ESAs astronomy missions

Kelkheimer Welttraumtag

27 May 2010

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European Space Operations Centre (ESOC)
European Space Agency (ESA)

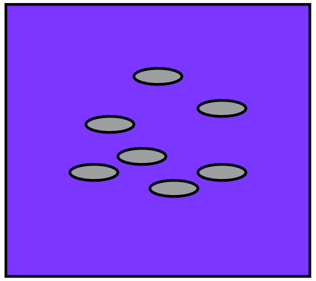
menu

- astronomy
- launch and operations
- ESA astronomy missions
- X-ray astronomy

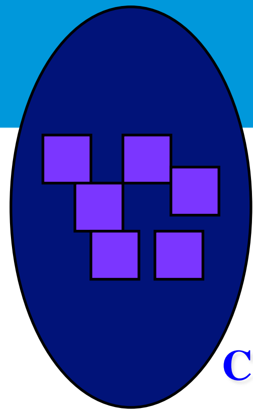
Was ist Astronomie?

- Astronomie:
  - griechisch ἀστρονομία / ástronomía: „Beobachtung der Sterne“
  - Wissenschaft von den Gestirnen
  - untersucht mit naturwissenschaftlichen Mitteln die Eigenschaften der Objekte im Universum
    - Himmelskörper (Planeten, Monde, Sterne einschließlich der Sonne, Sternenhaufen, Galaxien und Galaxienhaufen)
    - interstellaren Materie
    - im Weltall auftretende Strahlung.
  - Streben nach einem Verständnis des Universums als Ganzes, seiner Entstehung und seinem Aufbau.
- Astronomen beobachten Objekte die Licht aussenden mit Instrumenten
- Von der Erde aus:
  - Vorwiegend Optische und Radio Teleskope
- Ausserhalb der Erdatmosphaere:
  - Teleskope auf Satelliten

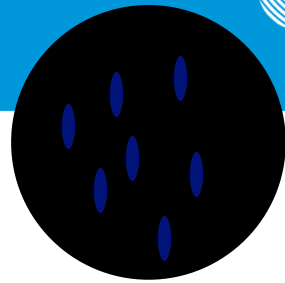
distances



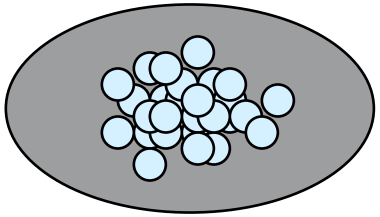
Lokale Group



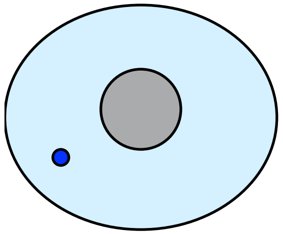
Cluster



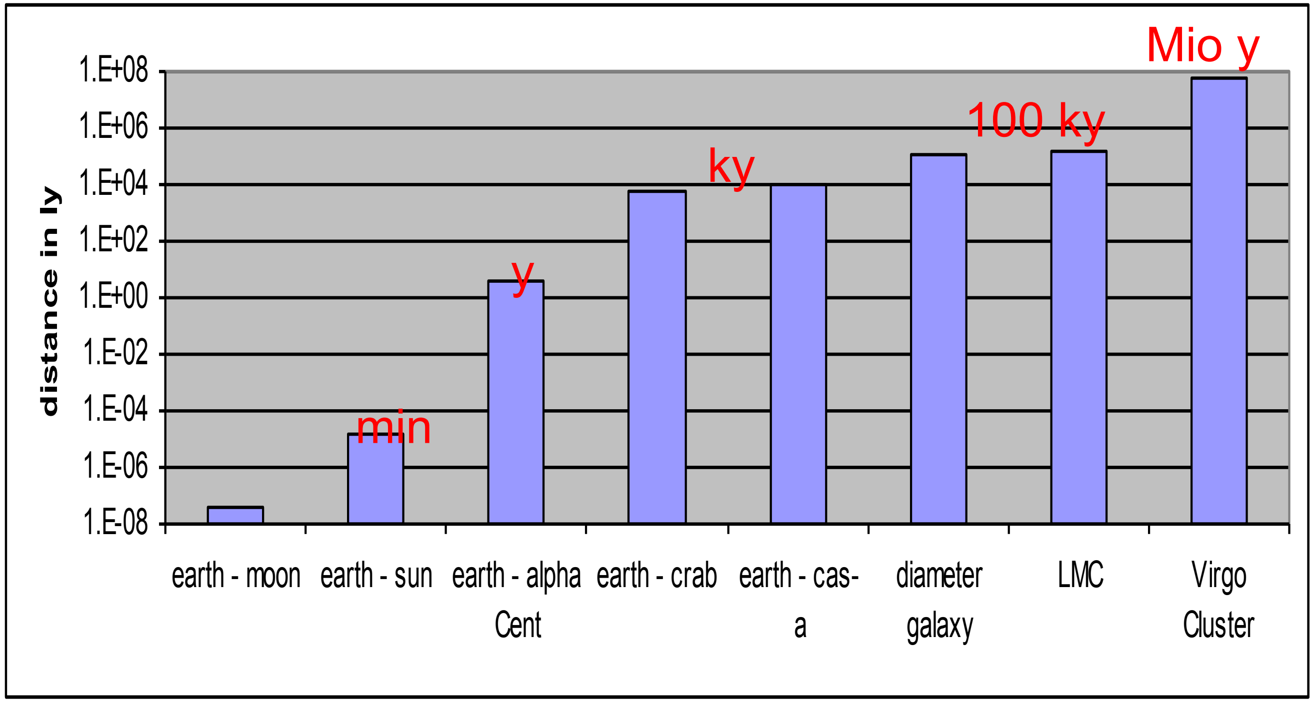
Super Cluster



Galaxy



Solar system



the zoo

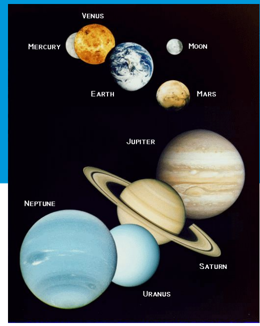
- Planets
- Sun (Stellar Coronae)
- Comets

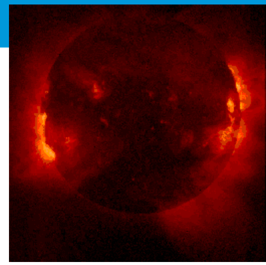
- Super Nova Remnants

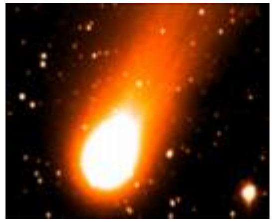
- Black Holes, Neutron Stars, Pulsars, X-ray binaries

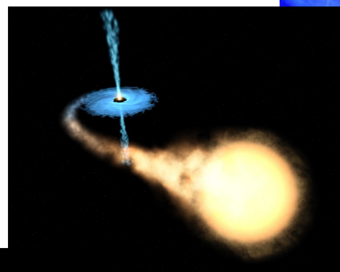
- Galaxies
- Active Galaxies (AGN)
- Cluster of Galaxies

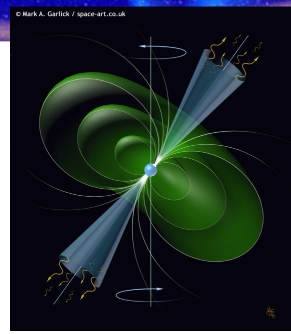
- Cosmic background

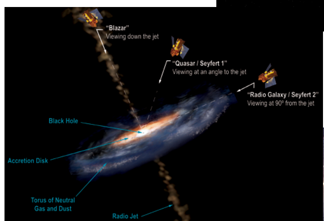




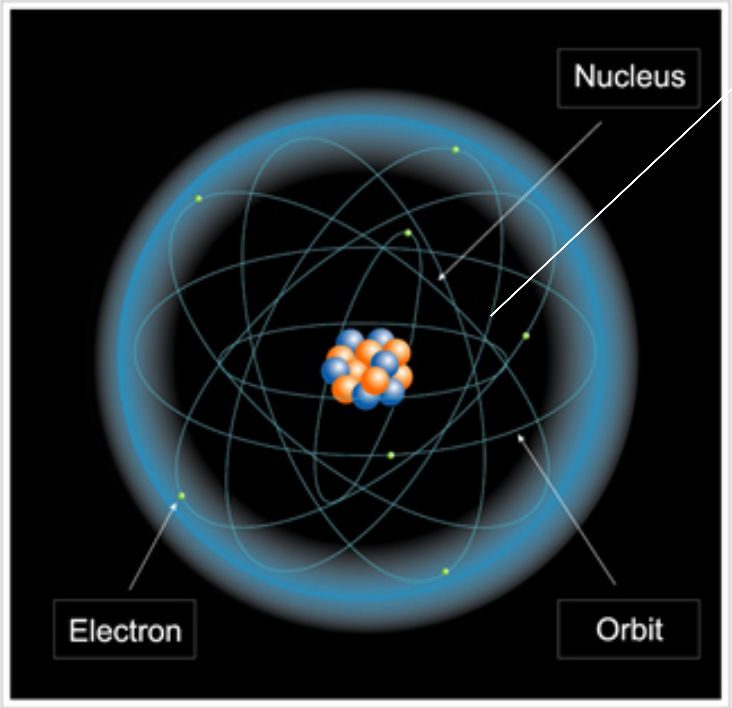








Was ist Licht

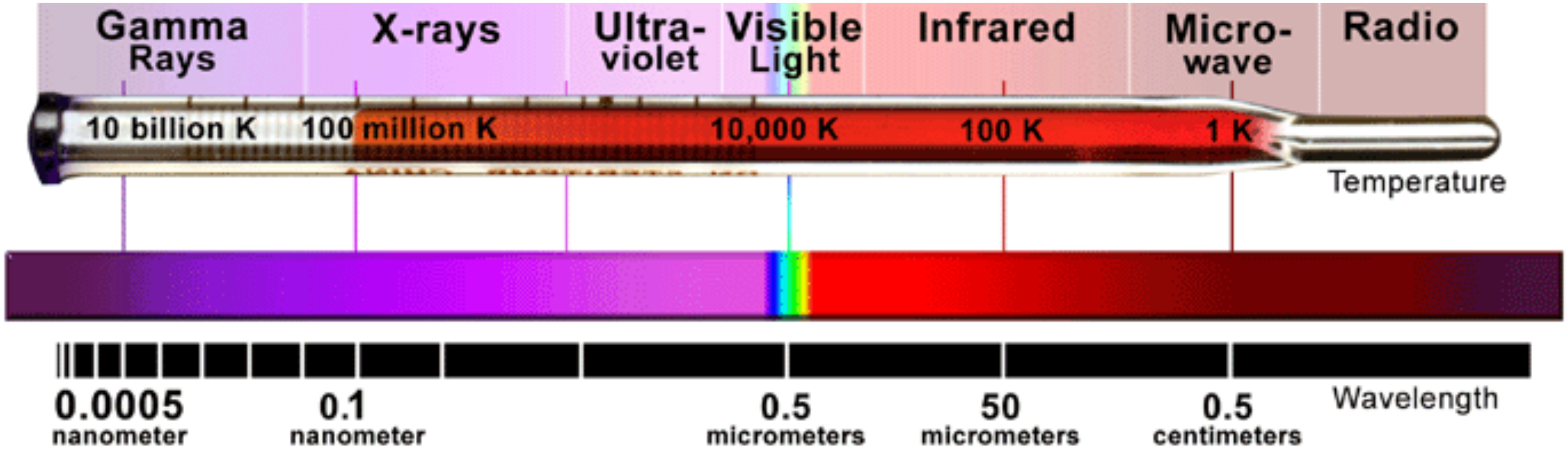


1. Materie besteht aus Atomen
2. Atome enthalten positiv (Protonen) und negativ geladene Teilchen (Elektronen)
3. Wenn ein Teilchen seinen Energiezustand ändert sendet das Atom eine Elektromagnetische Welle / ein Photon aus

 = 

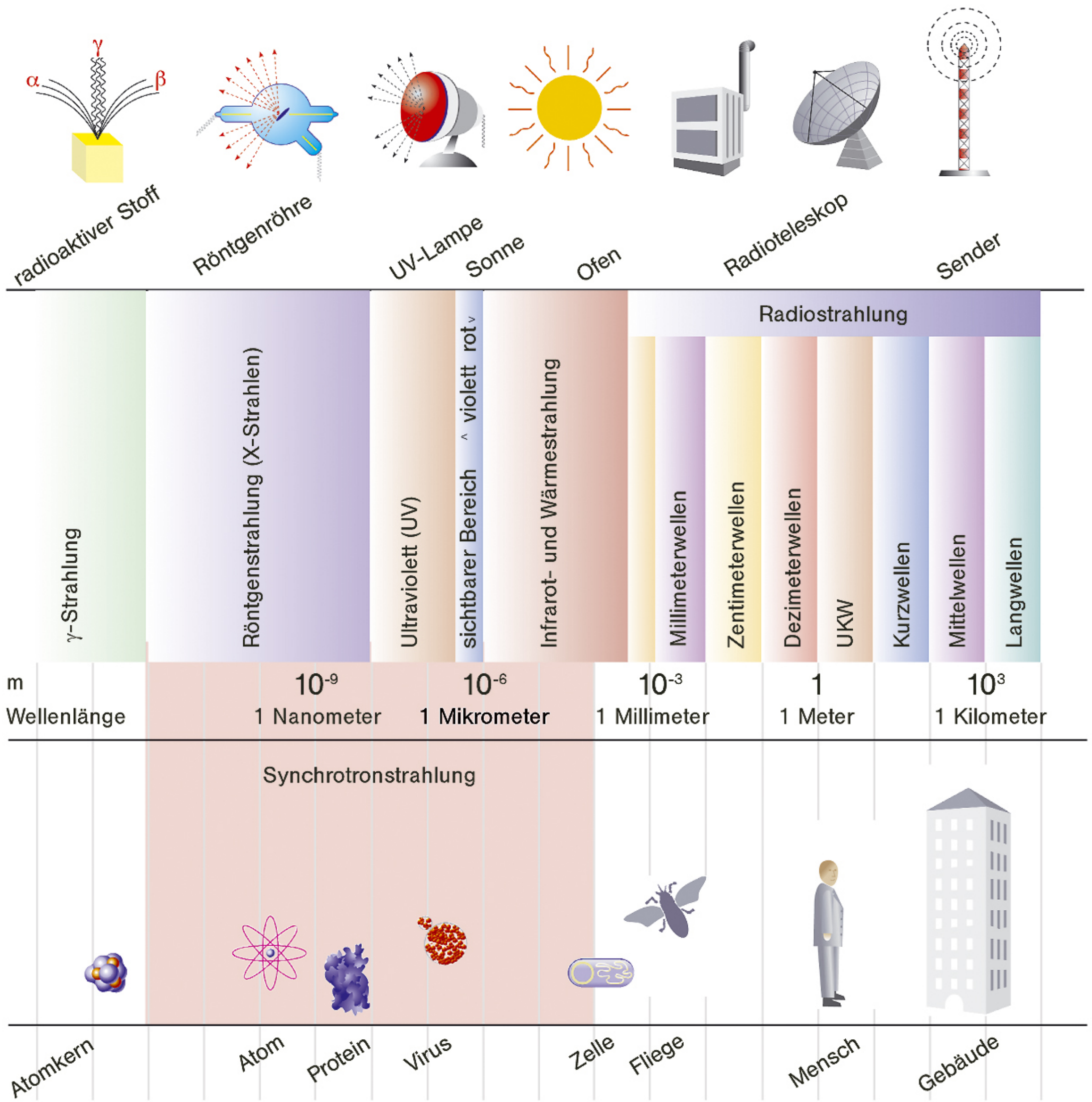
Fundamentales Konzept:
die Wellenlänge entspricht der Energie der Welle/ des Photons
Rotes Licht hat weniger Energie als blaues

Elektromagnetische Strahlung



- Körper können Licht mit verschiedener Energie aussenden. Die ausgesendete Wellenlänge kann einer Temperatur des Objektes zugeordnet werden

Energie des Lichts



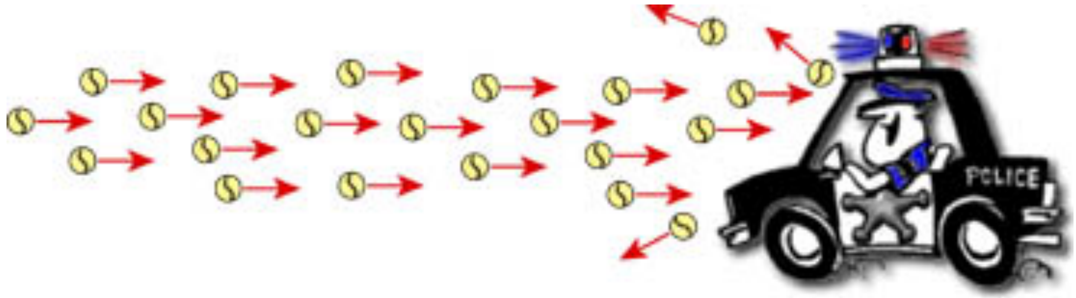
Sichtbares Licht:
Wellenlänge: 700 nm
Energie: ~1 eV

z.B. Röntgenlicht:
Wellenlänge < 1 nm
Energie: ~ 1 keV

= X-rays

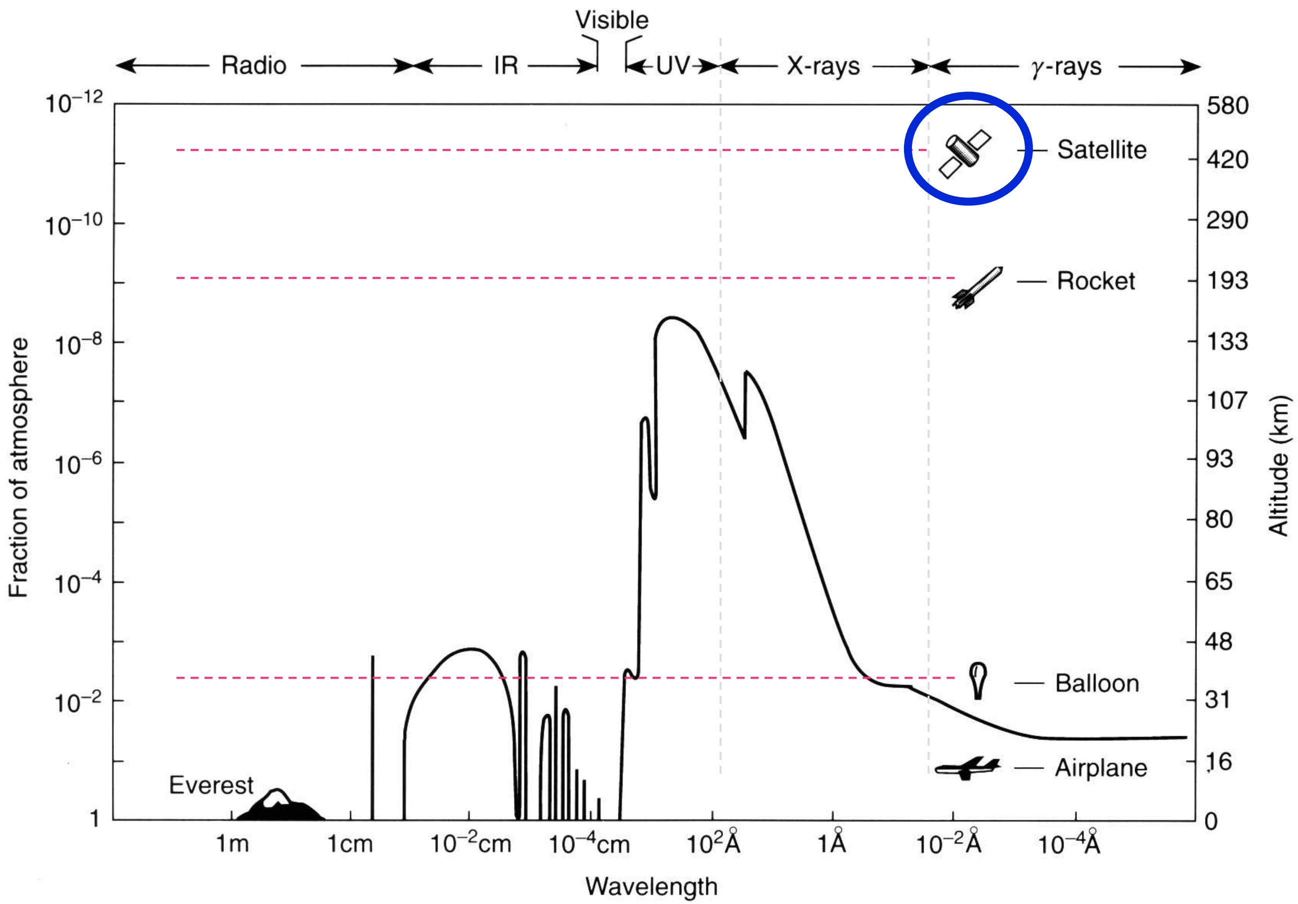
Licht – 2 Theorien

- Kügelchen mit Energie
  → Photonen



- Elektromagnetische Schwingungen
  → Wellen

Erdatmosphäre – Warum Satelliten

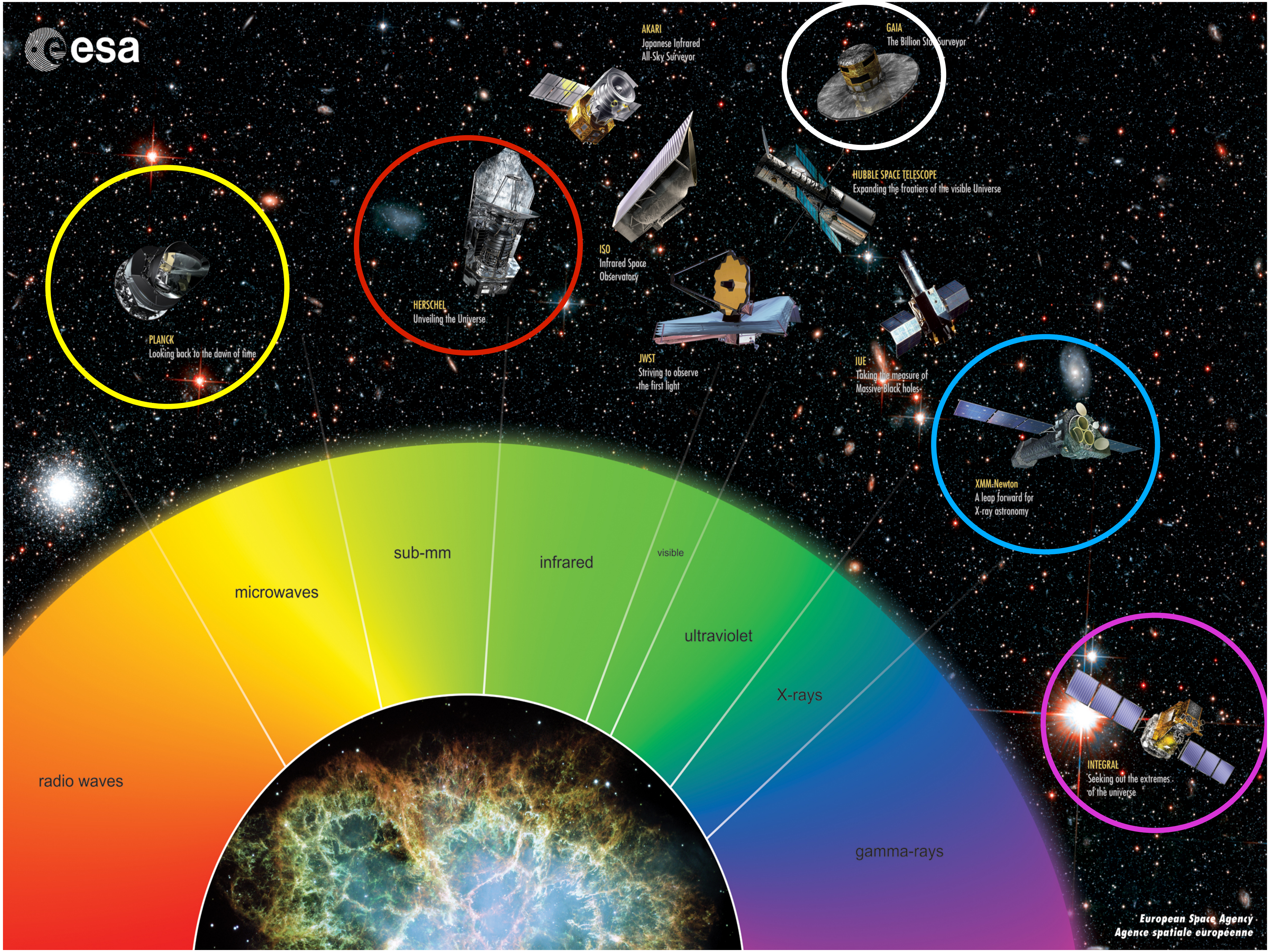


- Photonen werden von der Erdatmosphäre absorbiert
- dieser Effekt ist abhaengig von der Energie des Lichts

→ bestimmte Strahlung von kosmischen Objekten kann nur in großer Höhe beobachtet werden

→ Ballons, Satelliten

Die schwarze Linie zeigt die Höhe, bei der die Hälfte der auf die Atmosphäre auftreffenden Strahlung absorbiert ist.


esa
AKARI
Japanese Infrared All-Sky Surveyor
GAIA
The Billion Star Surveyor
HUBBLE SPACE TELESCOPE
Expanding the frontiers of the visible Universe
ISO
Infrared Space Observatory
HERSCHEL
Unveiling the Universe
PLANCK
Looking back to the dawn of time
JWST
Striving to observe the first light
IUE
Taking the measure of Massive Black holes
XMM-Newton
A leap forward for X-ray astronomy
INTEGRAL
Seeking out the extremes of the universe
radio waves
microwaves
sub-mm
infrared
visible
ultraviolet
X-rays
gamma-rays
European Space Agency
Agence spatiale européenne

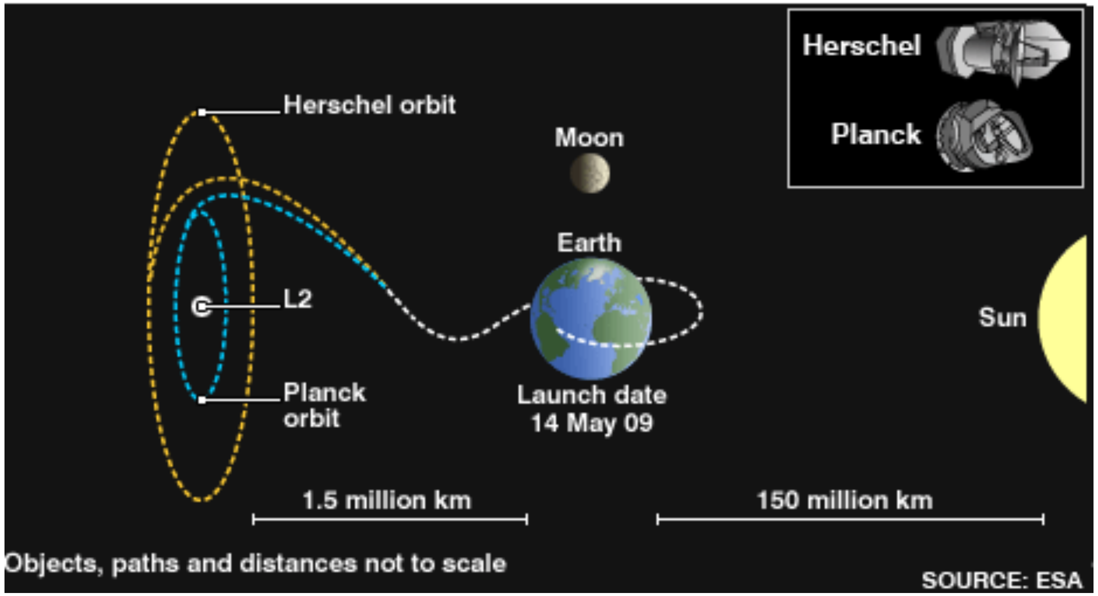
menu

- astronomy
- **launch and operations**
- ESA astronomy missions
- X-ray astronomy

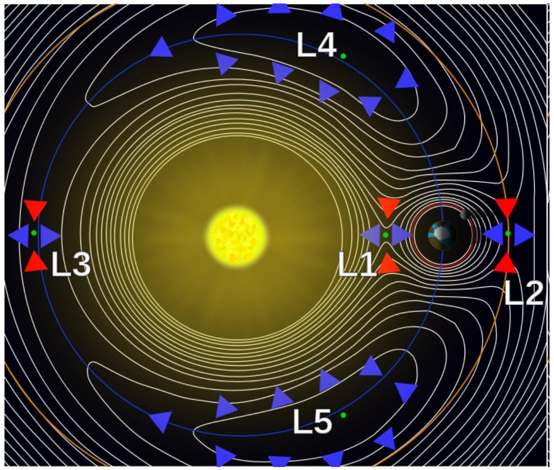
Launchers

LEOP Launch and early orbit phase

DISTANT OUTPOST: HERSCHEL AND PLANCK IN ORBIT



- critical first steps in a spacecraft's life beginning after the satellite separates from the launcher's upper-most stage
- Mission Control Team works 24 hours/day to activate, monitor and verify various subsystems on board the satellite
  - deployment of antennas
  - deployment of solar arrays
  - critical orbit and attitude control manoeuvres
- time is vital, and mission controllers must ensure that solar panels are deployed, power is flowing, all spacecraft systems are operating as expected and that the satellite's orbit is as planned.



H/P trajectory

Example H/P launch

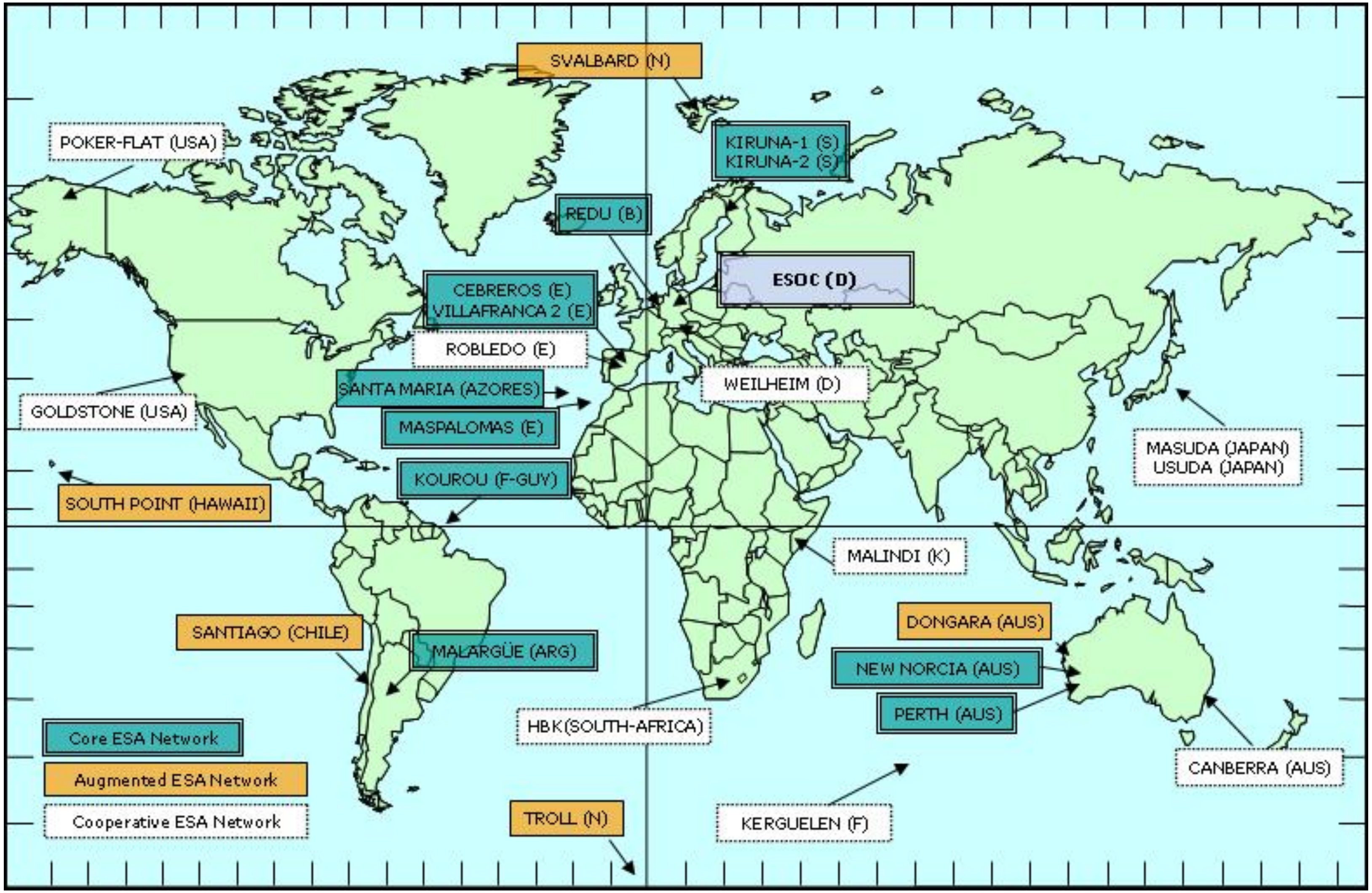
Herschel separation

Mission operations

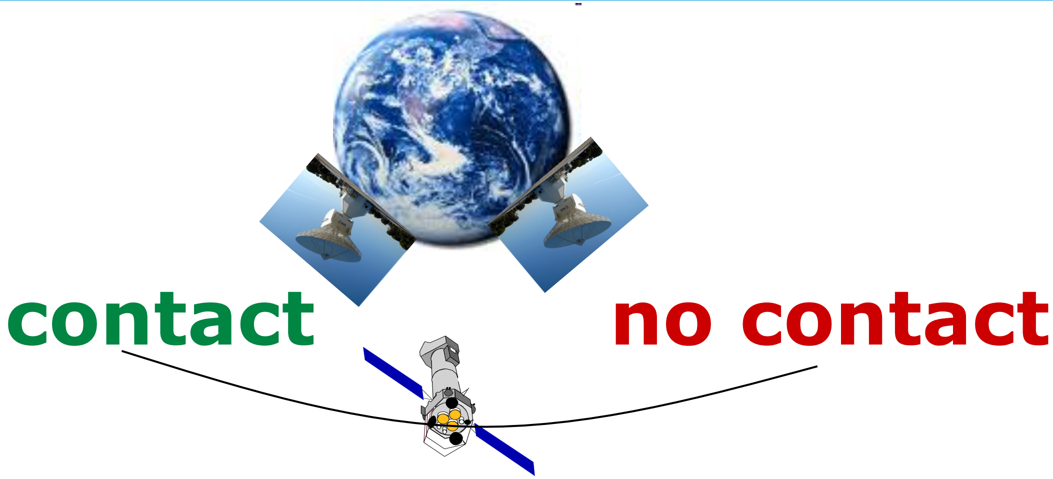
- the ground segment comprises the hardware, software, telecommunications and other resources on the ground used to operate the spacecraft and process data received from the instruments on board

- ESOC is specialised in designing, building, operating and maintaining the satellite control portions of ground segments and in conducting operations for all types of missions, from low-Earth orbit and geostationary to interplanetary and astronomical observatory missions

Globales Netz von Bodenstationen (ESTRACK)

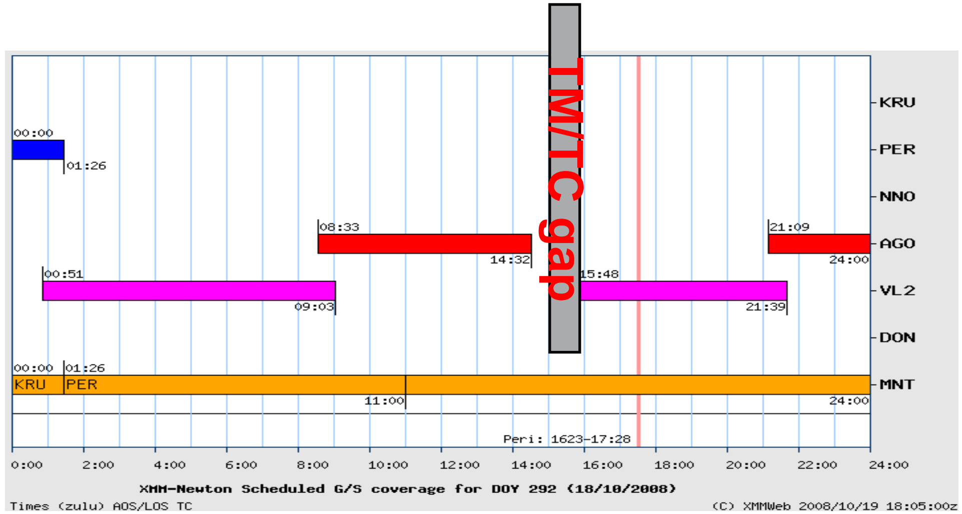


When your baby does not talk to you ...



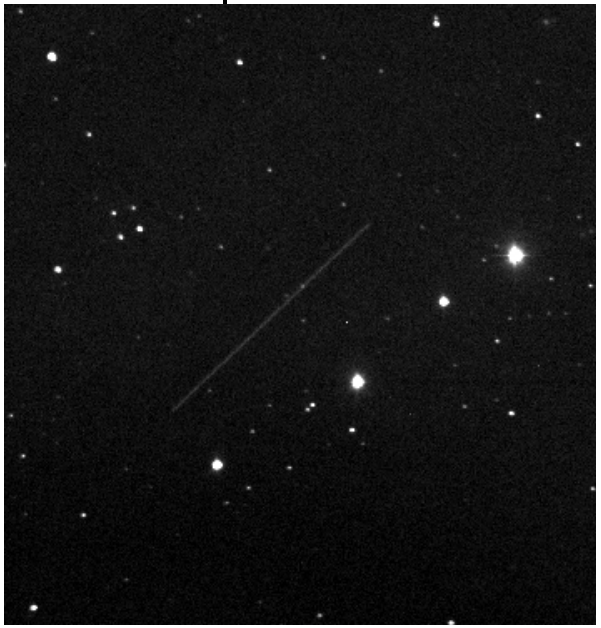
XMM Newton loss of contac in 2008

- 14.19: LOS Santiago
- 15.27: Time Tag Command RFDU SWA POS X
- 15.37: Expected AOS Villafranca → no signal



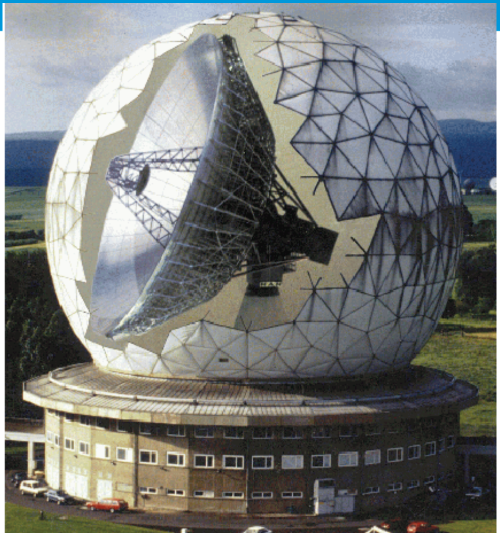
optical detection

- October 20th: amateur astronomers at Starkenburg observatory imaged track of XMM-Newton. Observations were also performed by two other telescopes, German radar and US Space Command → No catastrophic event such as an explosion, thruster malfunction, or collision with space debris or a meteorite.



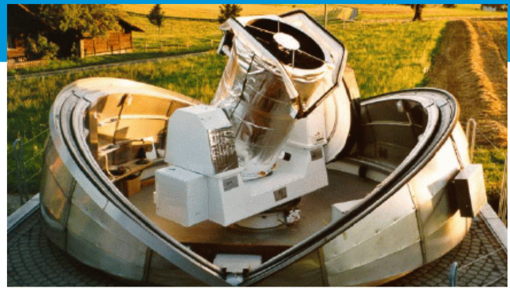
- Satellite on predicted path
- No visible debris
- No indication of light fluctuation caused by S/C spin

radar and optical follow up

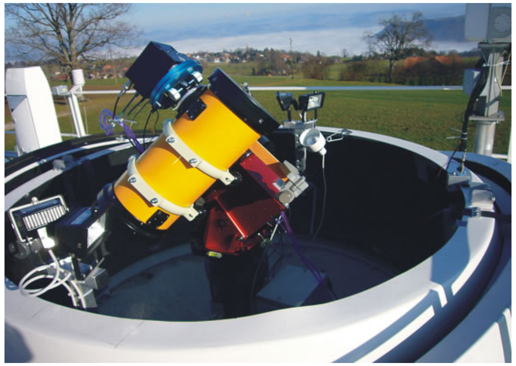


- **TIRA** (Tracking and Imaging Radar) at Wachtberg, Germany (lat: 50.62° North, 7.13° East)
- Monostatic L–band tracking radar and high resolution Ku–band imaging radar supported by one 34 m parabolic antenna
- This was the very first occasion for FGAN to track an object in more than 8000km range. XMM was at 22,000km (perigee) when FGAN started tracking

- ESA **Space Debris Telescope** in Tenerife
  1 m aperture, 0.7º field of view, Ritchey-Chrétien focus,
  2,401 m altitude, 28.2º North, 16.3º West
- CCD: 4096 x 4096 Pixel; ~ 2s integration time, ~ 19s read-out time
- Limiting magnitude: 19 – 21 mag (object of ~ 15 cm size in GEO); 120º of the GEO-ring are visible



- **Zimmerwald telescopes** (CH)
- Owned and operated by the Astronomical Institute, University of Berne, 950 m altitude at 46.9° North, 7.5° East



optical data

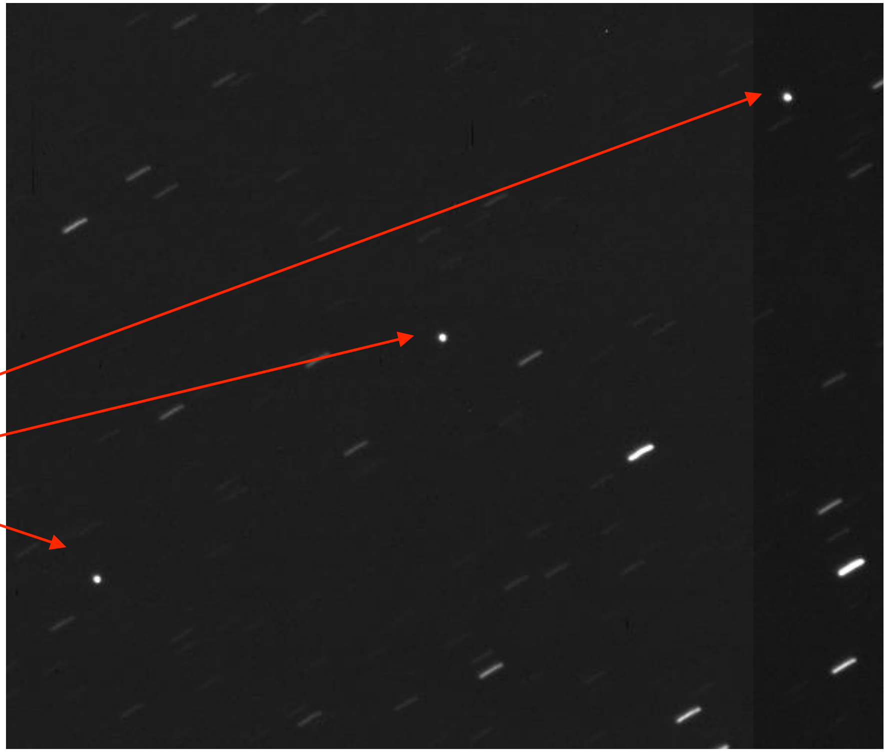
- ESA Space Debris images re-confirmed that XMM was intact and no debris (> 10cm) was visible in its vicinity (150km)

- Astrometry is precise down to a level of a few arcsec

- Post-processing and determination of object states was done within 1 hour

- The telescope was tracking with XMM's angular velocity

- Three overlayed frames showing XMM as dots and stars as trails (2-second exposures)

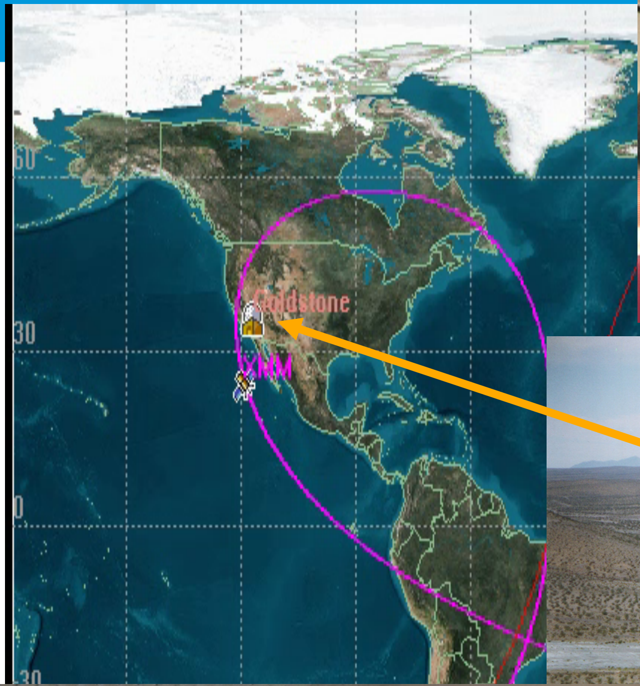


radio contact

- On 21 Oct a very weak signal was picked-up by ESA's 35-m antenna in New Norcia (West Australia) →Doppler information could be collected to confirm the orbit derived from the radar and optical tracking data
- Measurement of the signal attenuation (-55 db) indicating a failure of the switch → information concerning the required uplink power
- Commanding not possible via New Norcia, uplink power not sufficient
- Commanding not possible via Canberra, frequency not supported

final recovery

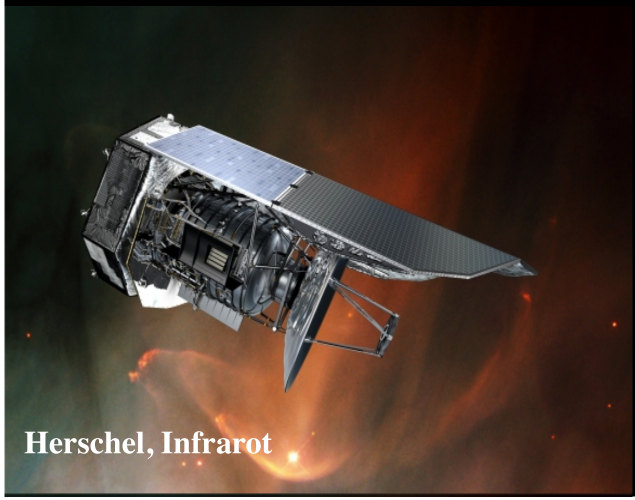
- 22nd Oct: Configuration of Goldstone to be able to support XMM
- Validate procedures on simulator
- Uplink command to put RF switch into = position using high uplink power of Goldstone
- Check Satellite status
- Update Platform and Payload configuration to put satellite into a safe state

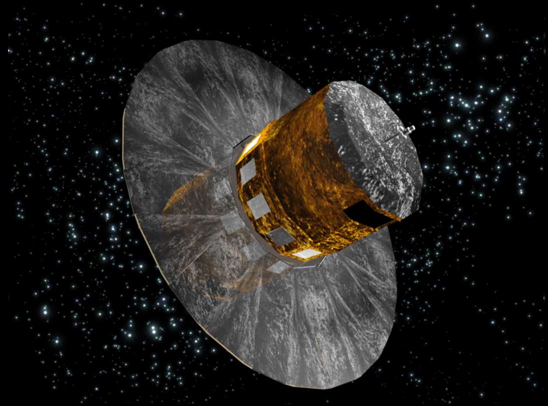


menu

- Astronomy
- Launch and operations
- **ESA astronomy missions**
- X-ray astronomy

the astronomy fleet



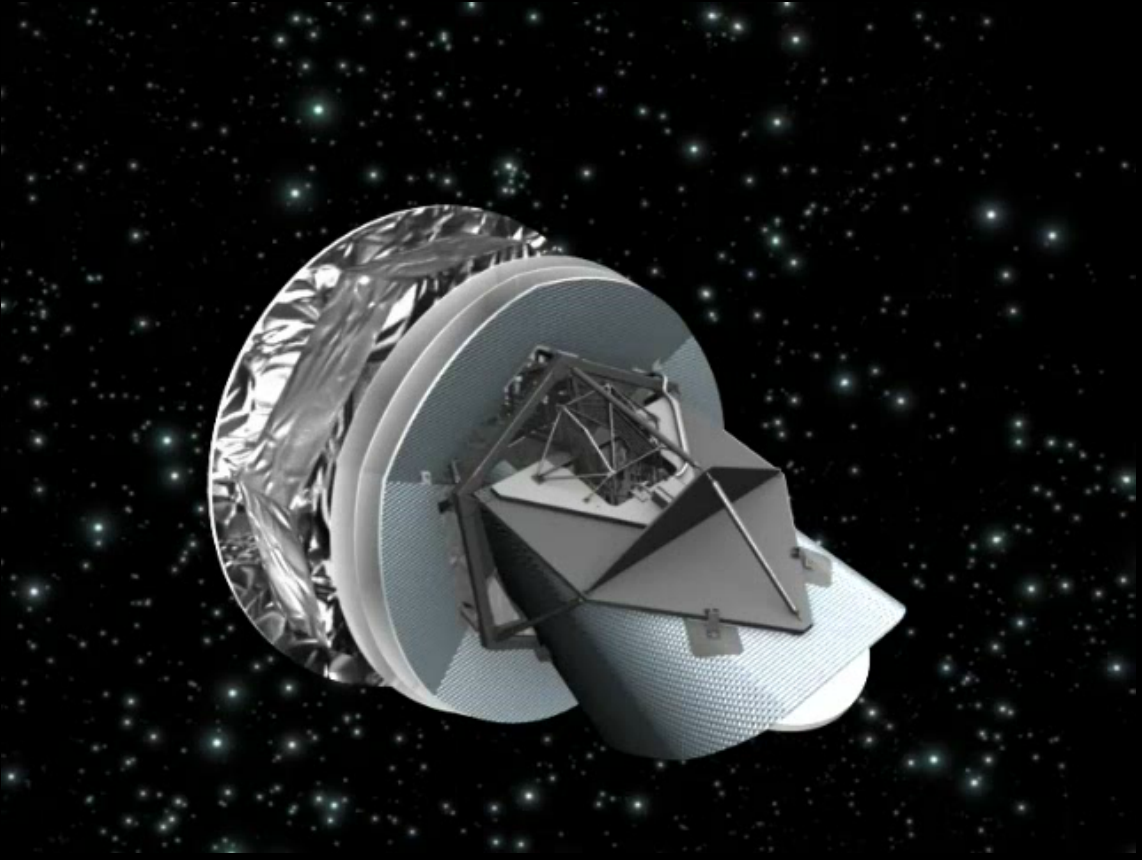


Gaia, optisch

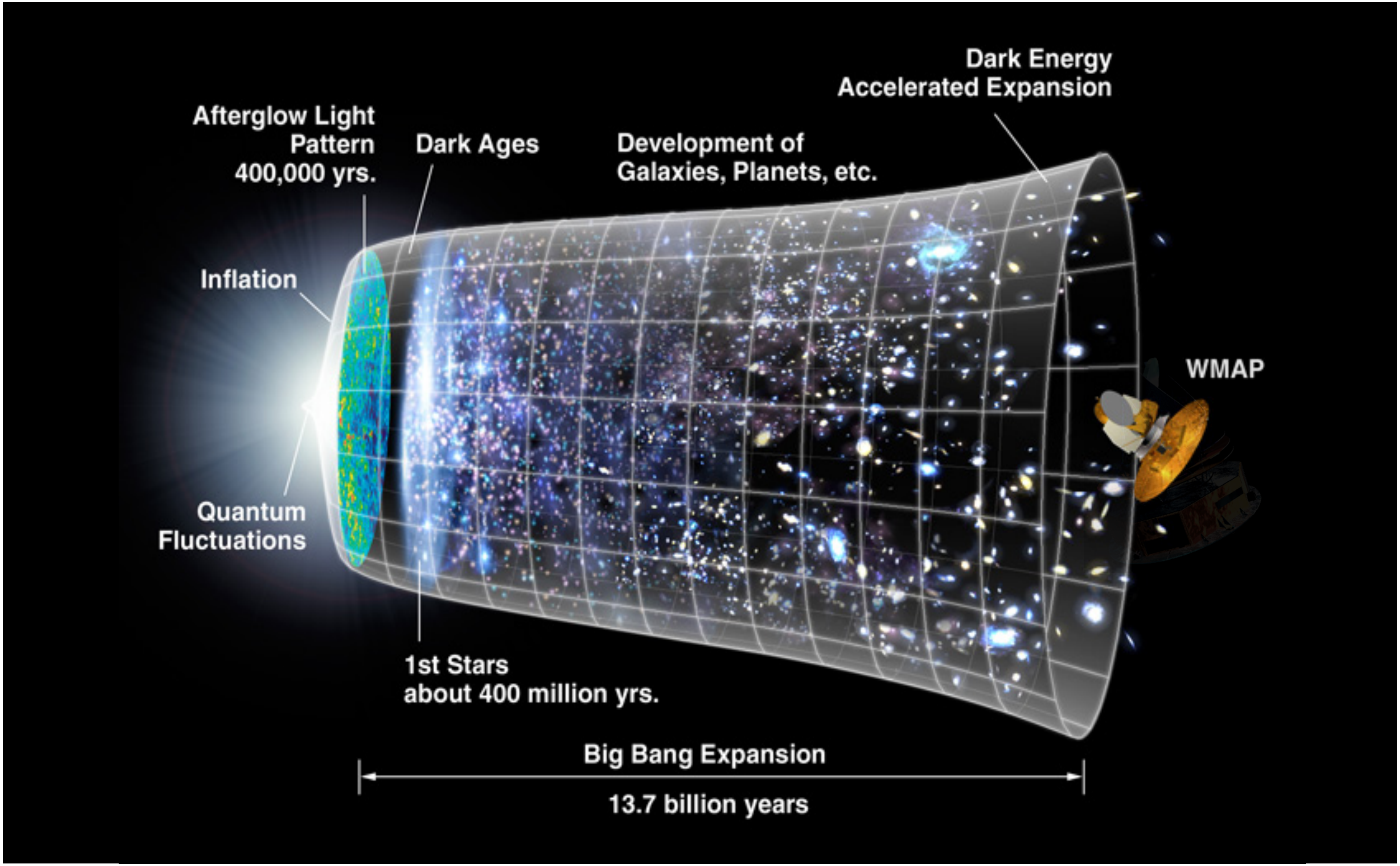
Planck: Micro waves

Planck will scan the entire sky to build the most accurate map ever of the Cosmic Microwave Background (CMB), the relic radiation from the Big Bang. The spacecraft will spin at 1 rotation per minute around an axis offset by ~85° so that the observed sky region will trace a large circle on the sky. As the spin axis follows the Sun the circle observed by the instruments sweeps through the sky at a rate of 1° per day.

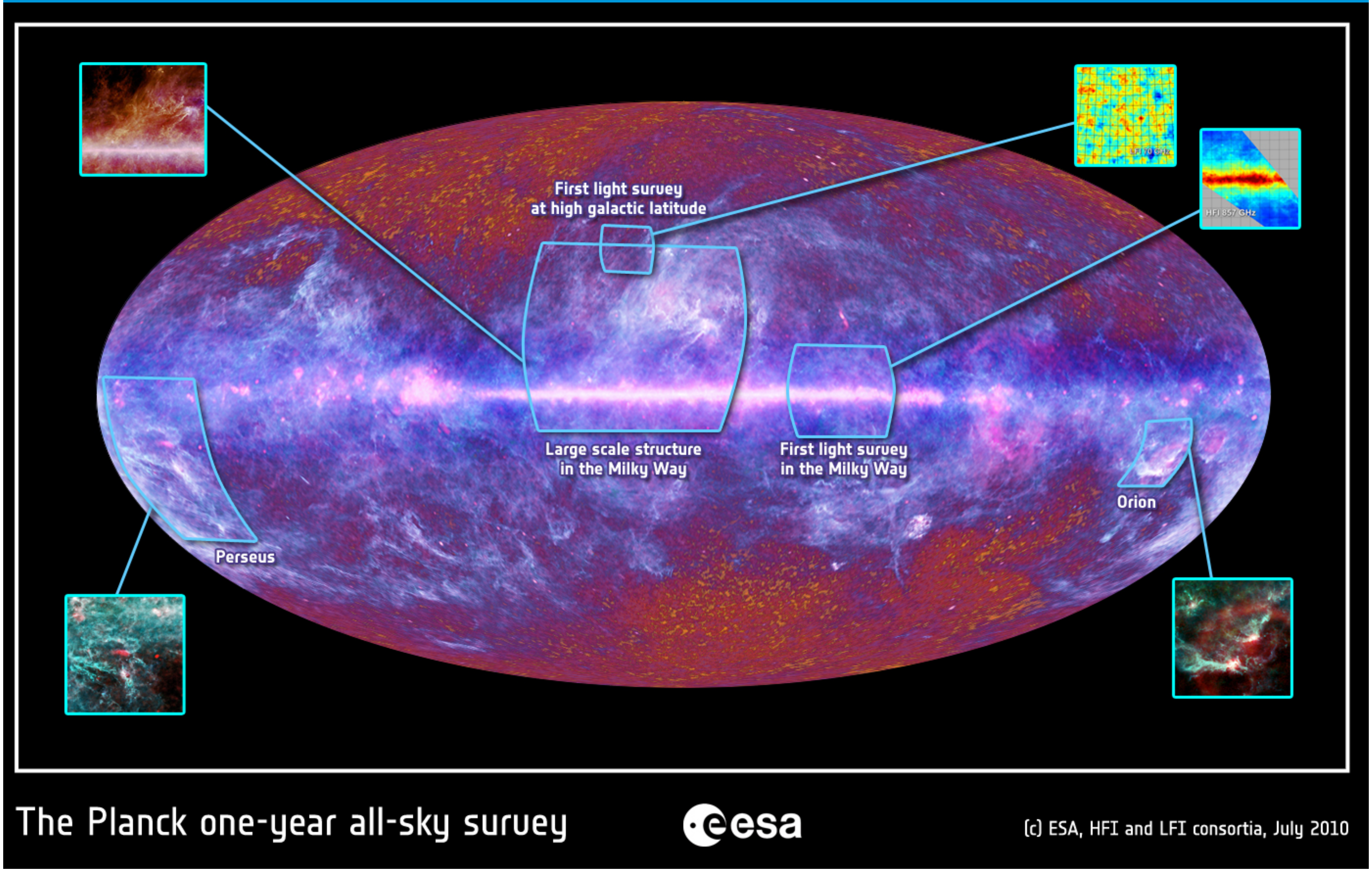
Planck will take about 6 months to complete a full scan of the sky, charting two complete sky maps during its nominal lifetime (about 15 months).



Planck: back to the Big Bang (almost ...)



Planck: one year of observations

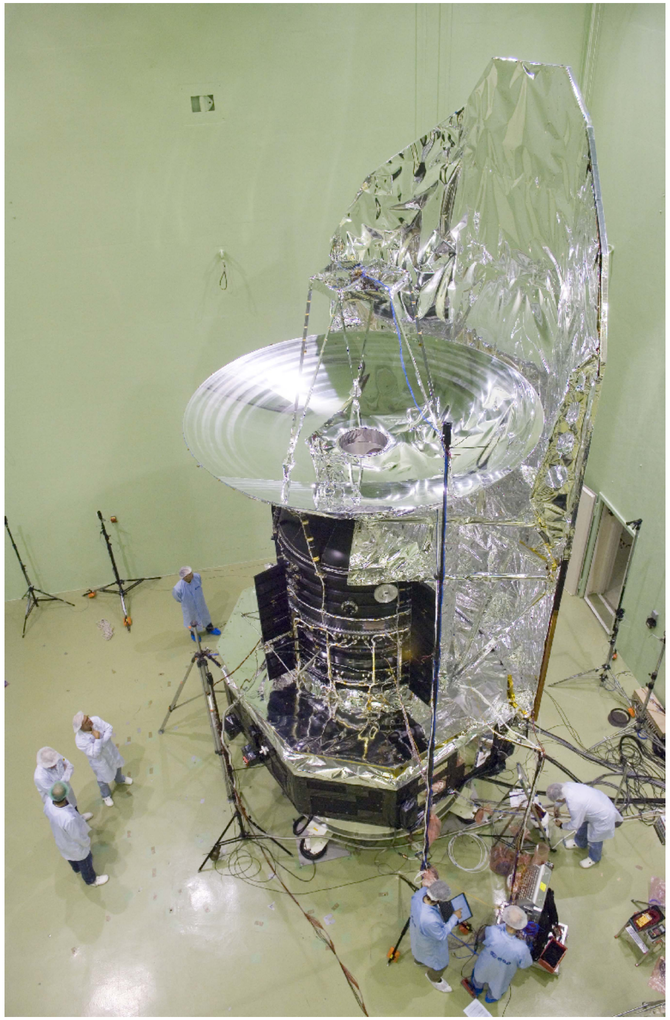


Herschel - Infra red

- to study the earliest stages in the life of a star
- largest telescope ever flown in space, with a primary mirror 3.5 m in diameter.
- The first space observatory to observe the entire range of wavebands from the far-infrared to submillimetre.

Herschel Spiegel

- Herschel' s telescope is carrying the largest mirror ever flown in space



Whirlpool galaxy M51

ISOCAM 15 µm image

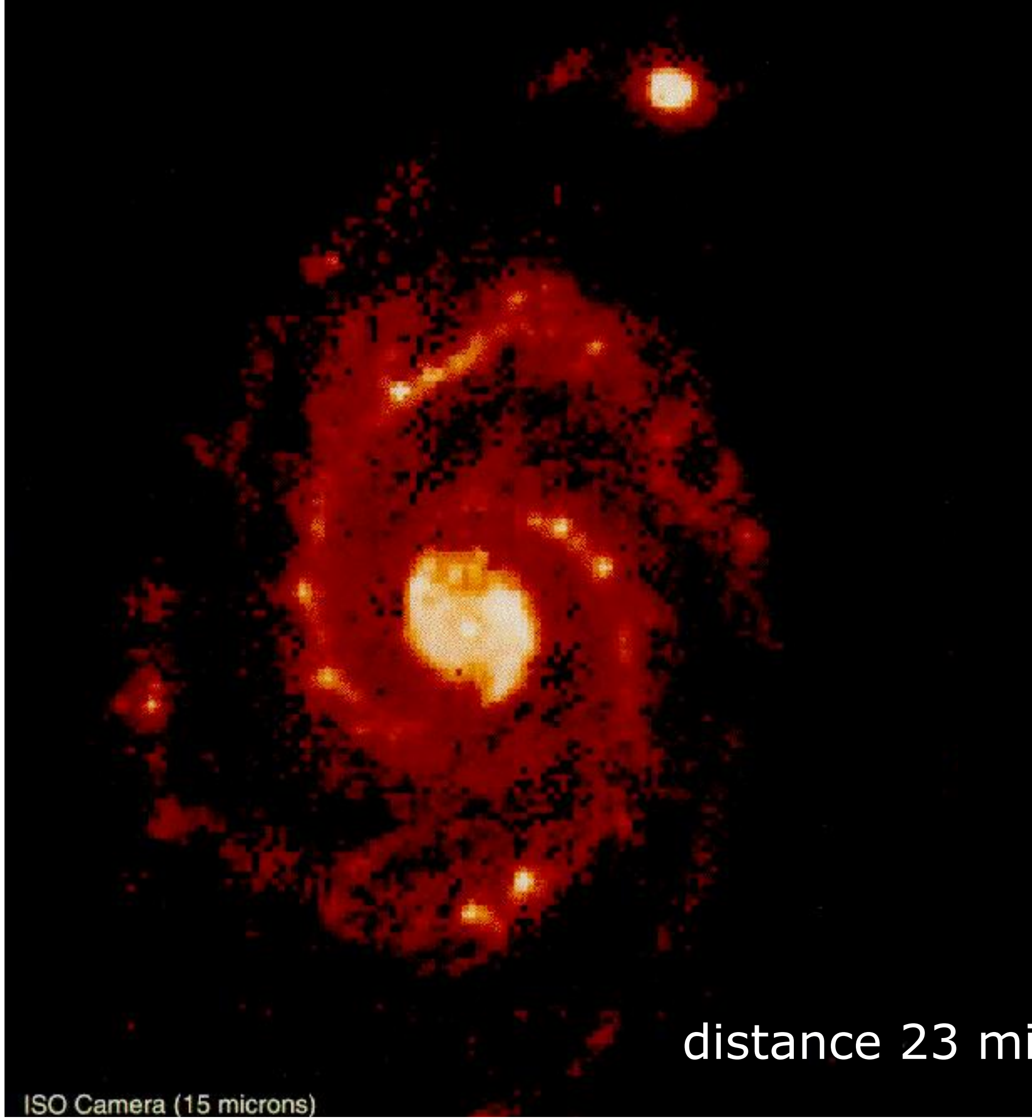
Best mosaic image in ISO archive

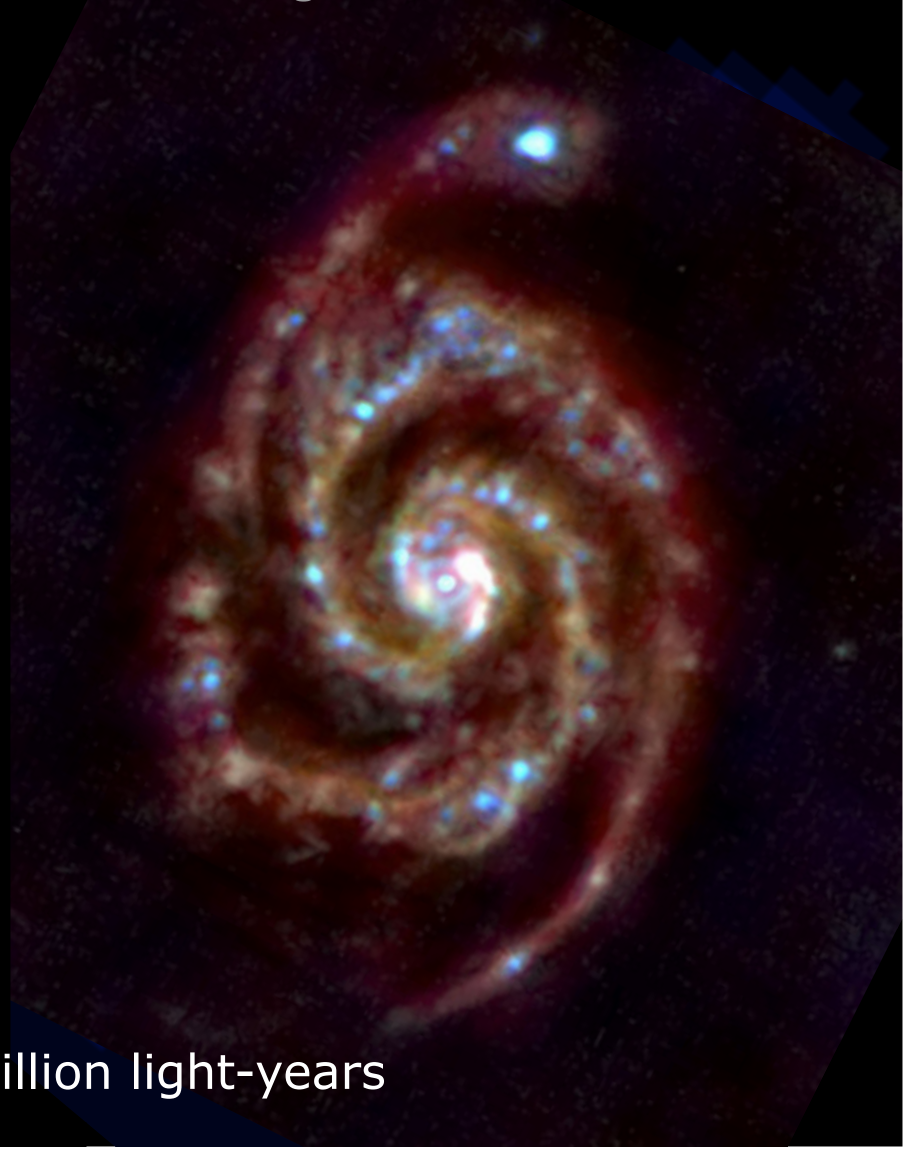
Whirlpool galaxy M51

PACS 3 color image (70, 100, 160 µm

IRAS

First image taken with Herschel



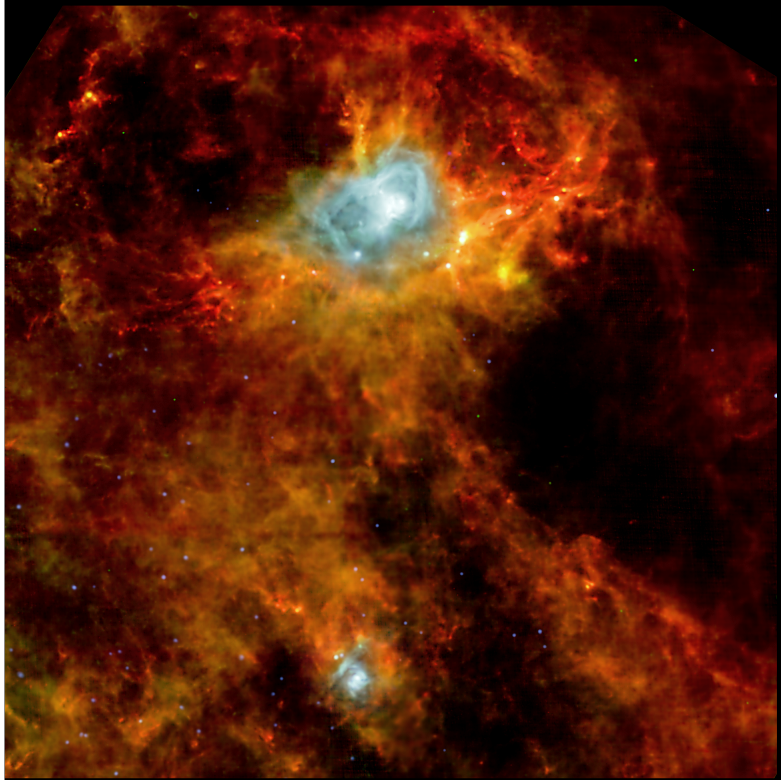


distance 23 million light-years

Filaments permeate the ISM on all scales

Herschel

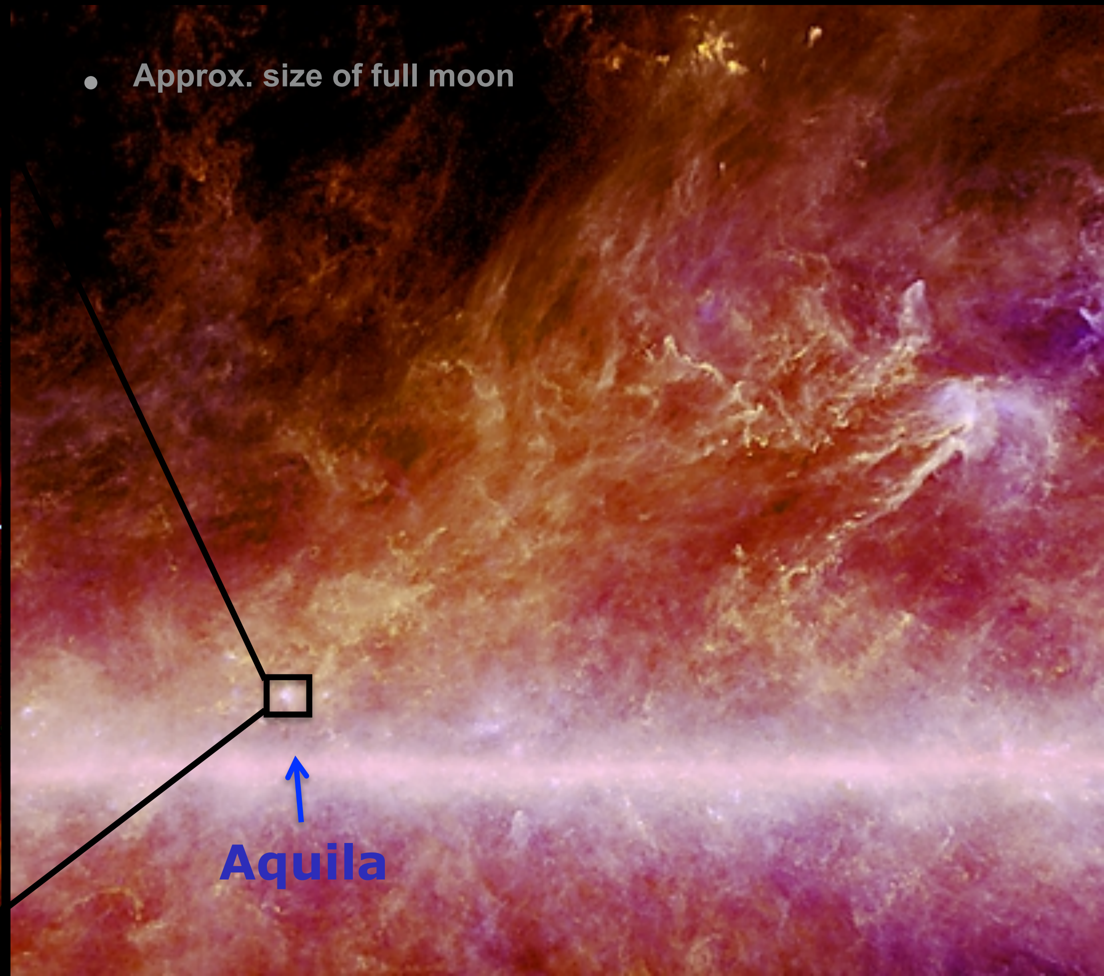
**SPIRE 500 μm +
PACS 160/70 μm**



ESA and the Gould Belt KP

Planck

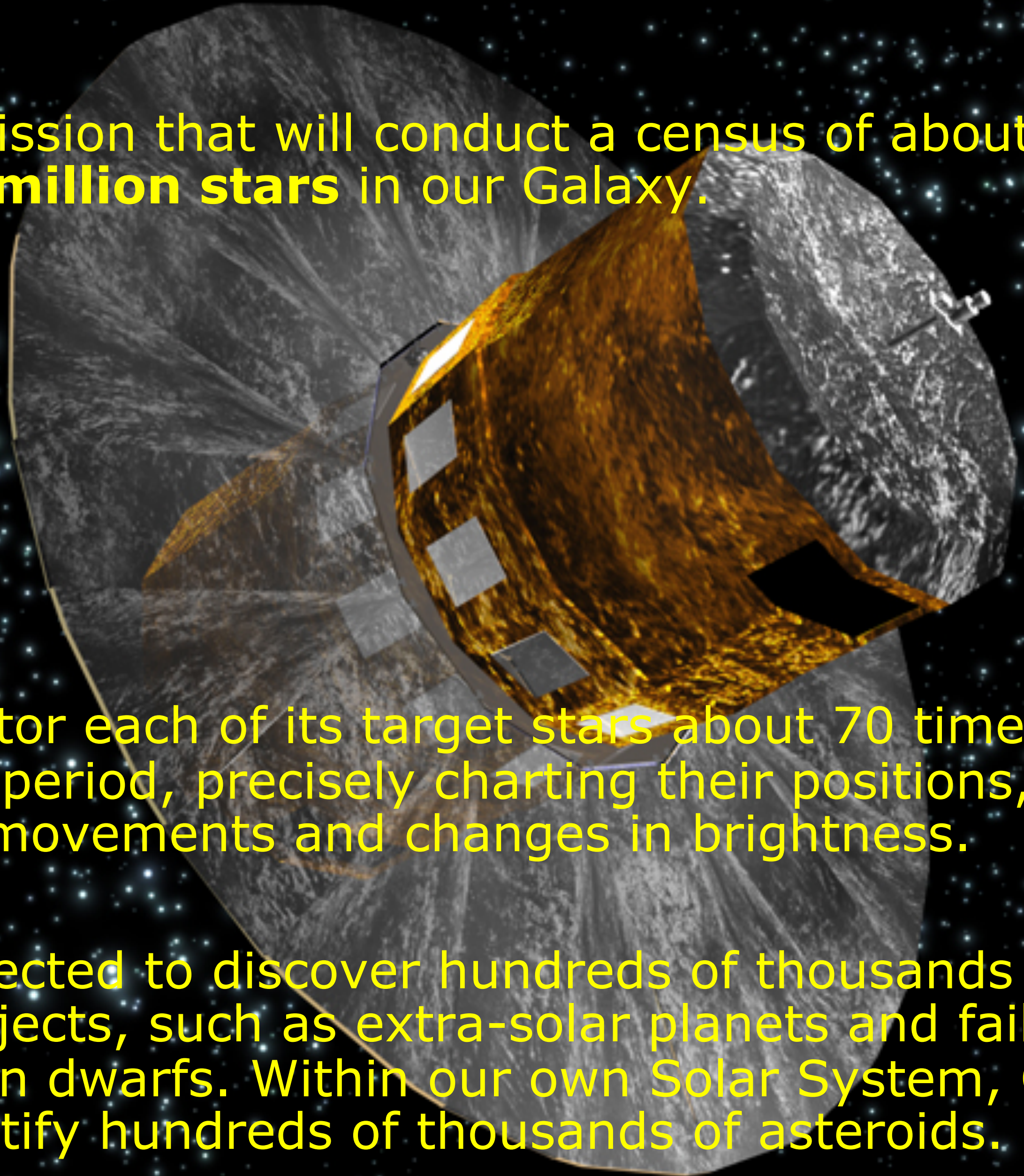
HFI 540/350 μm + IRAS 100 μm



ESA and the HFI Consortium

Gaia

- Gaia is a mission that will conduct a census of about **one thousand million stars** in our Galaxy.

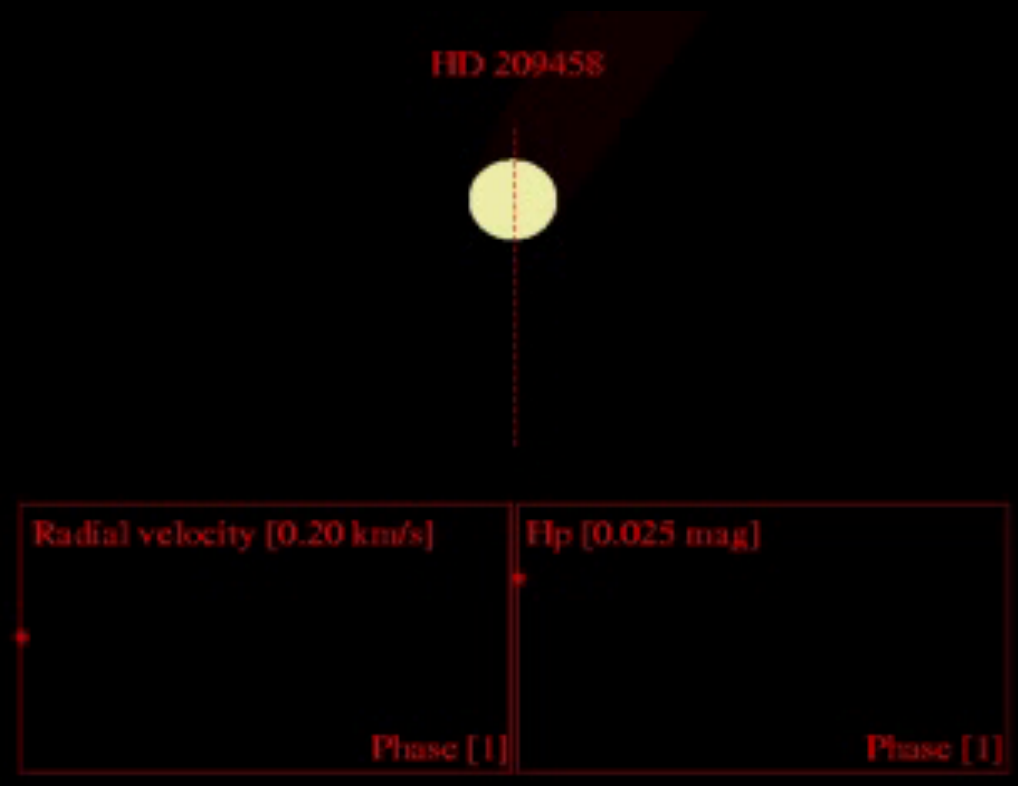


- It will monitor each of its target stars about 70 times during a five-year period, precisely charting their positions, distances, movements and changes in brightness.

- Gaia is expected to discover hundreds of thousands of new celestial objects, such as extra-solar planets and failed stars called brown dwarfs. Within our own Solar System, Gaia should identify hundreds of thousands of asteroids.

Planetary transients

- This animation shows how changes in the measured radial velocity and magnitude indicate the presence of a planet orbiting a star.

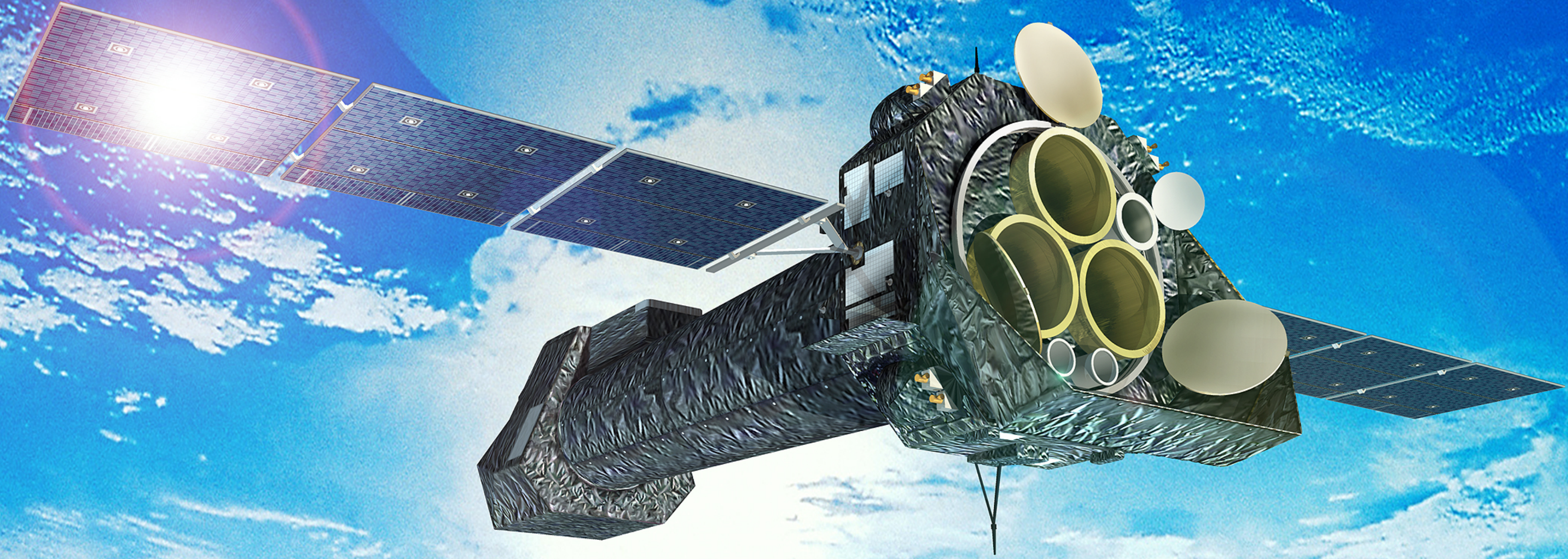


Light bending

- In this animation, the positions of background stars are seen to move as a star in the foreground passes along the line of sight of the observer.

XMM-Newton

Beobachtet Objekte die im Roentgenlicht strahlen mit Energien von 0.2-15 keV

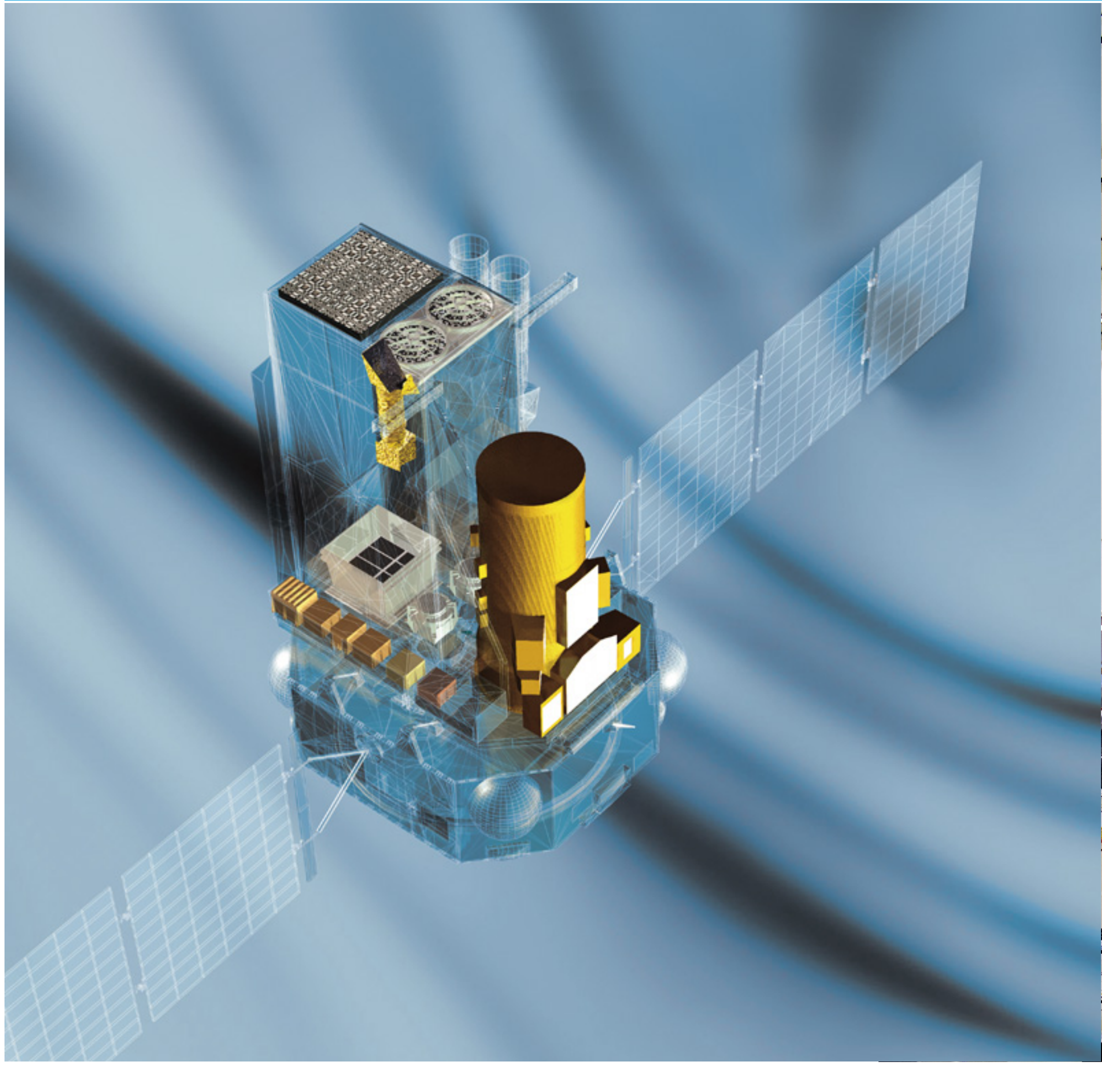


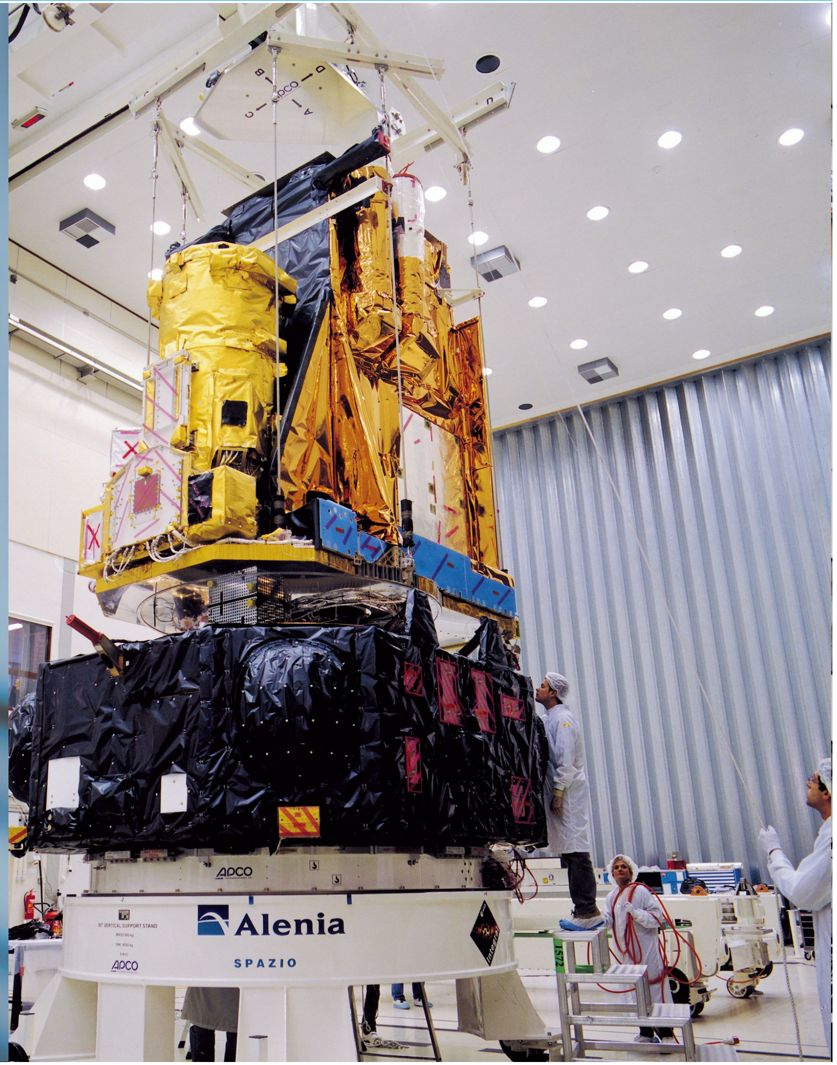
XMM-Newton can detect more X-ray sources than any previous satellite. It is helping to solve many cosmic mysteries of the violent Universe, from what happens in and around black holes to the formation of galaxies in the early universe.

XMM-Newton's high-tech design uses over 170 wafer-thin cylindrical mirrors spread over three telescopes. Its orbit takes it almost a third of the way to the Moon, so that astronomers can enjoy long, uninterrupted views of celestial objects.

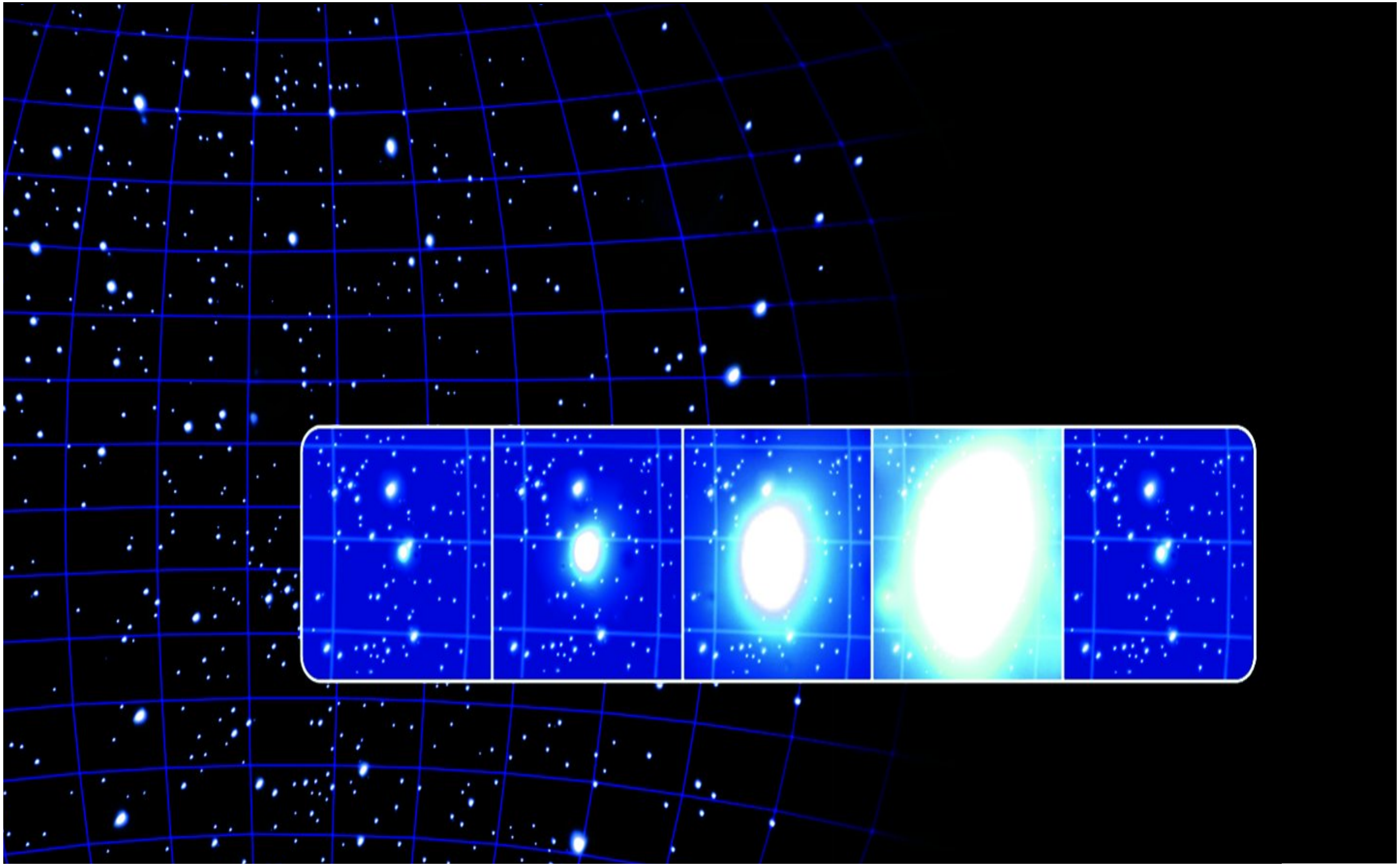
Vampire Stars

Integral and the Gamma-ray Universe





Gamma-Ray burst



menu

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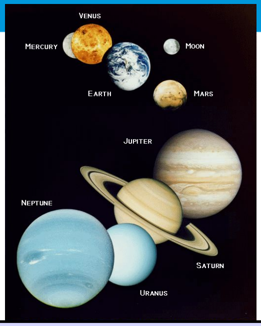
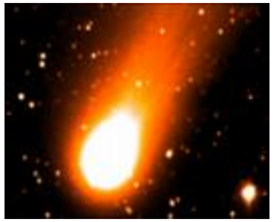
- ESA astronomy missions
- **X-ray astronomy**

Journey with X-ray results from XMM-Newton



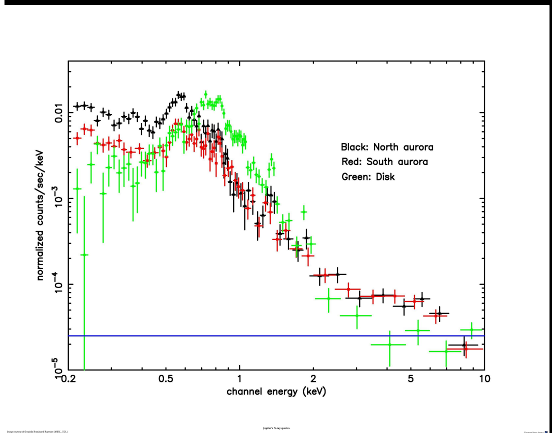


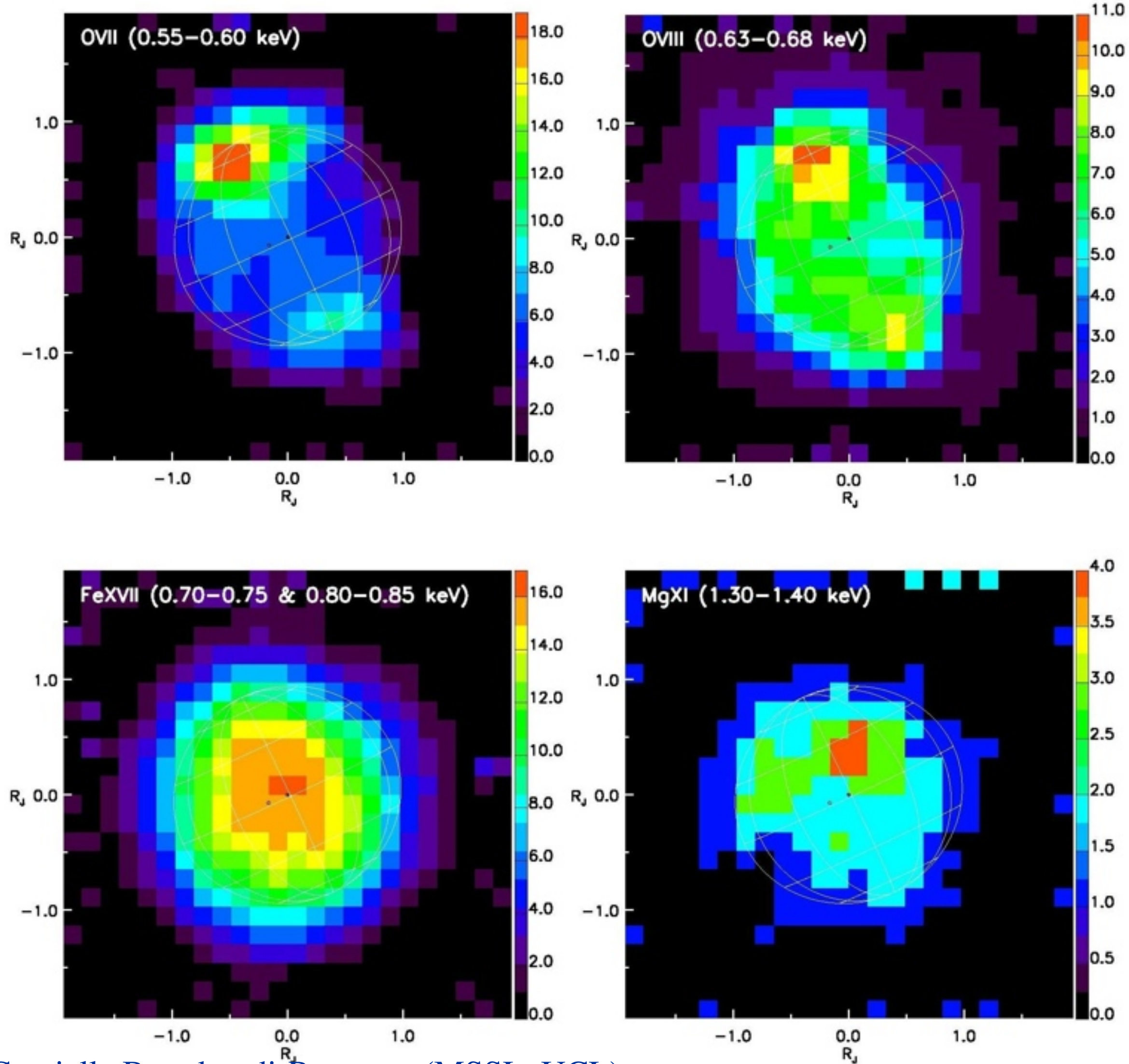
At home: our solar system

Spectral maps of Jupiter

- low energy X-rays are produced in the aurorae

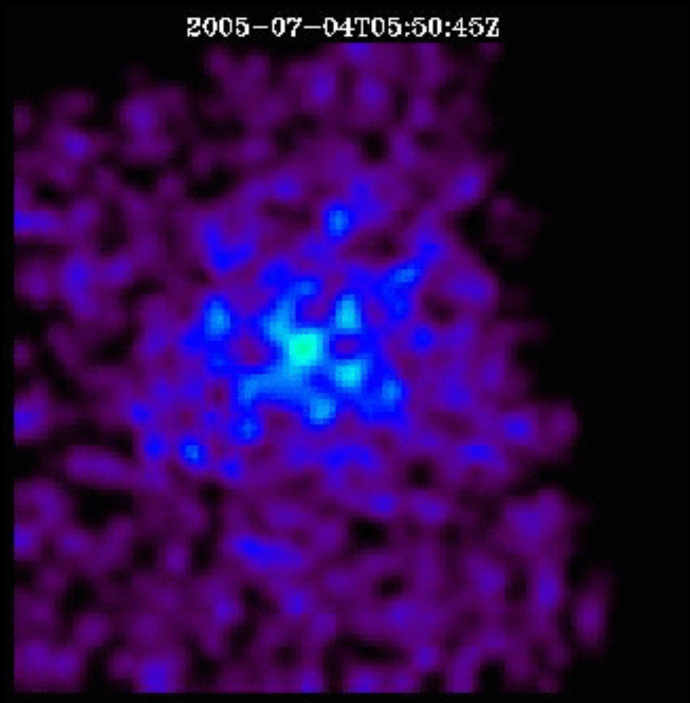
- higher energy emission comes from the whole disk of the planet

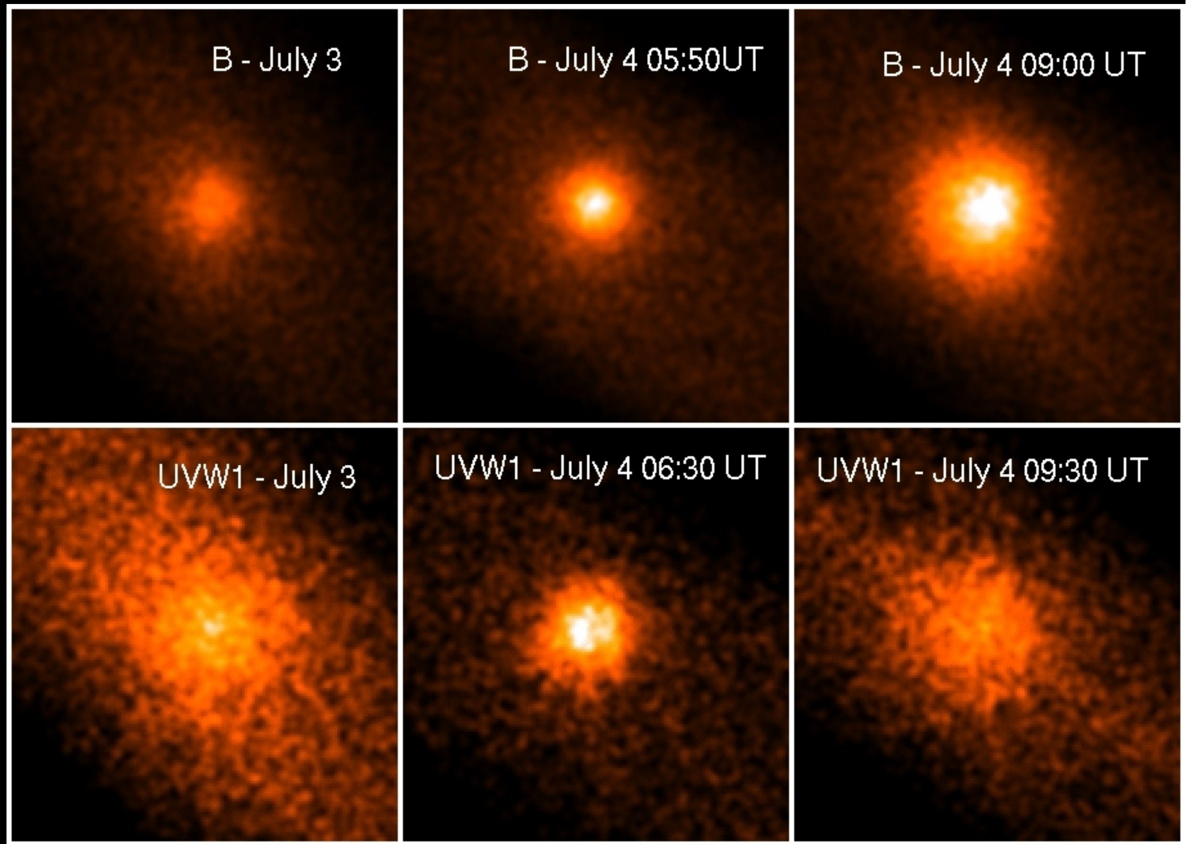




Graziella Branduardi-Raymont (MSSL, UCL)

"Deep Impact" on Comet 9P/Tempel-1

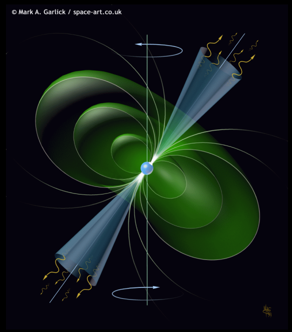


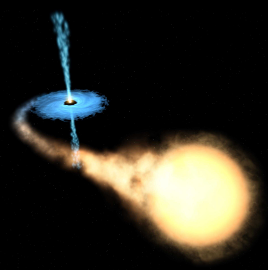


- R. Schulz, et al., 2006, A&A 448, L53

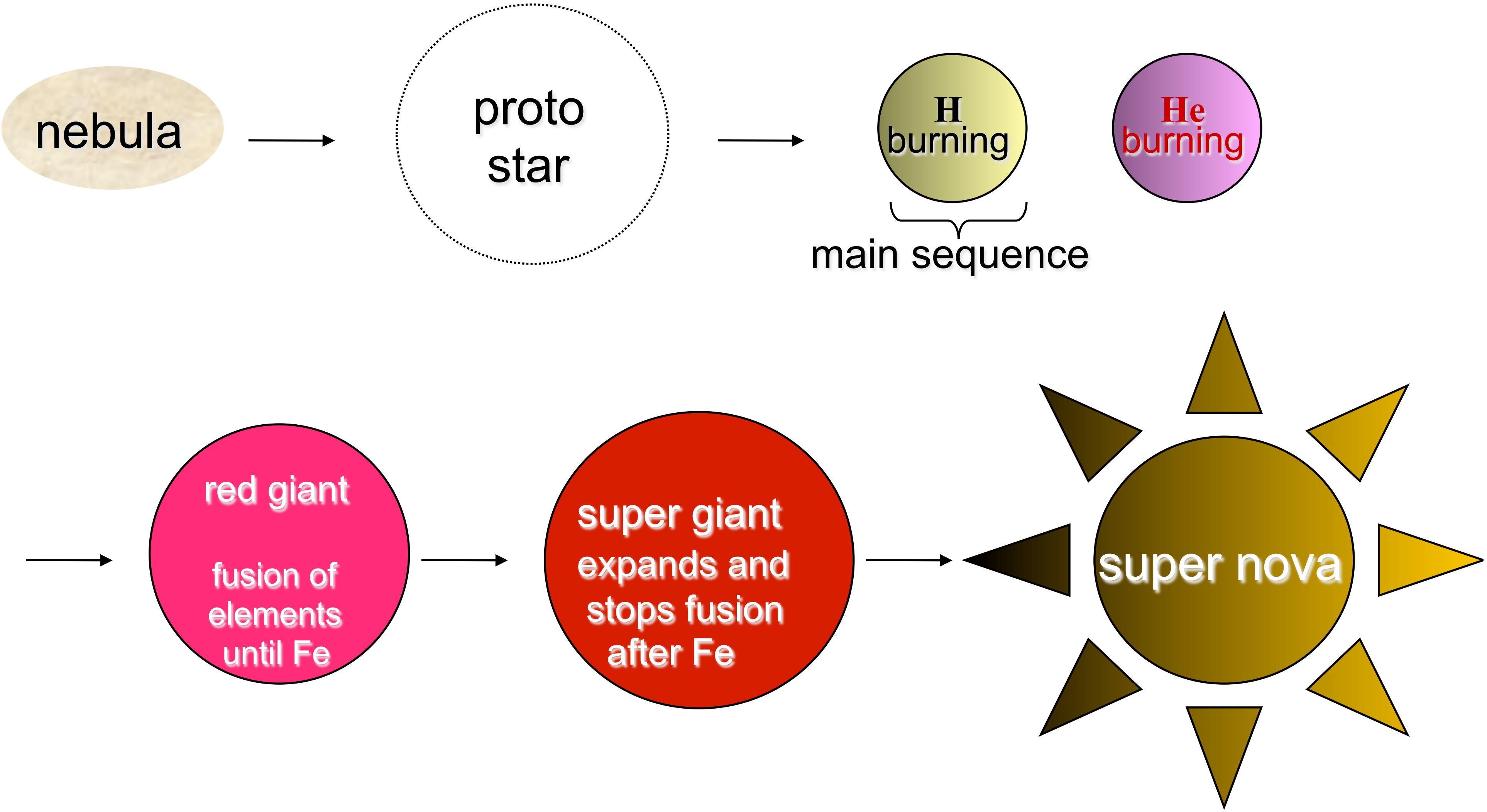
=> first detection of ice grains in material ejected from the nucleus of a comet at only 1.5 AU from the Sun

journey





star-evolution



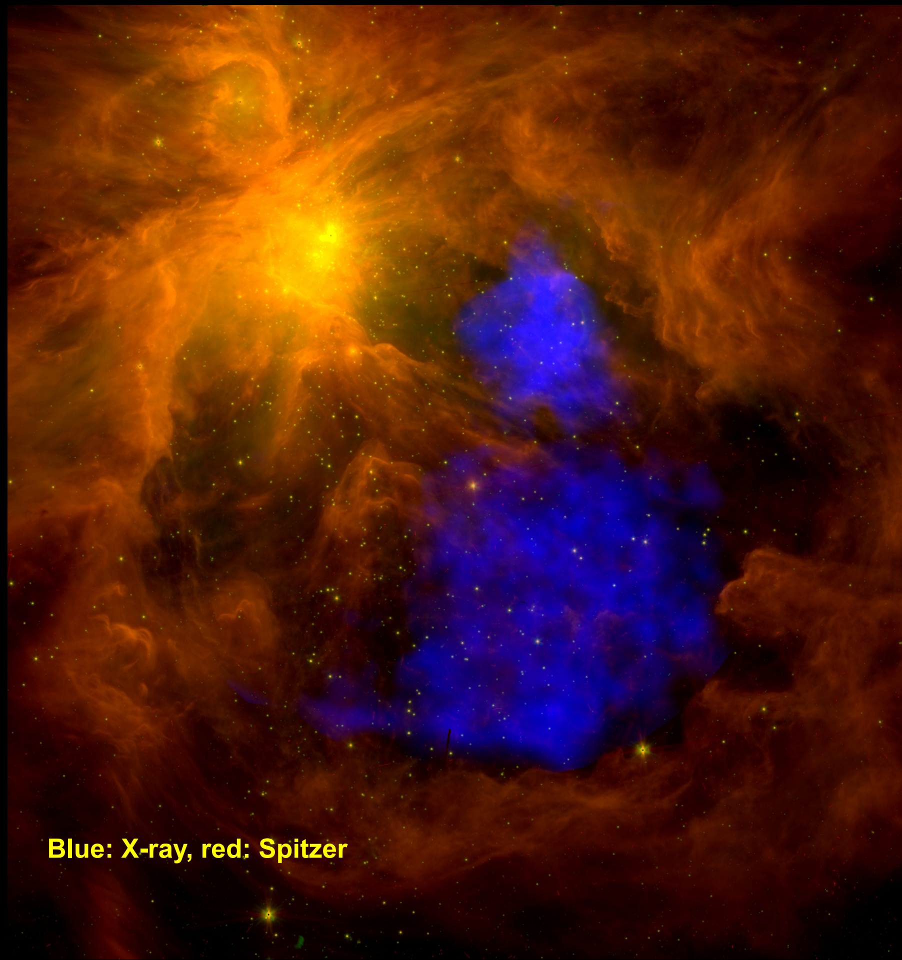
Million-Degree Plasma Pervading the Extended Orion Nebula

- The Orion nebula (near star forming region) is illuminated by a small group of massive stars (the Trapezium).
- XMM-Newton observations reveal a hot plasma with a temperature of 1.7-2.1 10^6 K pervading the southwest extension of the Orion nebula. The plasma flows into the adjacent interstellar medium.

➔ Single hot massive stars contribute to the enrichment of ISM

➔ Suggests that this is a common X-ray outflow phenomenon widespread across our Galaxy

- M. Guedel et al., Science 319, 309, 2008



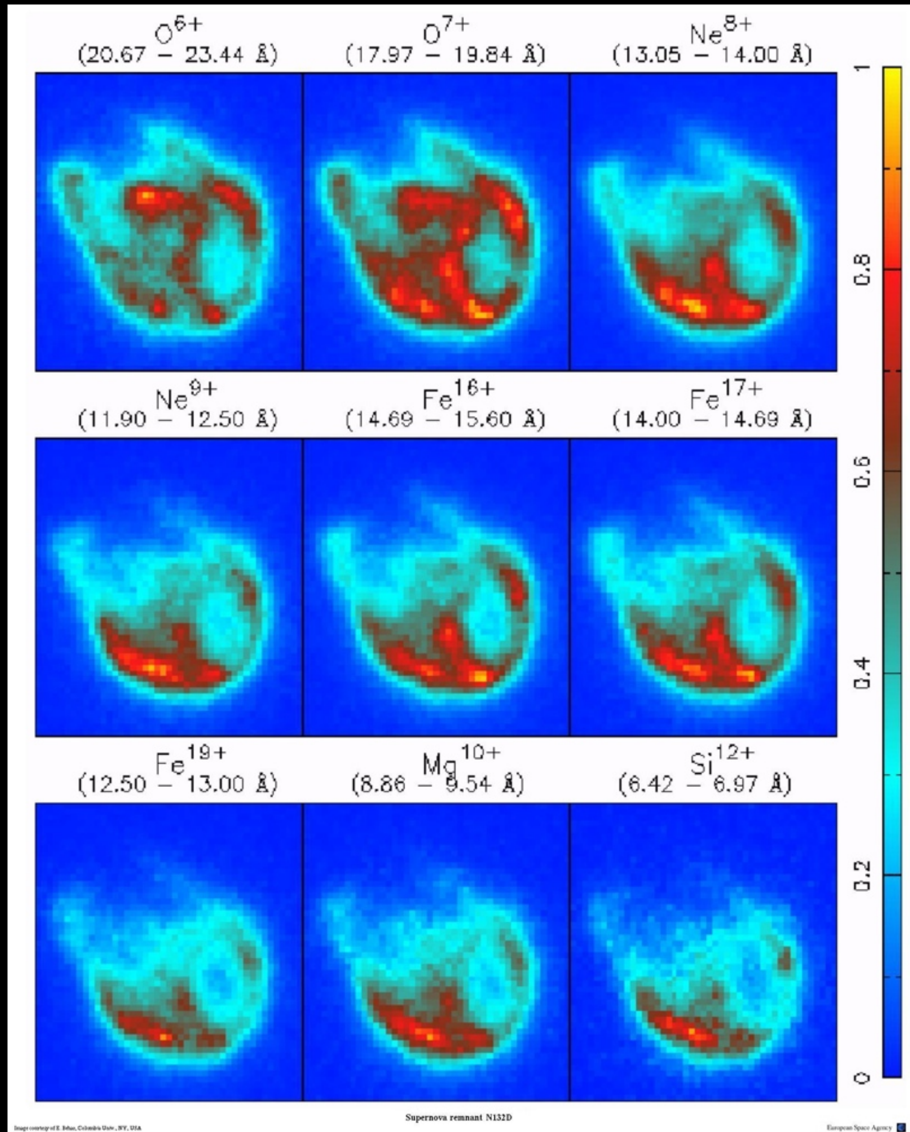
Super Nova Remnant N132D

esa

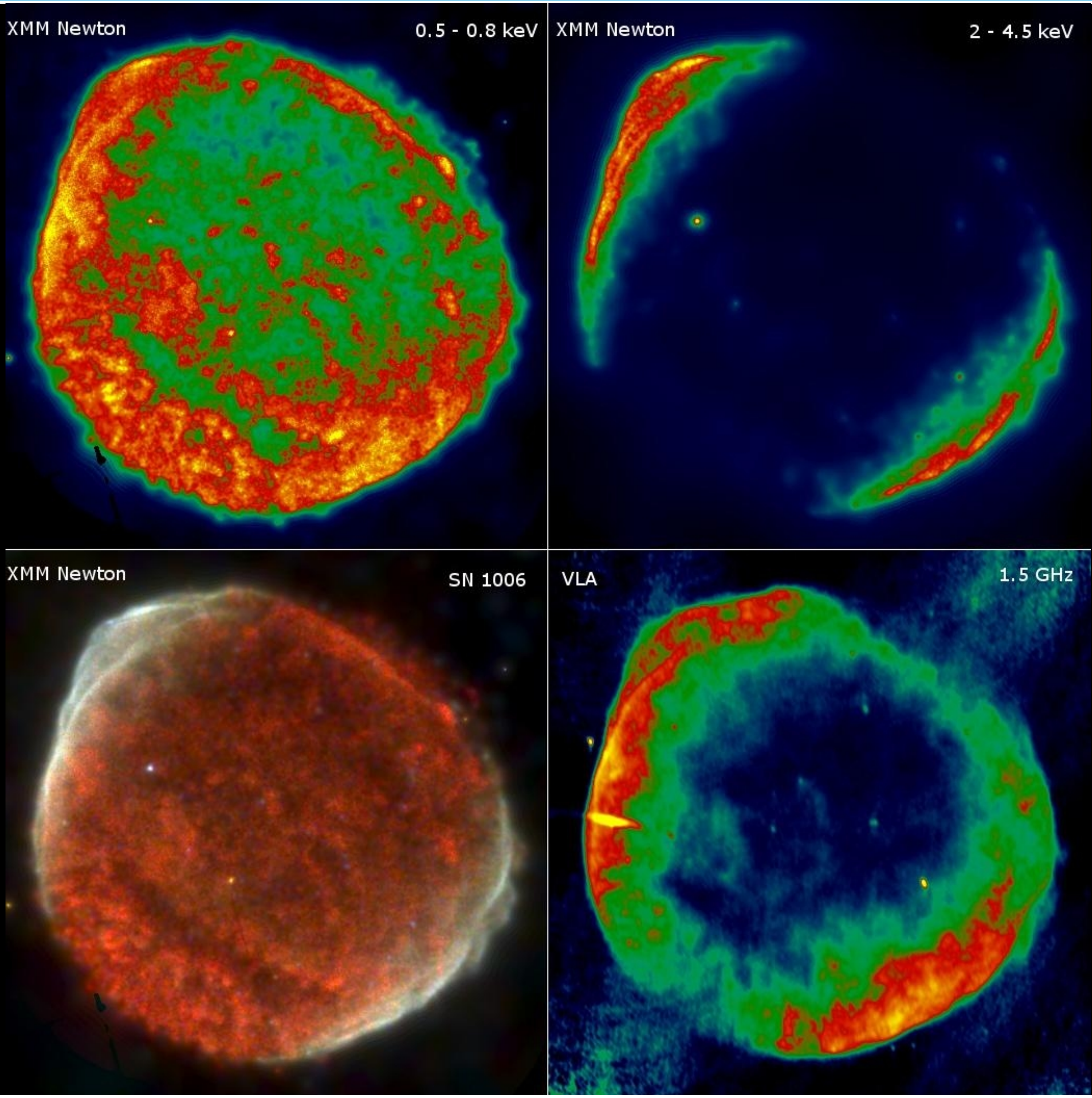
One of the brightest soft X-ray sources in the Large Magellanic Cloud:

the supernova remnant N132D in different energies

E. Behar, Columbia Univ.,



SN 1006: Variations of Cosmic-ray Acceleration



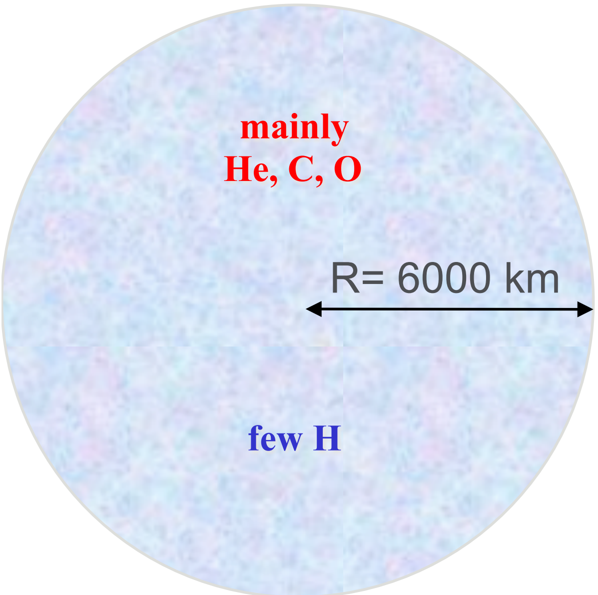
- R. Rothenflug et al., 2004, A&A 425, 121
- Prototype of shell supernova remnants
- Non-thermal synchrotron emission

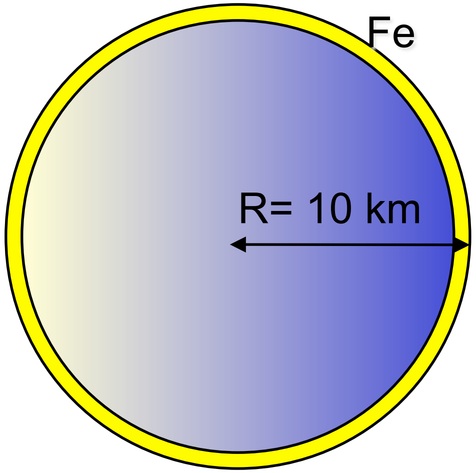
➔ The magnetic field is amplified where acceleration is efficient

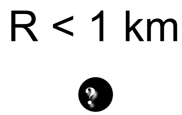
➔ Relation to the TeV emission

compact object classification

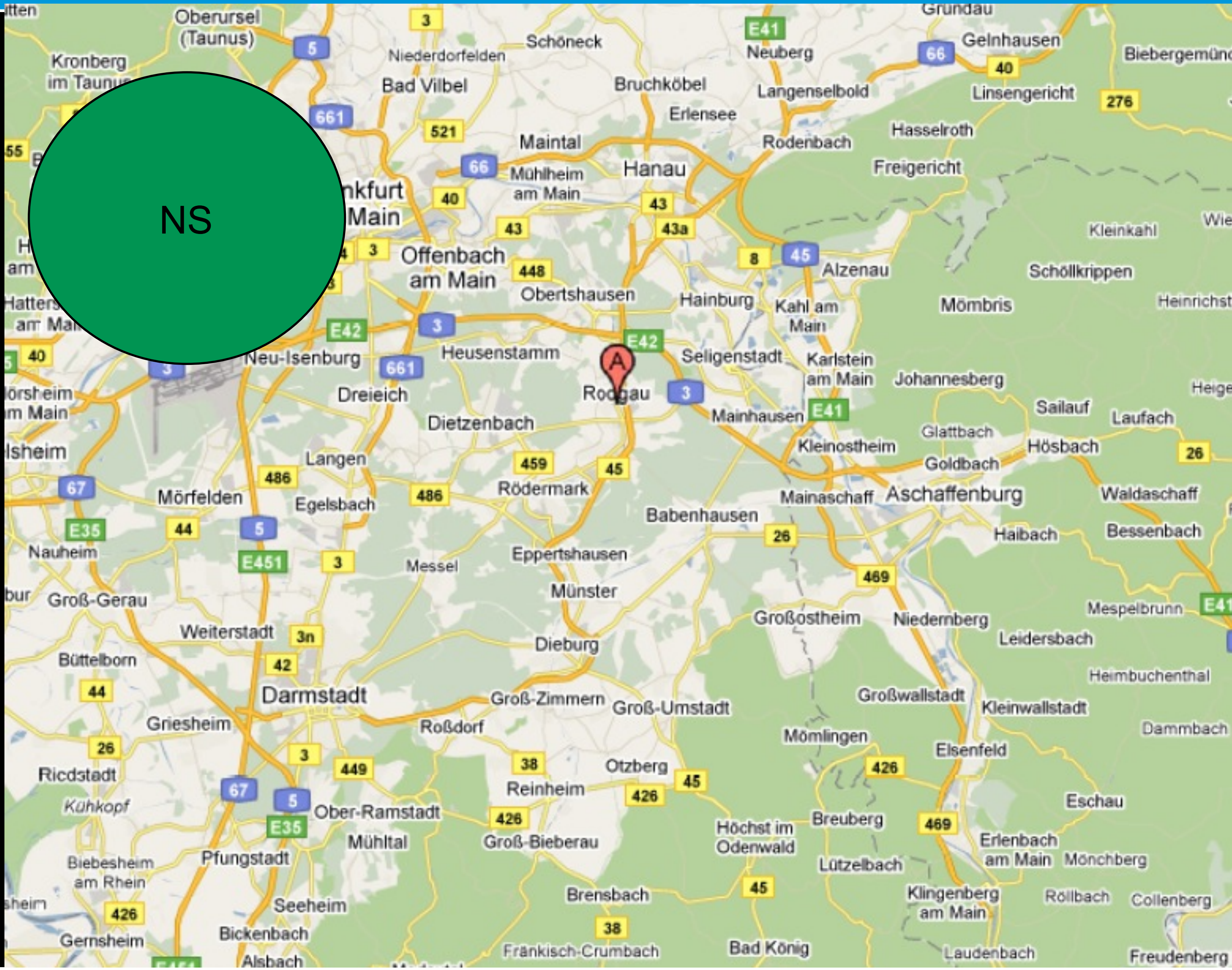
white dwarf	neutron star	black hole
$M < 1{,}4\ M_{sun}$	$1{,}4\ M_{sun} < M < 3{,}2\ M_{sun}$	$3{,}2\ M_{sun} < M$



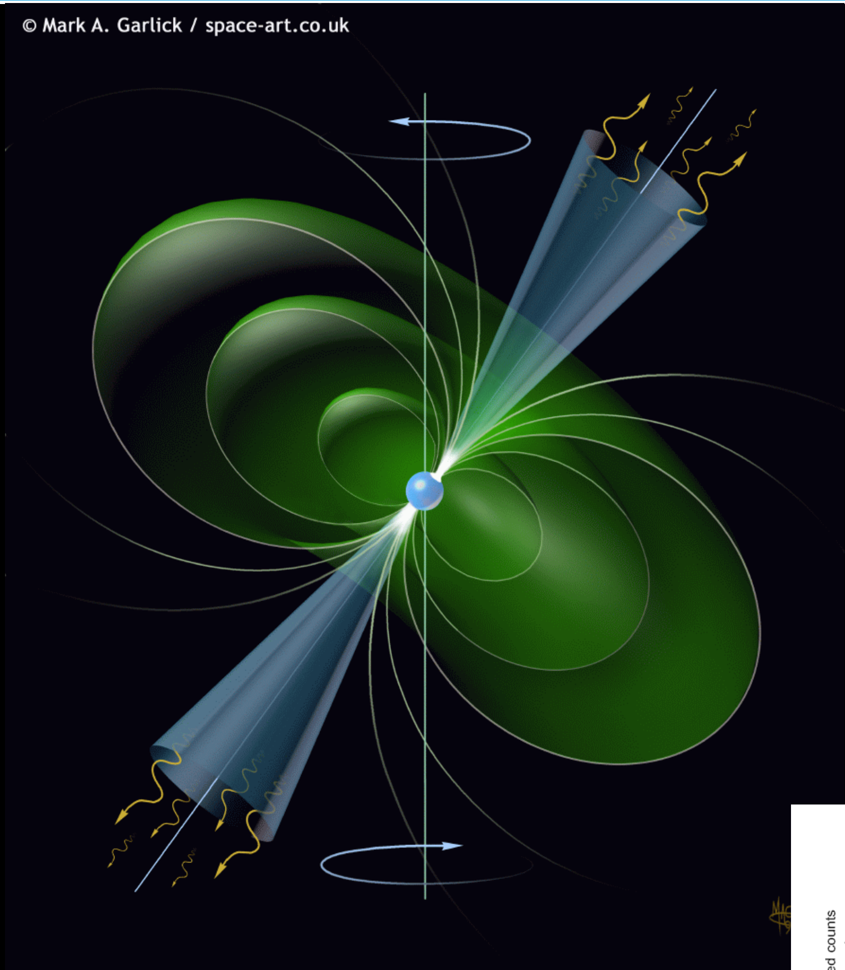




order of magnitude

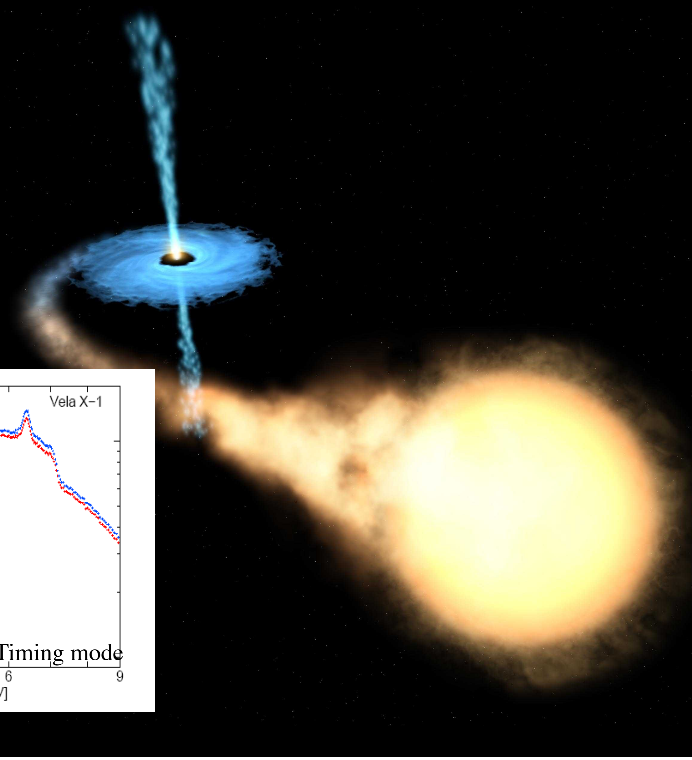


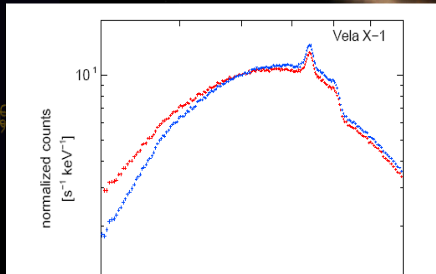
pulsars and binaries



- **Pulsars:** highly magnetized rotating neutron star (compact object) that emits a beam of electromagnetic radiation, since rotational and magnetic field axes are not parallel

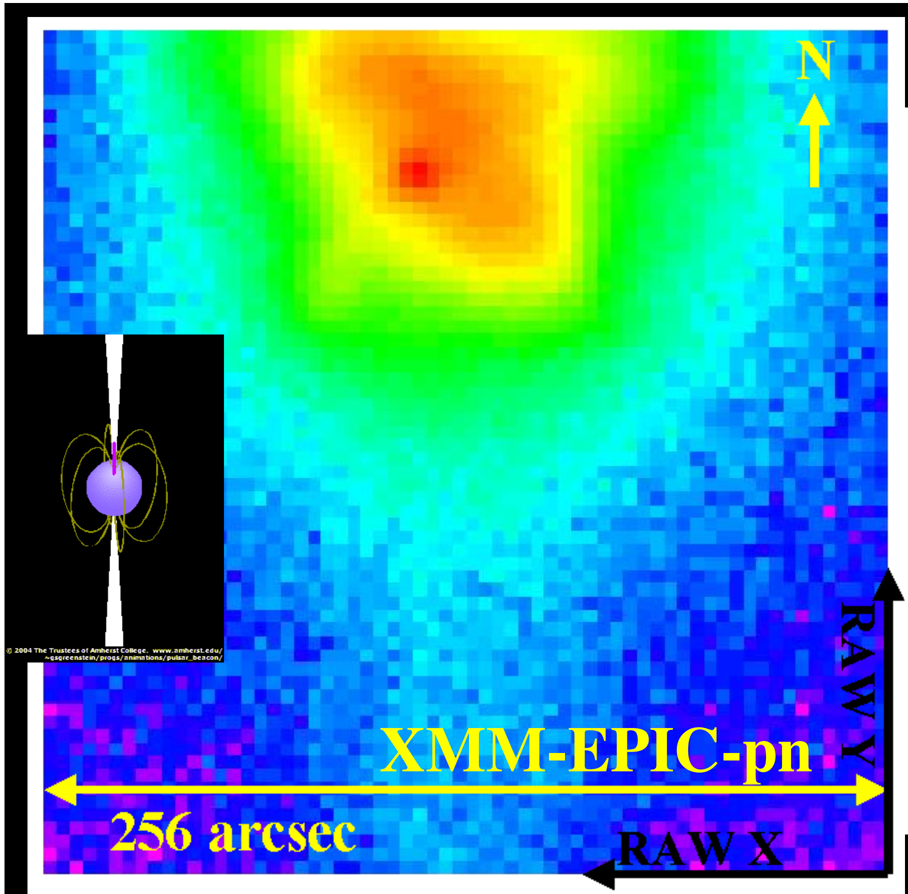
- **XRBs:** class of binary stars that are luminous in X-rays. X-rays are produced by matter falling from one component to the other component, which is a compact object: a white dwarf, neutron star, or black hole



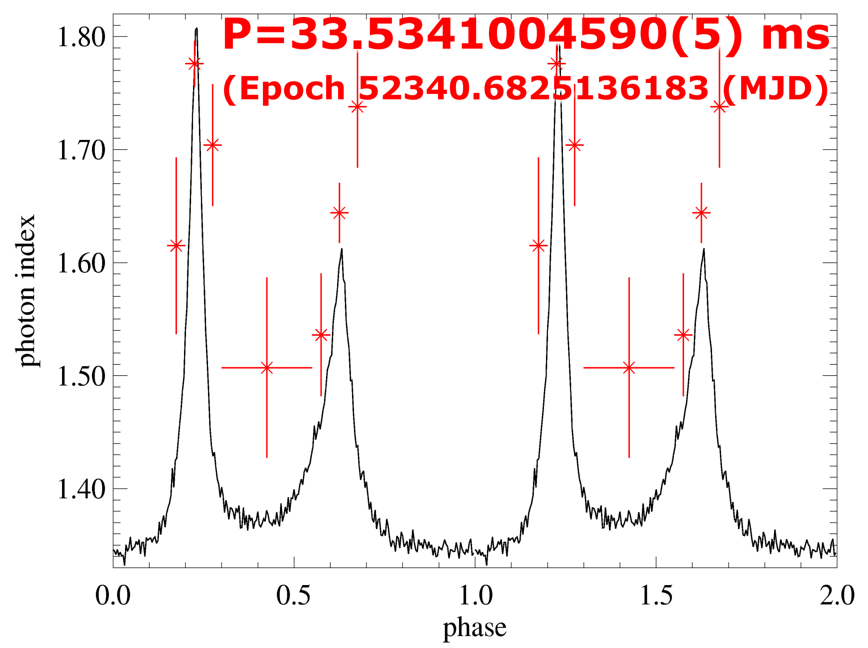


Spectrum in mod. EPIC-pn Timing mode
Dissertation S. Fritz 2008

the Crab pulsar in X-rays



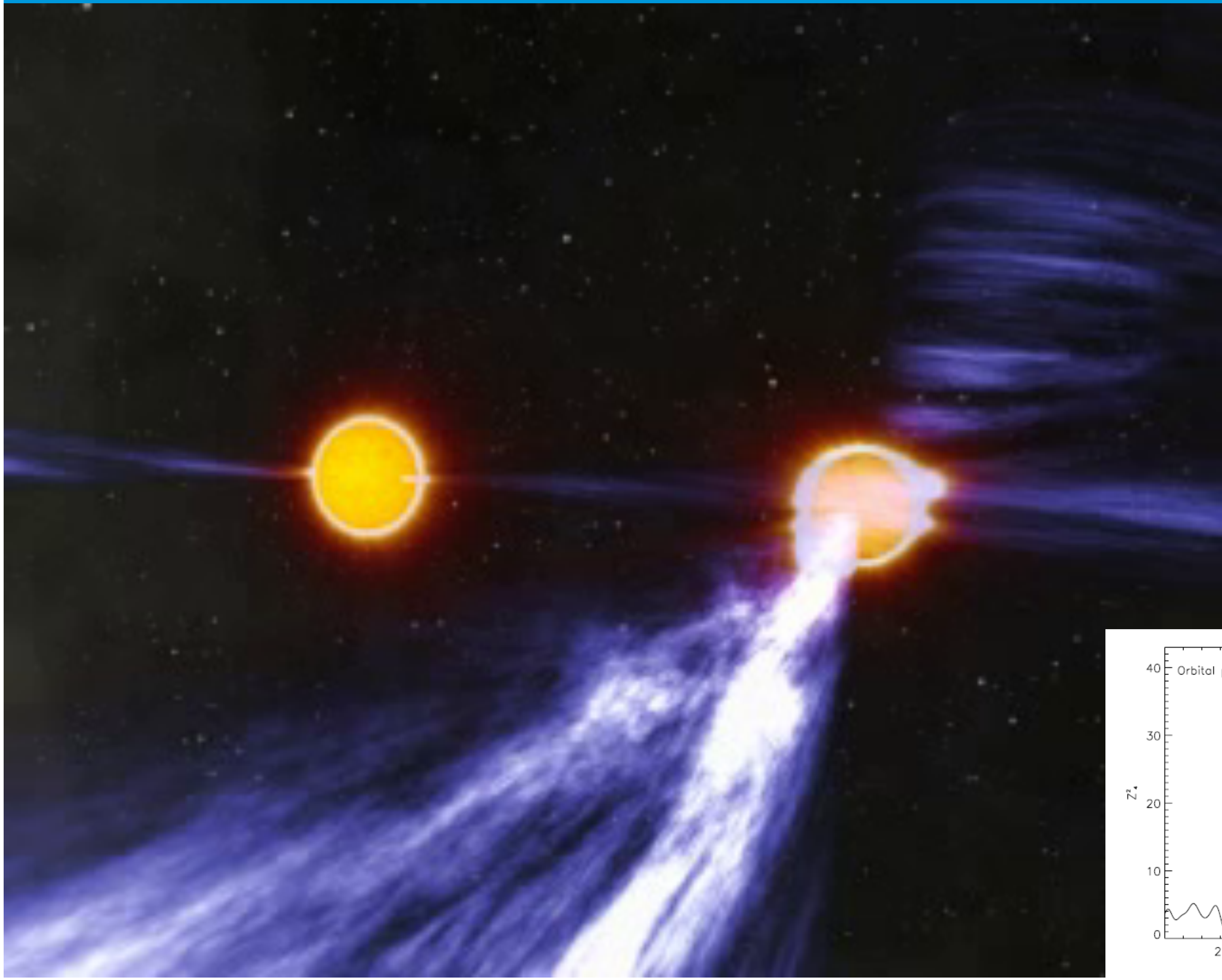
Folded light curve of the Crab pulsar

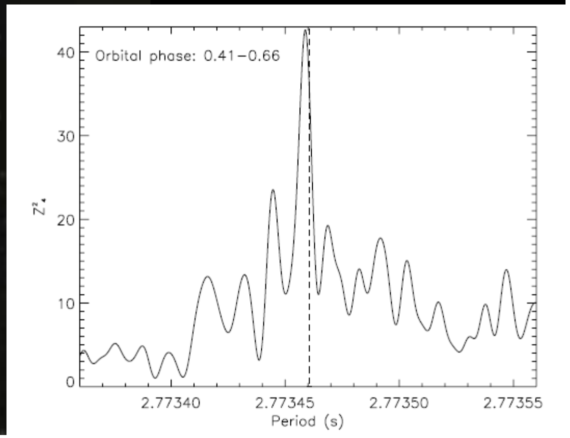


Kirsch et al. 2006, A&A 453, 173-180

- high accuracy measurement of a 33 ms pulsar (error +/- 5 x 10^{-10} ms)
- pulse phase spectroscopy

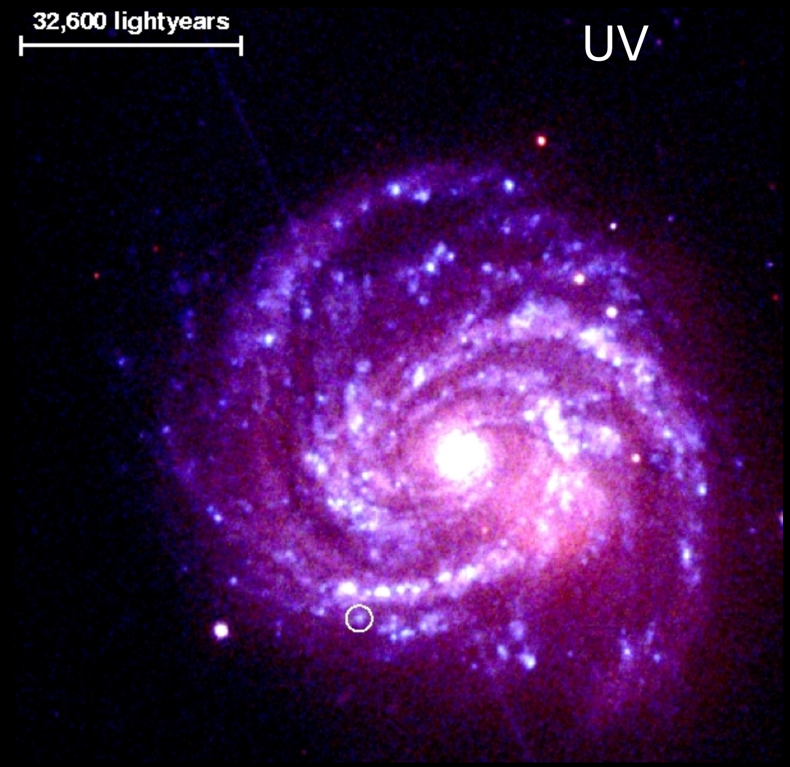
binary pulsar system

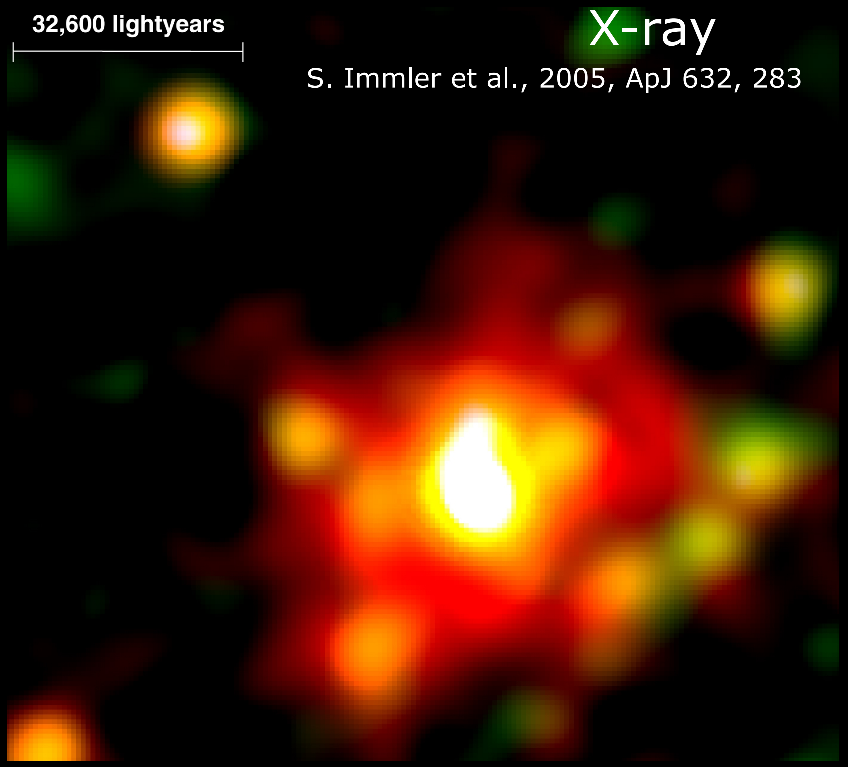




- two pulsars orbiting each other in a binary system
- PSR J0737-3039 contains a slowly-rotating 'lazy' neutron star (pulsar B) orbiting a faster and more energetic companion (pulsar A).
- A. Pellizzoni, Astrophysical Journal in May 2008.

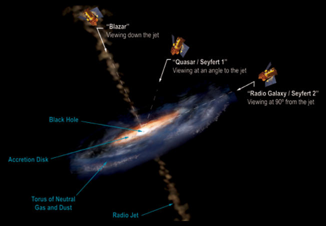
SN 1979C in M100: The supernova that just won't fade away





- M100: 56 million light years from Earth
- overall appearance of the galaxy is different in the X-ray compared to the UV/optical.
- OM image shows the spiral structure of the galaxy whilst in the X-ray image this structure is not visible and instead the galaxy X-ray luminosity tends to fall off from the galaxy centre, with some bright regions.
- The supernova 1979C is shown circled in the UV/optical image, and can be seen as an orange spot to the lower left of the galactic centre (which appears white) in the X-ray image.

journey



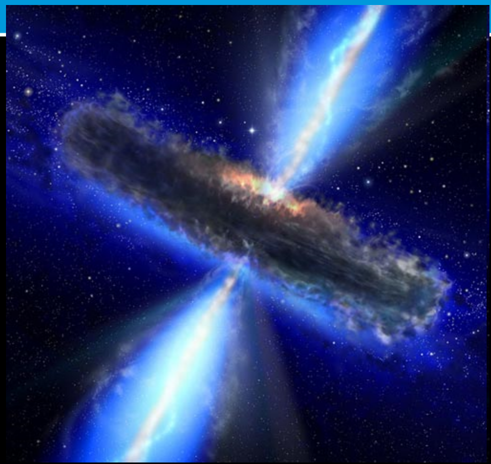
"Blazar"
Viewing down the jet
"Quasar / Seyfert 1"
Viewing at an angle to the jet
"Radio Galaxy / Seyfert 2"
Viewing at 90º from the jet
Black Hole
Accretion Disk
Torus of Neutral Gas and Dust
Radio Jet

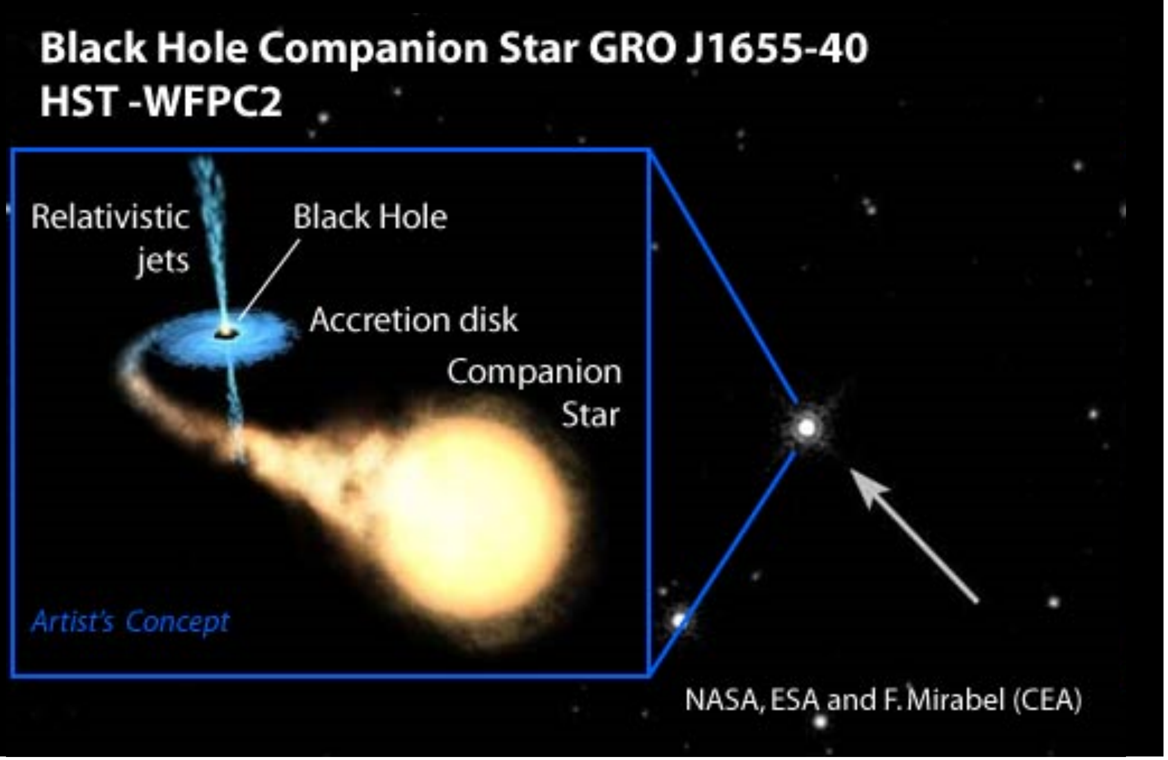
black holes

- region of space in which the gravitational field is so powerful that nothing, not even light, can escape its pull after having fallen past its event horizon

- Compact object with mass > 3.2 m_{sun}
  - Black hole
  - Super massive black hole (billions of solar masses

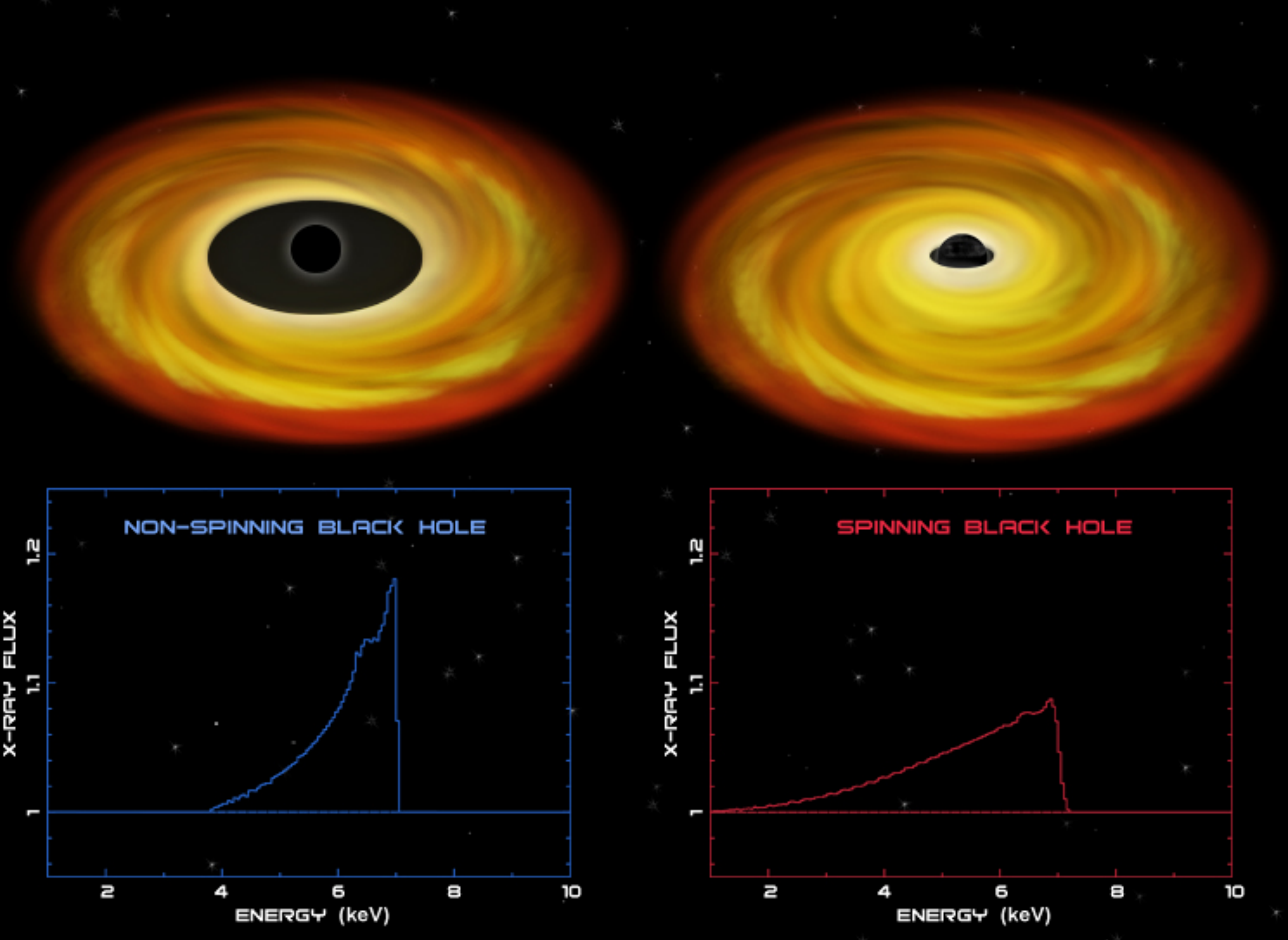
- ~20 BH confirmed in X-ray binaries with only three of them (Cyg X-1, LMC X-1, LMC X-3) being persistent sources





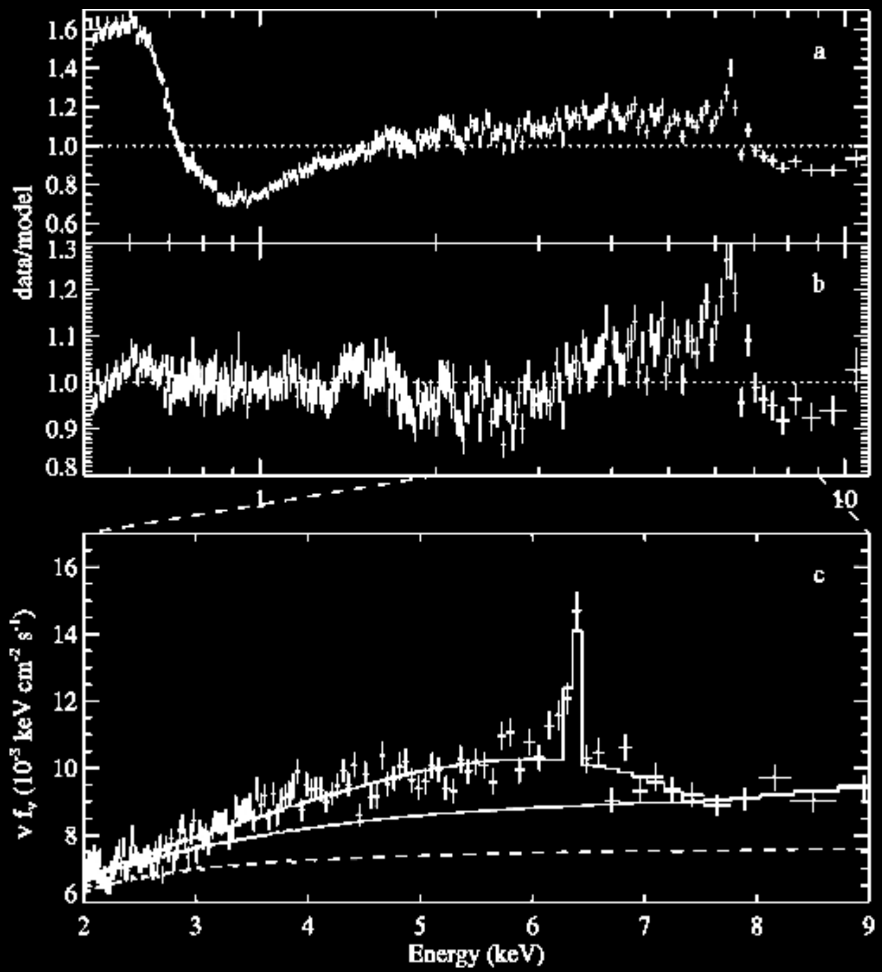
black holes – 4 types

- four known, exact, black hole solutions to Einstein's equations of gravity in General Relativity.
- BH can be characterized by three (and only three) quantities:
  - mass M,
  - angular momentum J,
  - electric charge Q



	Non-rotating (J = 0)	Rotating (J ≠ 0)
Uncharged (Q = 0)	Schwarzschild	Kerr
Charged (Q ≠ 0)	Reissner-Nordström	Kerr-Newman

MCG-6-30-15: Extraction of Energy from the Spinning Black Hole

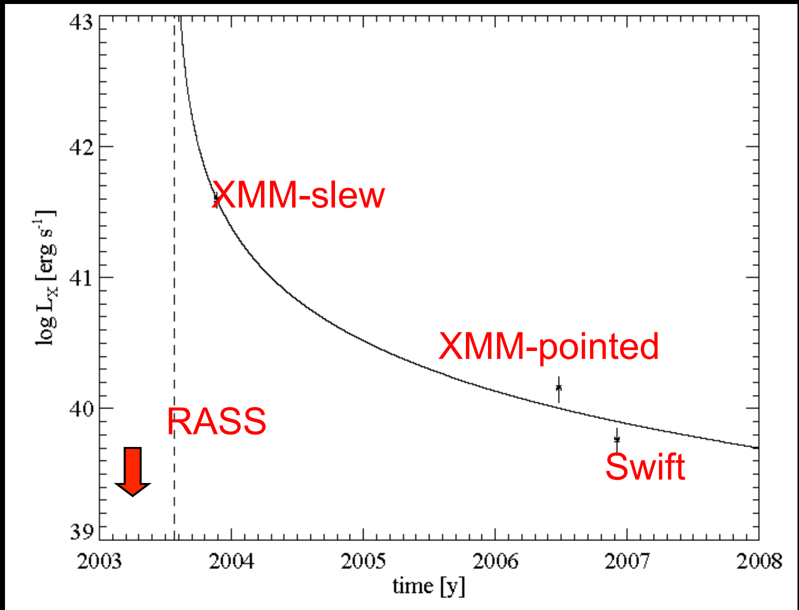


- Deep minimum' state
- Difficult to understand in any pure accretion disc model
- Extraction and dissipation of rotational energy from a spinning black hole
- J. Wilms et al., 2001, MNRAS 328, L27

10^6–10^8 solar masses

100 Million ly

Unveiling dormant supermassive black hole: Tidal disruption events



$$L_X = 6.7(\pm 1.2) \times 10^{40} \left[\frac{t - 2003.59(\pm 0.04)\,\mathrm{yr}}{1\,\mathrm{yr}} \right]^{-5/3} \mathrm{erg\,s^{-1}}$$

P. Esquej, A. Read. R. Saxton and other in 2007 and 2008

A star orbiting a SMBH will be disrupted when approaching the BH tidal radius

The process is expected to happen up to M_{BH}~108M_{sun} (for a solar mass star).

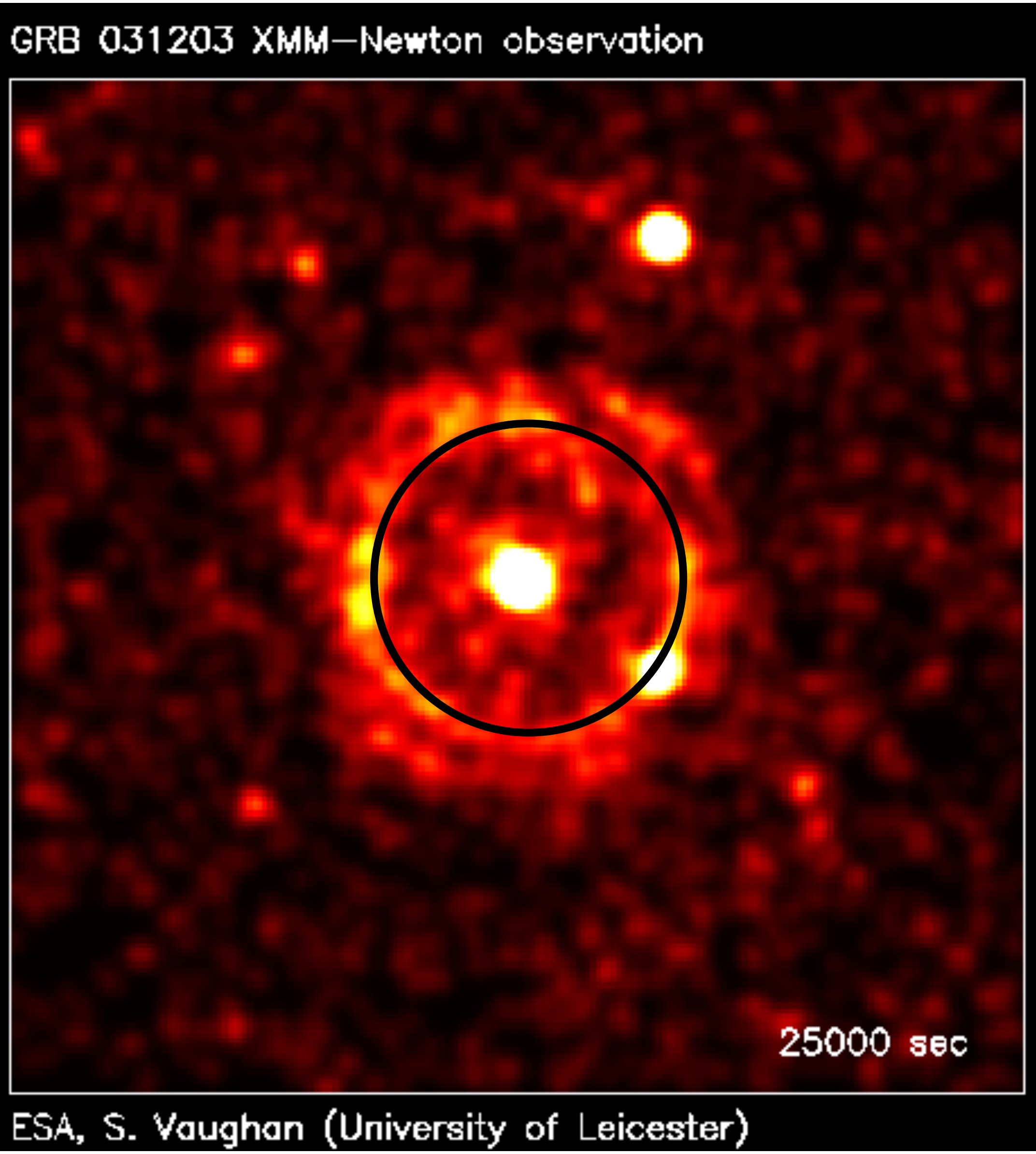
Once disrupted, half of the stellar material is ejected and the remaining half will be bound, returning peri-centre and circularizing, a fraction of it will be accreted by the hole (~10%).

Flare of radiation beginning when the most bound material returns to peri-centre.

Peak in soft X-rays!

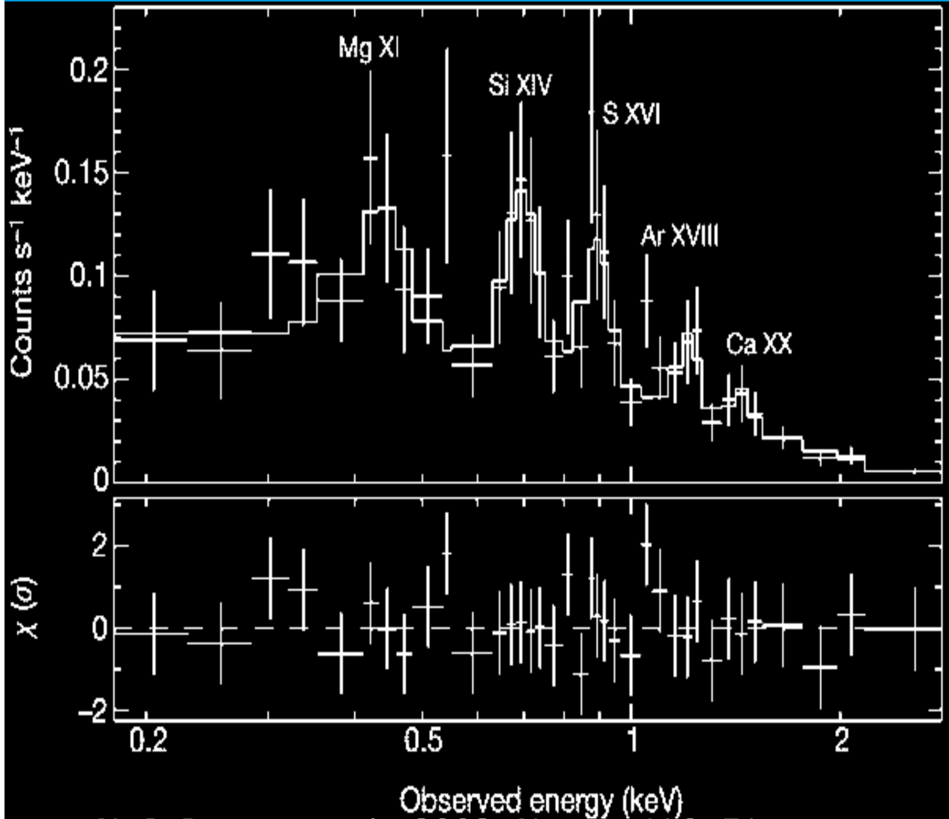
Luminosity declines as t-5/3

GRB 031203

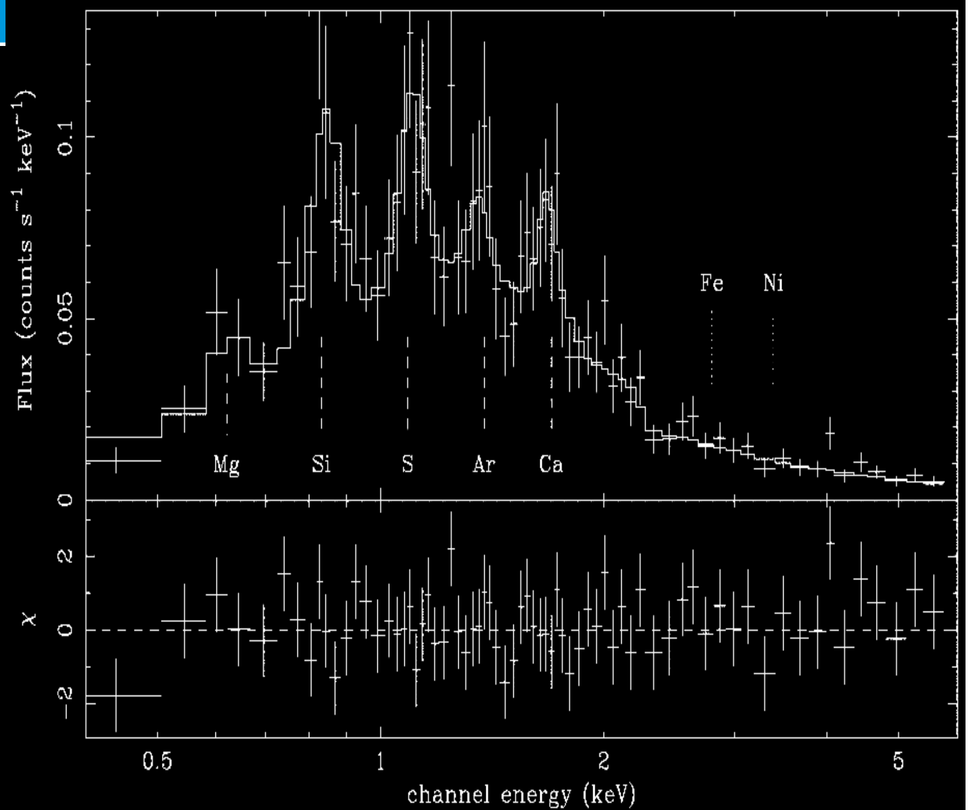


- discovery of an evolving dust-scattered X-ray halo
- S. Vaughan et al., 2004, ApJ 603, L 5
- will allow highly accurate distance determinations

GRB 011211 & GRB 030227



- N. J. Reeves et al., 2002, Nature 416, 51

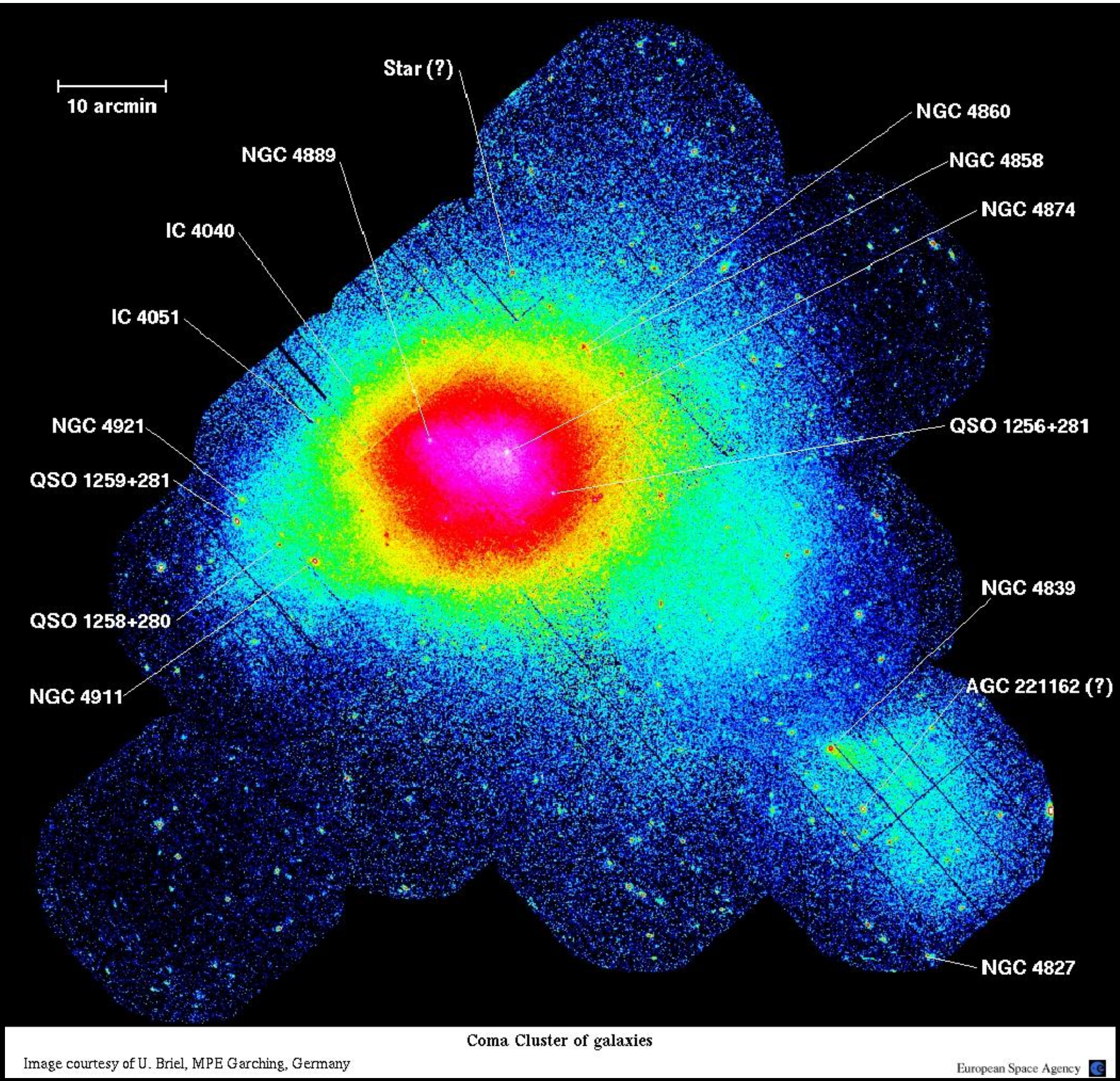


- D. Watson et al. 2003, ApJ 595, 29

in total 14 articles, e.g. R. E. Rutledge & M. Sako, 2003, MNRAS 339, 600 and N. Butler et al. , 2005, ApJ 627, L9

→ supernova explosion of a massive stellar progenitor precedes the GRB event and is responsible for the outflowing matter

Coma Cluster of Galaxies

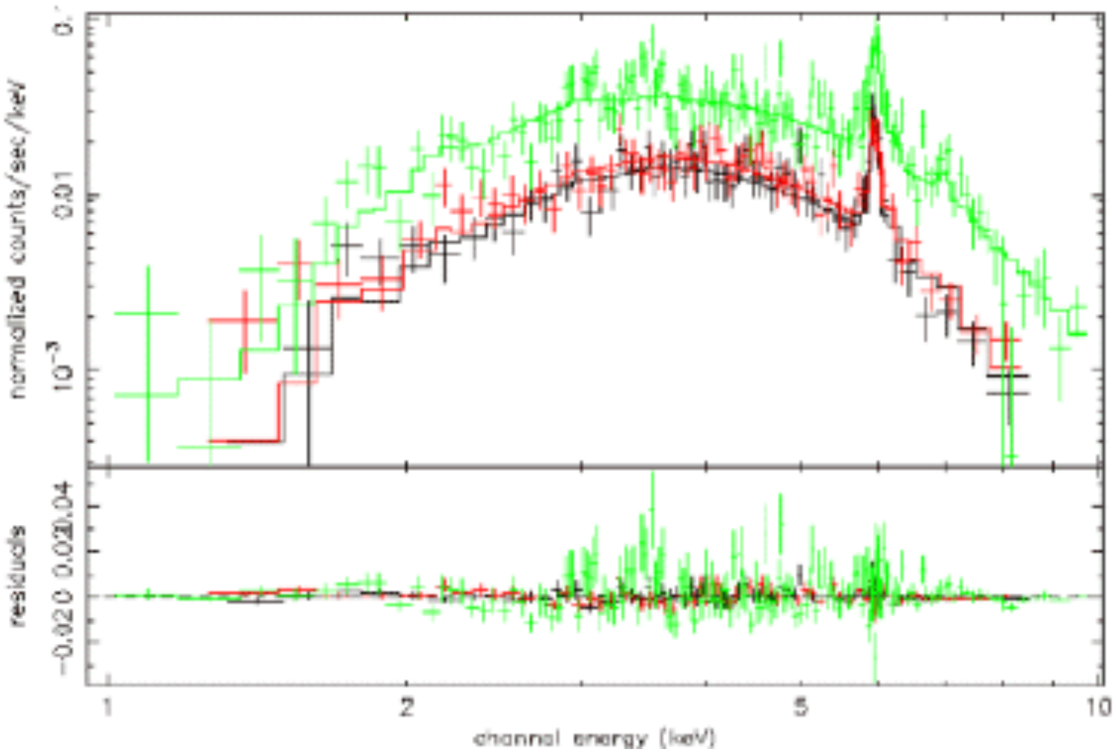


320 Million ly

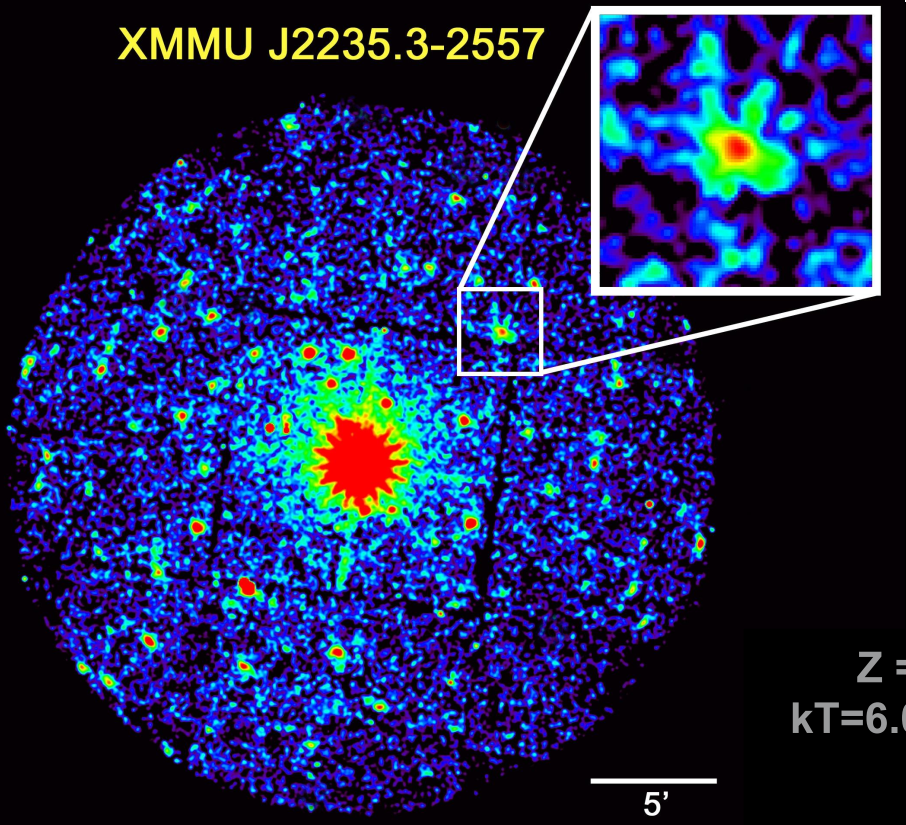
spectrum of a cluster of galaxies

- spectrum: thermal bremsstrahlung model, with a particularly strong iron feature at a **redshift of 0.12**.
- soft X-ray absorption corresponding to a column density of ~8 x 10^{22} cm^{-2} causes the spectrum to be cut-off below ~2 keV
- temperature: ~6 keV
- luminosity 4 x 10^{44} erg s^{-1}

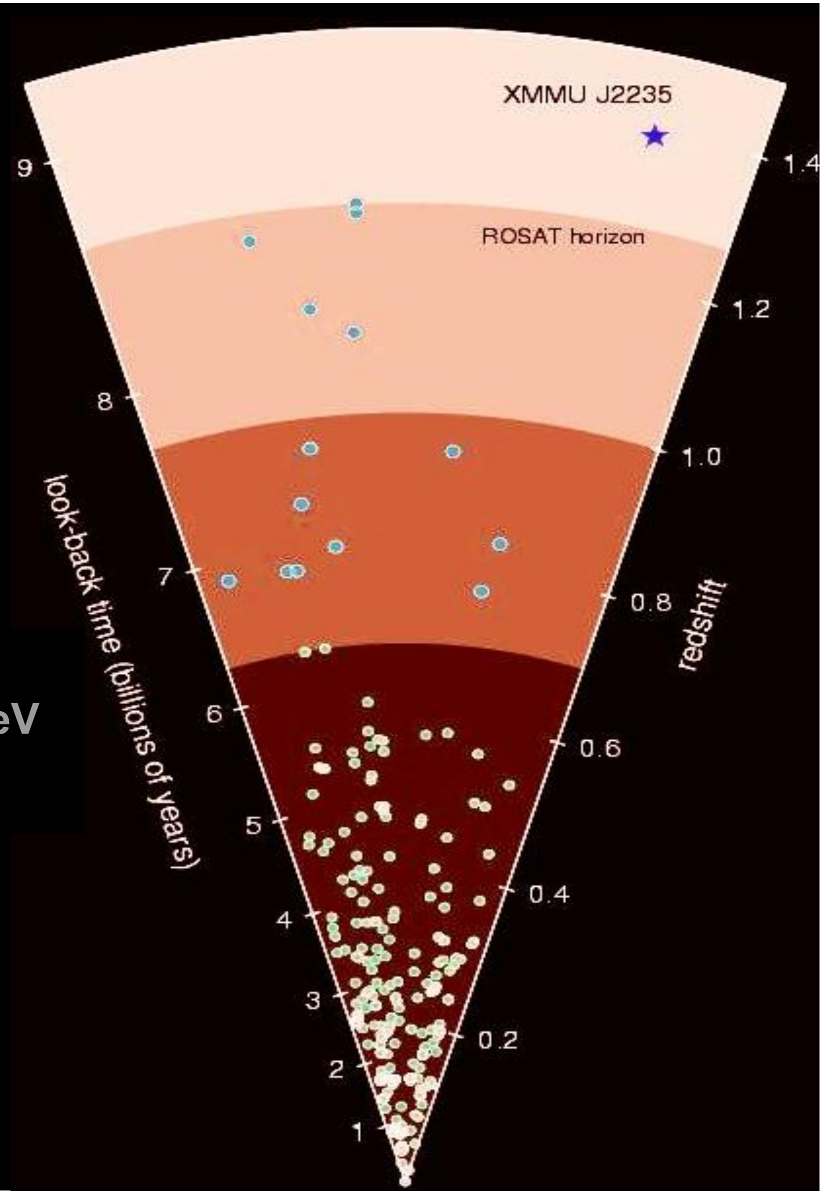
$$1 + z = \frac{\lambda_{\text{observed}}}{\lambda_{\text{emitted}}}$$



the most distant cluster of galaxies



Z = 1.393
$kT=6.0^{+2.5}_{-1.8}$ keV



- C. R. Mullis et al., 2005, ApJ 623, L85

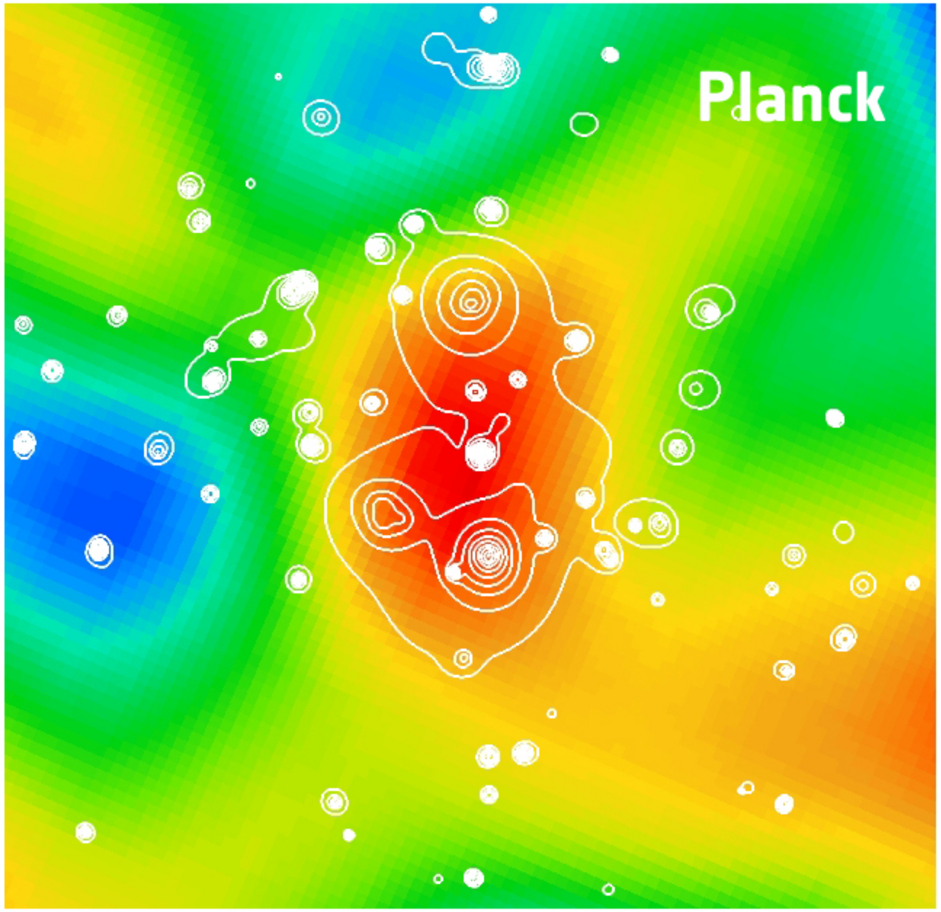
XMMXCS J2215.9-1738

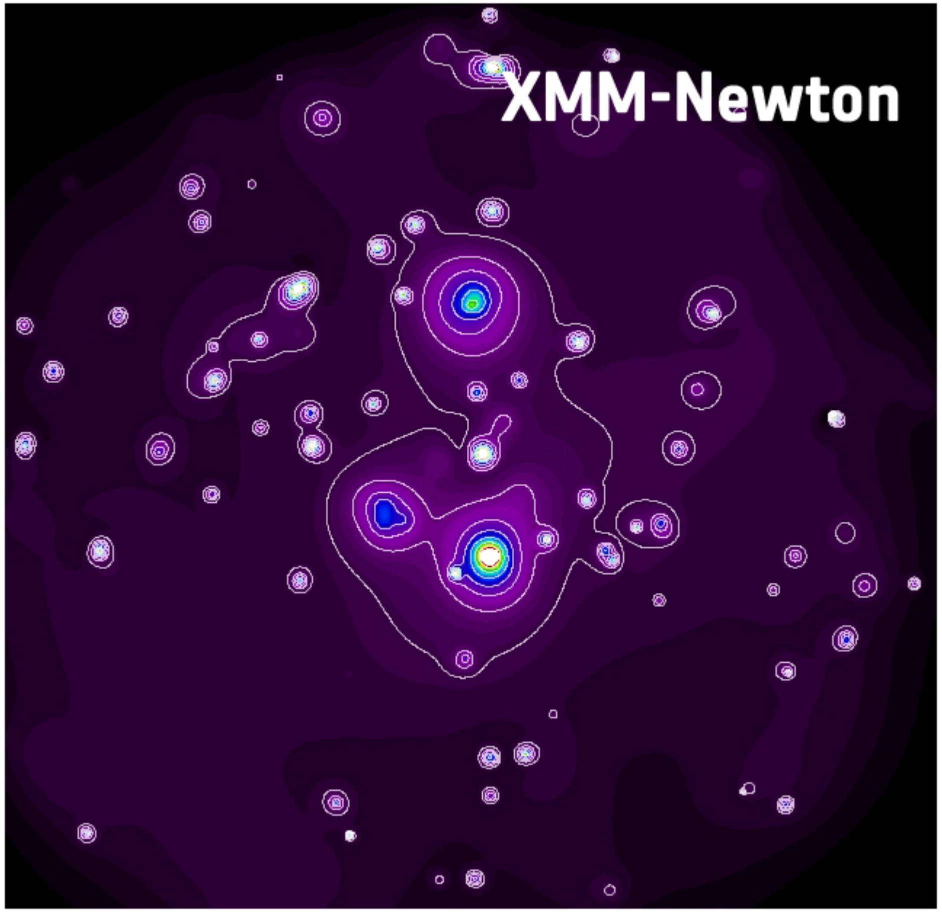
- **Massive galaxy cluster at z=1.45**
- **The redshift of XMMXCS J2215.9-1738 is the highest currently known for a spectroscopically confirmed cluster of galaxies**

- **Stanford et al., 2006 ApJ 646, L13**

Detection of new supercluster

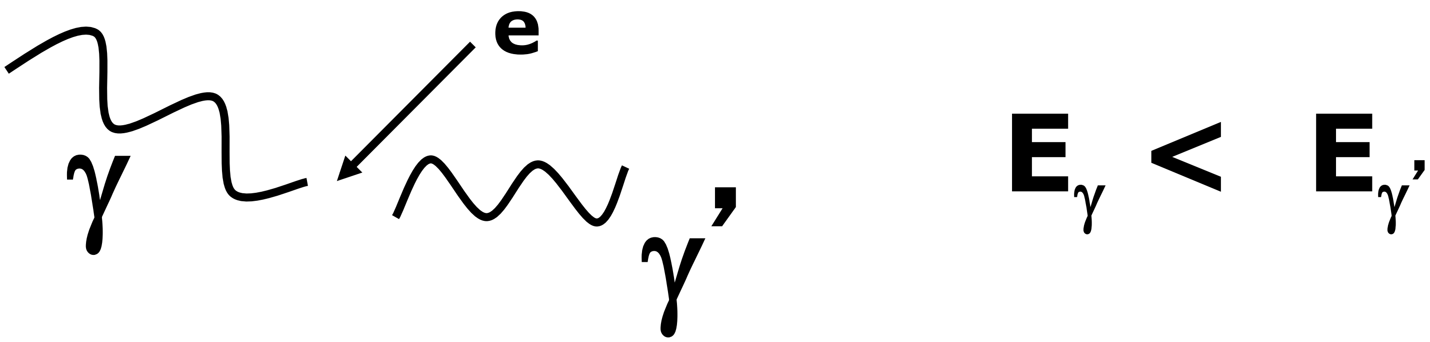
- Synergy between Planck and XMM Newton discovers a new supercluster via the Sunyaev-Zel'dovich effect (inverse compton scattering of CMB and follow up observation of distorted CMB region by XMM)

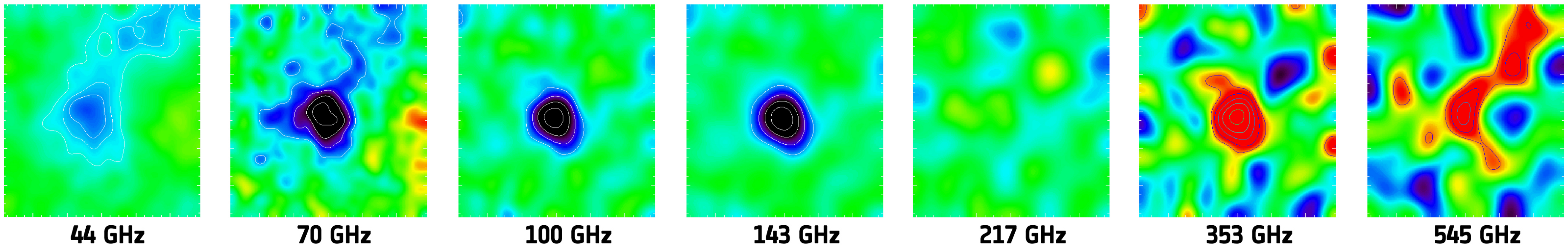




Sunyaev-Zel'dovich effect

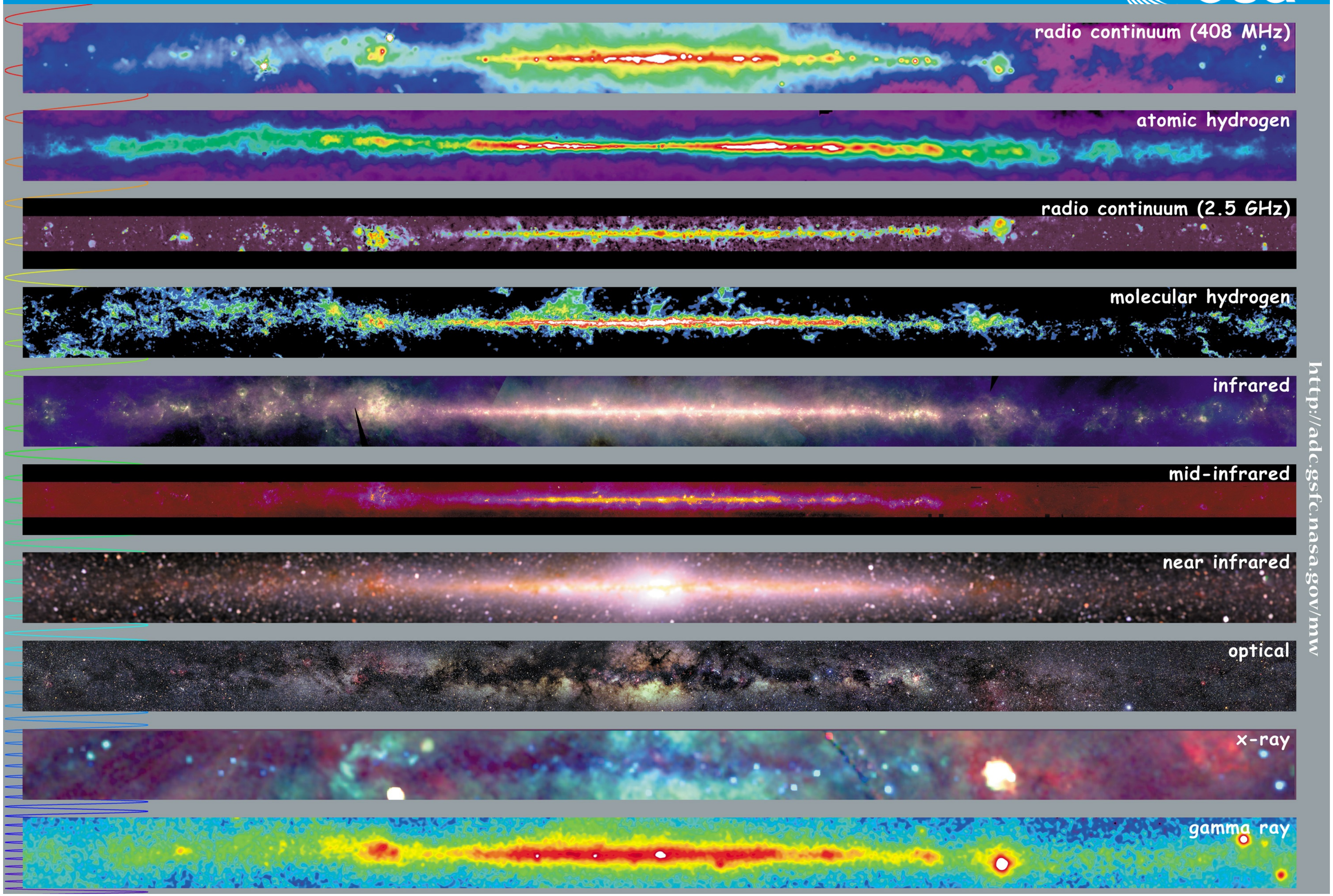
- high energy electrons distort the cosmic microwave background radiation through inverse Compton scattering, in which the low energy CMB photons receive energy boost during collision with the high energy cluster electrons





Multi-band observations of the galaxy cluster Abell 2319.
Credit: ESA/ LFI & HFI Consortia.

Our Milky Way, seen at different wavelengths



- Thanks for your interest