telescopes per site

[2] $E >$ 100 GeV