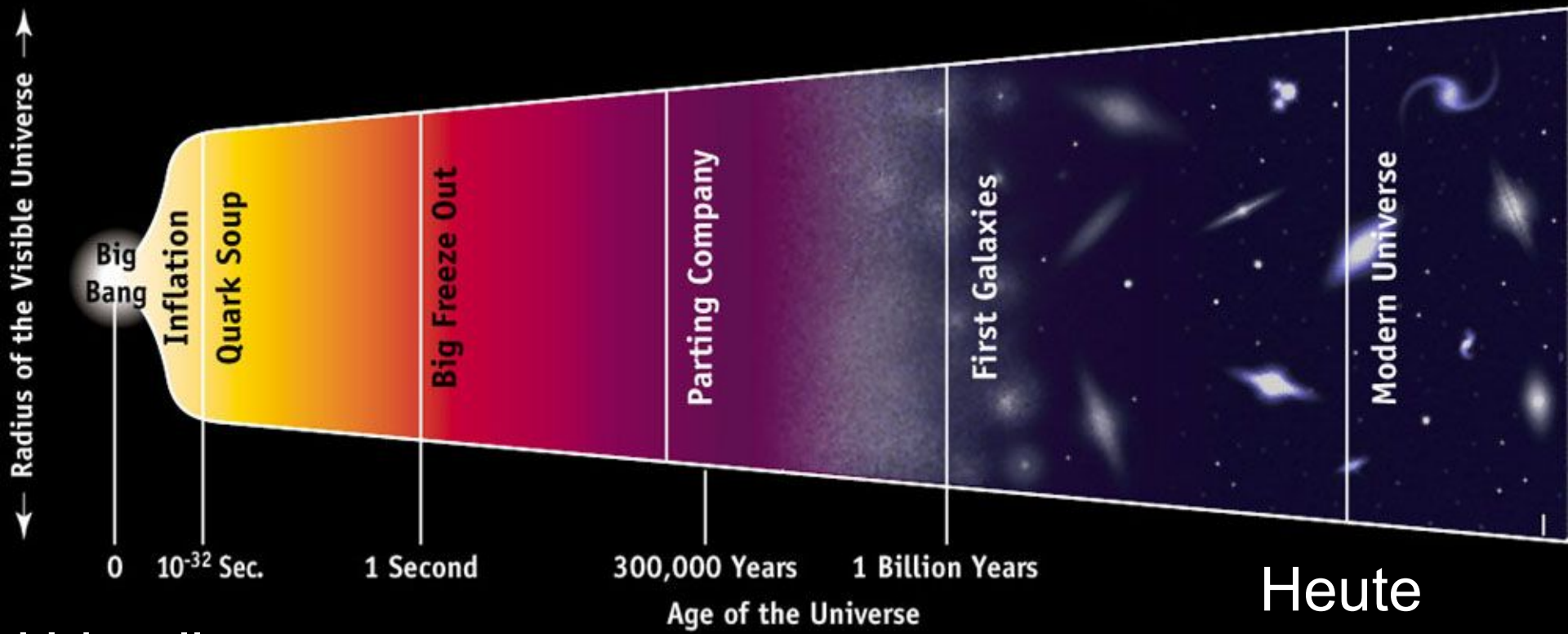
Schwarze Löcher

und ihre kosmologische Bedeutung

Peter Predehl, Max-Planck-Institut für extraterrestrische Physik, Garching

Astroteilchenschule, Obertrubach, 11.Oktober 2004

Die kosmische Zeitskala



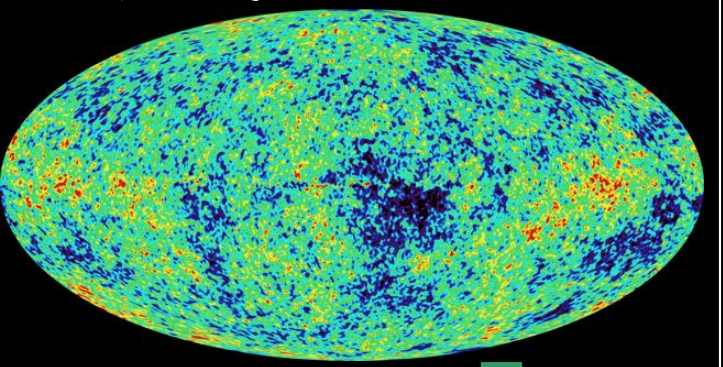
Urknall

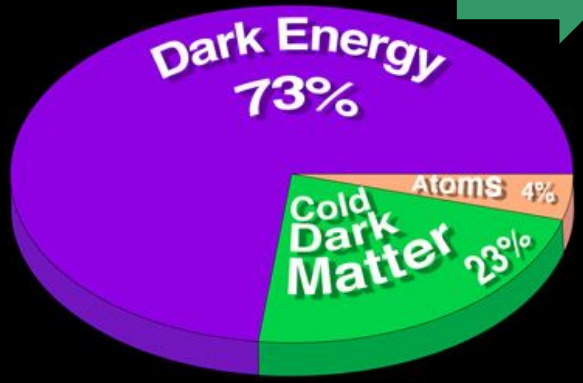
Heute
13.7 Mrd Jahre

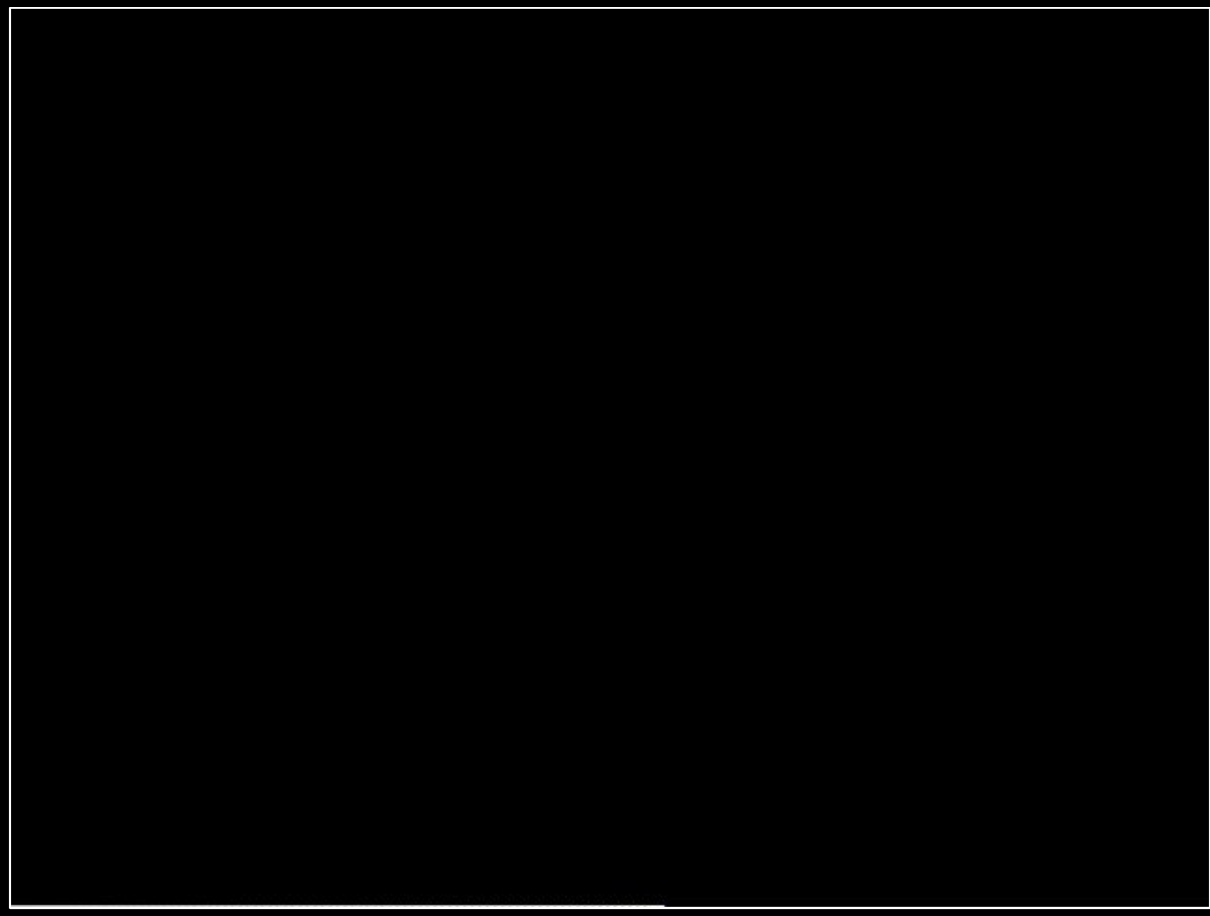
Rotverschiebung z

Bildung der großräumigen Strukturen

Bild des Universums
380.000 Jahre alt

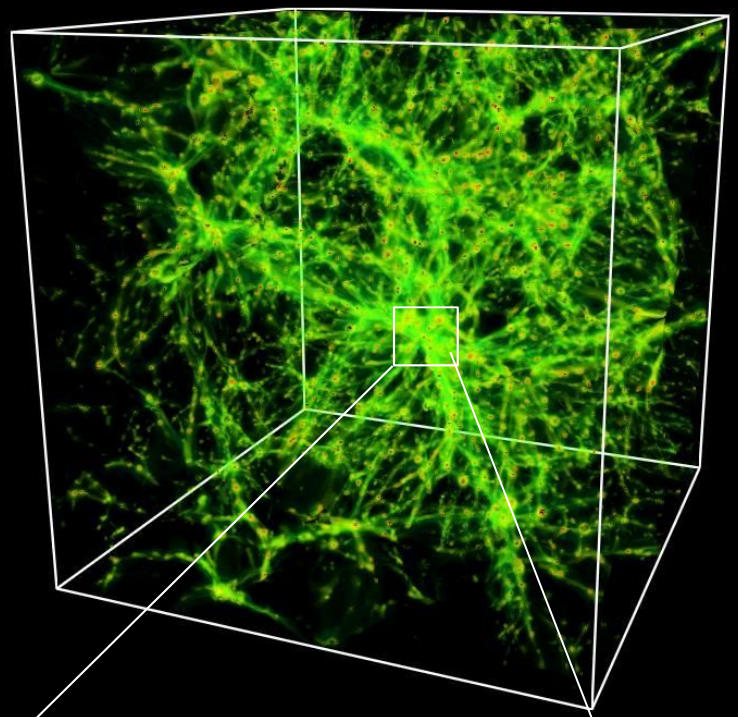






Simulation der Dunklen Materie

Klypin, Kravtsov, Gottlöber

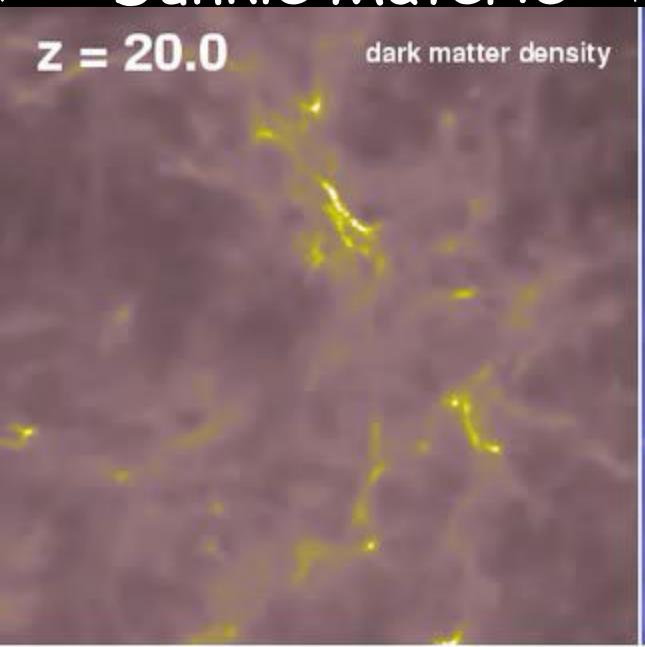


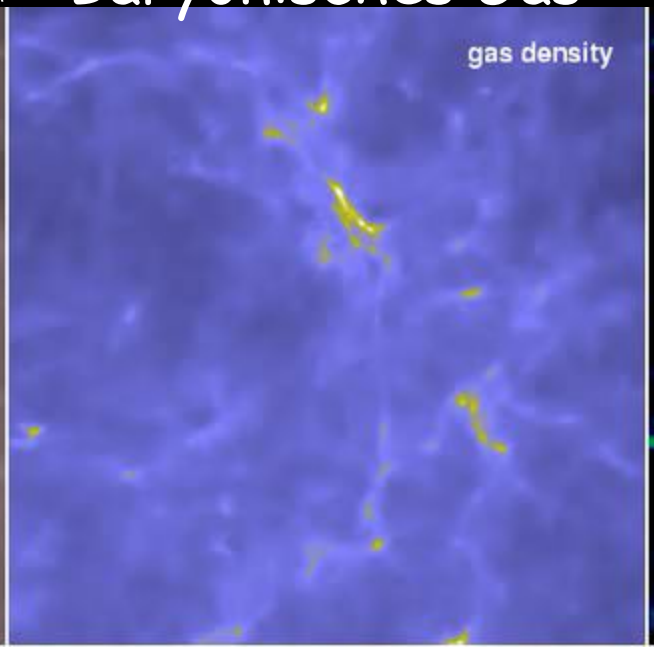
Bildung und Evolution der Galaxienhaufen

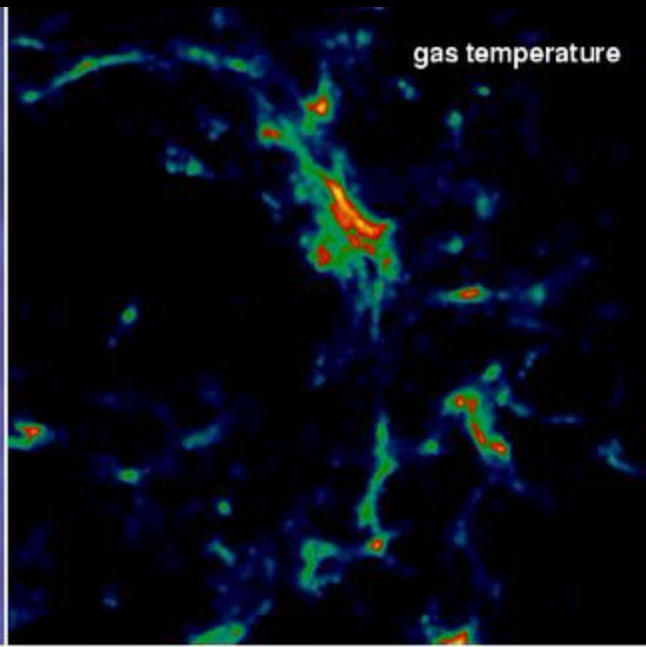
Dunkle Materie

Baryonisches Gas

Springel et al., 2003



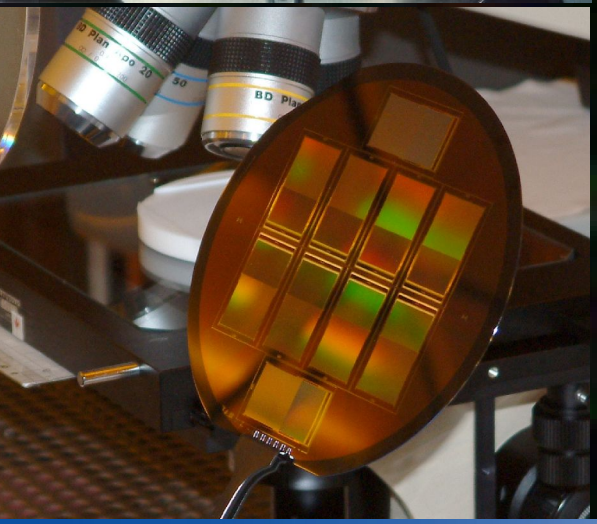


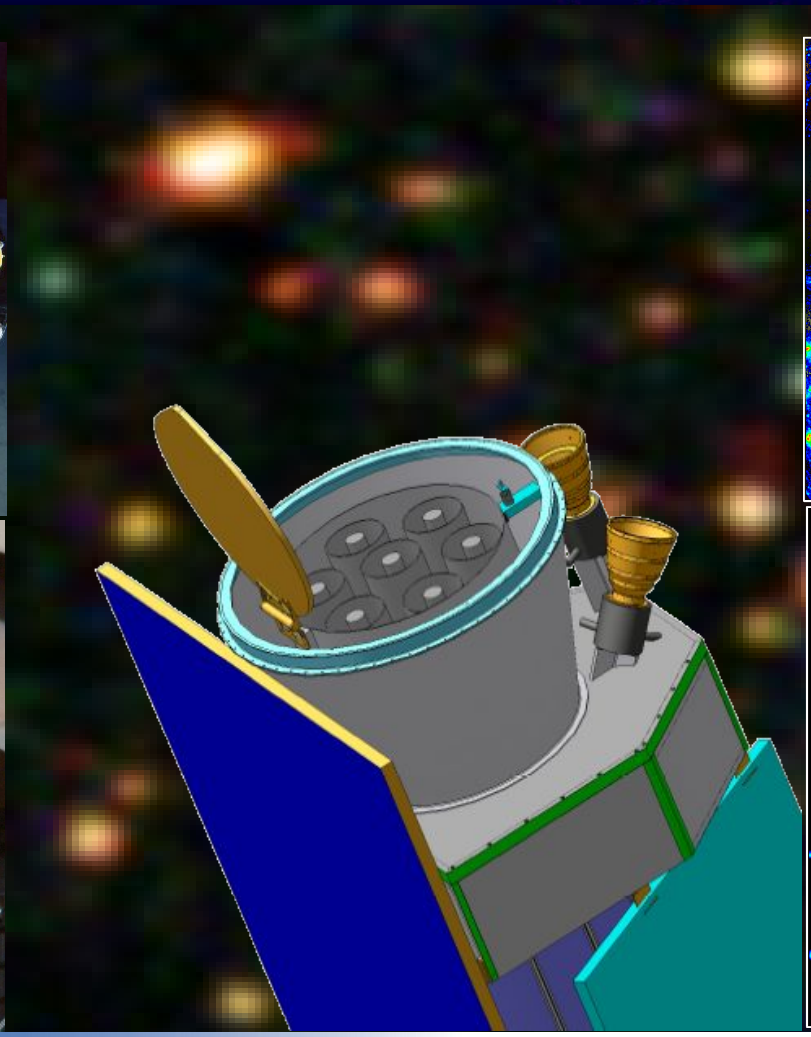


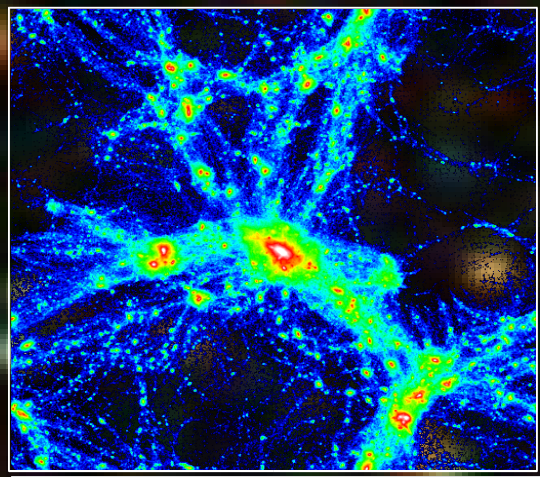
DUO

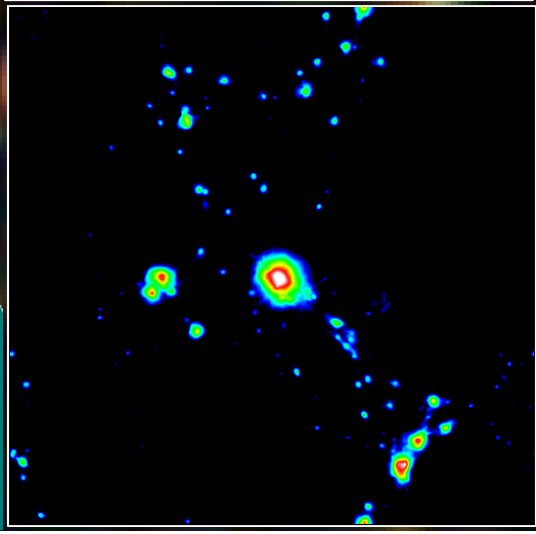
Dark Universe Observatory

Into the darkness peering…



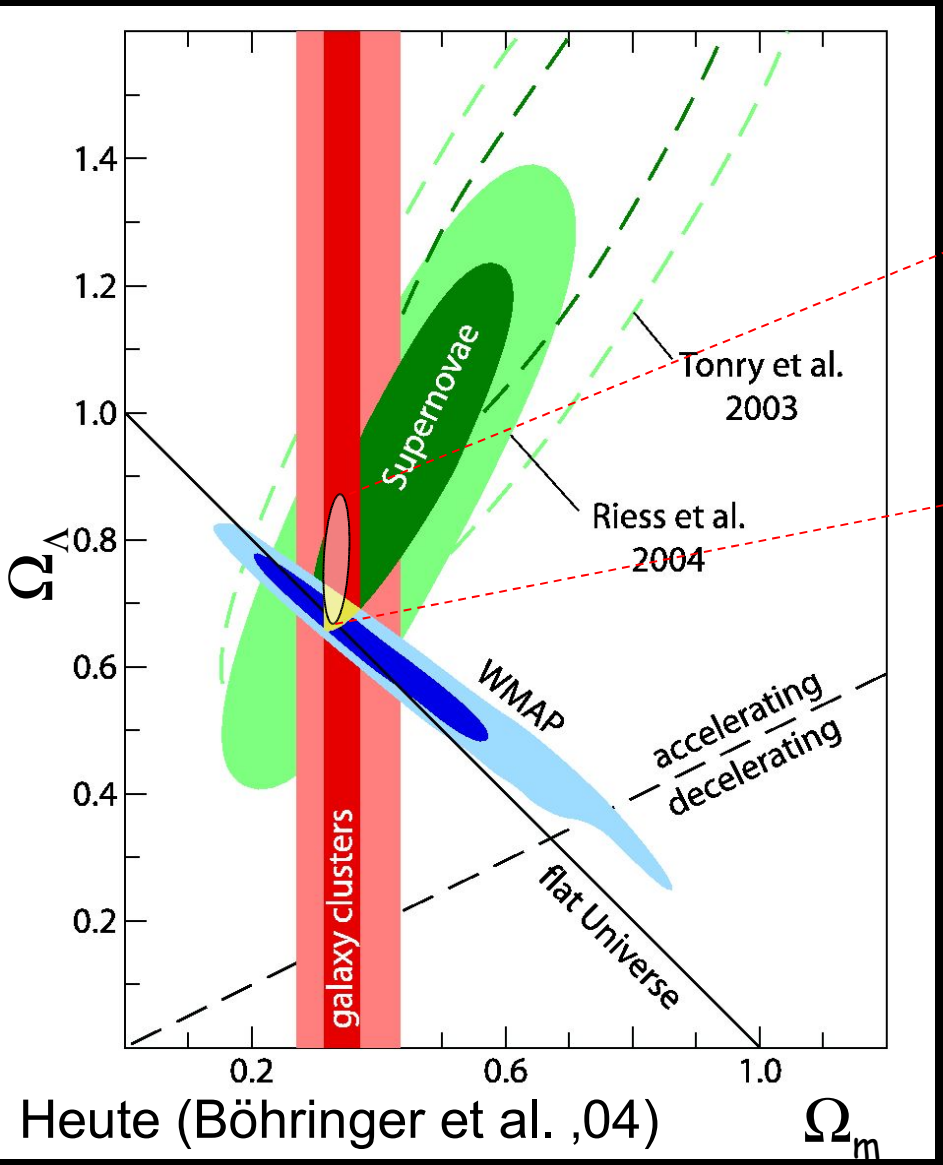




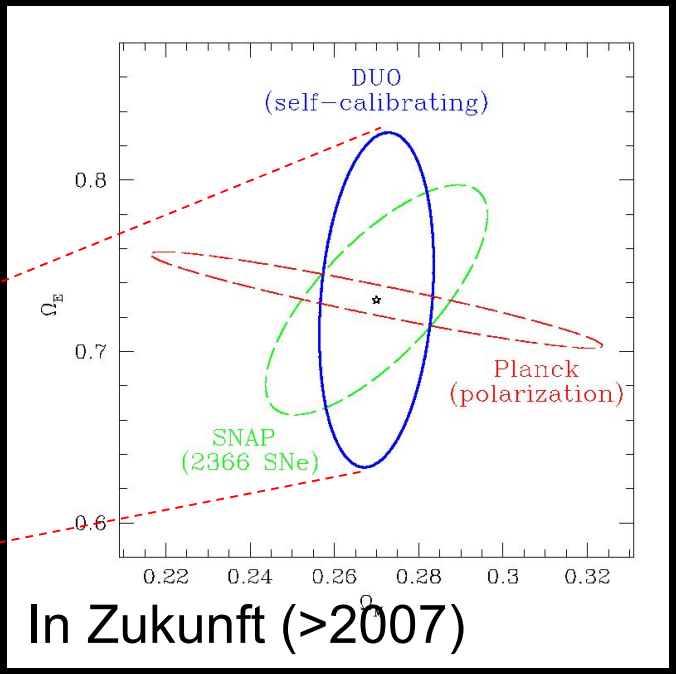


PI: R. Griffiths (CMU)
currently competitive NASA Phase-A study
0.1-10 keV sky survey for clusters
Study of Dark Energy

Dunkle Materie und Dunkler Energie



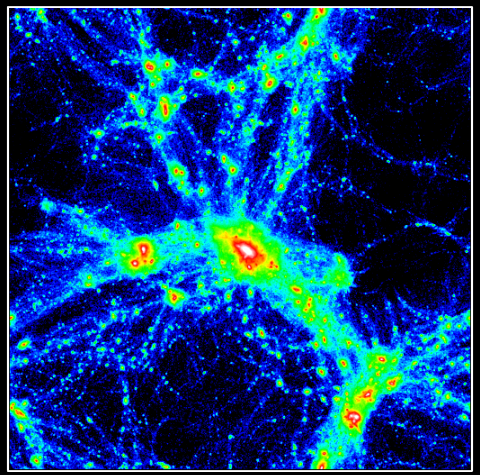
Heute (Böhringer et al. ,04)



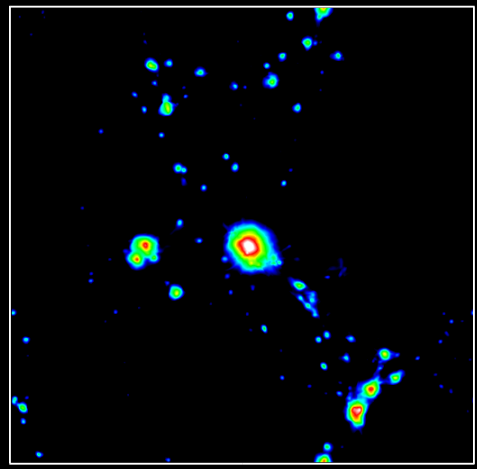
In Zukunft (>2007)

DUO

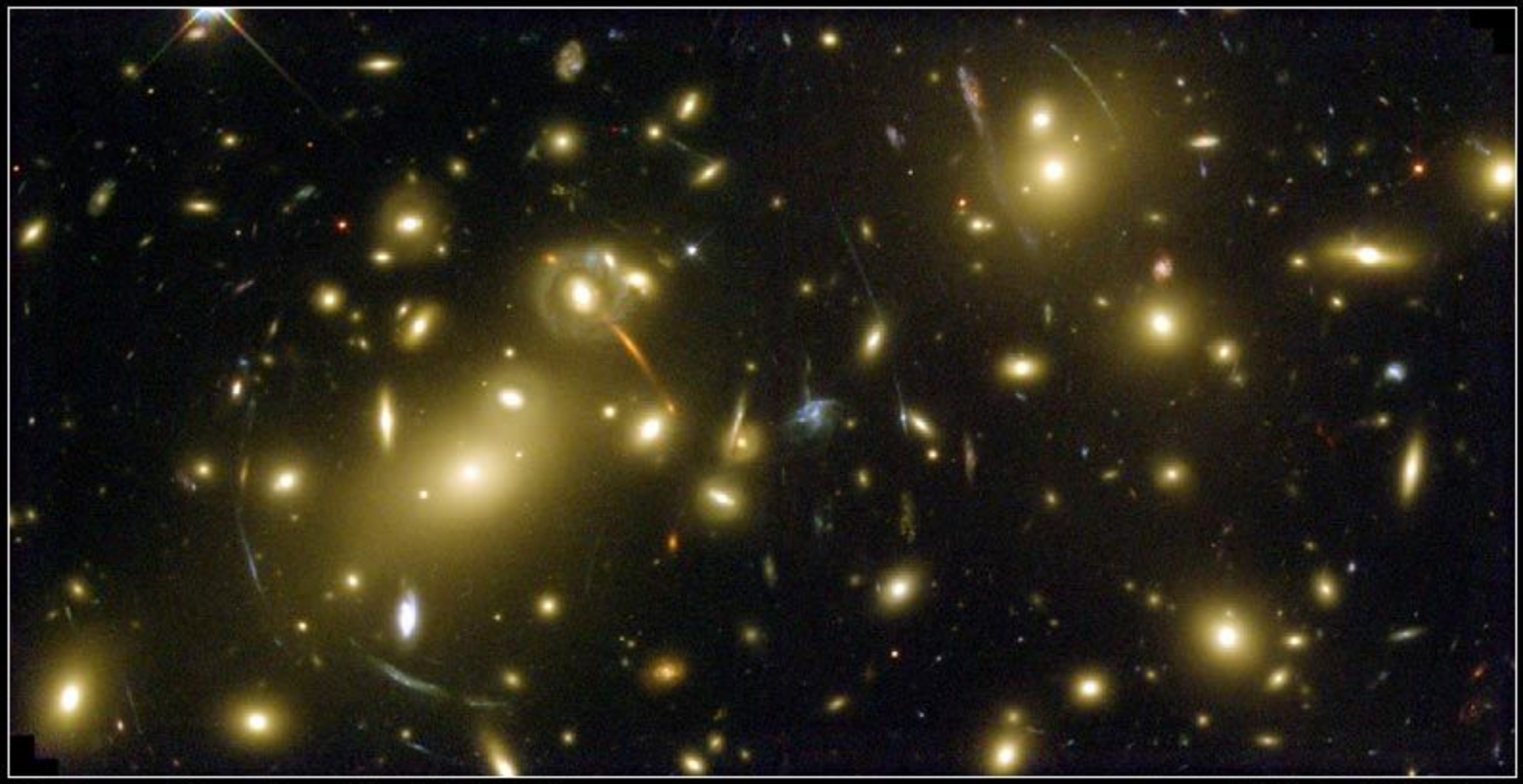
Dunkle Materie (23%)



X-ray Gas (4%)



Galaxienhaufen

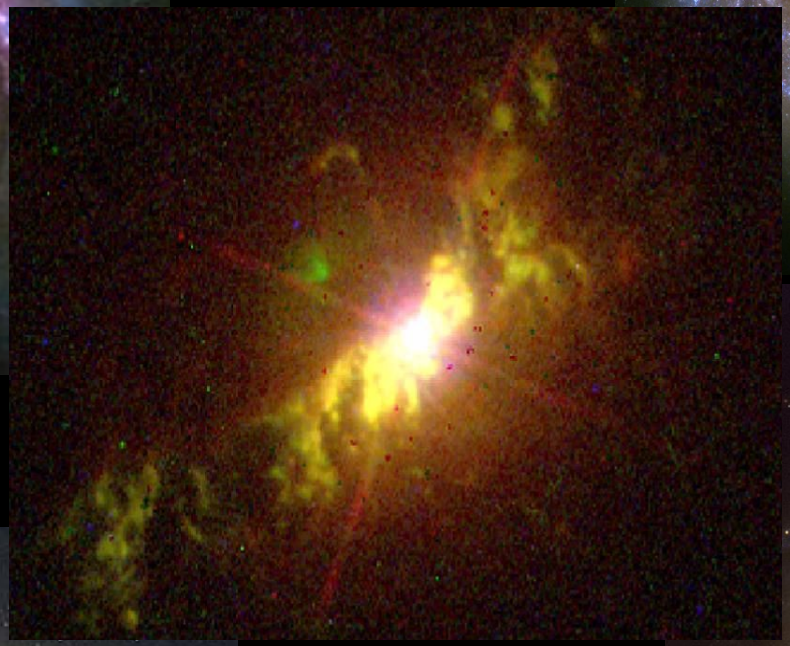


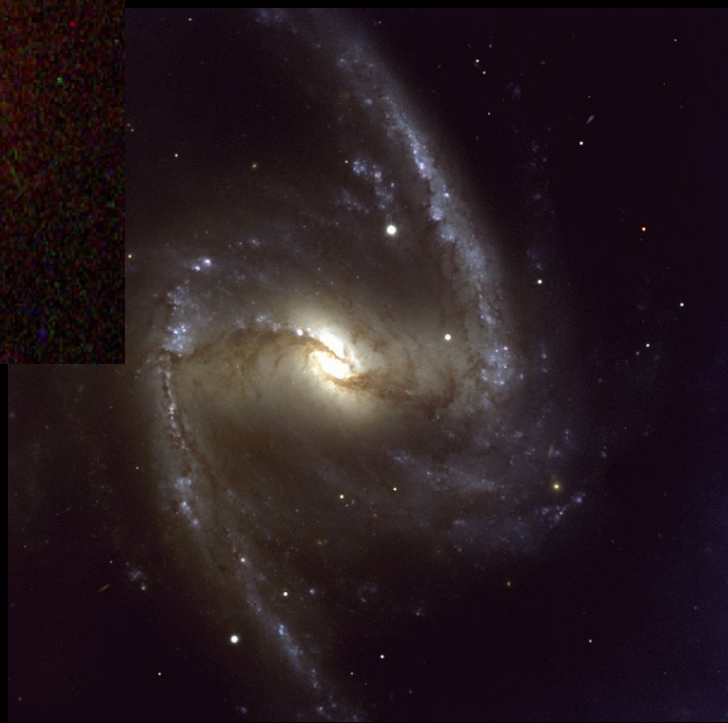
Galaxy Cluster Abell 2218 **HST • WFPC2**

NASA, A. Fruchter and the ERO Team (STScI, ST-ECF) • STScI-PRC00-08

⇒ Galaxien bilden nur einen kleinen (0.5%) Anteil, der Rest ist heißen Gas und Dunkler Materie

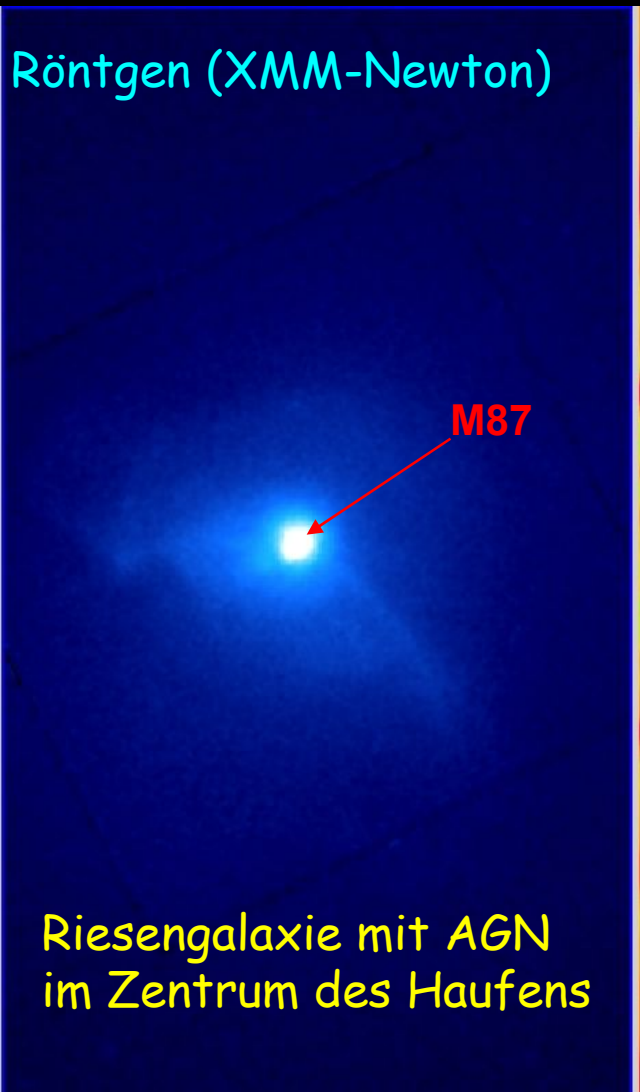
Die Welt der Galaxien

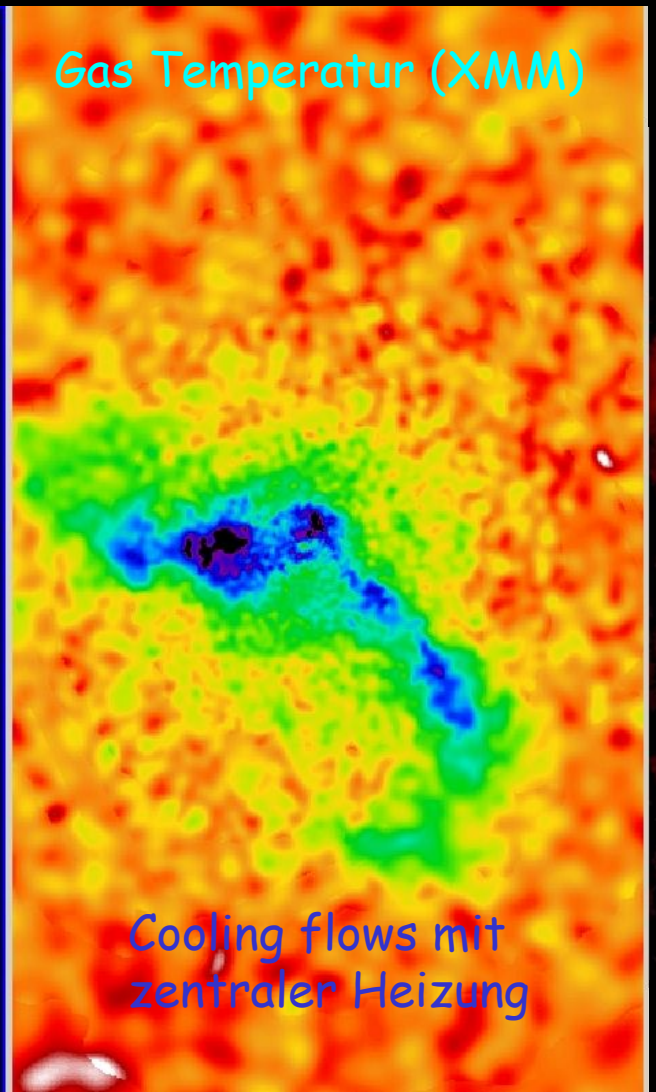


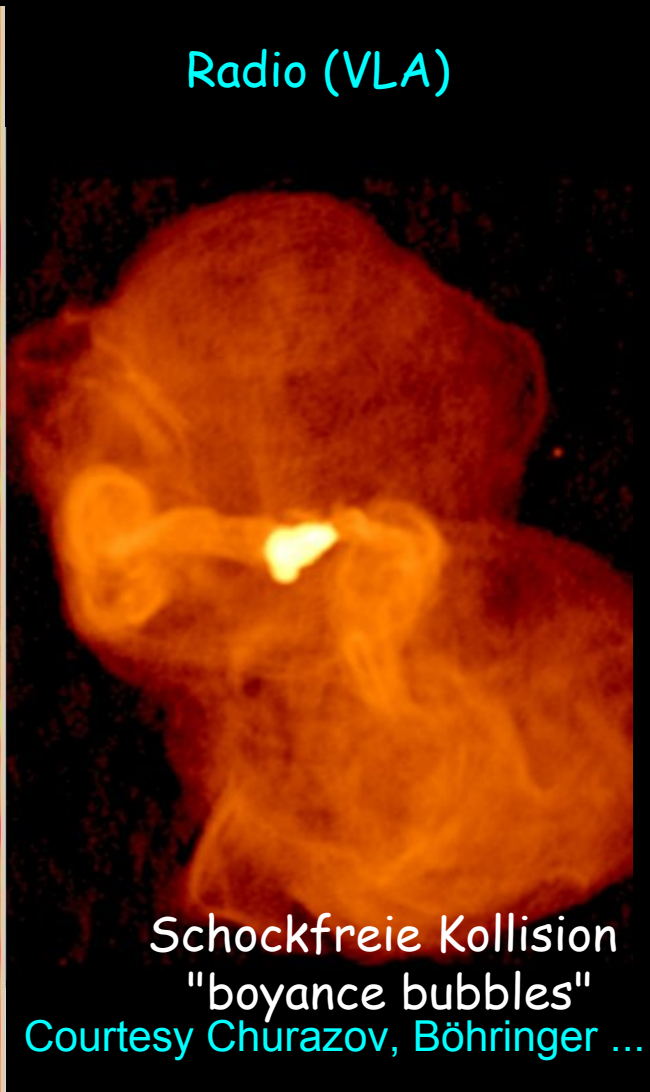


Einfluß eines energetischen AGN

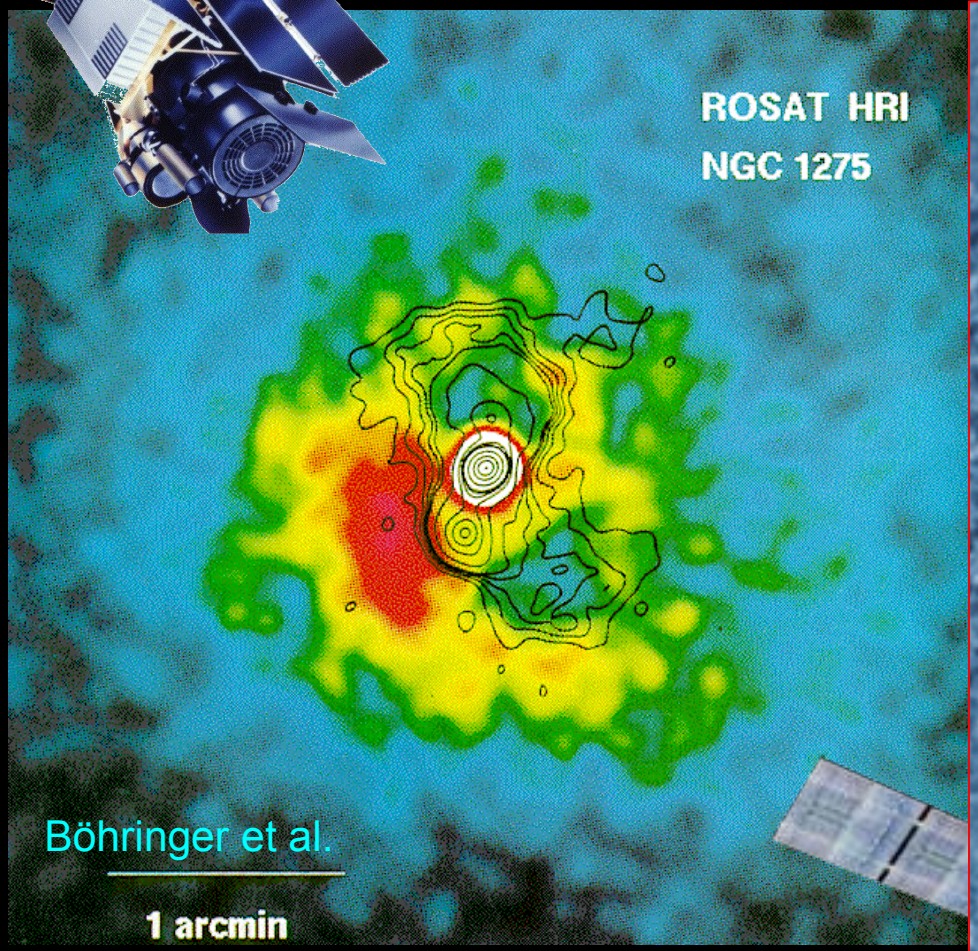
(z.B.) auf den Virgo-Haufen

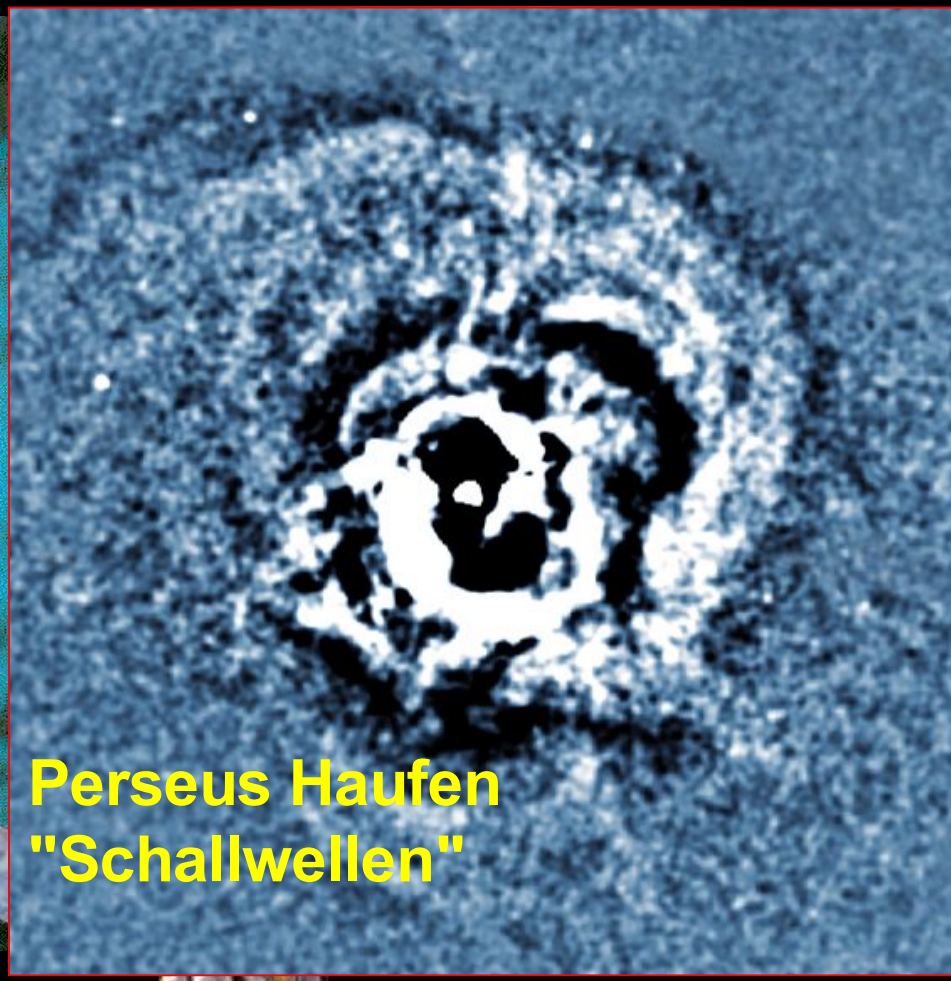






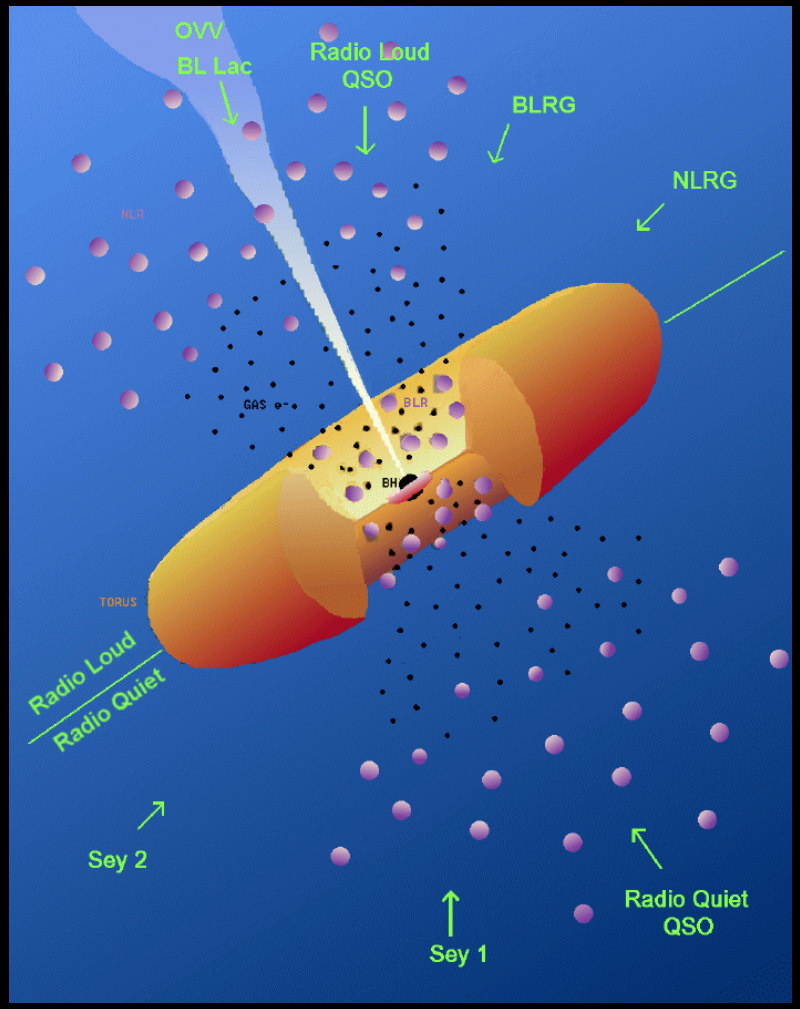
... oder auf den Perseus Haufen

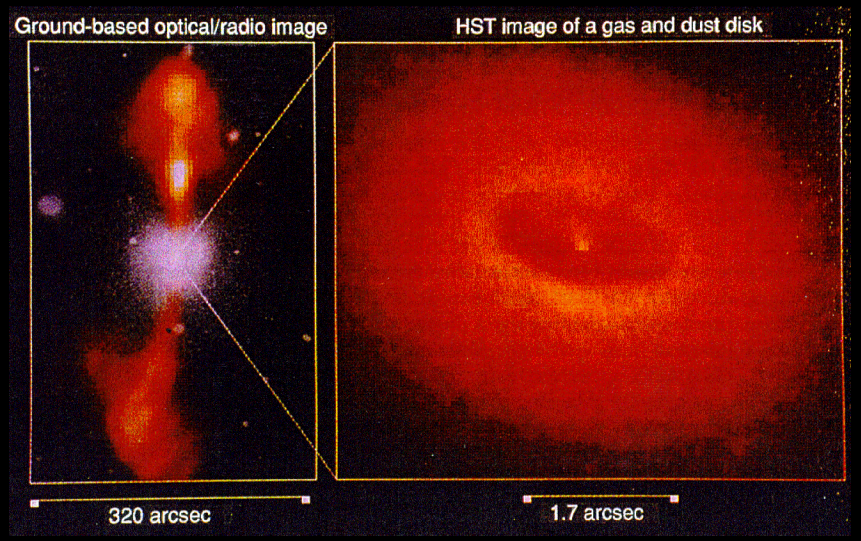




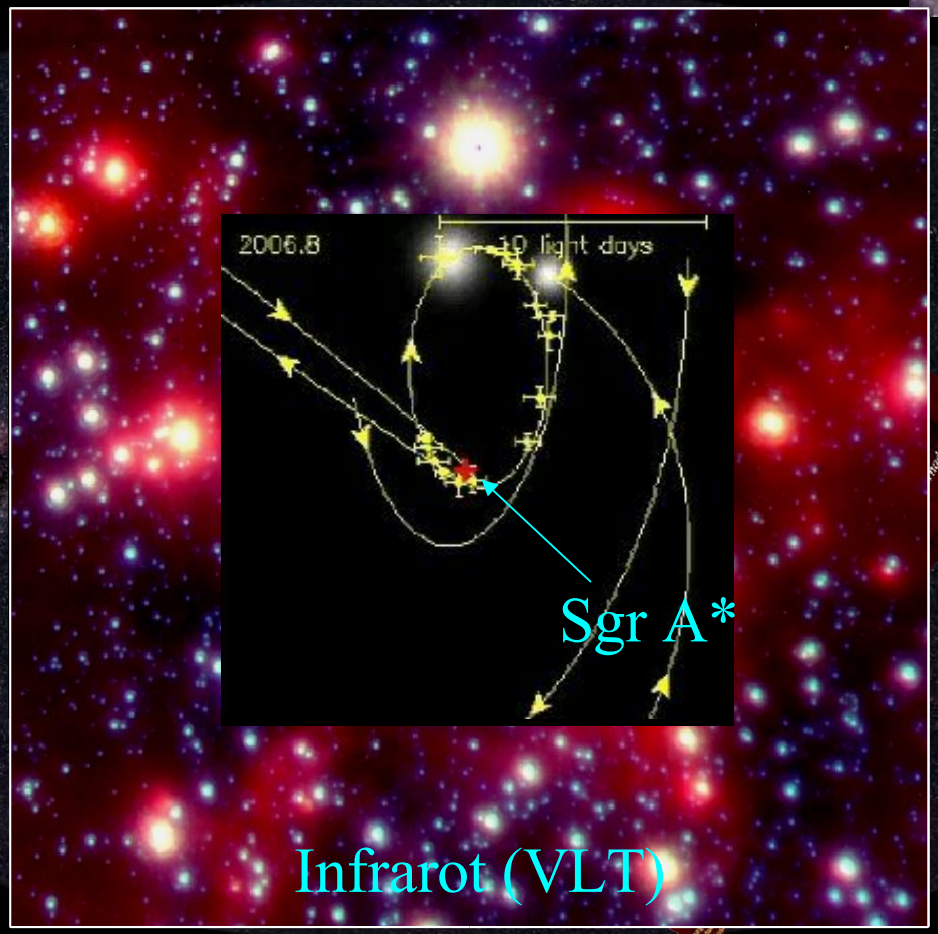
Energetsche zentrale Scharze Löcher beeinflussen die Struktur des Haufens!

Vereinheitlichtes Bild der AGN



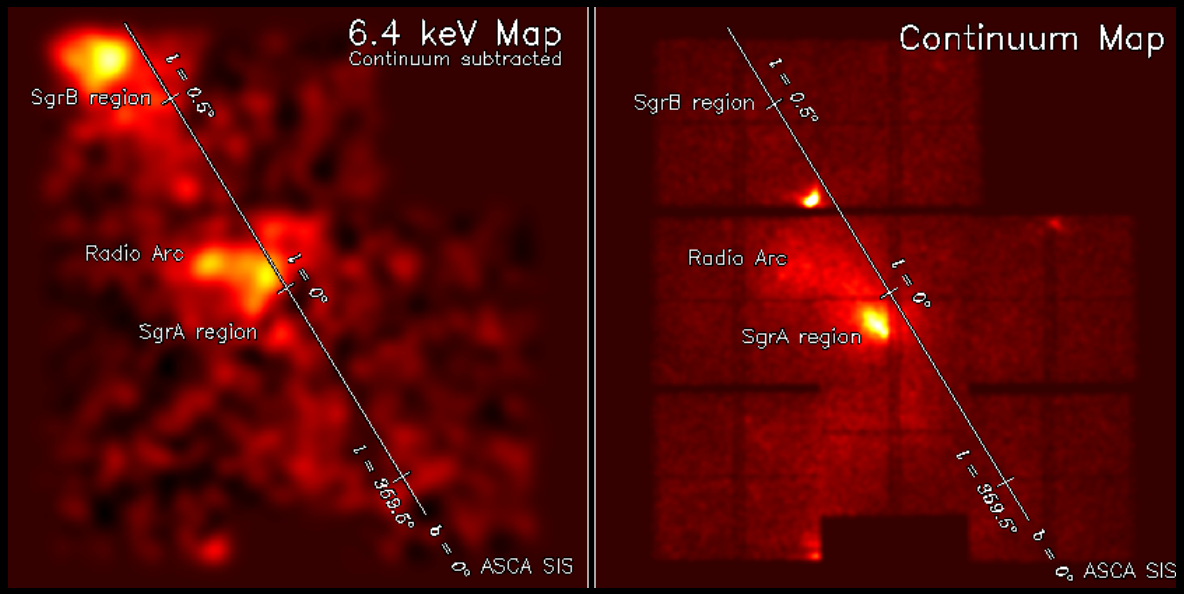


Unsere Milchstraße



Schwarzes Loch mit 3-4 × 10^6 M_o im Galaktischen Zentrum

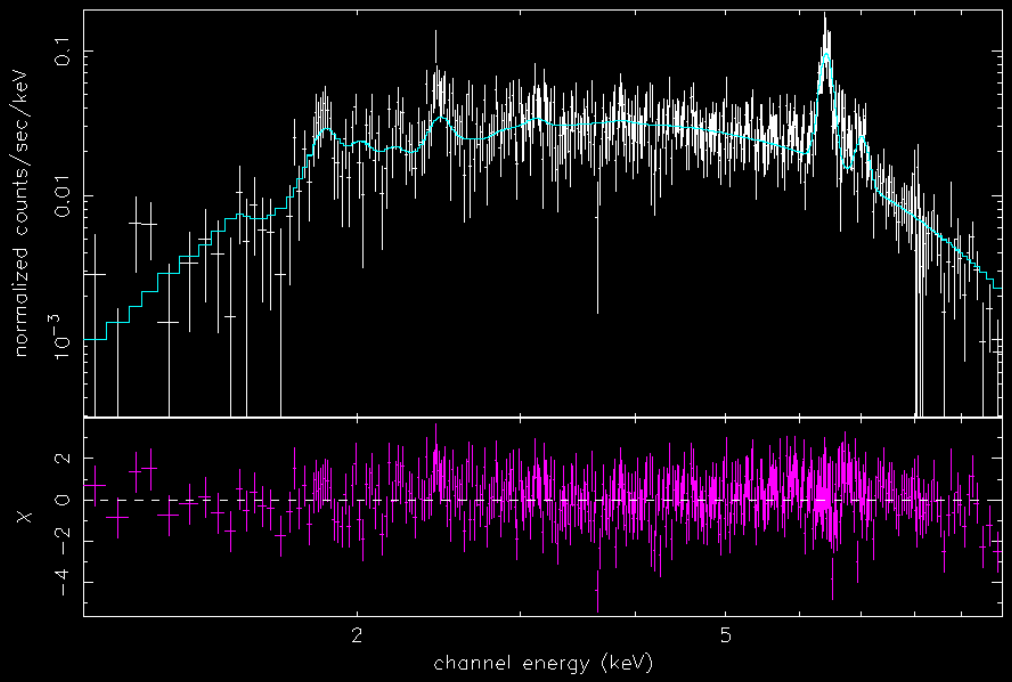
Frühere AGN-Tätigkeit?

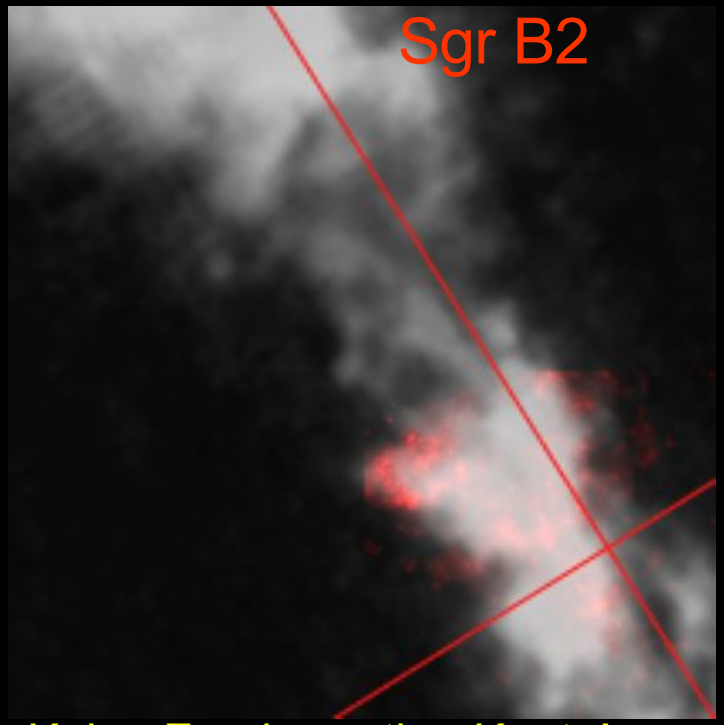


ASCA:
Fe Kα Fluoreszenz
Röntgenquelle?
> 10^{39} erg s^{-1} benötigt

Sunyaev 1993, Koyama 1996, Murakami 2000

6.4 keV Fe Kα





Keine Fe-absorption Kante!

\+ *Bremsstrahlung:* kT = 8.6 ± 1.2 keV

\+ *Linien* 6.4 keV, 7.05 keV, 8.04 keV

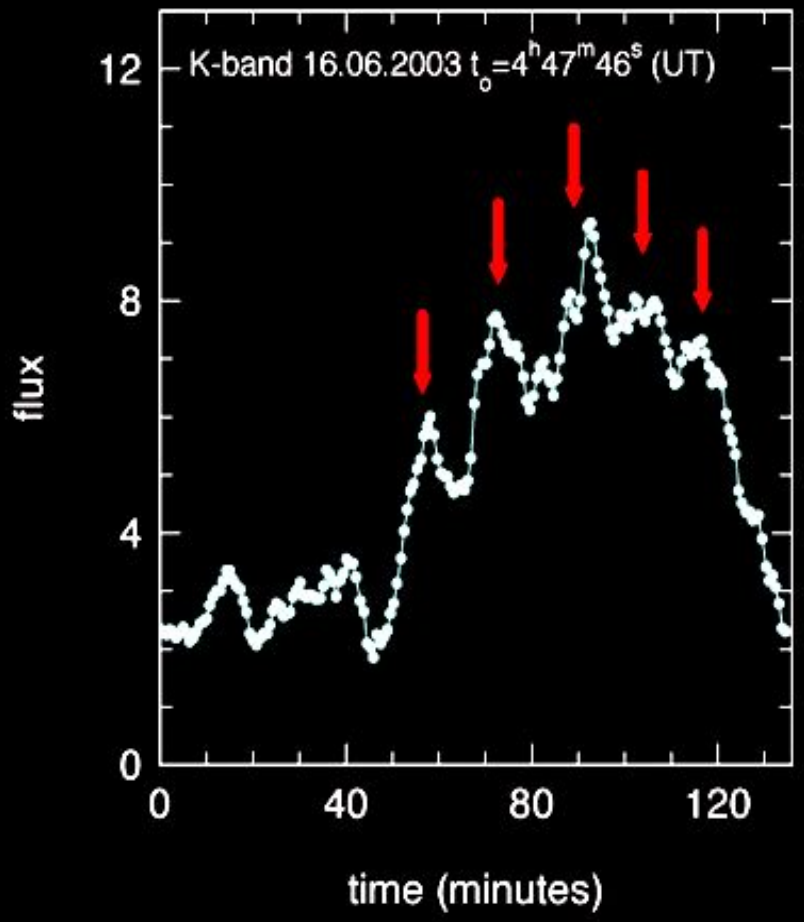
N_H ~ 4.7 ± 0.3 × 10^{22} cm-2

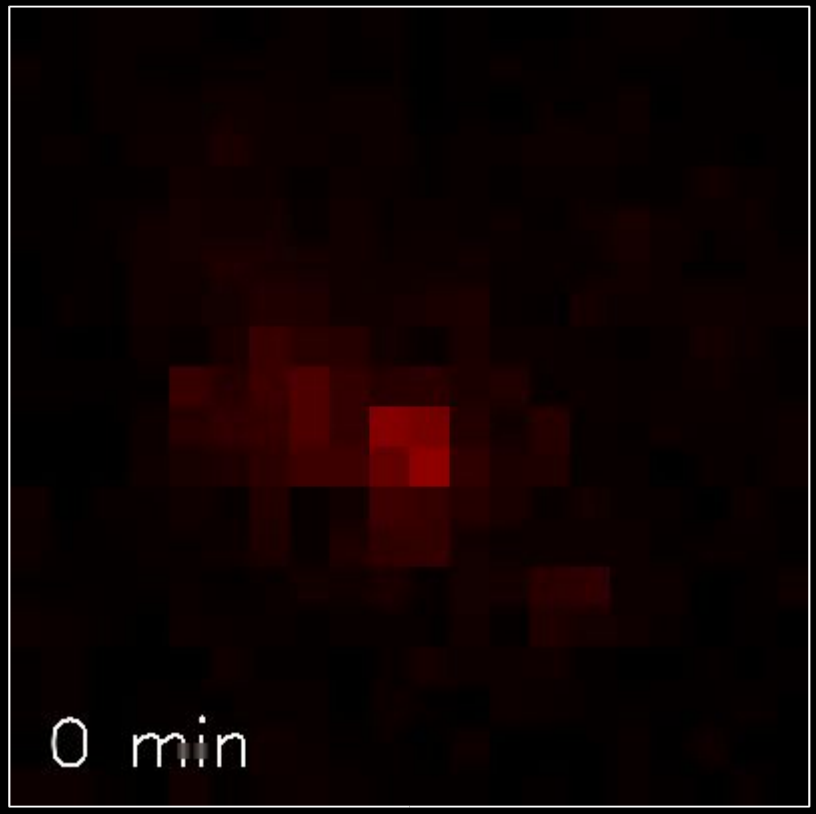
$EQW_{K\alpha}$ = 1.05 keV $EQW_{K\alpha}$ ~ 150 eV

Elektronen – Anregung

Predehl, Tanaka, 2002

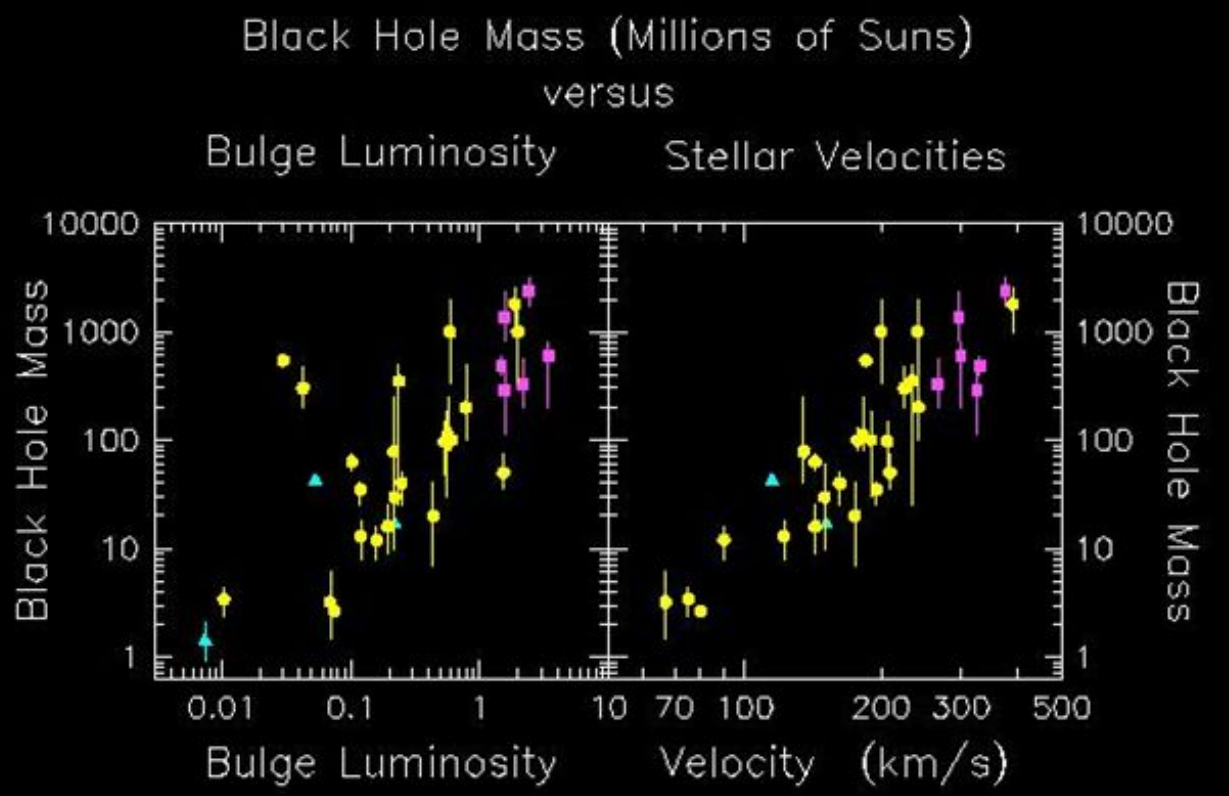
Sgr A*





Flares im X-ray und IR- Bereich,
quasiperiodische Substrukturen
$\rightarrow$ schnell rotierendes BH

"Demoskopie" Scharzer Löcher

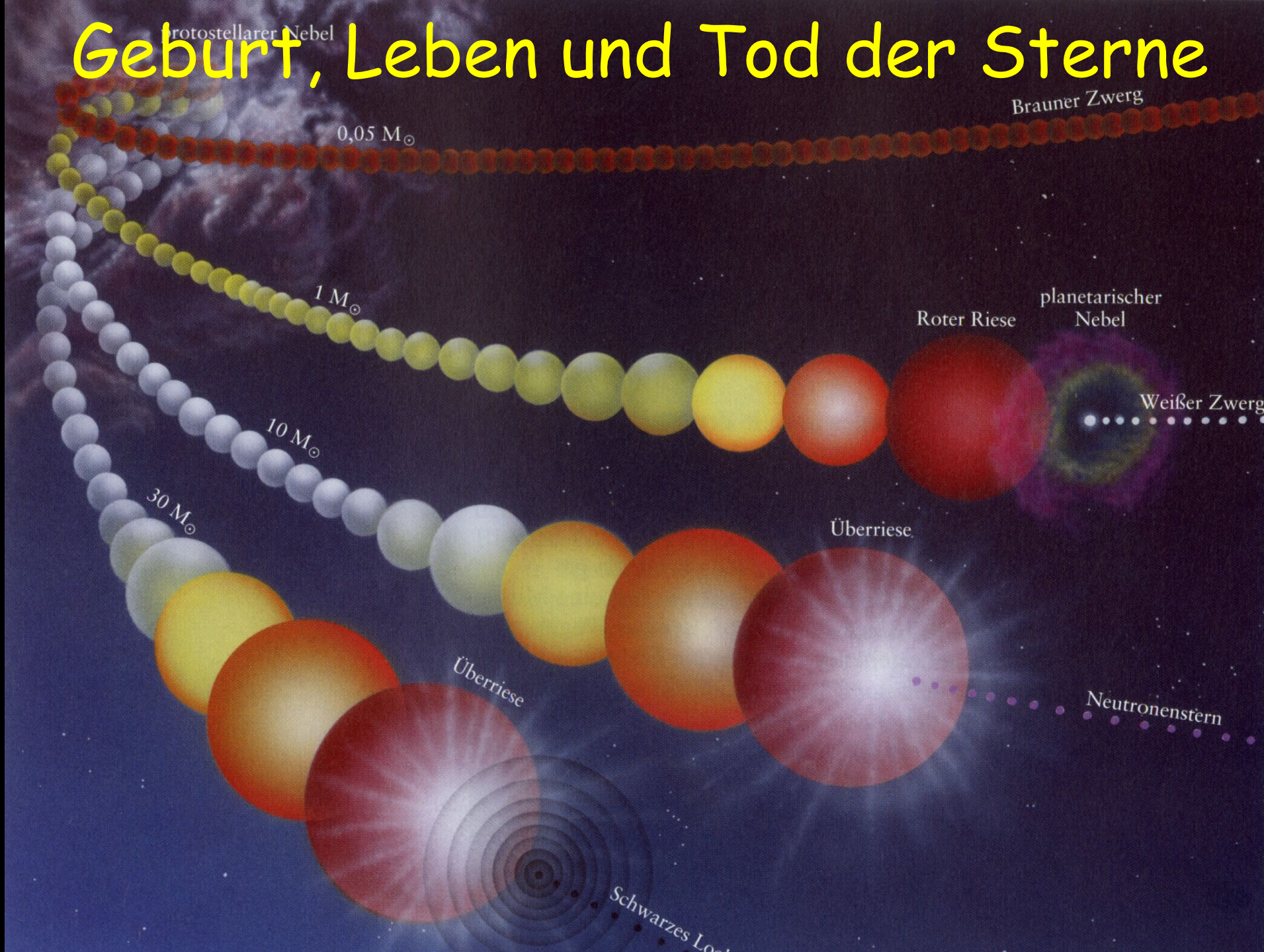


Supermassive Schwarze Löcher in jeder Galaxie mit einem zentralen "Bulge".

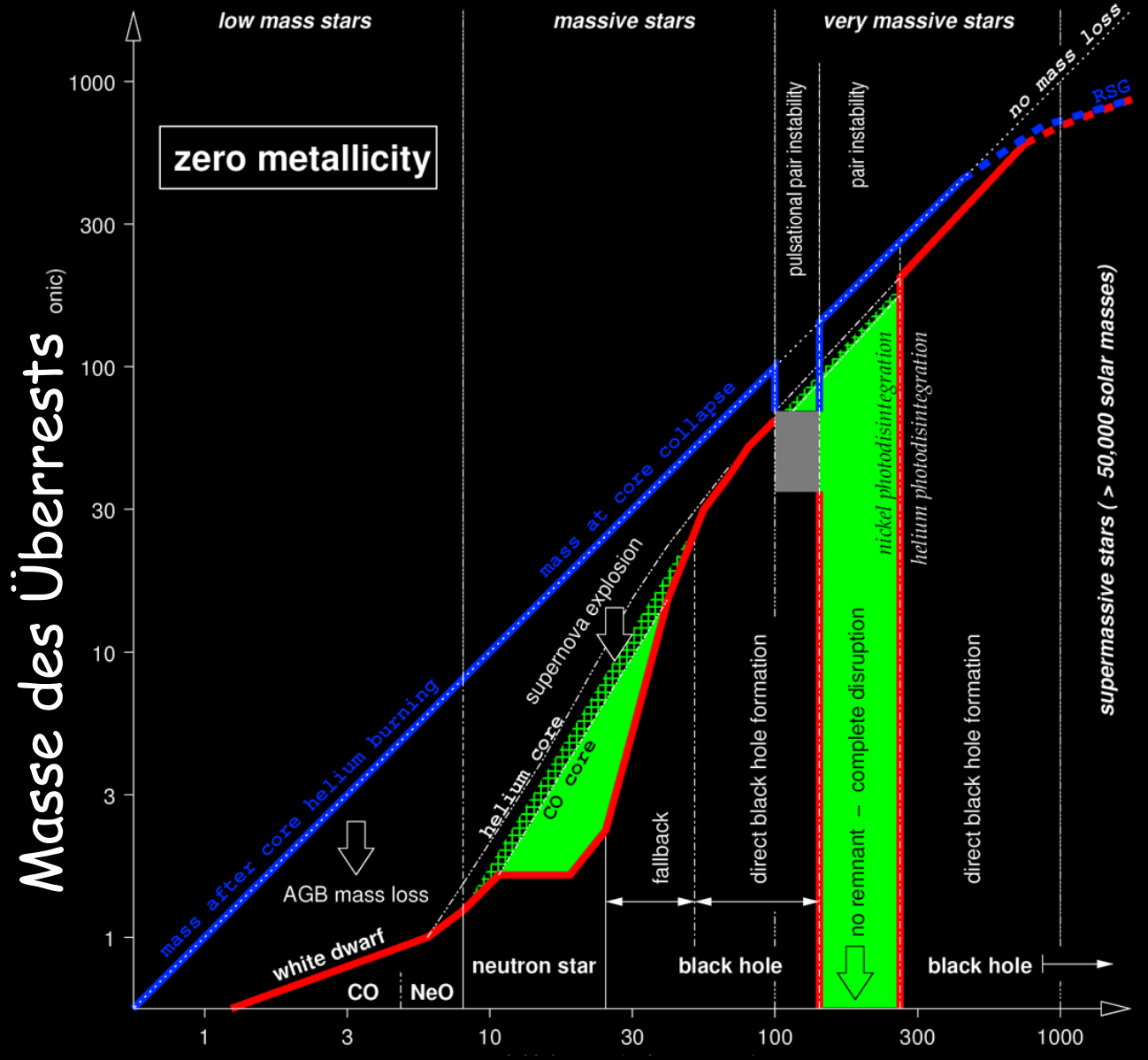
⟶ Wechselwirkung zwischen Schwarzem Loch und Galaxie!

Entstehung supermassiver Schwarzer Löcher

Geburt, Leben und Tod der Sterne



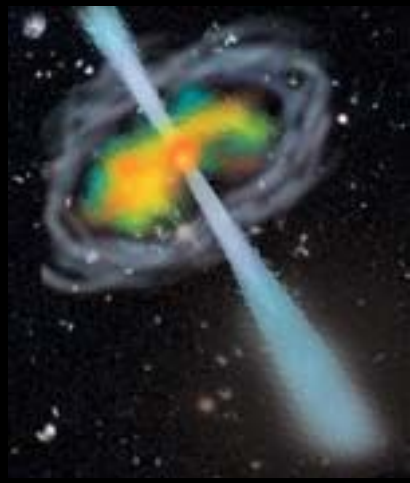
Stellare Überreste

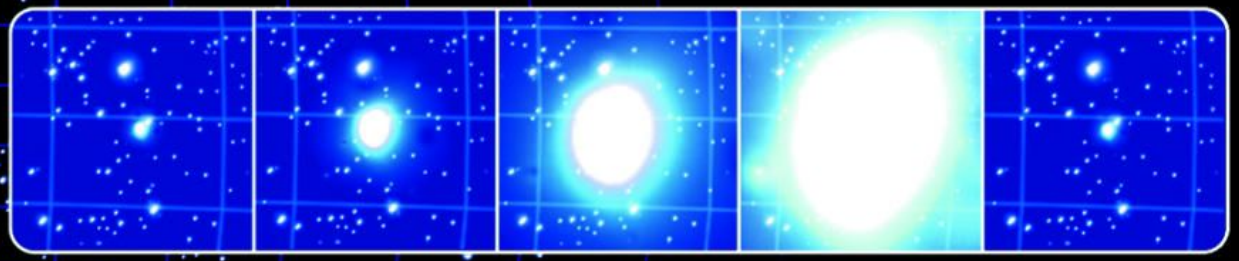


Anfängliche Sternmasse

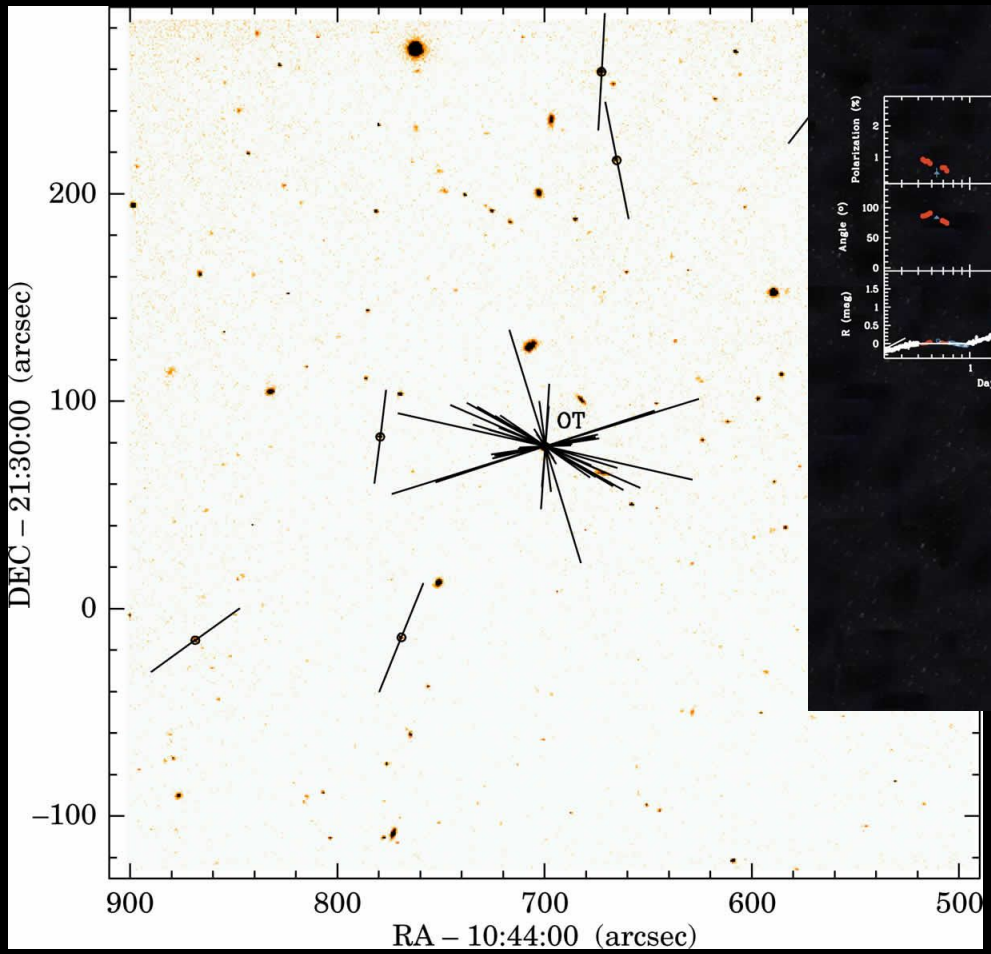
Gamma-ray Bursts

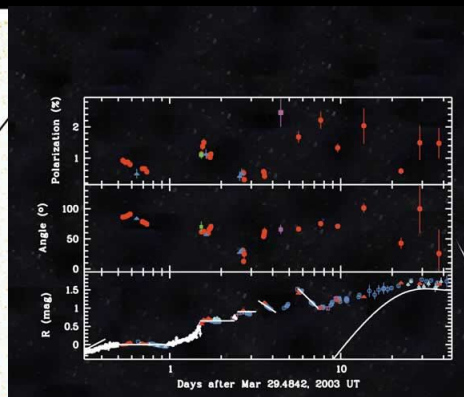
Geburt stellarer Schwarzer Löcher in Hypernova?!

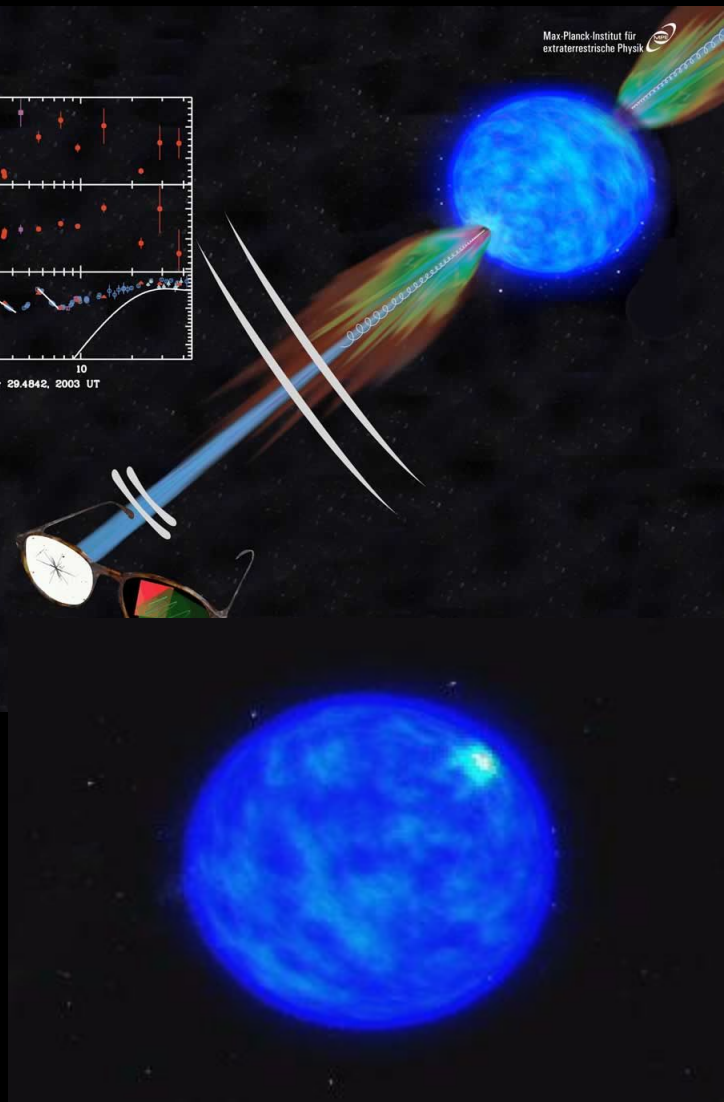


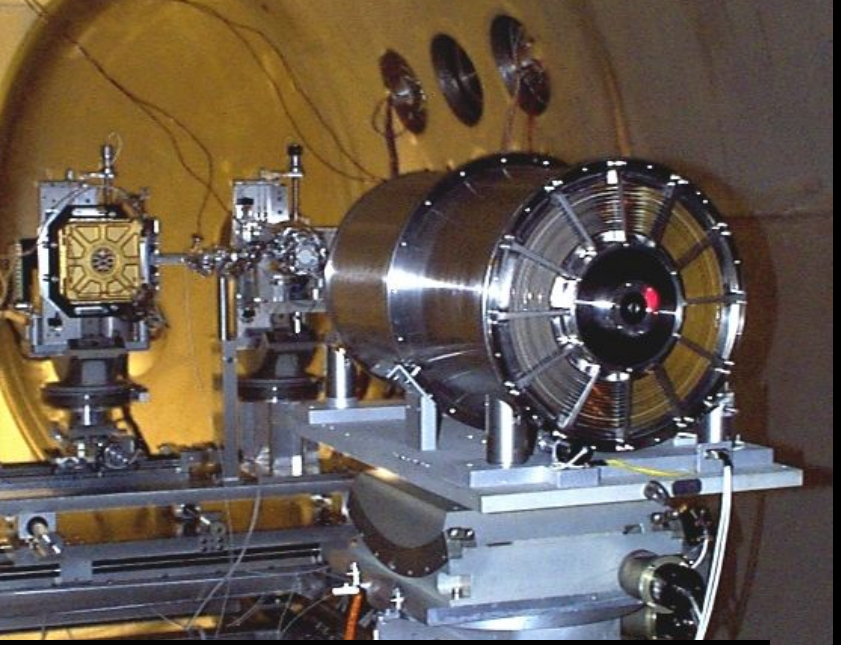


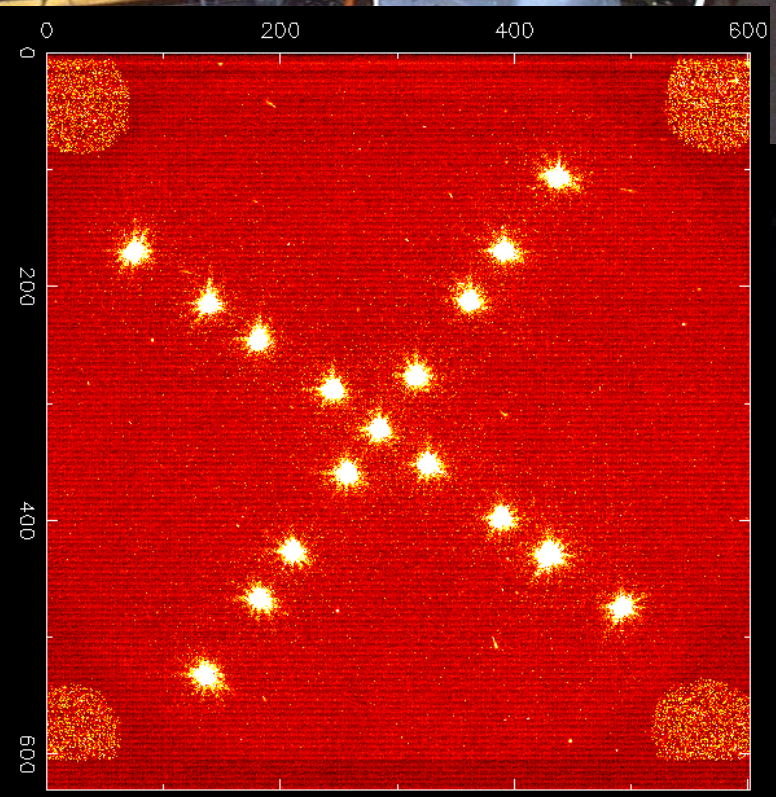
Polarization des Afterglows









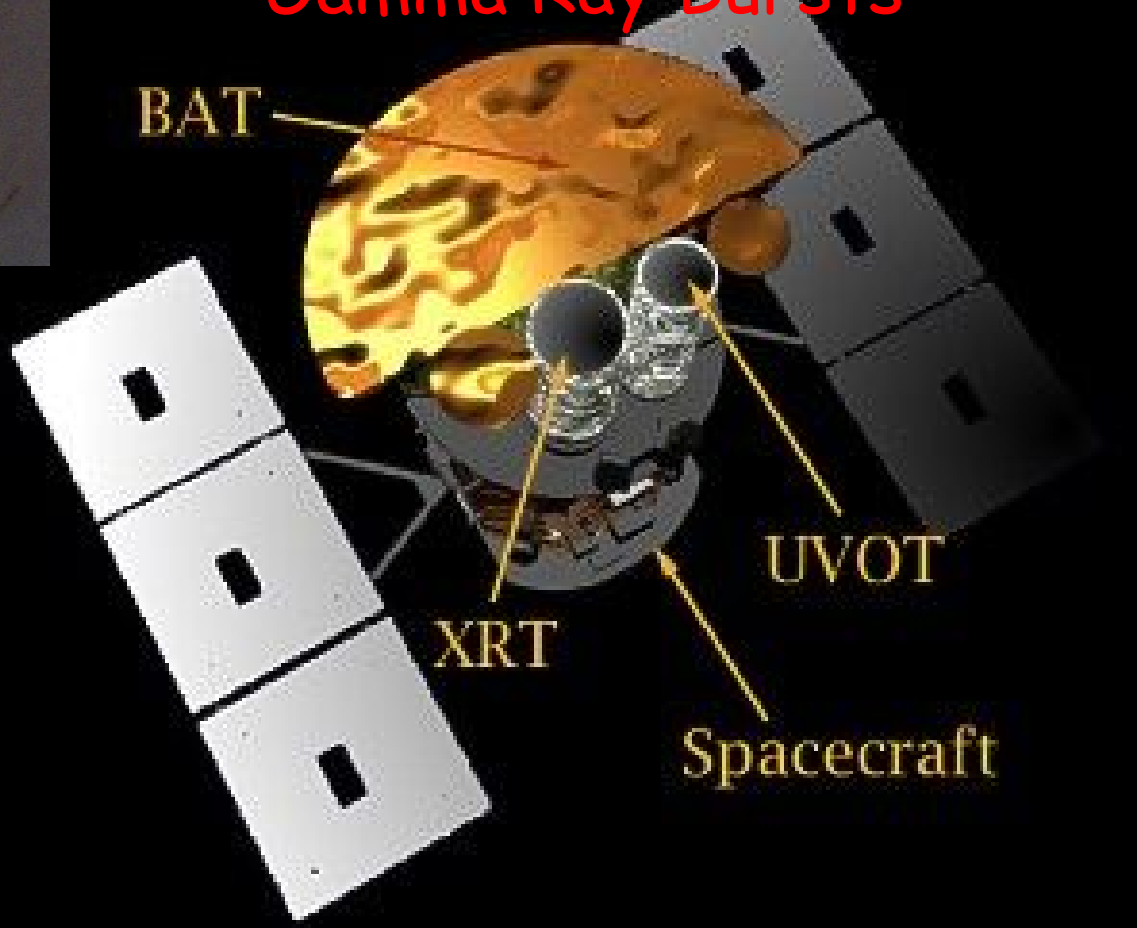


Swift

NASA/UK/I/D

Launch Oct 28th, 2004

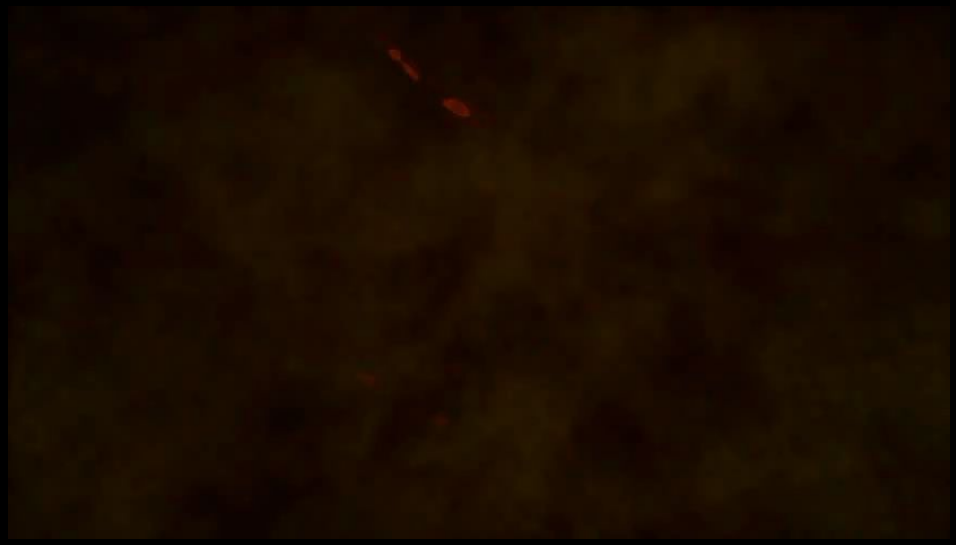
Chase high-redshift Gamma Ray Bursts



Entstehung der ersten Sterne und Schwarzen Löcher

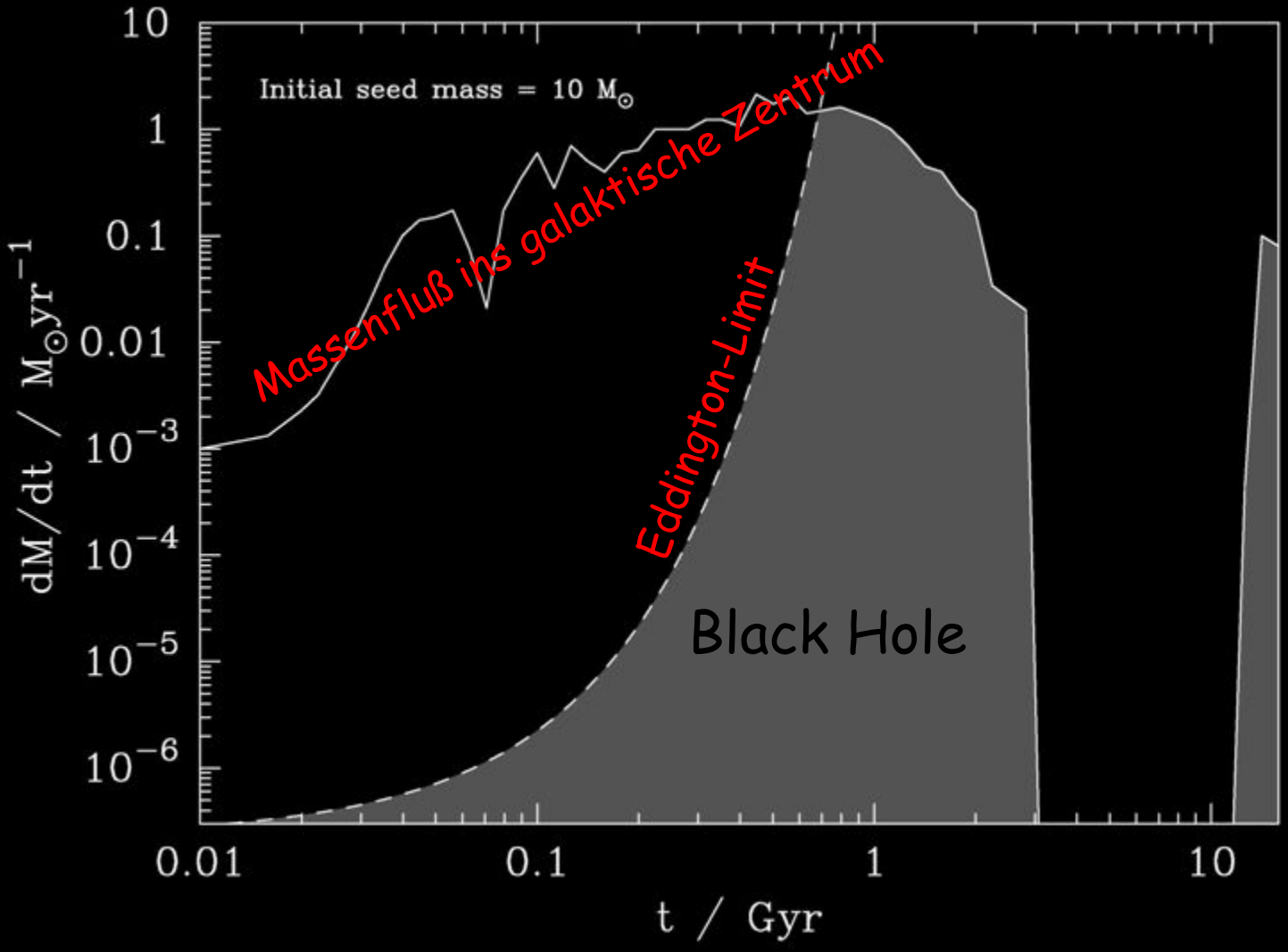
Bevor der erste Stern überhaupt entstehen kann, muss sich das Universum genügen (~100K) abgekühlt haben!

Tom Abel &
Discovery Channel



Der erste Stern war wahrscheinlich sehr massiv (300-1000 $M_\odot$), strahlte während etwa ~1 Mio Jahre, "sterilisierte" seine Umgebung, explodierte in einer Hypernova, reicherte seine Umgebung mit schweren Elementen an und hinterließ ein Schwarzes Loch als Keimzelle für späteren AGN.

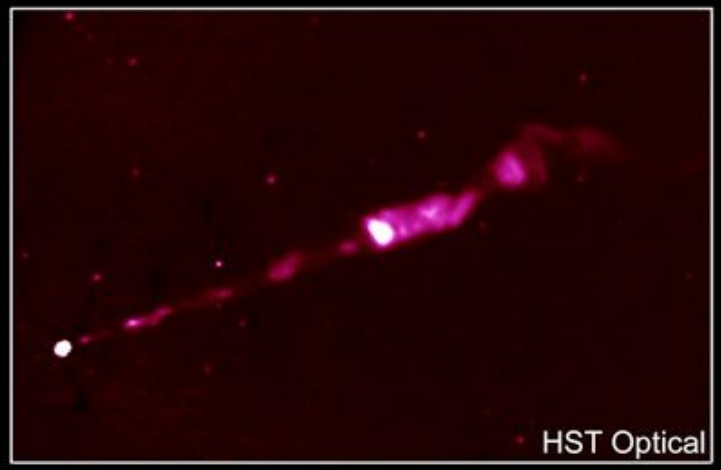
Entstehung der Quasare ?

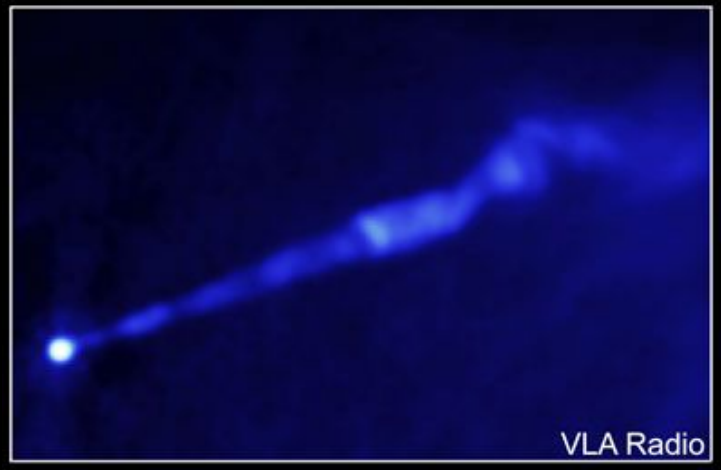


Archibald et al., 2001

Wie werden Schwarze Löcher gefüttert?

1. Aktive Schwarze Löcher

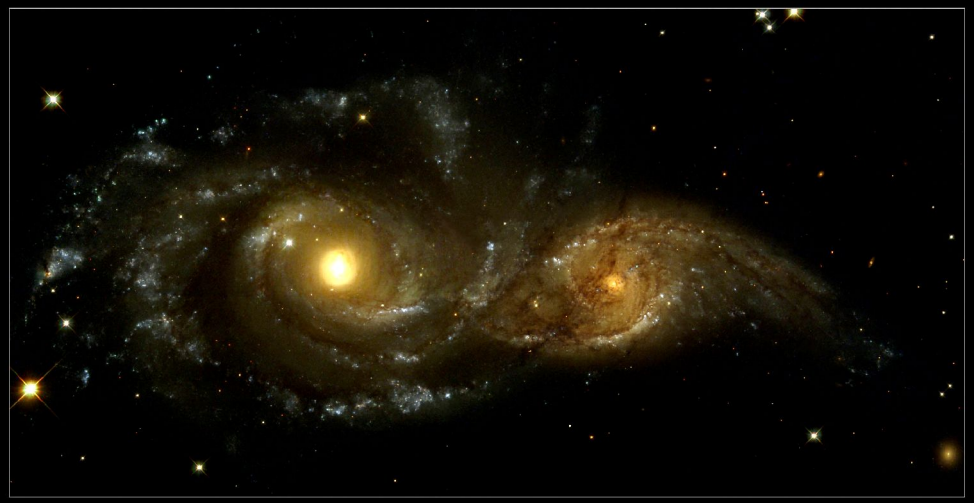


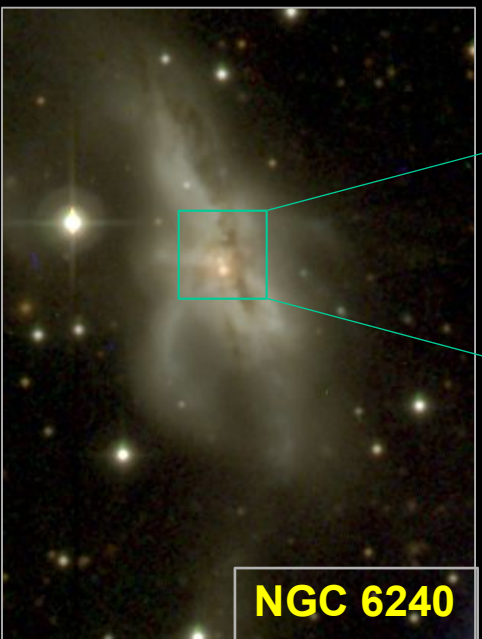


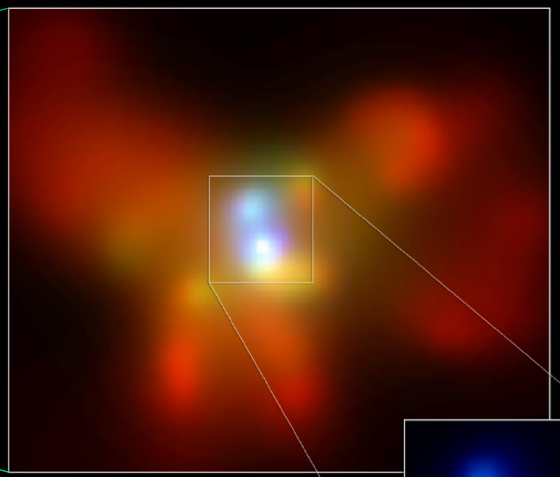
Animation: W. Steffen, Guadalajara

Problem: Materie muss Drehmoment verlieren, bevor sie auf das Schwarze Loch fallen kann.

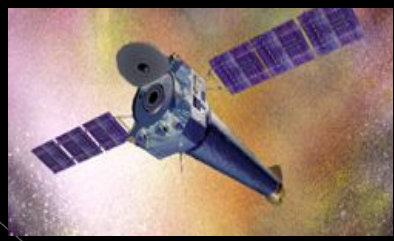
2. "Merger": Kollision von zwei Galaxien mit Schwarzen Löchern







Komossa et al., 2003 (MPE)



3. "Tidal Capture"

Ein ganzer Stern wir eingefangen und durch Gezeitenreibung zerrissen.

Nach einem hellen Aufleuchten im Röntgenlicht nimmt die Helligkeit kontinuierlich über etwa 10 Jahre ab.

Etwa 5 solcher Ereignisse wurden während der ROSAT Mission beobachtet.

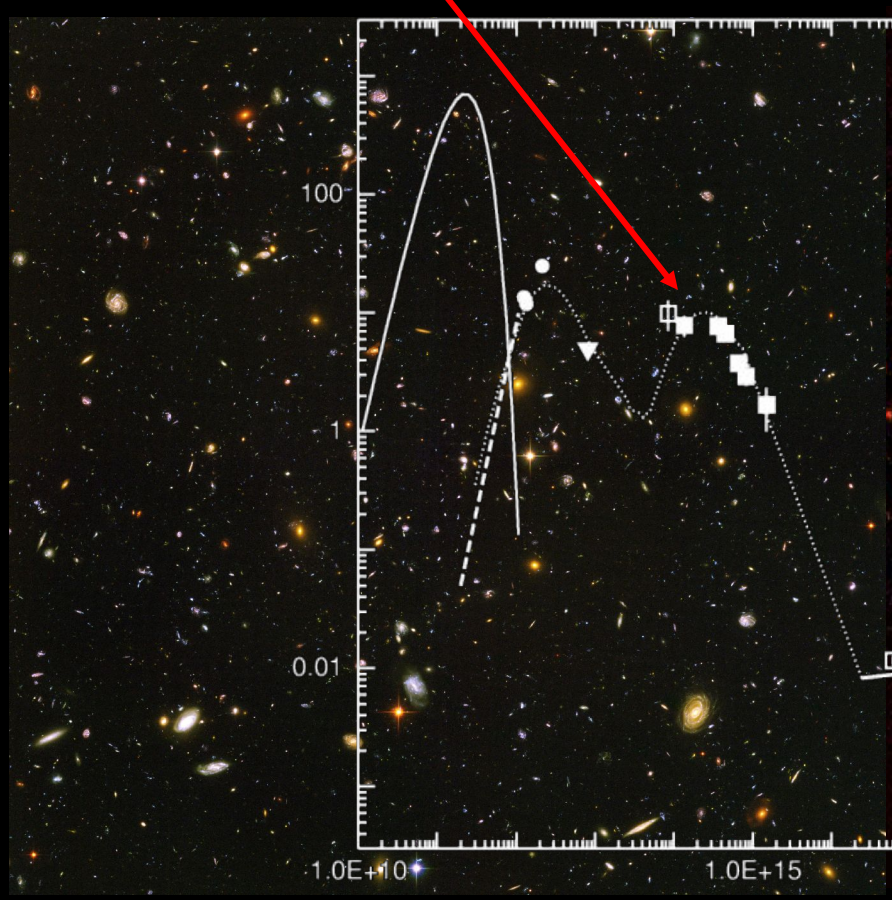
ROSAT, Chandra, XMM: Komossa et al., 2004

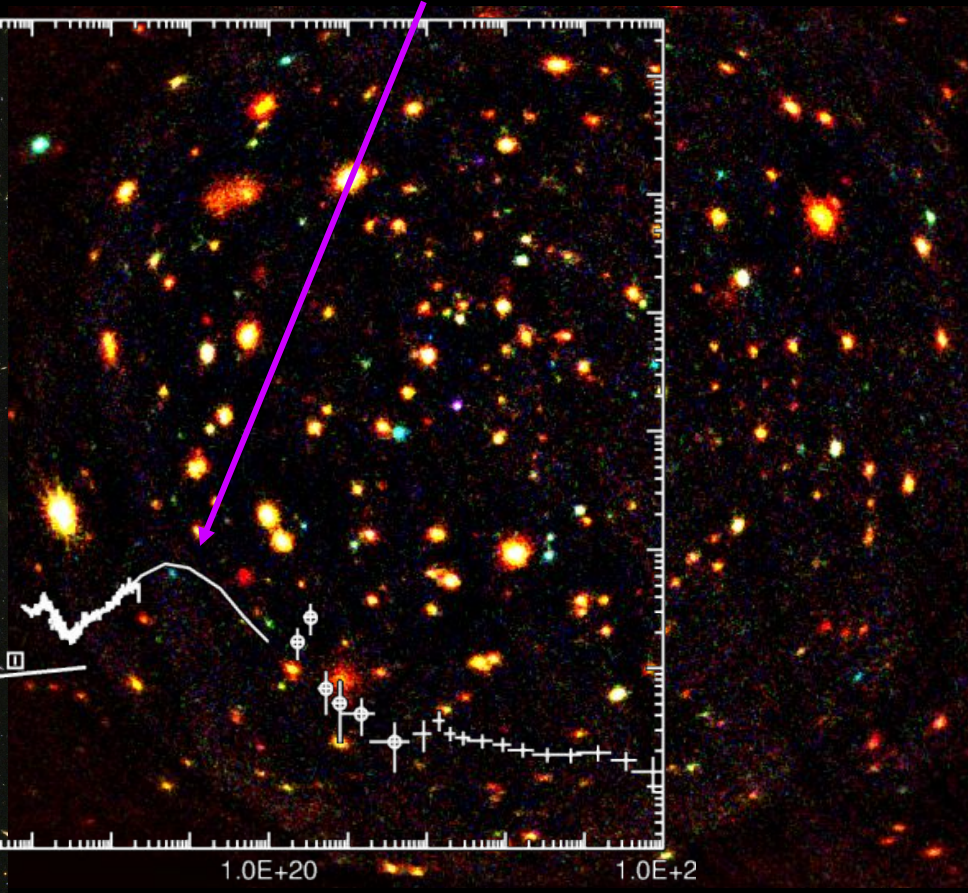
Kosmologische Entwicklung supermassiver Scharzer Löcher

Kalt und heiß

Das 6,000 K Universum:
Sterne

Das 1,000,000 K Universum:
Schwarze Löcher & heißes Gas





Hubble ACS Ultradeep Field

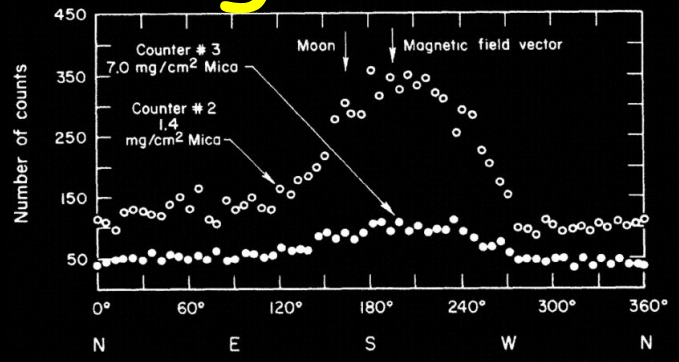
XMM-Newton 1 Msec Field

Der Röntgenhintergrund

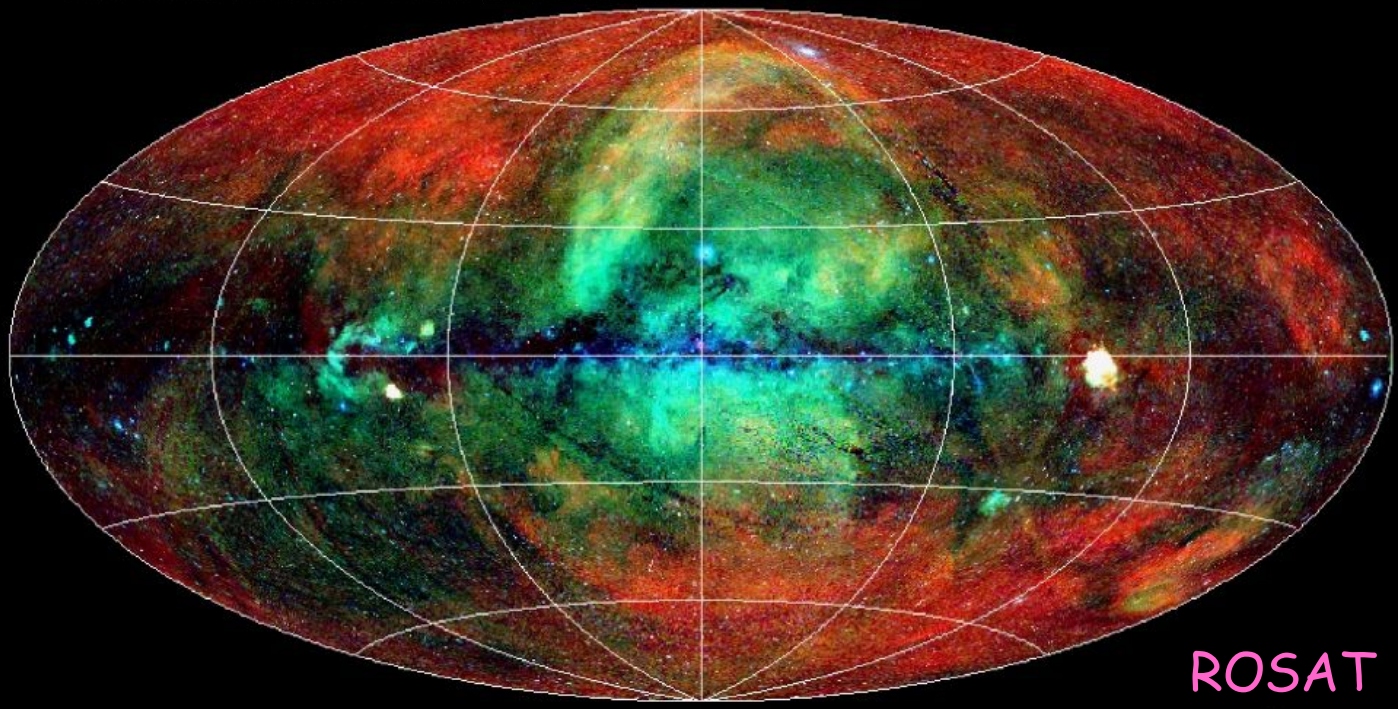
ROSAT

XMM-Newton

Chandra



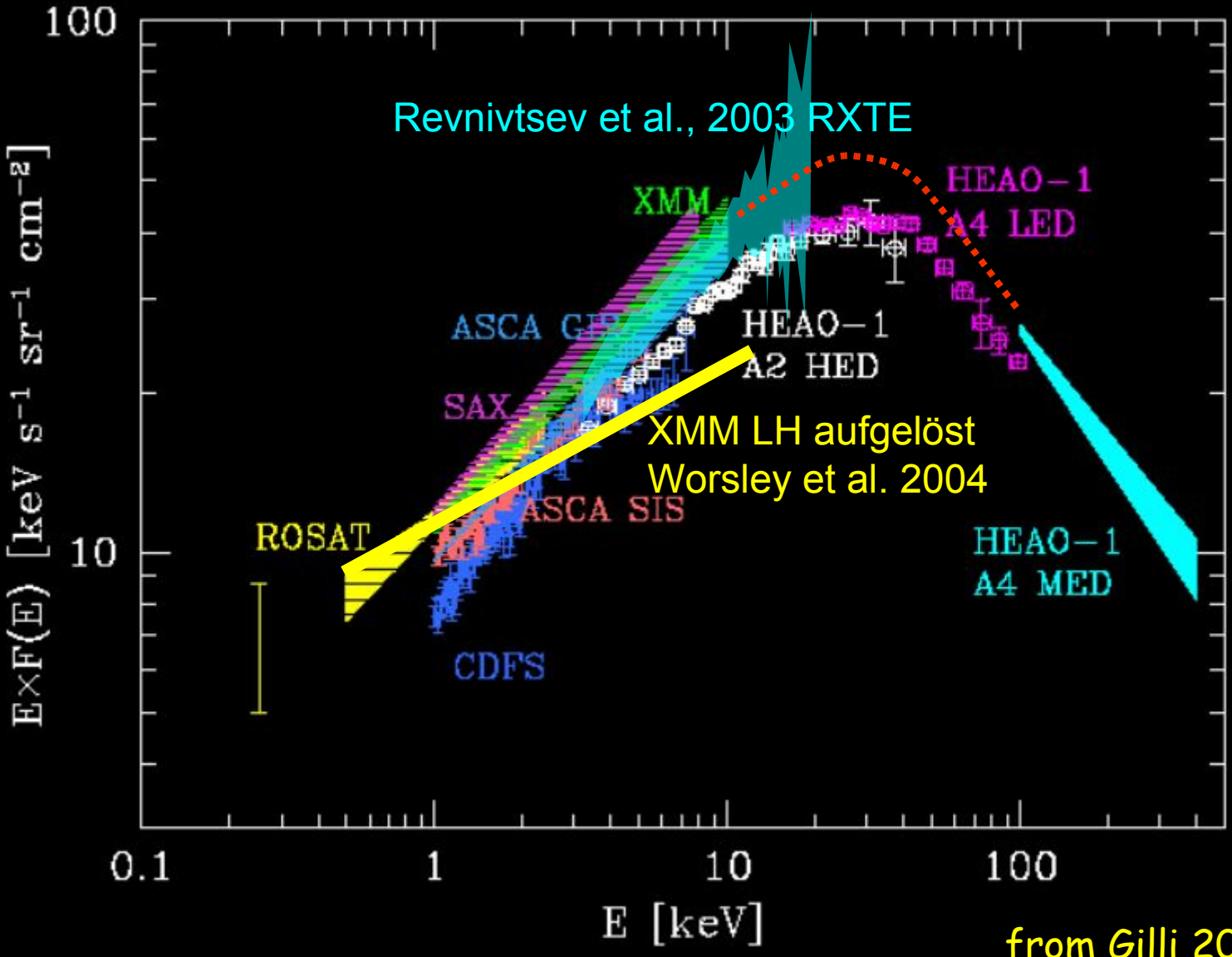
ROSAT



ROSAT

Der Hintergrund ist das Echo der Entstehung supermassiver Schwarzer Löcher während der ganzen Geschichte des Universums!

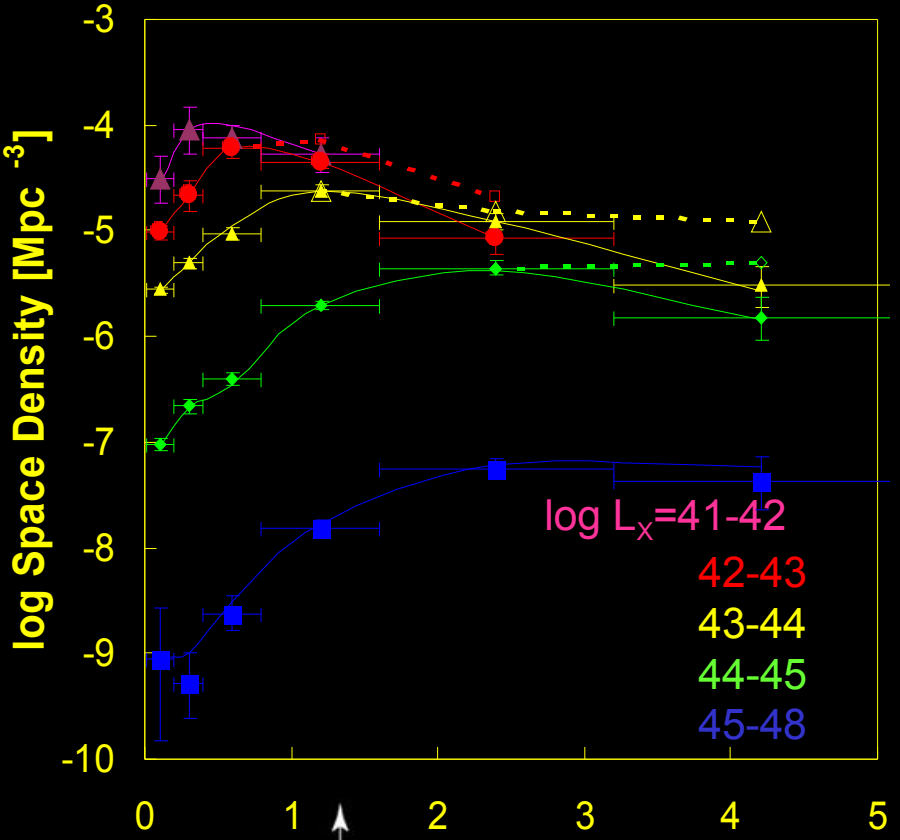
Der Röntgenhintergrund



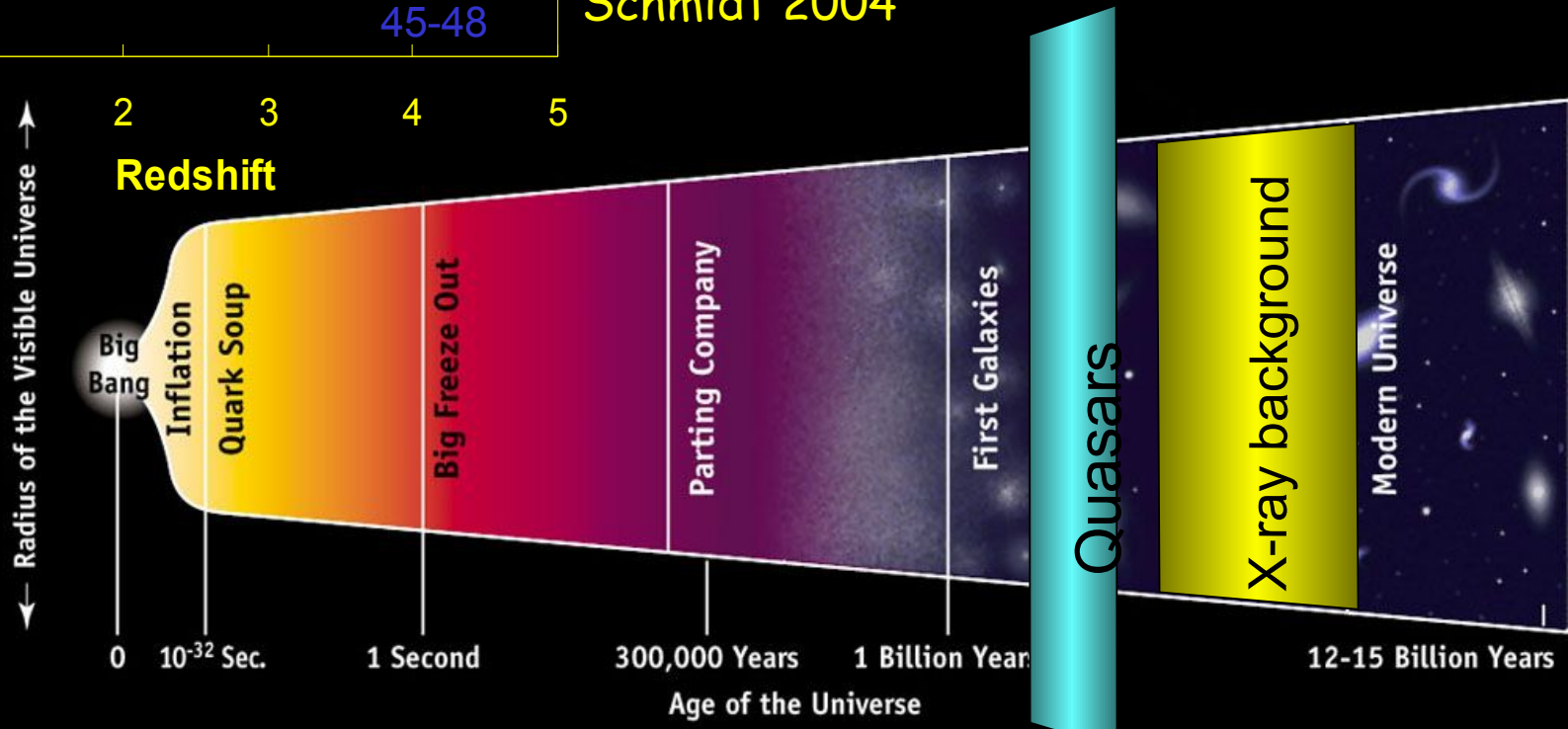
from Gilli 2003

=> E<2keV XRB aufgelöst, oberhalb von E>5keV noch nicht!

Aufstieg und Fall der Quasare und AGN



Hasinger, Miyaji, Schmidt 2004

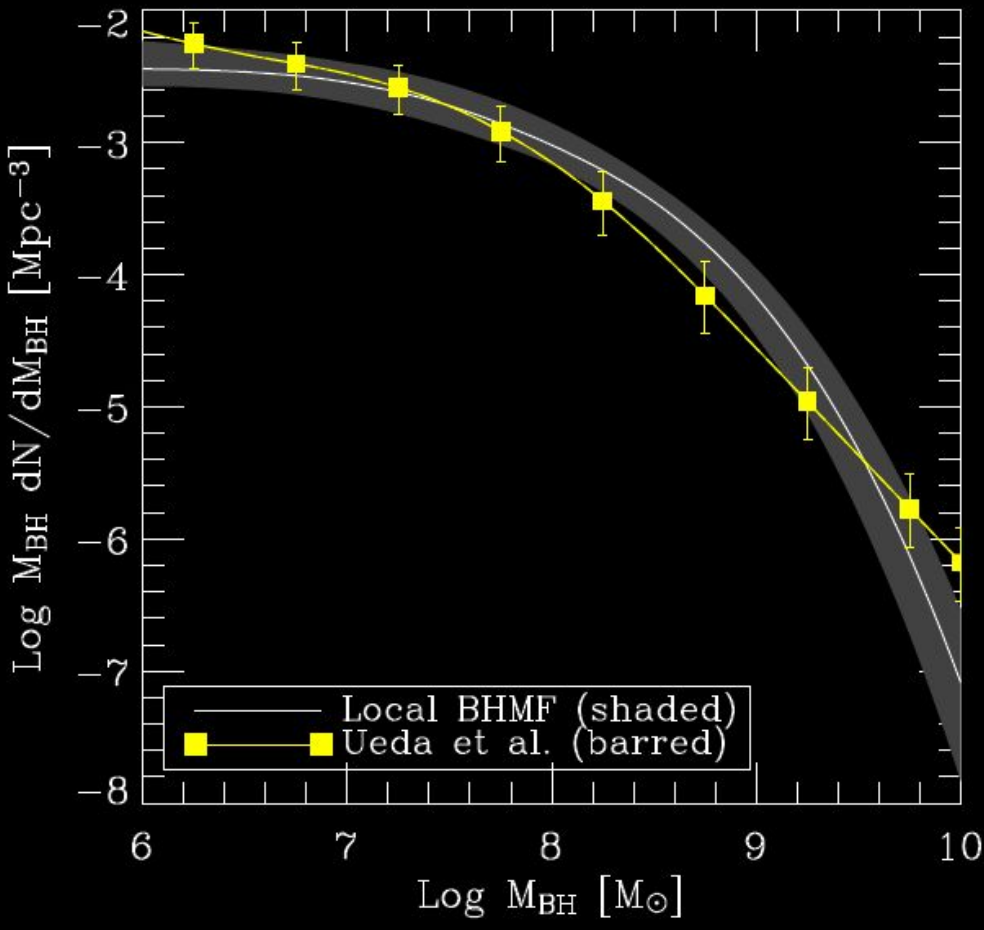


Local BH mass vs. accreted BH mass function

- Accreted Black Hole mass function derived from X-ray background can be compared with the mass function of dormant relic black holes in local galaxies.

- These two estimates can be reconciled, if an energy conversion efficiency of $\varepsilon=0.1$ is assumed.

- Such high efficiency requires a spinning Kerr-BH!

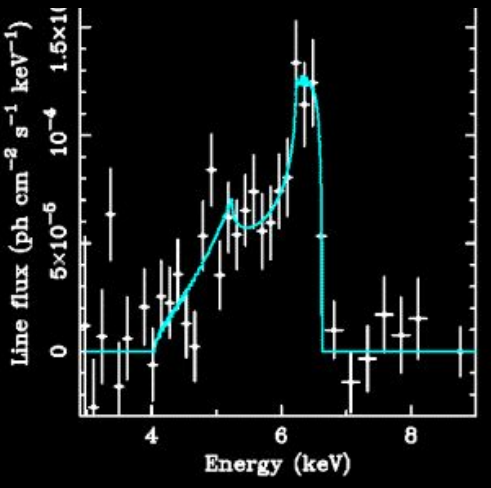


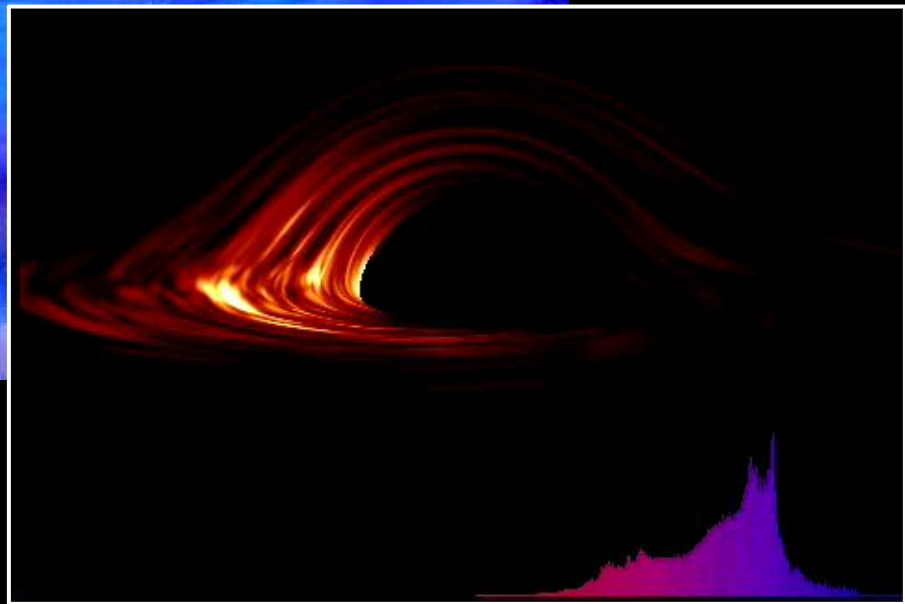
Marconi et al., 2004, MNRAS

Röntgenbeobachtung Schwarzer Löcher

Simulation courtesy Chris Reynolds

ASCA: Relativistische Eisenlinie
Tanaka et al. 1995

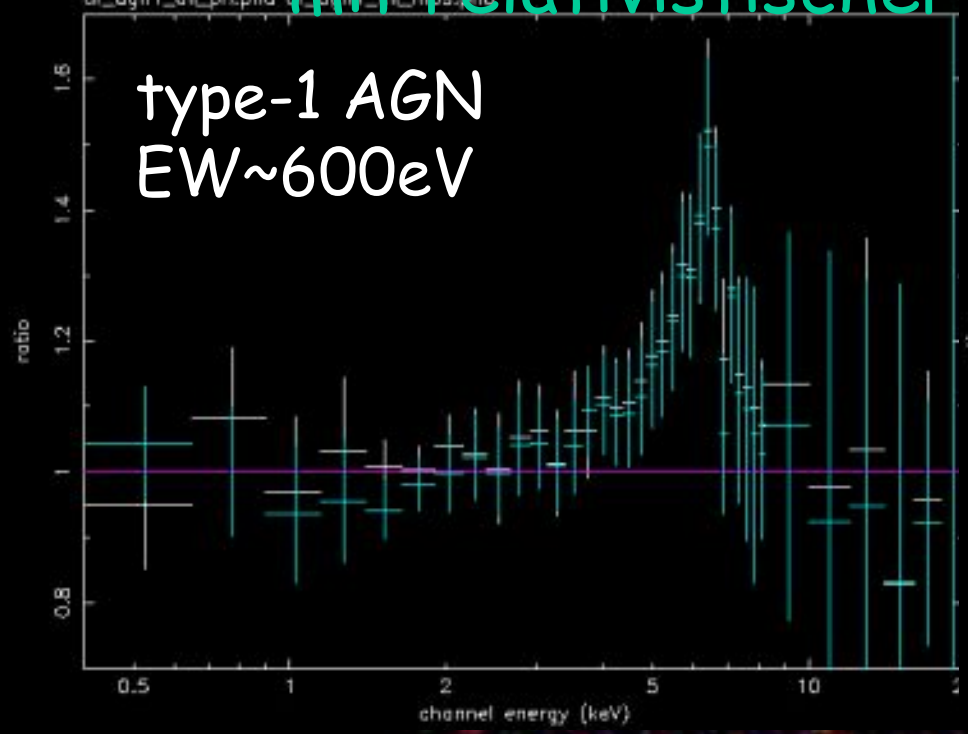


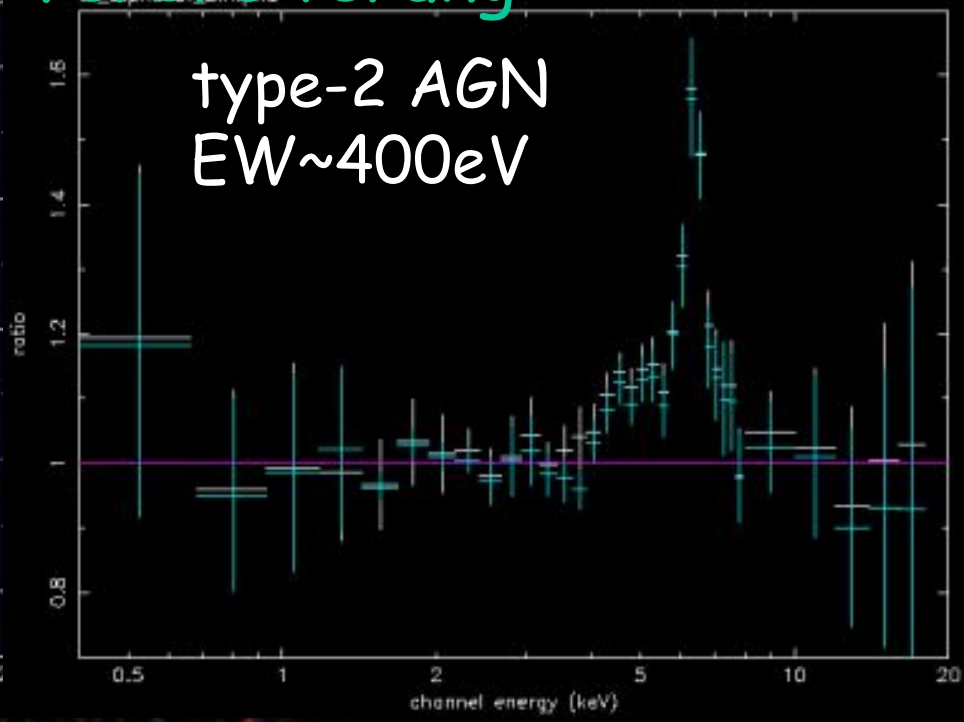


Lockman Hole

800 ks XMM-Newton Beobachtung

Summierte Spektren zeigen Eisenlinie mit relativistischer Verbreiterung



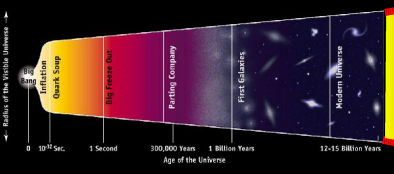


Streblyanskaya et al., 2004

Wenn die Dunkle Energie das Universum dominiert, geschieht der Urknall noch immer!

log (Years)

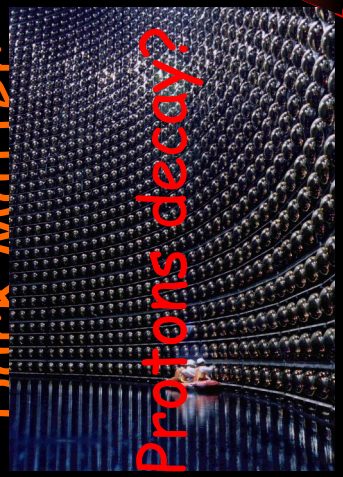
10 20 40 50 60 70



Stellar blackout

White Dwarfs annihilate

Dark Matter



Protons decay?

Black Holes terminate by Hawking Radiation