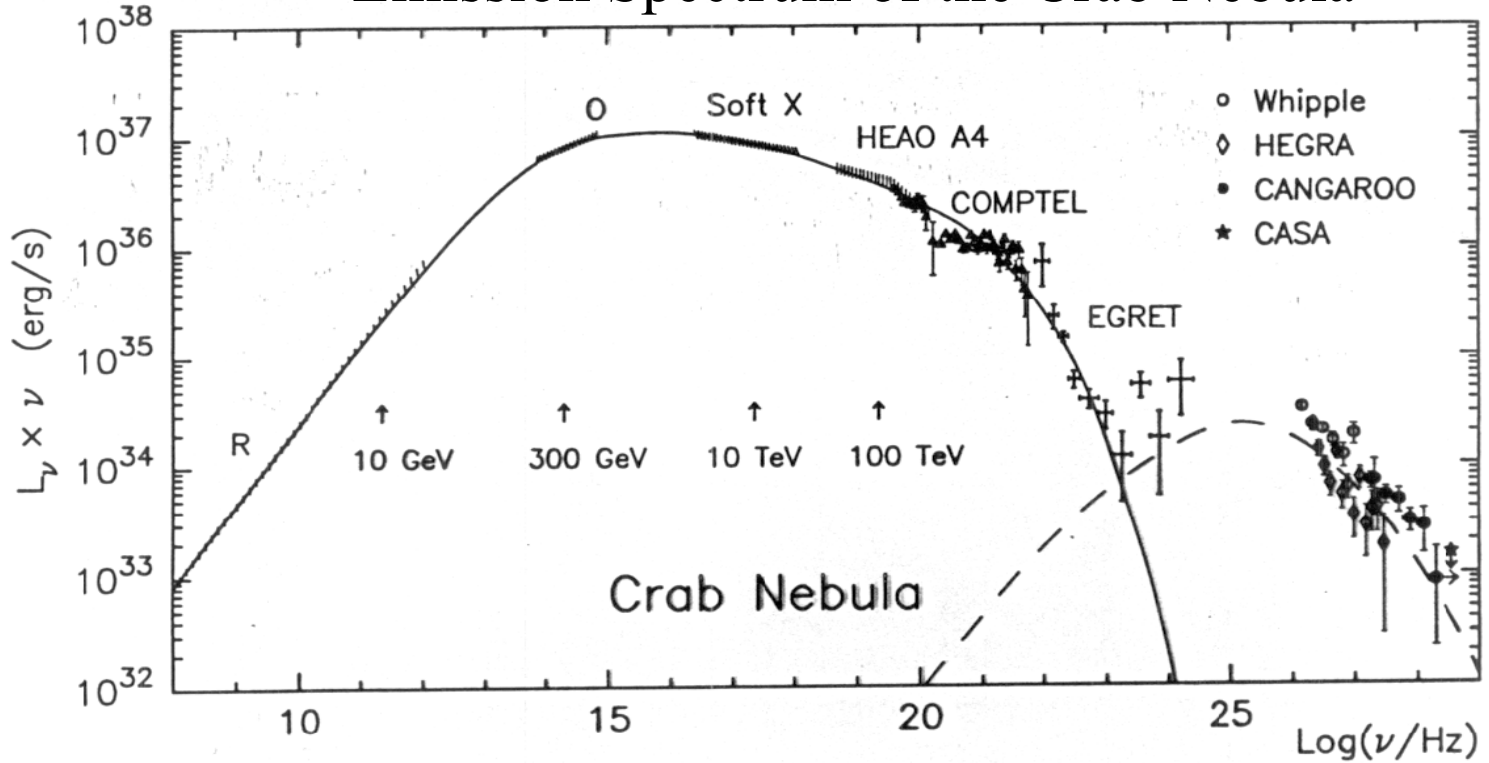


γ -Astronomie

optical

1 lightyear

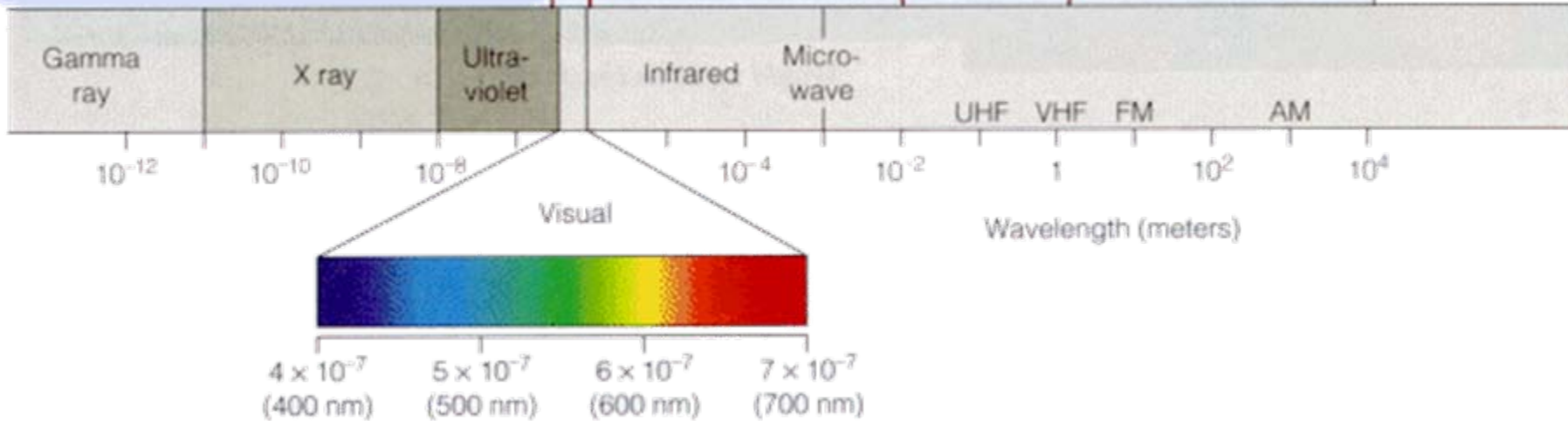
Emission Spectrum of the Crab Nebula



Synchrotron radiation

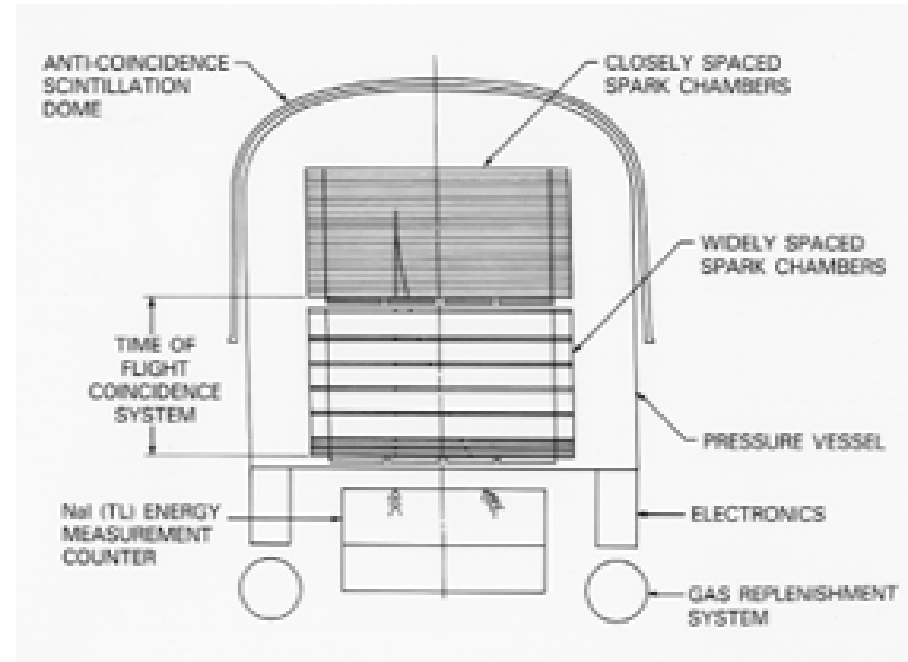
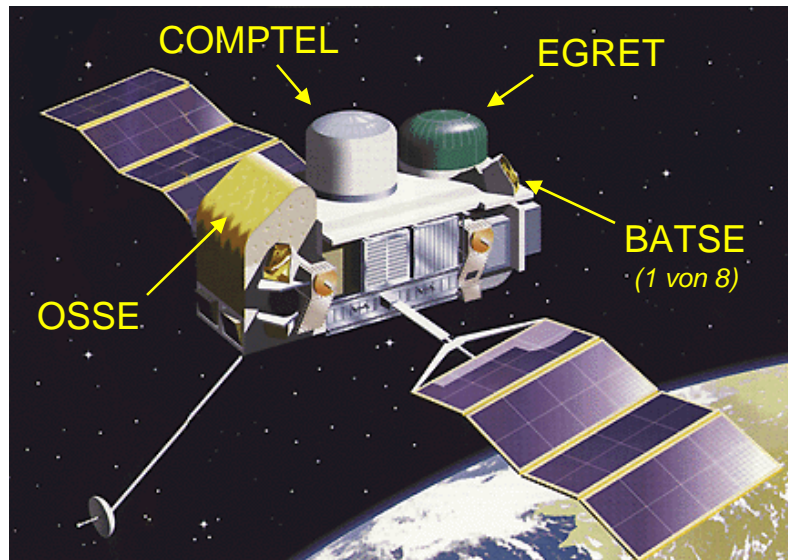
Goldene Zeiten...

...für Astronomie, Astro(teilchen)physik, Kosmologie, ...



Satelliten-Experimente

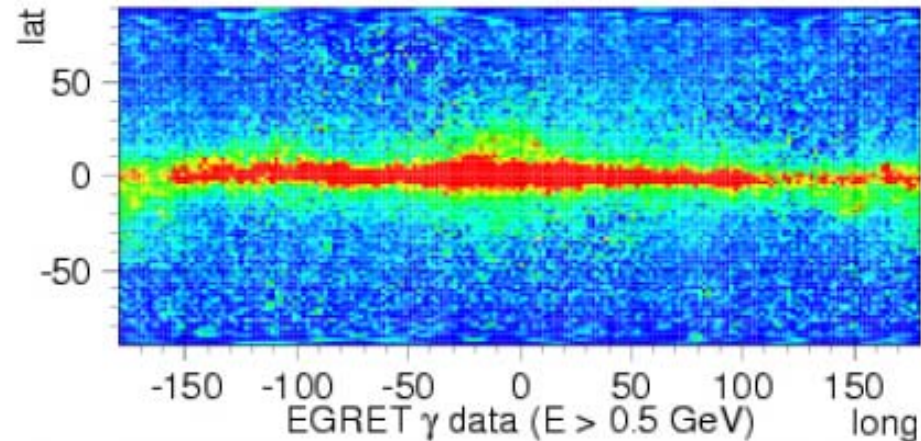
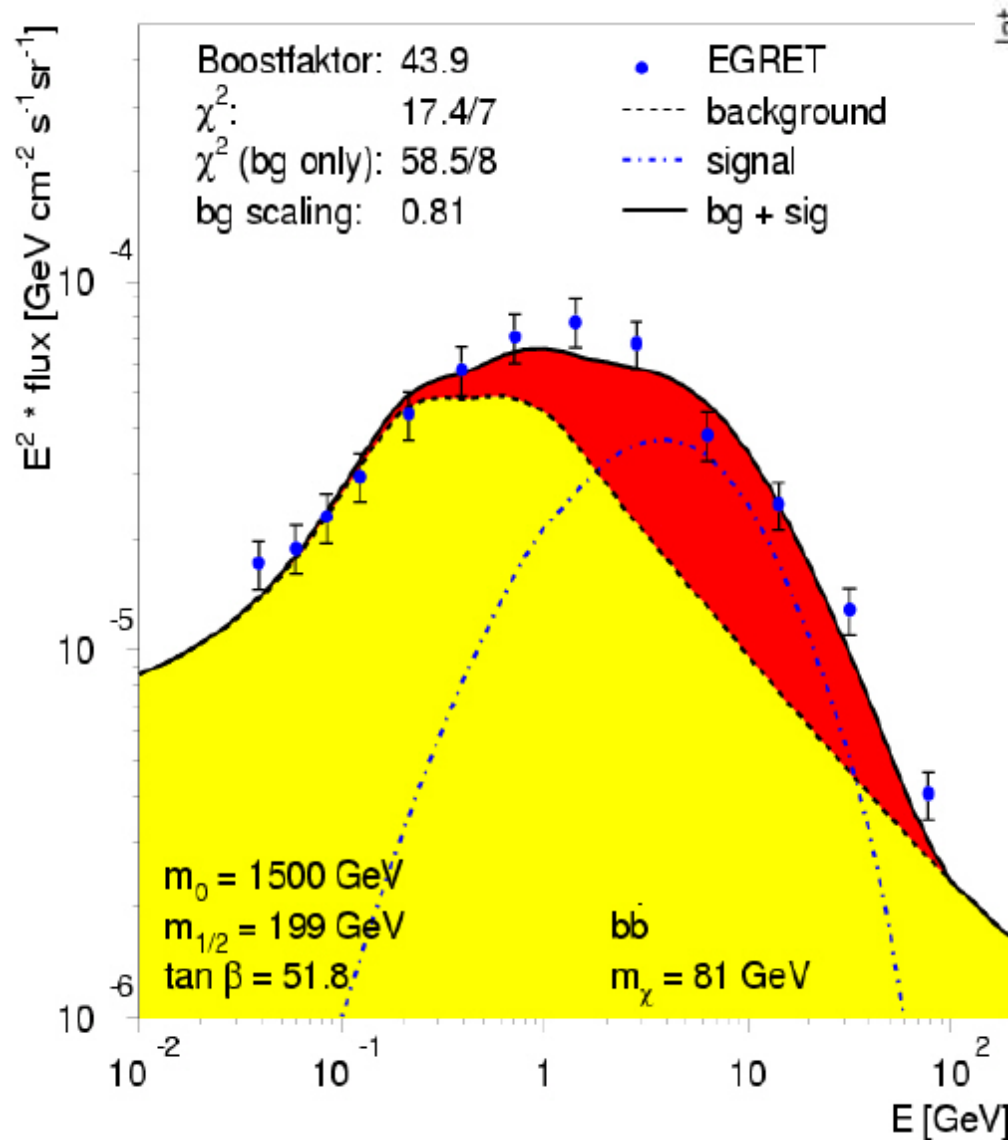
Compton Gamma Ray Observatory (1991-2000)



4 Detektoren decken 20 keV bis 30 GeV ab:

- Burst And Transient Source Experiment ([BATSE](#)),
- Oriented Scintillation Spectrometer Experiment ([OSSE](#)),
- the Imaging Compton Telescope ([COMPTTEL](#)),
- Energetic Gamma Ray Experiment Telescope ([EGRET](#)).

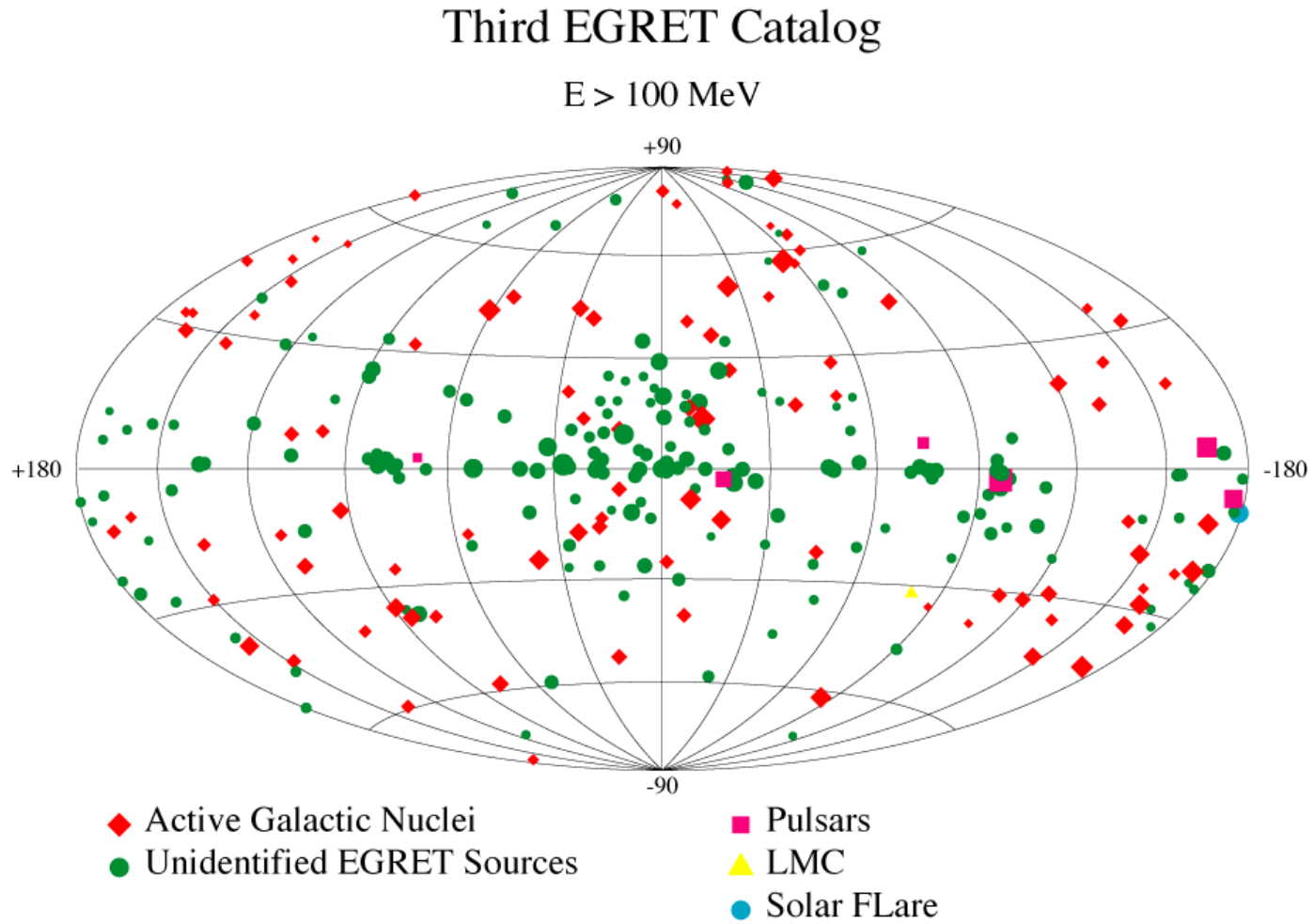
EGRET-Daten und Dunkle Materie



Beobachteter Überschuß kann als Annihilations-Signal dunkler Materie interpretiert werden.

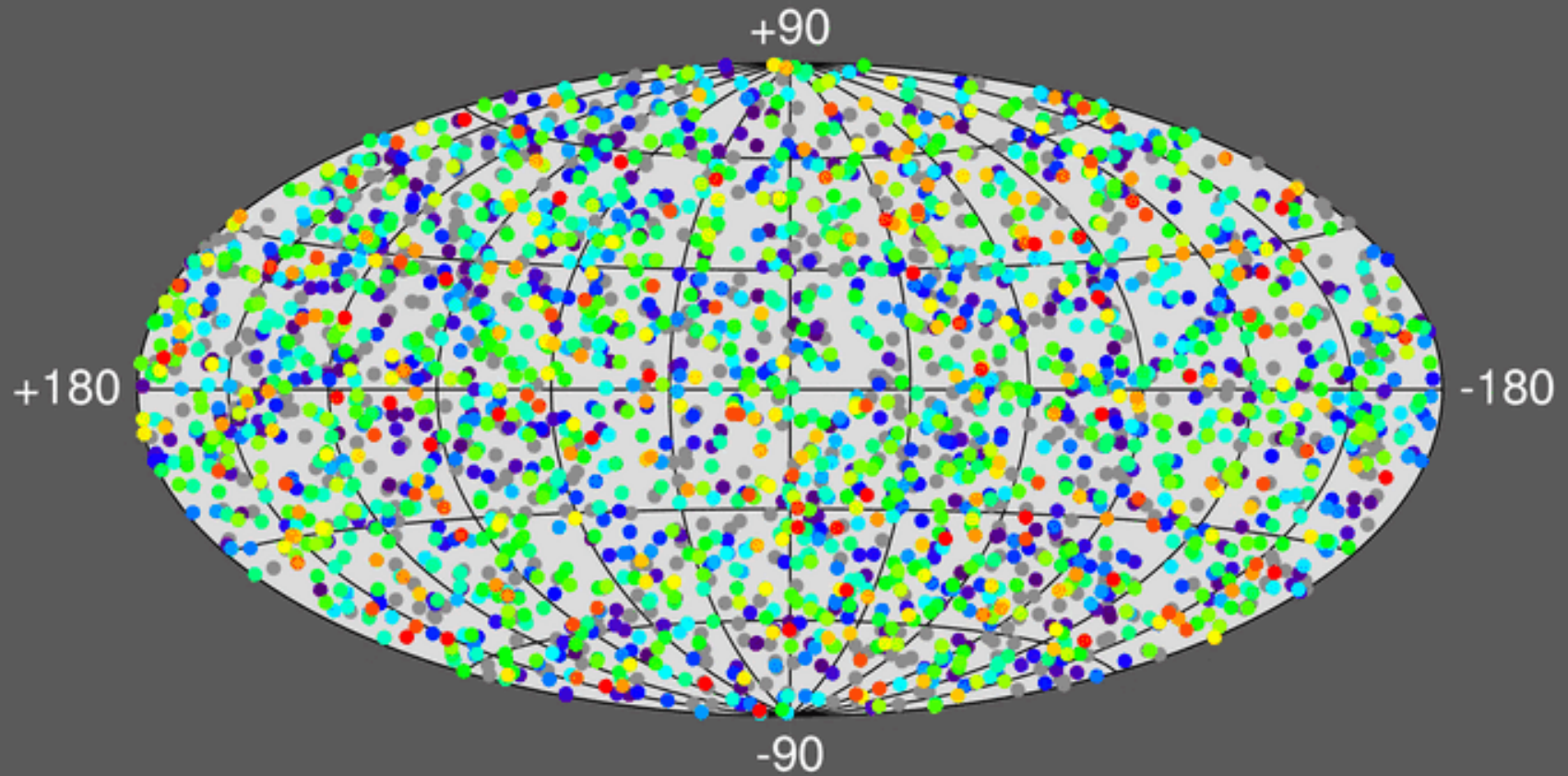
→ Wurde inzwischen von Fermi widerlegt!

EGRET-Punktquellen



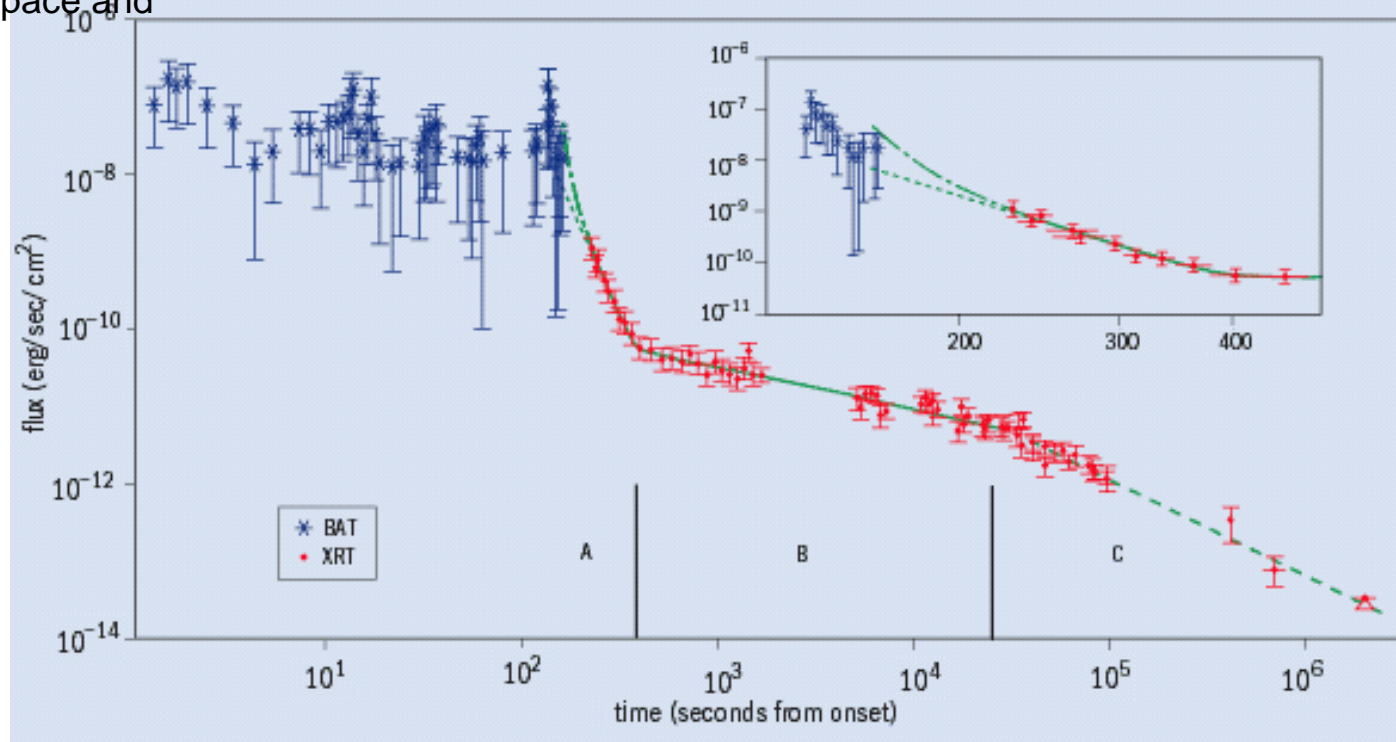
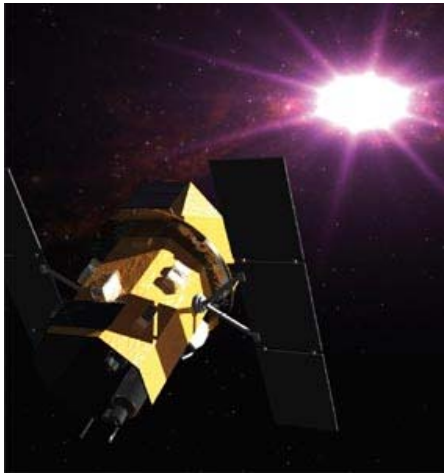
BATSE: Gamma Ray Bursts

2691 BATSE Gamma-Ray Bursts



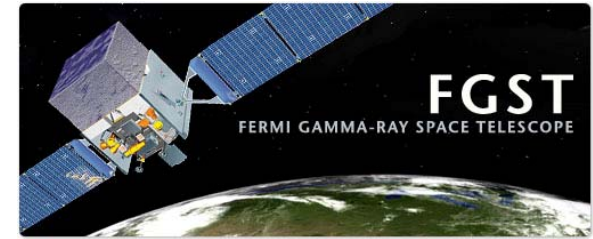
Swift: GRB 050319

NASA's Swift satellite, which was launched in 2004, has proved a great success in its mission to detect and localize gamma-ray bursts quickly and precisely so that their afterglows can be promptly studied from both space and Earth.

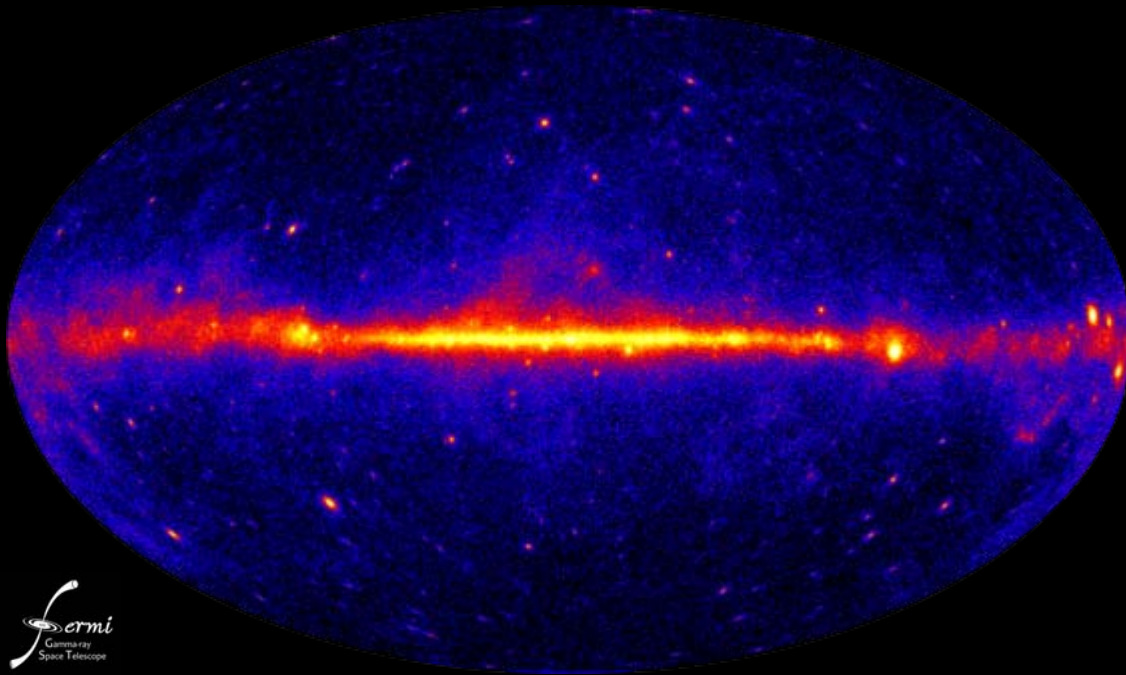


The gamma-ray (15-150 keV) light curve of GRB 050319 and its X-ray afterglow (0.2-10 keV) as measured by the Burst Alert Telescope (BAT) and the X-ray Telescope (XRT) on-board Swift (G Cusumano *et al.* 2005 <http://arxiv.org/abs/astro-ph/0509689>).

Fermi-Glast



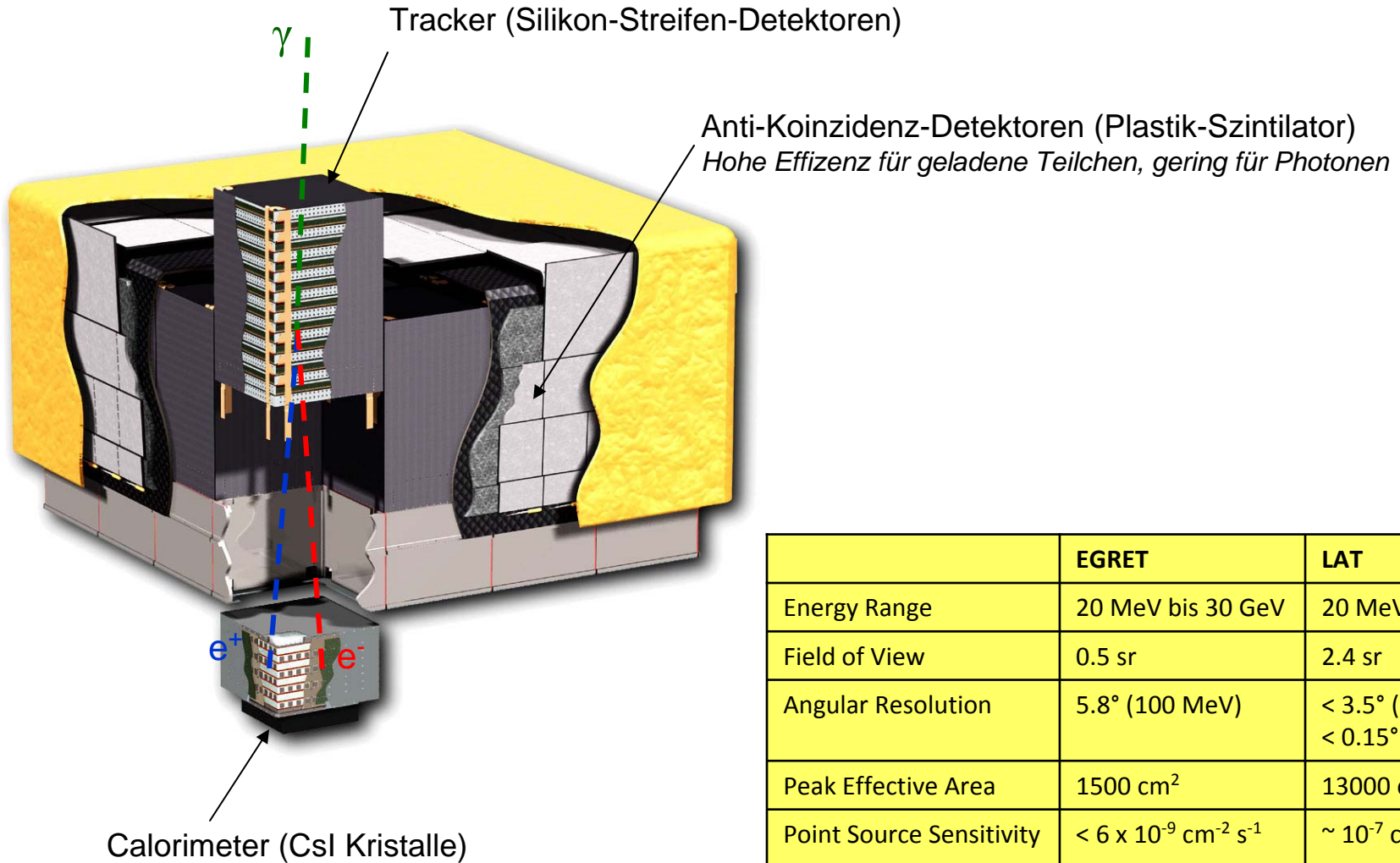
Fermi 1-year All-Sky Map above 300 MeV



Start am 11. Juni 2008

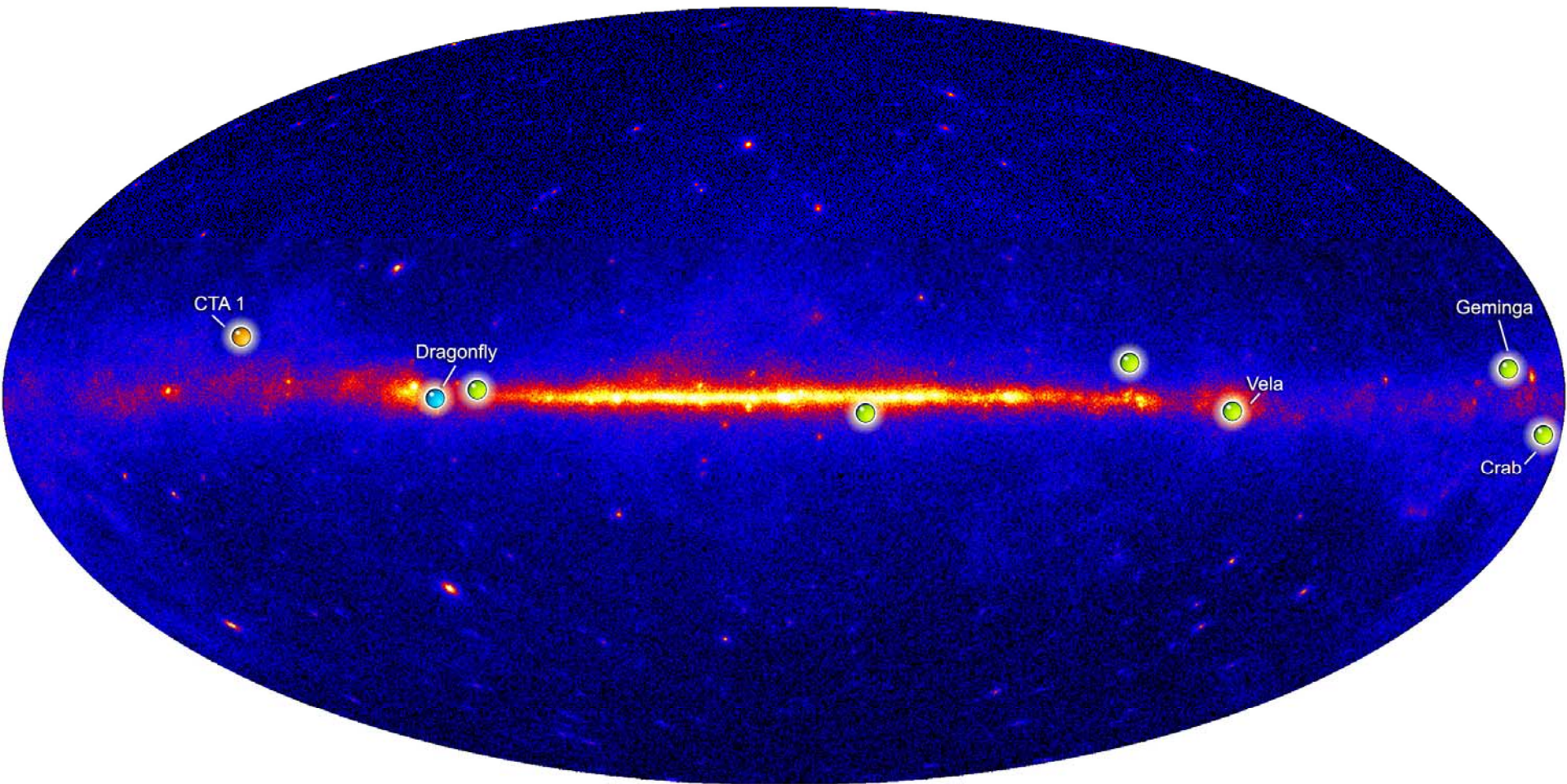


Fermi: Large Area Telescope

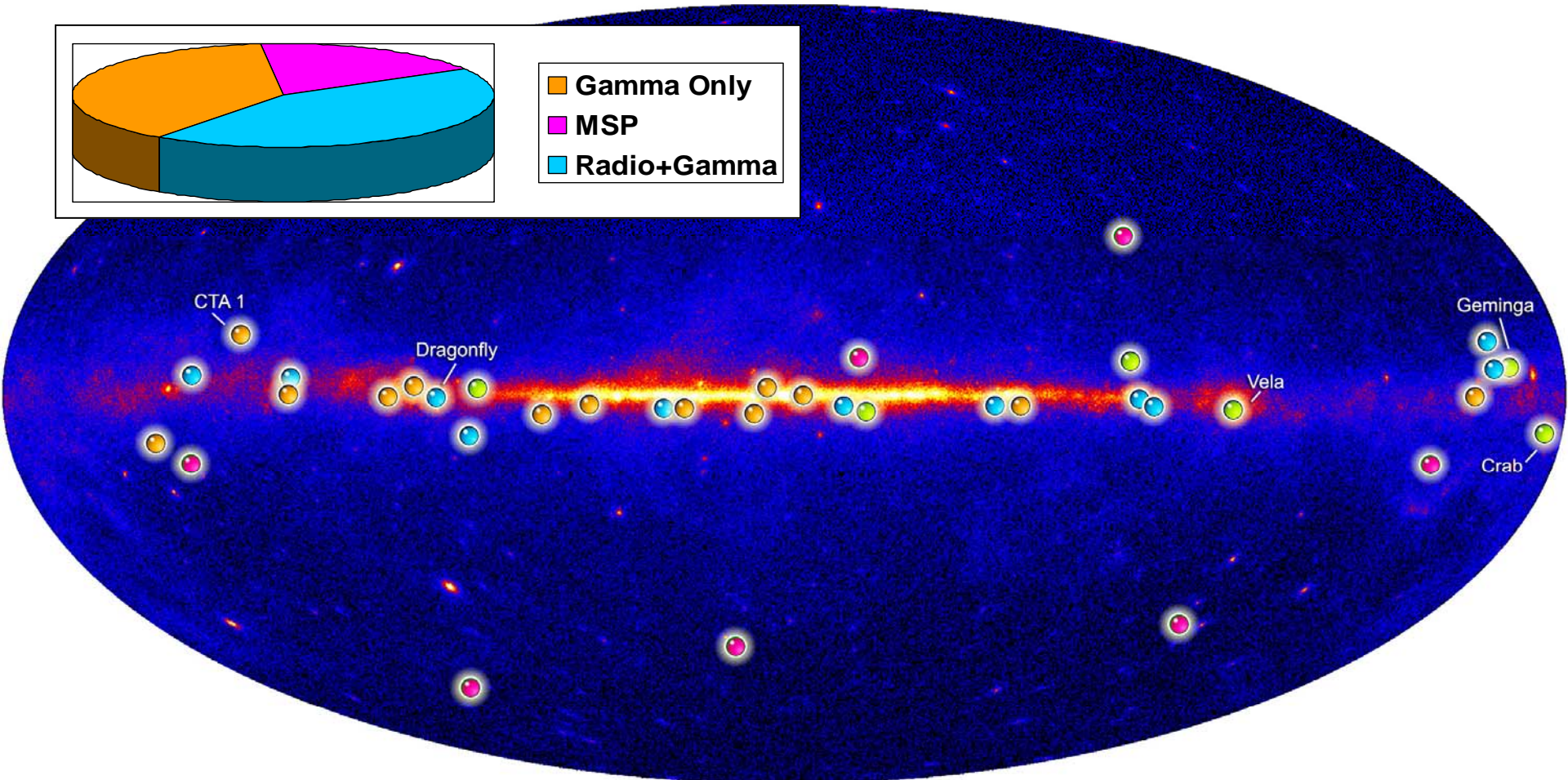
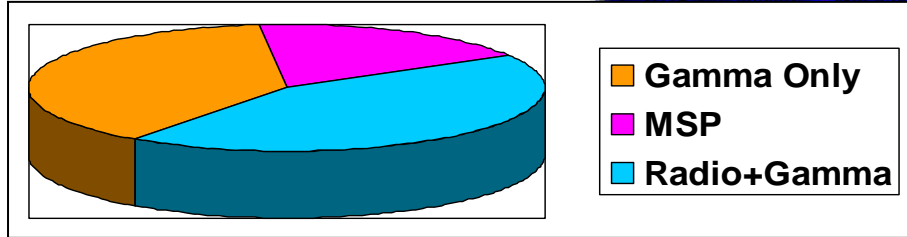


	EGRET	LAT
Energy Range	20 MeV bis 30 GeV	20 MeV bis 300 GeV
Field of View	0.5 sr	2.4 sr
Angular Resolution	5.8° (100 MeV)	< 3.5° (100 MeV) < 0.15° (>10 GeV)
Peak Effective Area	1500 cm ²	13000 cm ²
Point Source Sensitivity	< 6 x 10 ⁻⁹ cm ⁻² s ⁻¹	~ 10 ⁻⁷ cm ⁻² s ⁻¹
Deadtime per Event	100 ms	< 100 μs

Bekannte γ -Pulsare vor Fermi



Von Fermi LAT entdeckte/gesehene Pulsare

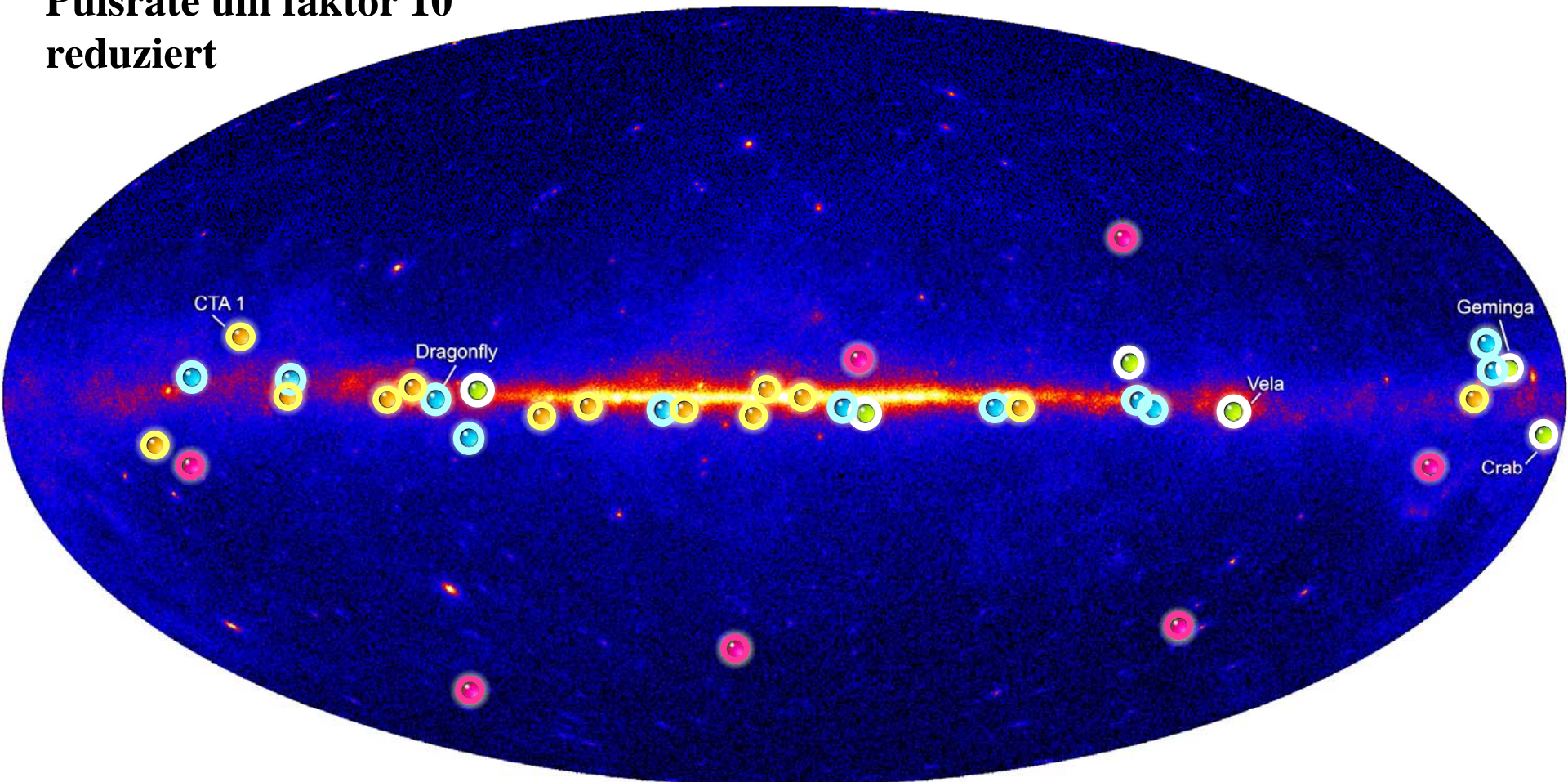


Fermi Pulsar Detections

- New pulsars discovered in a blind search
- Millisecond radio pulsars
- Young radio pulsars
- Pulsars seen by Compton Observatory EGRET instrument

Der pulsierende γ -Ray Himmel

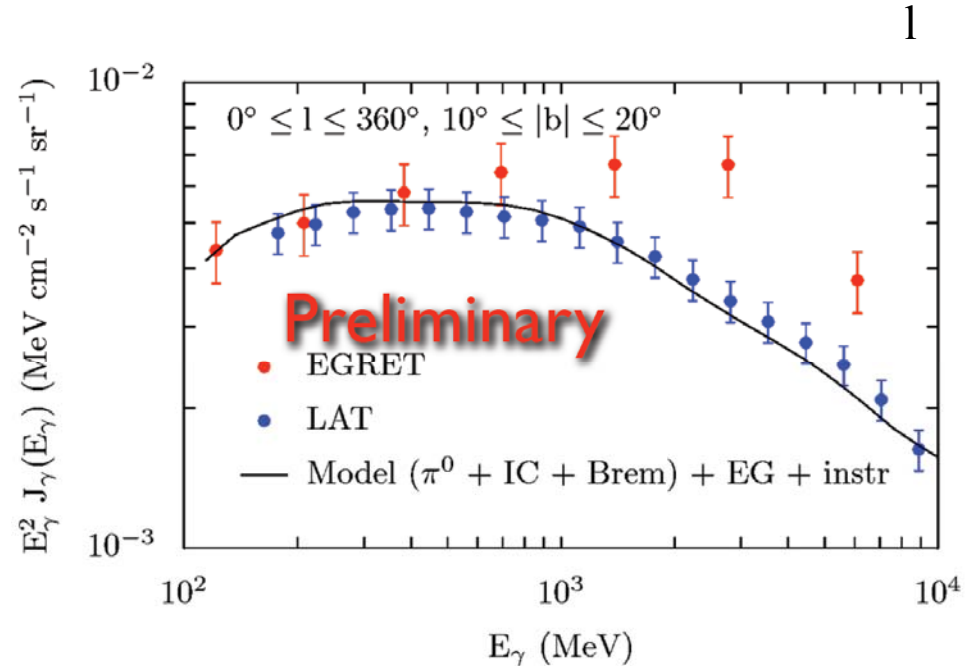
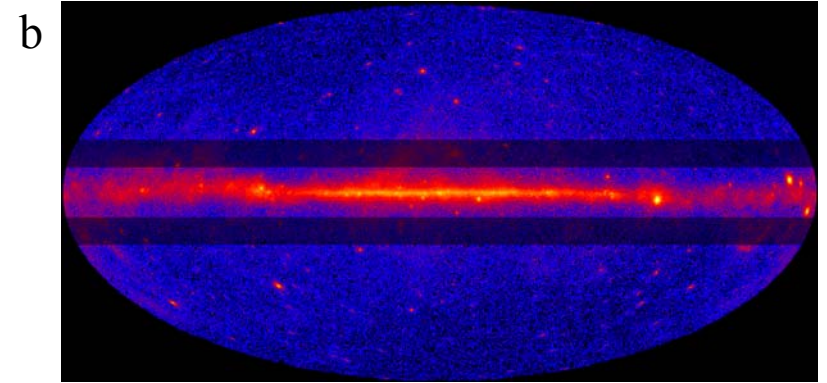
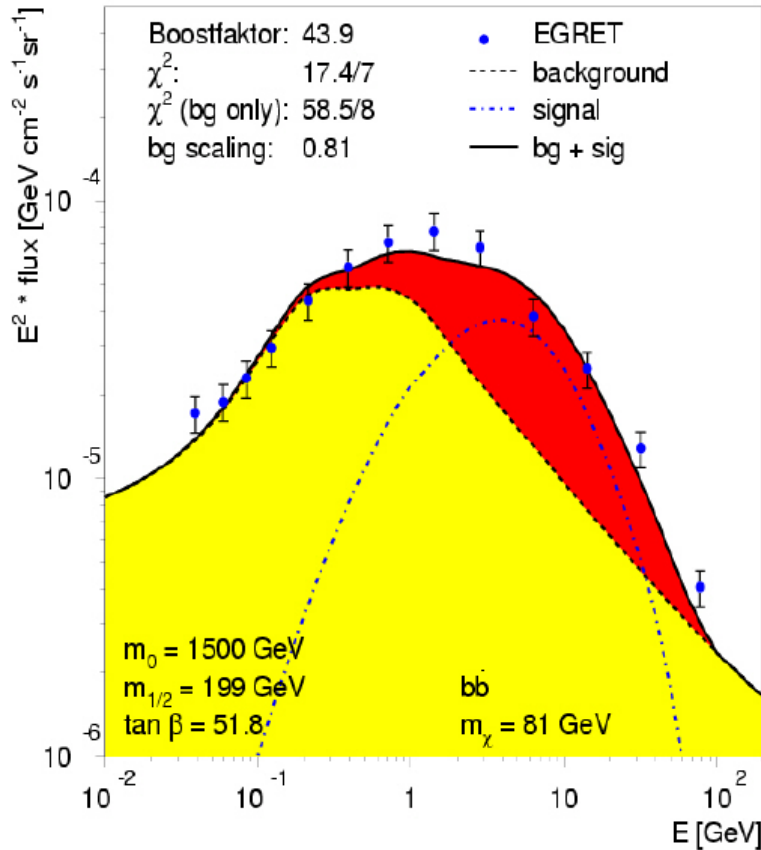
**Pulsrate um faktor 10
reduziert**



Fermi Pulsar Detections

- New pulsars discovered in a blind search
- Millisecond radio pulsars
- Young radio pulsars
- Pulsars seen by Compton Observatory EGRET instrument

Fermi: Diffuser γ -Flu β



→ Fermi LAT kann EGRET \ddot{U} berschu β nicht best \ddot{a} tigen!

Gamma Rays from 100 GeV – 10 TeV

Gamma-
quant

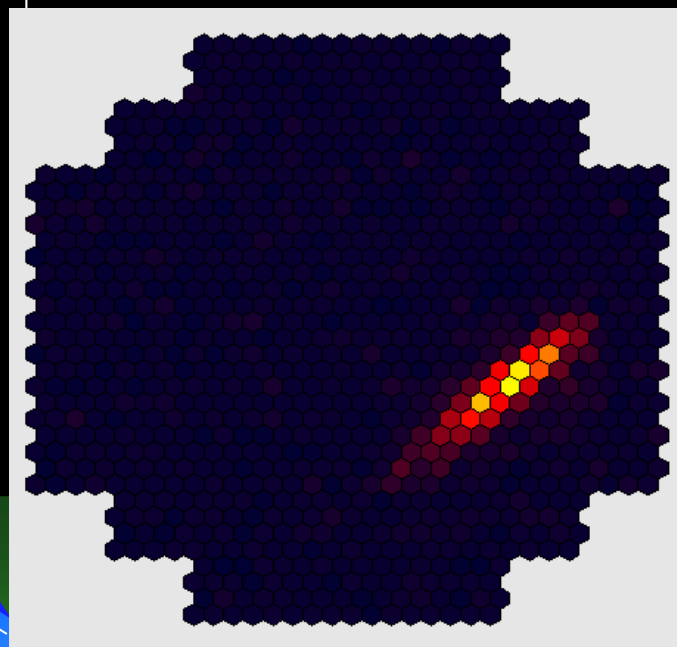
Particle
Shower

Cherenkov Light

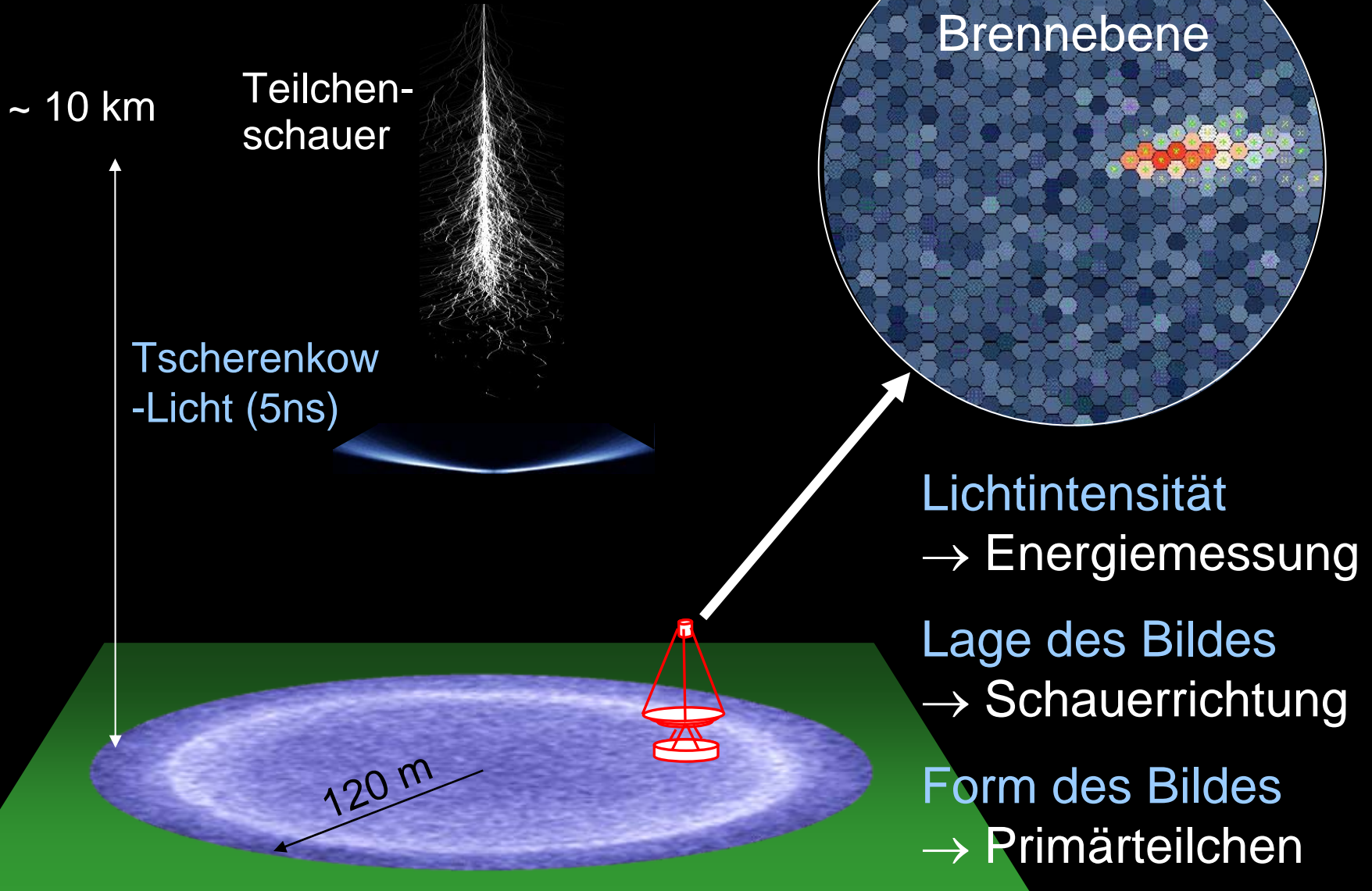
~ 10 km

~ 1°

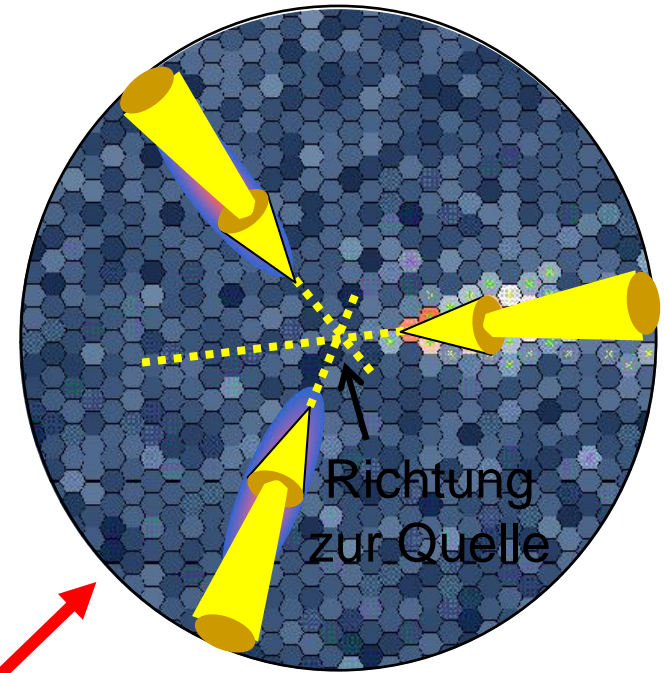
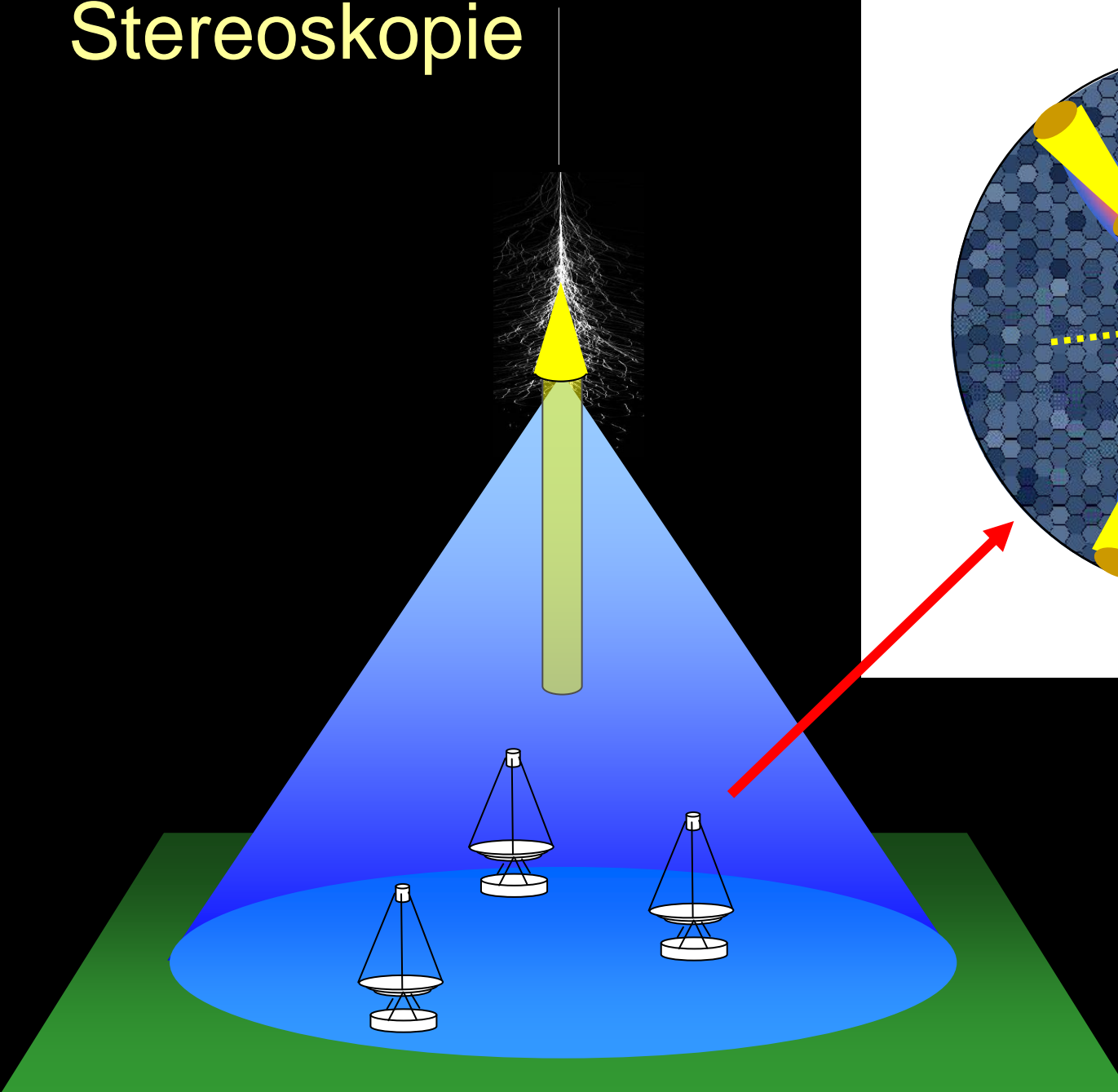
~ 120 m



Schauerdetektion



Stereoskopie



Mehrere Beobachtungswinkel erlauben Rekonstruktion der Quellposition für jedes Ereignis

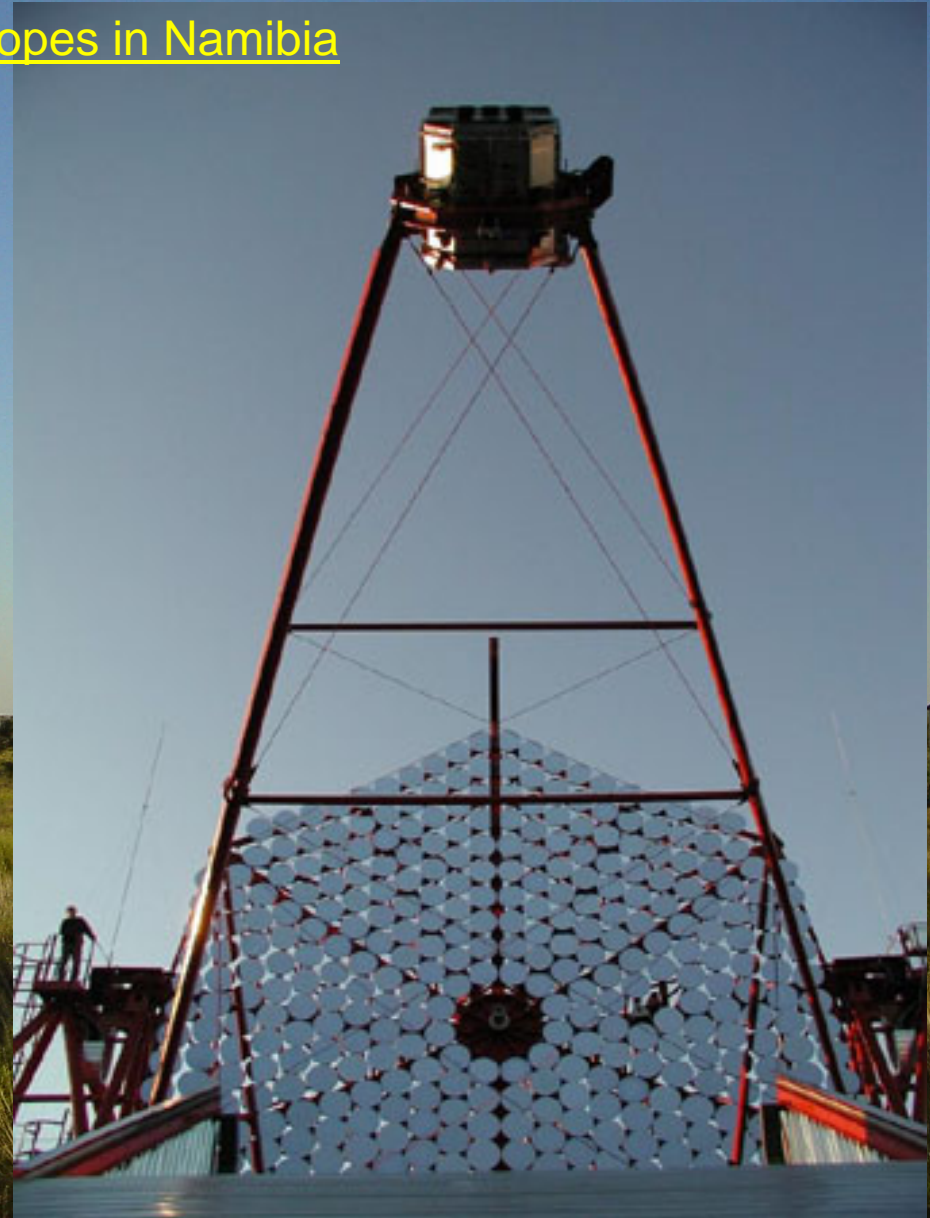
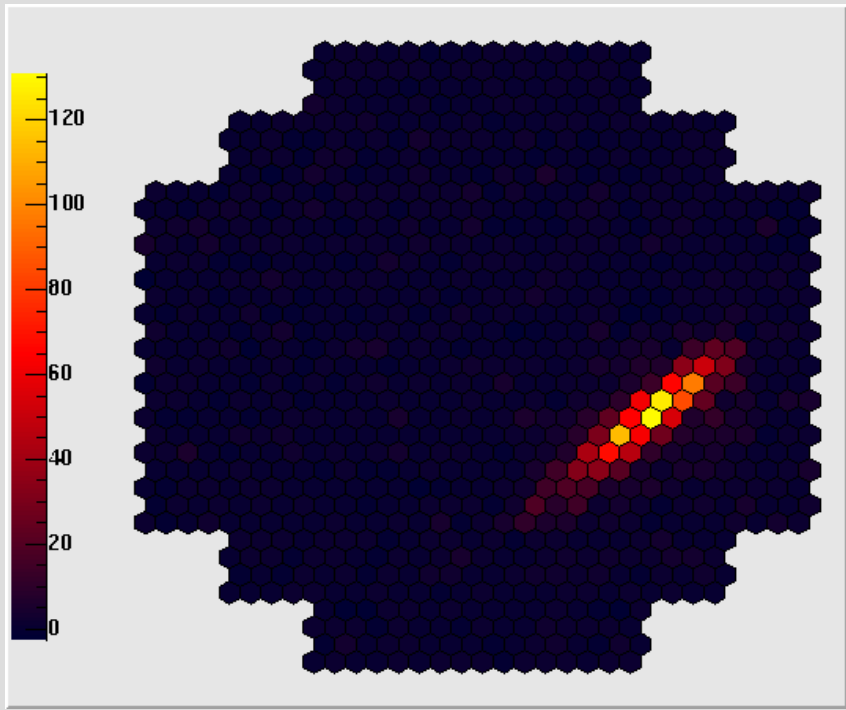
Tscherenkow-Systeme



Air Showers from HE γ Rays

- HESS Telescopes in Namibia

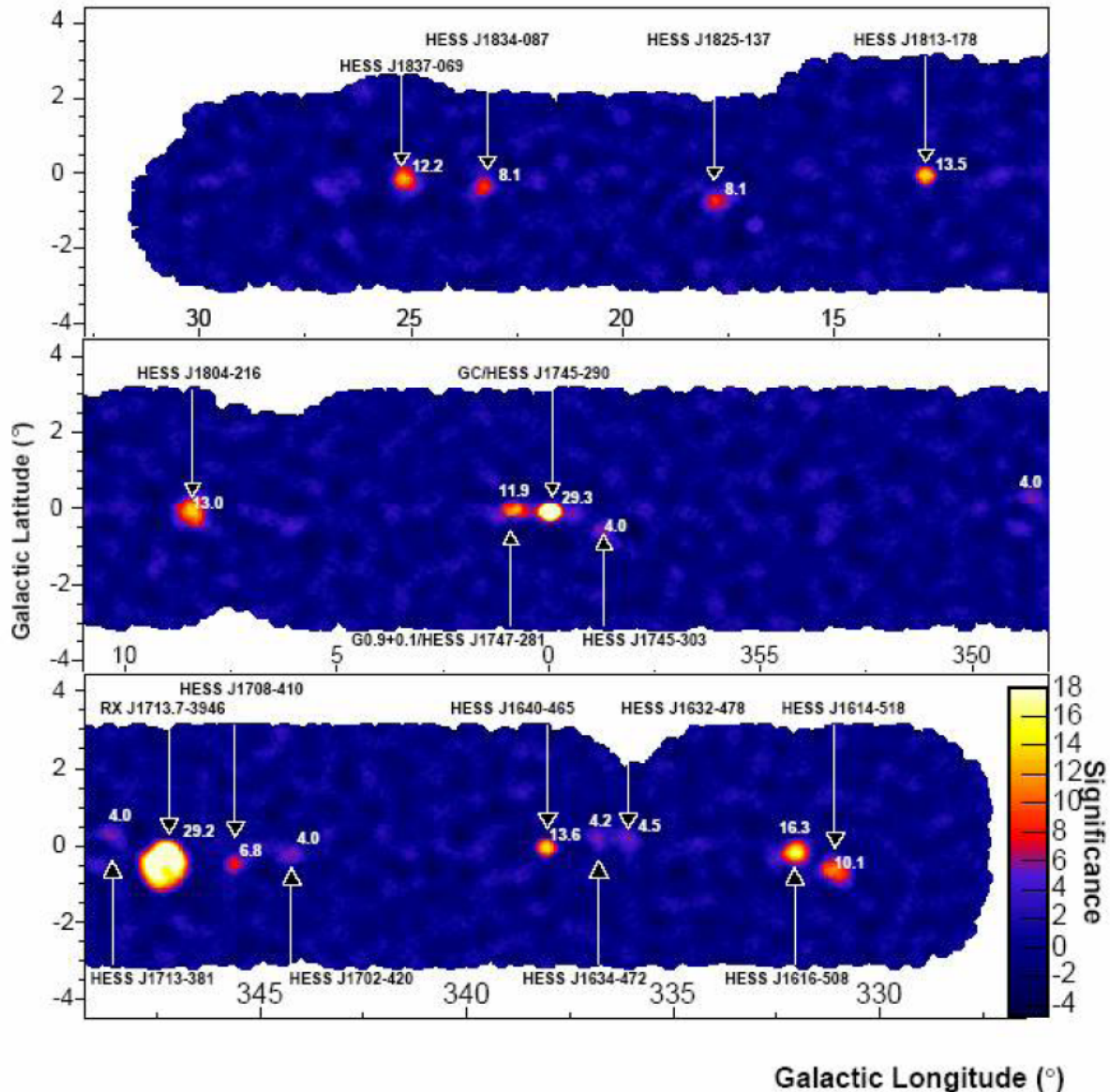
Camera in action



H.E.S.S. Resultate – Eine Auswahl

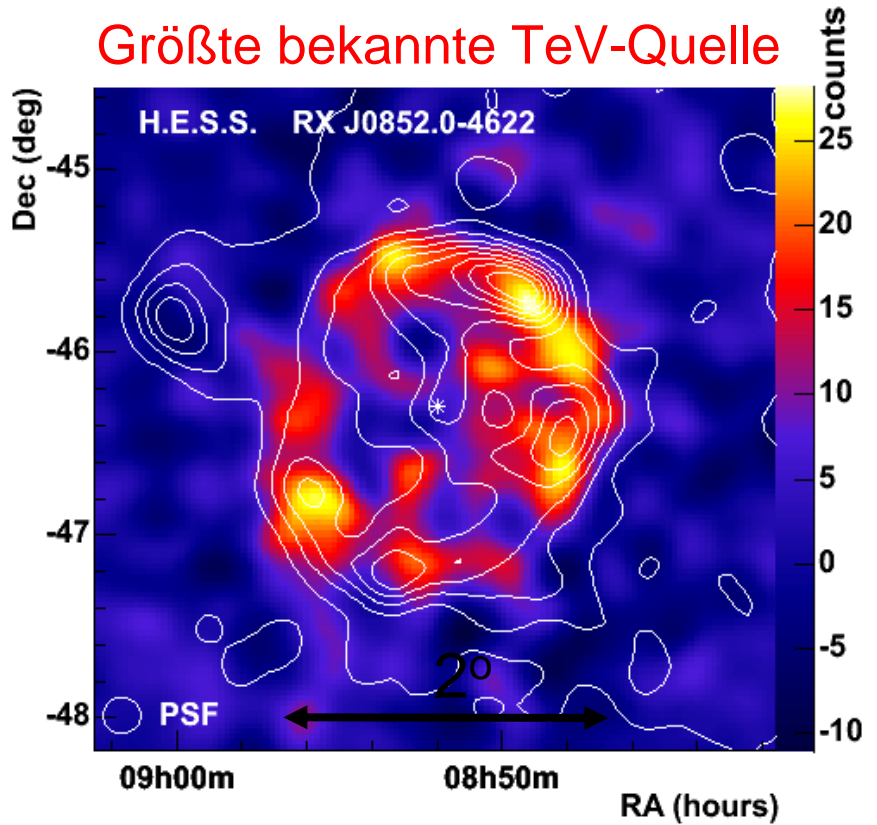
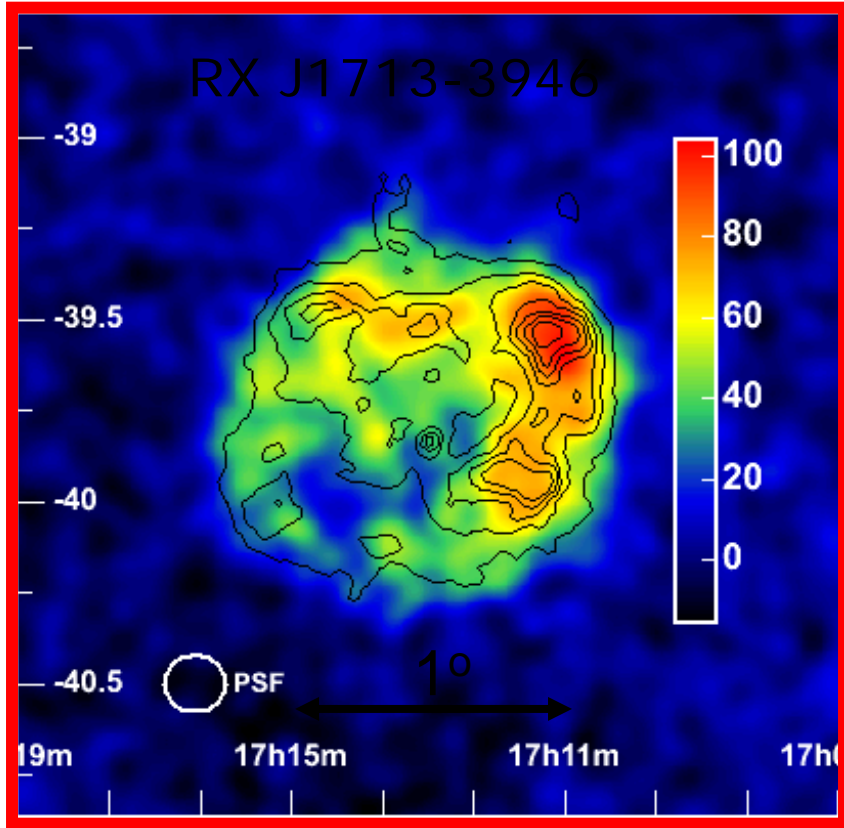
- Durchmusterung der Inneren Galaxie nach TeV γ -Quellen
- Unidentifizierte Quellen („Dunkle Beschleuniger“)
- Supernova-Reste als mögliche Quellen der Kosmischen Strahlung
- Binärsysteme als TeV γ -Quellen
- Das Zentrum der Galaxie als Emitter von γ -Strahlung
- Aktive Galaxienkerne: Wieviel Licht gibt es im Universum?

TeV γ -Quellen in der Galaktischen Ebene



- Mehrheit der Quellen ist ausgedehnt
- 5 Quellen fallen mit SNR zusammen

Aufgelöste SNR

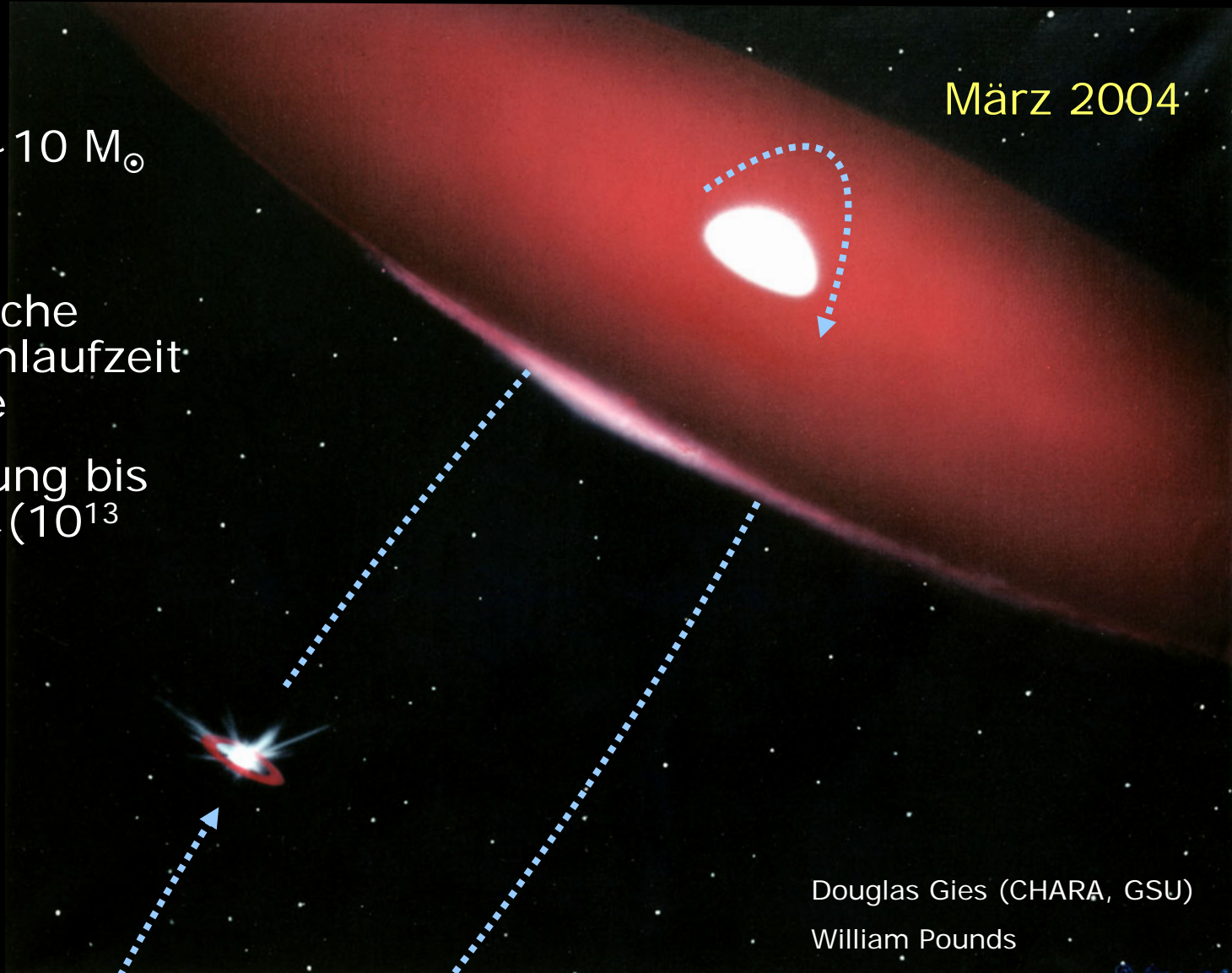


Konturen: Röntgen-Daten (ASCA bzw. ROSAT)

Binärsysteme (1/2): PSR B1259

- Pulsar + $\sim 10 M_{\odot}$
Be Stern
- Stark
exzentrische
Bahn, Umlaufzeit
3.4 Jahre
- Annäherung bis
auf $10 R_{*}$ (10^{13}
cm)

März 2004

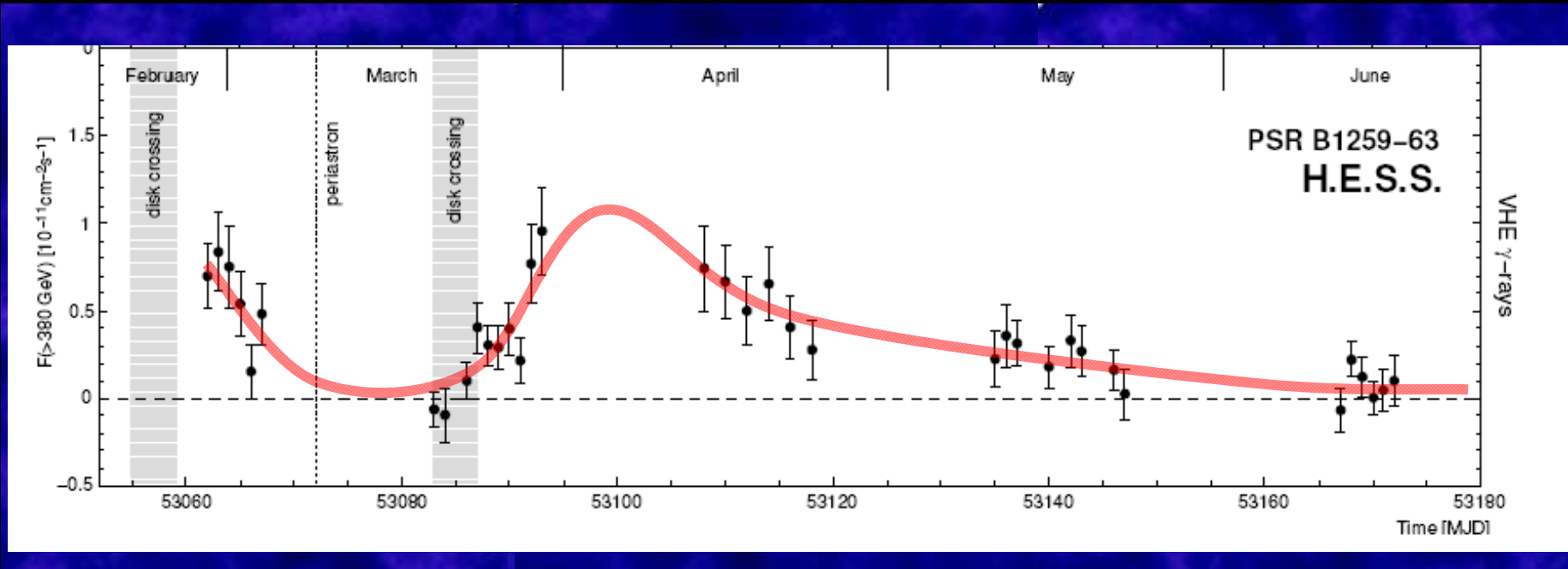


Douglas Gies (CHARA, GSU)

William Pounds

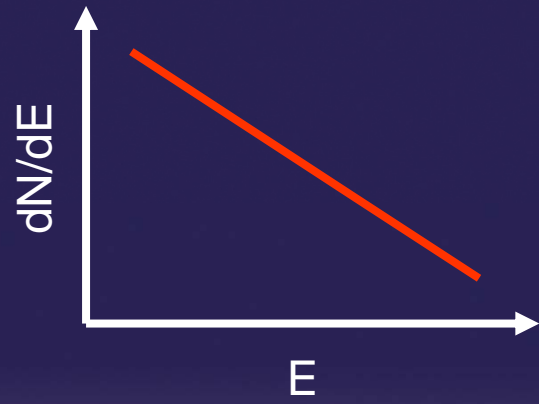
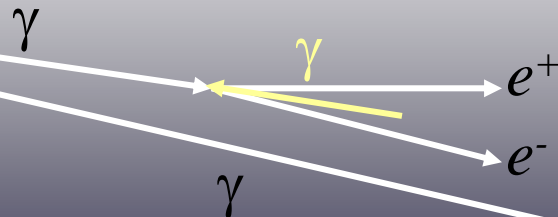
Binärsysteme (1/2): PSR B1259

- Mechanismus: IC am Sternenwind?

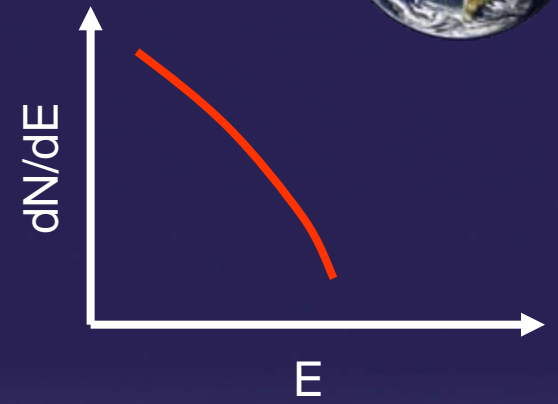


→ Erste variable galaktische Quelle im TeV Bereich

Extragalaktische Quellen - Blazare

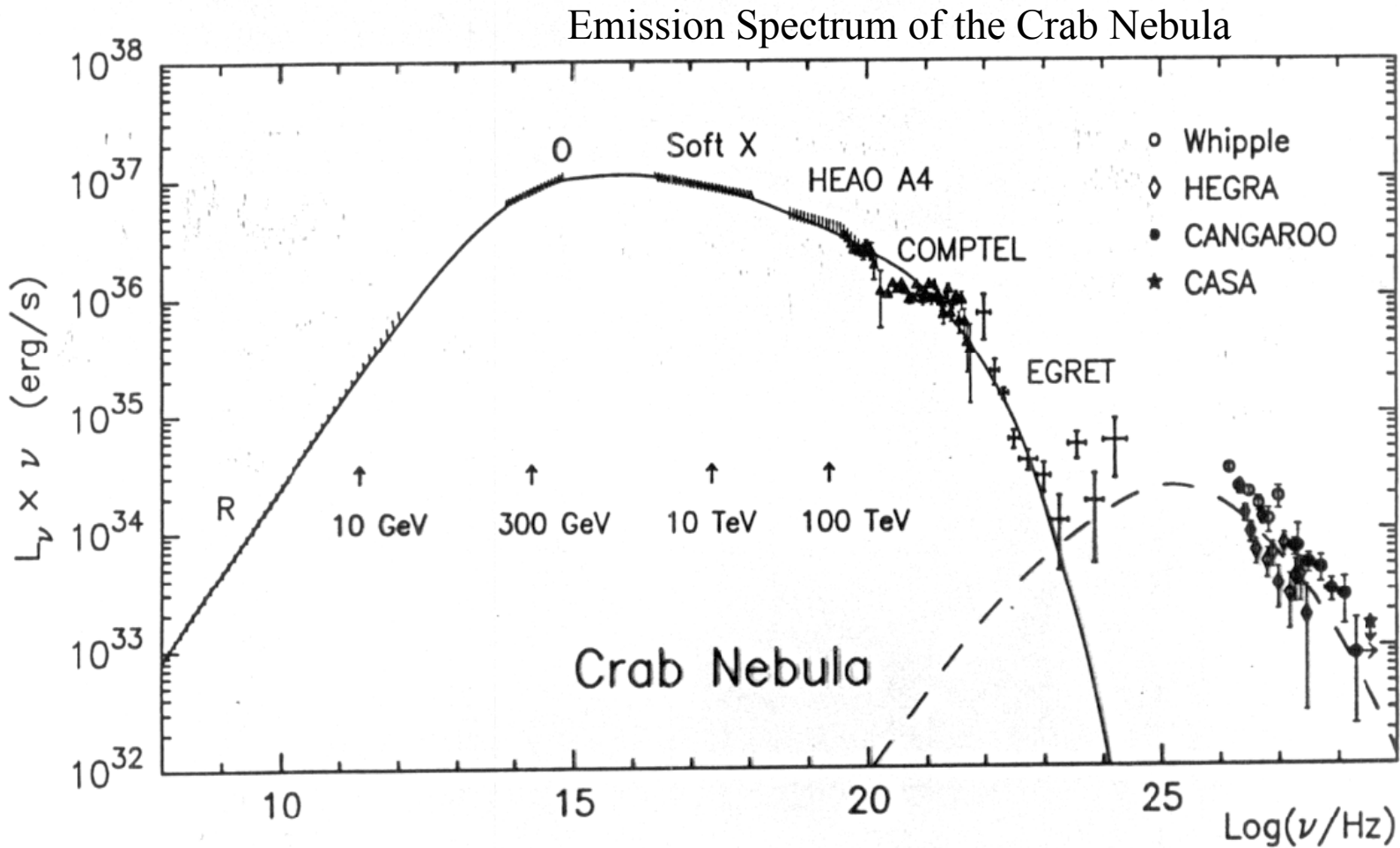


Absorption im (infraroten) extragalaktischen Untergrundlicht (EBL)
 $\gamma(\text{TeV}) + \gamma(\text{EBL}) \rightarrow e^+e^-$



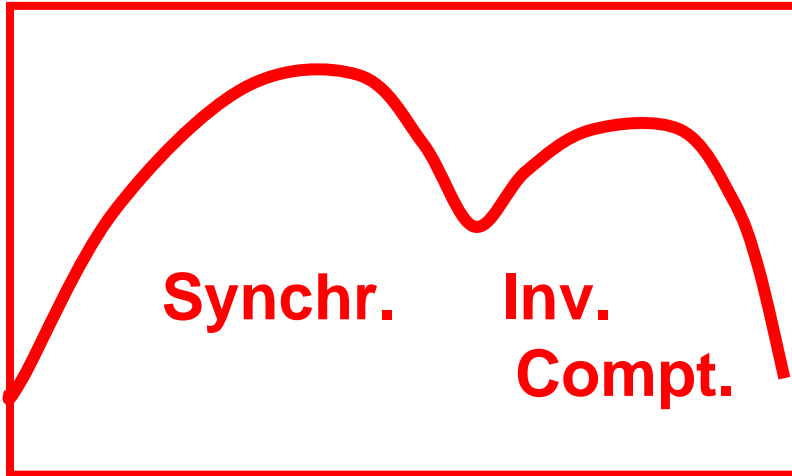
→ Kosmologie

Emissionsspektrum des Krebsnebels

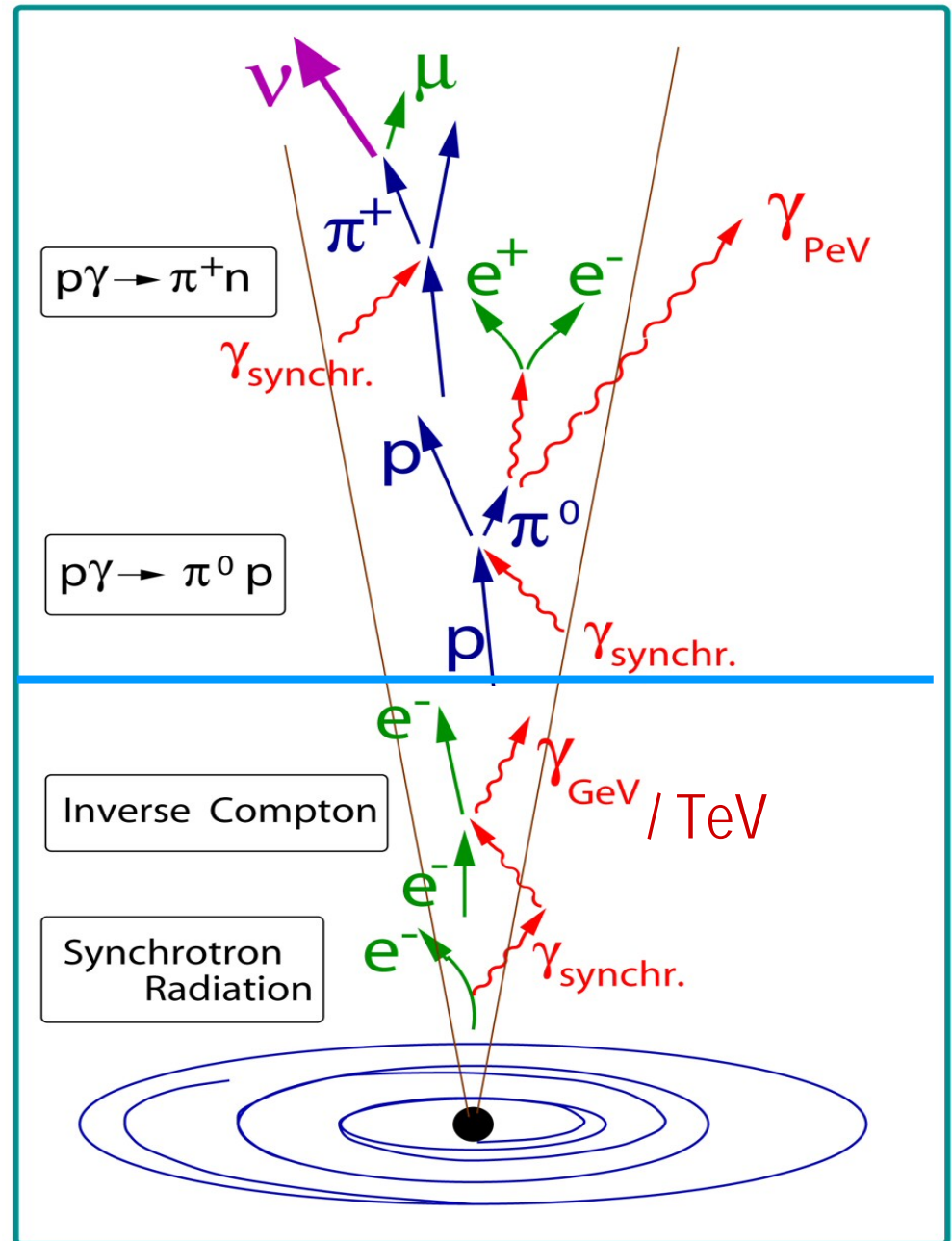


Particle Generation in AGN Jets

The electromagnetic spectrum of the TeV Gamma-sources known until now

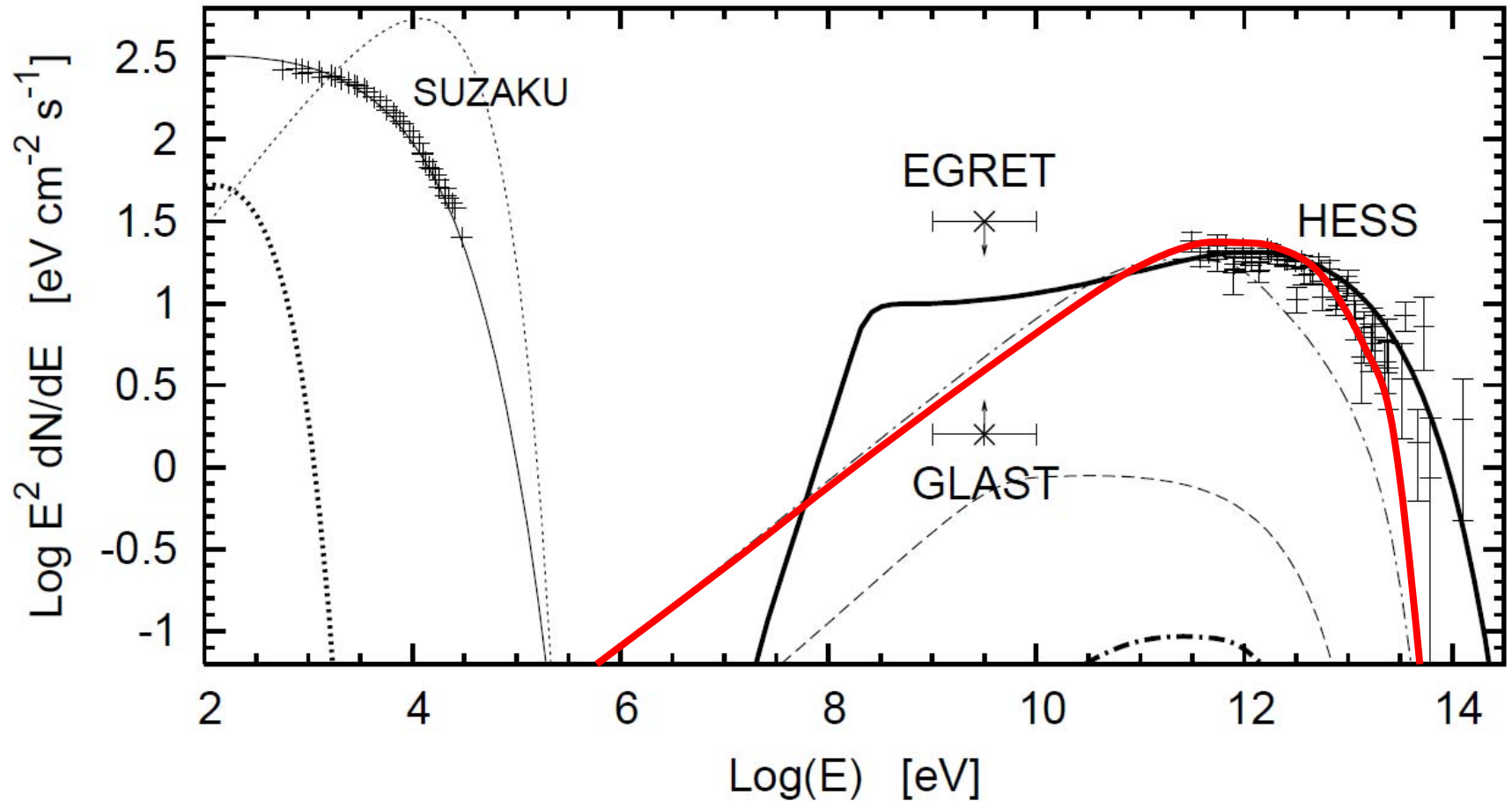


Radio optical X-ray GeV TeV
 IR UV MeV



Hadron- oder Elektron Beschleuniger?

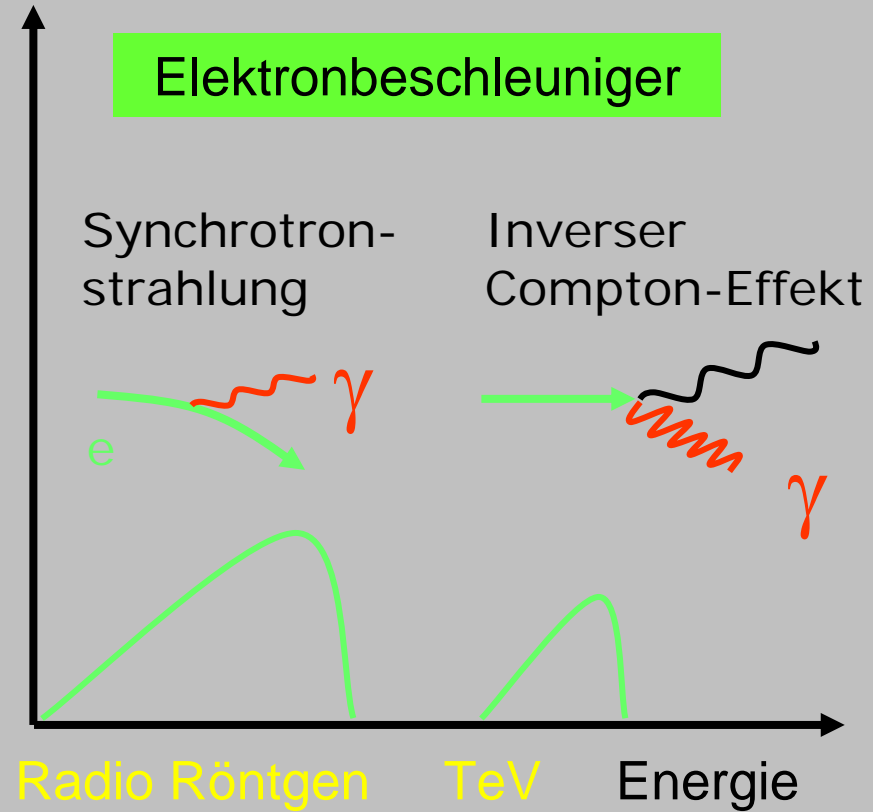
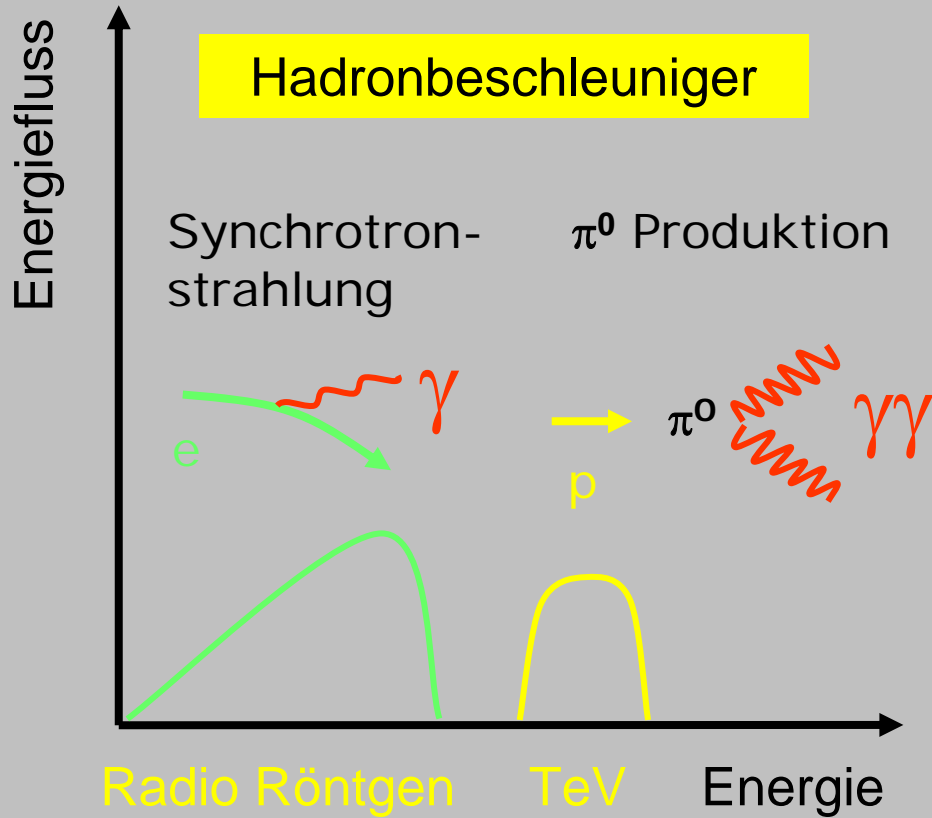
Gamma-Spektrum von SNR RXJ1713.7-3946



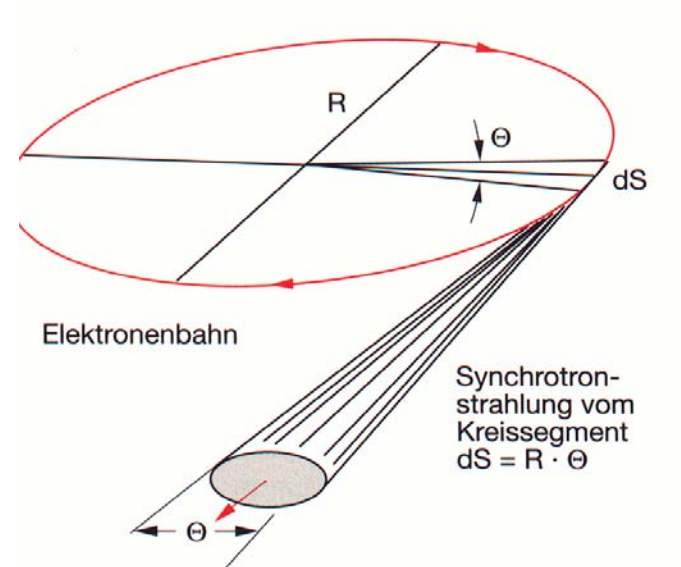
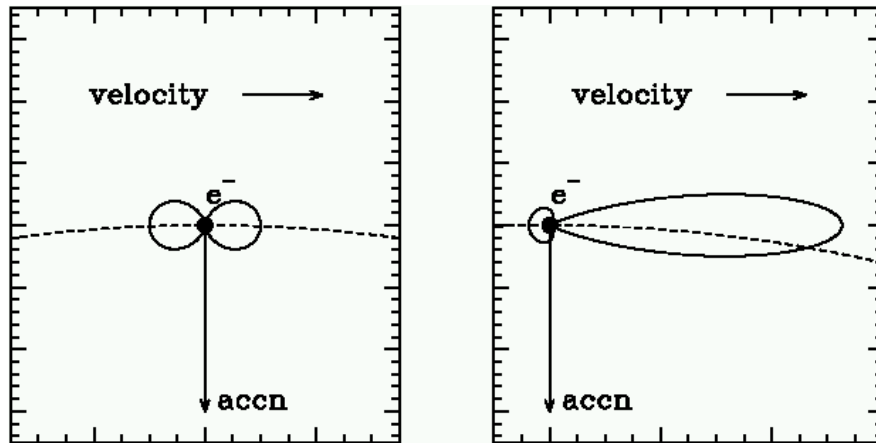
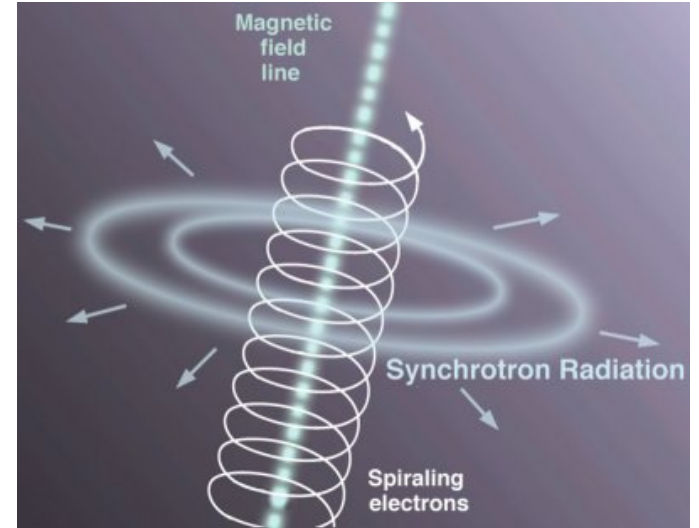
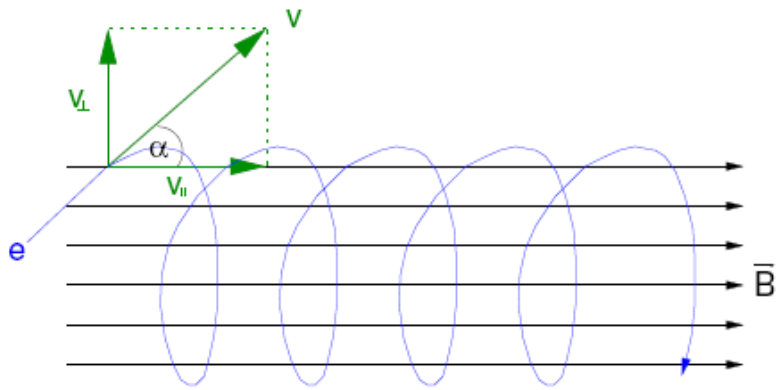
Pionen-Zerfall \rightarrow Hadronen

Inverse Compton-Streuung \rightarrow Elektronen

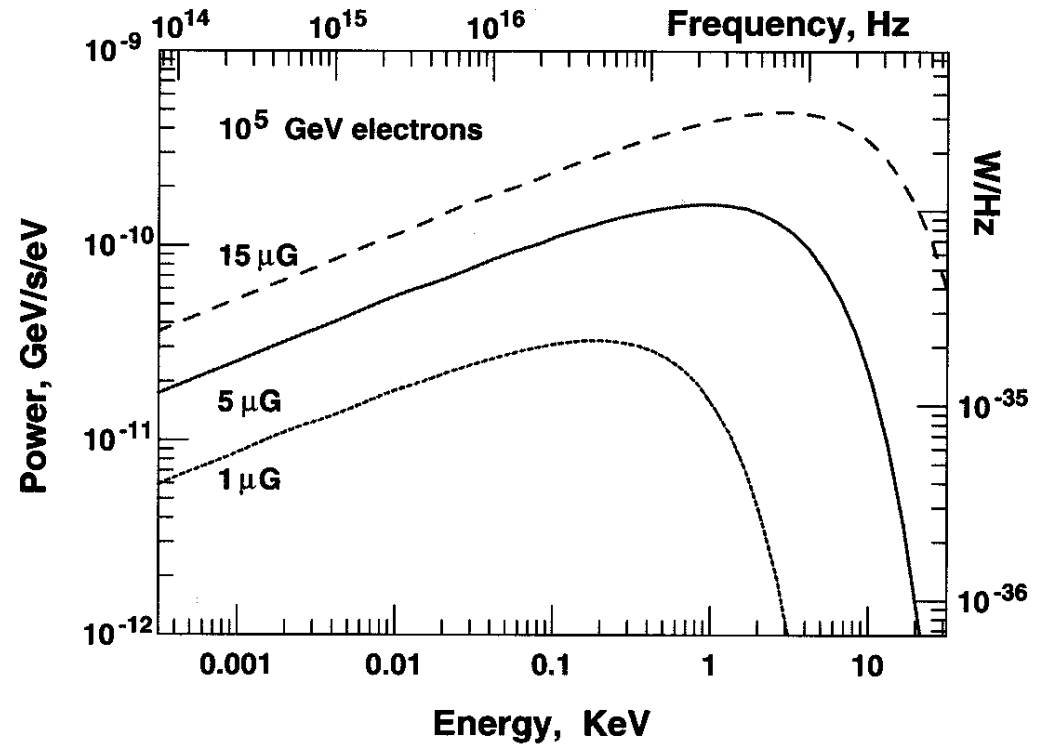
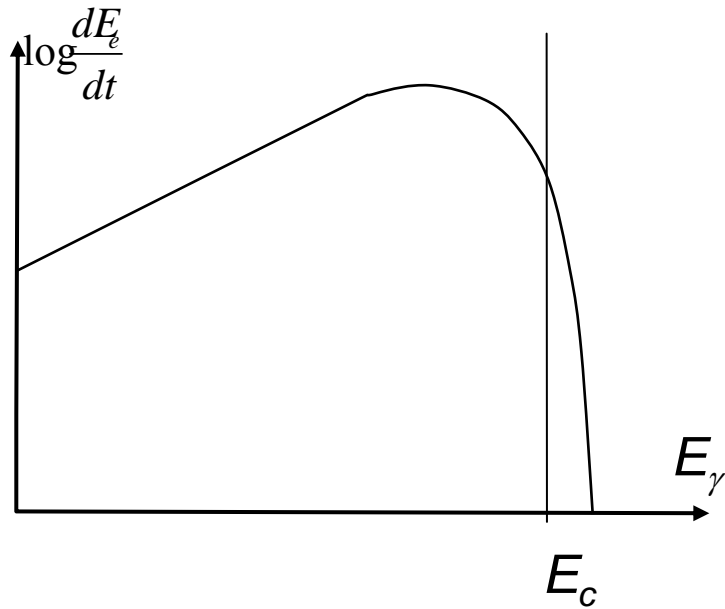
Gamma-Erzeugung



Synchrotronstrahlung

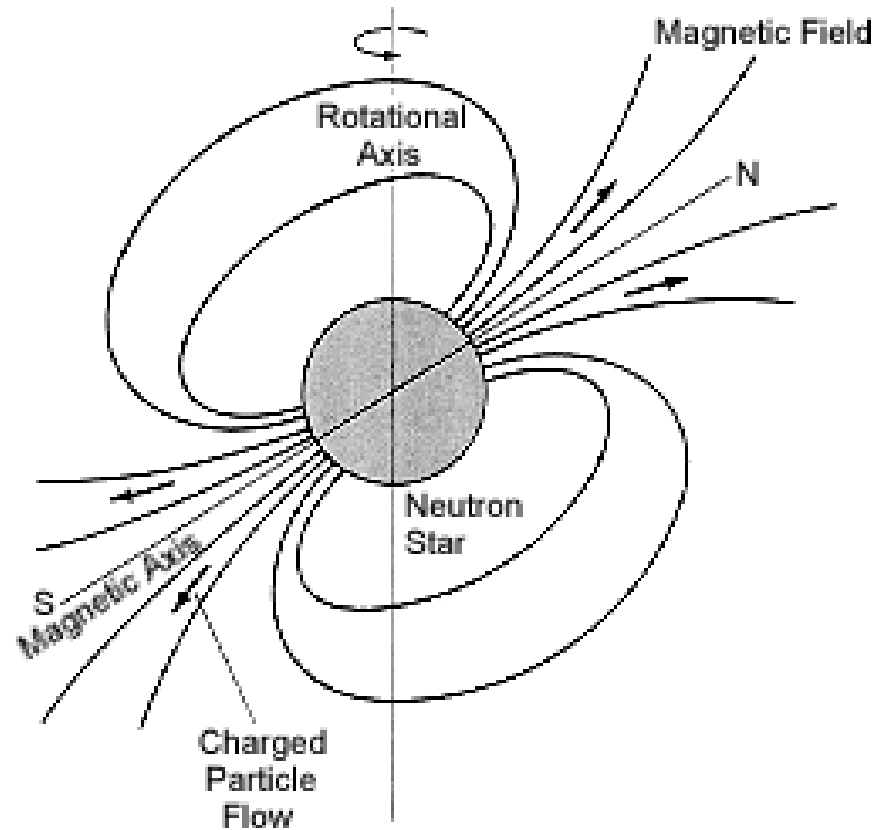
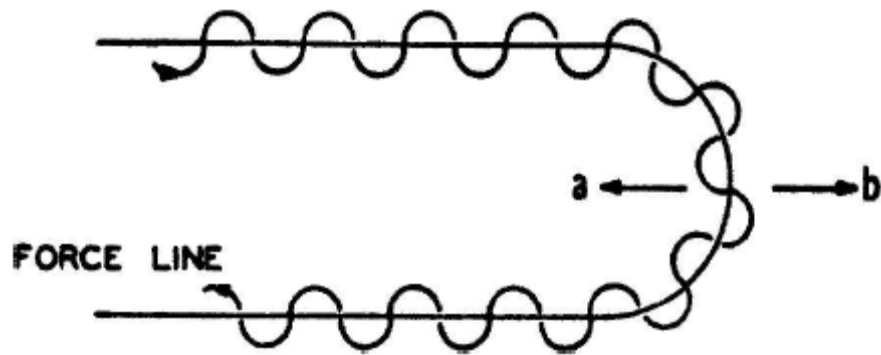


Synchrotronstrahlung

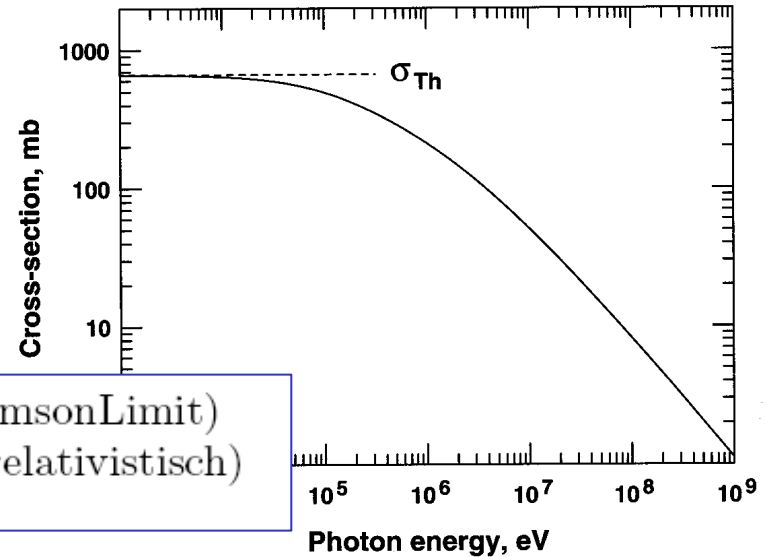
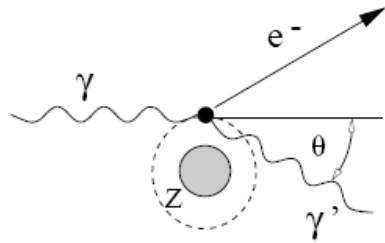


Krümmungsstrahlung

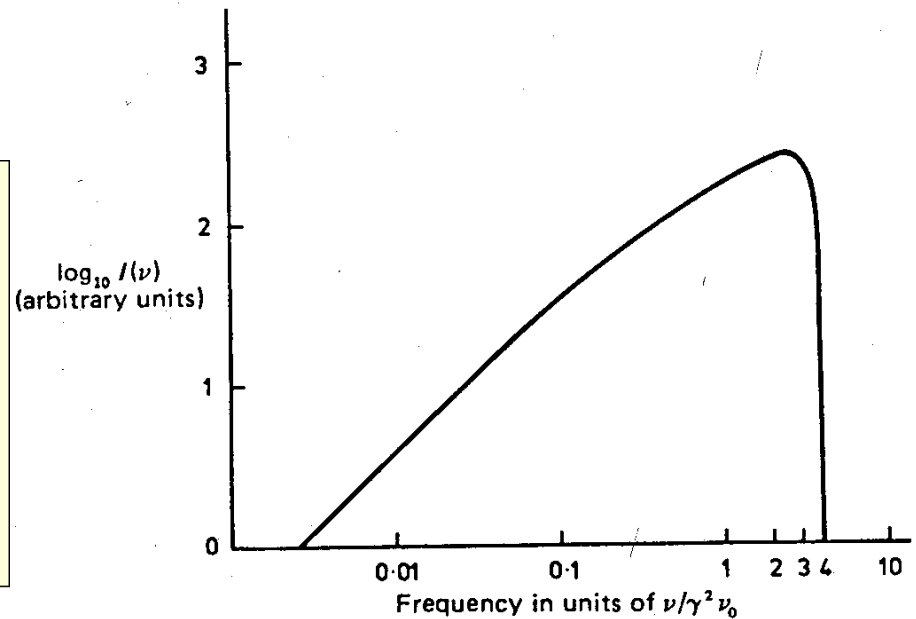
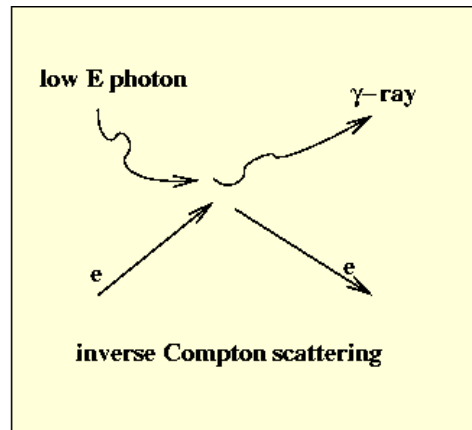
„Magnetische Flasche“



Compton- und inverser Compton-Effekt



$$\sigma_C \approx \begin{cases} \sigma_T(1 - 2\epsilon) \approx \sigma_T & \text{für } \epsilon \ll 1 \quad (\text{Thomson Limit}) \\ \frac{3}{8}\sigma_T \frac{1}{\epsilon} (\ln(2\epsilon) + \frac{1}{2}) & \epsilon \gg 1 \quad (\text{hochrelativistisch}) \end{cases}$$



Energieverlust von Elektronen (Sternenlicht)

- Sternenlicht (im Optischen) hat in Galaxien eine Energiedichte von $u_{rad} \approx 0.6 \text{ MeV/m}^3$ und typische Magnetfelder sind $B \approx 3 \cdot 10^{-10} \text{ T}$. Damit ergibt sich:

$$\left\langle -\frac{dE}{dt} \right\rangle_{IC} = 1.6 \cdot 10^{-14} (\beta\gamma)^2 \text{ eV/s} \quad (5.43)$$

$$\left\langle -\frac{dE}{dt} \right\rangle_{syn} = 0.6 \cdot 10^{-14} (\beta\gamma)^2 \text{ eV/s} \quad (5.44)$$

Für die ‘Kühlungszeit’

$$\tau = \frac{E}{\left\langle -\frac{dE}{dt} \right\rangle} \quad (5.45)$$

ergibt sich bei einer Elektronenergie von $E_e = 100 \text{ GeV}$:

$$\tau_{IC} \approx 0.5 \cdot 10^7 \text{ a}, \quad \lambda_{IC} \approx 1.5 \text{ Mpc} \quad (5.46)$$

$$\tau_{syn} \approx 1.5 \cdot 10^7 \text{ a}, \quad \lambda_{syn} \approx 4 \text{ Mpc} \quad (5.47)$$

Die Größen λ sind die Wege, die in der Kühlungszeit zurückgelegt werden können ($1 \text{ pc} = 3.26 \text{ Lj}$).

Energieverlust von Elektronen (CMB)

- Im intergalaktischen Raum dominiert die Mikrowellenhintergrundstrahlung mit einer Dichte von $u_{rad} \approx 0.26 \text{ MeV/m}^3$. Damit ist:

$$\left\langle -\frac{dE}{dt} \right\rangle_{IC} = 0.7 \cdot 10^{-14} (\beta\gamma)^2 \text{ eV/s} \quad (5.48)$$

Mit einem typischen intergalaktischen Magnetfeld von $B \approx 3 \cdot 10^{-12} \text{ T}$ ist der Synchrotronstrahlungsverlust vernachlässigbar. Für die inverse Compton-Streuung an den CMB-Photonen ergibt sich für $E_e = 100 \text{ GeV}$:

$$\tau_{IC} \approx 1.2 \cdot 10^7 \text{ a}, \quad \lambda_{IC} \approx 3.7 \text{ Mpc} \quad (5.49)$$

Absorption von γ 's durch $\gamma \gamma \rightarrow e^+ e^-$

