

Astroteilchenphysik II: Gammastrahlung

Vorlesung 6

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Messmethoden für den Nachweis von Gamma-Strahlung

- ...
- indirekte Messung mit Cherenkov-Teleskopen
- indirekte Messung mit Luftschauerdetektoren

Übersicht zur Sternentwicklung und möglichen Endstadien

- typische massenabhängige Verläufe der Sternentwicklung
- Weiße Zwerge, Neutronensterne und Schwarze Löcher
- Klassifikation von Supernova-Überresten

Supernova-Überreste

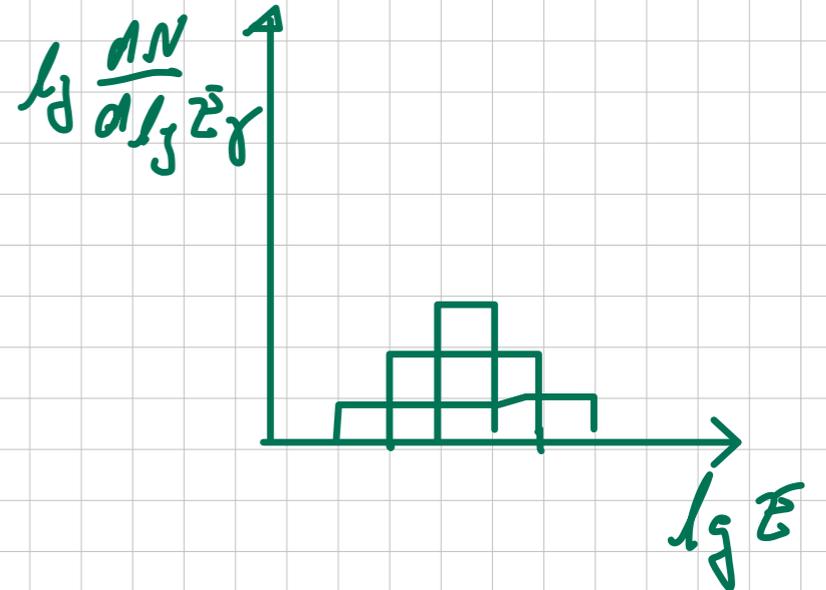
- Expansionsphasen, kinematische Betrachtungen
- Beobachtungsergebnisse von Supernova-Überresten
- Interpretation der Ergebnisse
- Vergleich der Vorhersagen
leptonischer und hadronischer Modelle

Vorlesung: Termine

Dienstag		Donnerstag	
		23.04.2020	Vorlesung
		30.04.2020	Vorlesung
		07.05.2020	Vorlesung
12.05.2020	Übung	14.05.2020	Vorlesung
		-	Feiertag
		28.05.2020	Vorlesung
		04.06.2020	Vorlesung
09.06.2020	Übung	-	Feiertag
		18.06.2020	Vorlesung
23.06.2020	Übung	25.06.2020	Vorlesung
		02.07.2020	Vorlesung
07.07.2020	Übung	09.07.2020	Vorlesung
		16.07.2020	Vorlesung
21.07.2020	Übung	23.07.2020	Vorlesung

Photonspektrum

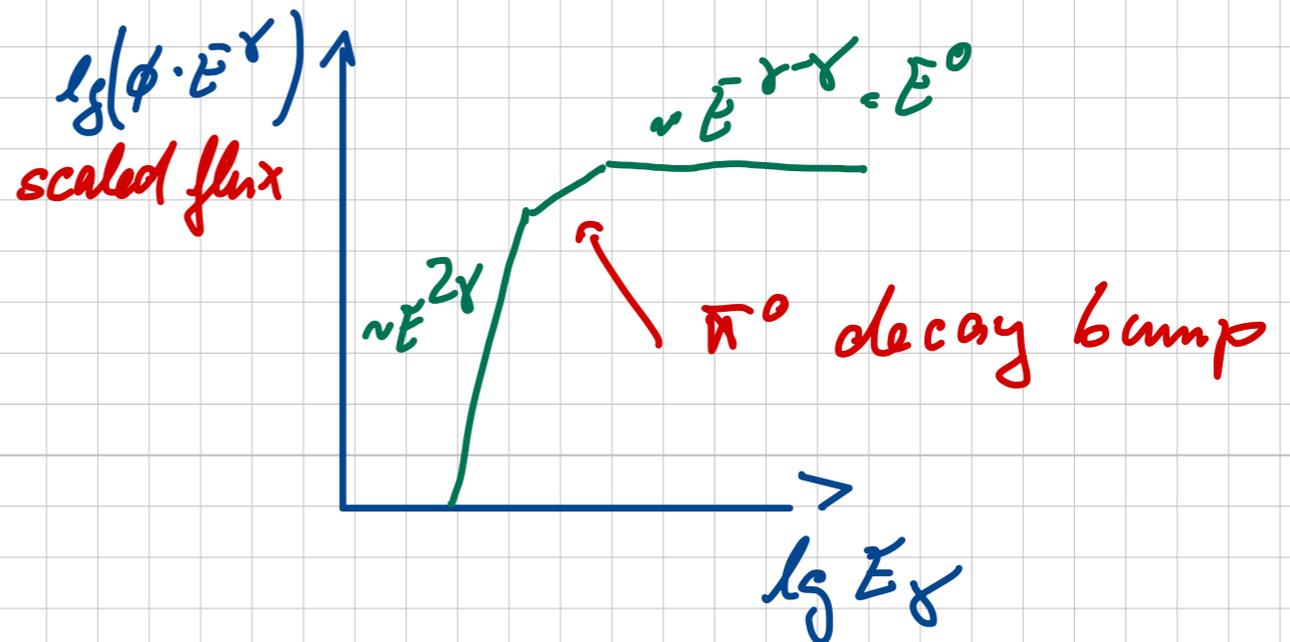
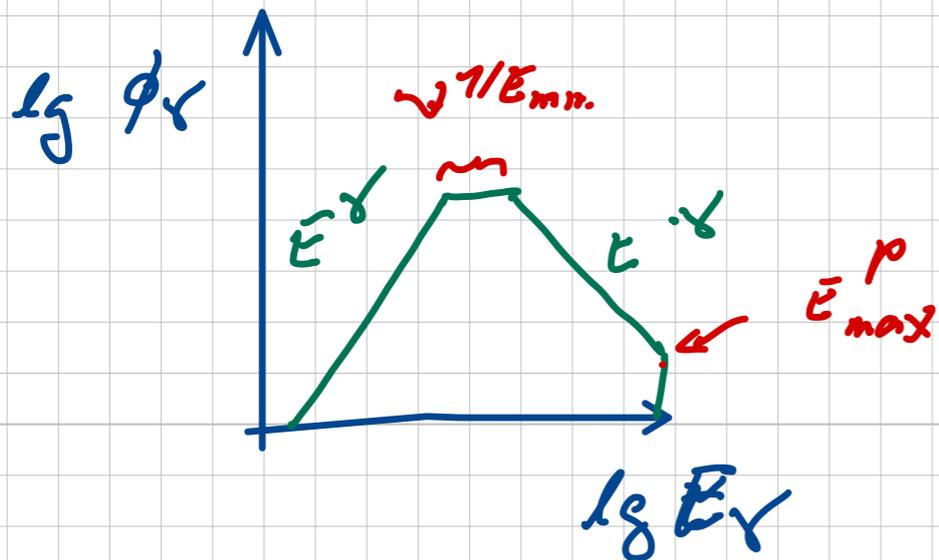
- $\frac{dn}{d\bar{E}_\gamma} = \frac{Z}{\gamma \beta m_\pi} \quad (\bar{E}_\gamma^{\min} < \bar{E}_\gamma < \bar{E}_\gamma^{\max})$

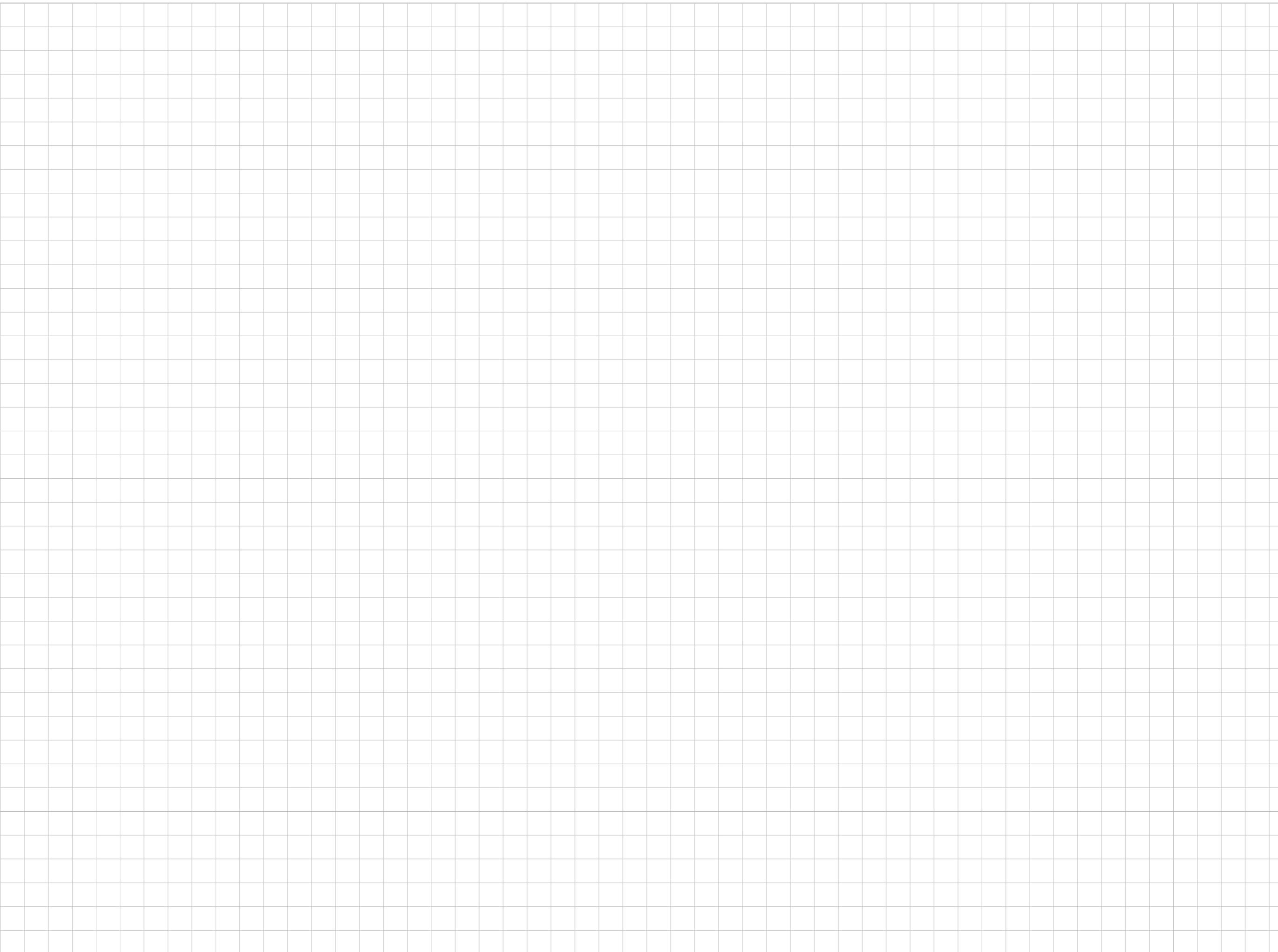


- $\phi_\gamma = \int \frac{dn}{d\bar{E}_\gamma} \phi_{\pi^0} d\bar{E}_\gamma$

⇒ γ -Spektrum sym. in \lg - \lg -Darstellung

- Potenzgesetz: $\phi_p \sim \bar{E}^{-\gamma} \rightarrow \phi_{\pi^0} \sim \bar{E}^{-\gamma}$





Das elektromagnetische Spektrum

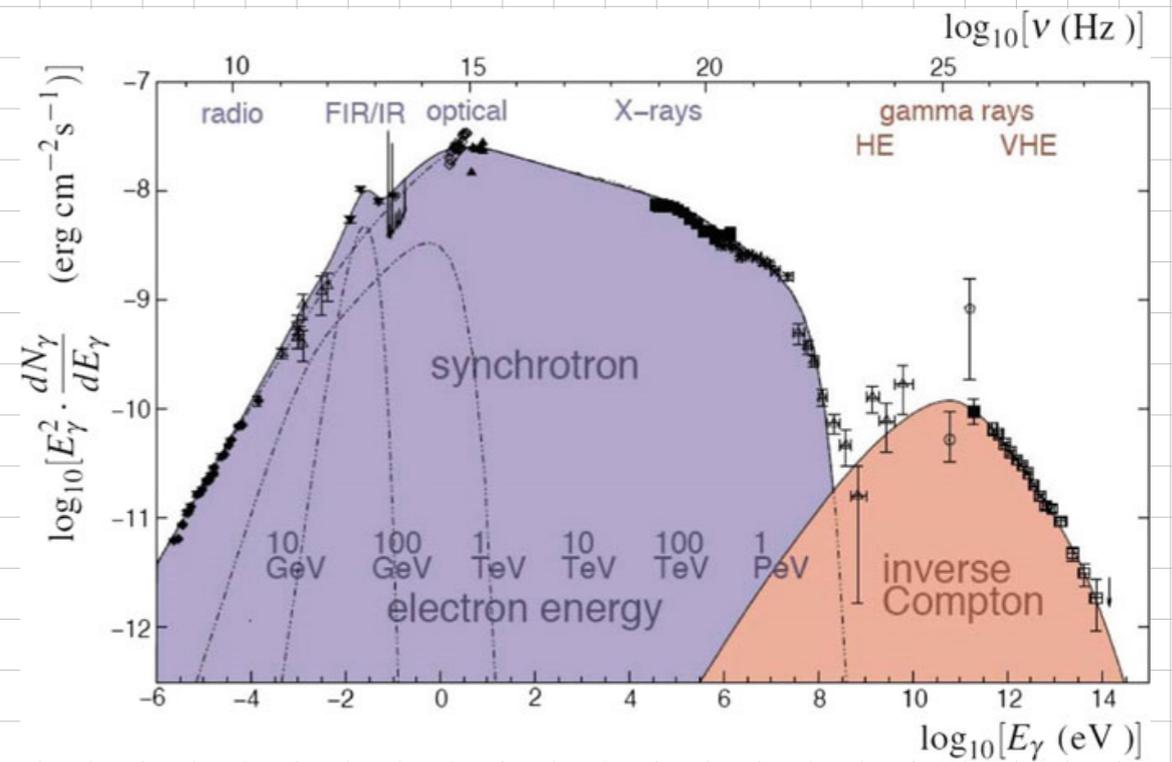
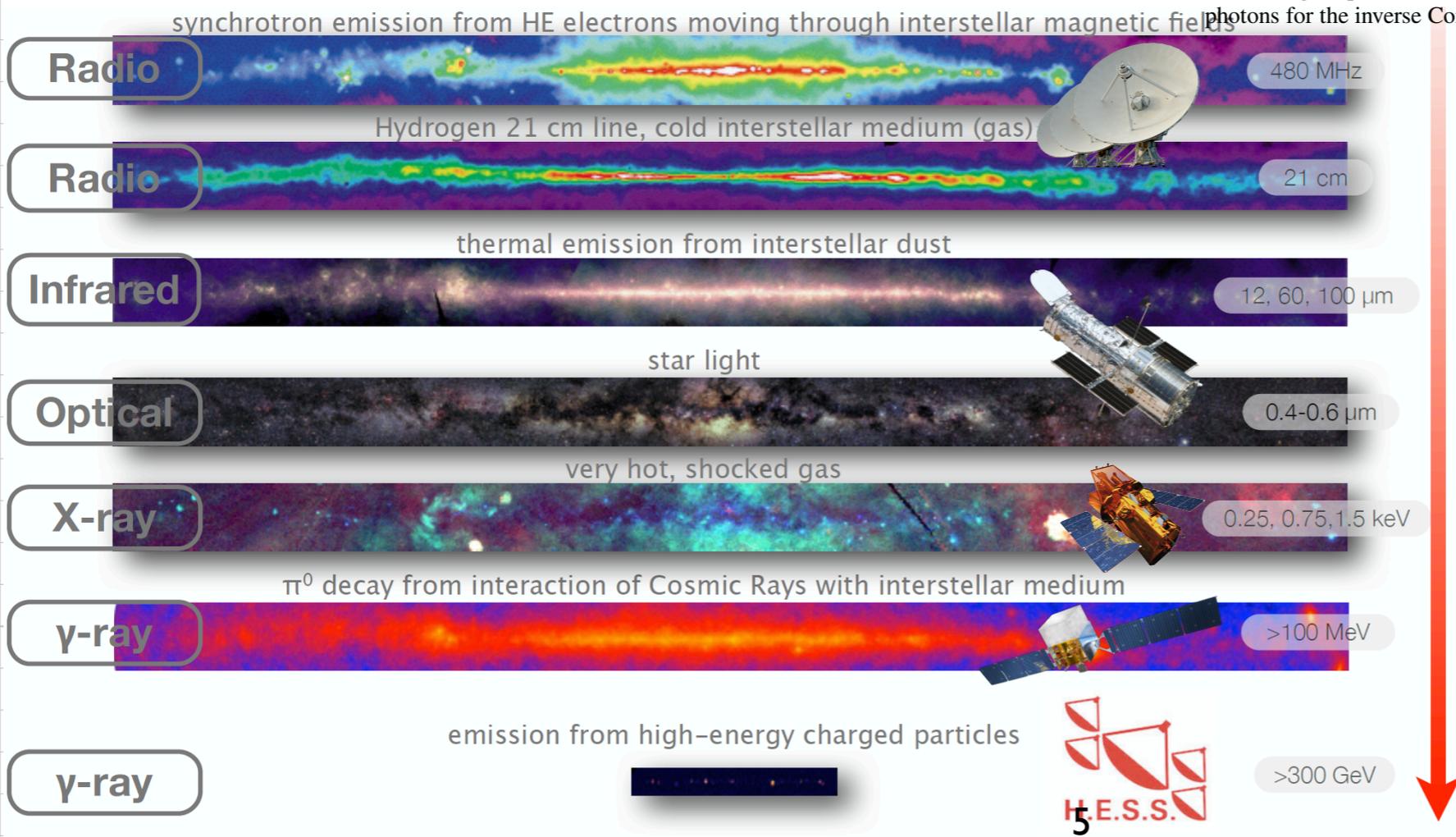
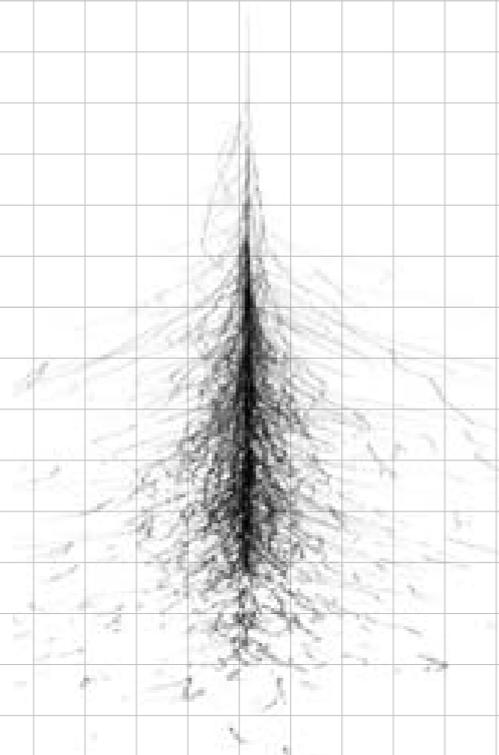


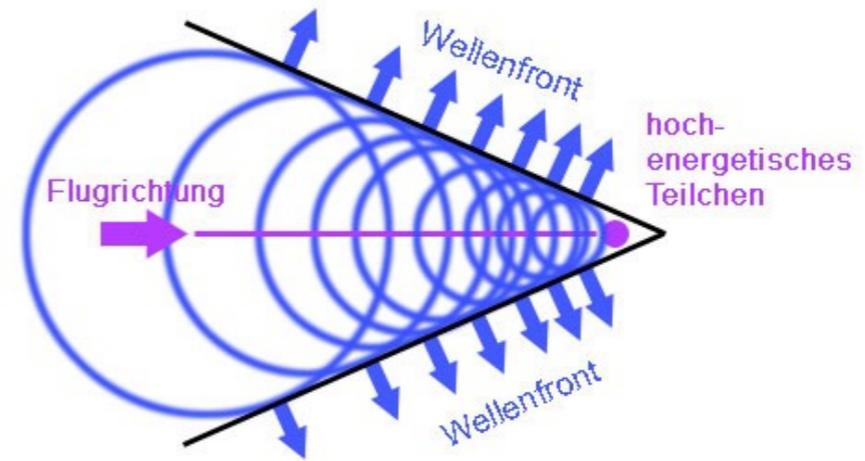
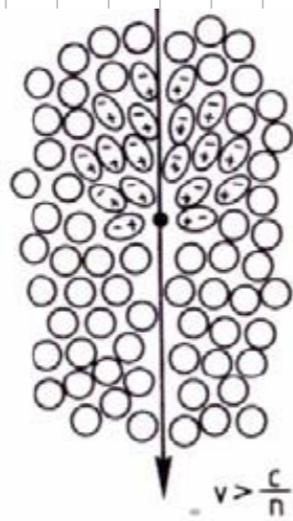
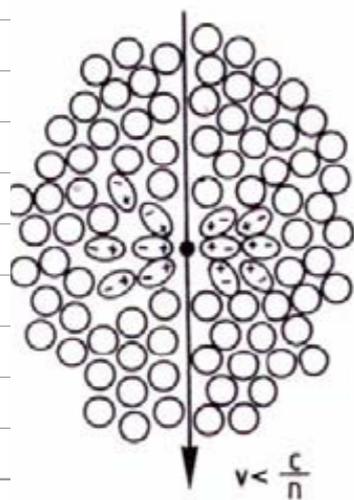
Fig. 9.10 Multiwavelength observations of the Crab nebula. The synchrotron emission is given by the superposition of the contributions of electrons with different energies. Mono-energetic electrons contribute with photons with peaked spectra, according to Eq. (8.7). For instance, 1 TeV electrons give photons in the visible wavelength. The synchrotron spectrum provides the target photons for the inverse Compton (IC) process (Funk 2011)



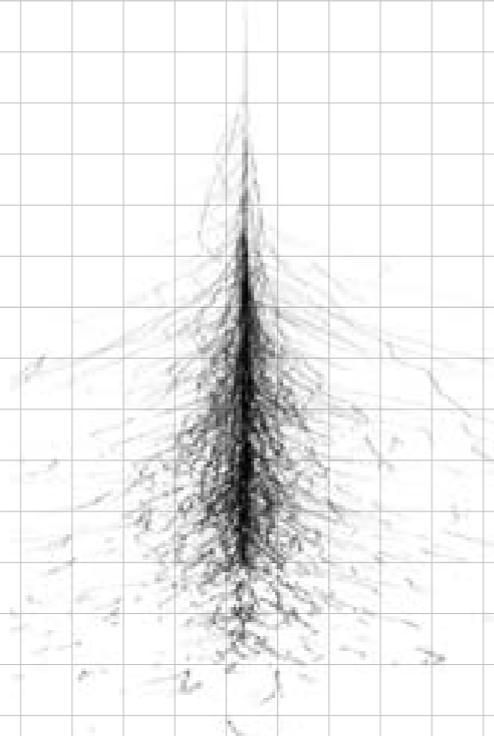
Indirekte Messung: Cherenkov-Teleskope



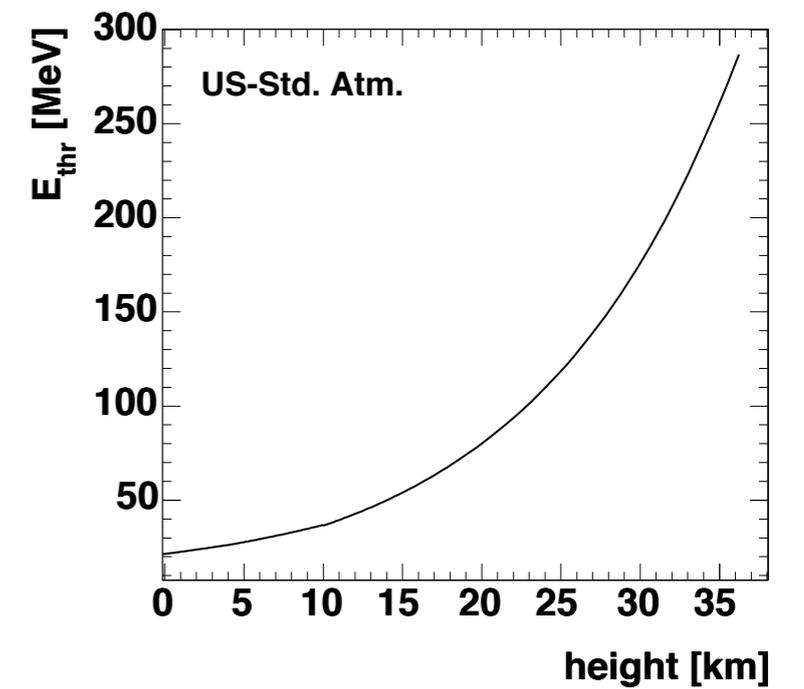
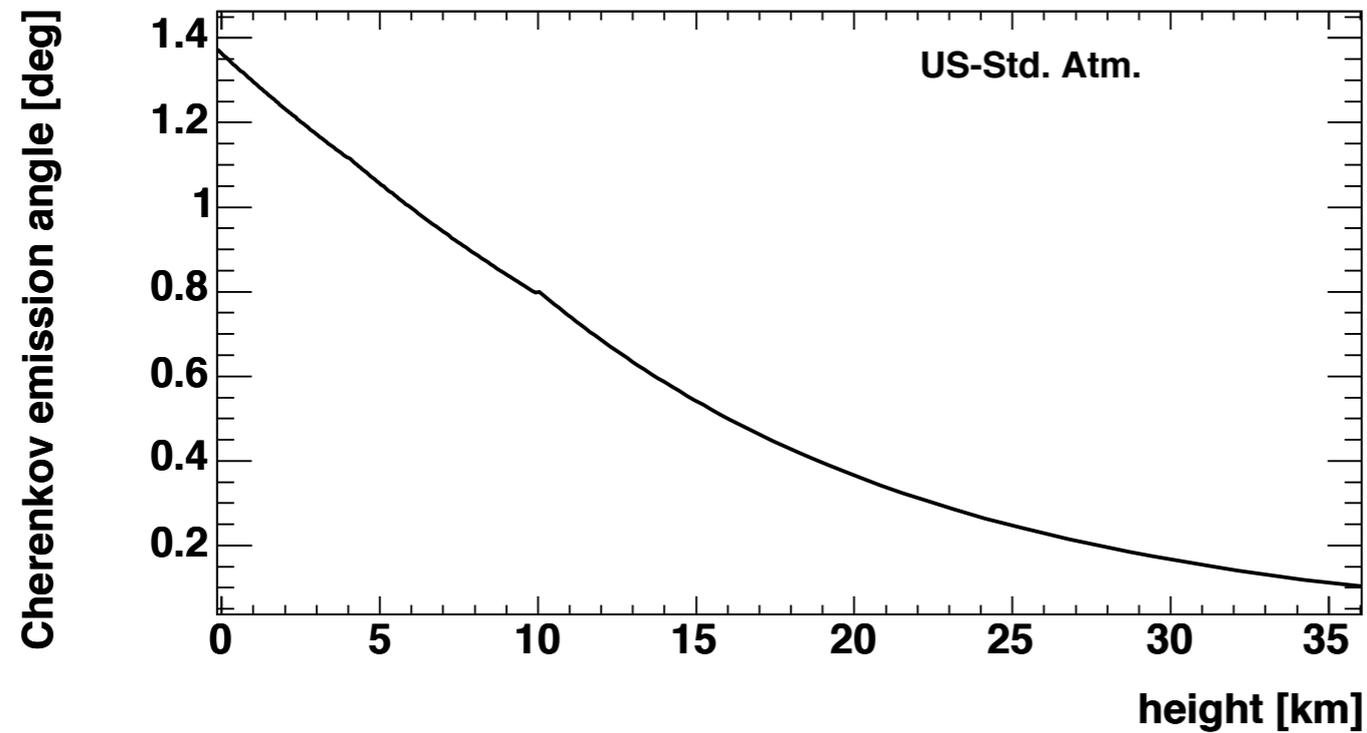
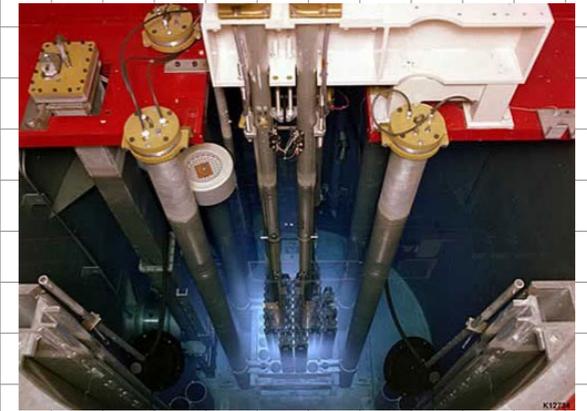
Gamma shower

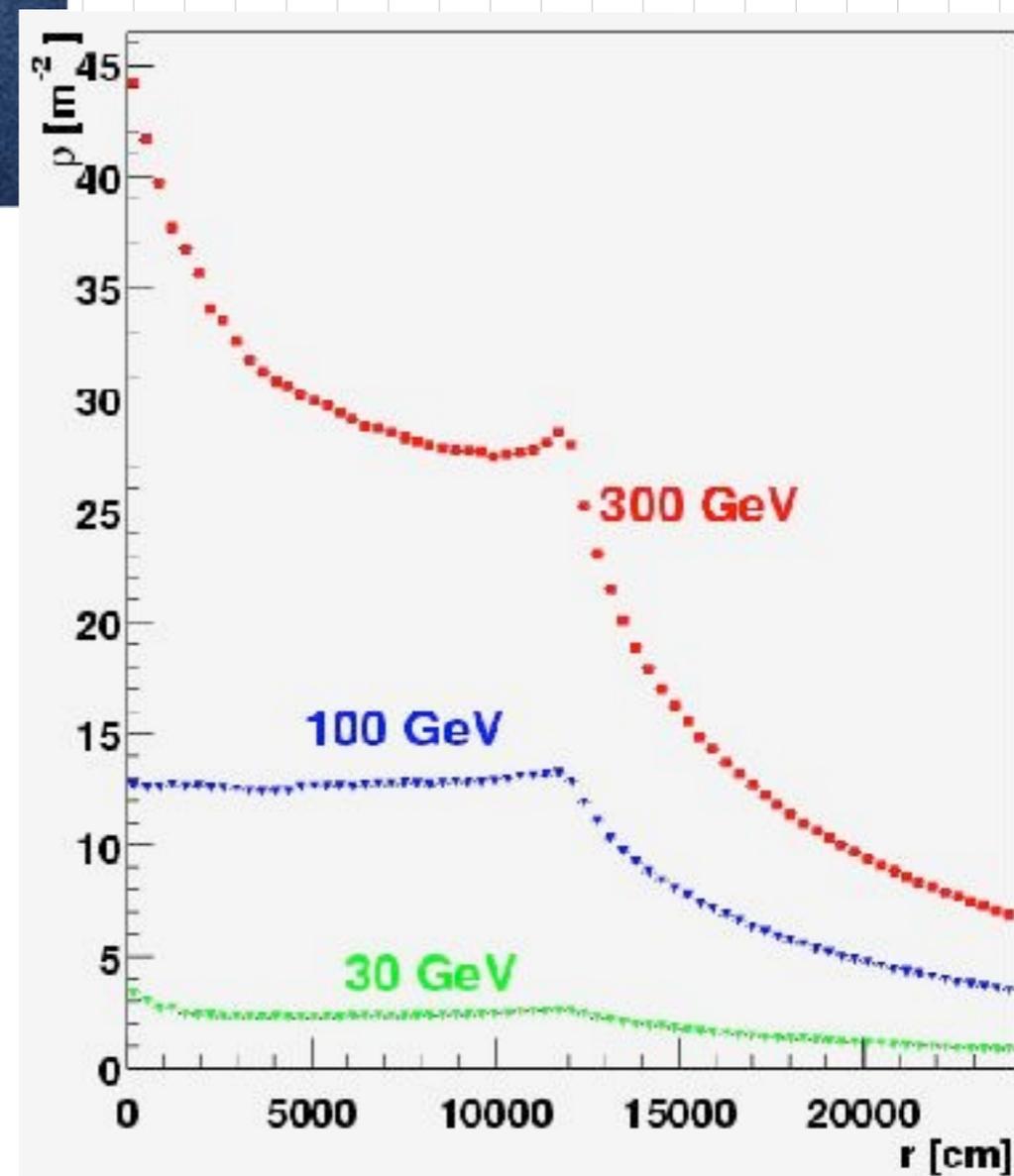
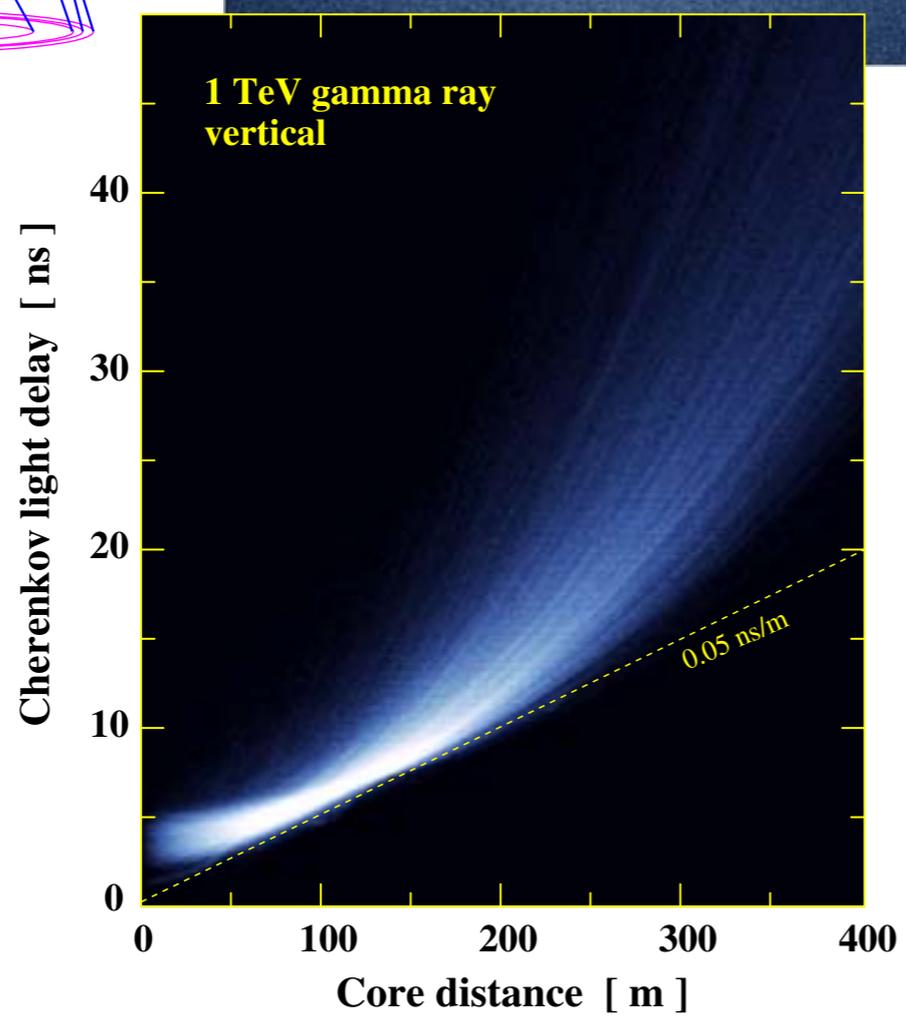
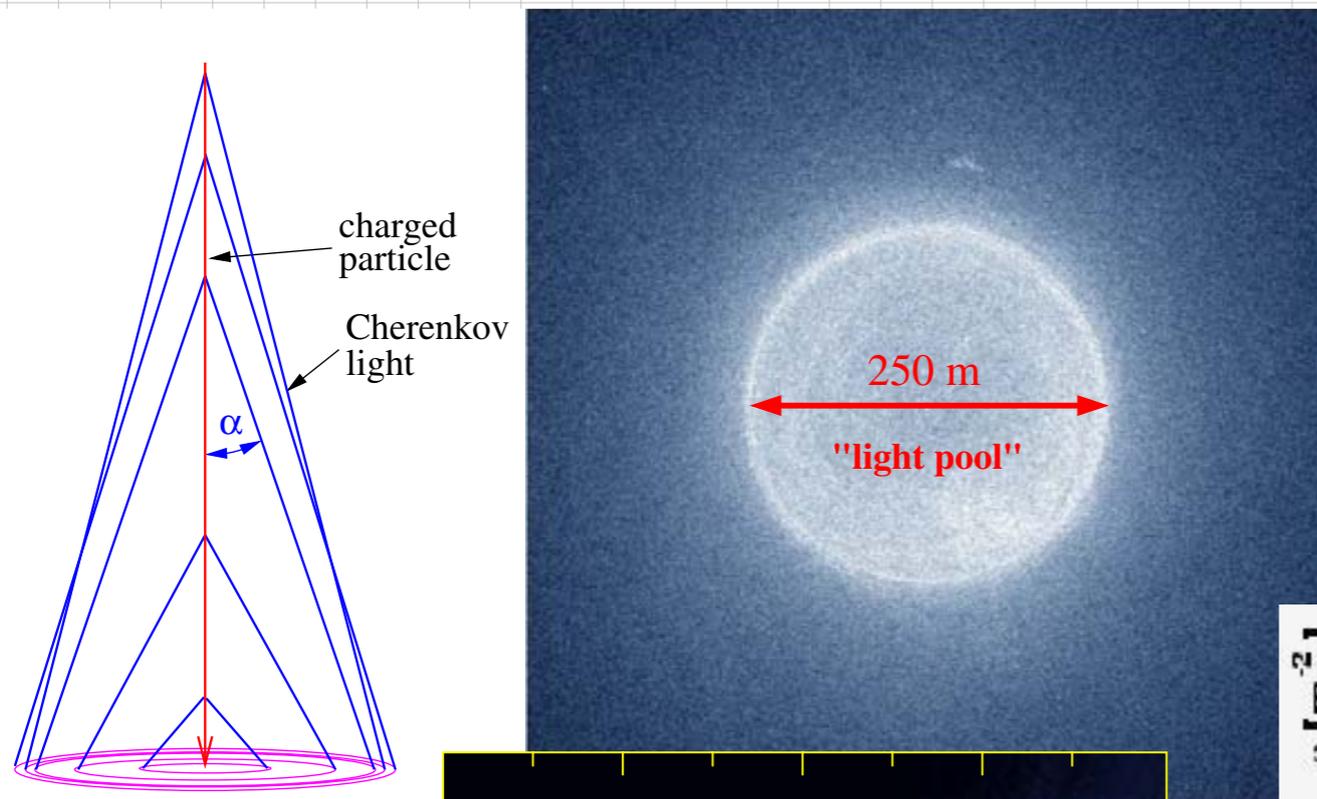


Indirekte Messung: Cherenkov-Teleskope

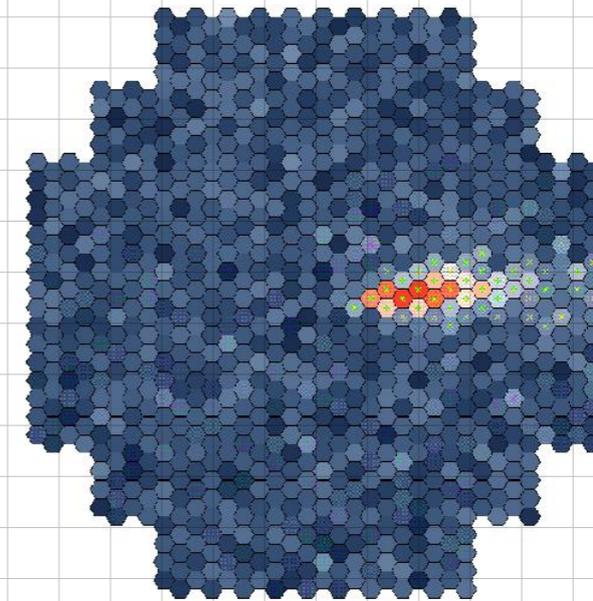
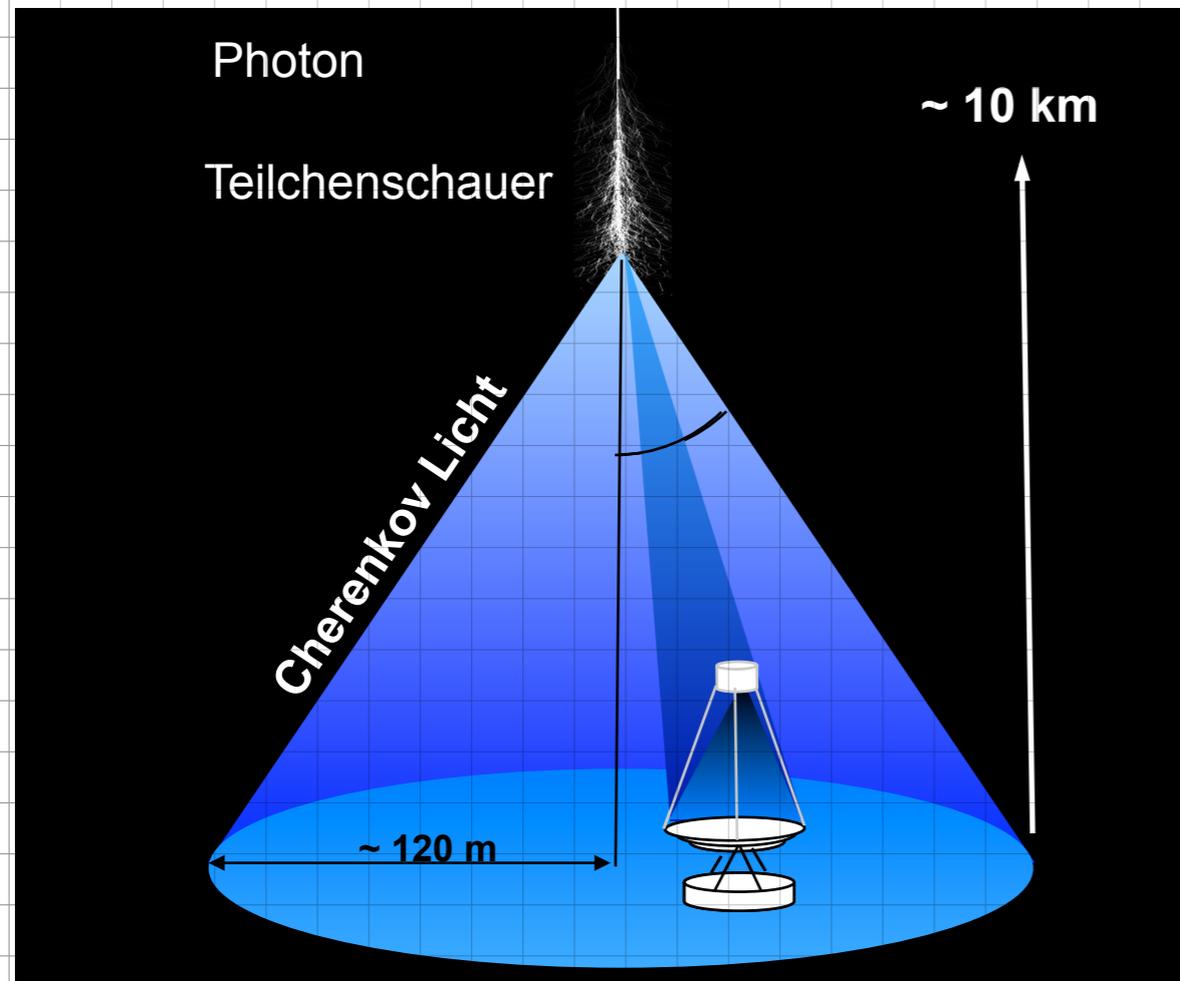


Gamma shower





Primärteilchenrekonstruktion

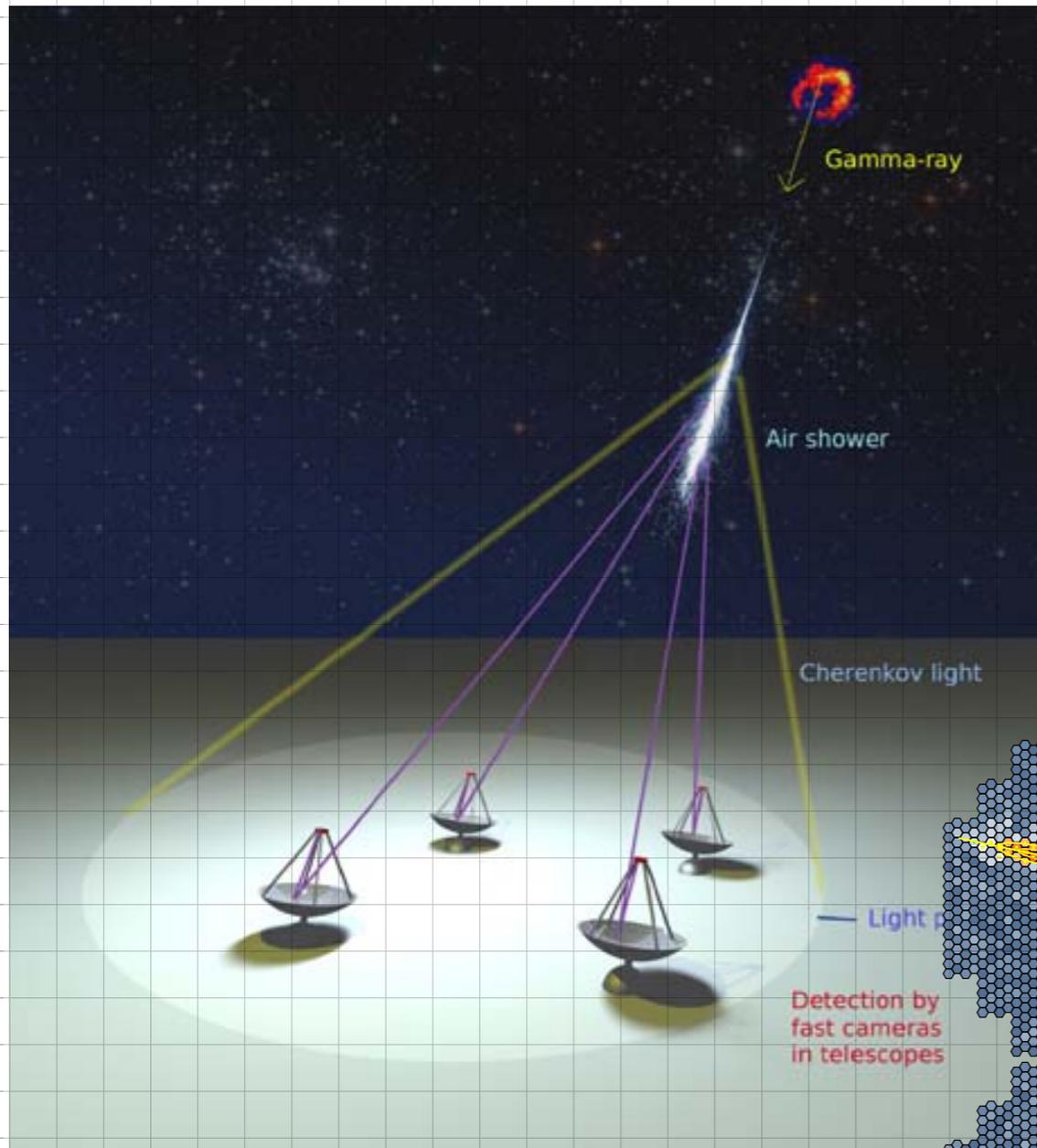


Bildintensität: Energie

Schnittpunkt: Richtung

Bildform: Primärteilchen

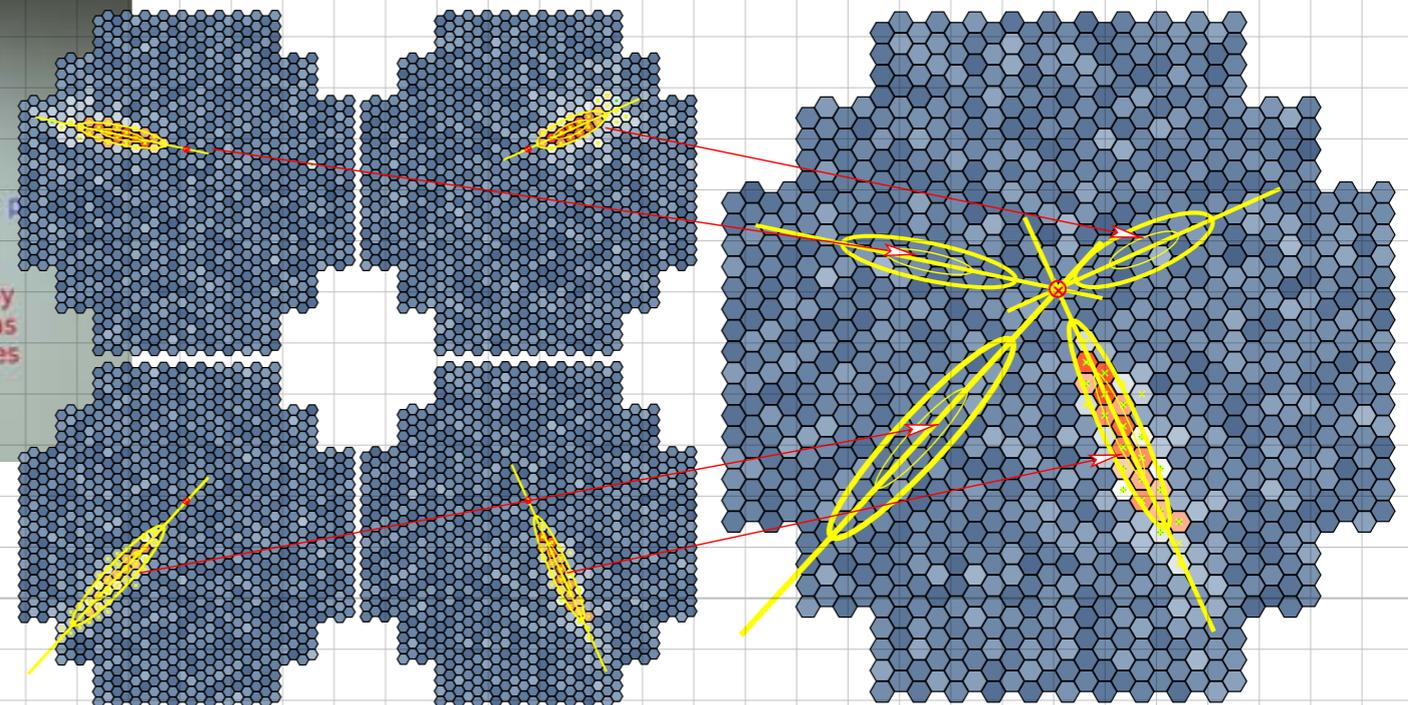
Cherenkov-Teleskope: Ankunftsrichtung



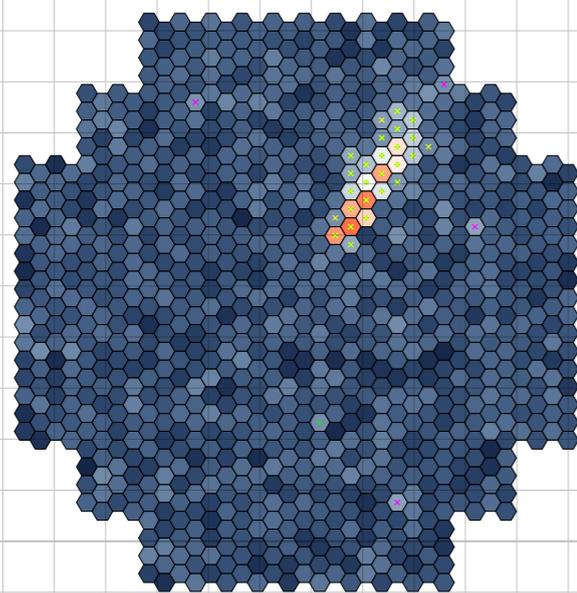
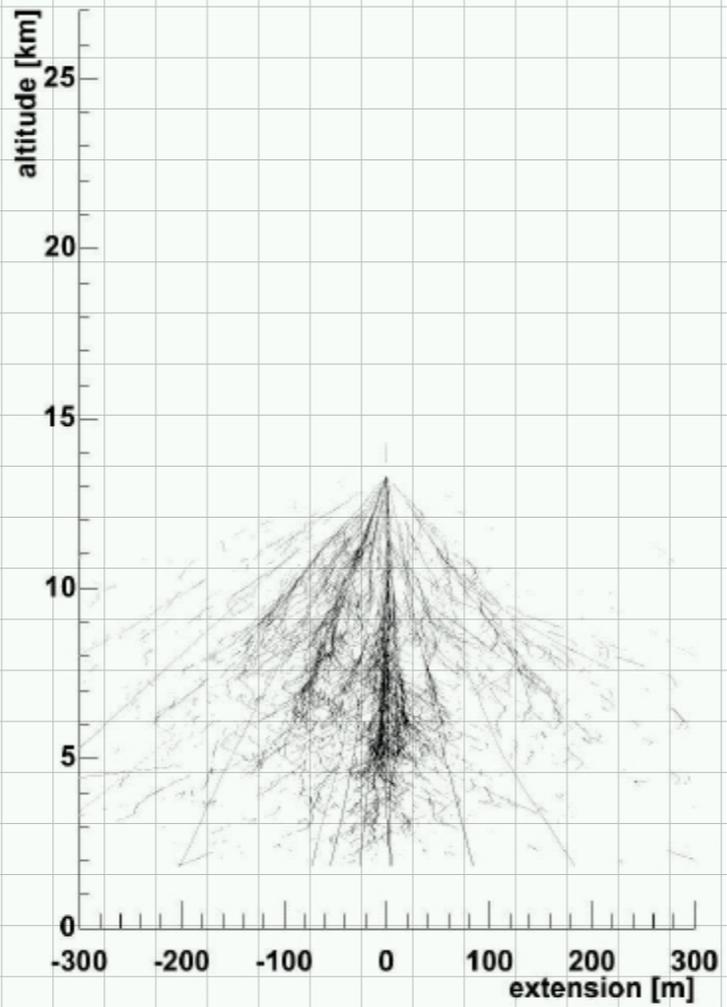
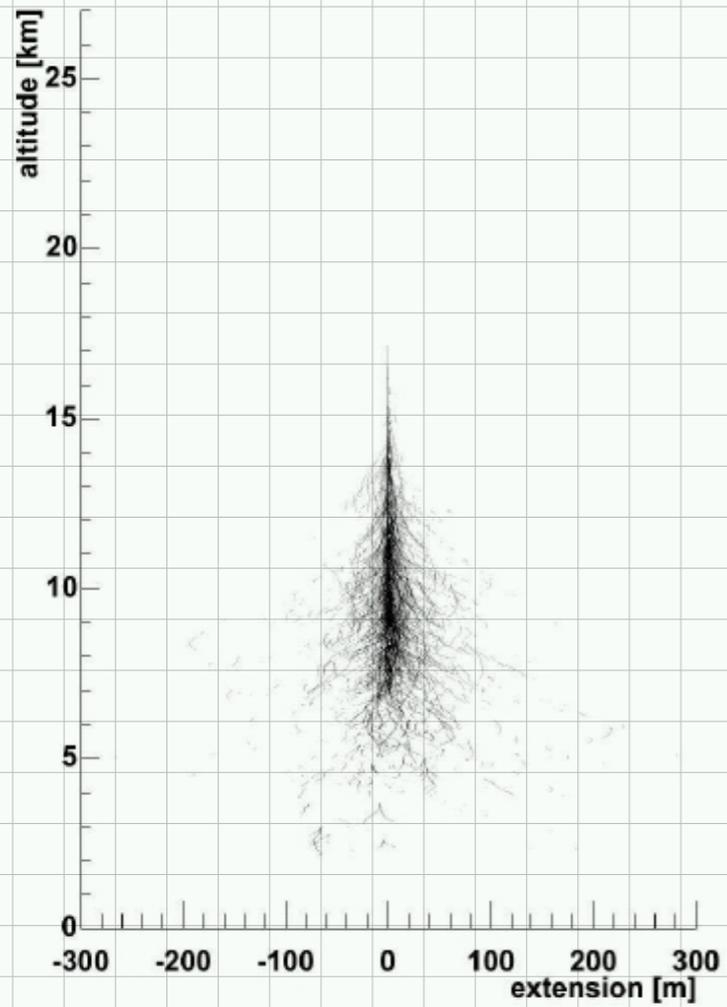
Bildintensität: Energie

Schnittpunkt: Richtung

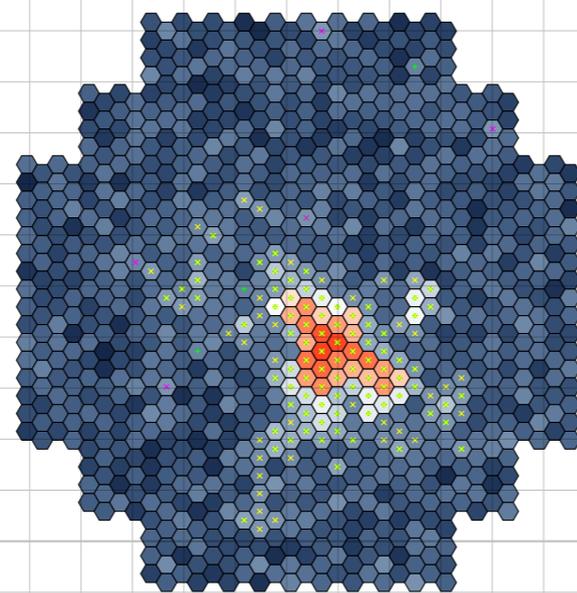
Bildform: Primärteilchen



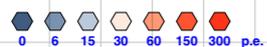
Photon-Hadron-Separation



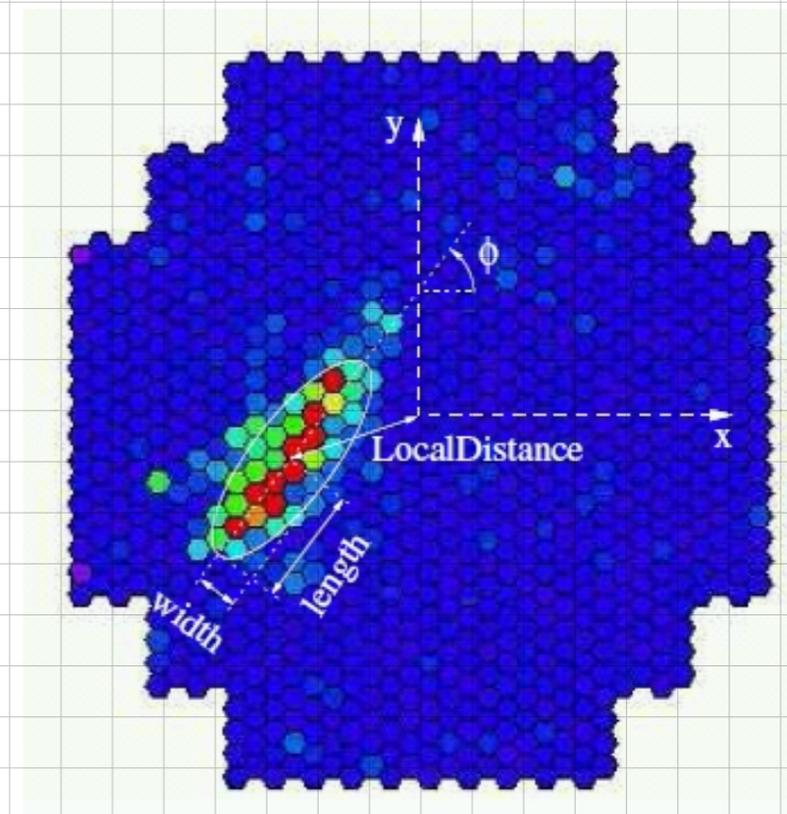
1.0 TeV gamma shower



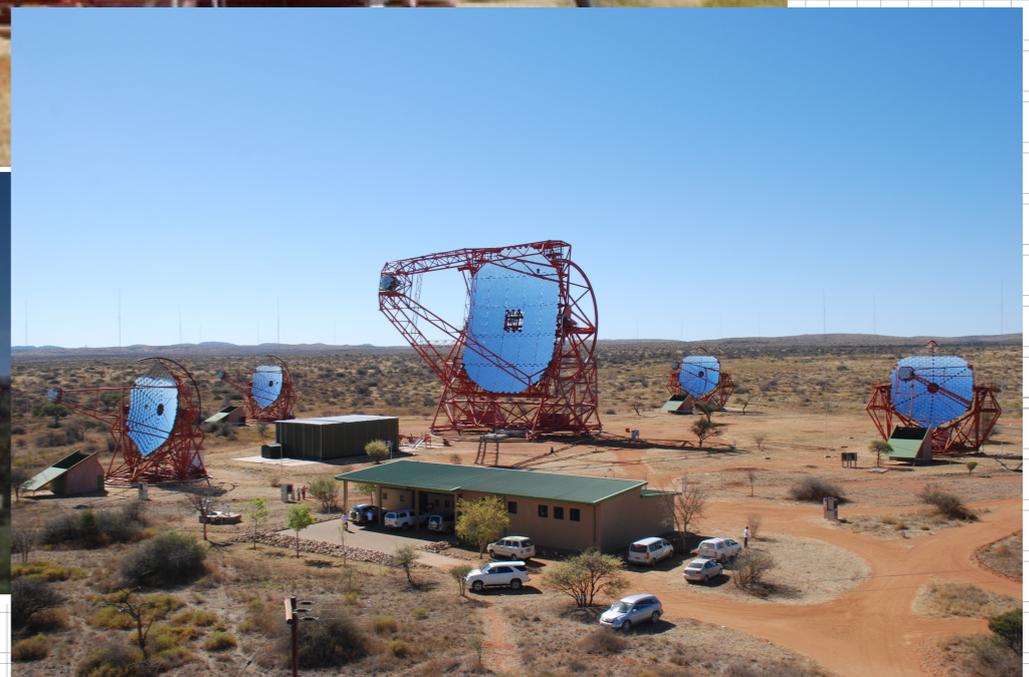
2.6 TeV proton shower



Hillas-Parameter

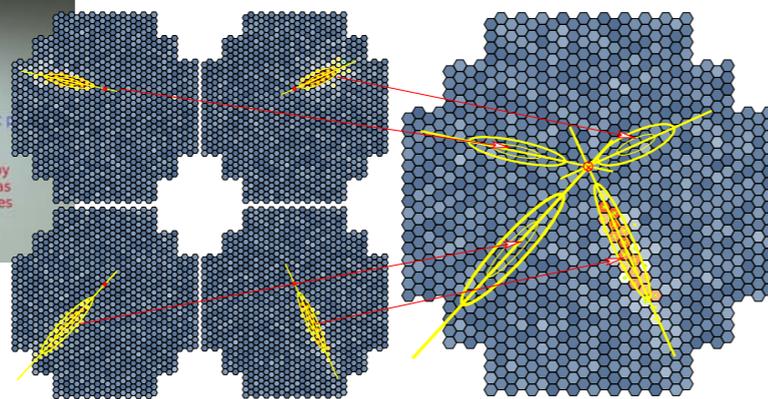
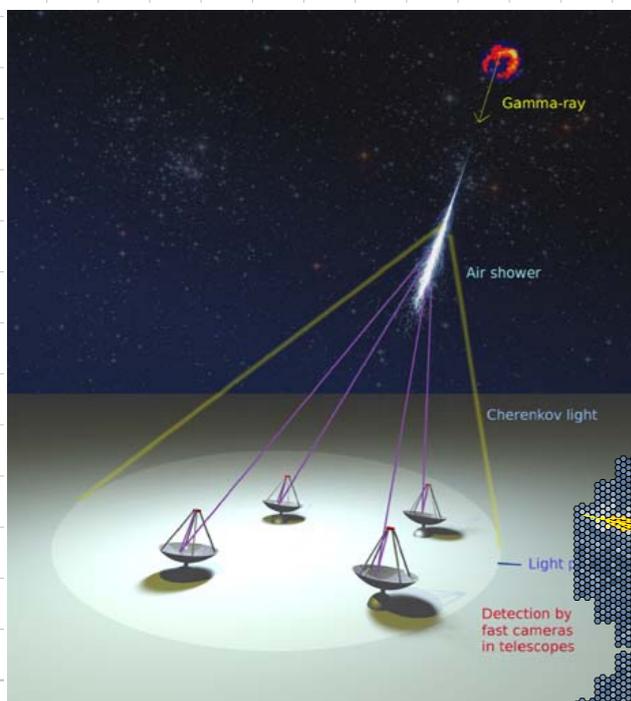


Indirekte Messung: Cherenkov-Teleskope (ii)





Wichtigste Cherenkov-Teleskope

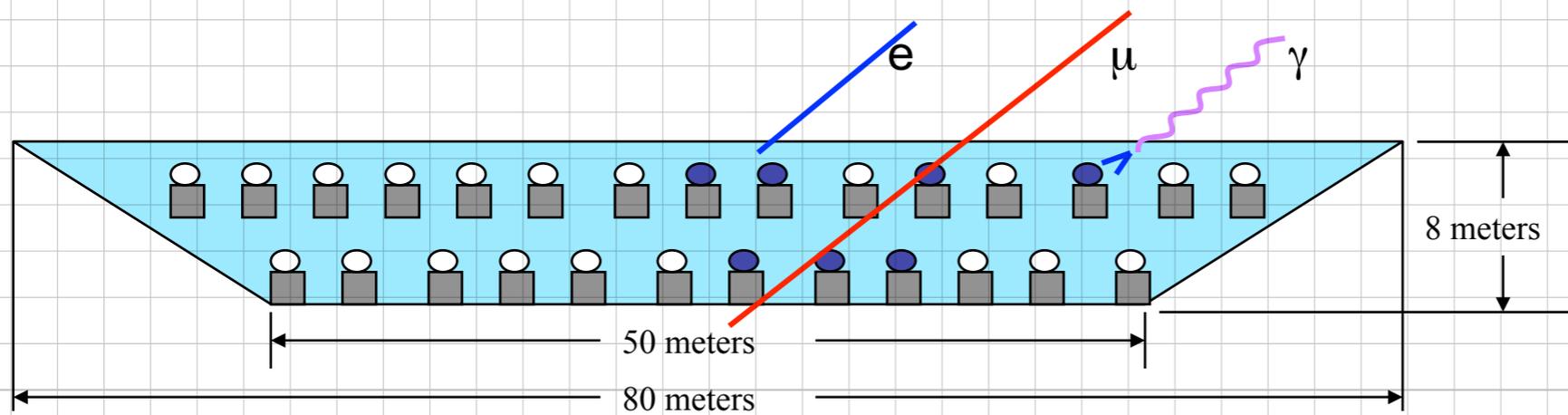
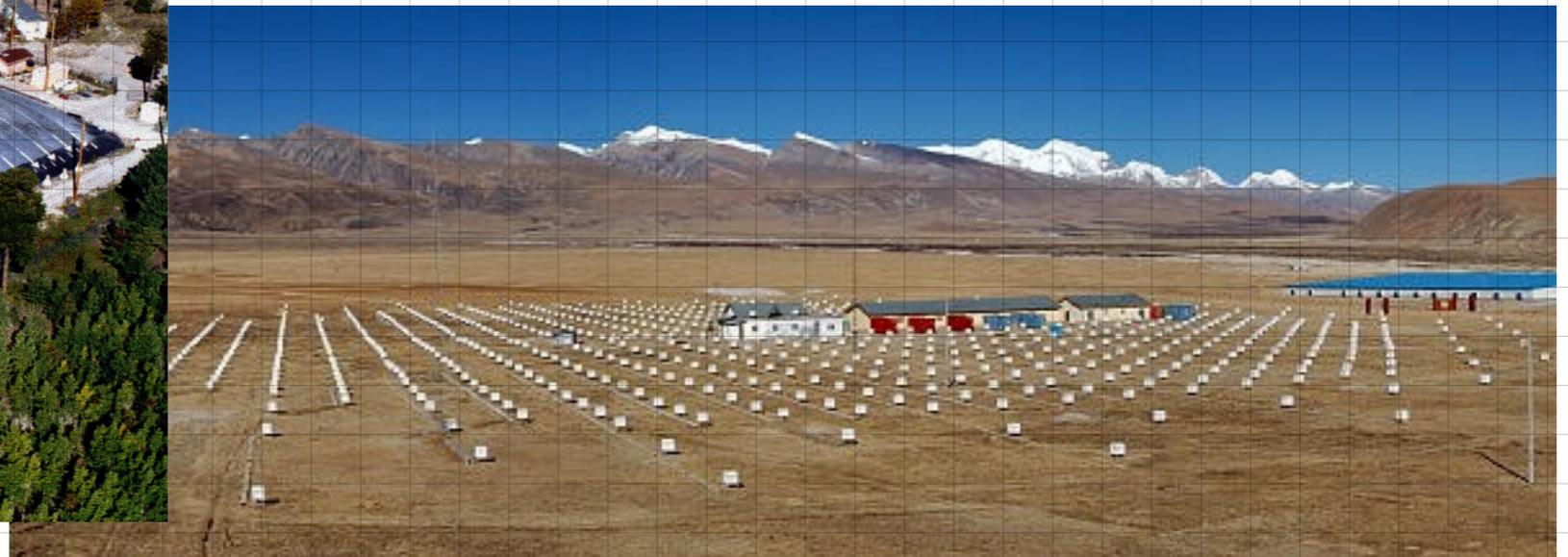


Indirekte Messung: Luftschauerfelder

Milagro, Los Alamos, 2350m



ARGO-YBJ, AS-gamma, Tibet, 4300m



High Altitude Water Cherenkov Experiment (HAWC)



Mapping the Northern Sky in High-Energy Gamma Rays

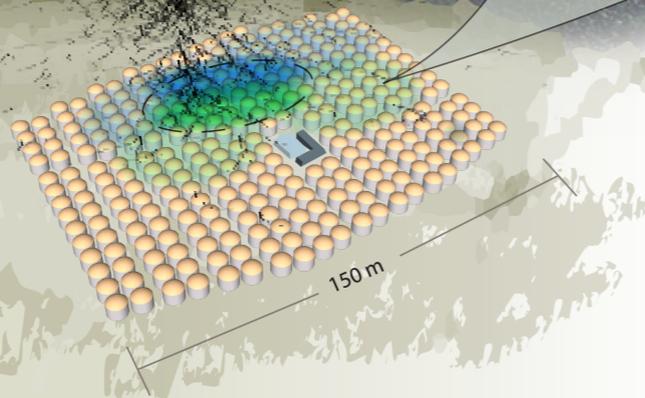
HAWC Observatory

HAWC operates day and night, providing a large field of view for the observation of the highest energy gamma rays.



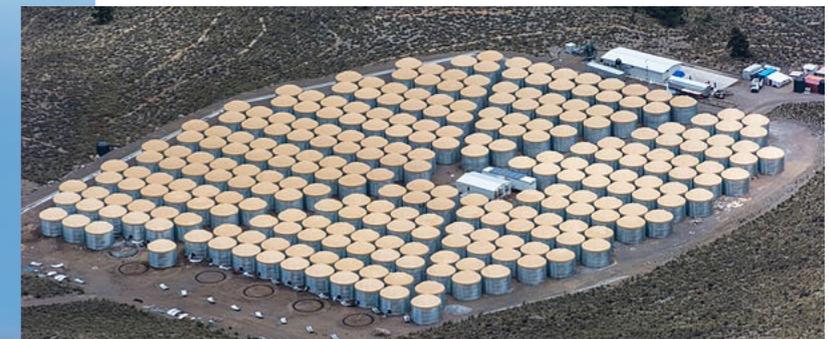
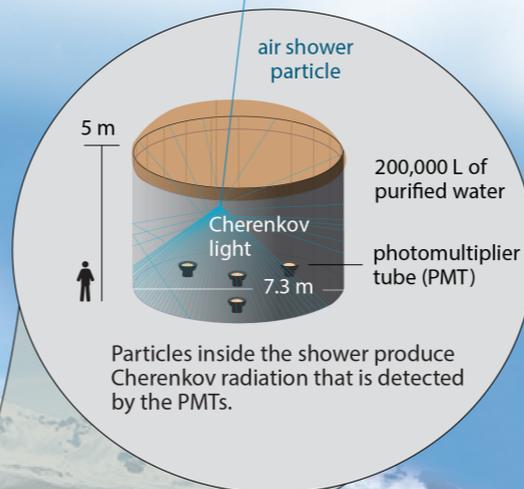
Pico de Orizaba (5,626 m)

HAWC is located at 4,100 m above sea level, covering an area of 20,000 m².



Water Cherenkov tank

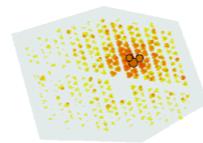
HAWC comprises an array of 300 tanks that record the particles created in gamma-ray and cosmic-ray showers.



Gamma rays vs cosmic rays

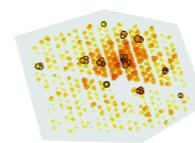
HAWC selects gamma rays from among a much more abundant background of cosmic rays.

gamma-ray shower



"hot" spots concentrate around the core

cosmic-ray shower



"hot" spots are more dispersed



CTA



Project Phases

Pre-Construction
Current Phase

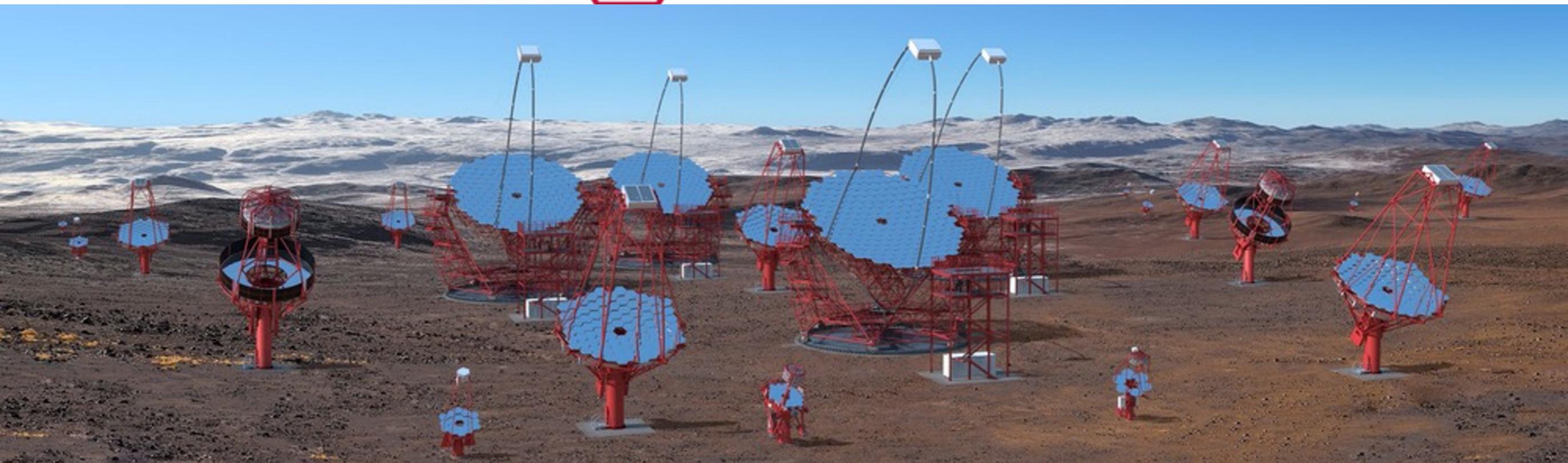
Pre-Production
2022-2023

Production
2023-2027

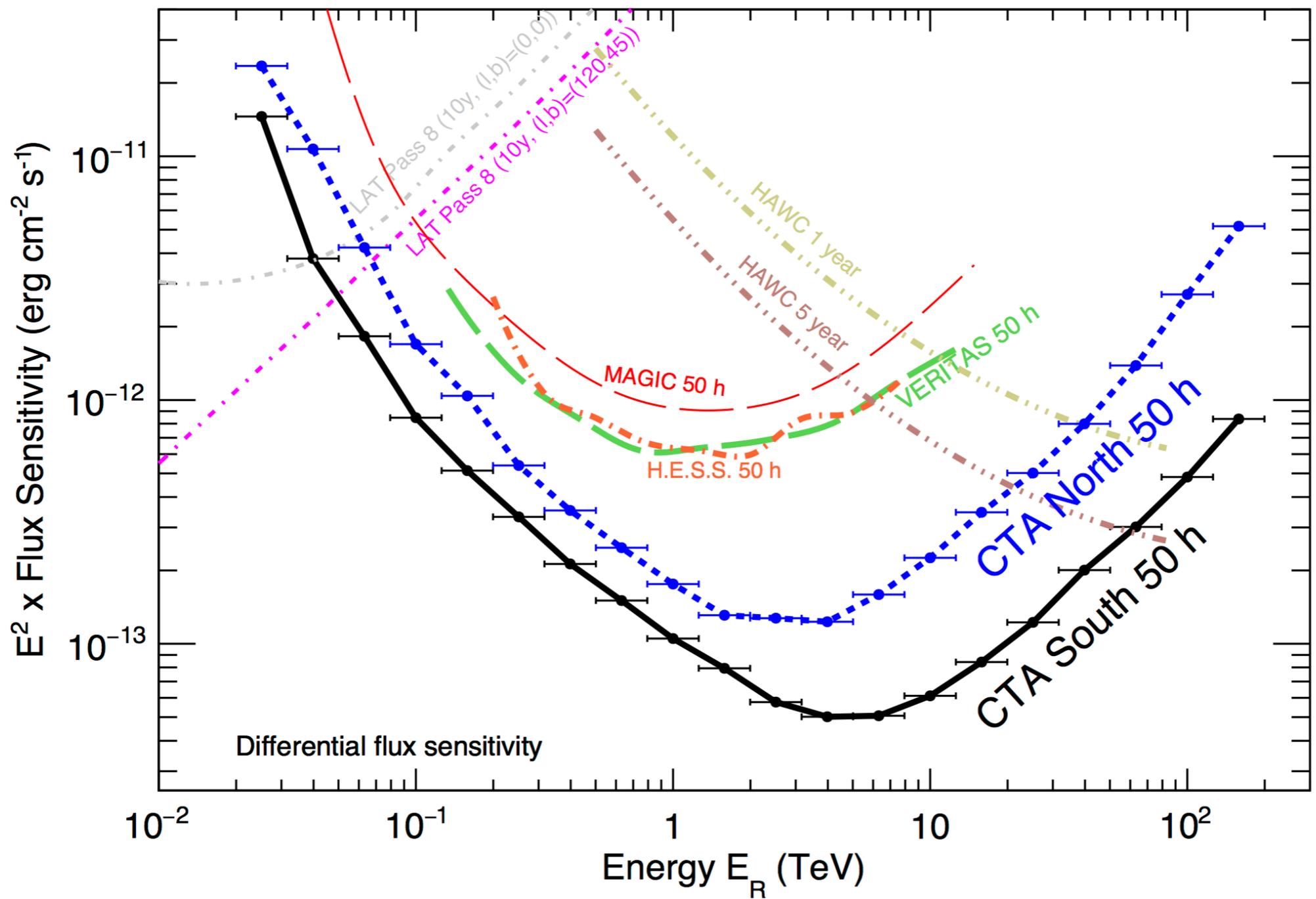


First Pre-Production
Telescopes on Site

CTA Northern and Southern Hemisphere Site Rendering; credit: Gabriel Pérez Diaz

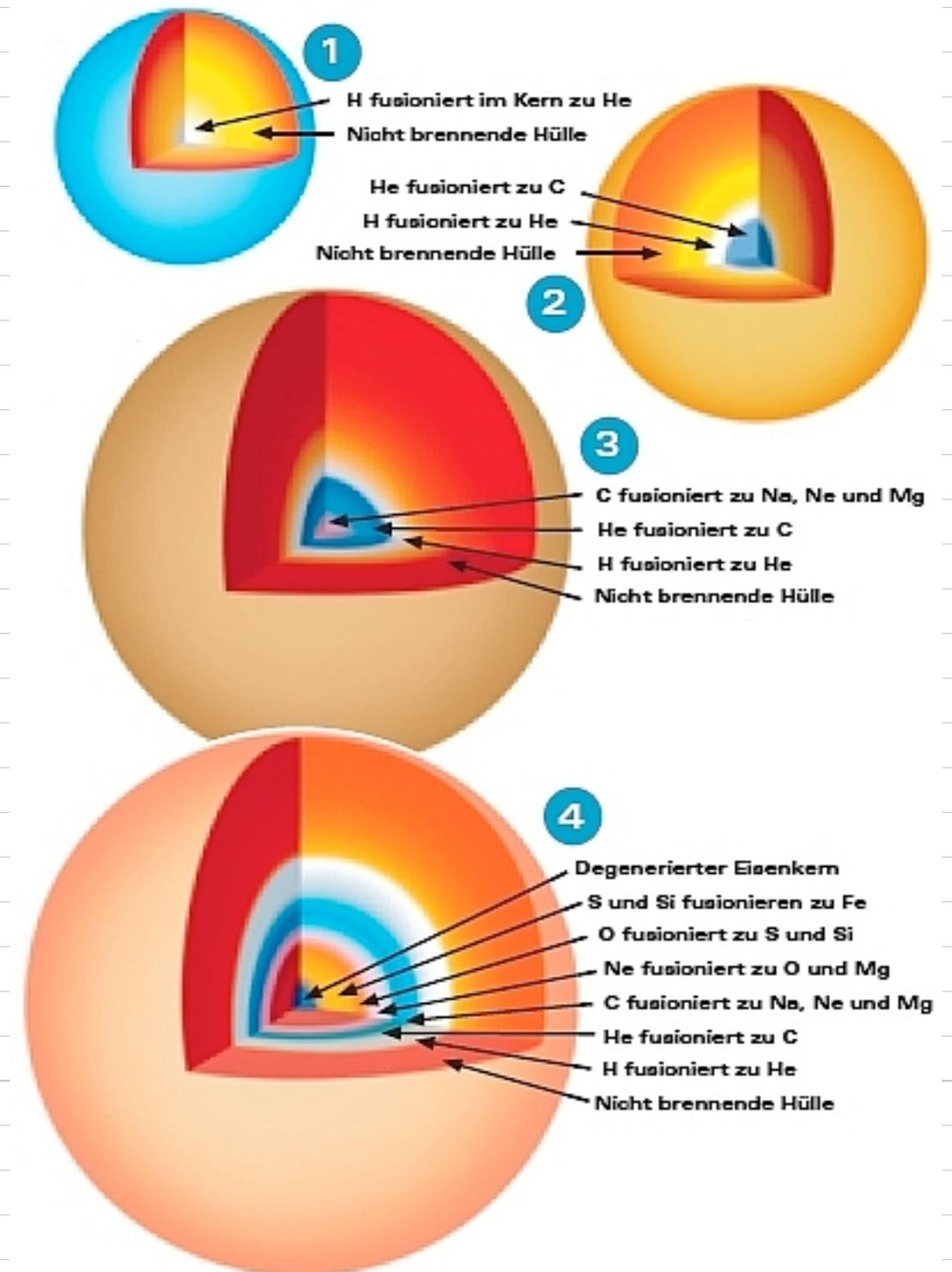
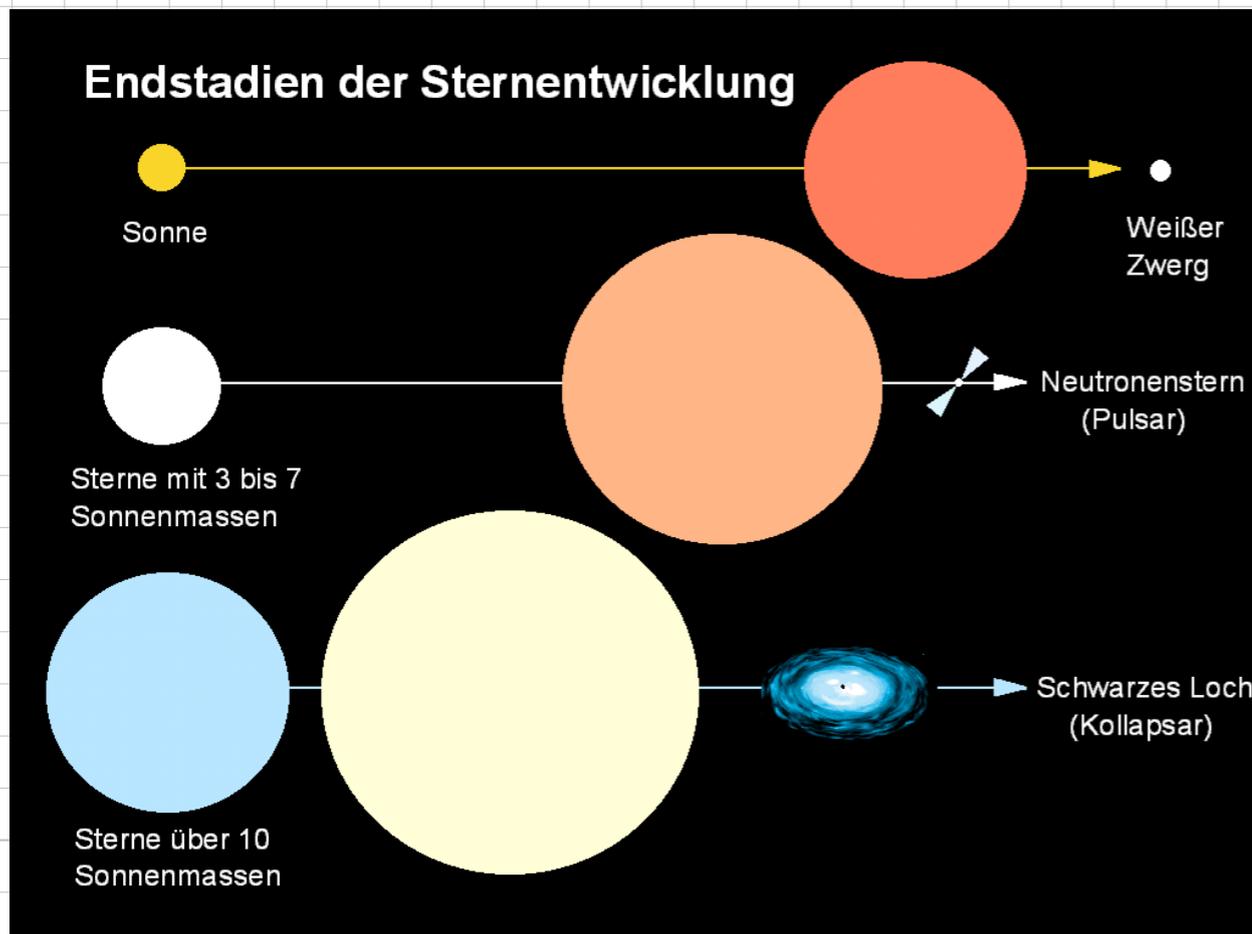


Sensitivität

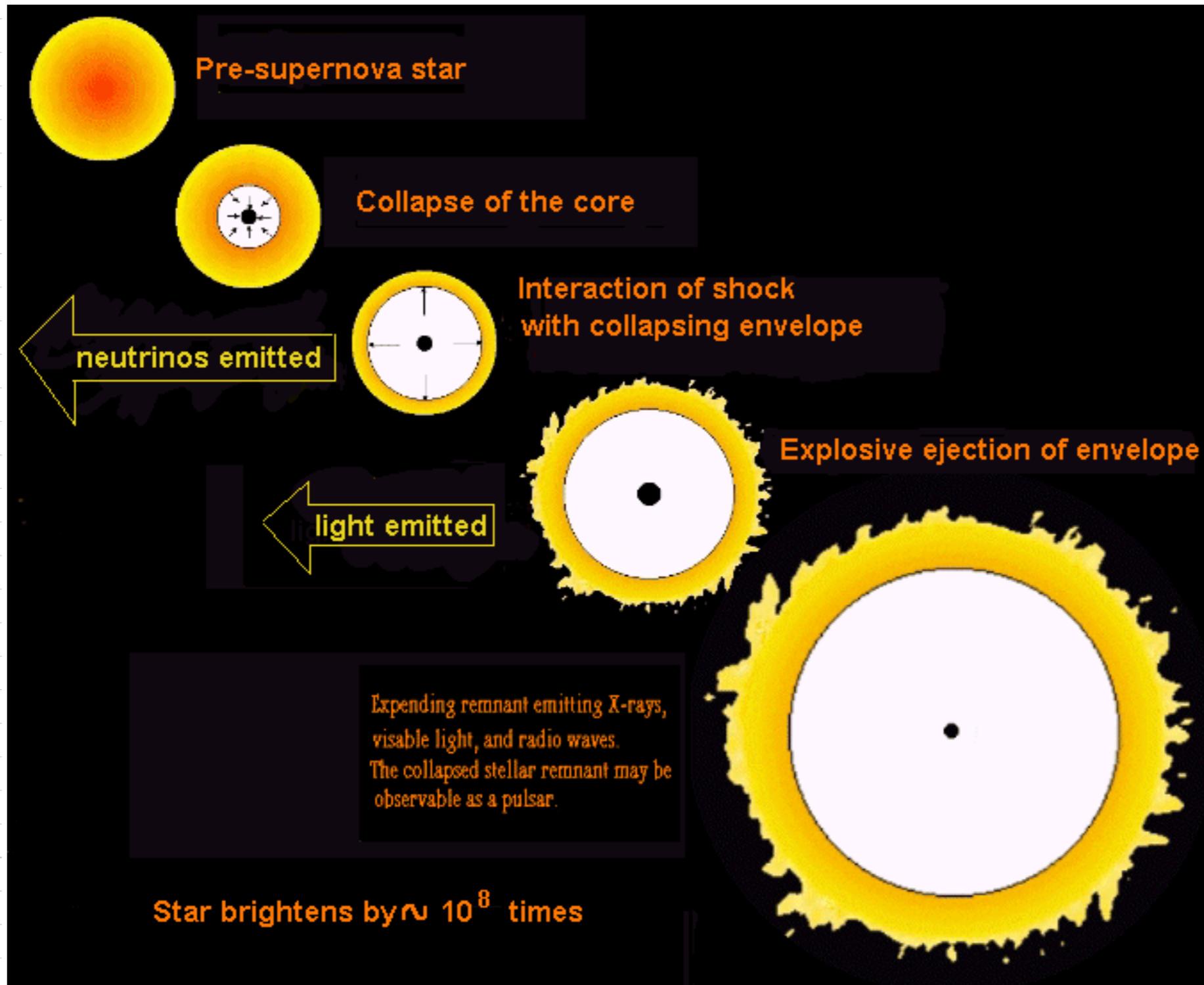


www.cta-observatory.org (2017-07-05)

Endstadien der Sternentwicklung



SN II: Hydrodynamische SN oder Kernkollaps-SN

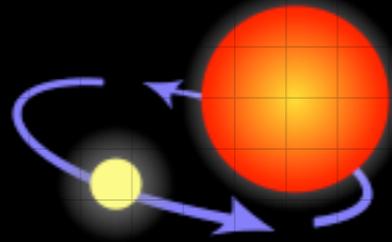


SN Ia: Thermonukleare Explosion

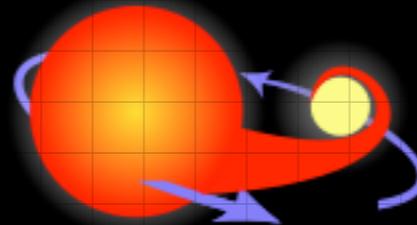
Vorläufer einer Typ Ia Supernova



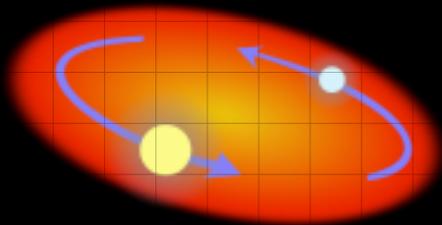
Zwei normale Sterne in einem Binärsystem.



Der größere Stern wird zum roten Riesen...



...der Gas an den zweiten Stern abgibt und diesen einhüllt und wachsen läßt.



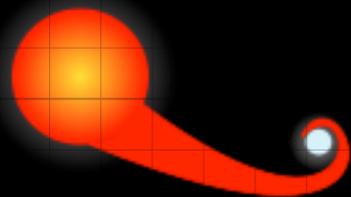
Der zweite, leichtere Stern und der Kern des Riesen winden sich in einer gemeinsamen Hülle aufeinander zu.



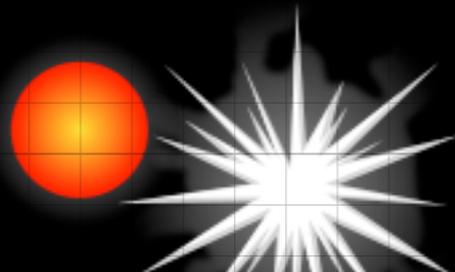
Die gemeinsame Hülle wird abgestoßen, während der Abstand zwischen Kern und Sekundärstern schrumpft.



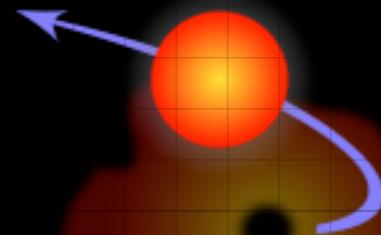
Der verbleibende Kern des Riesen kollabiert und wird zum weißen Zwerg.



Der alternde Begleitstern schwillt an und gibt nun Gas an den Zwerg ab.

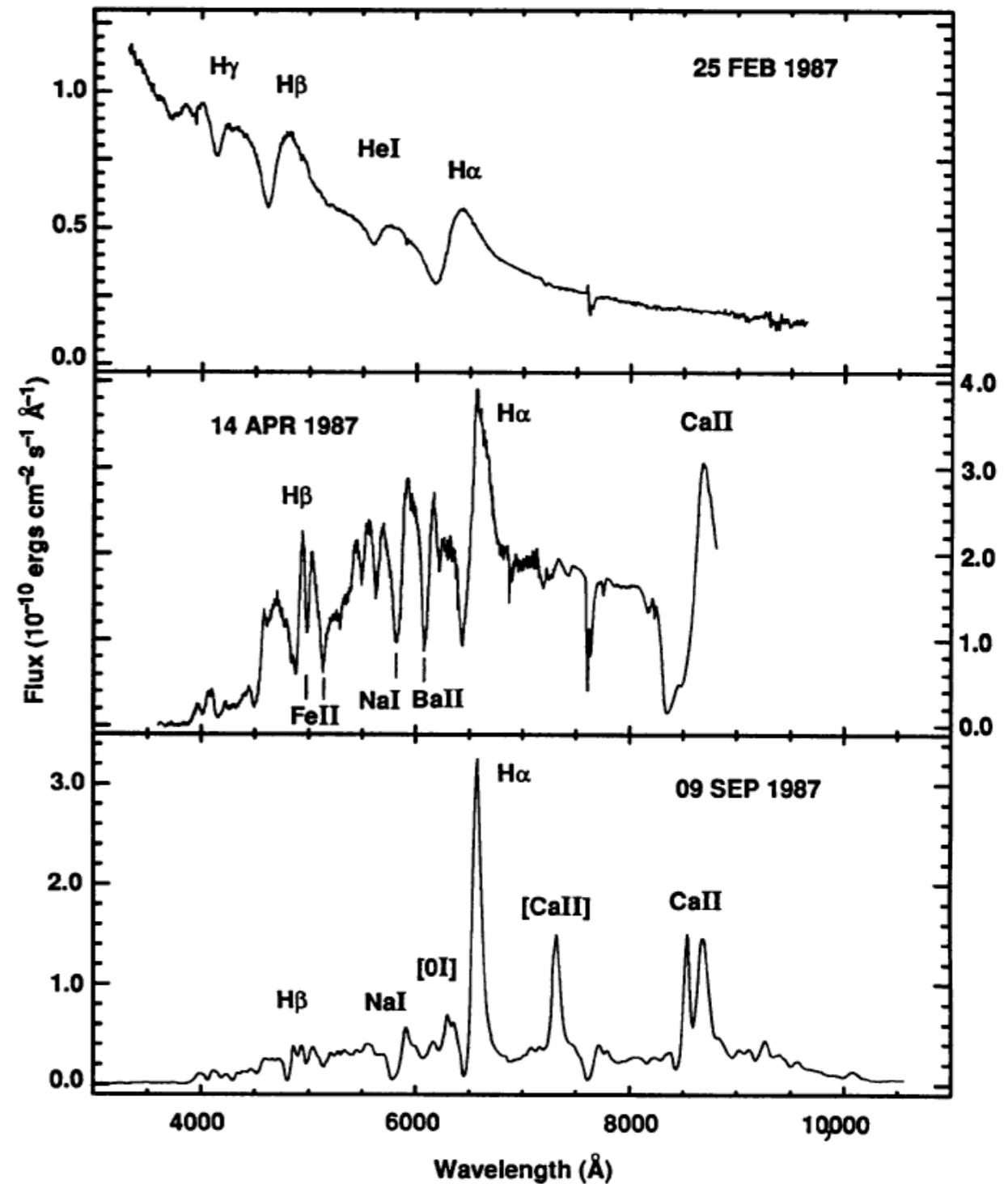
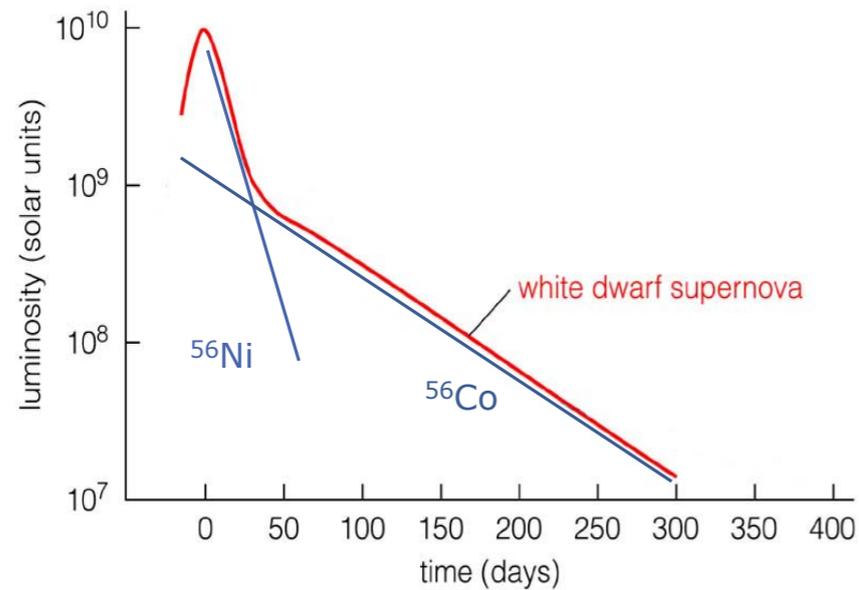
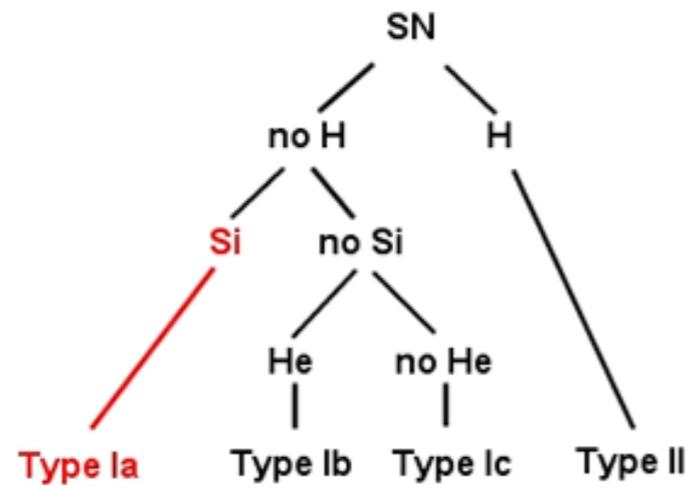


Der weiße Zwerg wächst an, bis er eine kritische Masse erreicht und explodiert...

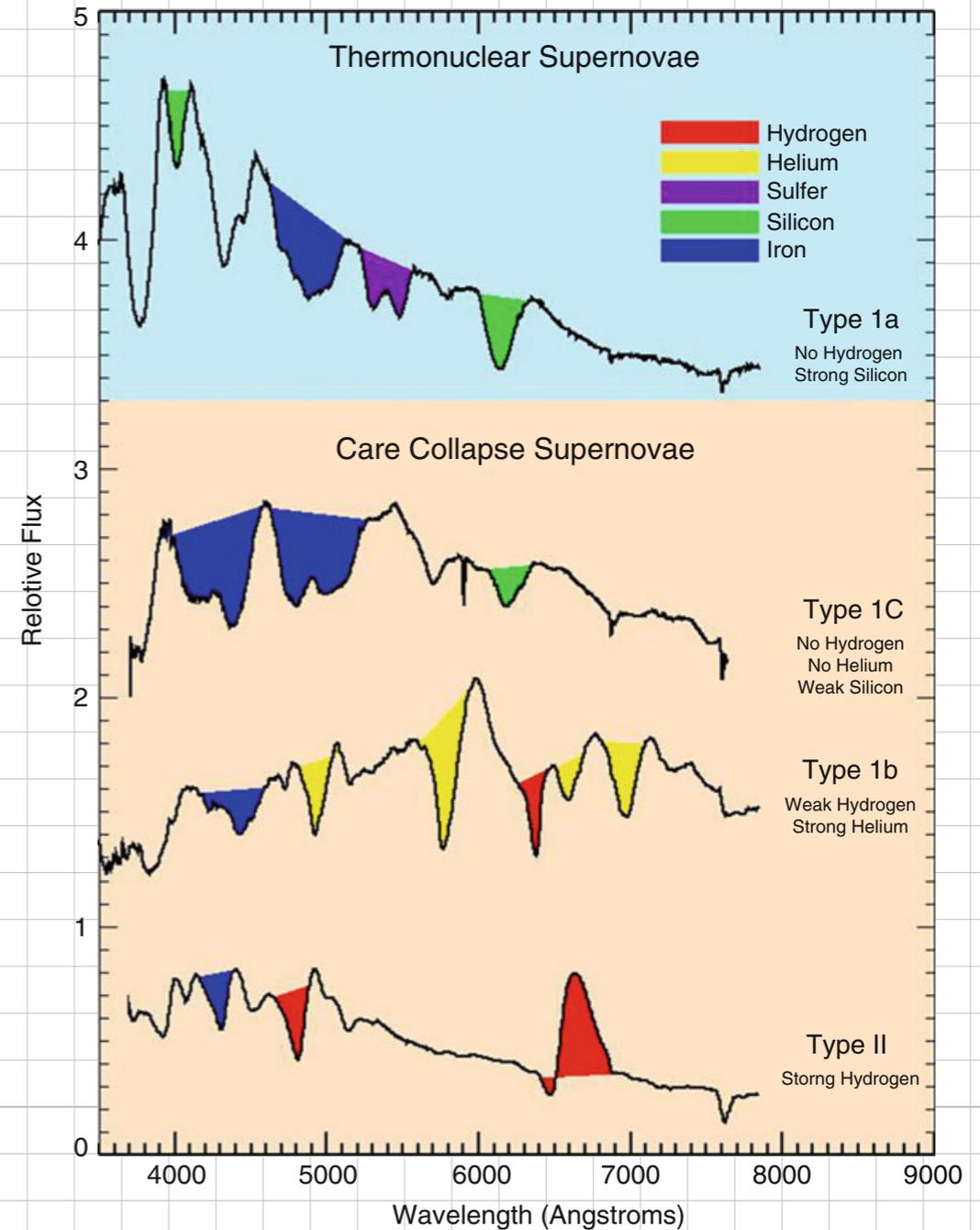
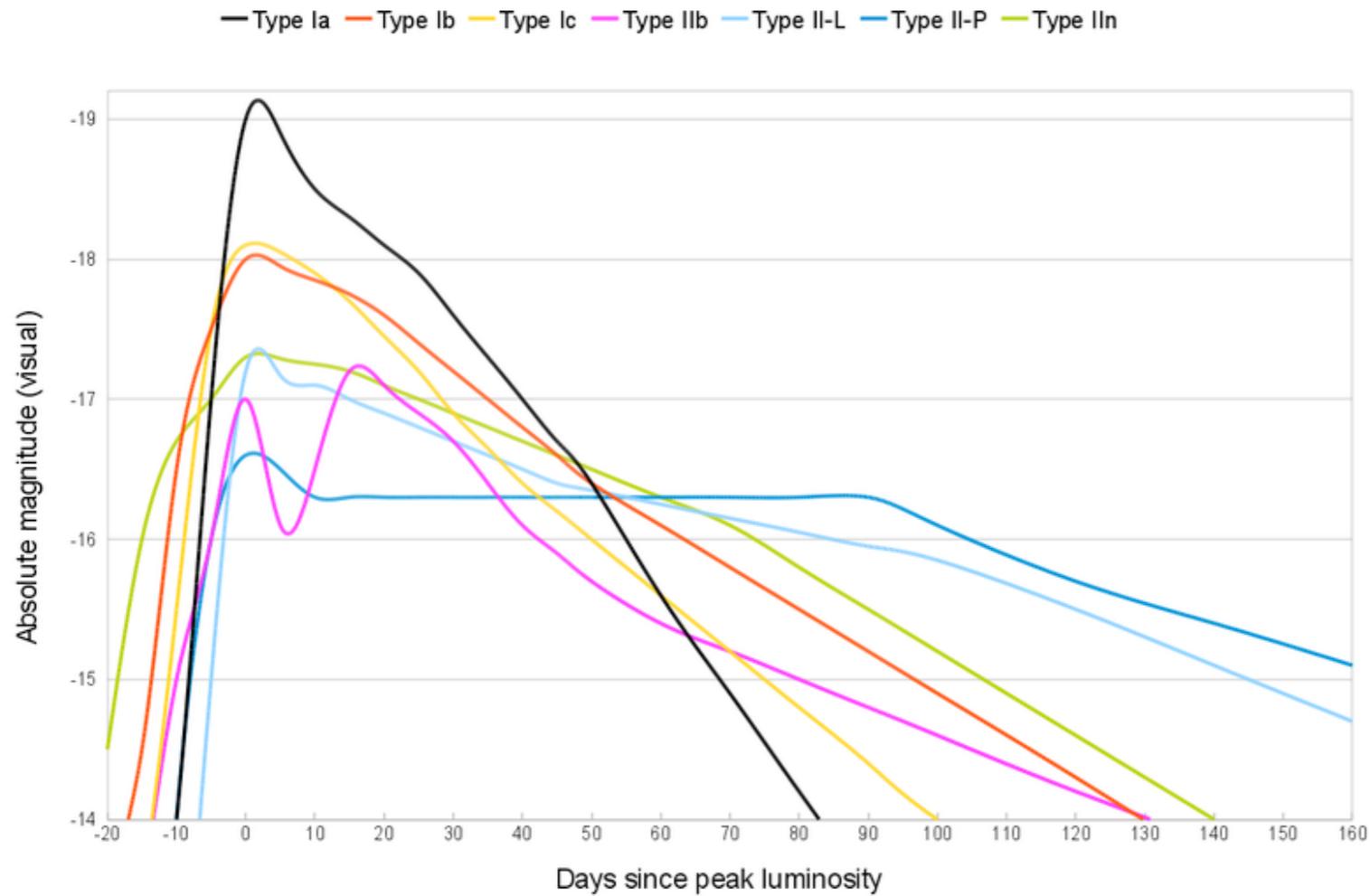


... und schleudert damit den Begleitstern davon.

Klassifikation von Supernova-Explosionen

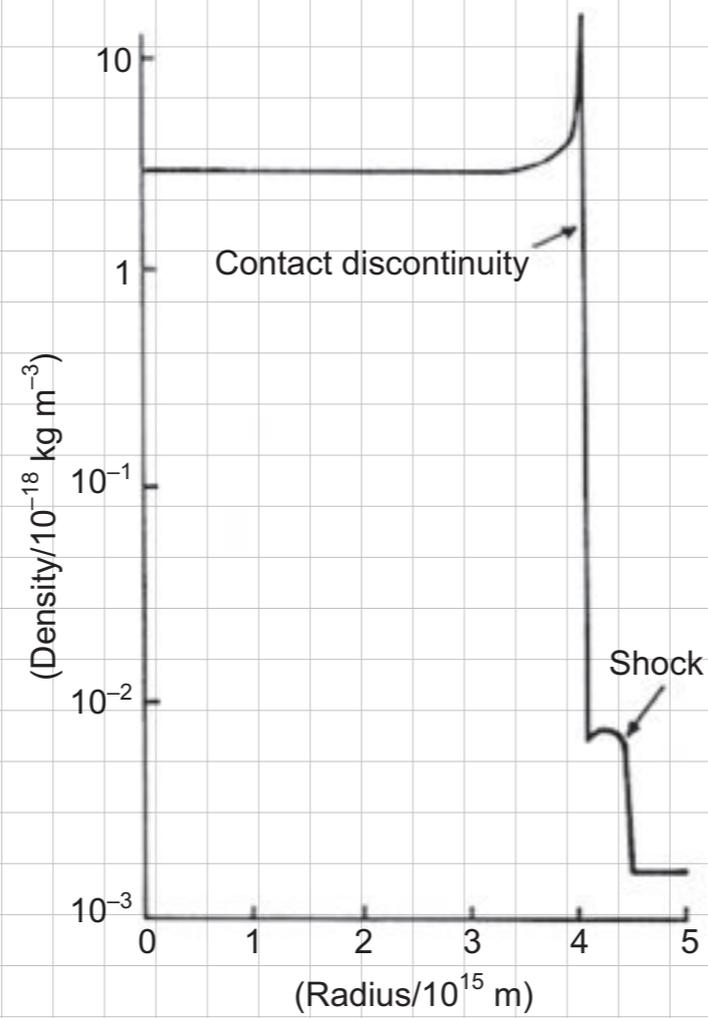
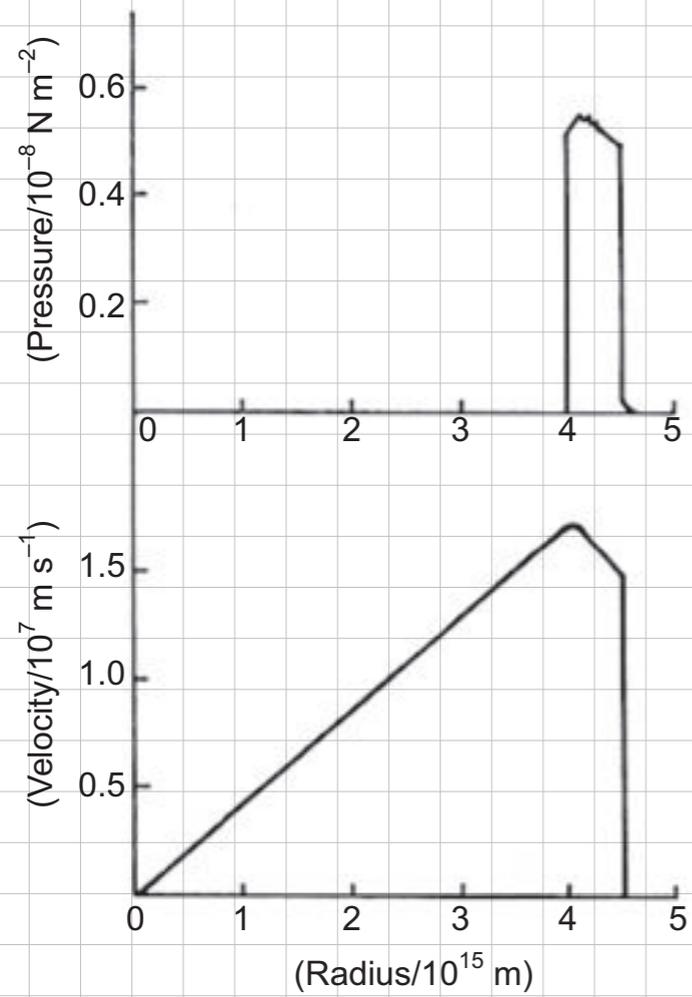


Beispiele für Lichtkurven

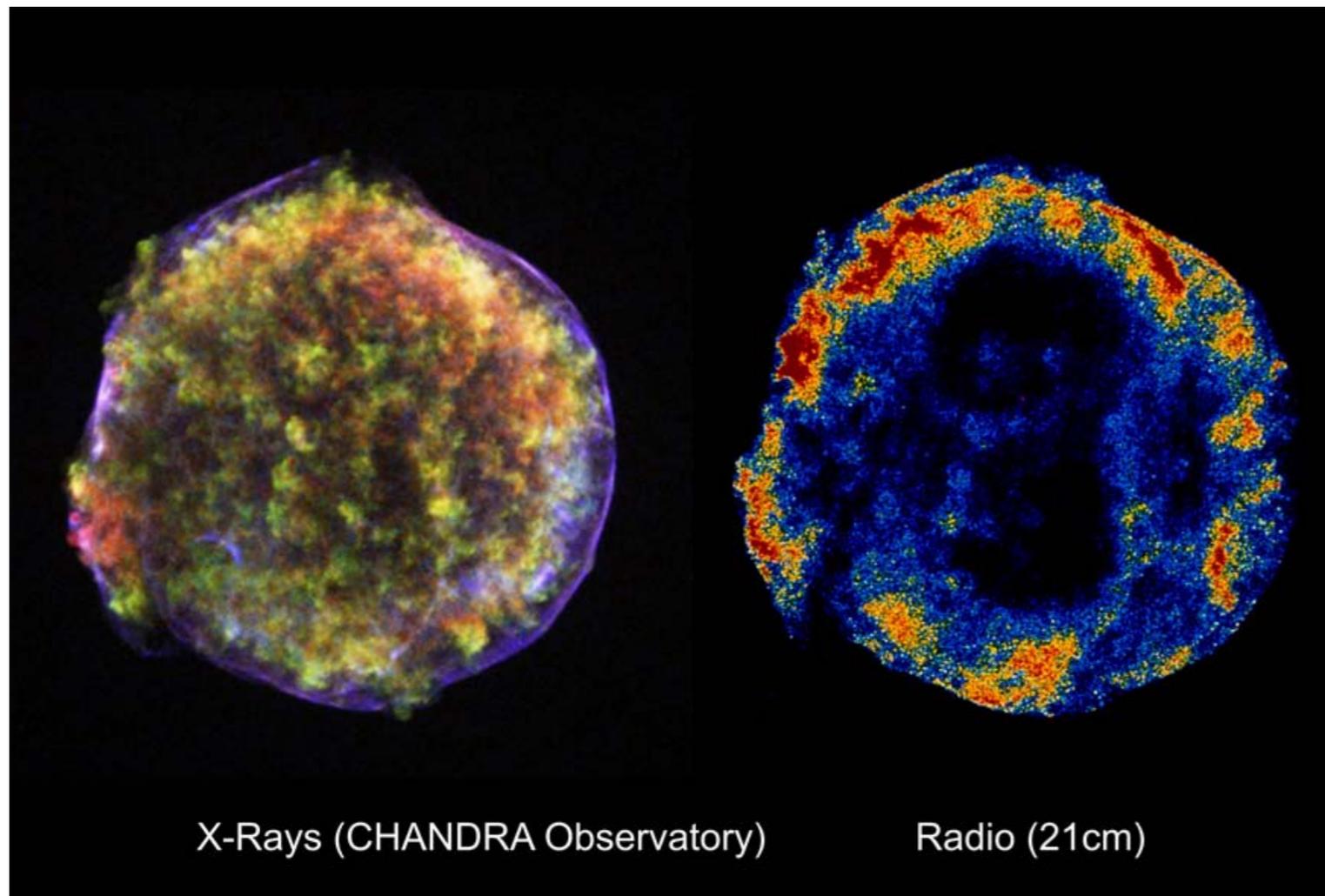


Abschätzung der kinetischen Energie

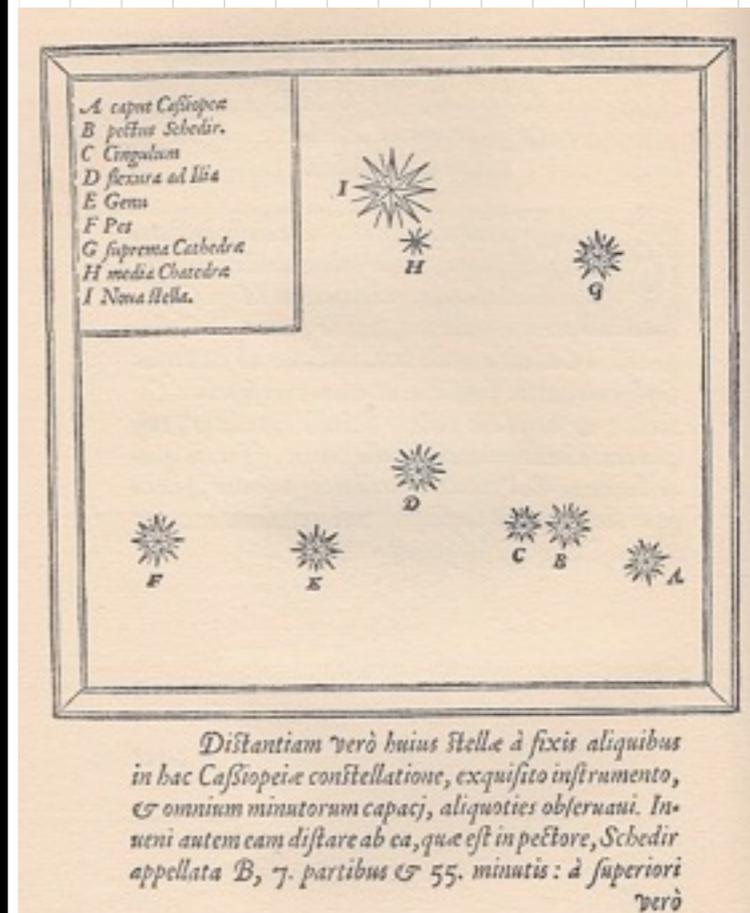
Phase des freien Strömens (free streaming)



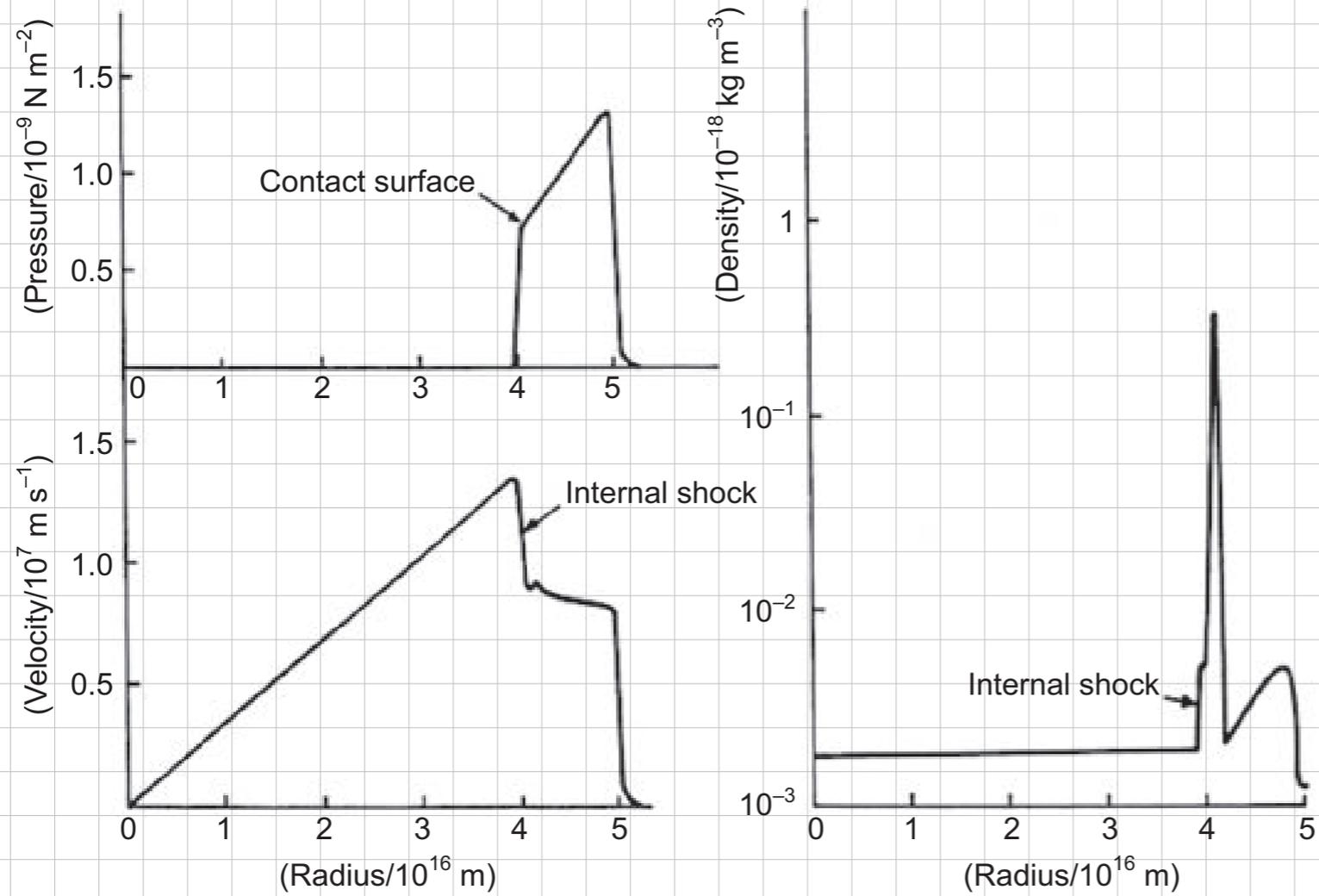
Beispiel: Supernova-Überrest SN 1573



(Tycho's Supernova, AD 1572)

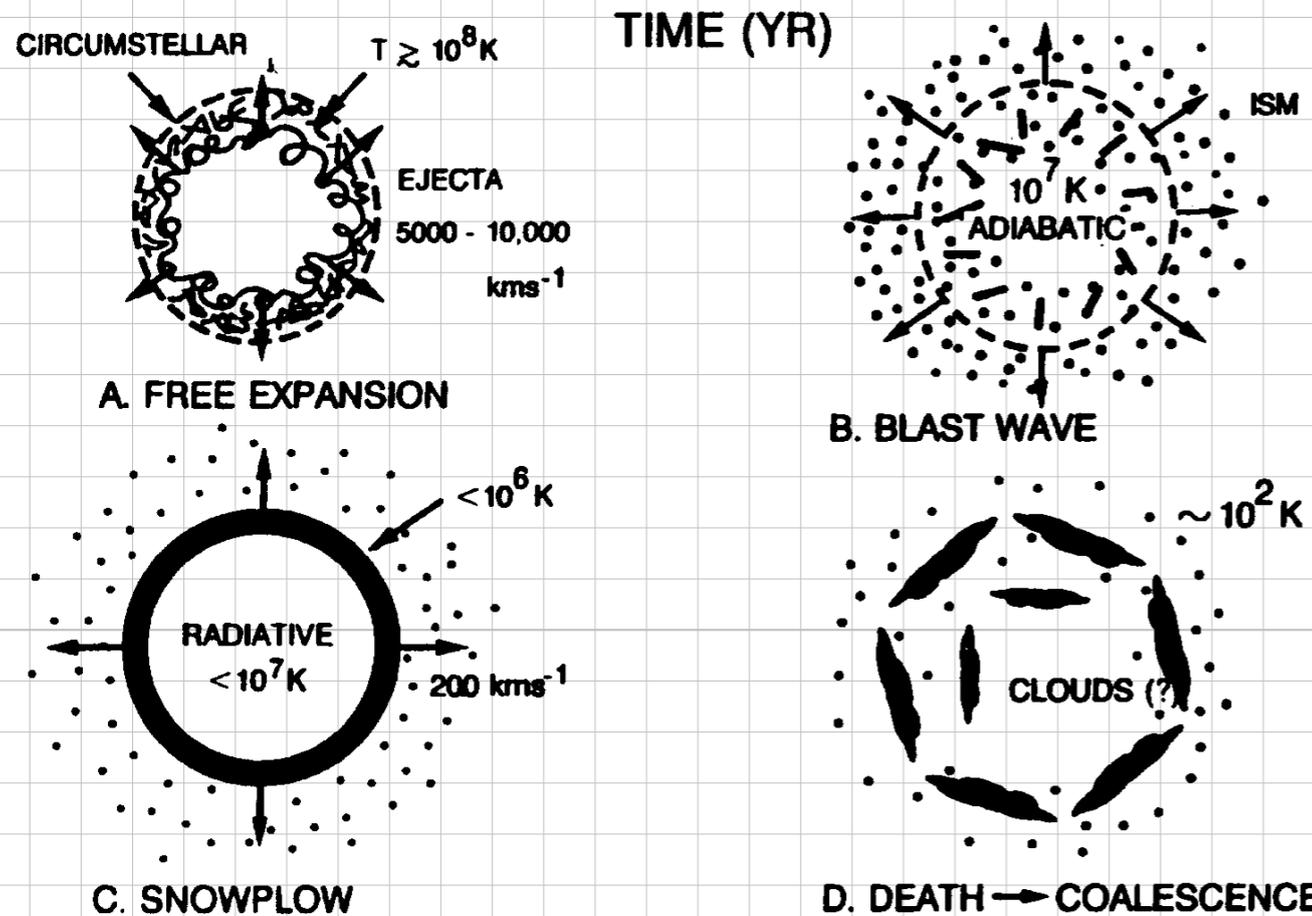
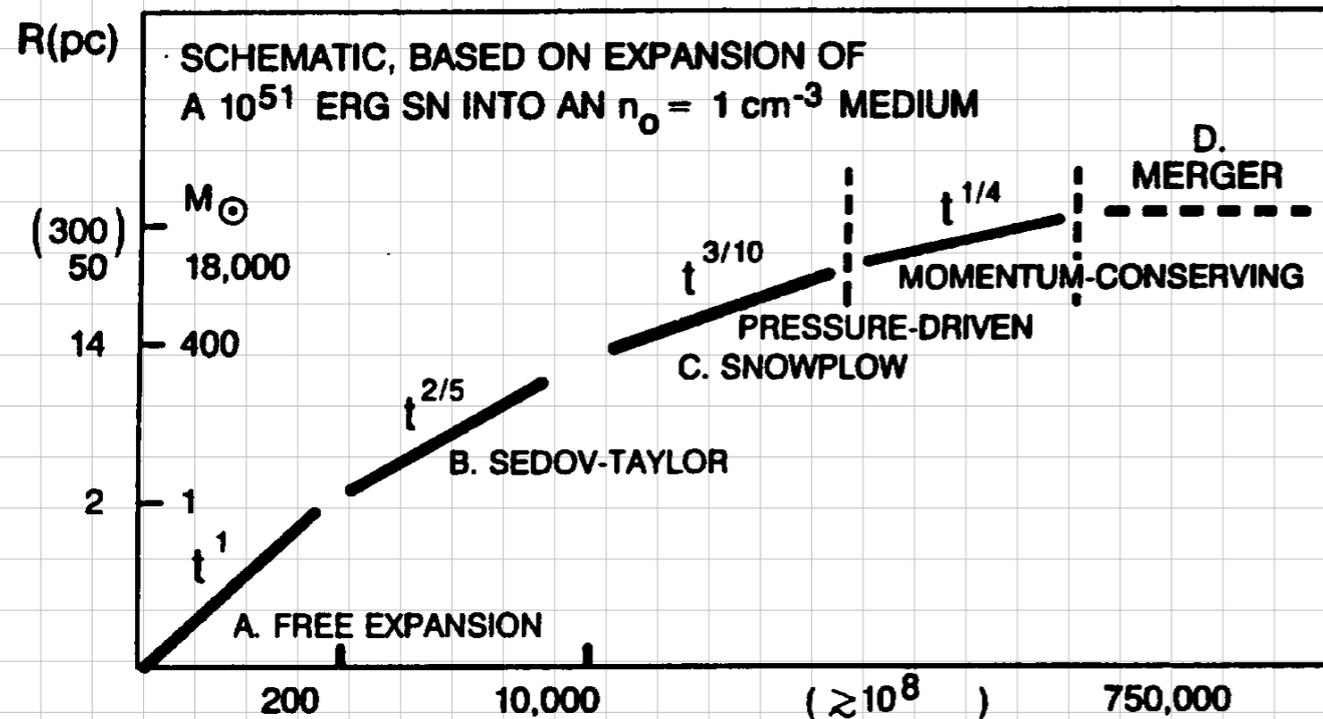


Sedov-Taylor-Phase

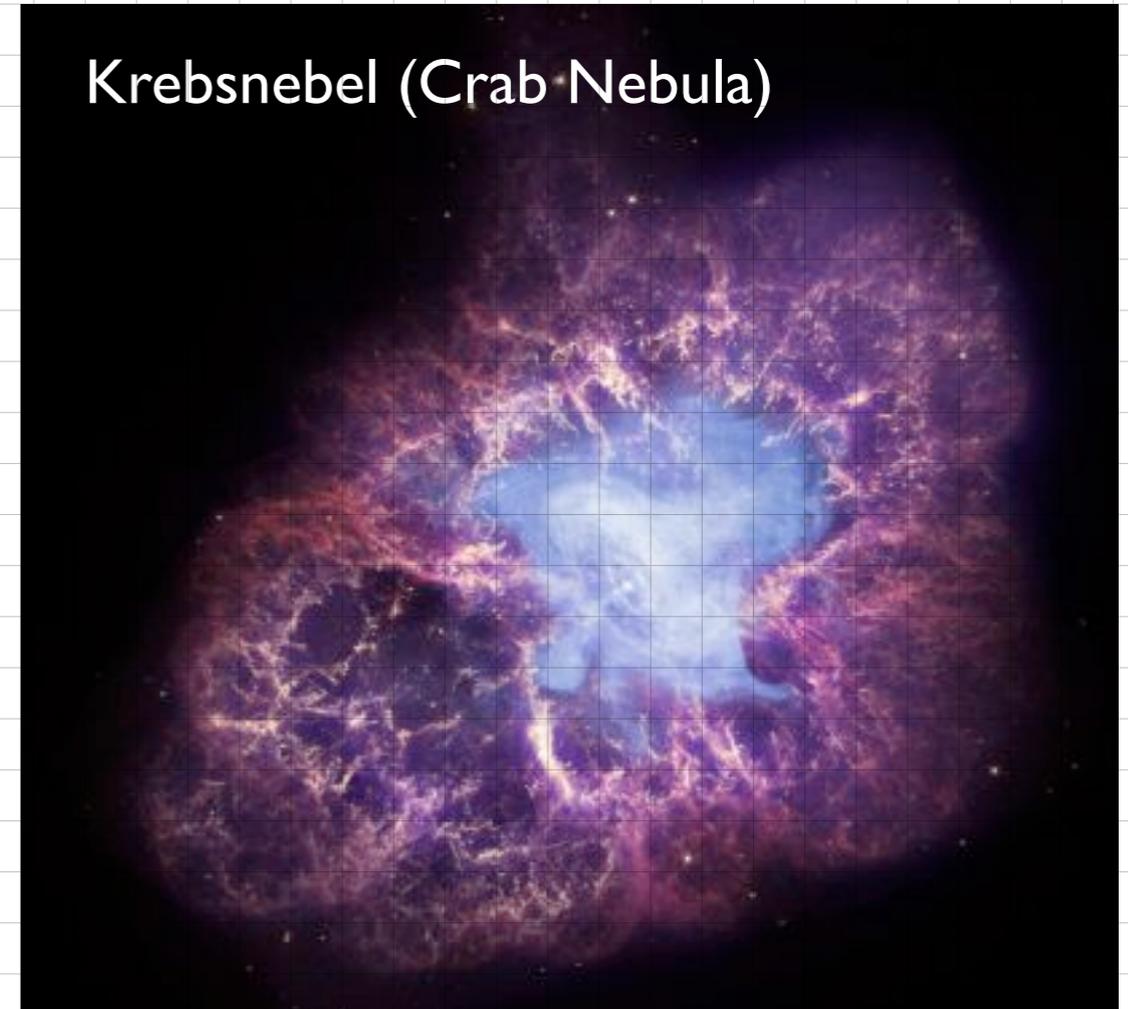
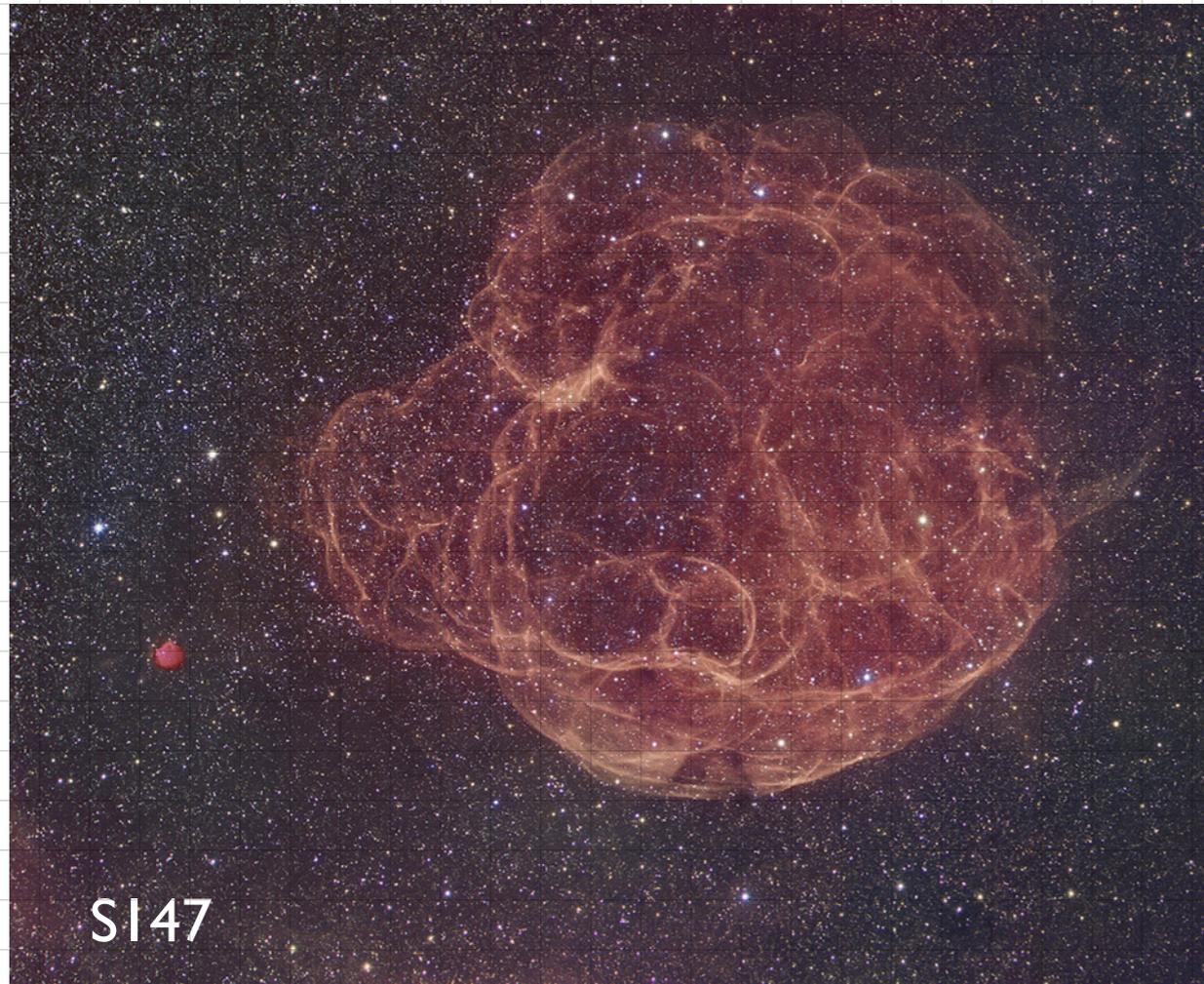


Abschätzung der Expansionsgeschwindigkeit

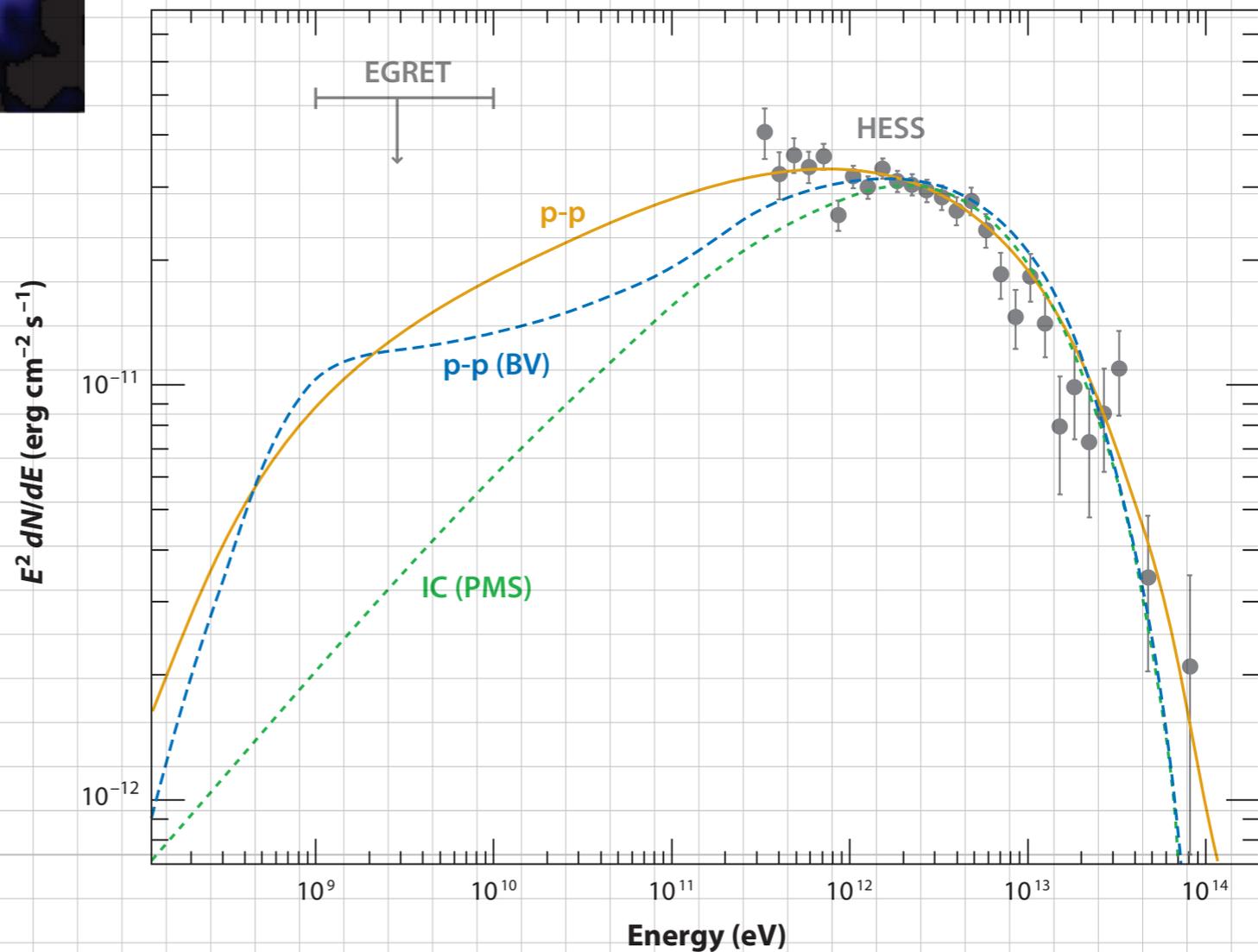
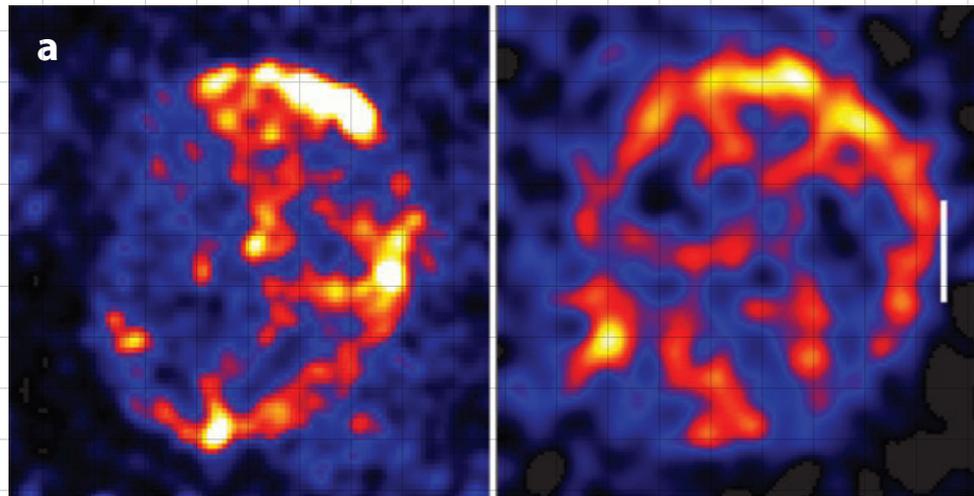
Entwicklung von SN-Überresten



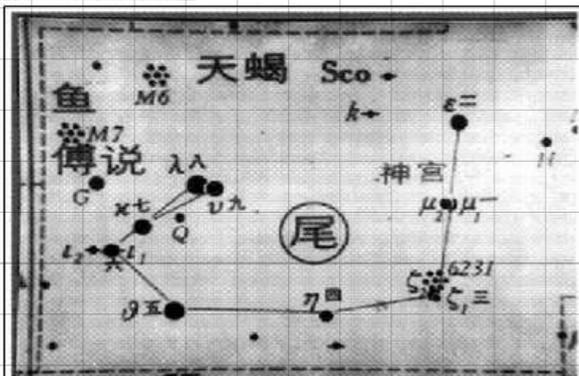
Beispiele für Supernova-Überreste



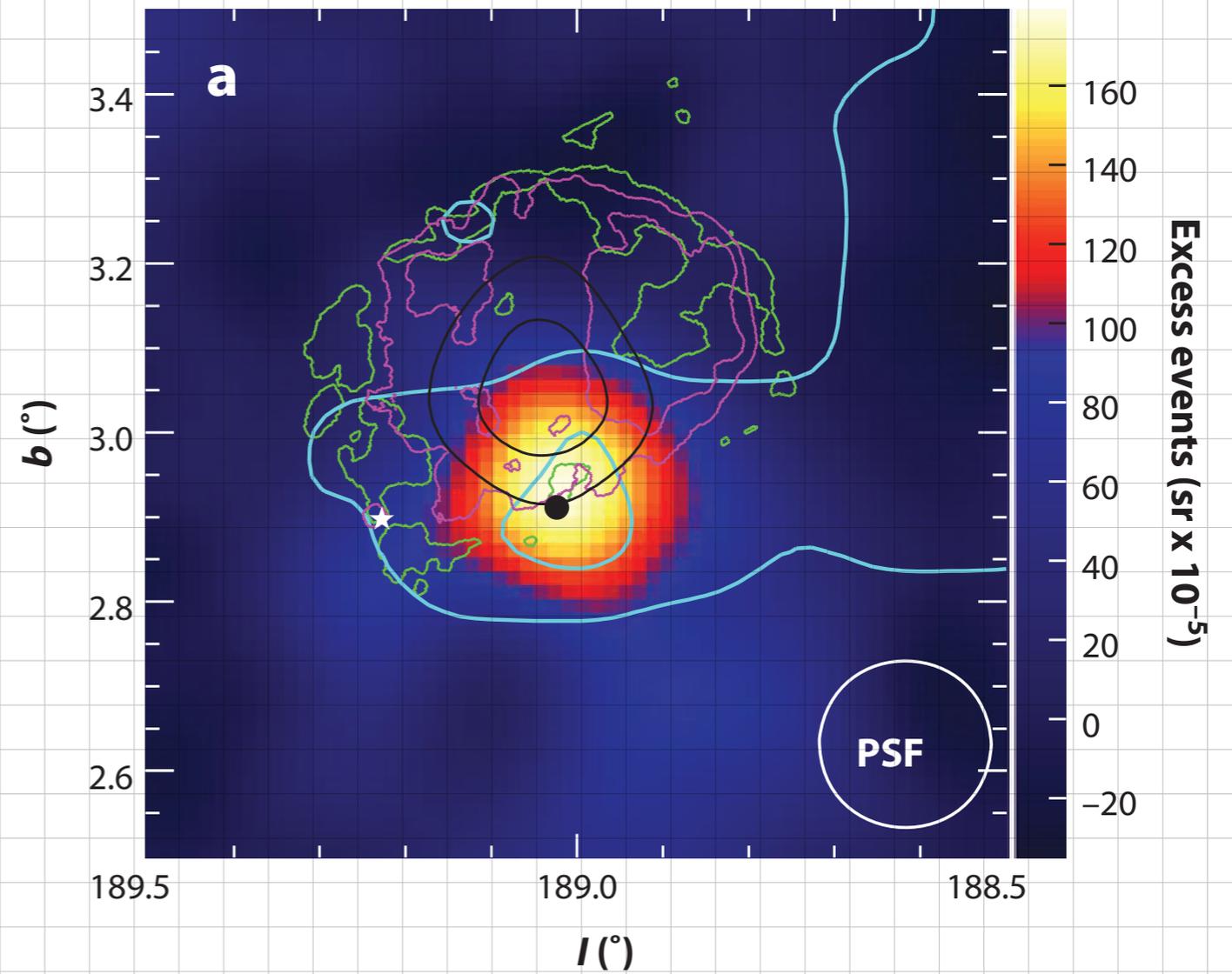
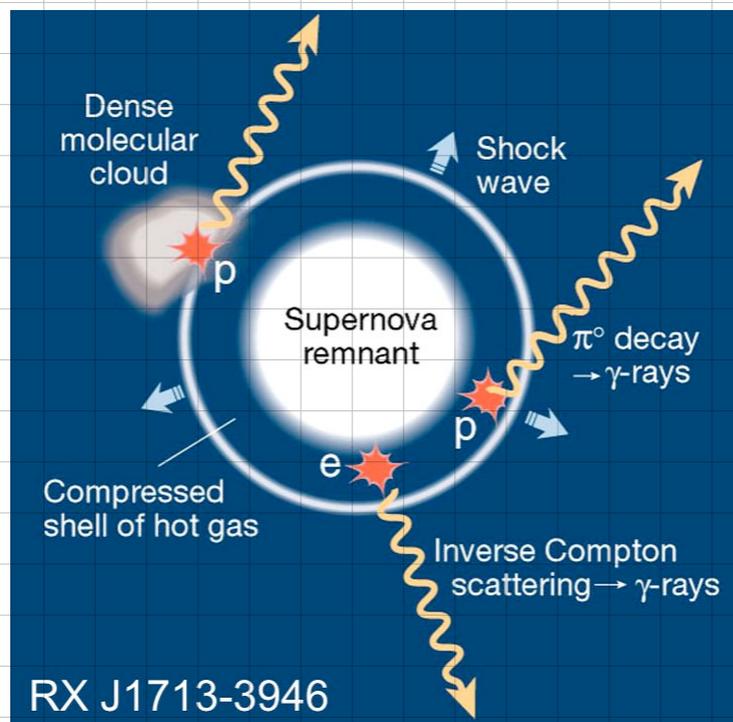
Supernova-Überrest RX J1713.7-3946



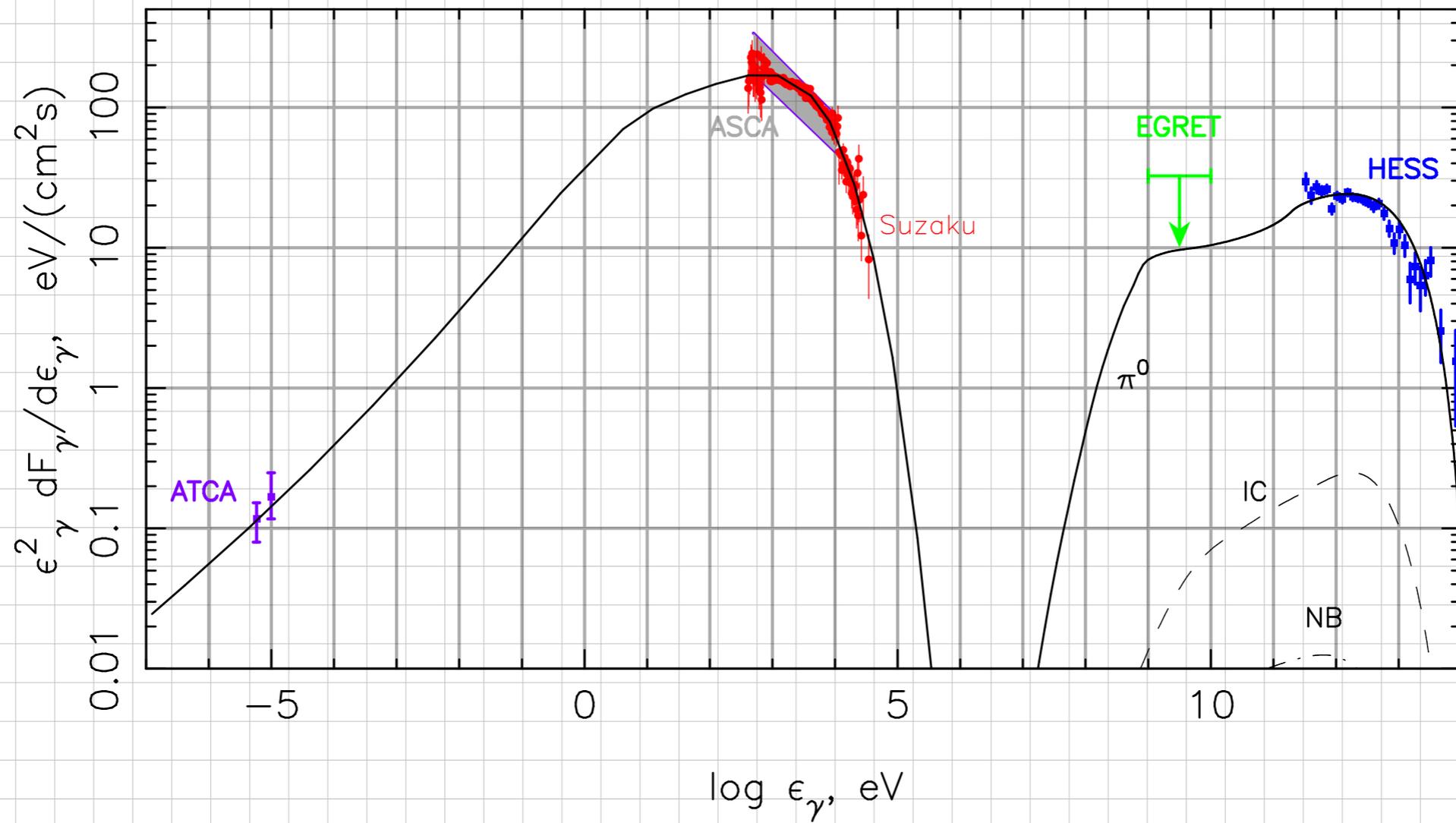
之并斬其從弟緒司馬道子
 太元十六年十一月癸巳月
 時太子常有篤疾
 太元十七年九月丁丑歲星
 三星合是謂驚位絕行內外有兵喪與飢改立王公
 太元十八年正月乙酉熒惑入月占曰憂在宮中非賊
 乃盜也一曰有亂臣若有戮者二十一年九月帝暴崩
 內殿兆庶宣言夫人張氏潛行大逆于時朝政闇緩不
 加顯戮但默責而已又王國寶邪狡卒伏其辜
 太元十八年二月有客星在尾中至九月乃滅占曰燕



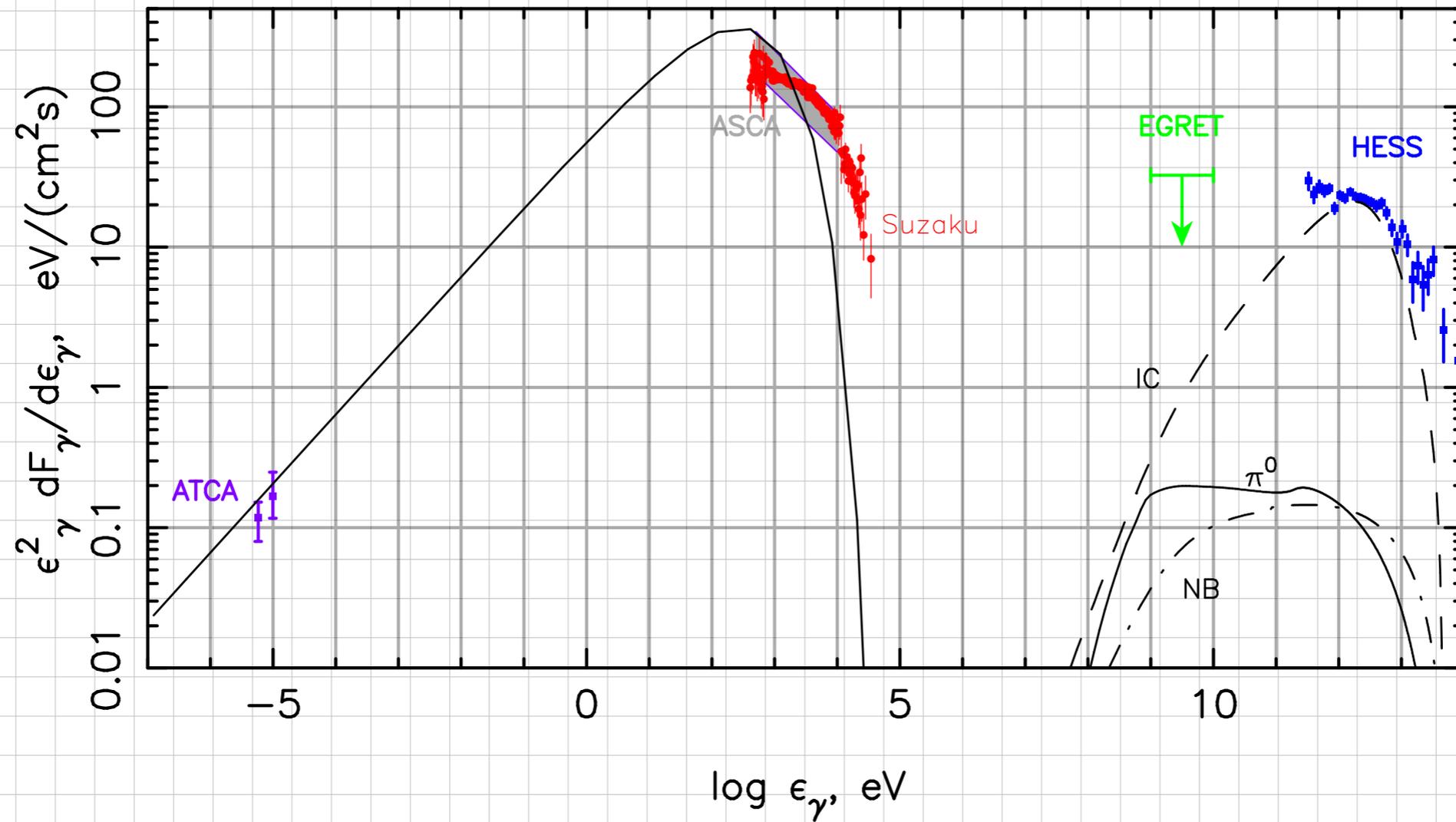
Wechselwirkung mit Molekülwolke: RX J1713.7-3946



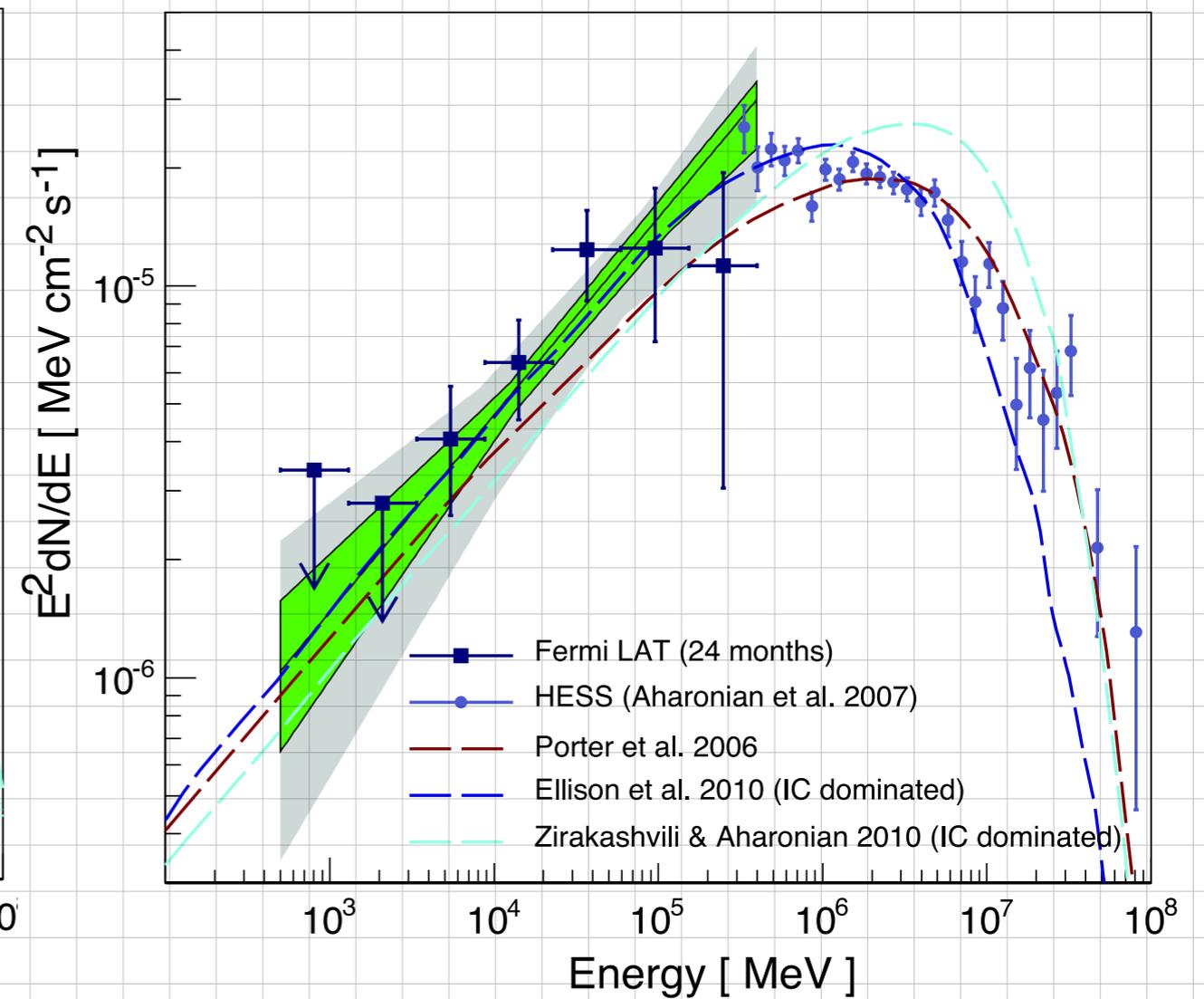
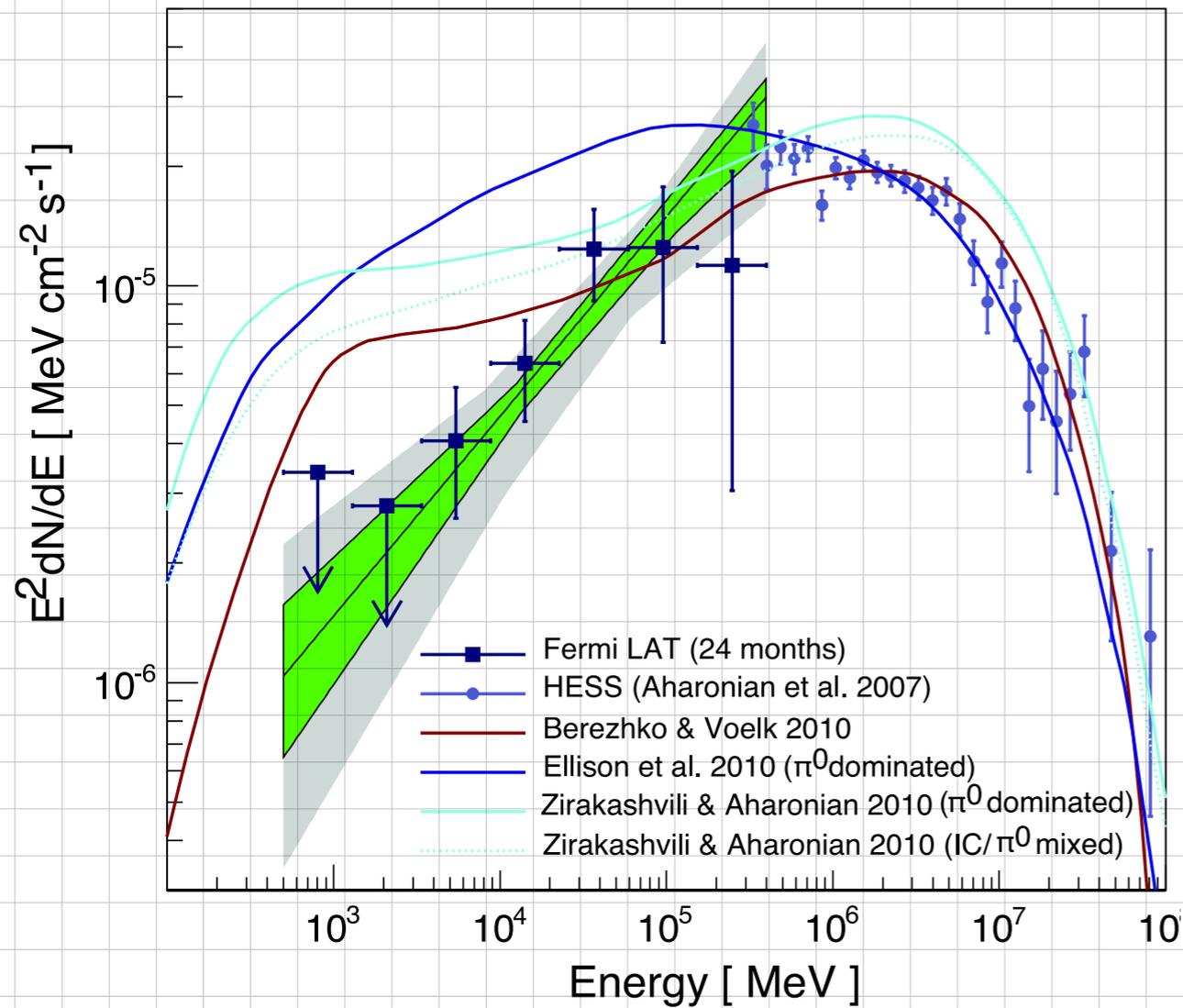
Modellrechnung: hadronische Erzeugung



Modellrechnung: leptonische Erzeugung

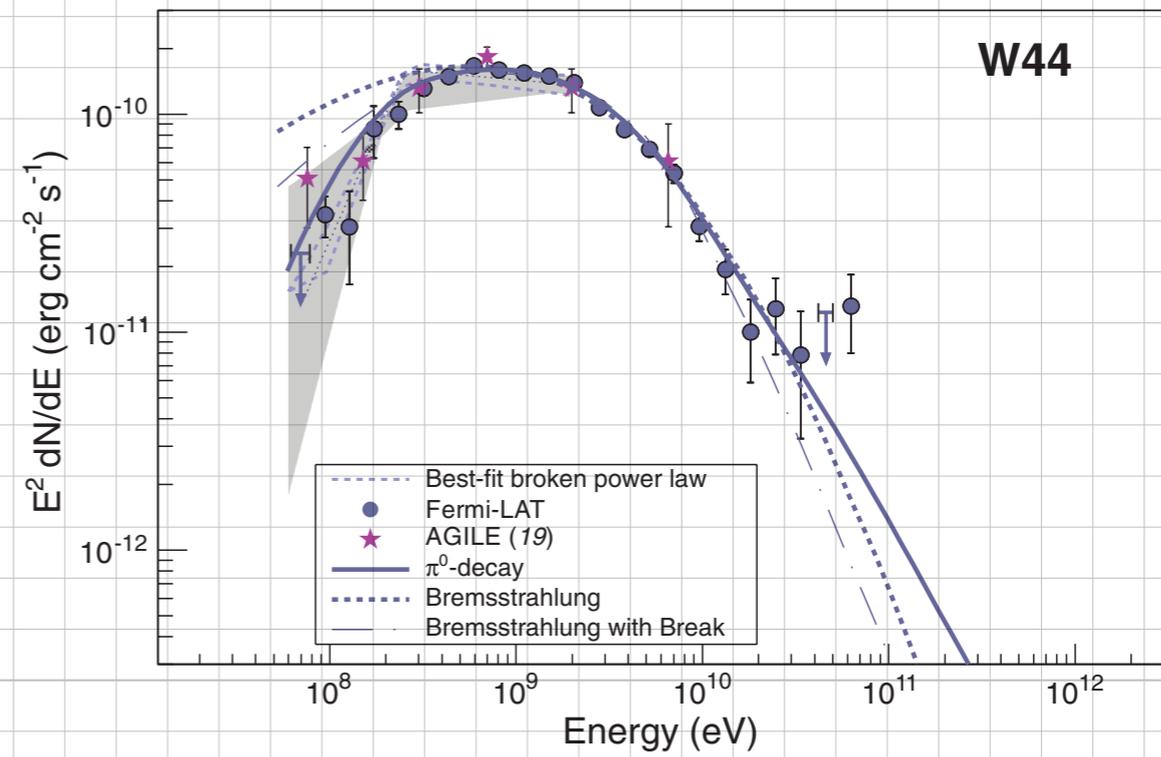
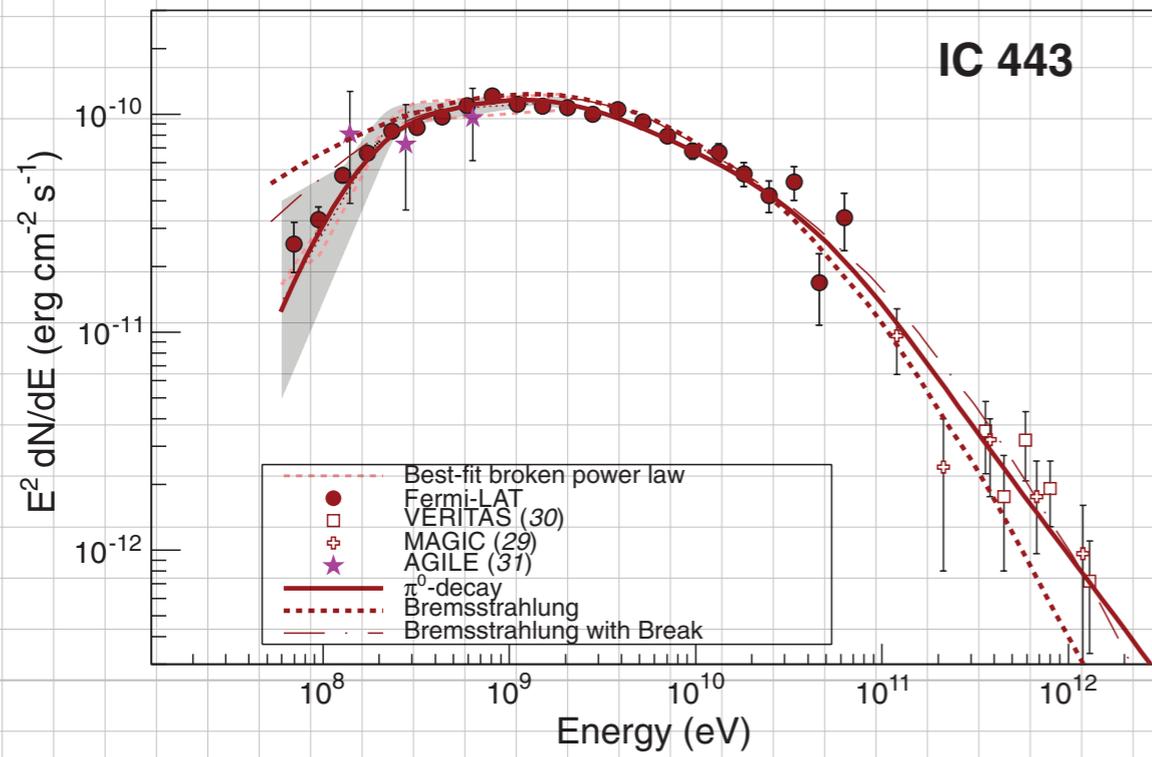
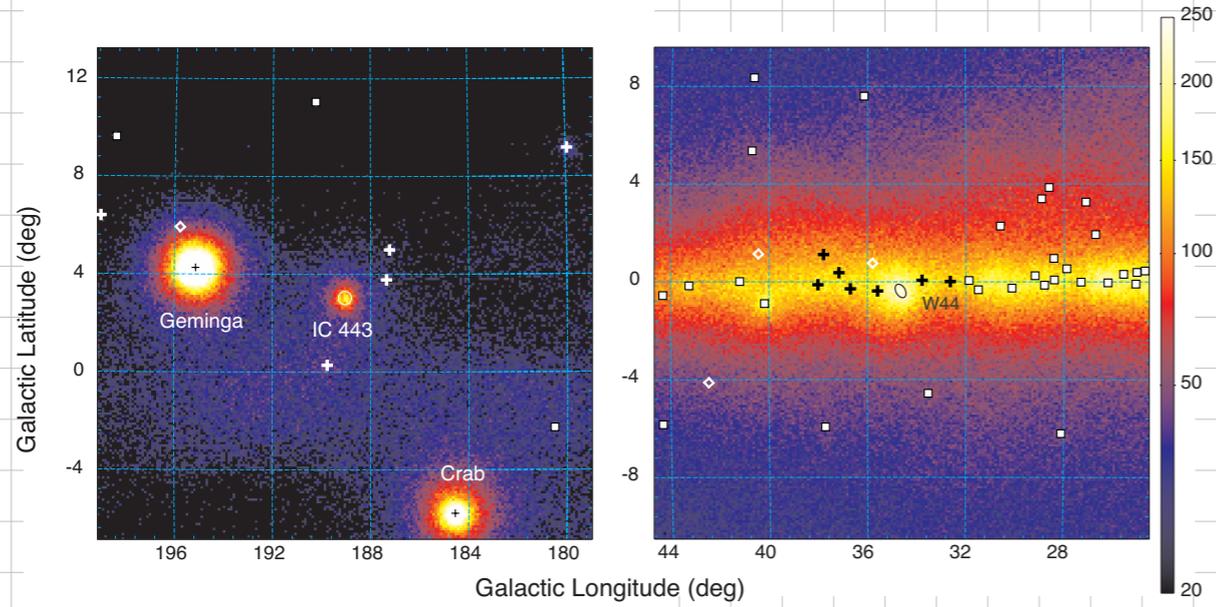


FERMI-LAT-Messung



arXiv:1103.5727v1

Fermi-Beobachtungen von IC 443 und W44



Abgeleitete Protonflüsse

