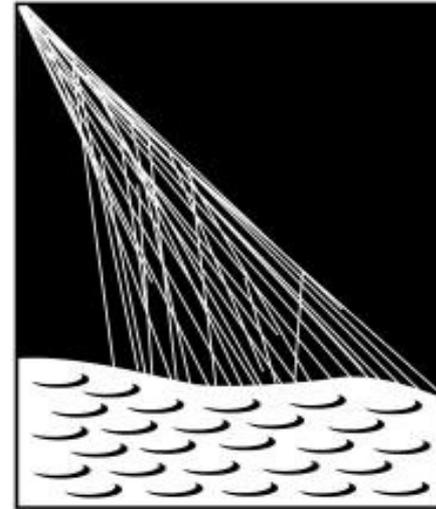


# Os mensageiros de mais alta energia no universo

Vitor de Souza  
vitor@ifsc.usp.br



PIERRE  
AUGER  
OBSERVATORY

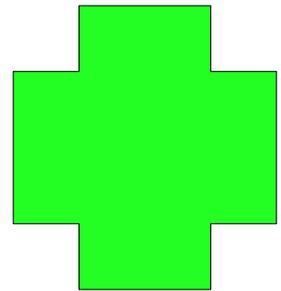
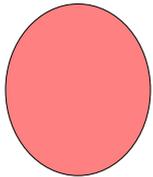
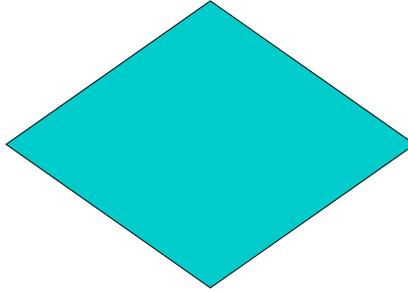
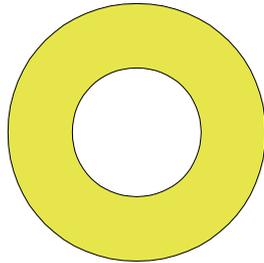


**Instituto de Física de São Carlos**

**Universidade de São Paulo**



Se algo me atinge ...



Se algo me atinge ... Eu quero saber o que é !



Se algo me atinge ... Eu quero saber o que é !



Se algo me atinge ... Eu quero saber o que é !



Se algo me atinge ... Eu quero saber o que é !



Se algo me atinge ... Eu quero saber o que é !



Se algo me atinge ...

Eu quero saber:

O QUE ?

Se algo me atinge ... Eu quero saber quem jogou !



sps0433 www.fotosearch.com

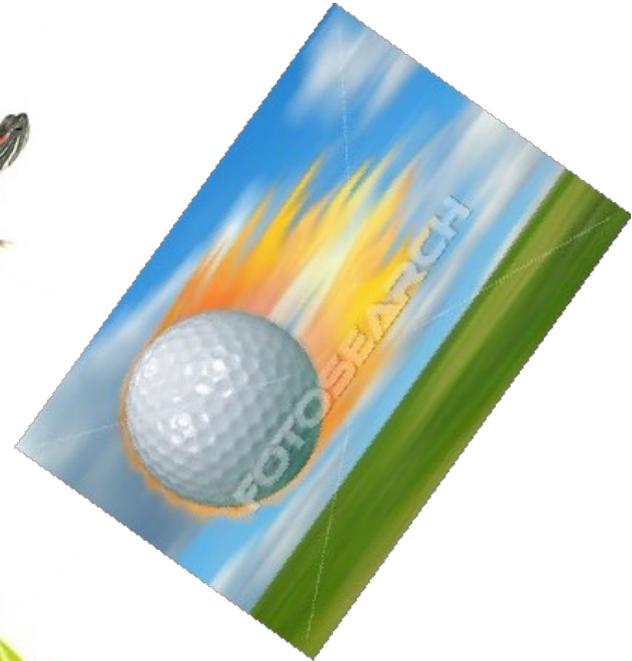
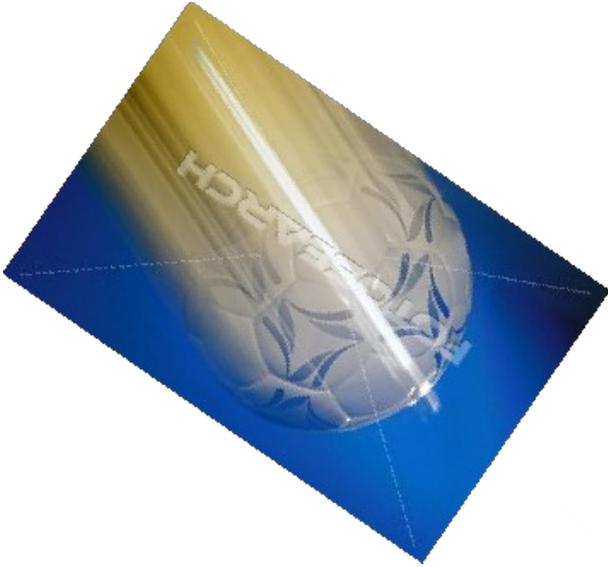
Se algo me atinge ...

Eu quero saber:

O QUE ?

QUEM ?

Se algo me atinge ... Eu quero saber a **velocidade** !



Se algo me atinge ...

Eu quero saber:

O QUE ?

QUEM ?

VELOCIDADE ?

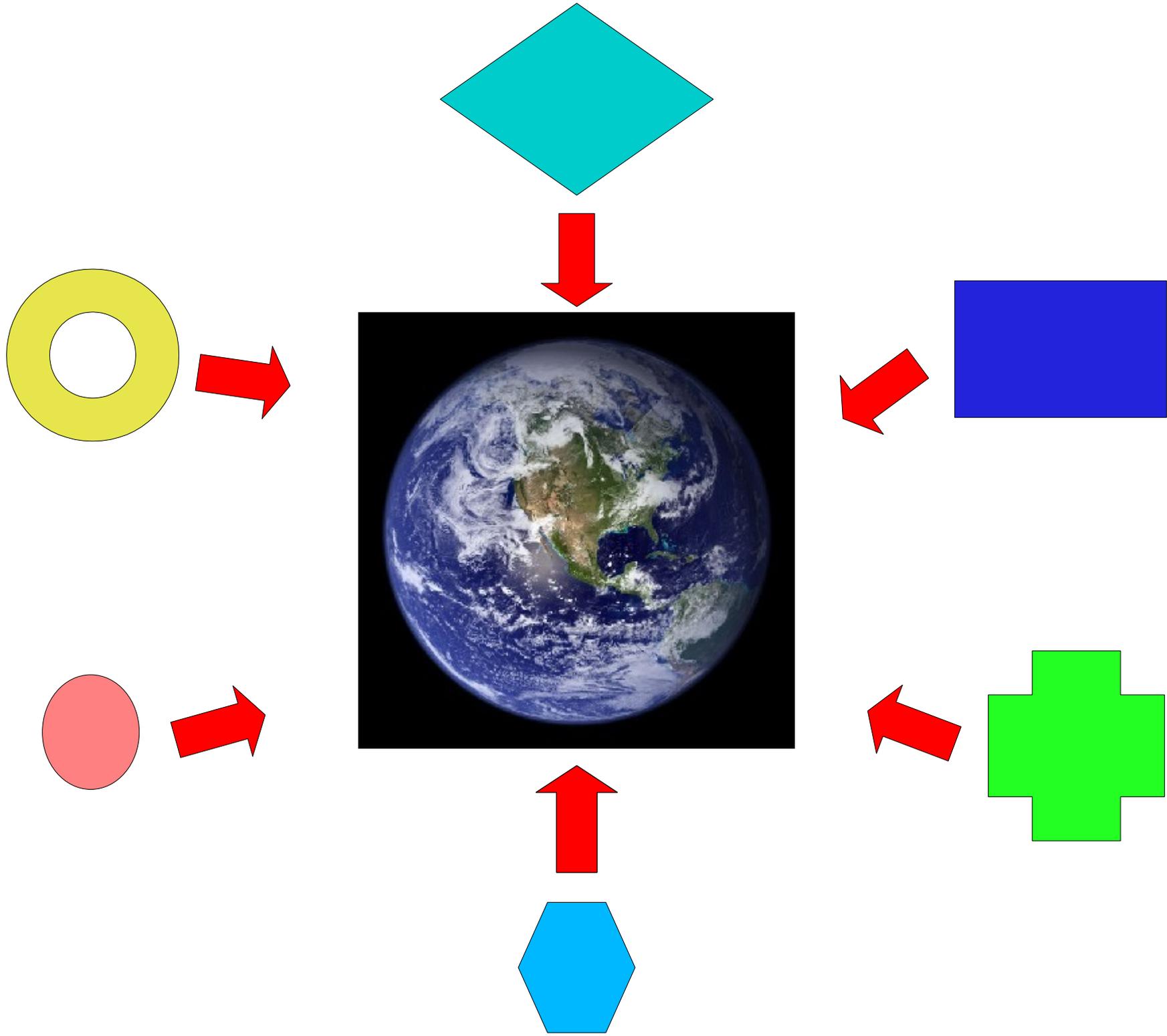
Se algo me atinge ...

Eu quero saber:

O QUE ?

QUEM ?

ENERGIA ?



Se algo me atinge ...

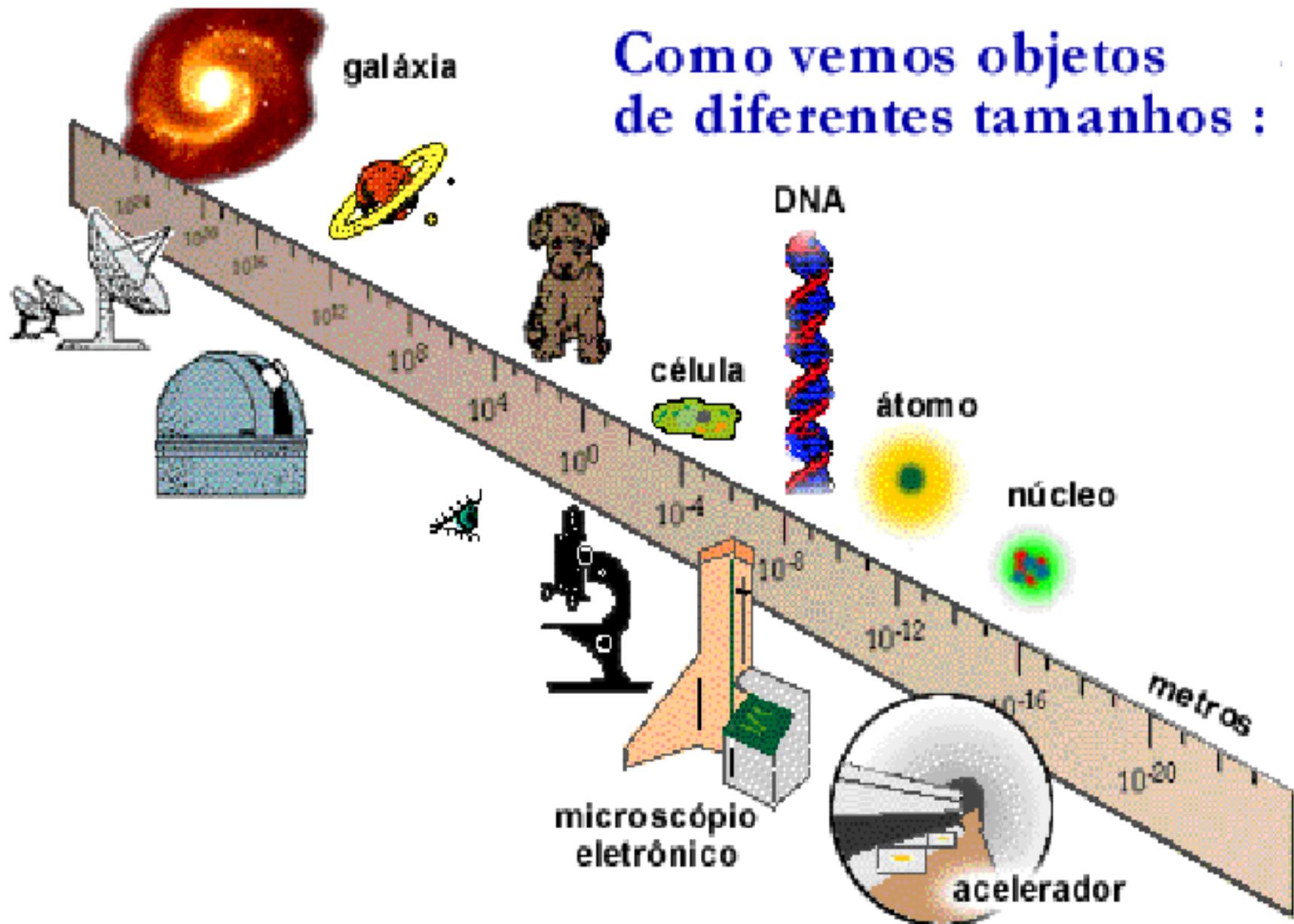
Eu quero saber:

O QUE ?

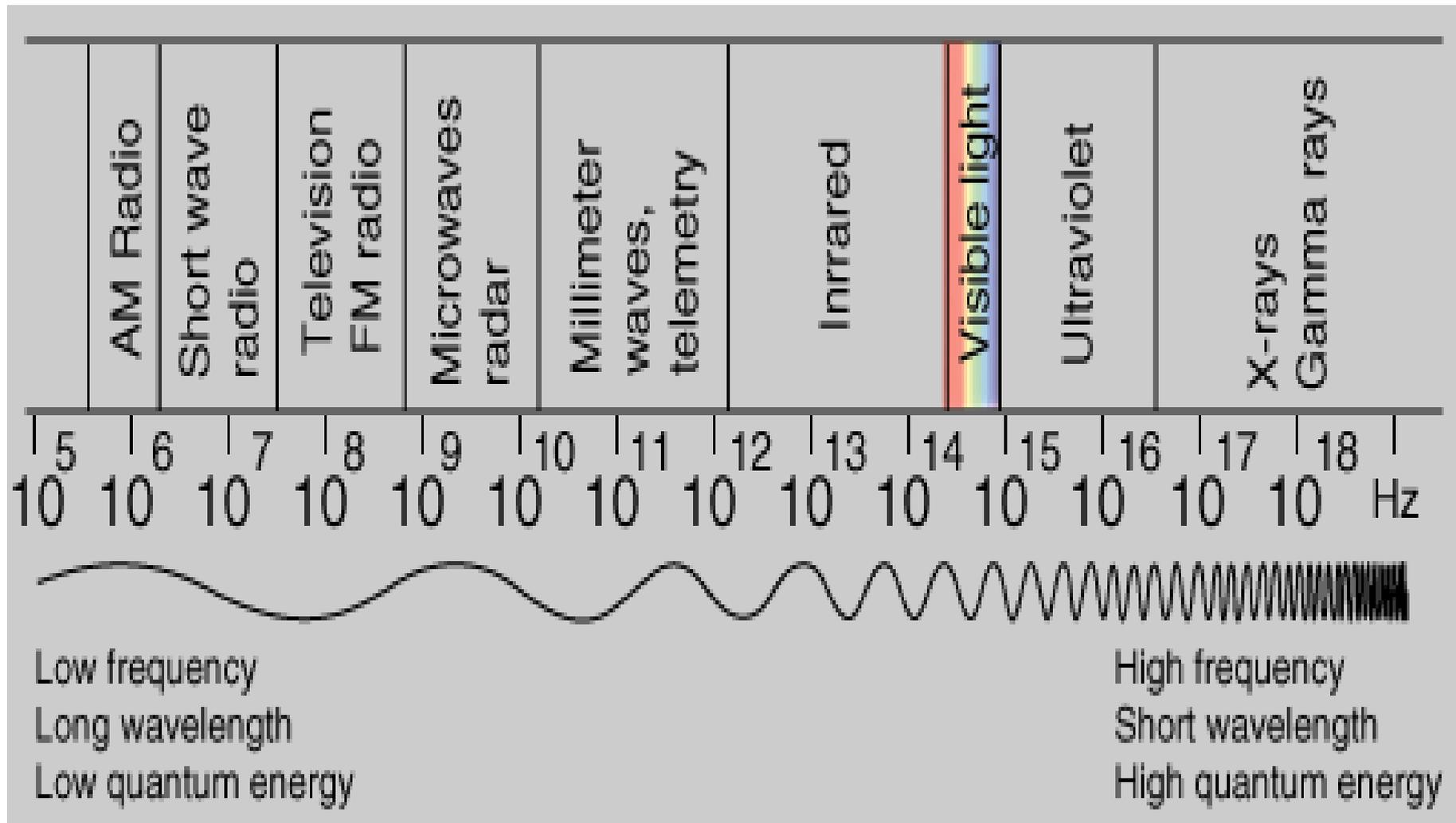
QUEM ?

ENERGIA ?

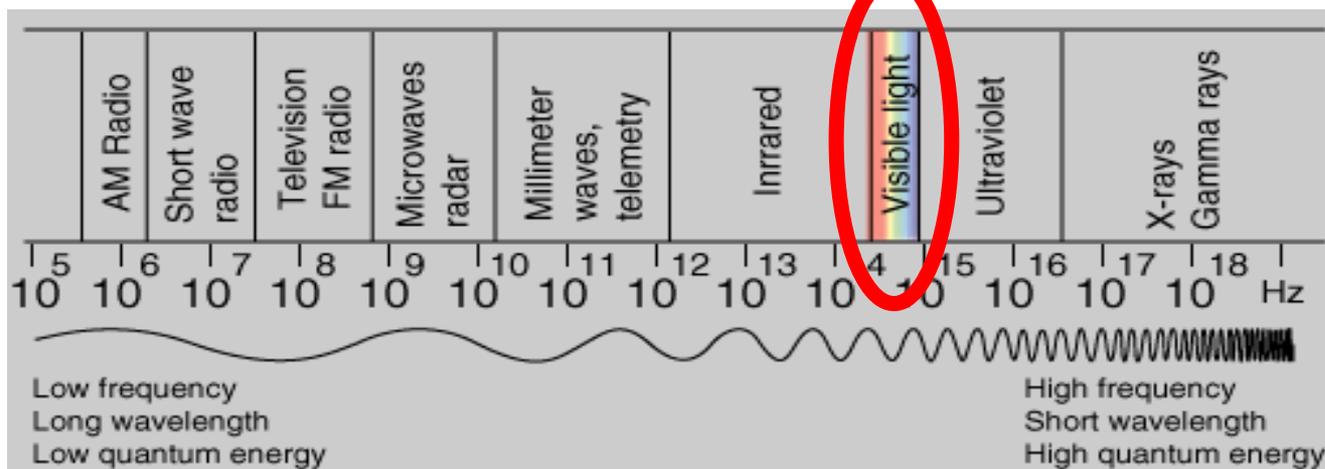
# Como vemos objetos de diferentes tamanhos :



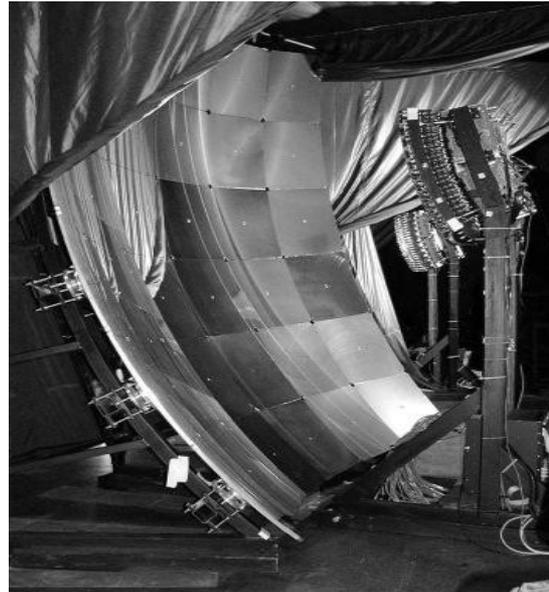
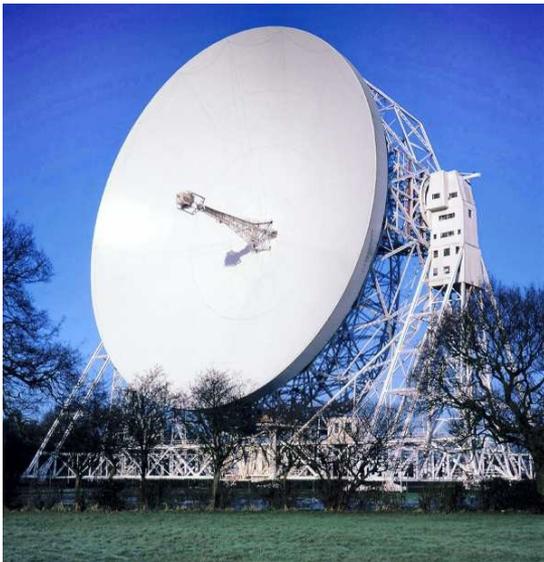
# “Tamanho” equivalente pra luz



# Olhando pro céu com o nosso olho:

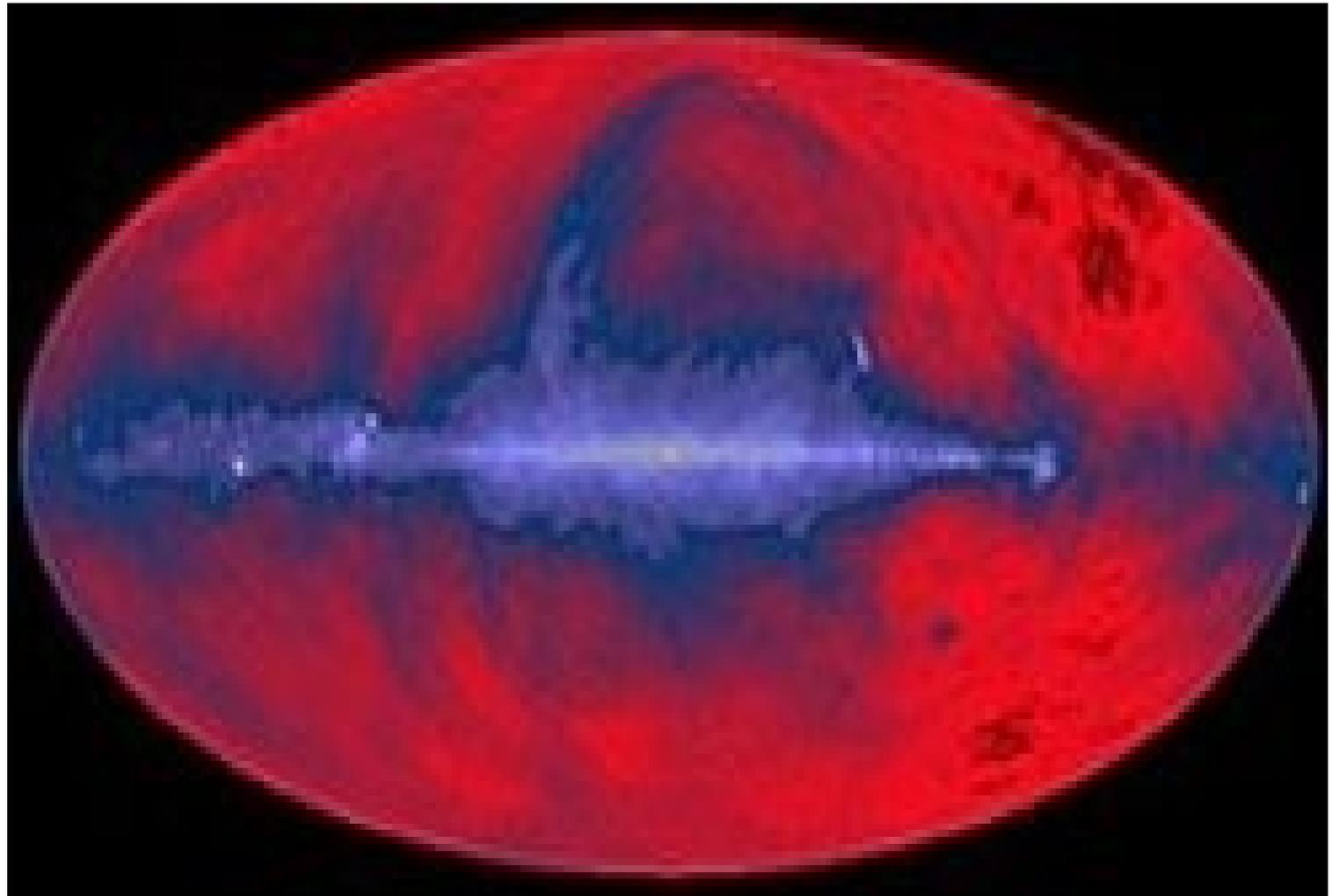
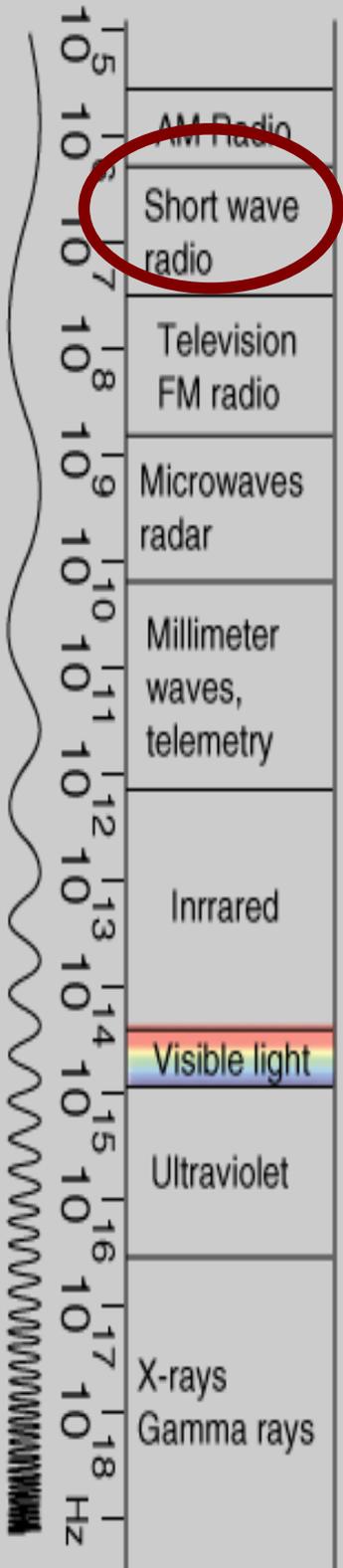


# Olhando para o céu com instrumentos:



# Via Láctea: Rádio (408 MHz) C. Haslam et al., MPIfR, SkyView)

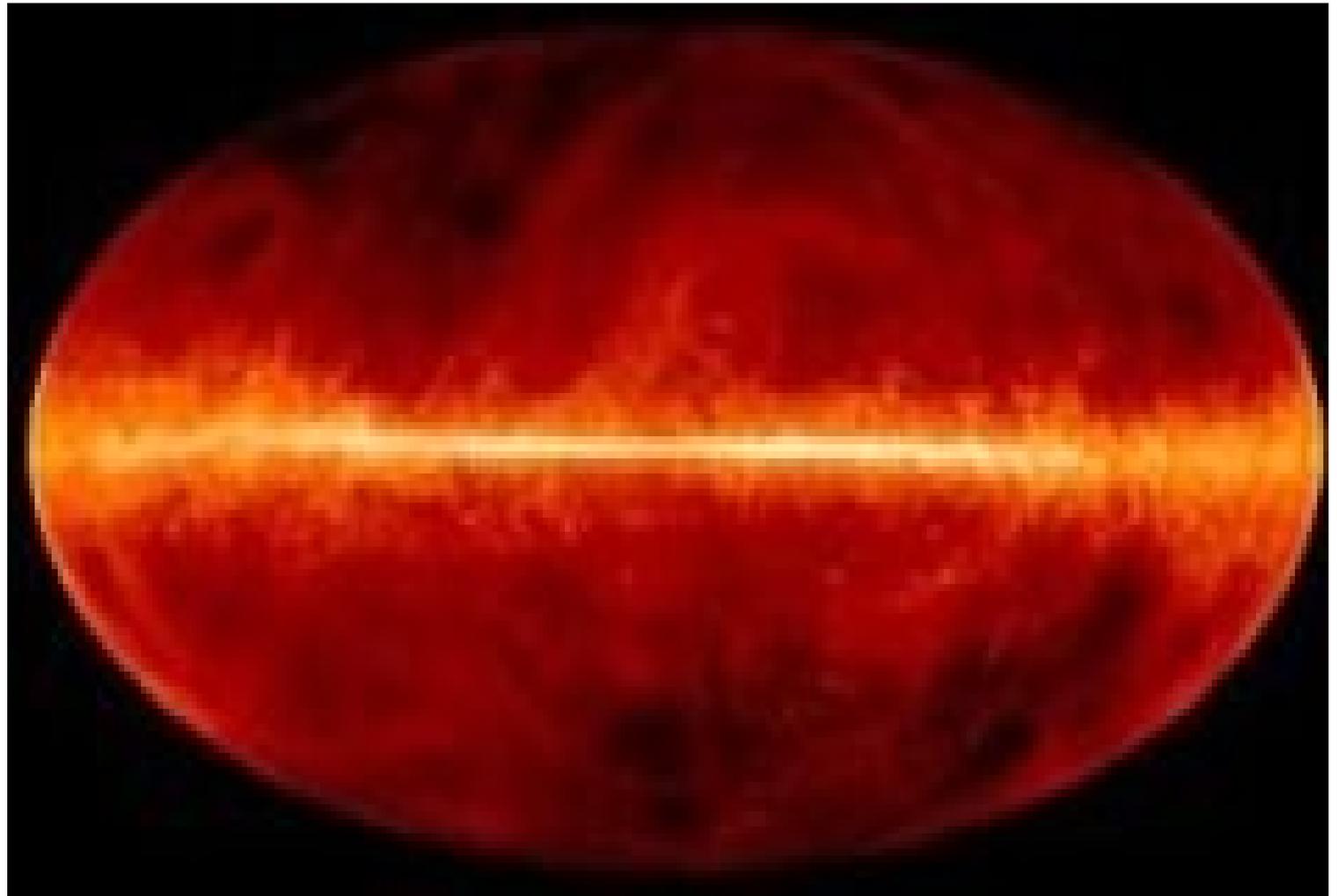
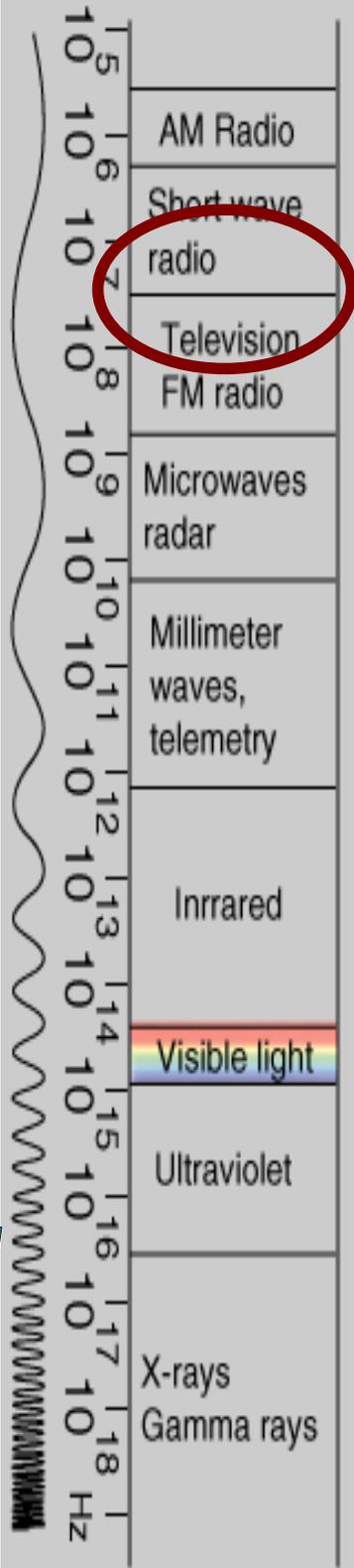
ENERGIA



# Via Láctea: Rádio (1420 MHz)

J. Dickey et.al. UMn. NRAO SkyView

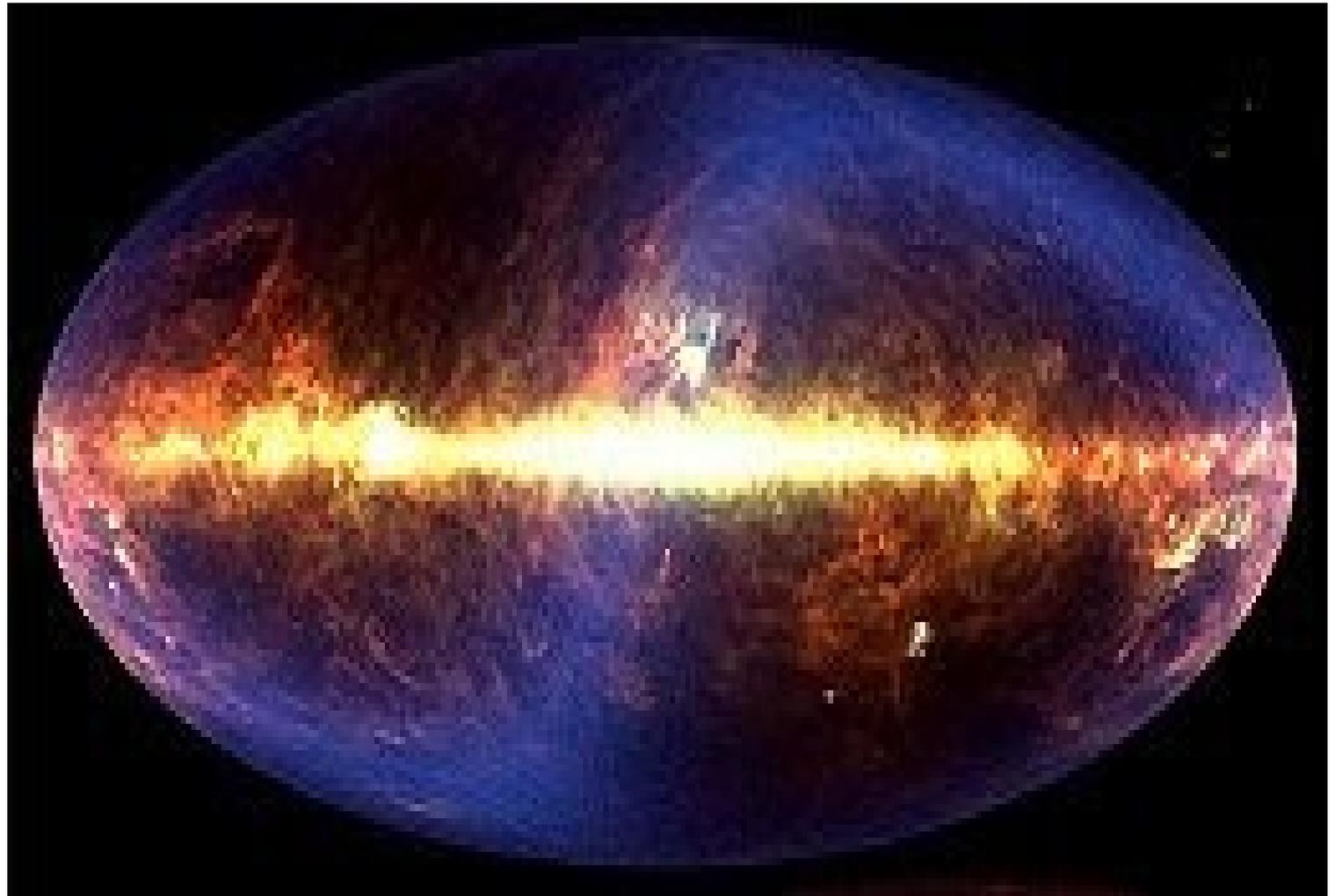
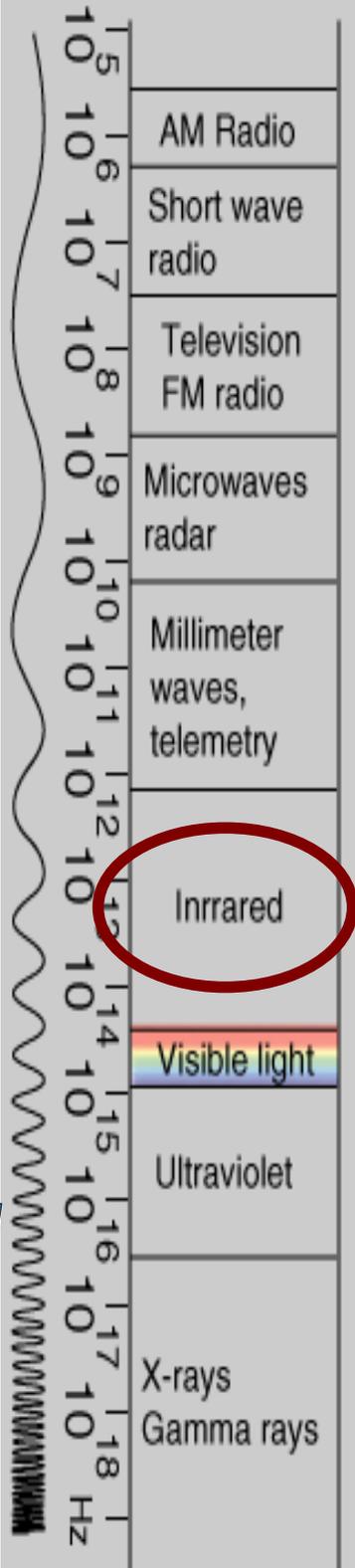
ENERGIA



# Via Láctea: Infravermelho

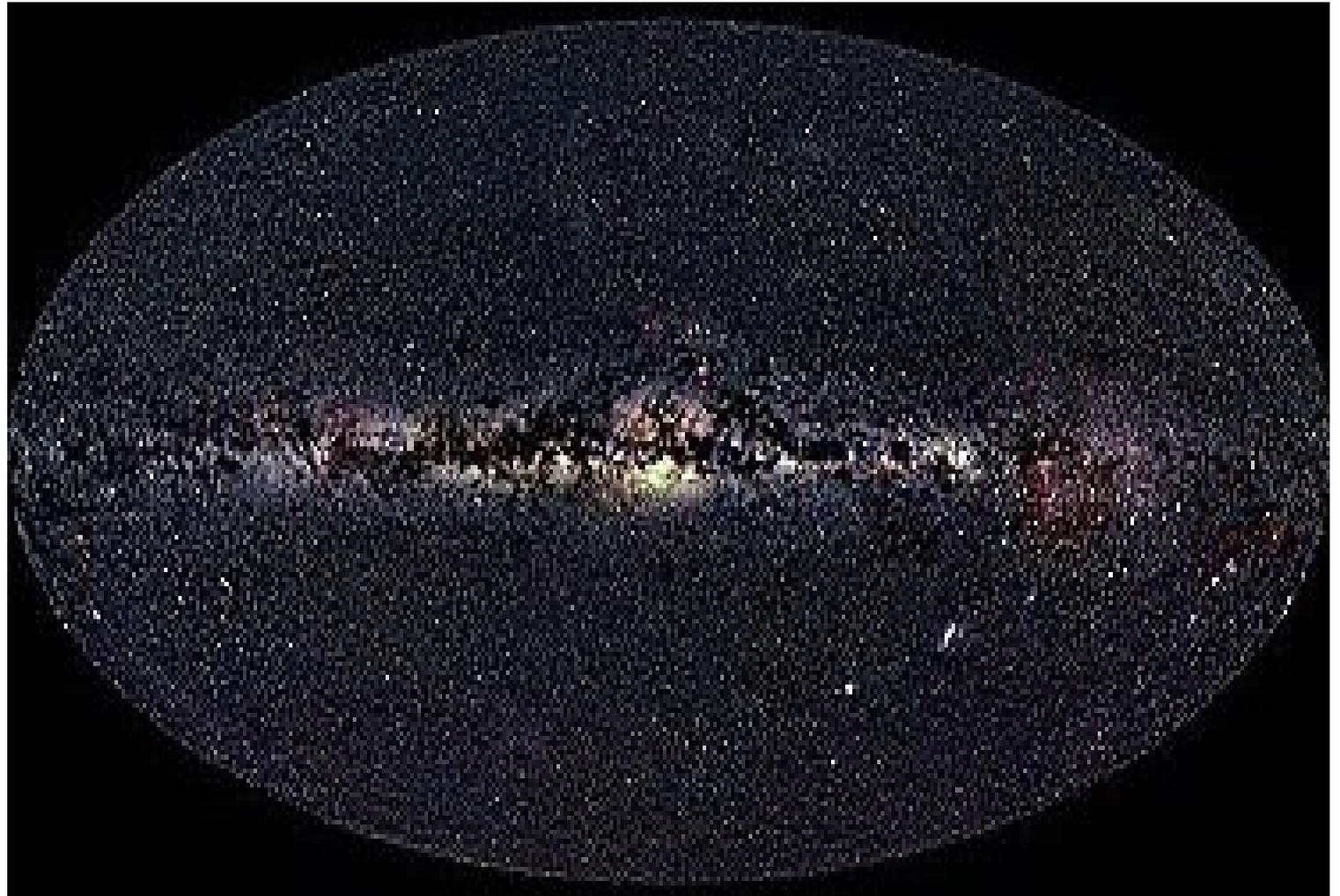
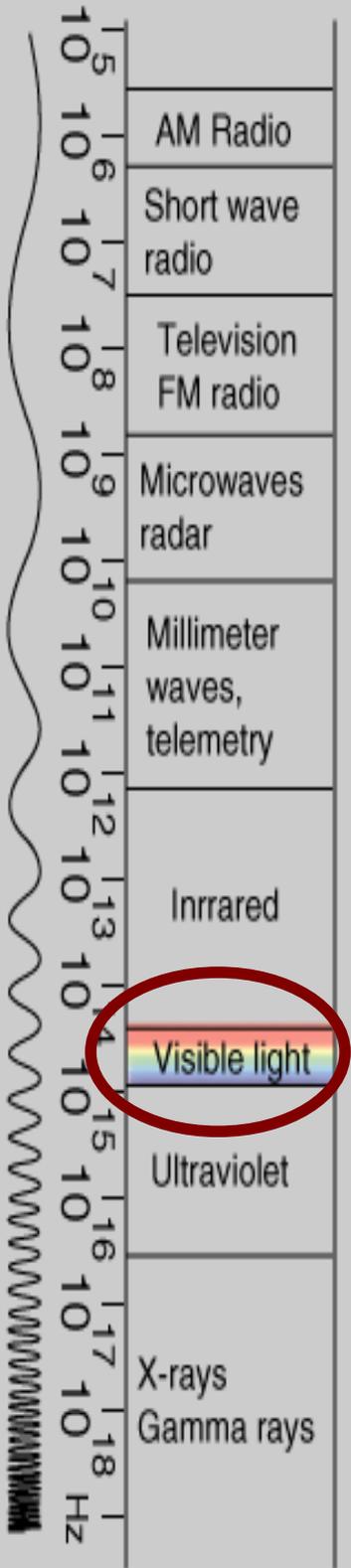
Dirbe Team, COBE, NASA

E  
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A



# Via Láctea: Vísivel por Axel Melinger

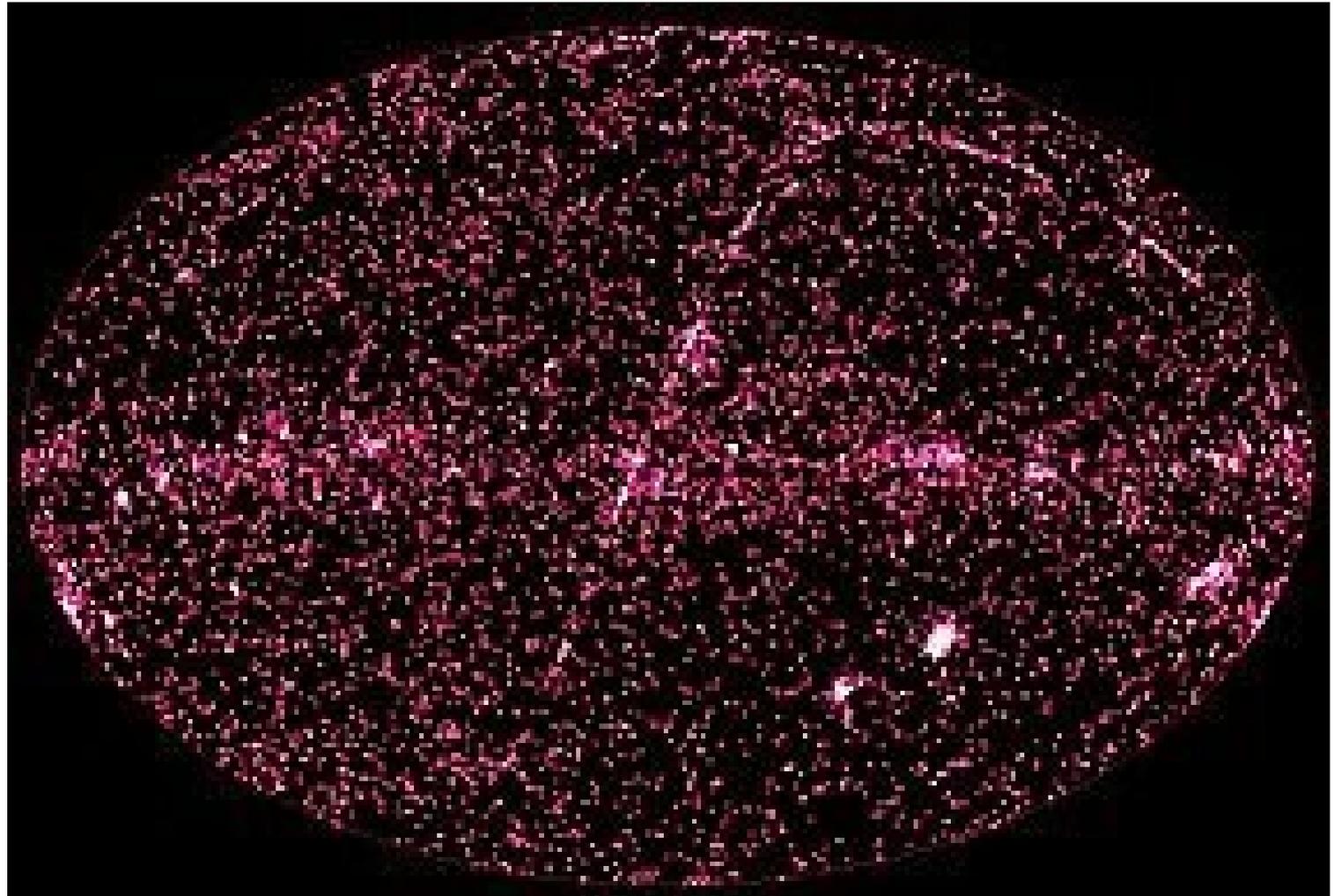
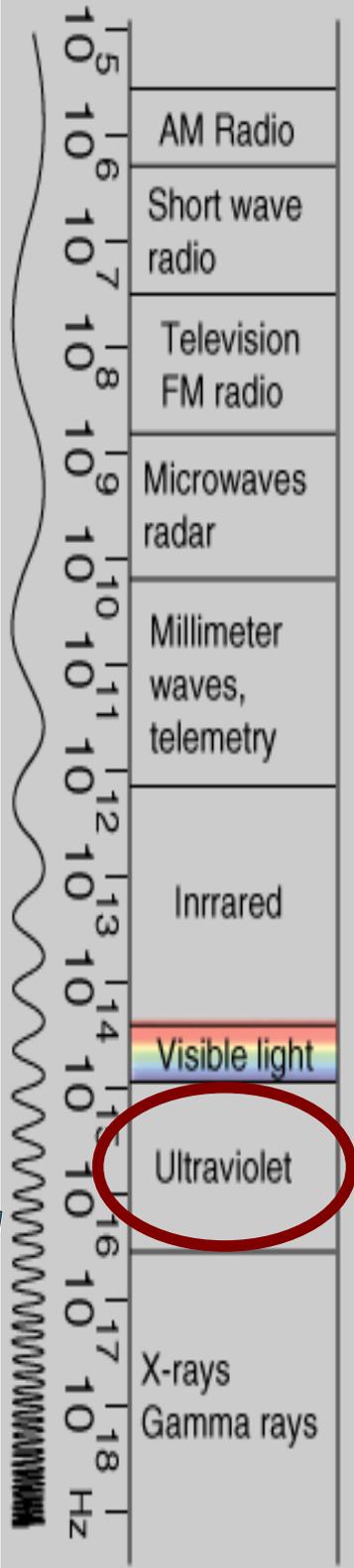
ENERGIA



# Via Láctea: Ultravioleta

J. Bonnell et.al.(GSFC, NASA)

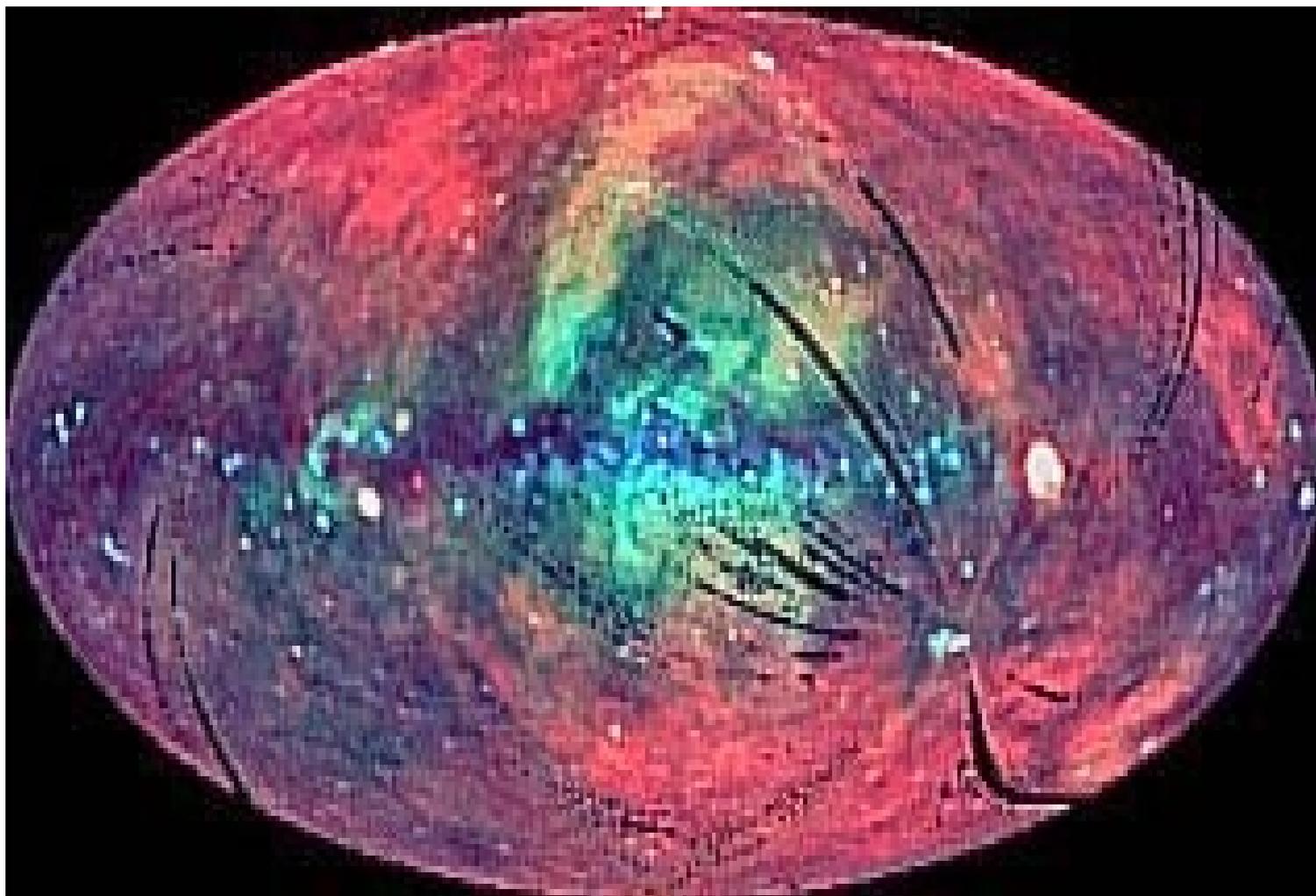
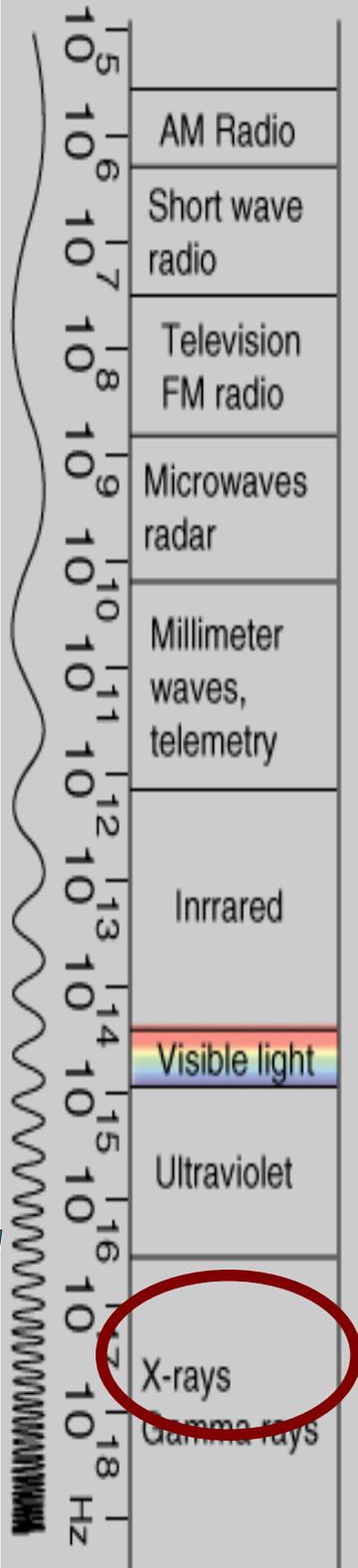
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# Via Láctea: Raios X

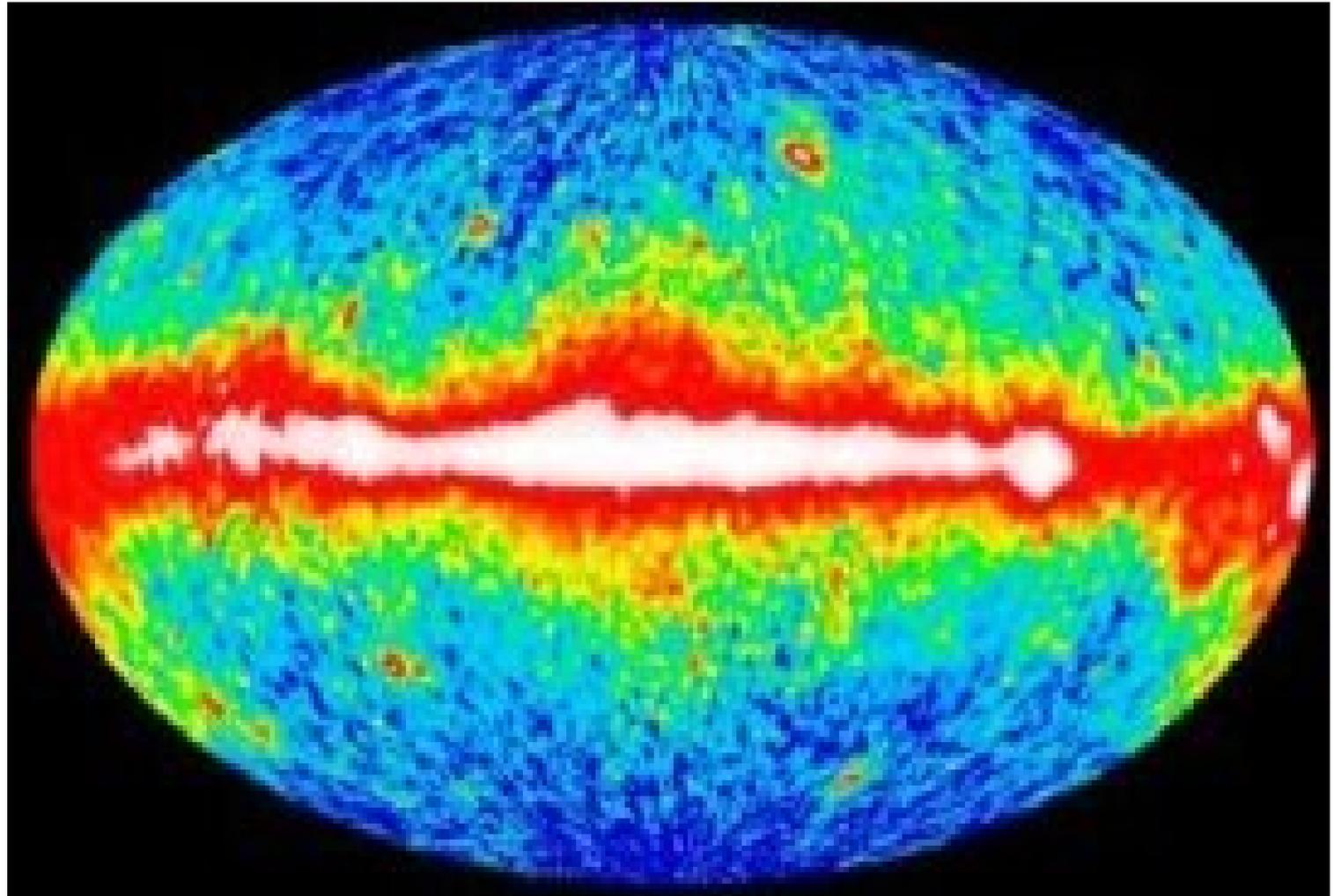
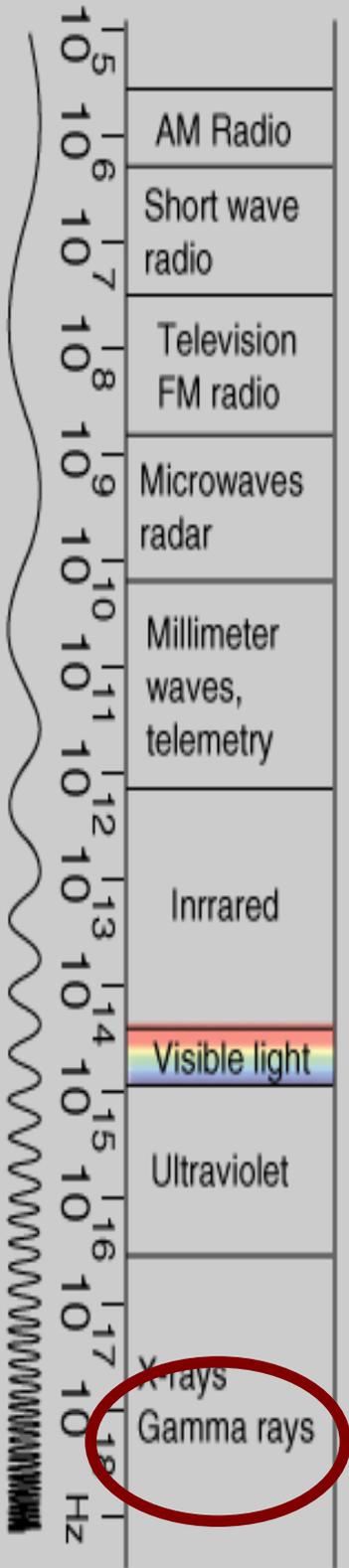
0.25, 0.75, 1.5 keV (S. Digel et. al. GSFC, ROSAT, NASA)

ENERGIA



# Via Láctea: Raios Gama > 100 MeV (CGRO, NASA)

ENERGIA

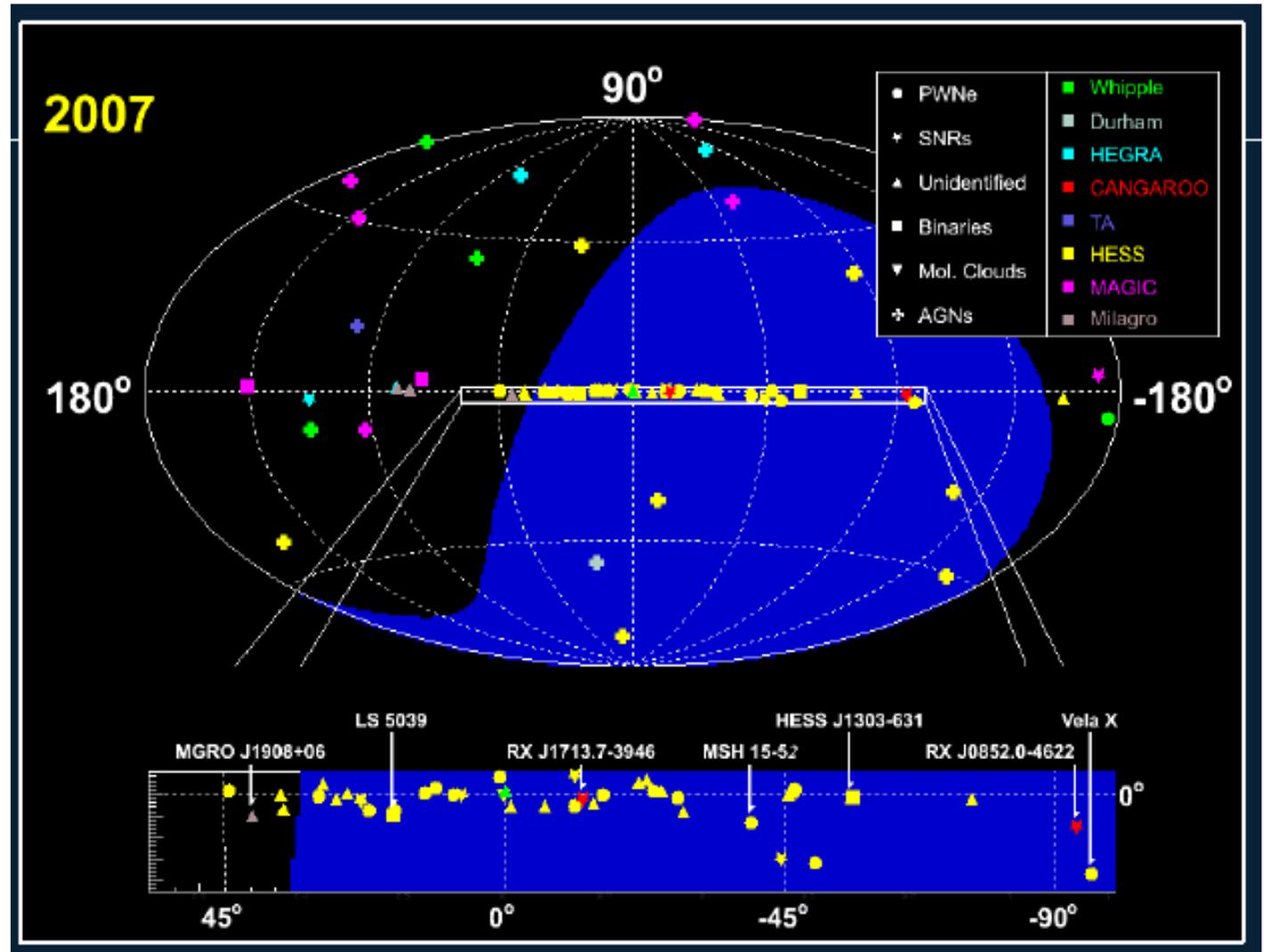
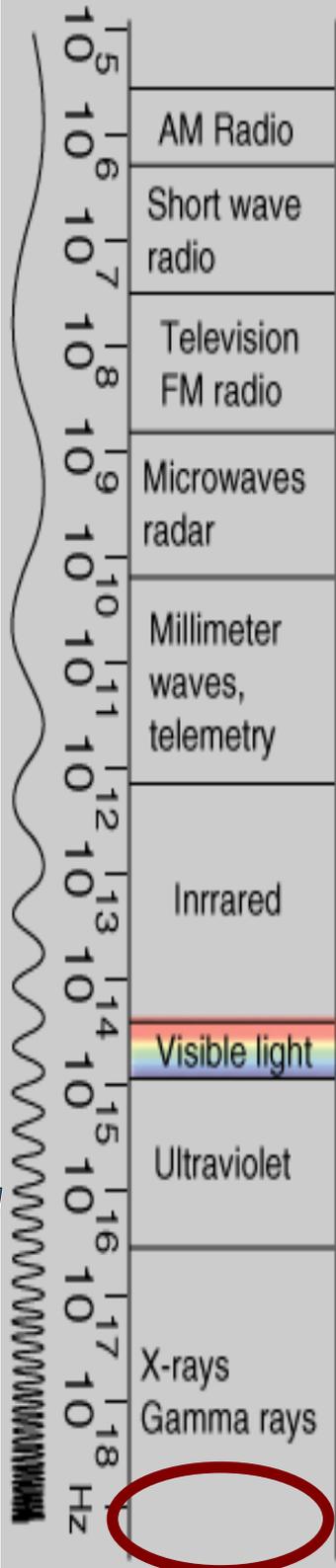


# Fontes Pontuais

## Raios Gama $> 10^{12}$ eV

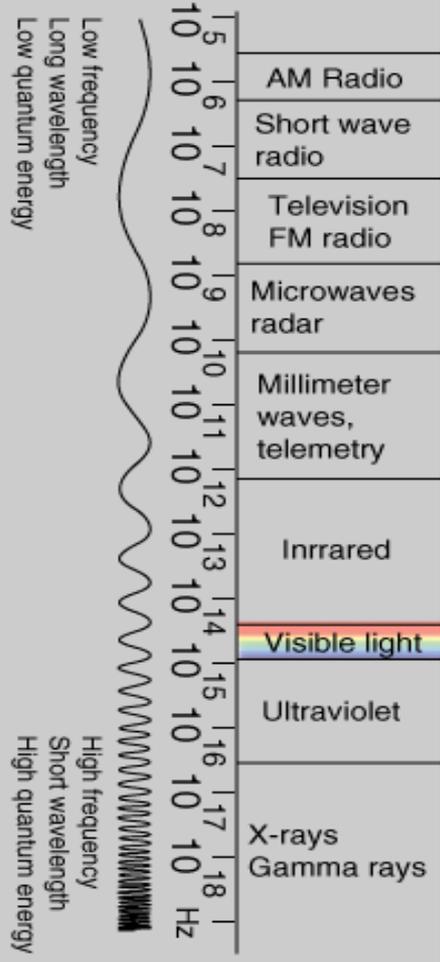
### Telescópios Cerenkov, por Jim Hinton

ENERGIA

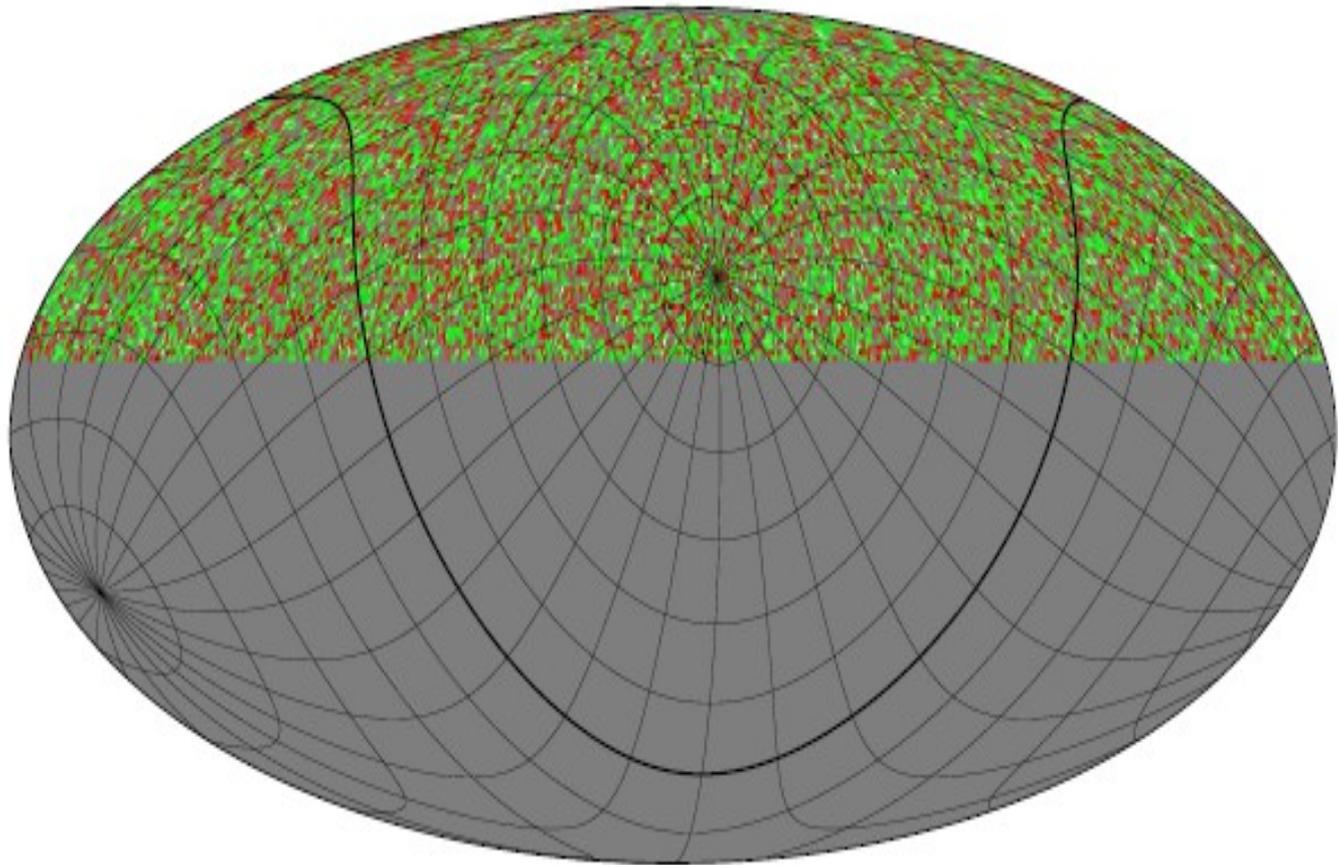


# KASCADE

$E \sim 10^{16}$  eV



E  
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TeV = 10<sup>12</sup> eV

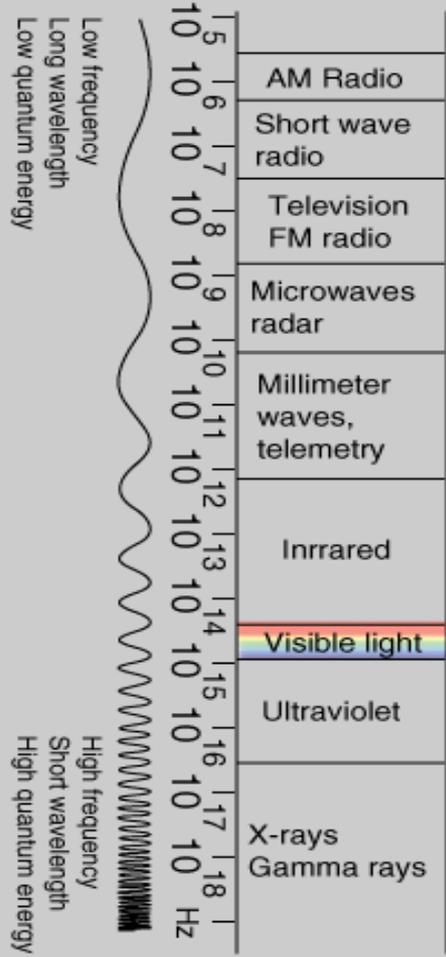
PeV = 10<sup>15</sup> eV

EeV = 10<sup>18</sup> eV

ZeV = 10<sup>21</sup> eV

# AGASA

$E > 10^{18}$  eV

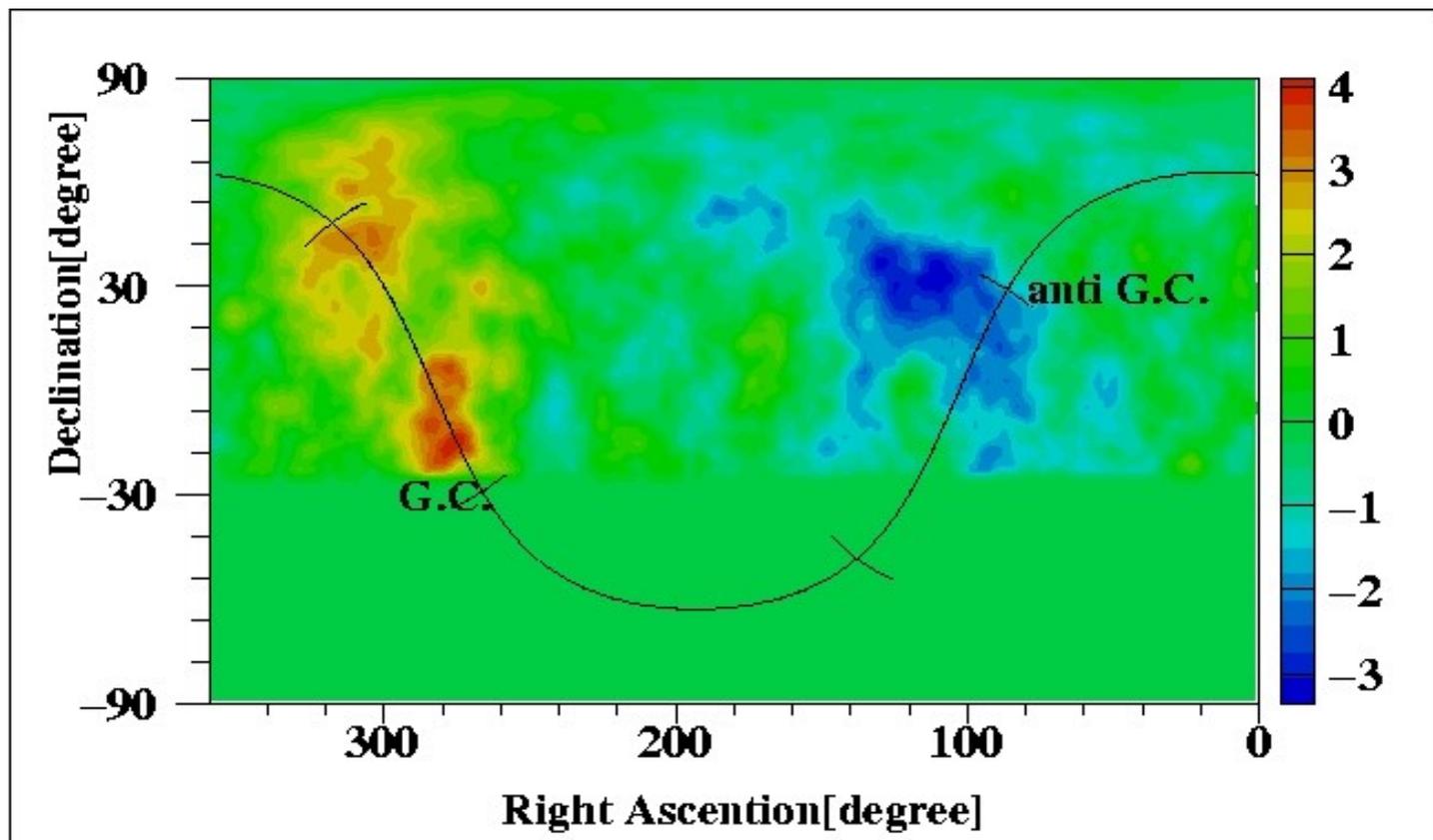


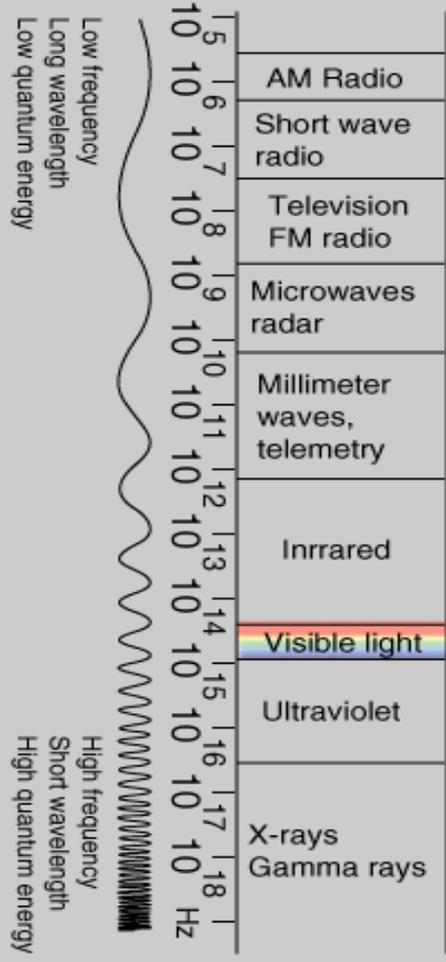
TeV

PeV

**EeV**

ZeV

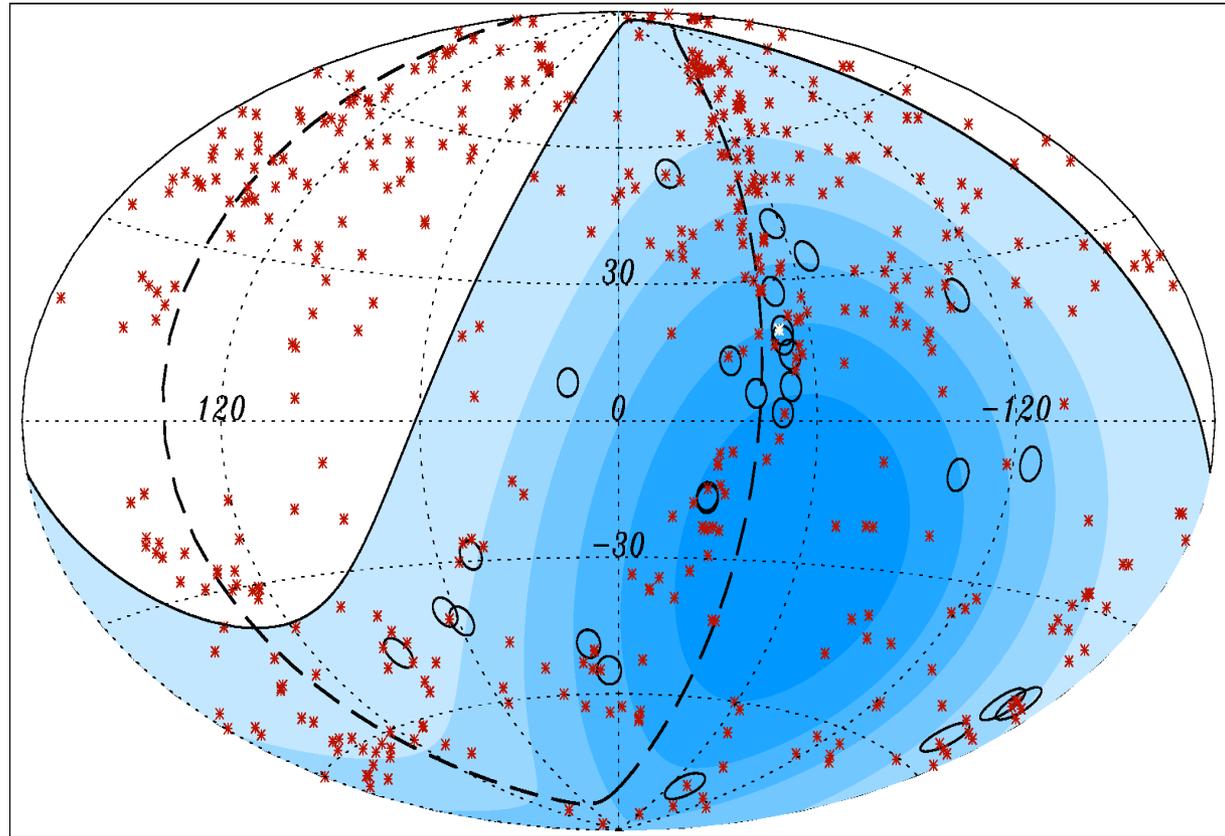




E  
N  
E  
R  
G  
Y

# Auger

$E > 5.7 \times 10^{19} \text{ eV}$



TeV = 10<sup>12</sup> eV

PeV = 10<sup>15</sup> eV

**EeV = 10<sup>18</sup> eV**

ZeV = 10<sup>21</sup> eV

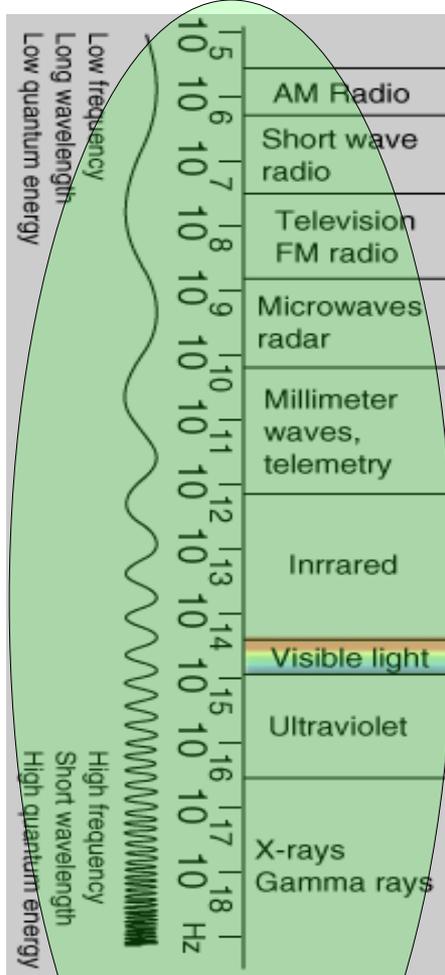
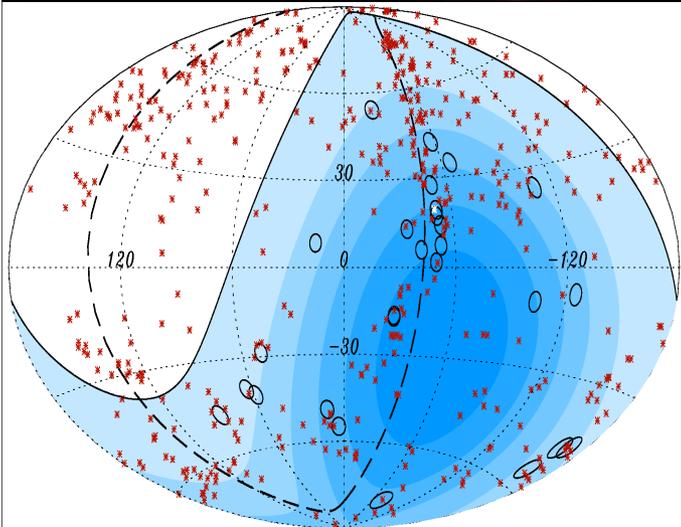
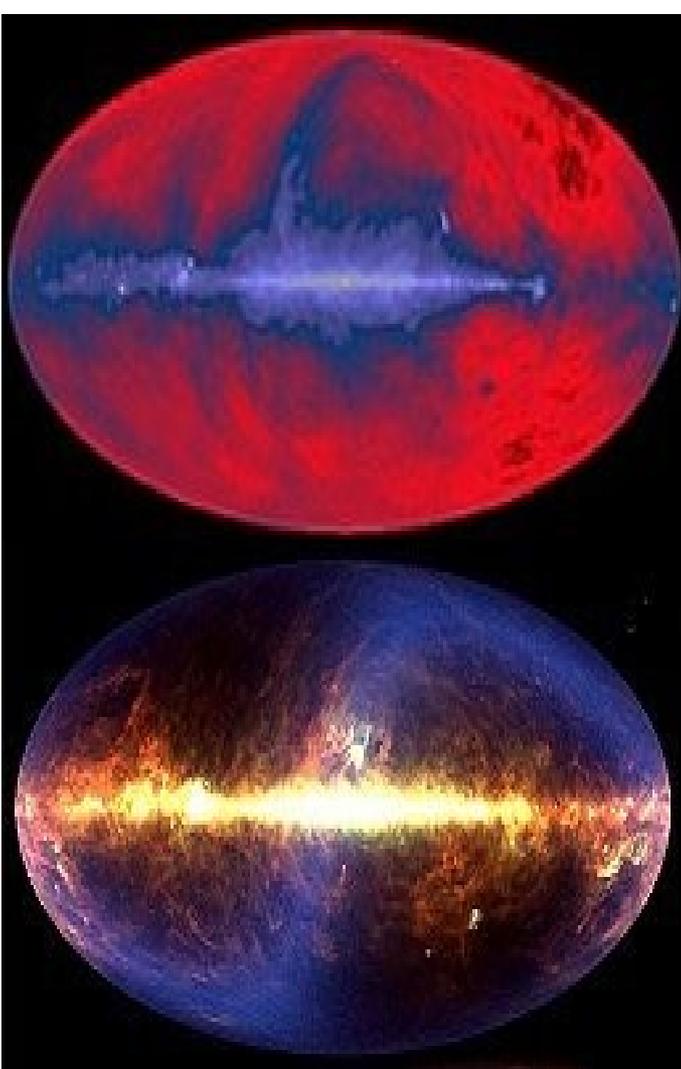
Se algo me atinge ...

Eu quero saber:

O QUE ?

QUEM ?

ENERGIA ?

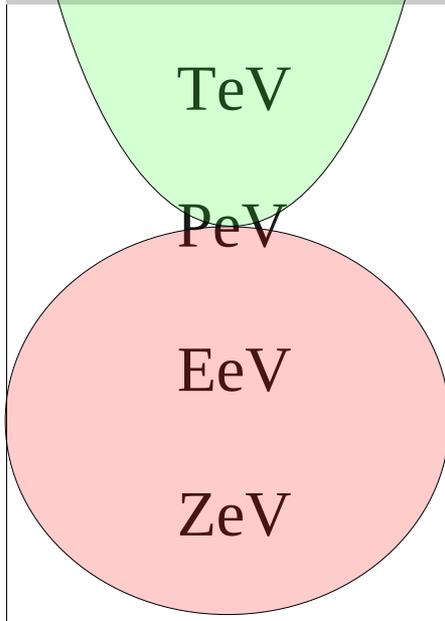


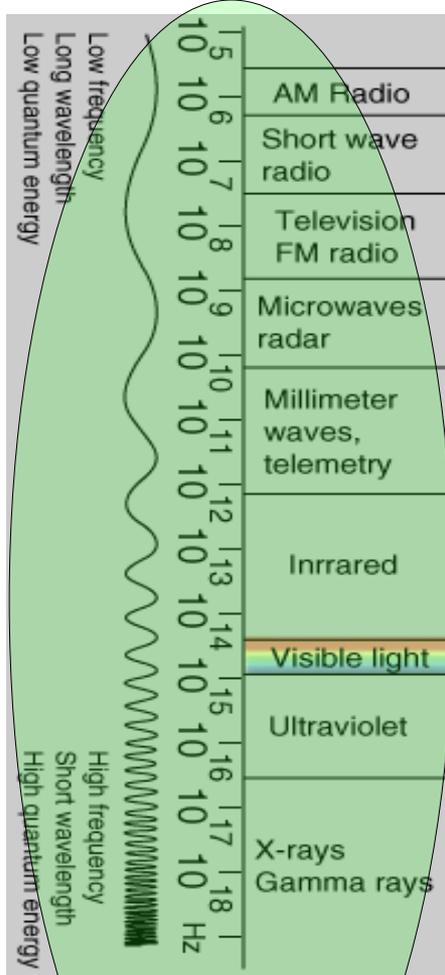
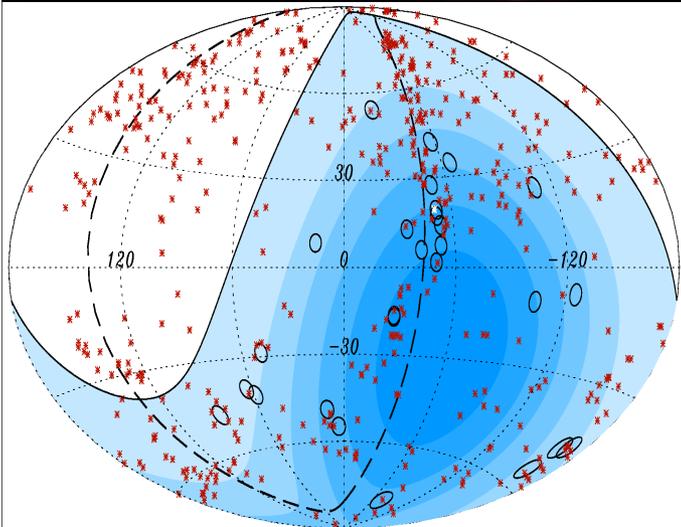
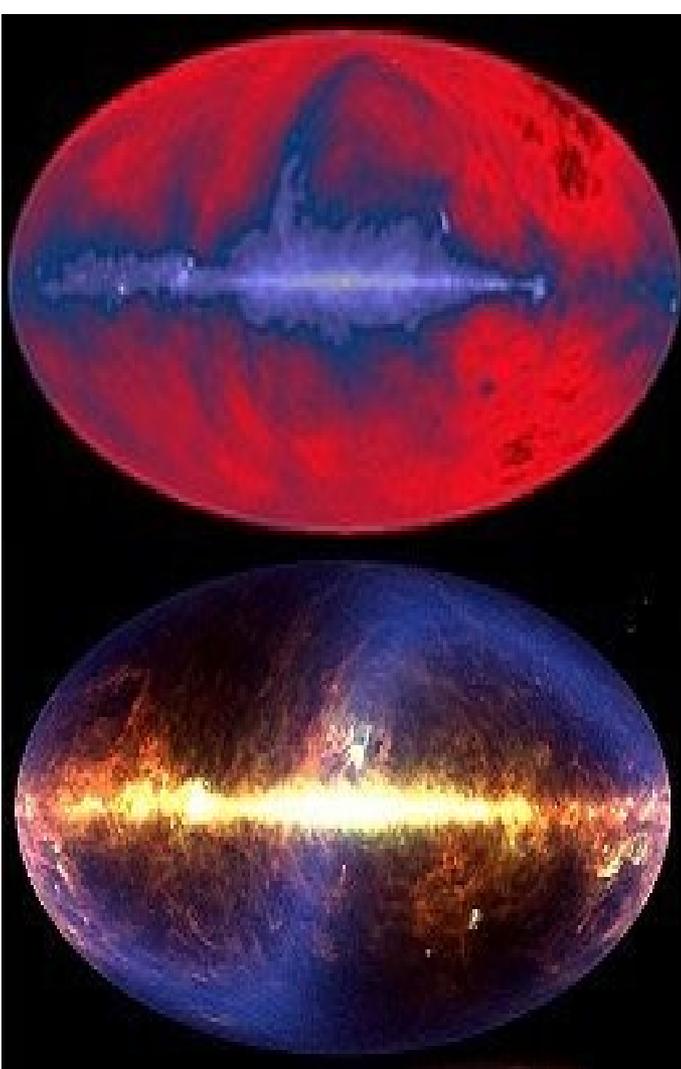
ENERGIA

O QUE ?

QUEM ?

ENERGIA ?



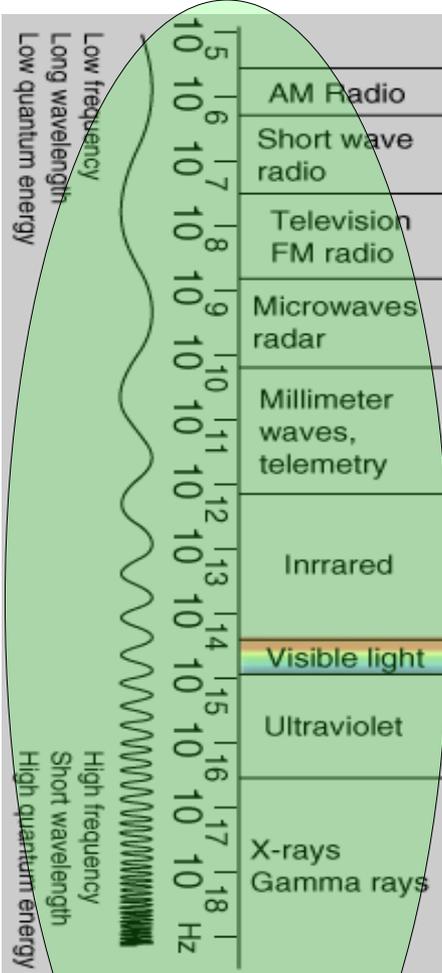
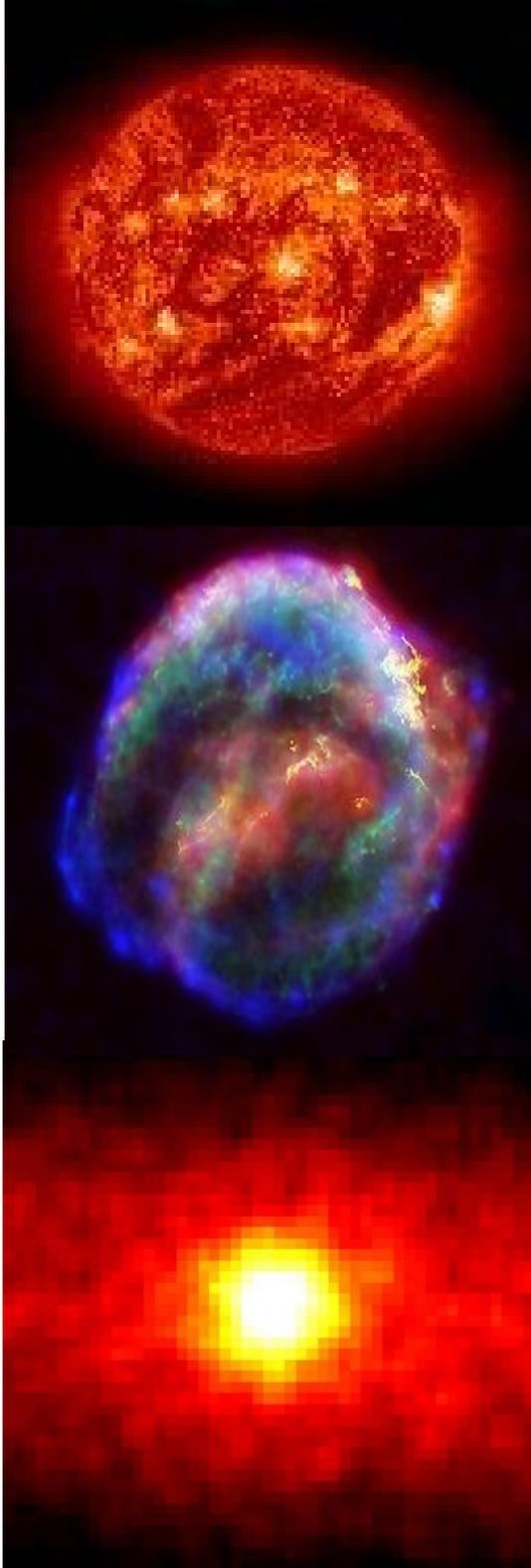


ENERGIA

O QUE ?

A maior parte é luz

mas não só...  
neutrinos  
e  
partículas



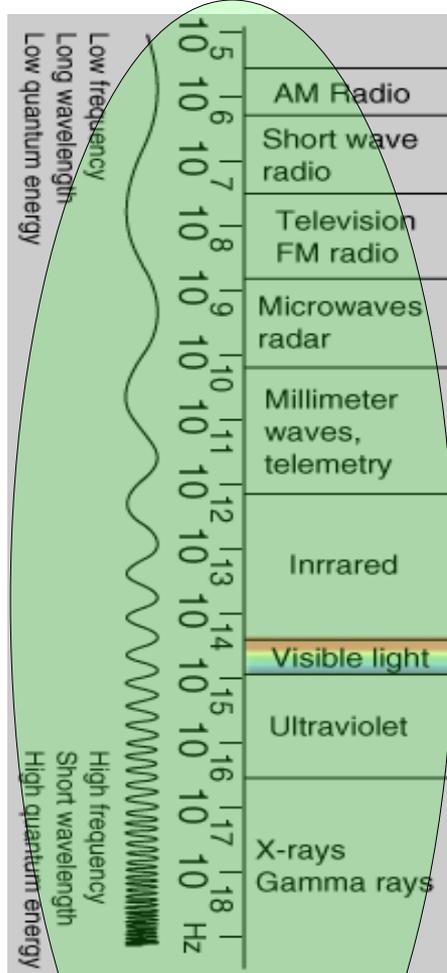
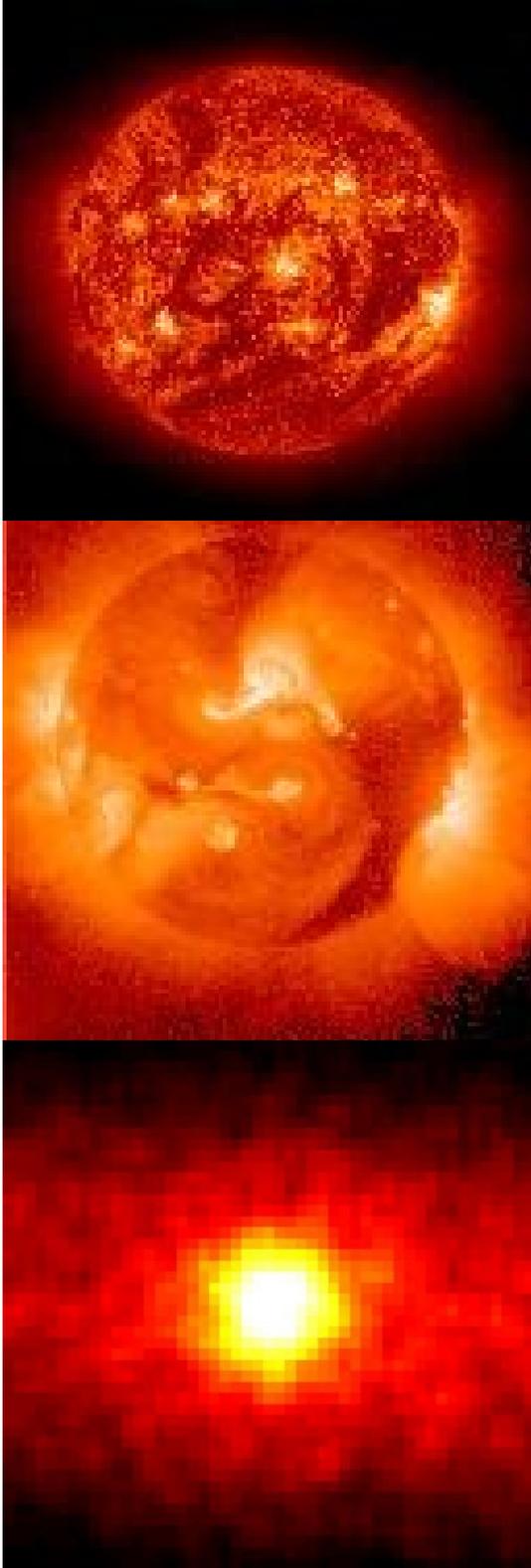
E  
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QUEM ?

Sol e Estrelas

TeV

PeV

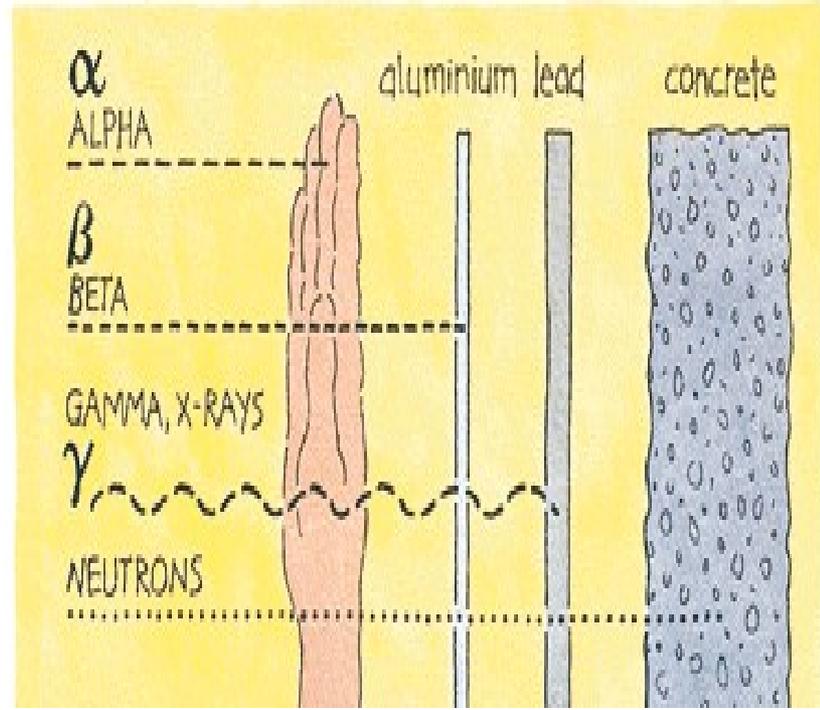


TeV

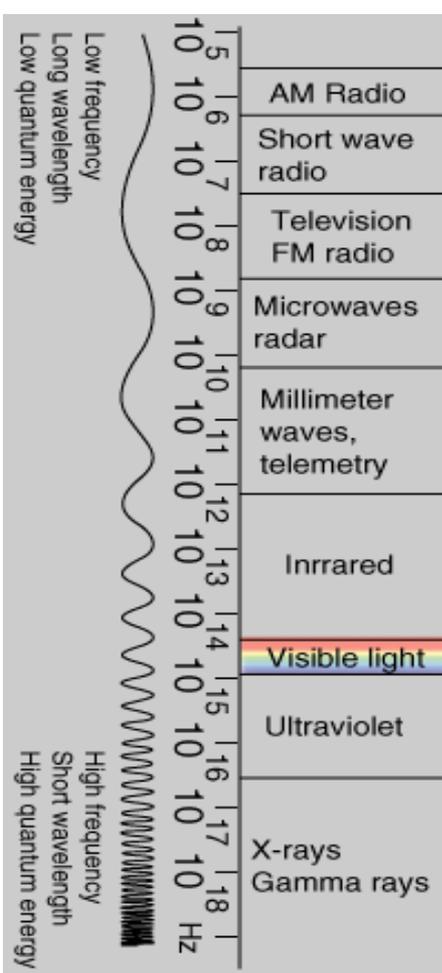
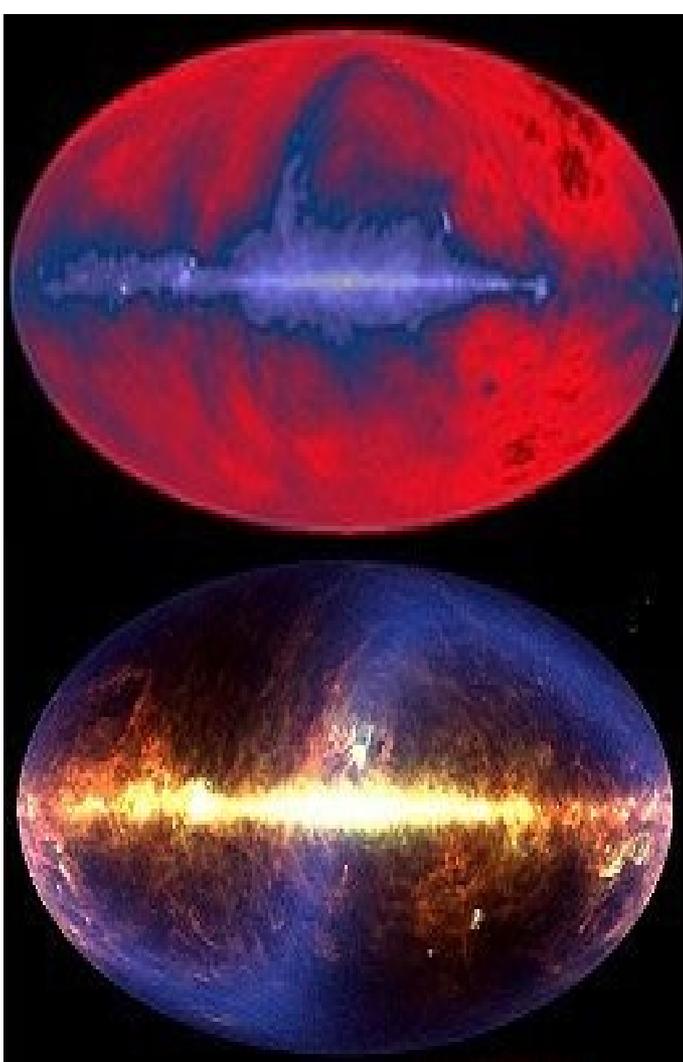
PeV



# ENERGIA ?



Quanto maior a energia da partícula mais matéria ela atravessa !

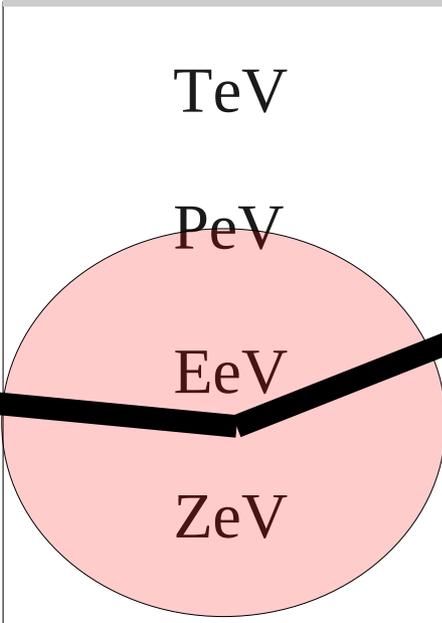
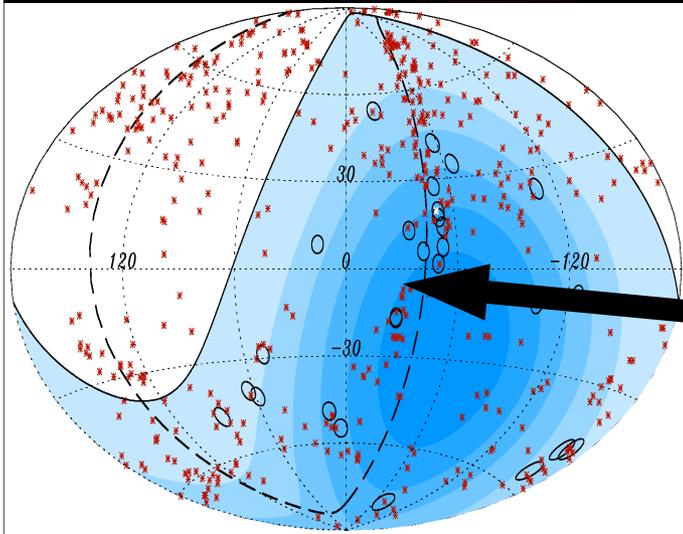


E N E R G I A

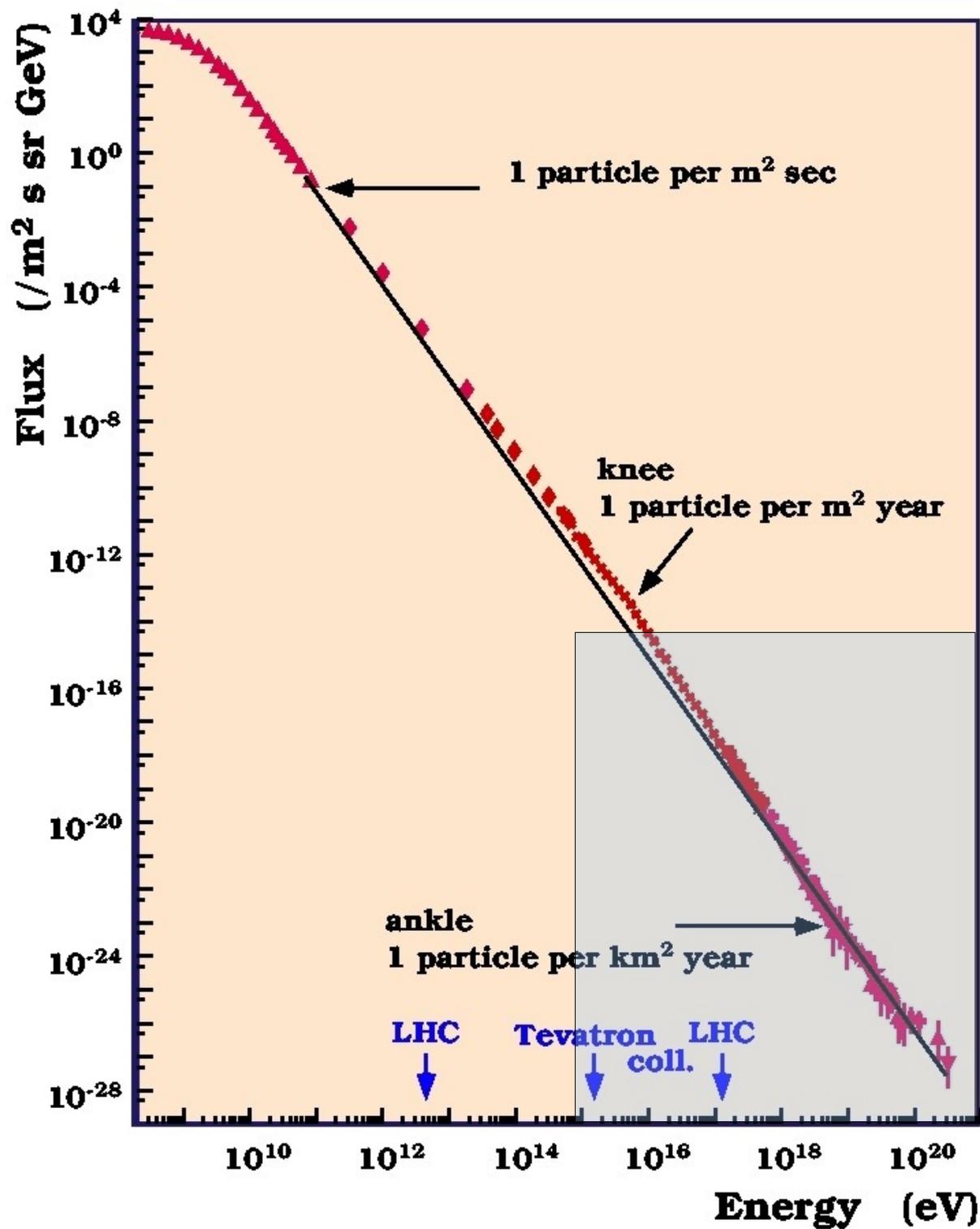
O QUE ?

QUEM ?

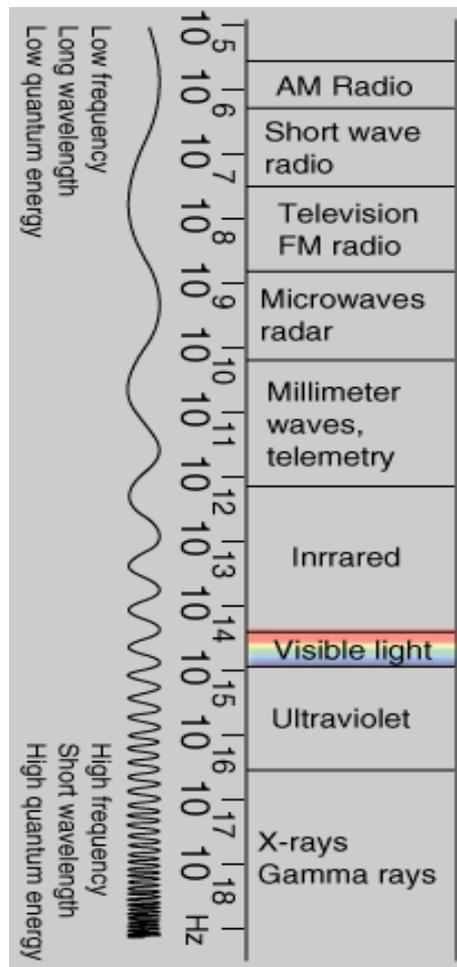
ENERGIA ?



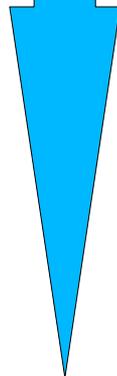
Não sabemos quase nada !



Filme desenvolvimento do chuveiro



E N E R G I A



NÃO SABEMOS:

O QUE ?

QUEM ?

SABEMOS:

ENERGIA

Não sabemos quase nada !

MAS NÃO SABEMOS:

COMO PRODUZIR ESSA ENERGIA

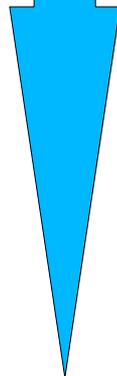
NÃO CONHECEMOS NENHUM

PROCESSO FÍSICO CAPAZ

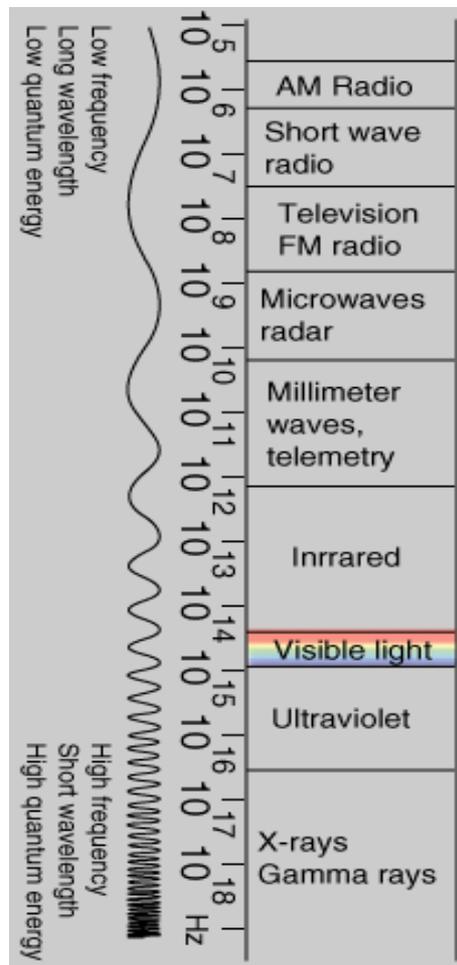
DE GERAR ESSA

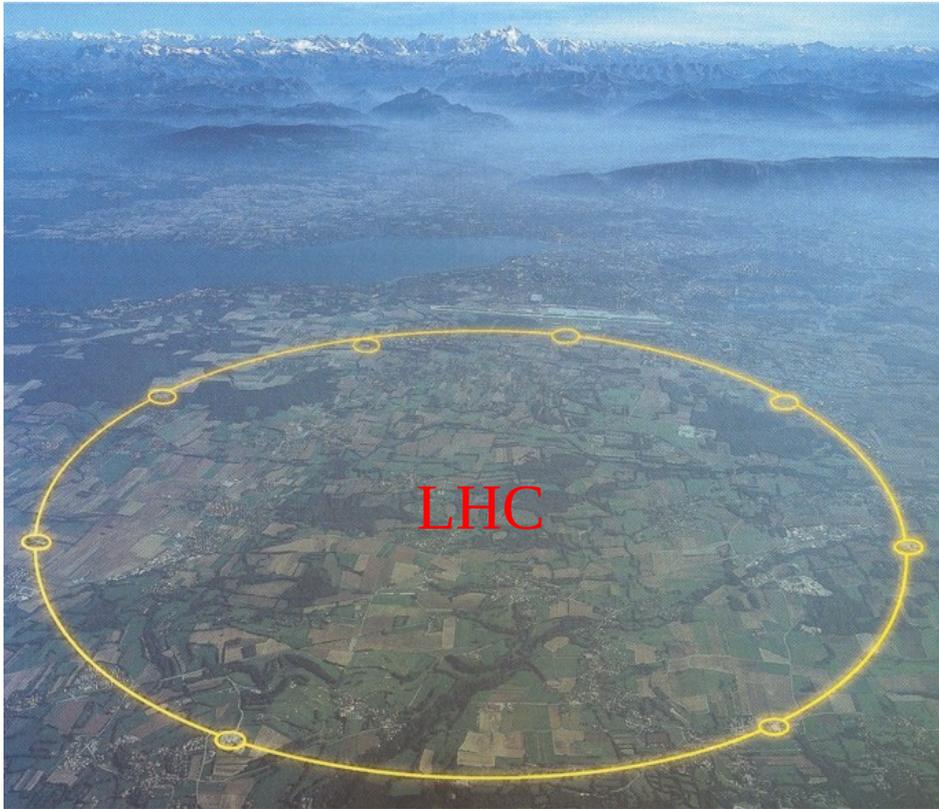
ENERGIA

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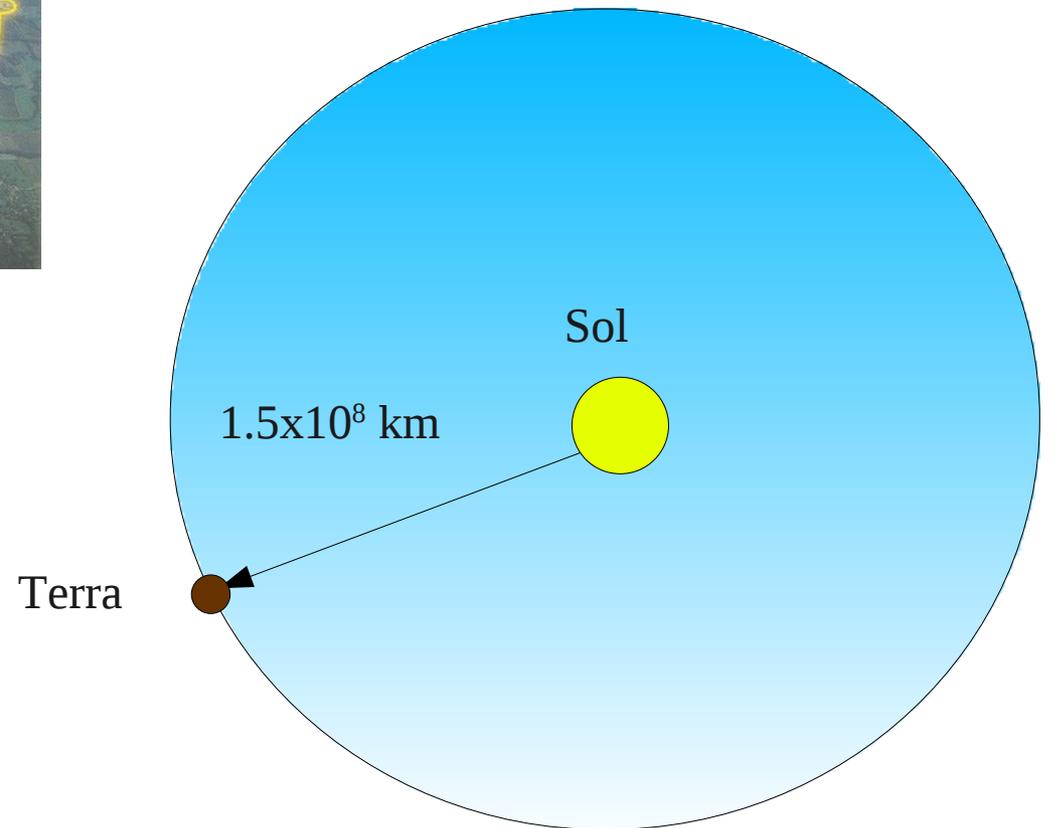
Não sabemos  
quase nada !





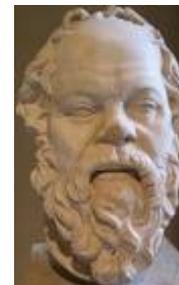
Vamos construir um LHC para acelerar prótons a  $10^{20}$  eV ?

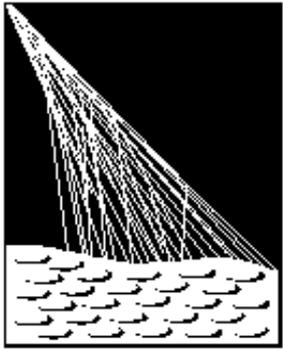
Seria necessário um anel com a distância da Terra ao Sol



TUDO QUE SEI  
É QUE NADA SEI !

Sócrates



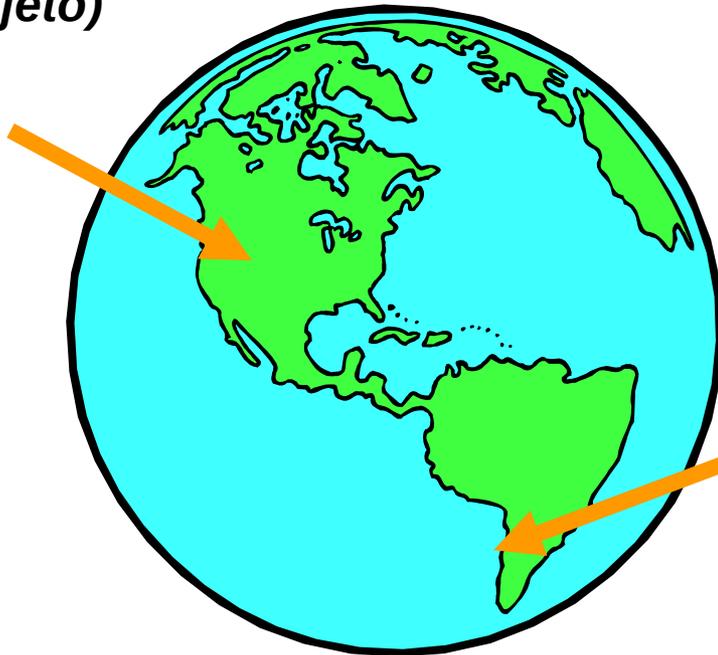


**PIERRE  
AUGER**  
OBSERVATORY

# Observatório Pierre Auger

O maior experimento de raios cósmicos já construído para medir com grande estatística a região de energia acima de  $10^{18}$  eV

*Colorado, EUA  
(em projeto)*



*Mendoza, Argentina  
(em funcionamento)*



## Colaboração Auger: 16 Países

Argentina

Australia

Bolívia\*

Brasil

República Tcheca

França

Alemanha

Itália

México

Holanda

Polônia

Eslovênia

Espanha

Reino Unido

EUA

Vietnam\*

*\*Associados*

> 60 Instituições, > 400 Colaboradores

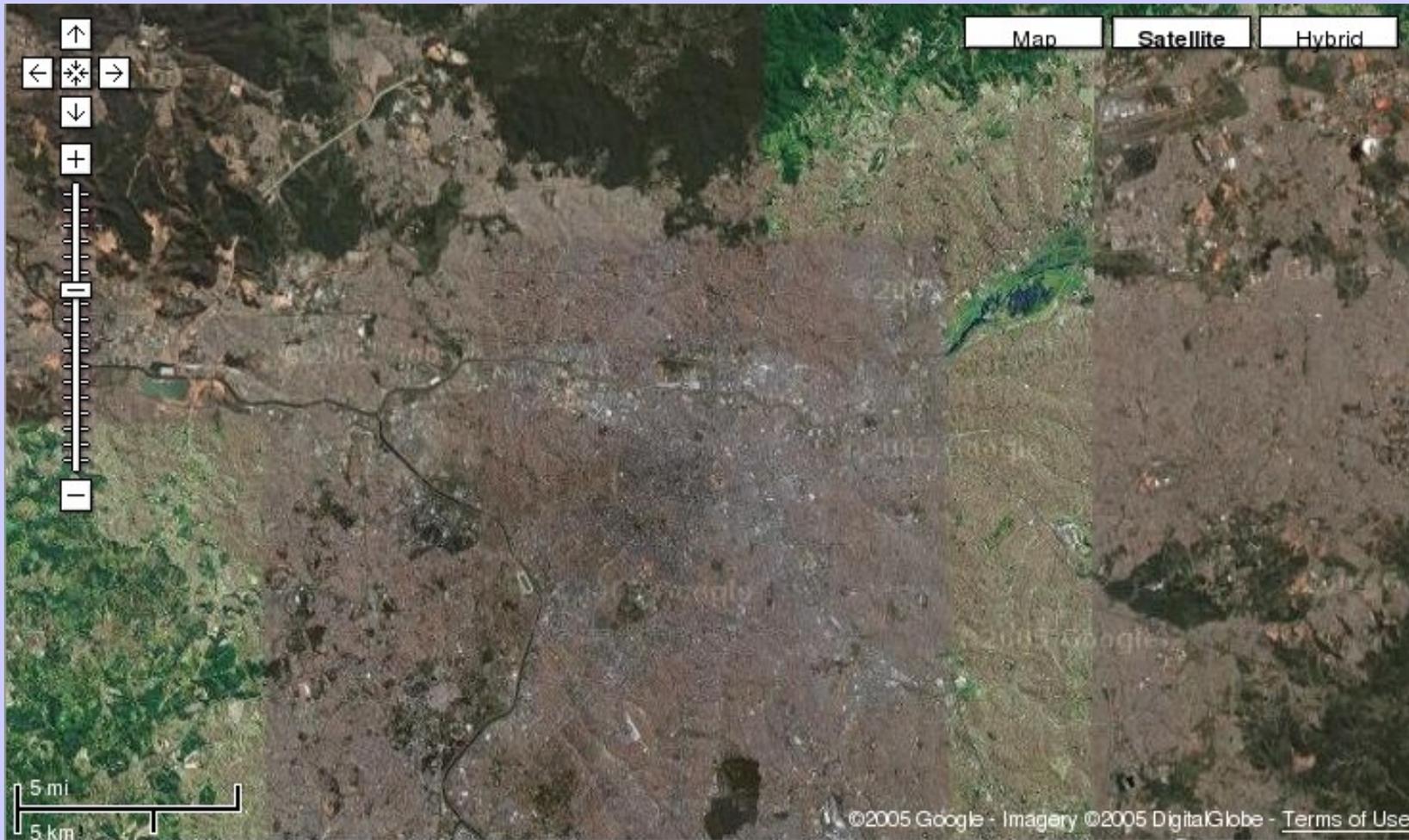
<http://www.auger.org/>

# Colaboração Auger



# Filme Google Earth

# Observatório Auger



50 km

60 km

# Observatório Auger



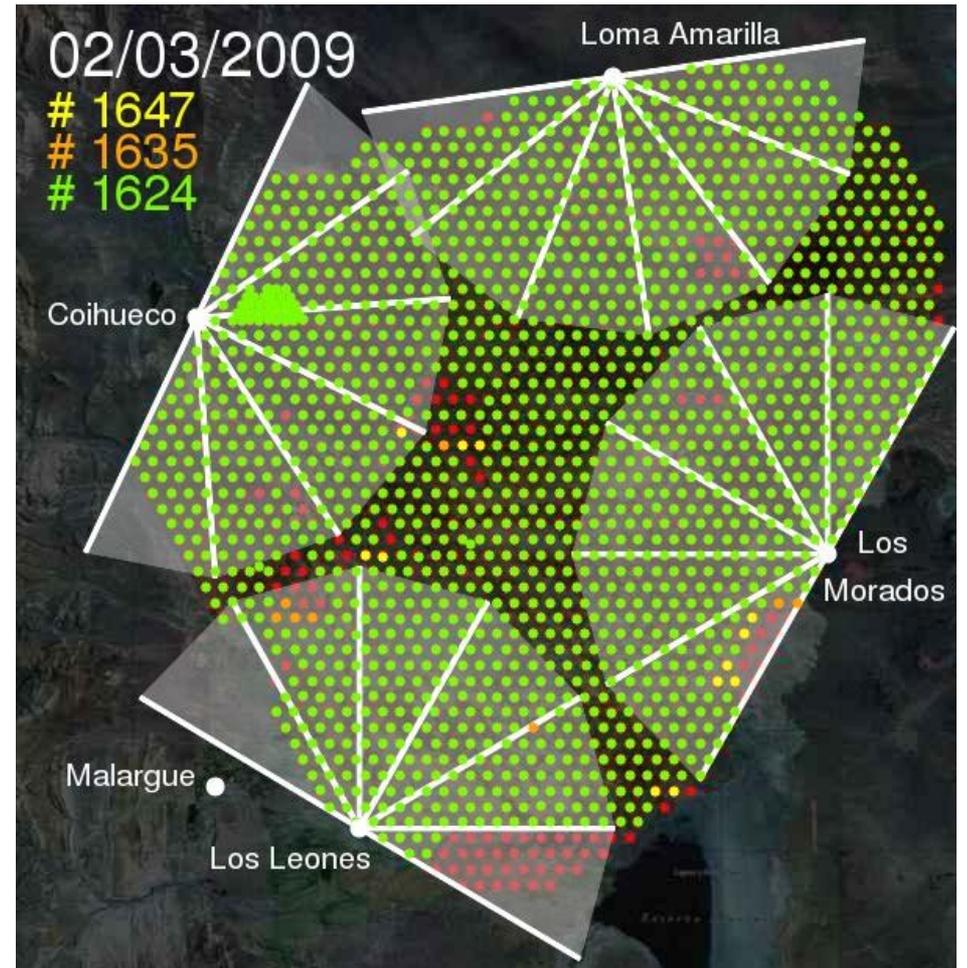
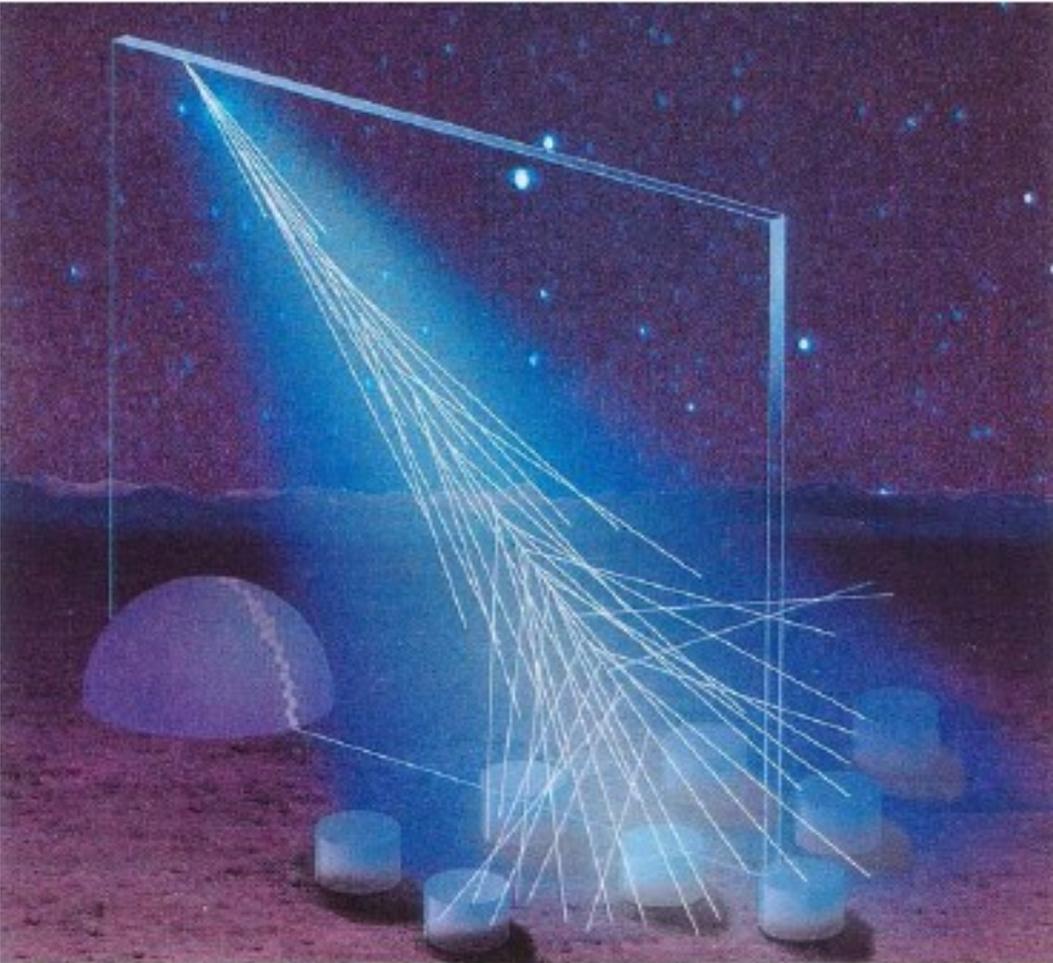
**Em funcionamento:**

**- 1624 tanques**

**- 24 telescópios**



# Observatório Auger

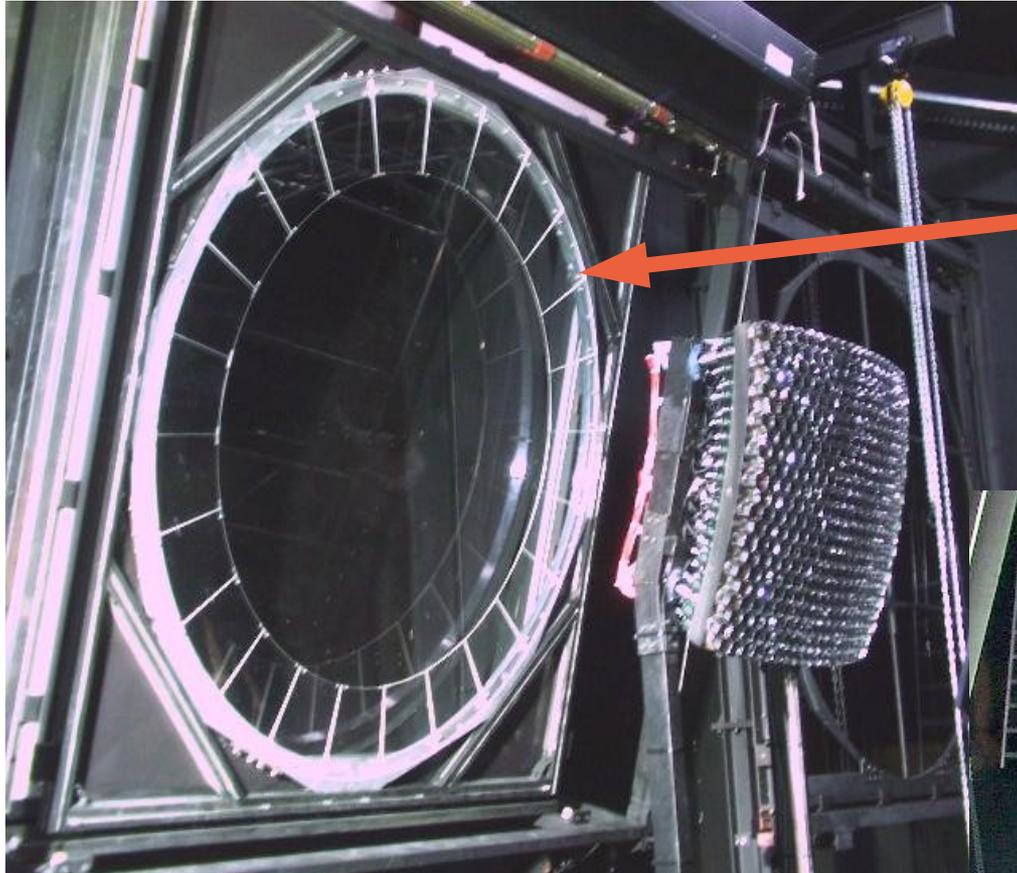


# Observatório Auger: Telescópios

*Los Leones*



# Observatório Auger: Telescópios

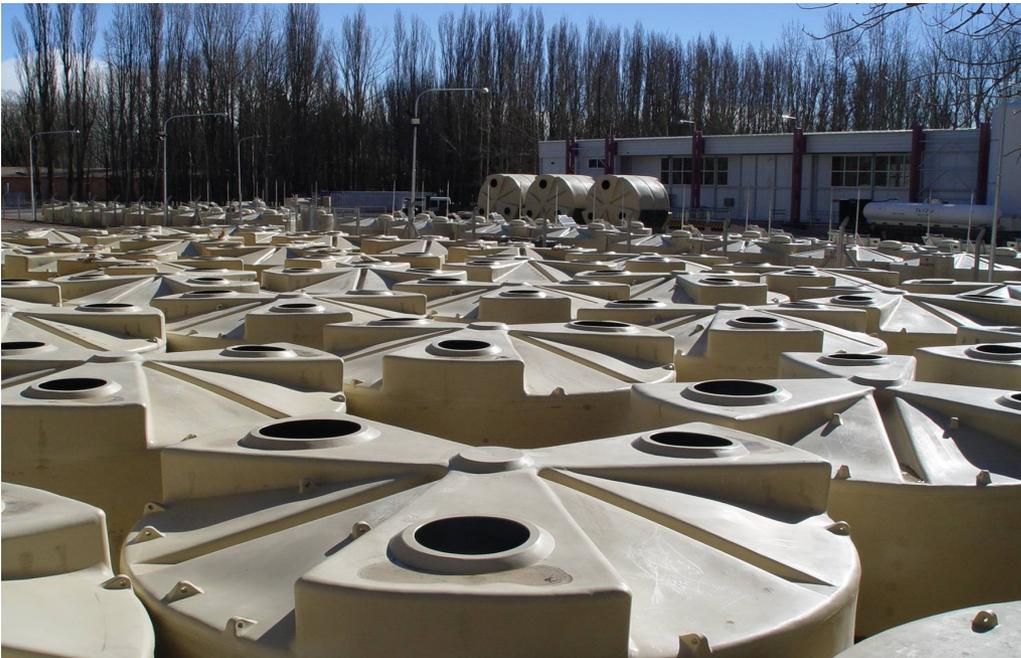


Lente Corretora:  
Fabricada em Indaiatuba  
Caixa de Abertura:  
Projeto Brasileiro

24 Telescópios  
em operação



# Observatório Auger: Tanques



# Observatório Auger: Tanques



# O que já aprendemos ?



Calma ? O Observatório foi inaugurado em Novembro de 2008.

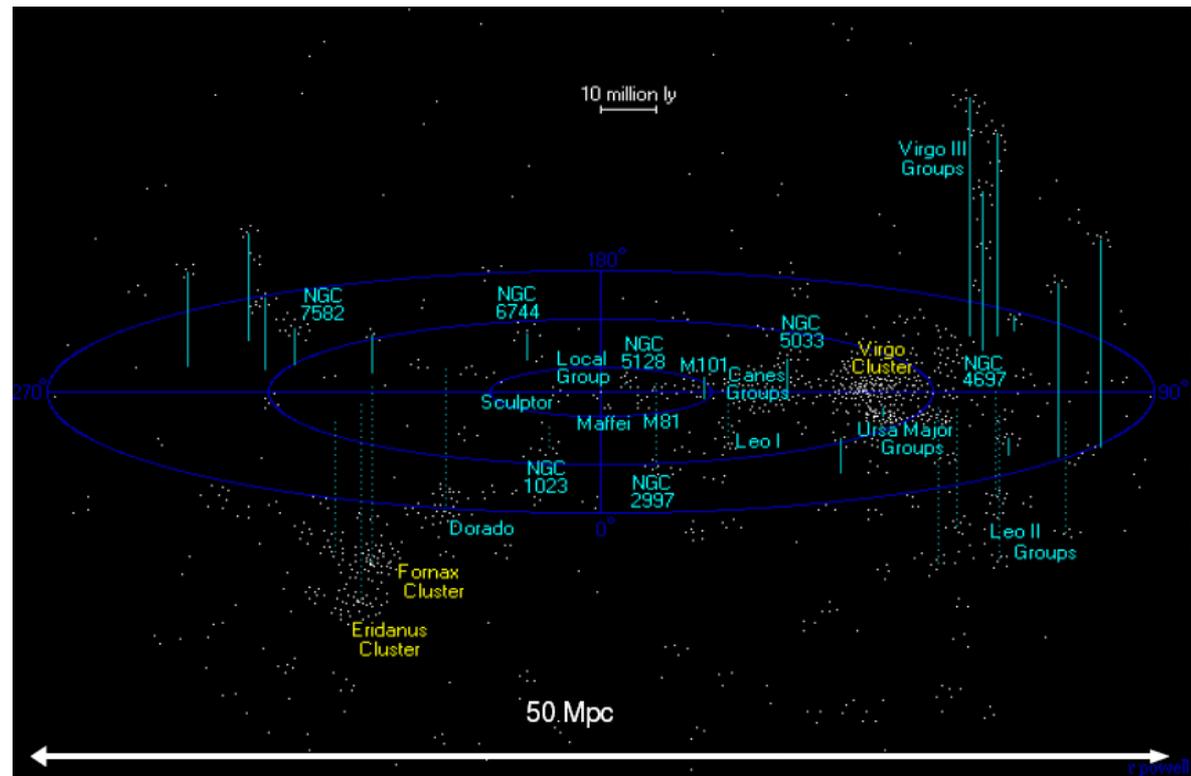
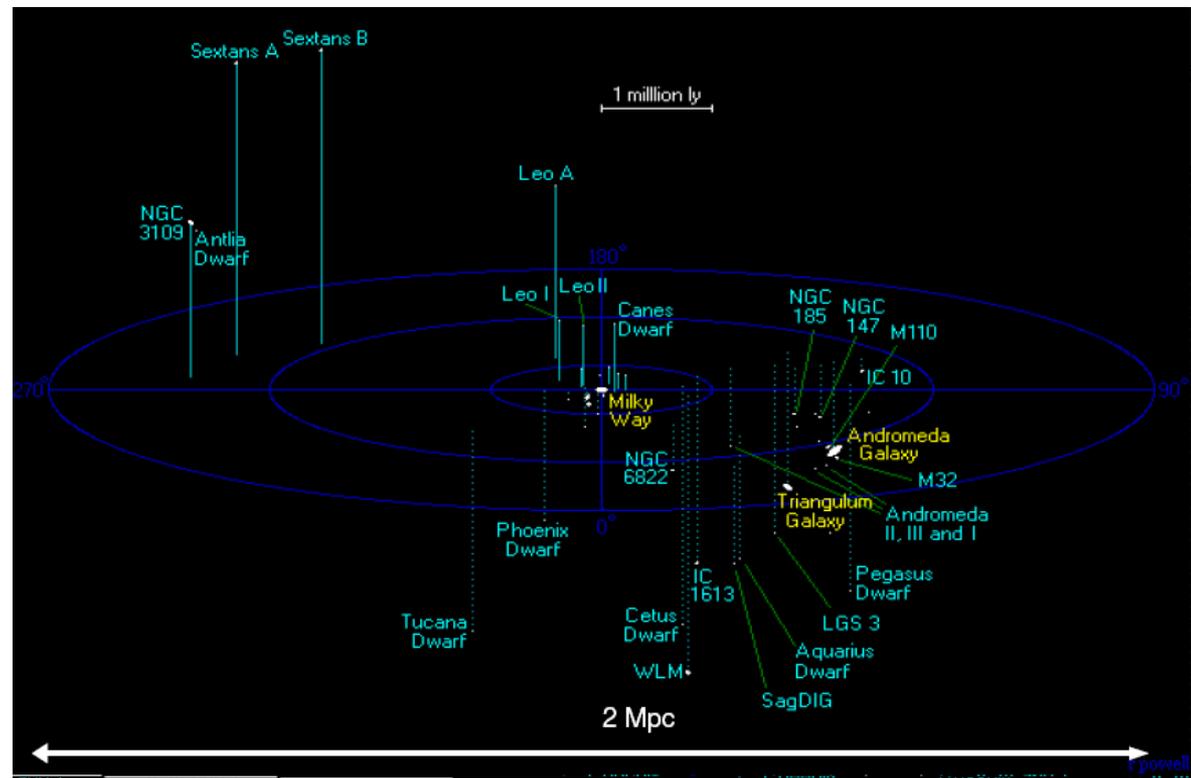
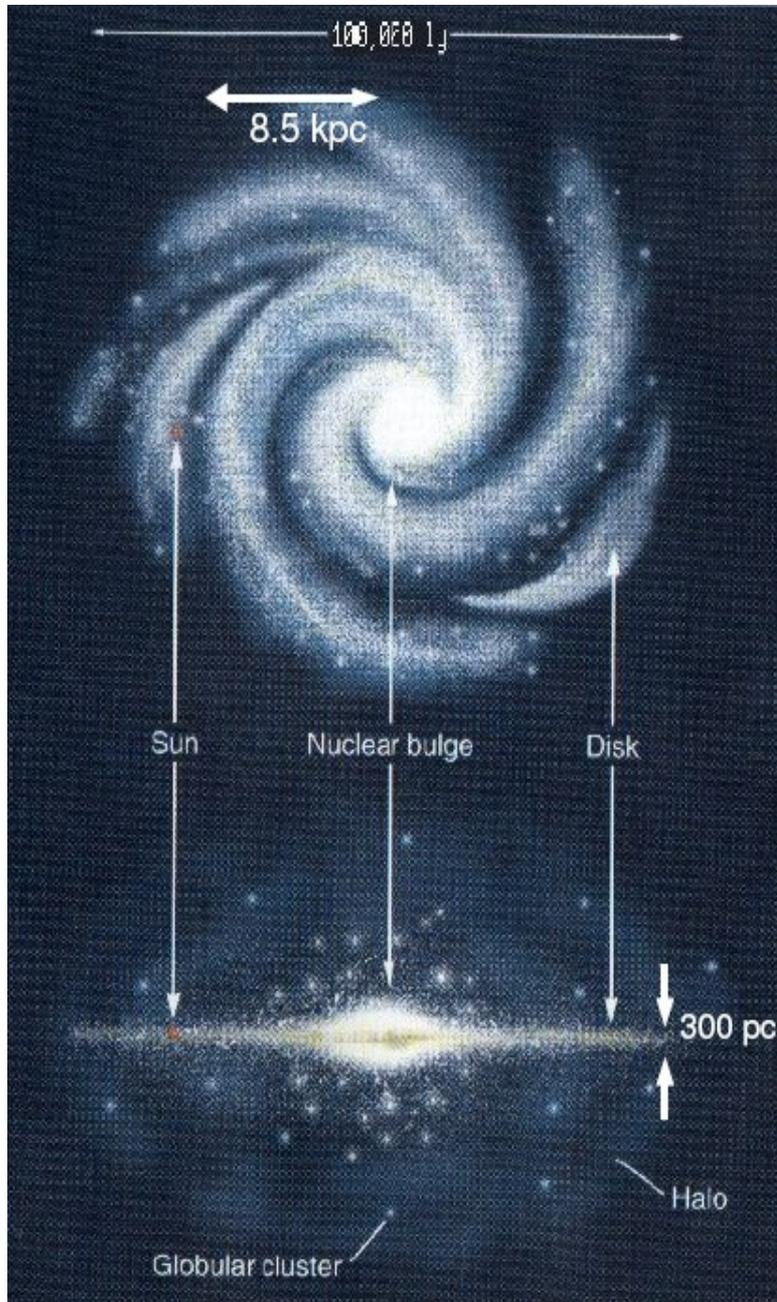
Se algo me atinge ...

Eu quero saber:

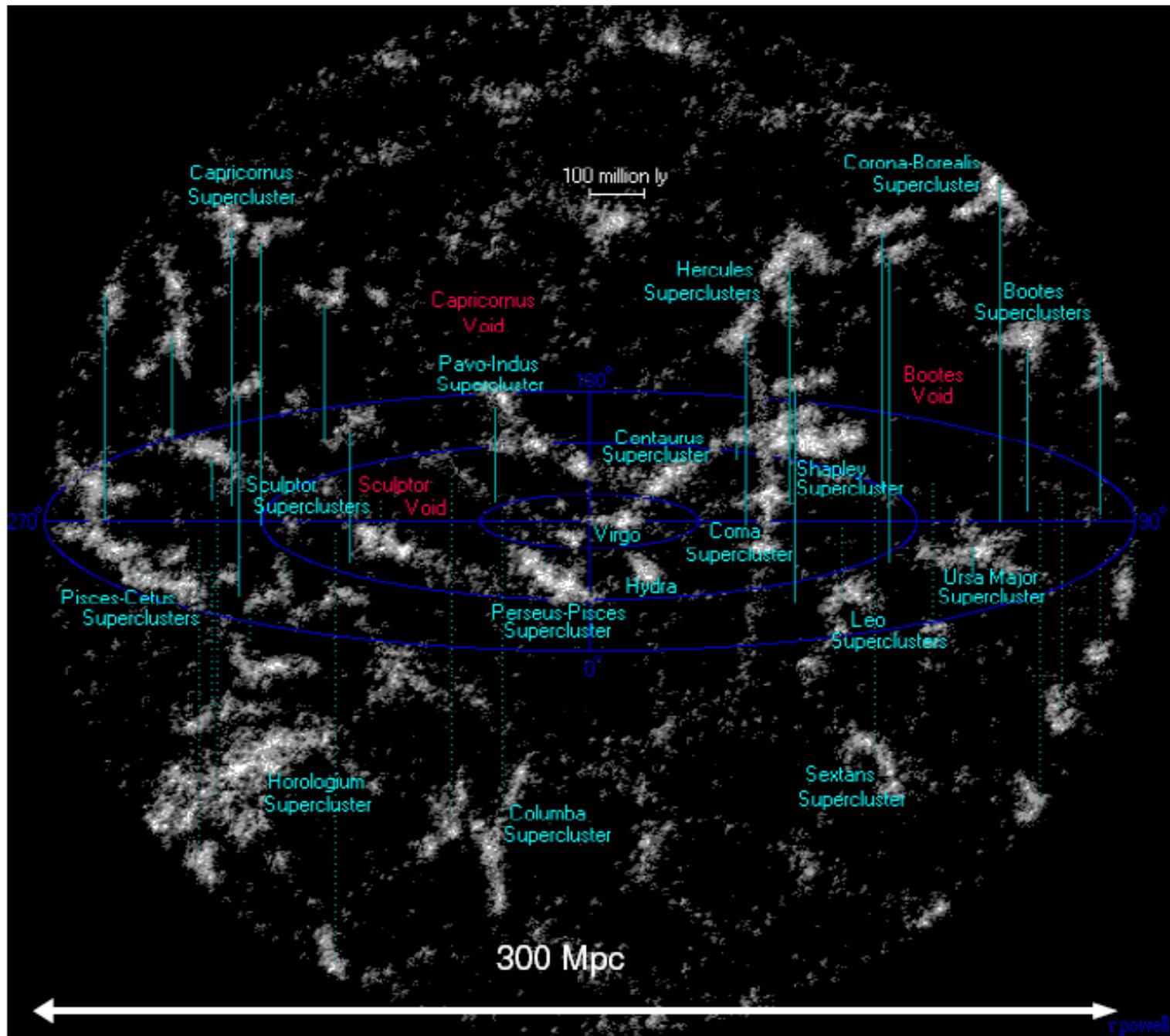
O QUE ?

QUEM ?

COMO PRODUZIR ESSA ENERGIA ?

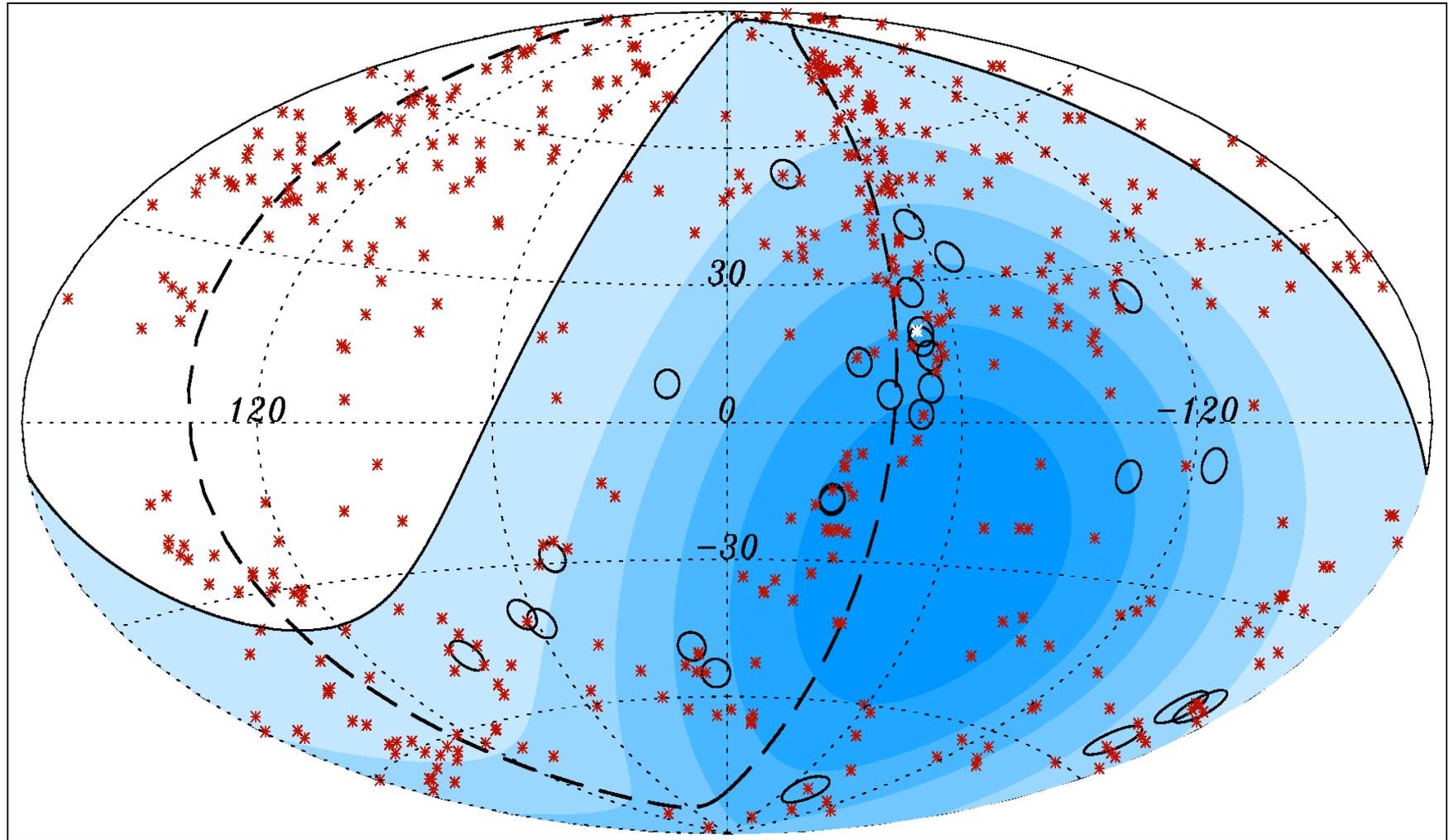


1 pc =  $3 \times 10^{16}$  metros



1 pc =  $3 \times 10^{16}$  metros

# Pierre Auger Collaboration, Science (2007)



Eventos com energia acima de  $5.7 \times 10^{19}$  eV



Núcleos Ativos de Galáxias (AGN)



Exposição do Observatório

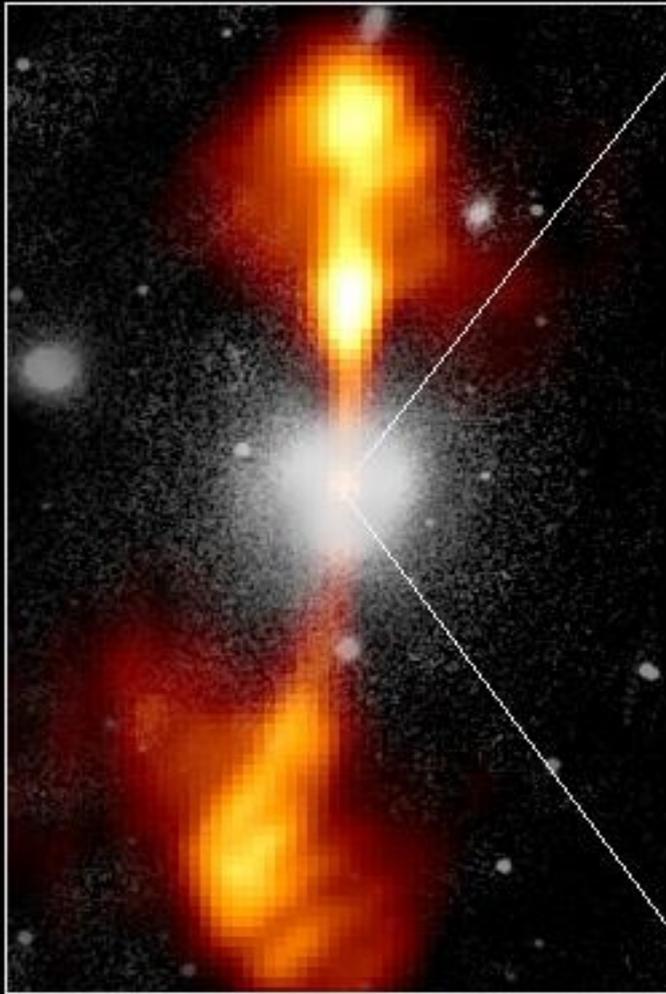
# Core of Galaxy NGC 4261

Hubble Space Telescope

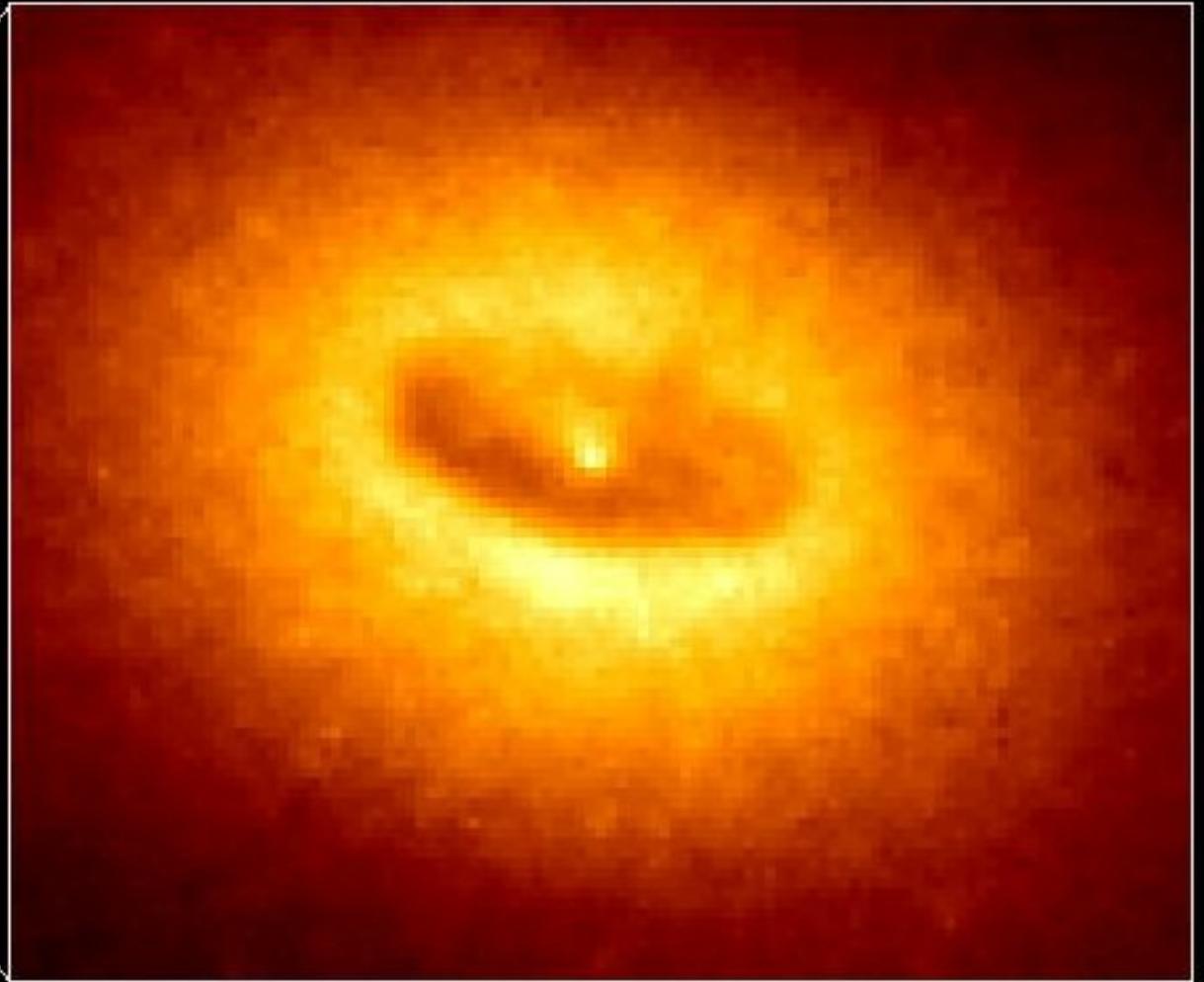
Wide Field / Planetary Camera

Ground-Based Optical/Radio Image

HST Image of a Gas and Dust Disk



380 Arc Seconds  
88,000 LIGHTYEARS



17 Arc Seconds  
400 LIGHTYEARS

# Quem é ?

AGNs são candidatos fortes mas não são a única possibilidade

Gáxias radio ativas é outro tipo de fonte possível

Se algo me atinge ...

Eu quero saber:

O QUE ?

QUEM ?

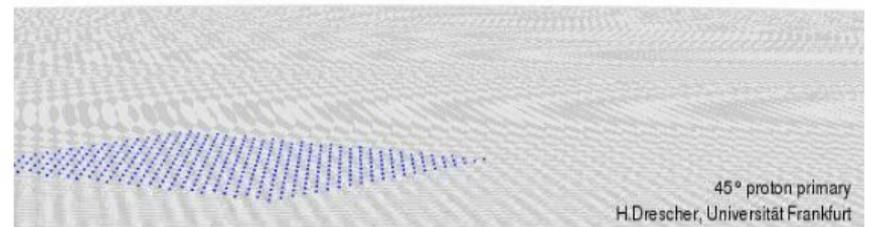
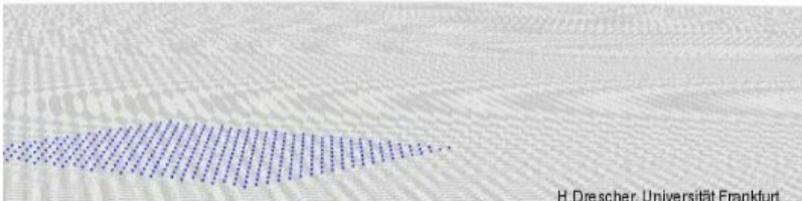
COMO PRODUZIR ESSA ENERGIA ?

# Ferro



# Próton

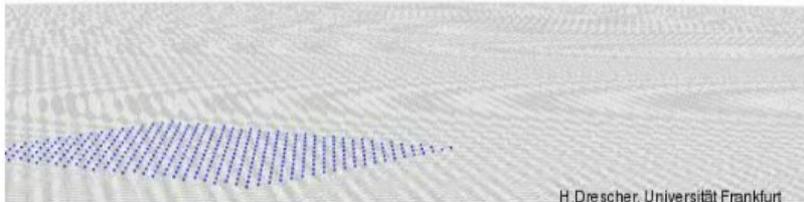
time=-160 $\mu$ s



# Ferro

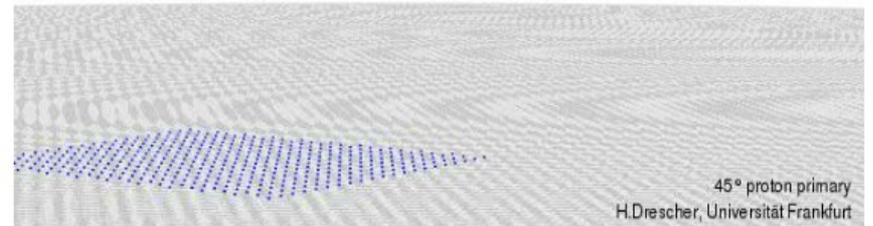


time=-106 $\mu$ s



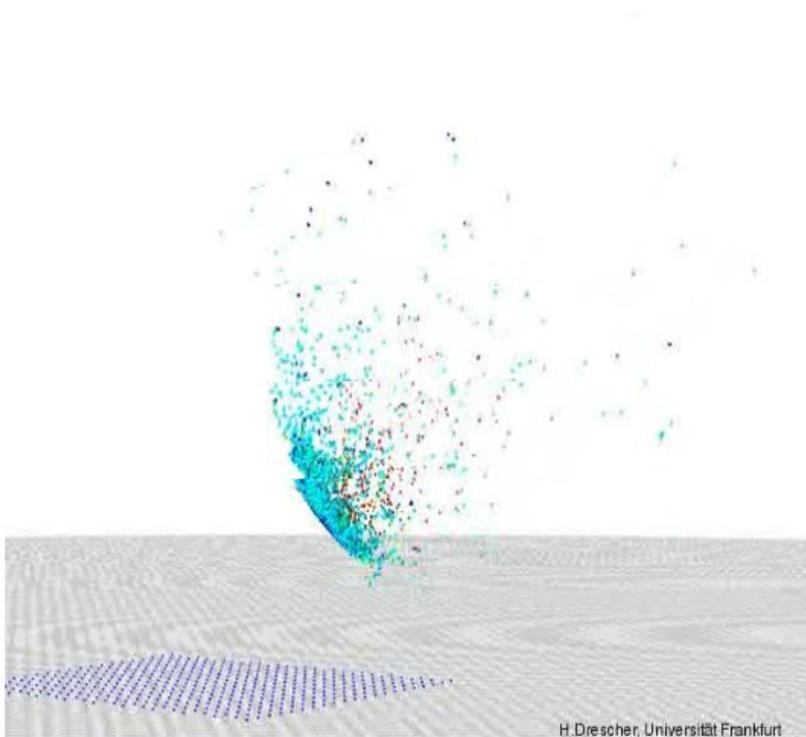
H.Drescher, Universität Frankfurt

# Próton



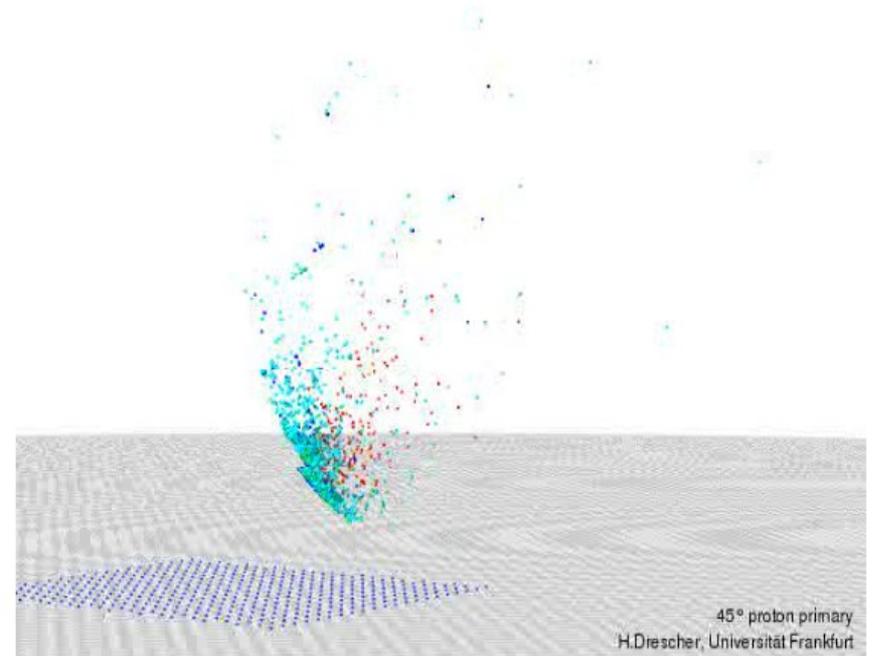
45° proton primary  
H.Drescher, Universität Frankfurt

# Ferro

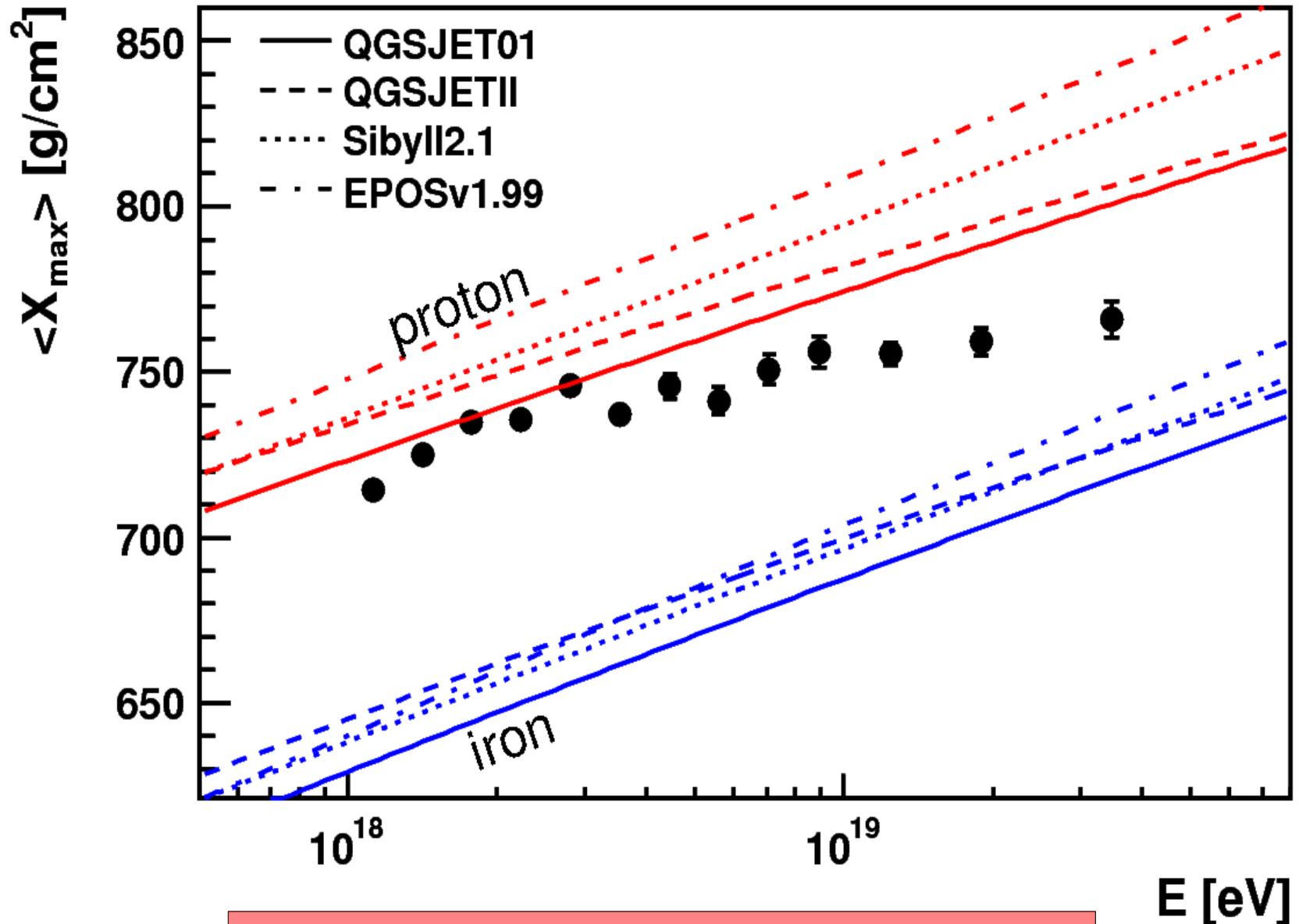


# Próton

time=-43 $\mu$ s



# O que é ?



Massa intermediária !!

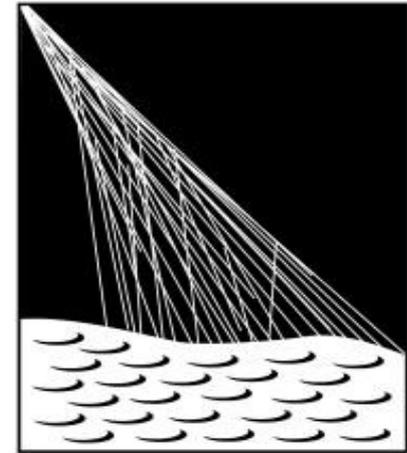
Se algo me atinge ...

Eu quero saber:

O QUE ?

QUEM ?

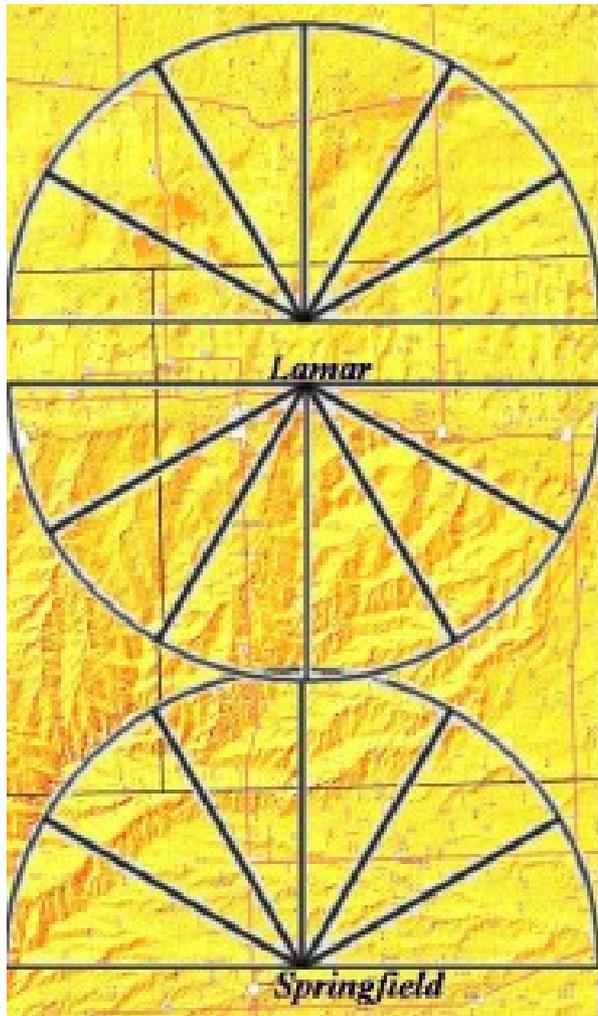
COMO PRODUZIR ESSA ENERGIA ?



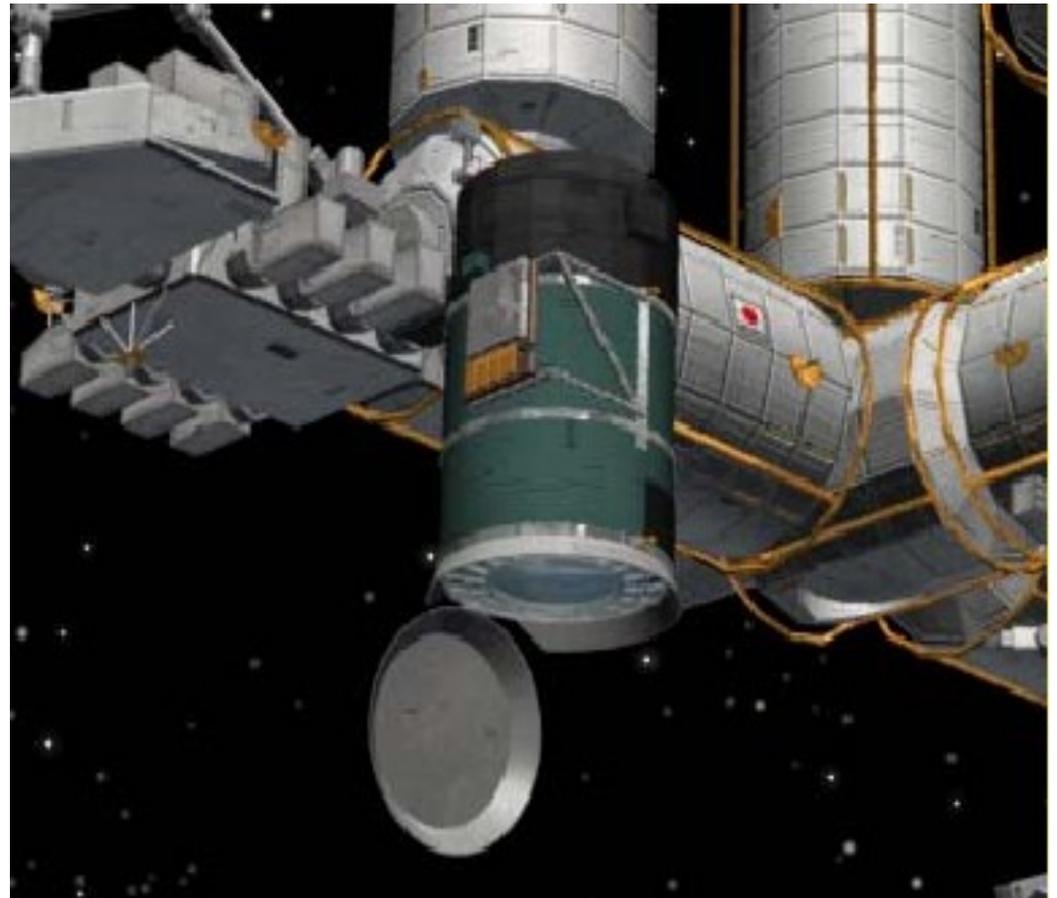
PIERRE  
AUGER  
OBSERVATORY

# FUTURO

Auger Norte  
 $10^4 \text{ km}^2$



JEM-EUSO  
 $10^6 \text{ km}^2$



# Astronomia:

LUZ



1609 Galileu Galilei

PARTÍCULAS

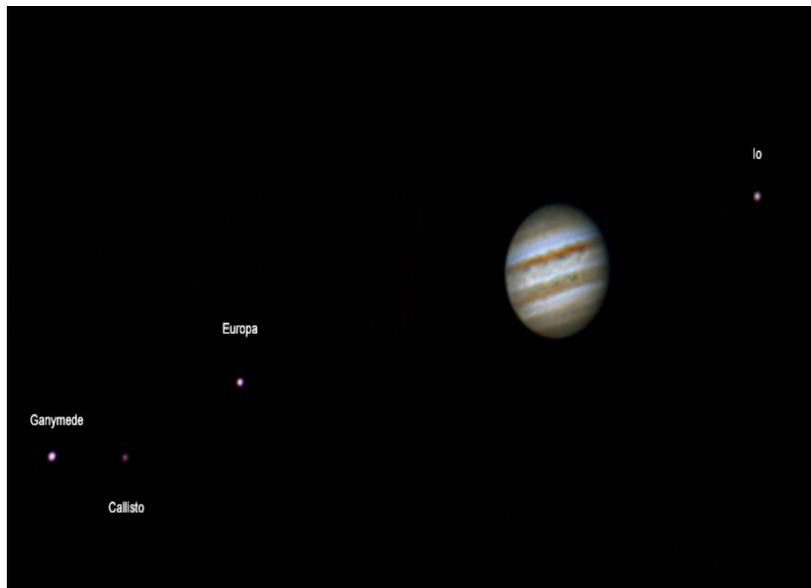


2009 Observatório  
Pierre Auger

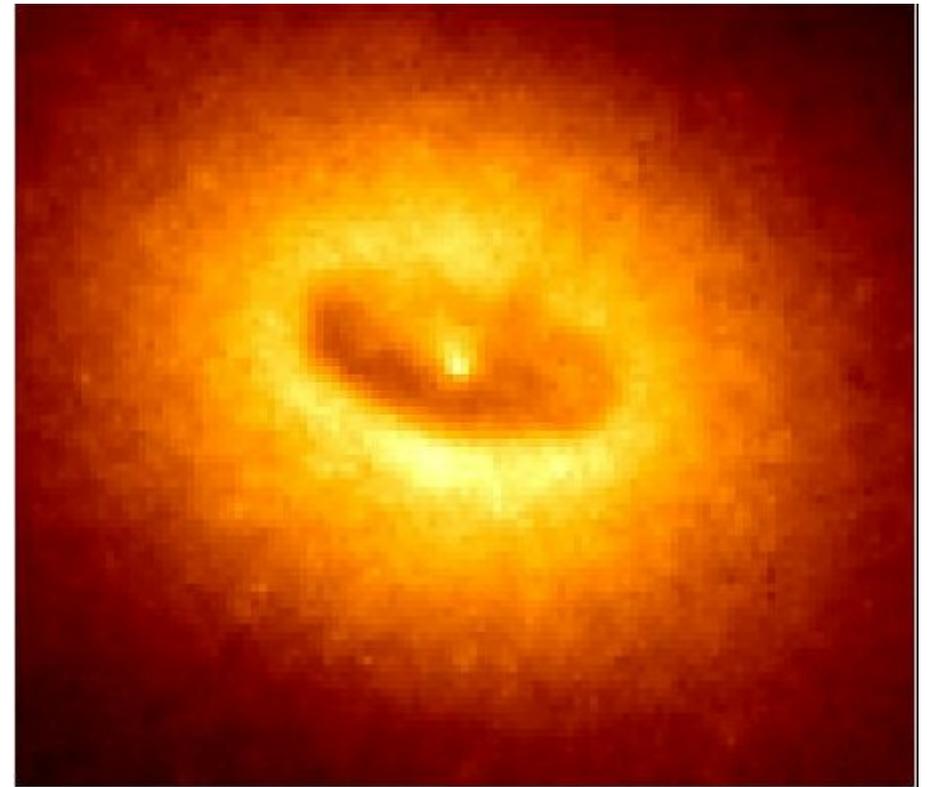
# Astronomia:

LUZ

PARTÍCULAS



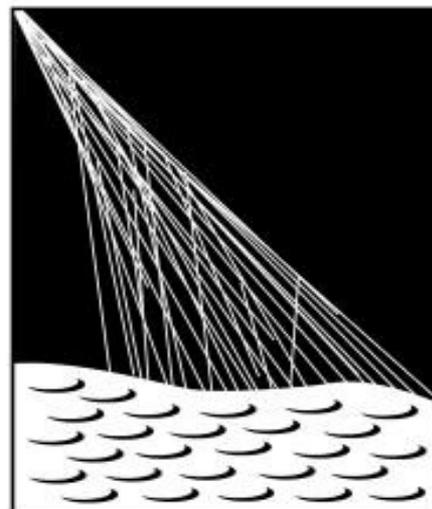
1609 Galileu Galilei



2009 Observatório  
Pierre Auger

# Obrigado !!

Vitor de Souza  
vitor@ifsc.usp.br



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**Instituto de Física de São Carlos**

**Universidade de São Paulo**

