ESAs astronomy missions

Rodgauer Weltraumtage

6 November 2010

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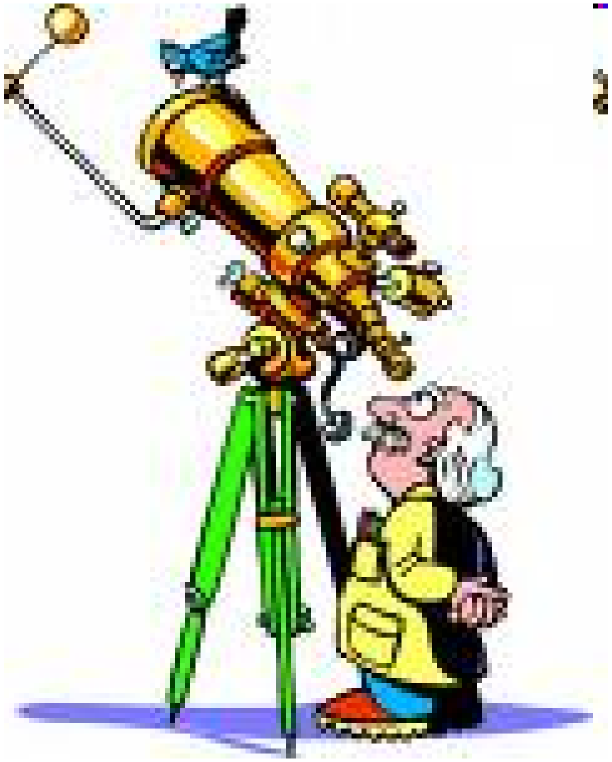
European Space Operations Centre (ESOC)
European Space Agency (ESA)

menu

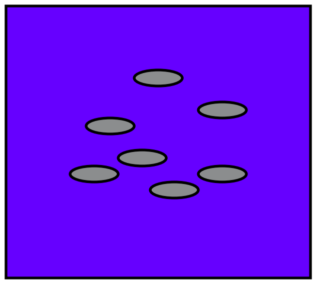
- astronomy
- launch and operations
- ESA astronomy missions
- X-ray astronomy

Was ist Astronomie?

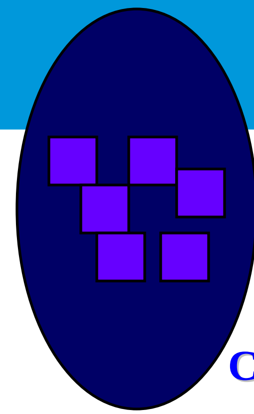
- Astronomie:
  - griechisch ἀστρονομία / ástronomía: „Beobachtung der Sterne"
  - Wissenschaft von den Gestirnen
  - untersucht mit naturwissenschaftlichen Mitteln die Eigenschaften der Objekte im Universum
    - Himmelskörper (Planeten, Monde, Sterne einschließlich der Sonne, Sternenhaufen, Galaxien 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



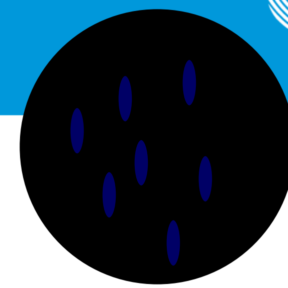
distances



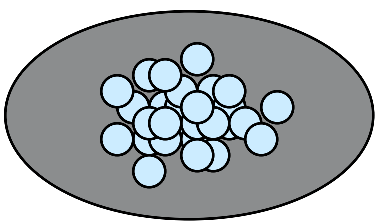
Lokale Group



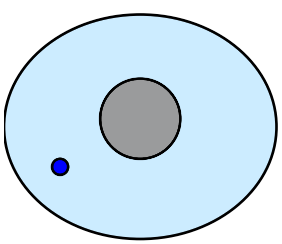
Cluster



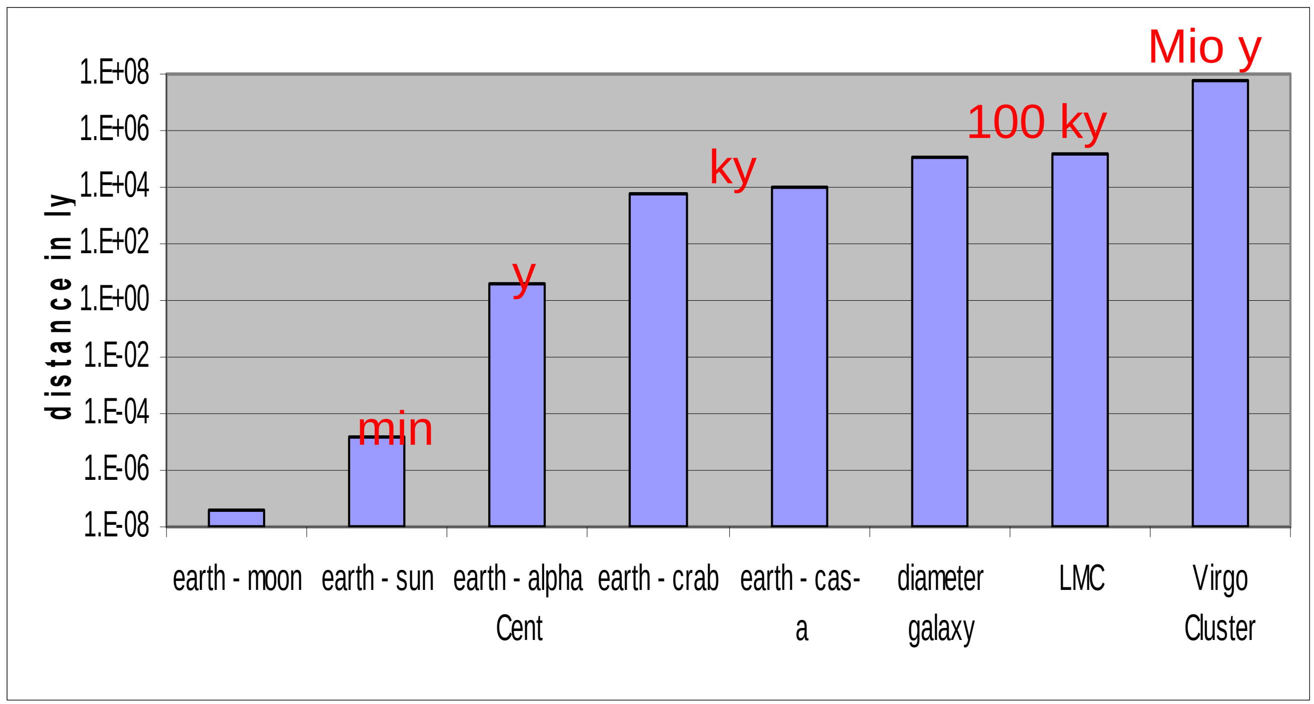
Super Cluster



Galaxy

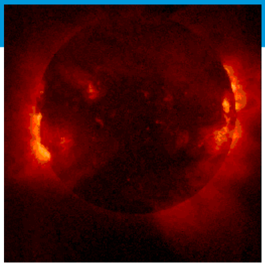
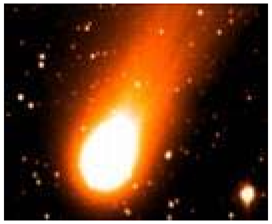


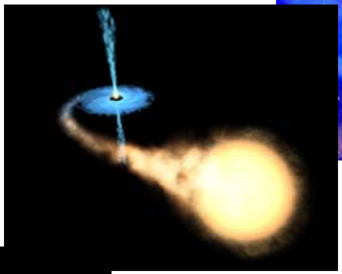
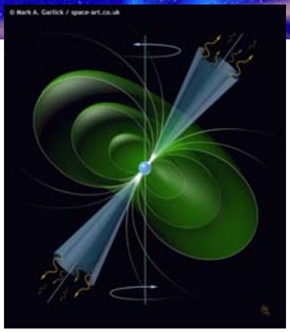
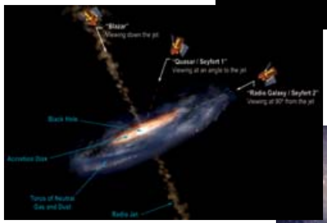
Solar system



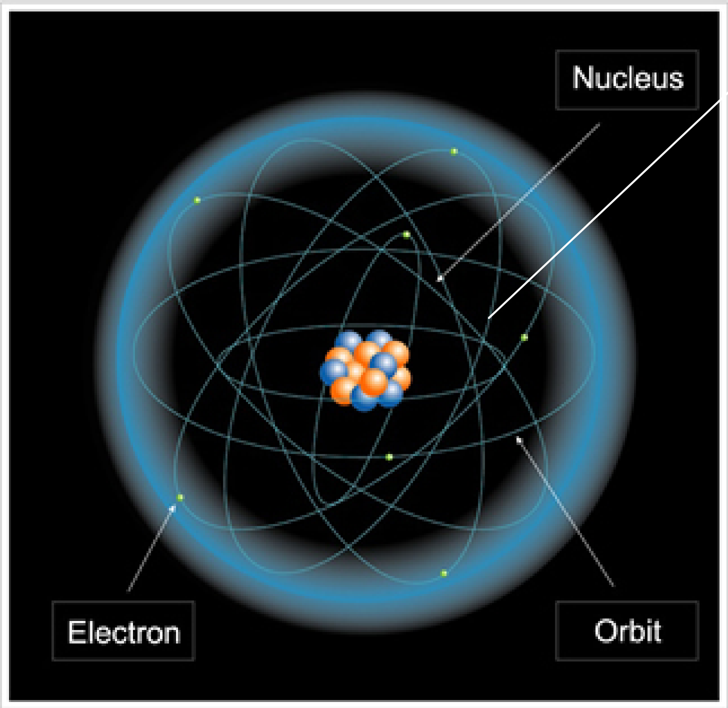
the zoo

- 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

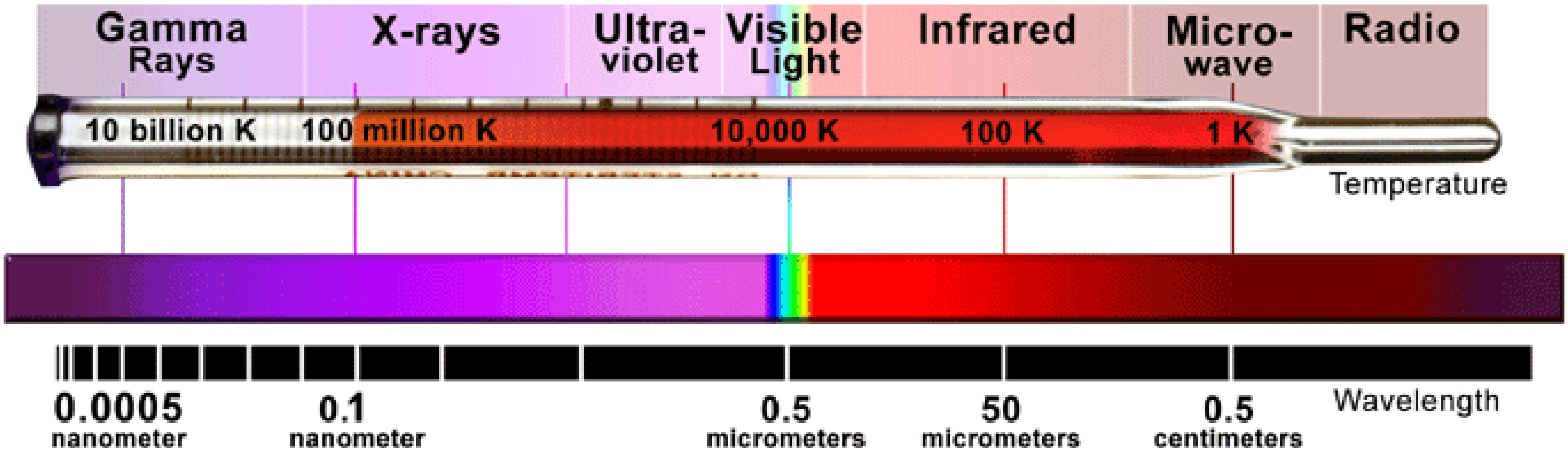


1. Materie besteht aus Atomen
2. Atome enthalten positiv (Protonen) und negativ geladene Teilchen (Elektronen)
3. Wenn ein Teilchen seinen Energiezustand ändert sendet das Atom eine Elektromagnetische Welle / ein Photon aus

=

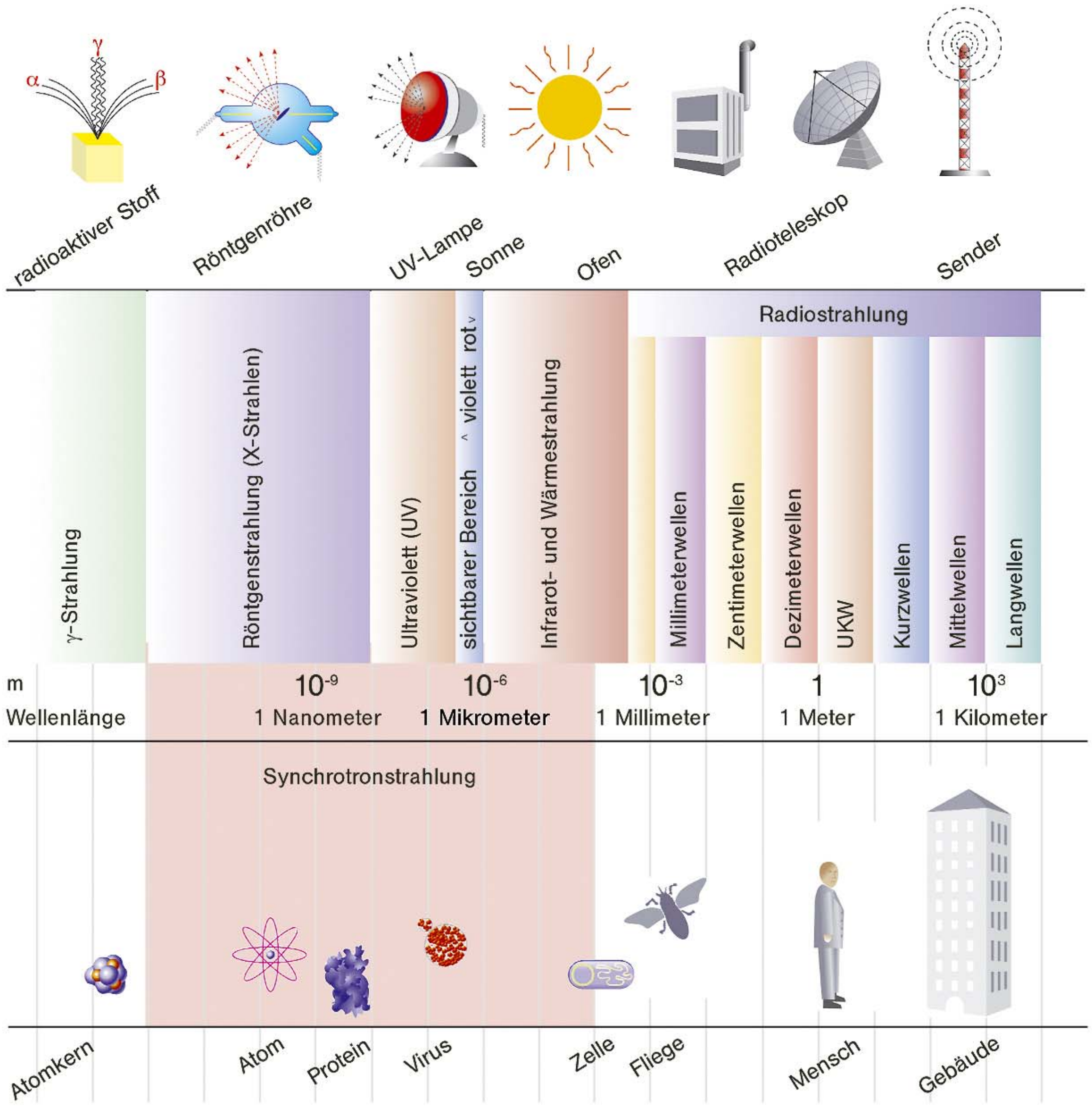
Fundamentales Konzept:
die Wellenlänge entspricht der Energie der Welle/ des Photons
Rotes Licht hat weniger Energie als blaues

Elektromagnetische Strahlung



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

Energie des Lichts



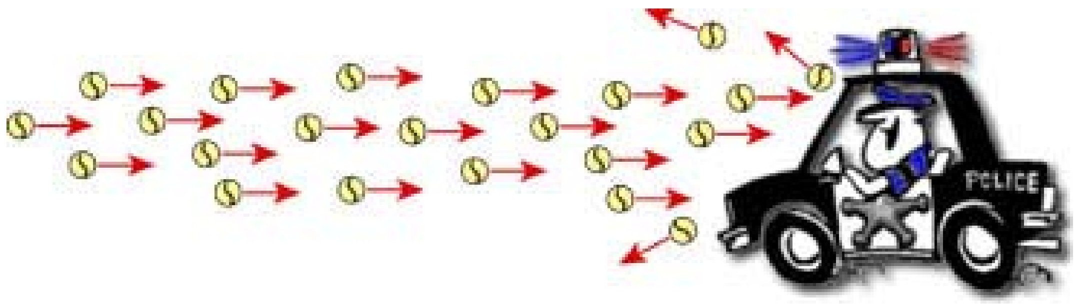
Sichtbares Licht:
Wellenlänge: 700 nm
Energie: ~1 eV

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

= X-rays

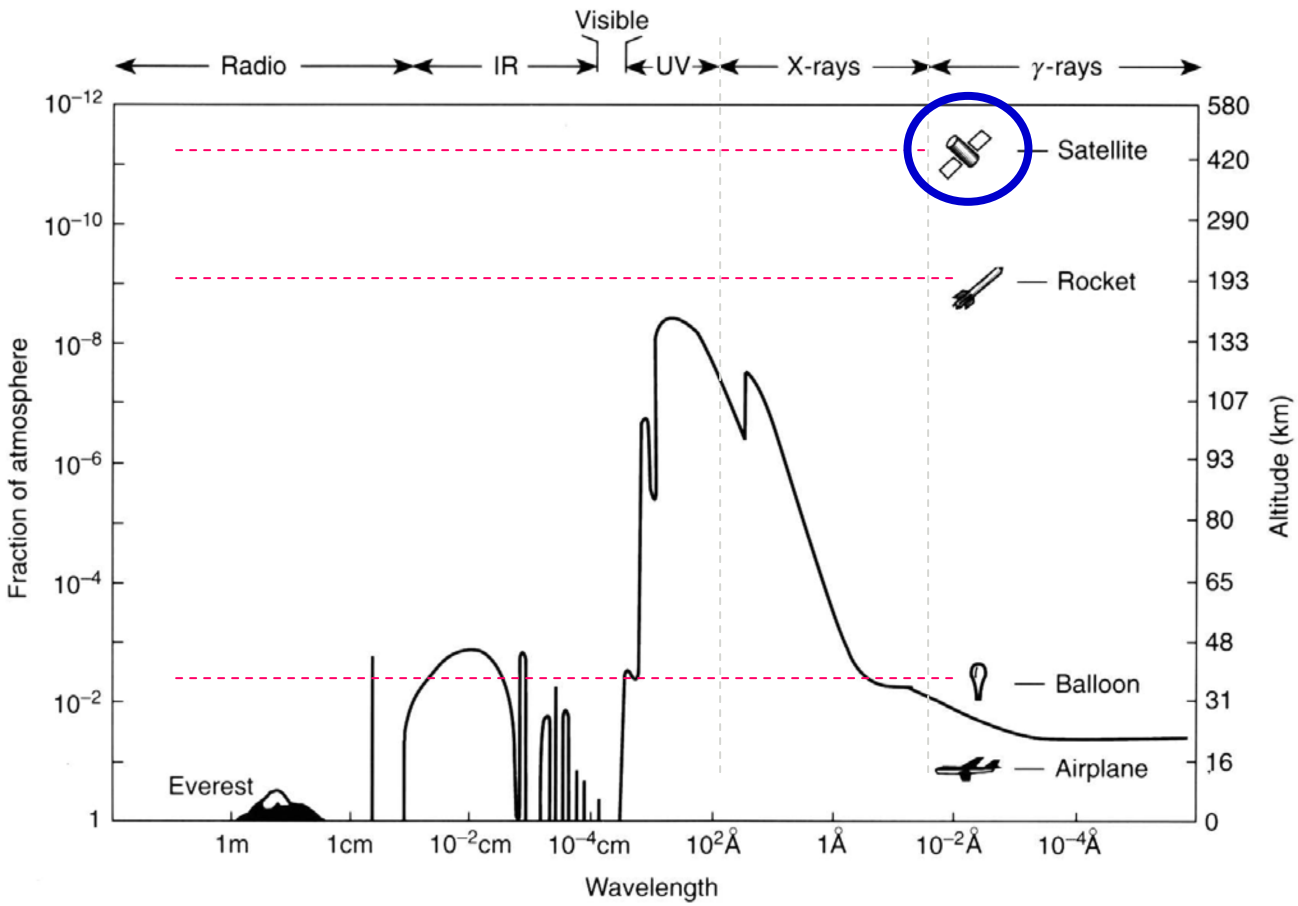
Licht – 2 Theorien

- Kügelchen mit Energie
  → Photonen



- Elektromagnetische Schwingungen
  → Wellen

Erdatmosphäre – Warum Satelliten

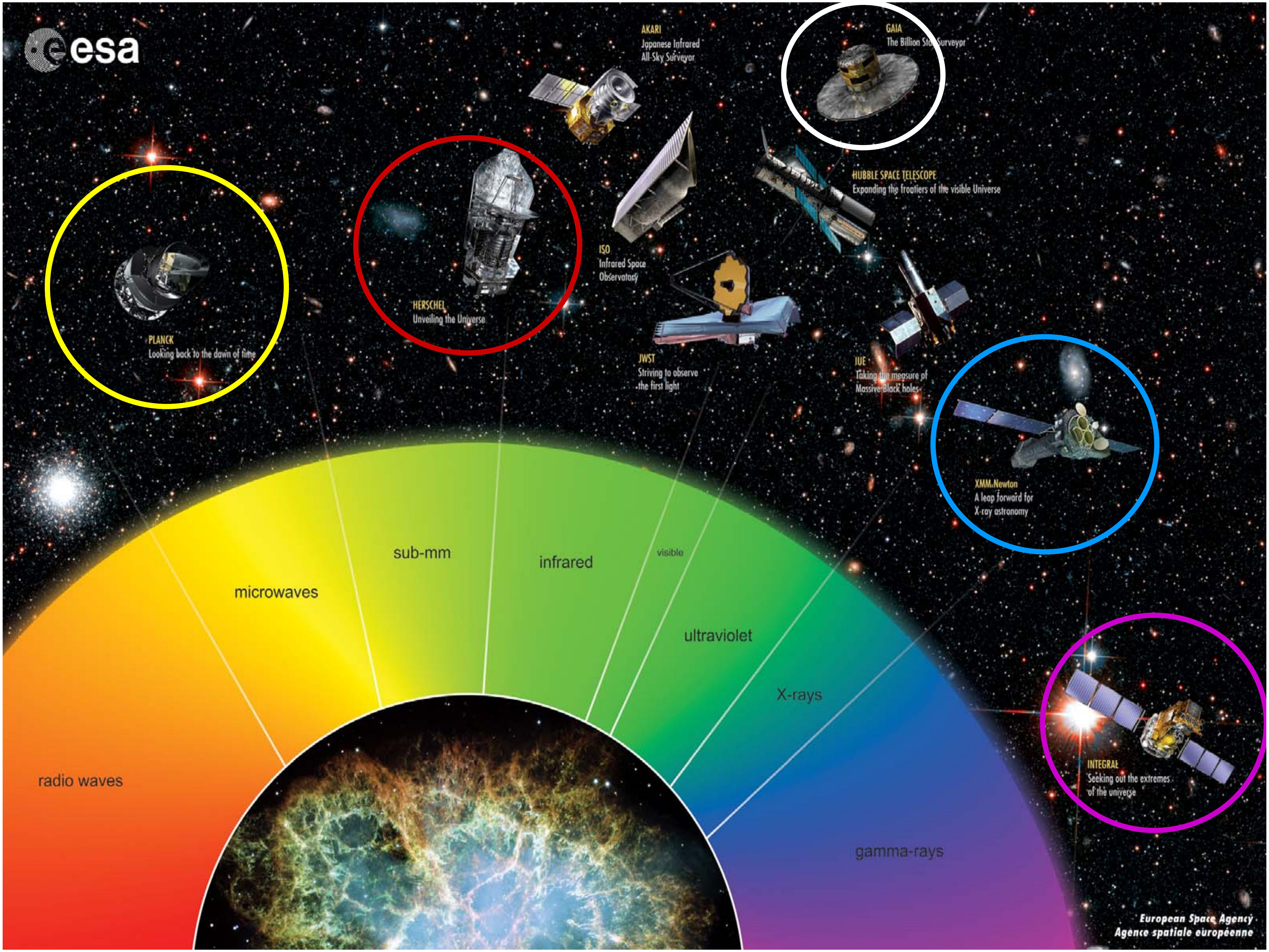


- Photonen werden von der Erdatmosphäre absorbiert
- dieser Effekt ist abhaengig von der Energie des Lichts

→ 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
HERSCHEL
Unveiling the Universe
ISO
Infrared Space Observatory
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

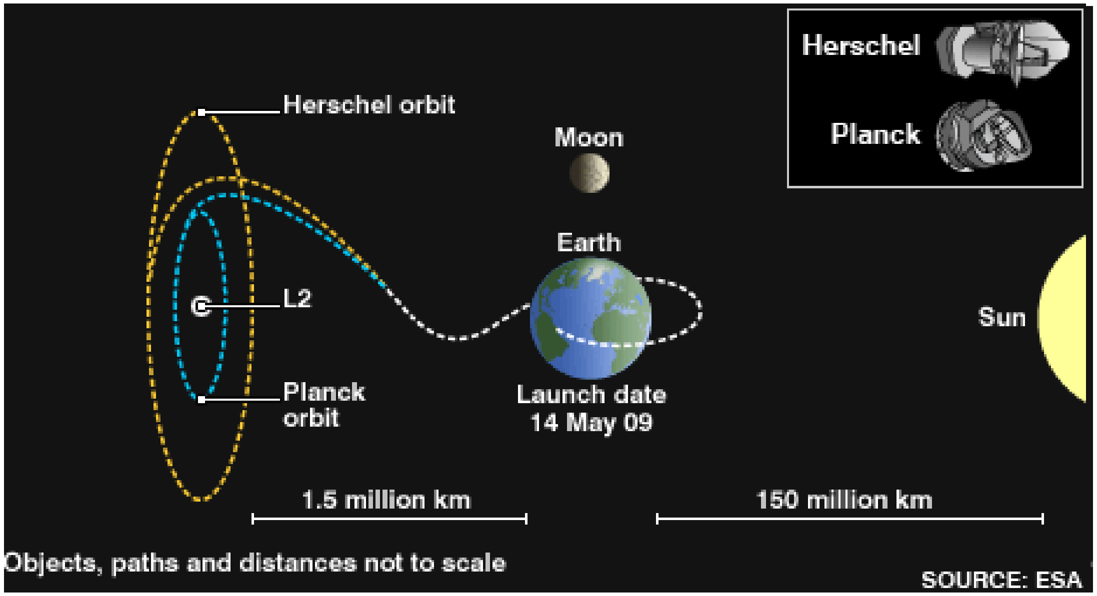
menu

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

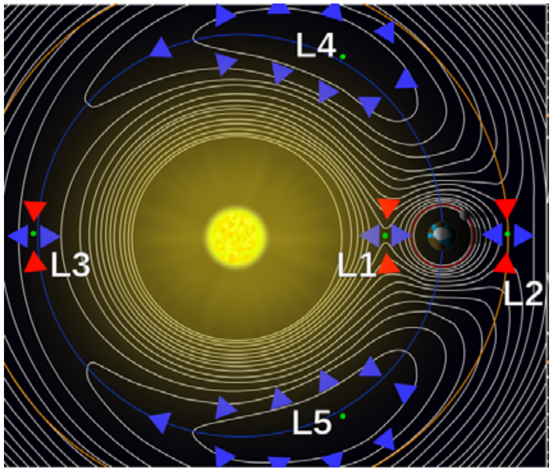
Launchers

LEOP Launch and early orbit phase

DISTANT OUTPOST: HERSCHEL AND PLANCK IN ORBIT



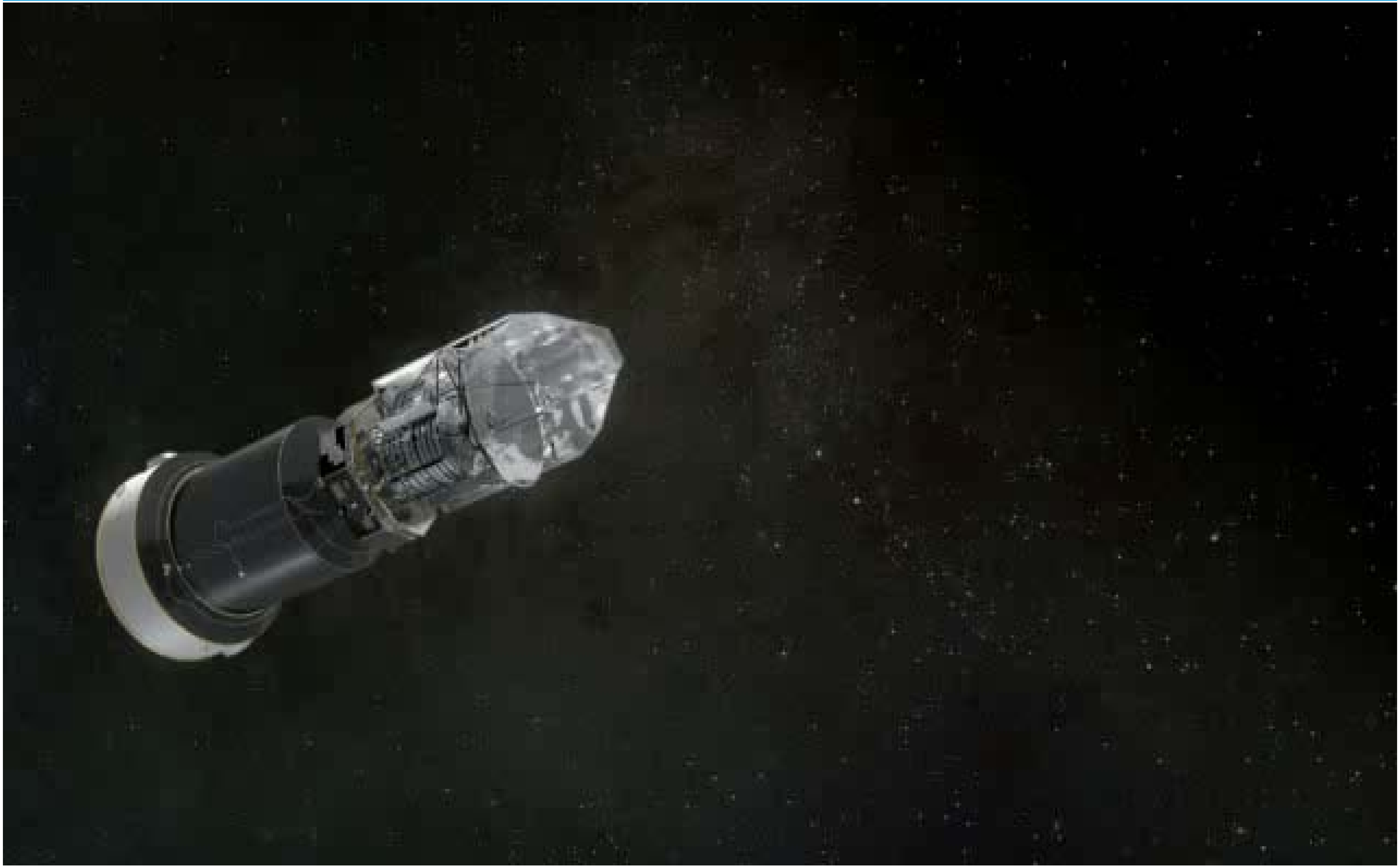
- critical first steps in a spacecraft's life beginning after the satellite separates from the launcher's upper-most stage
- Mission Control Team works 24 hours/day to activate, monitor and verify various subsystems on board the satellite
  - deployment of antennas
  - deployment of solar arrays
  - 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



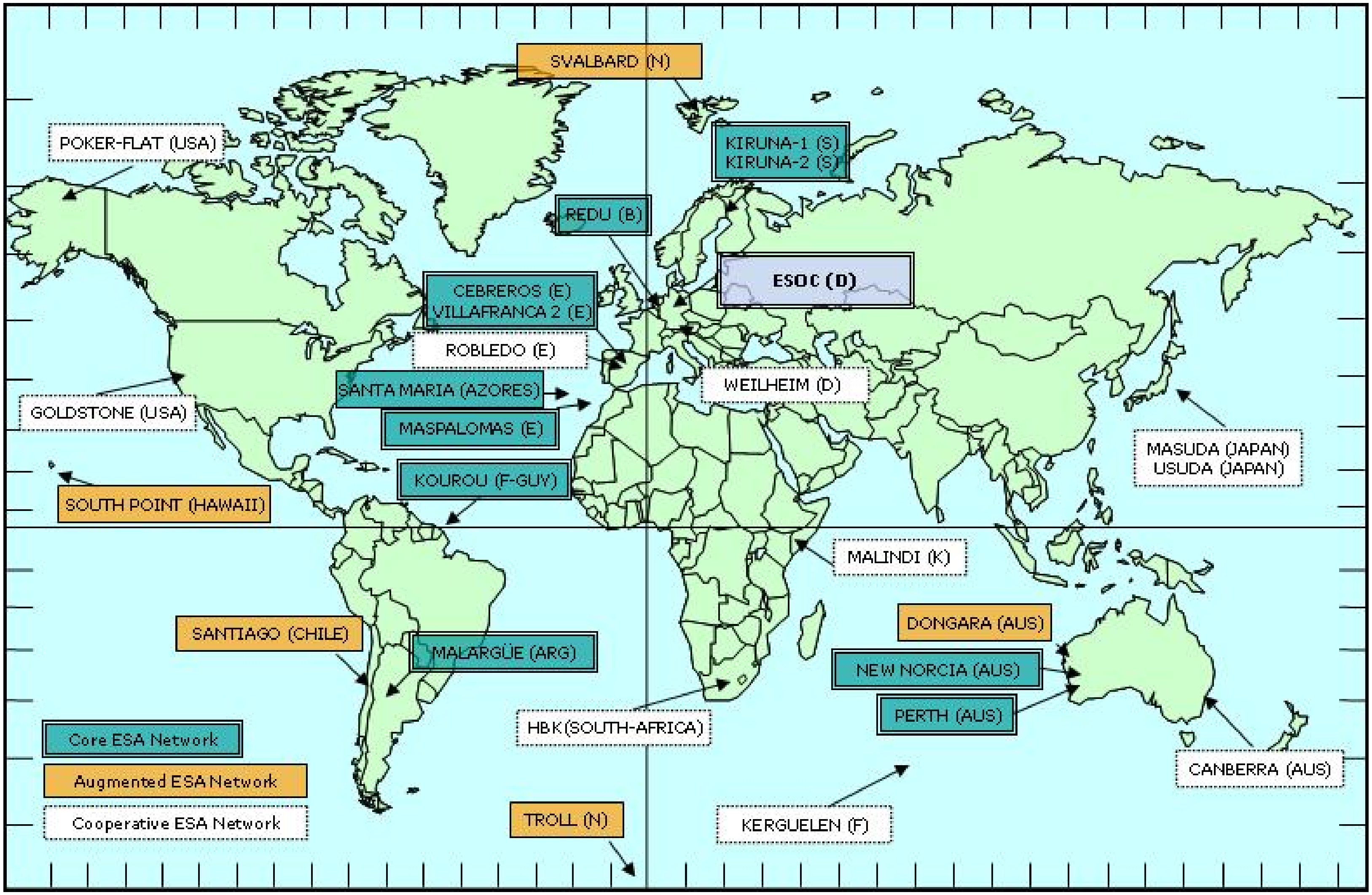
Planck separation

Mission operations

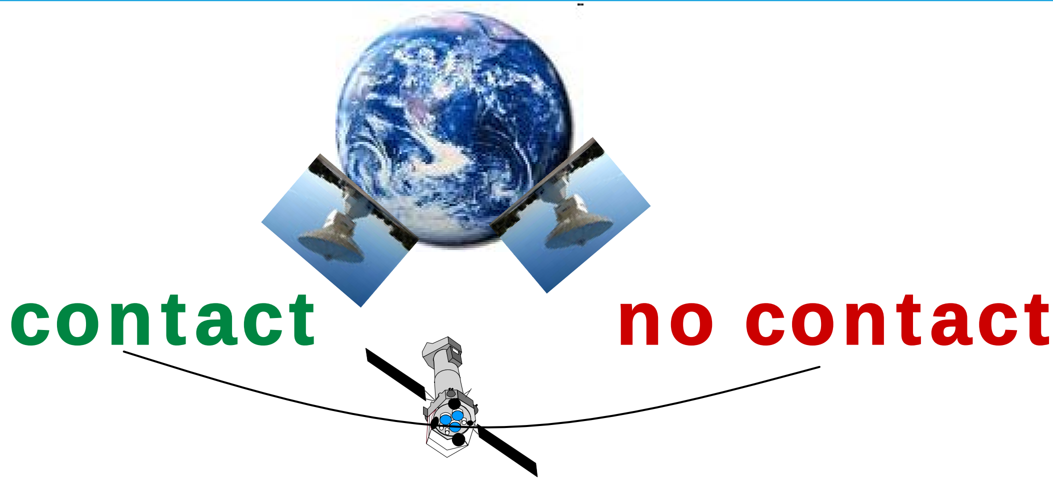
- the ground segment comprises the hardware, software, telecommunications and other resources on the ground used to operate the spacecraft and process data received from the instruments on board

- 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)

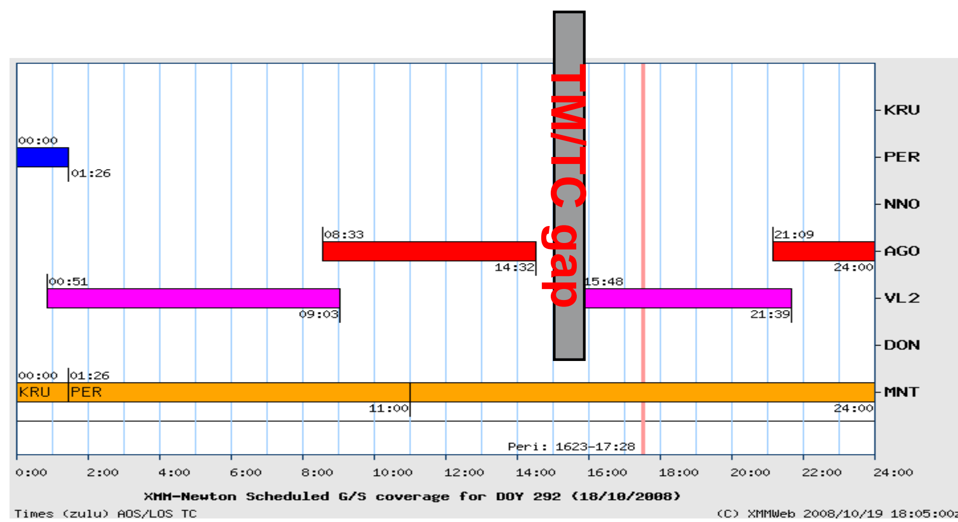


When your baby does not talk to you …



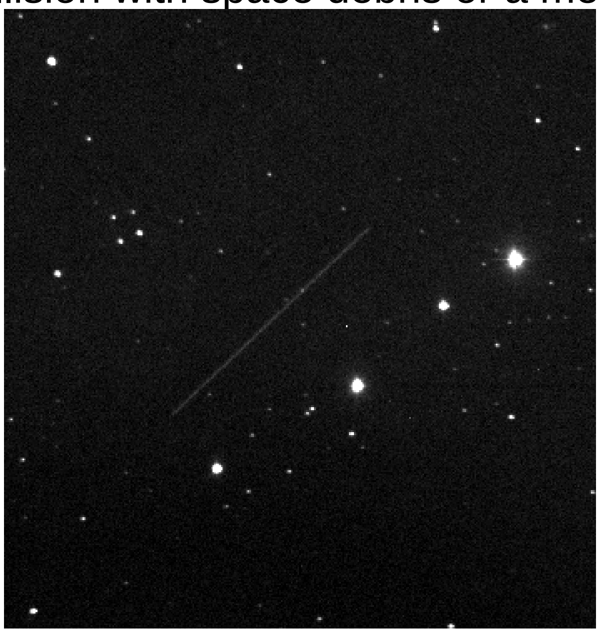
XMM Newton loss of contac in 2008

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



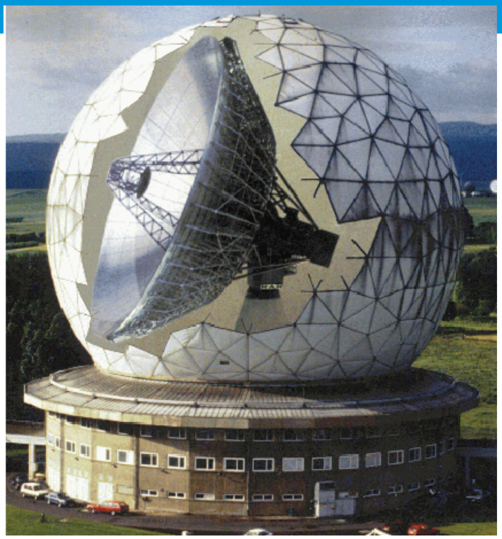
optical detection

- 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.



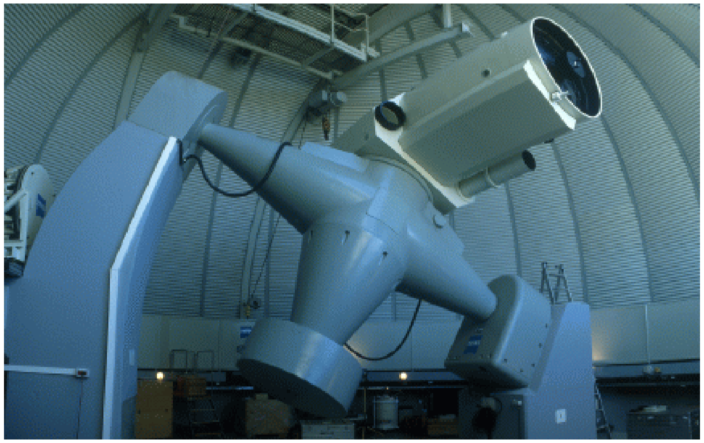
- Satellite on predicted path
- No visible debris
- No indication of light fluctuation caused by S/C spin

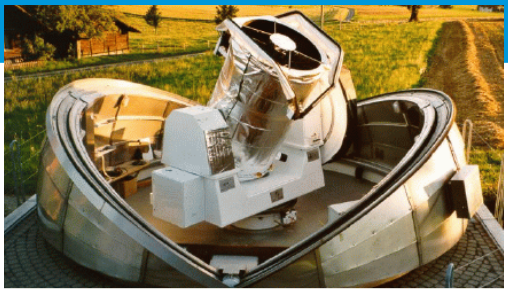
radar and optical follow up



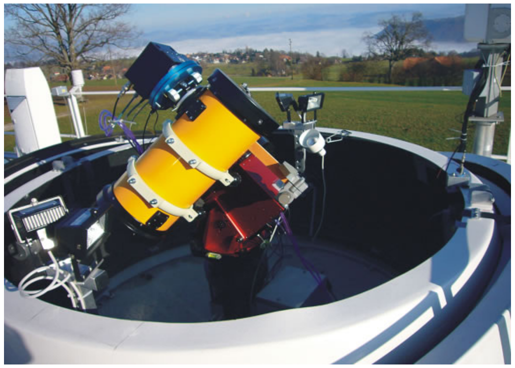
- **TIRA** (Tracking and Imaging Radar) at Wachtberg, Germany (lat: 50.62° North, 7.13° East)
- Monostatic L–band tracking radar and high resolution Ku–band imaging radar supported by one 34 m parabolic antenna
- This was the very first occasion for FGAN to track an object in more than 8000km range.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



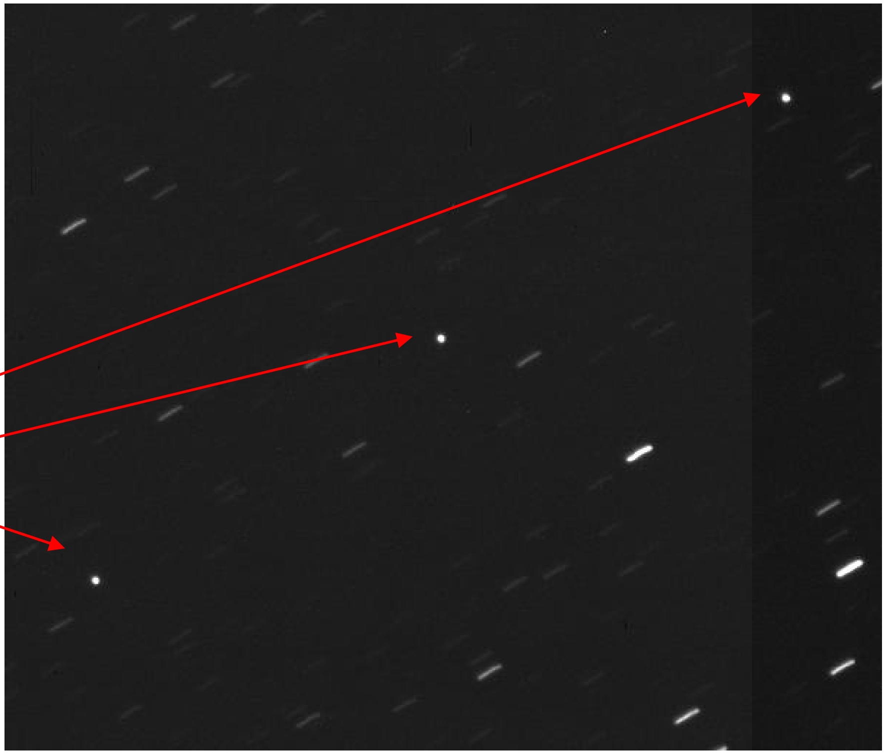


- **Zimmerwald telescopes** (CH)
- Owned and operated by the Astronomical Institute, University of Berne, 950 m altitude at 46.9° North, 7.5° East



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

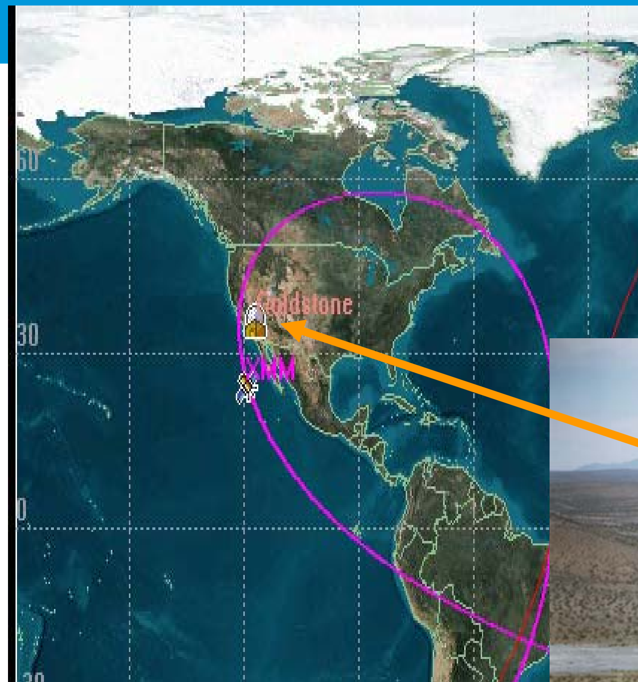
- Measurement of the signal attenuation (-55 db) indicating a failure of the switch → information concerning the required uplink power

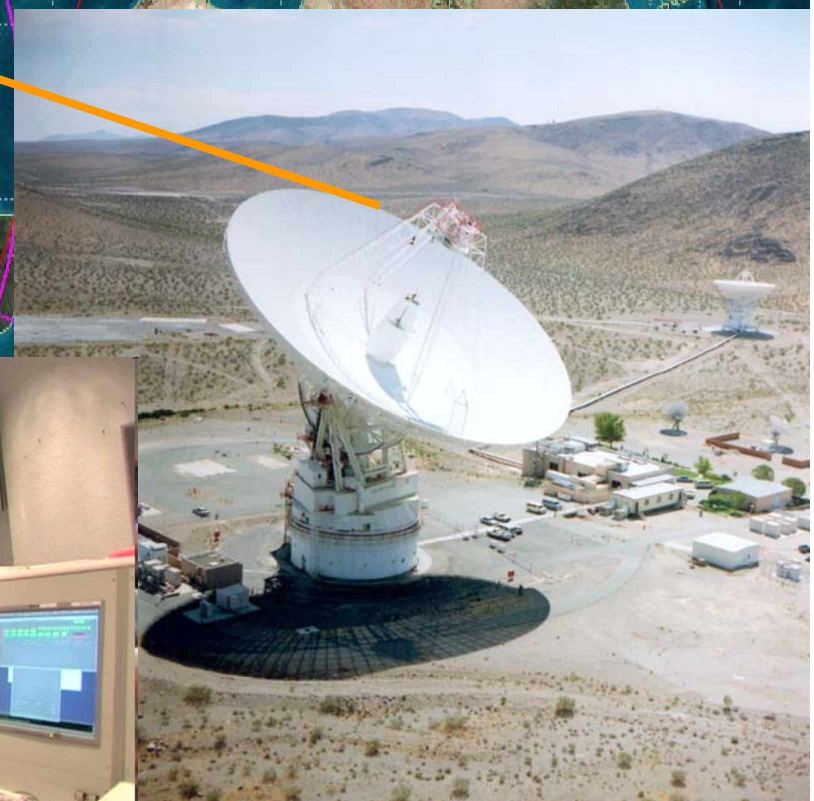
- Commanding not possible via New Norcia, uplink power not sufficient

- 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

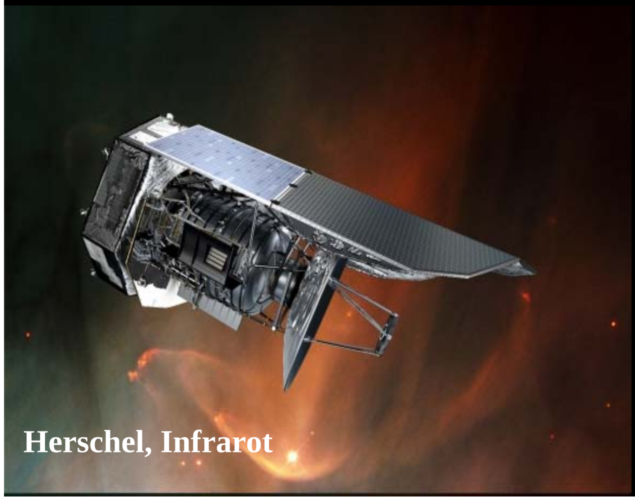


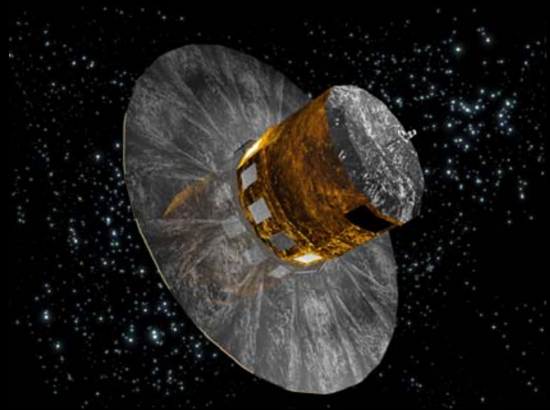


menu

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

the astronomy fleet

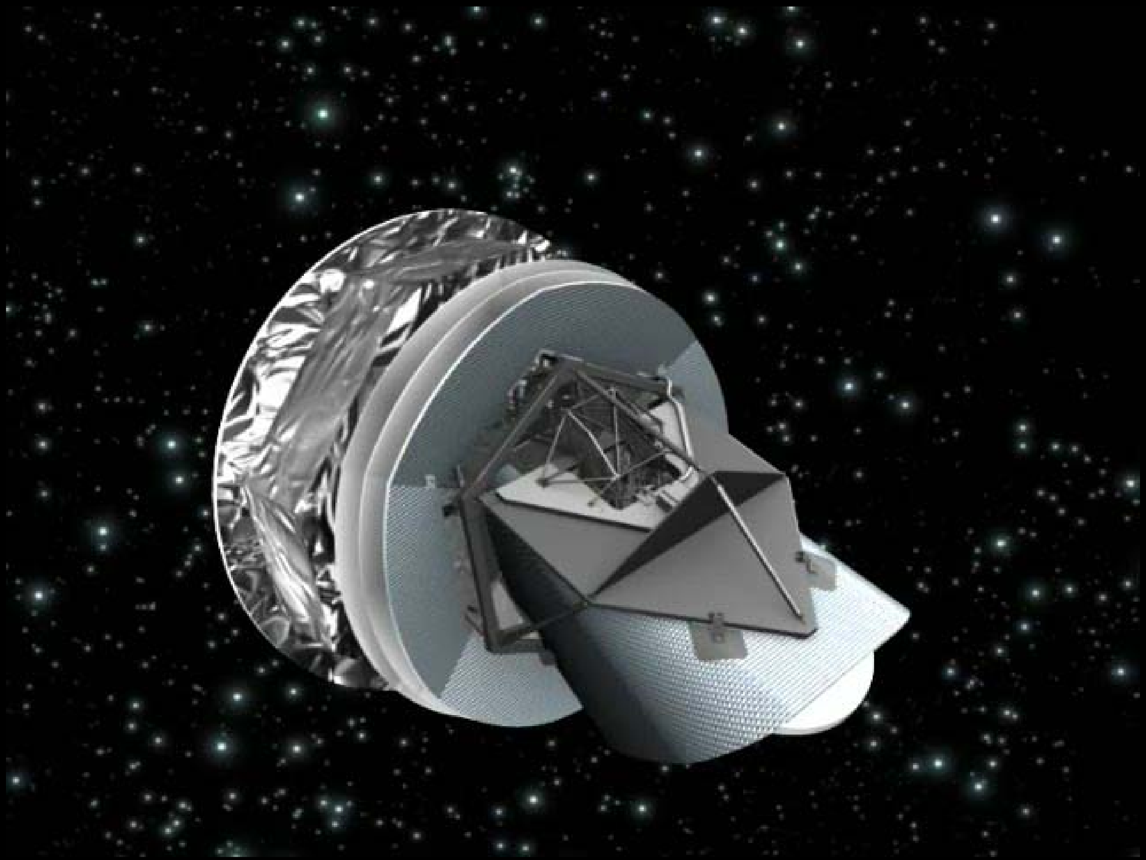



Gaia, optisch

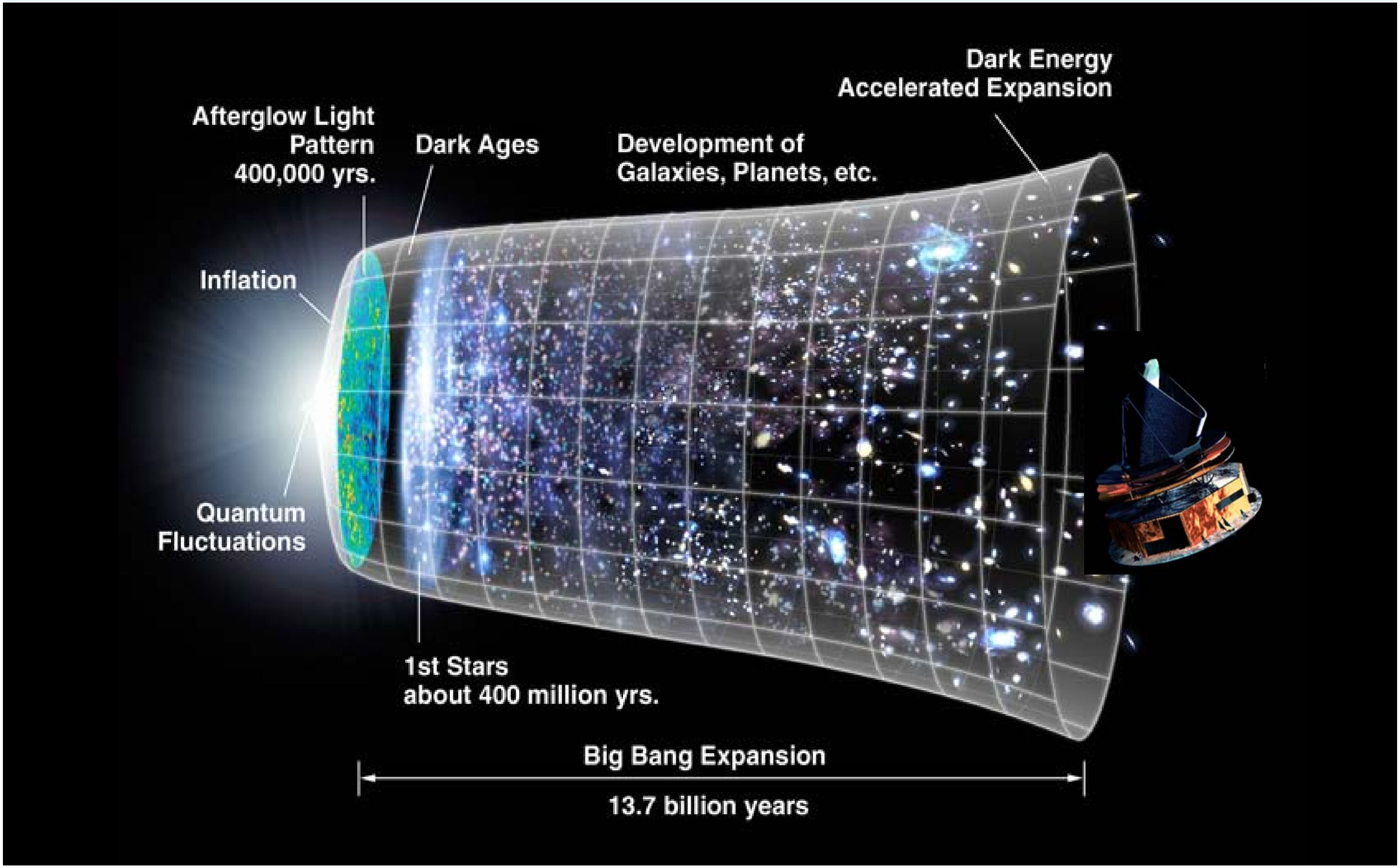
Planck: Micro waves

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.

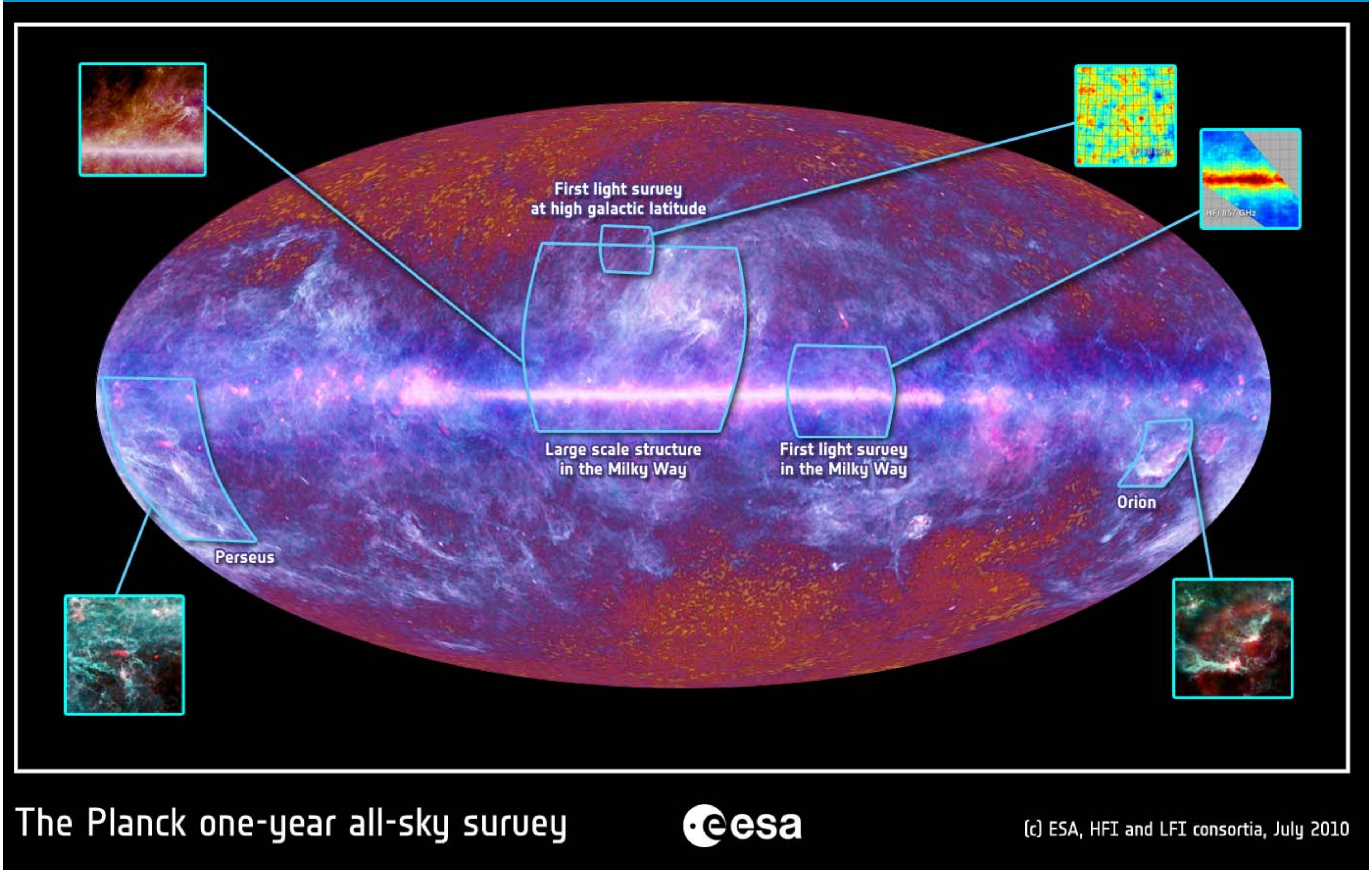
Planck will take about 6 months to complete a full scan of the sky, charting two complete sky maps during its nominal lifetime (about 15 months).



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



Planck: one year of observations

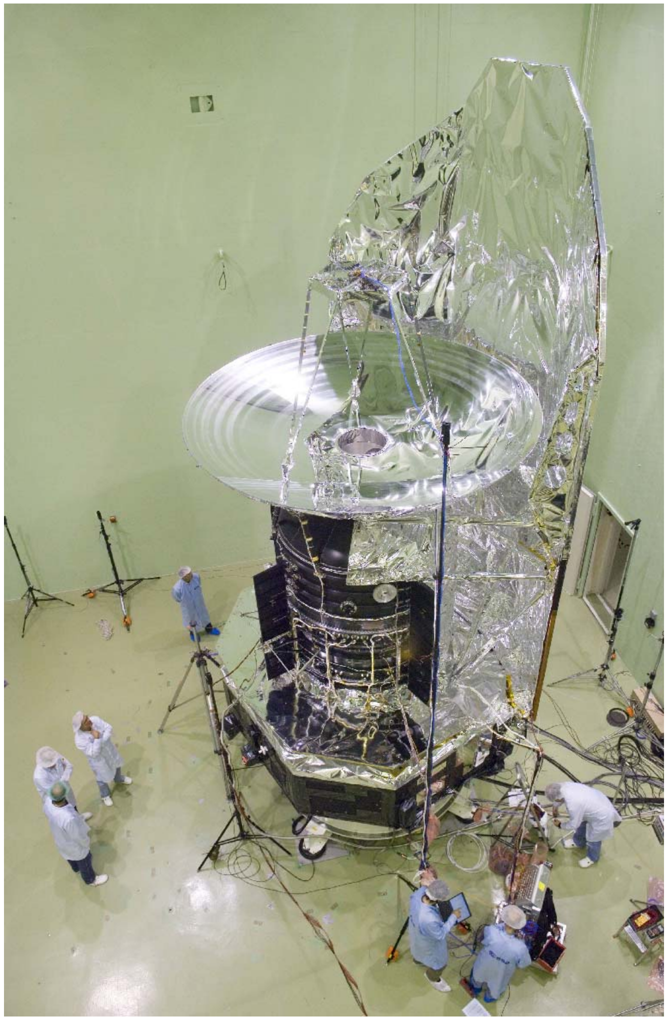


Herschel - Infra red

- 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

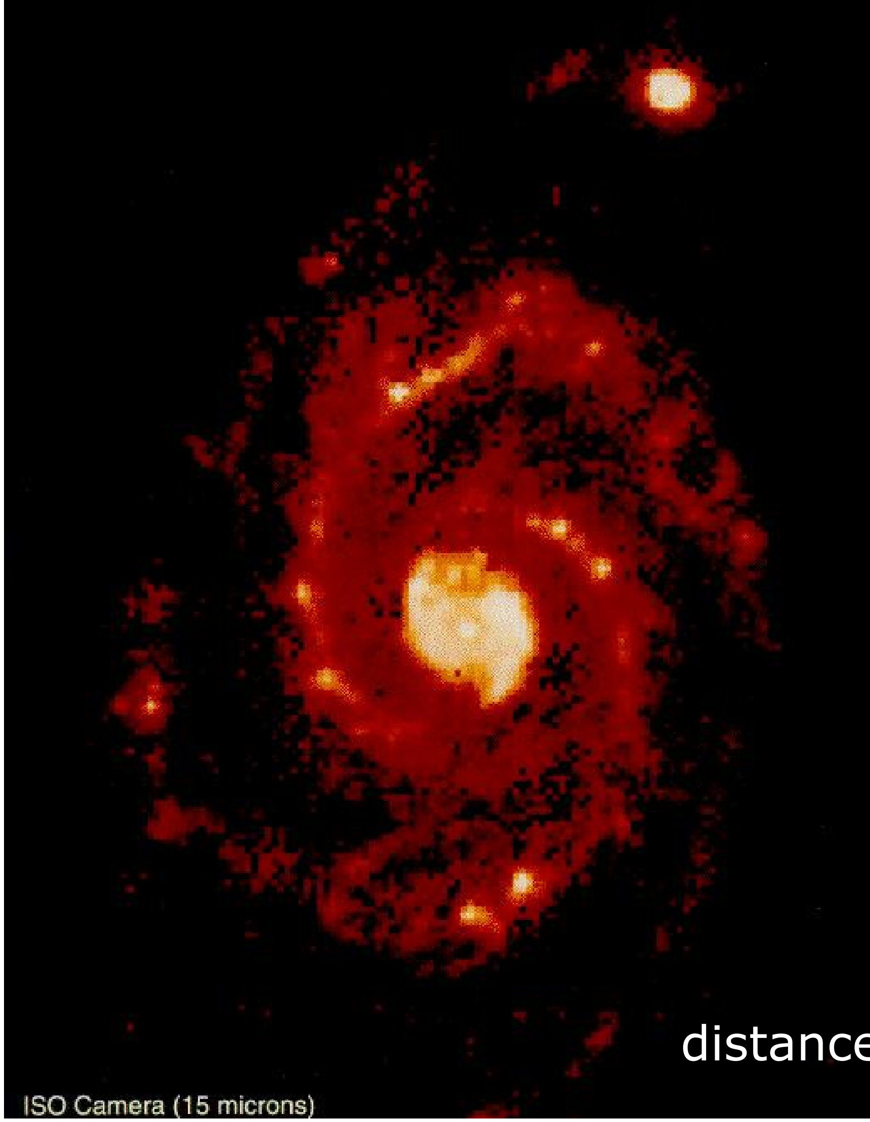
- Herschel's telescope is carrying the largest mirror ever flown in space



Whirlpool galaxy M51

ISOCAM 15 µm image

Best mosaic image in ISO archive

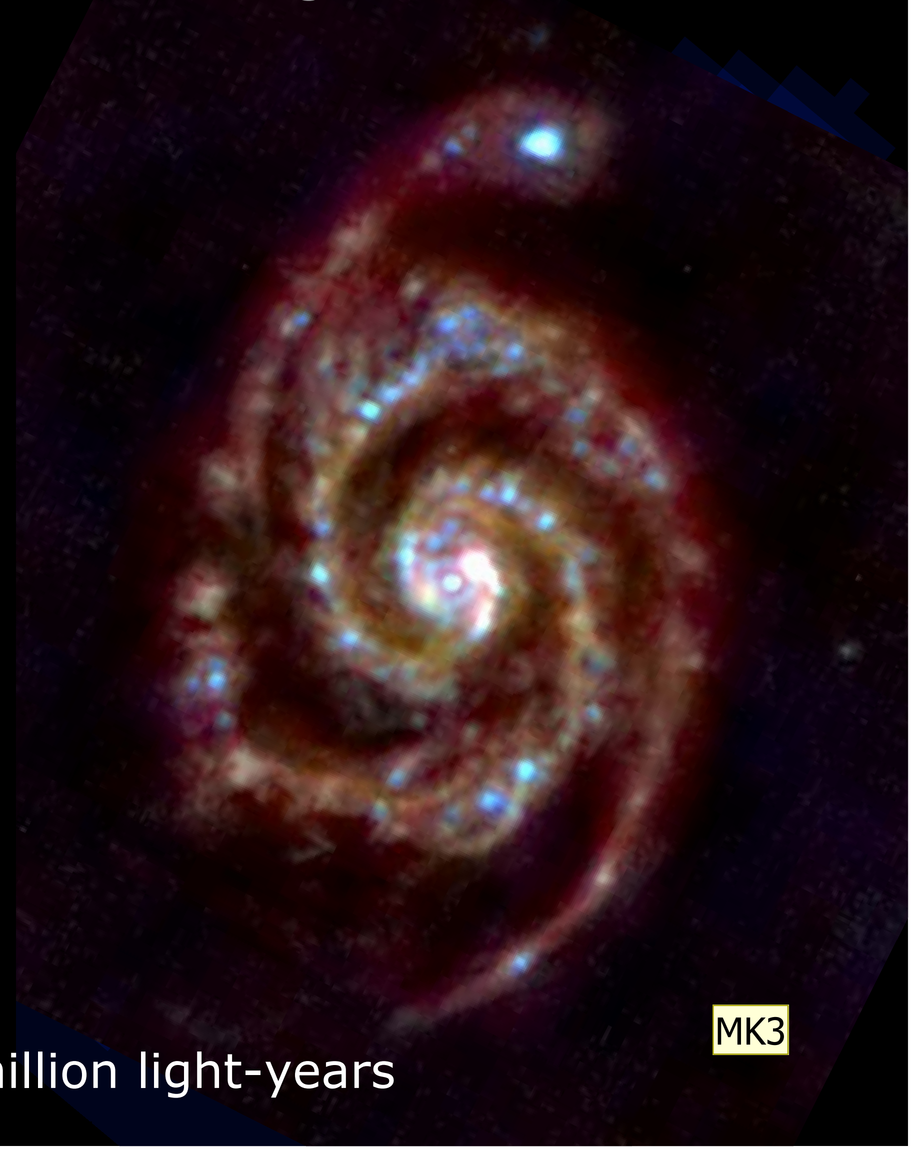


Whirlpool galaxy M51

PACS 3 color image (70, 100, 160 µm

IRAS

First image taken with Herschel



distance 23 million light-years

MK3 Three-colour far-infrared image of M51, the ‘whirlpool galaxy’.

Red, green and blue correspond to the 160-micron, 100-micron and 70-micron wavelength bands of the Herschel’s Photoconductor Array Camera and Spectrometer, PACS.

Glowing light from clouds of dust and gas around and between the stars is visible clearly. These clouds are a reservoir of raw material for ongoing star formation in this galaxy. Blue indicates regions of warm dust that is heated by young stars, while the colder dust shows up in red.

Credits: ESA and the PACS Consortium

Marcus Kirsch, 22/10/2010

Filaments permeate the ISM on all scales

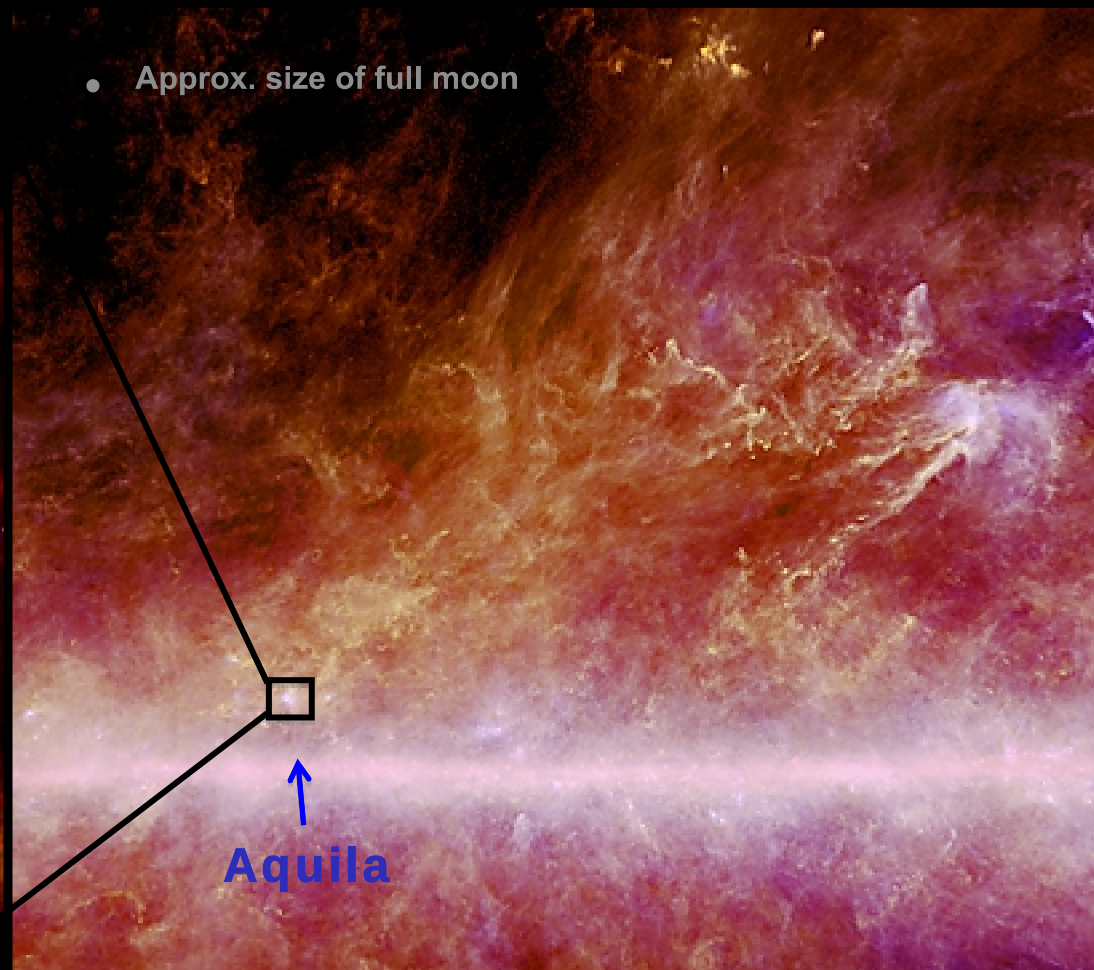
Herschel

SPIRE 500 μm + PACS 160 / 70 μm

ESA and the Gould Belt KP

Planck

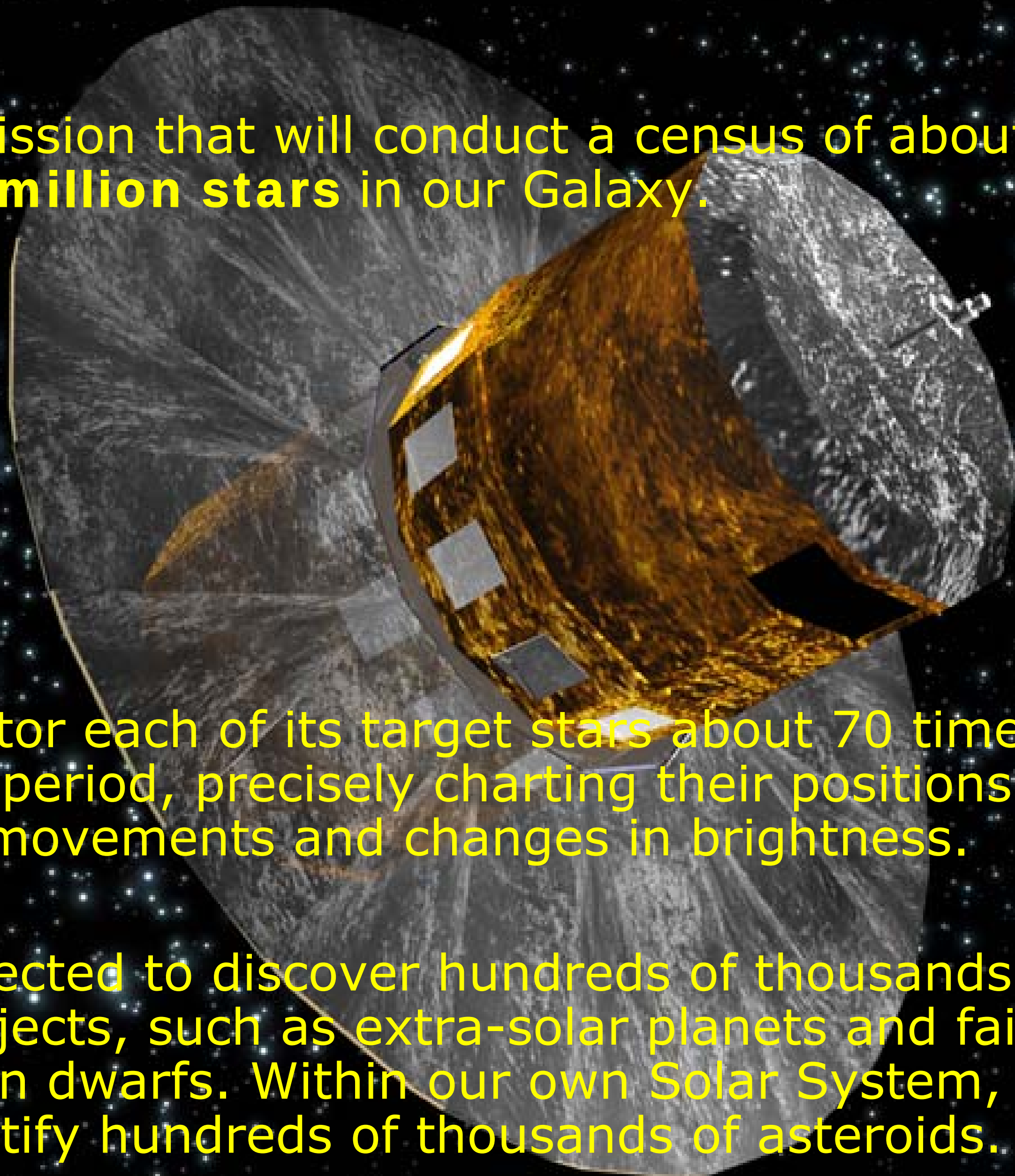
HFI 540 / 350 μm + IRAS 100 μm



ESA and the HFI Consortium

Gaia

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

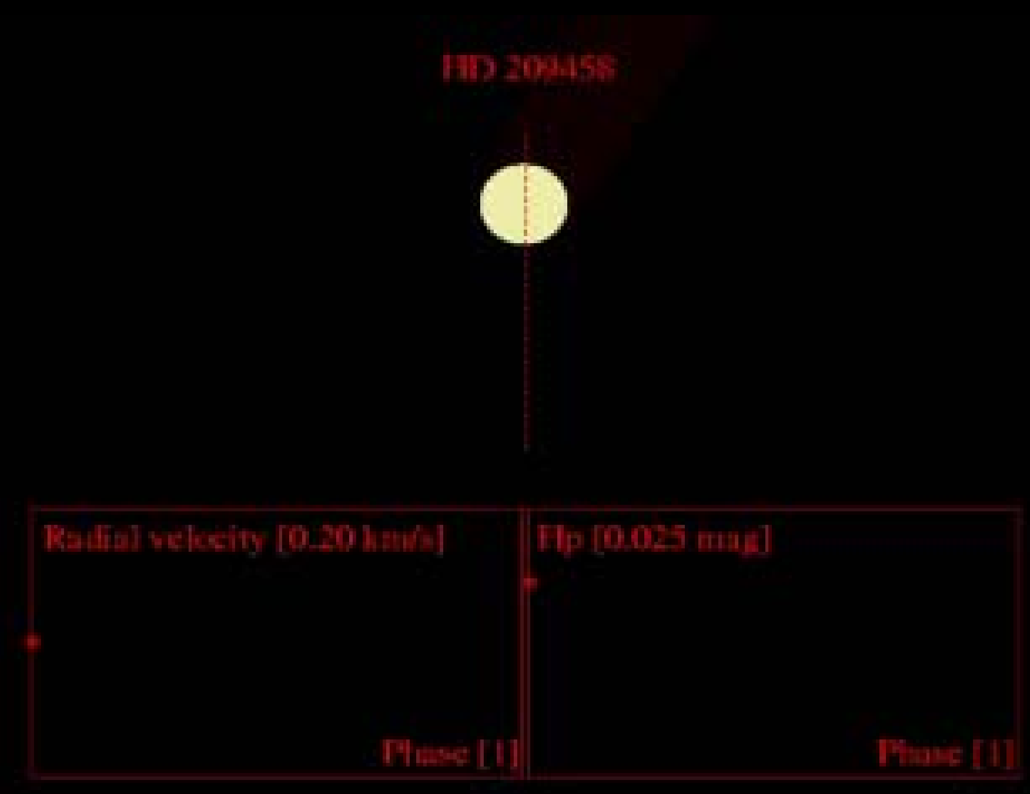


- It will monitor each of its target stars about 70 times during a five-year period, precisely charting their positions, distances, movements and changes in brightness.

- 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.

X-Ray-Binaries

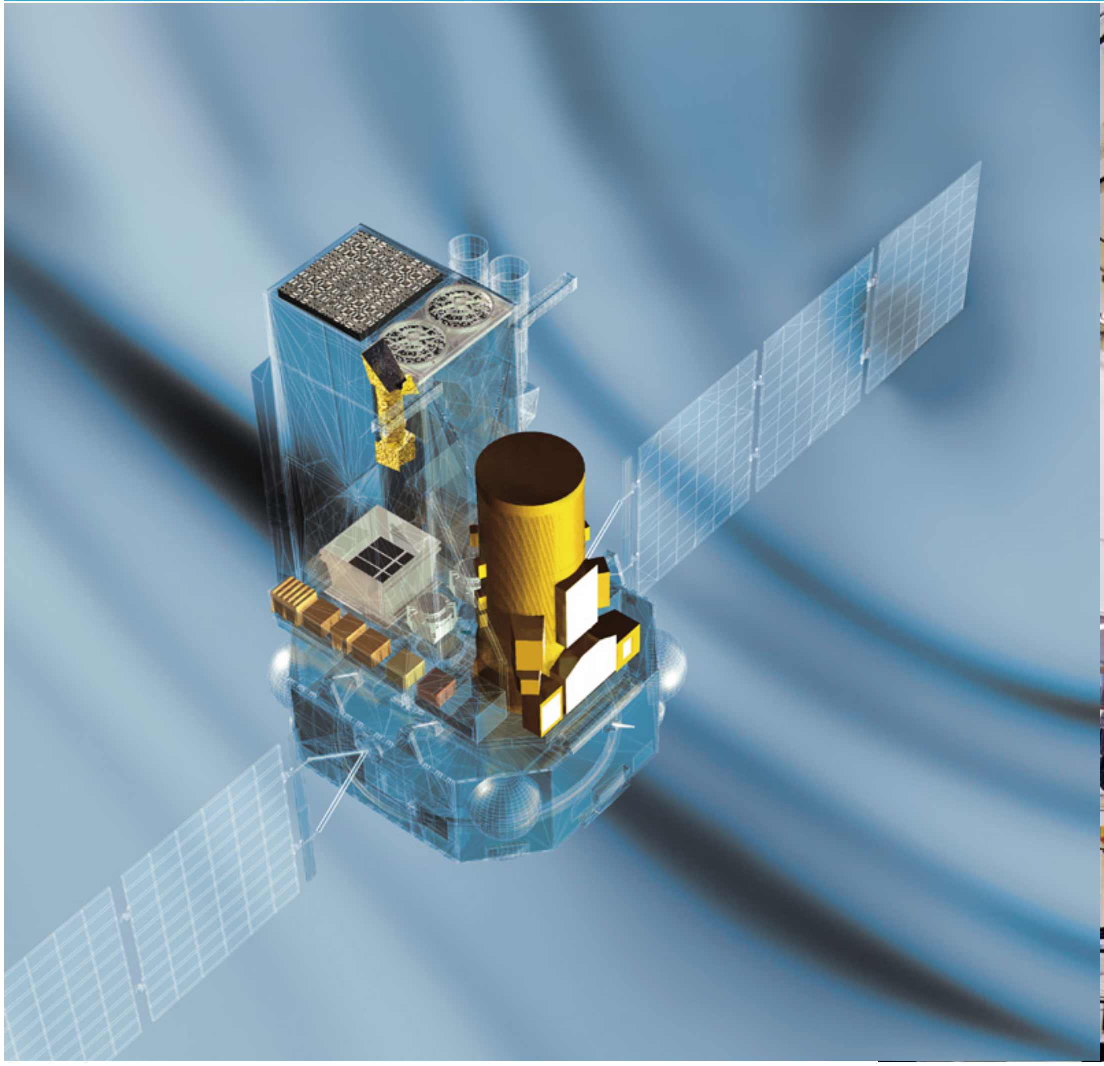
(Röntgendoppelsterne)

KO & optischer Stern

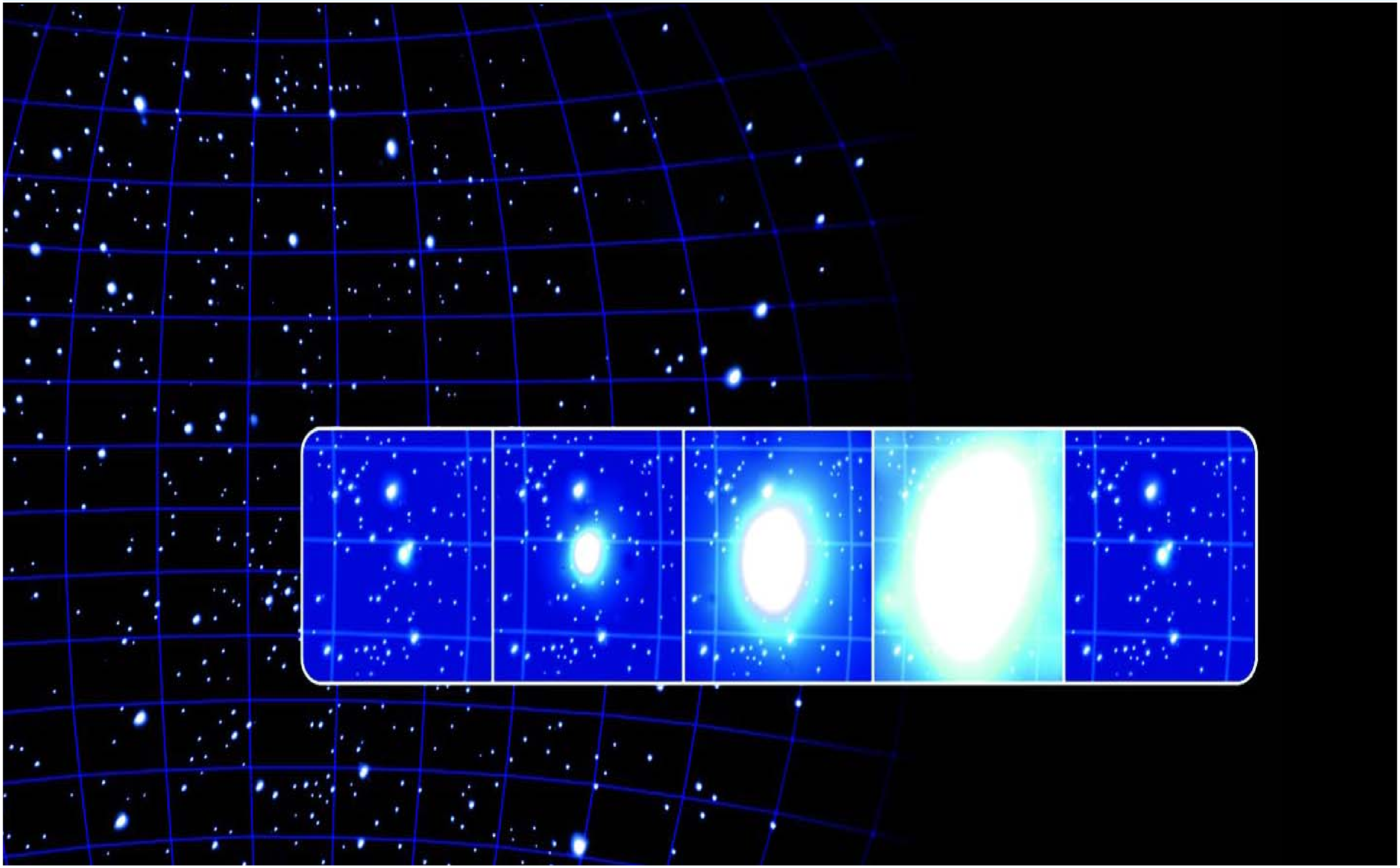
- Masse geht von optischem Stern auf KO über
- Masse stürzt mit sehr hoher Geschwindigkeit (~ 0,5 Lichtgeschwindigkeit) auf KO
- sehr hohe Temperaturen (100 Millionen K)

Vampire Stars

Integral and the Gamma-ray Universe



Gamma-Ray burst



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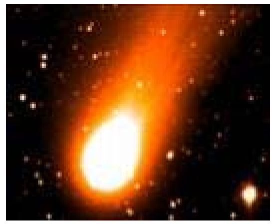
- **X-ray astronomy**

Journey with X-ray results from XMM-Newton



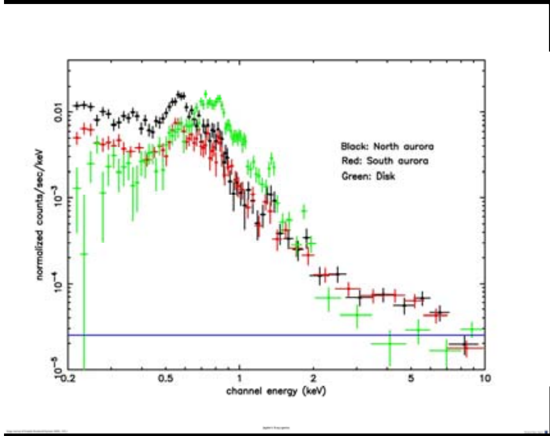
At home: our solar system

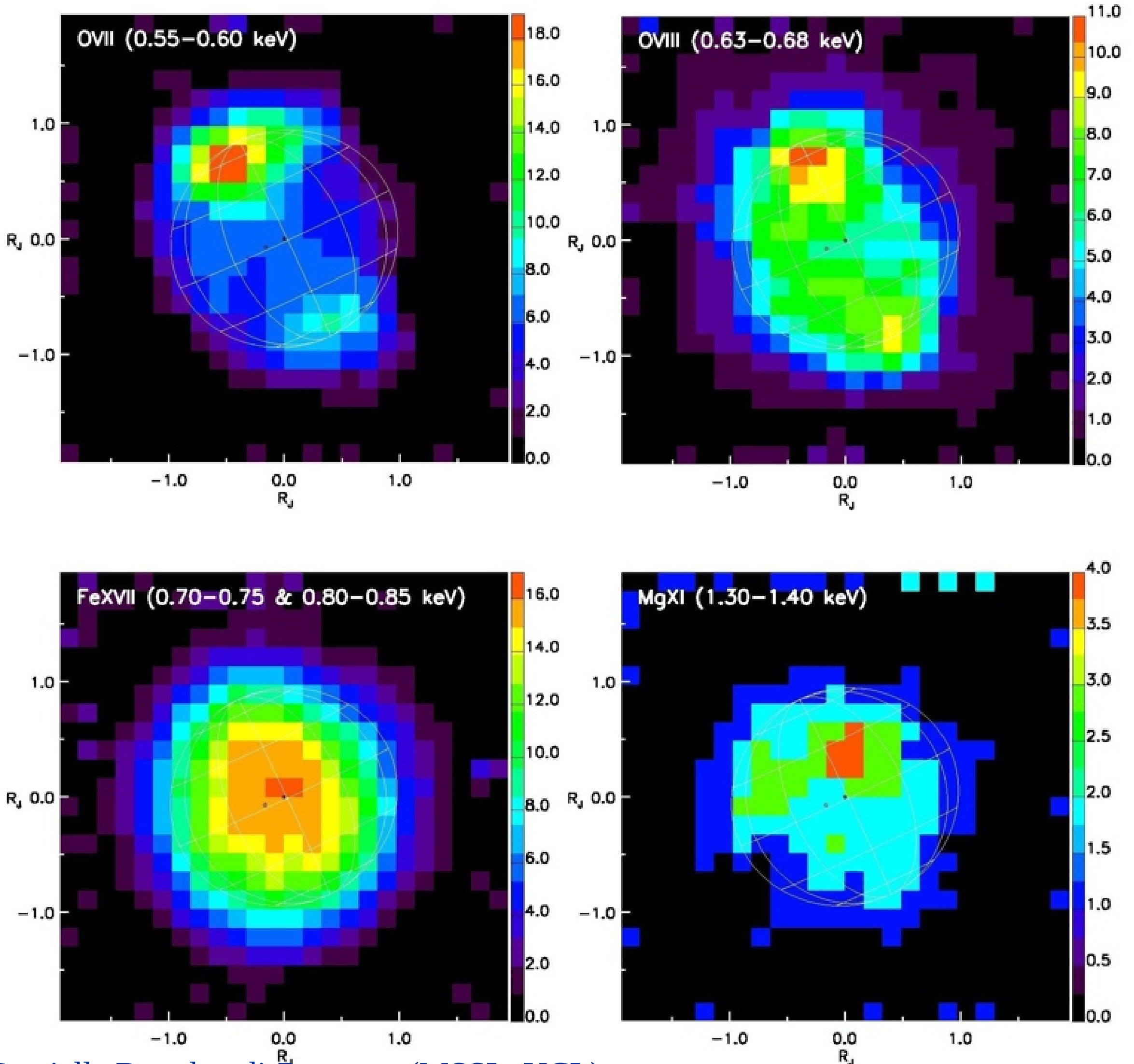
MGFK2

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)

MGFK2

IMAGES:
Smoothed XMM-Newton EPIC images of Jupiter in narrow spectral bands. From top left, clockwise: band centred on ionic transitions of OVII (0.55 - 0.60 keV), OVIII (0.63 - 0.68 keV), MgXI (1.30 - 1.40 keV), FeXVII (0.70 - 0.75 and 0.80 - 0.85 keV). The colour scale bar is in units of EPIC counts.

The OVII emission peaks clearly on the North and (more weakly) the South auroral spots, OVIII extends to lower latitudes, with an enhancement at the North spot, while MgXI and especially FeXVII display a more uniform distribution over the planet's disk. The different spatial distribution of the emissions is thus clue to their origin: low energy X-rays are produced in the aurorae and higher energy emission comes from the whole disk of the planet.

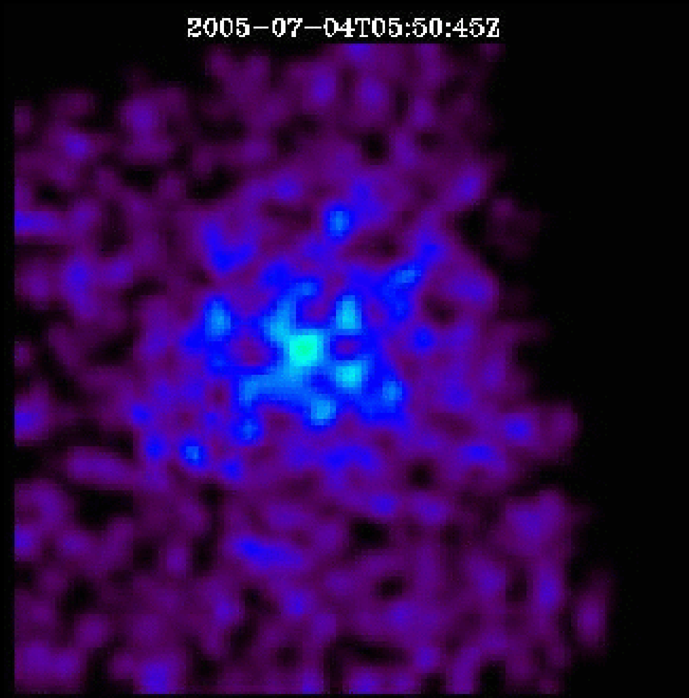
Investigator(s): G. Branduardi-Raymont, A. Bhardwaj, R. F. Elsner, G. R. Gladstone, G. Ramsay, P. Rodriguez, R. Soria, J. H. Waite Jr., T. E. Cravens

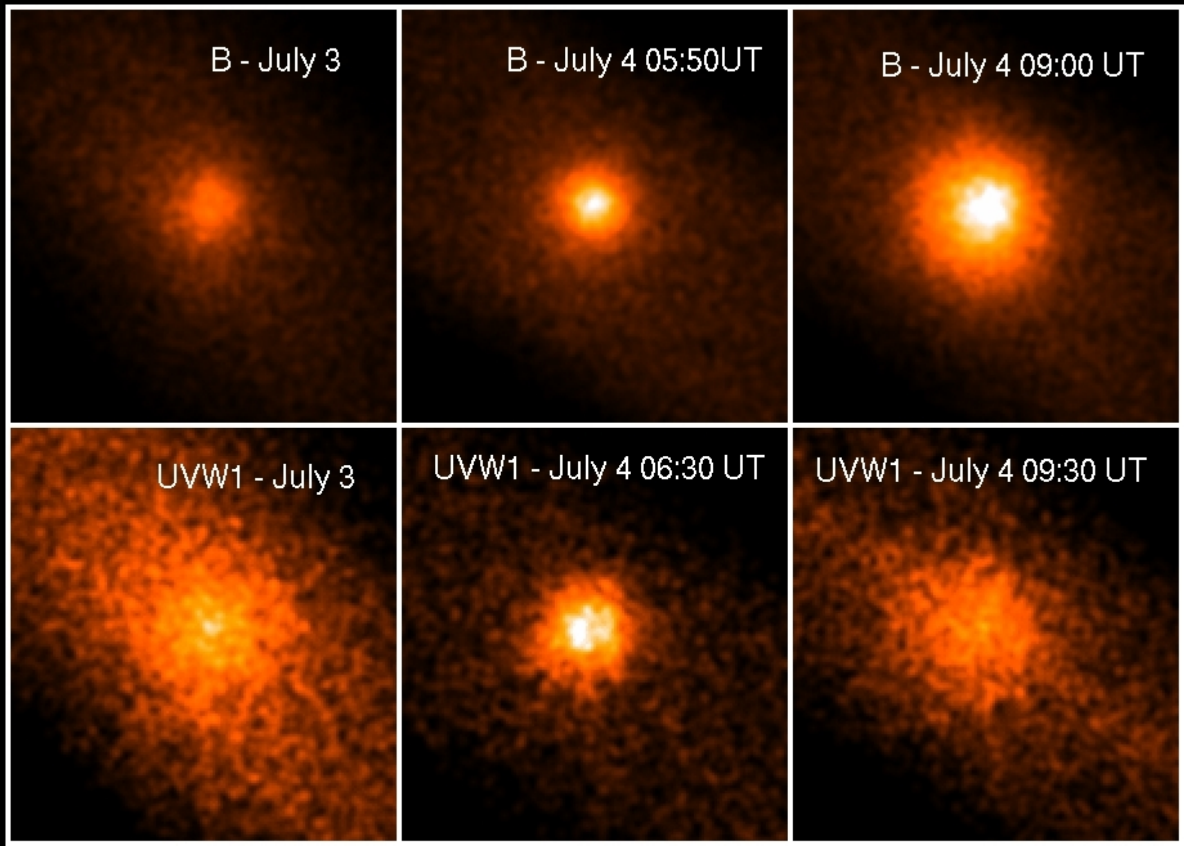
SPECTRA
Combined EPIC-MOS and -pn spectra of the North (black) and South (red) aurorae, and of the low-latitude disk emission (green) of Jupiter. Differences in spectral shape between auroral and disk spectra are clear. The presence of a high energy component in the spectra of the aurorae is very evident, with a substantial excess relative to the disk emission extending to 7 keV. The horizontal blue line shows the estimated level of the EPIC particle background.

The different shapes of the auroral and disk spectra are representative of the different physical processes responsible for the X-ray emission in the two cases: charge exchange by ions precipitating in Jupiter's magnetosphere into the auroral zones (leading to the peaks around 0.5 - 0.6 keV), and scattering of solar X-rays in the upper atmosphere of the planet producing the disk emission (i.e. the planet acts as a mirror for the Sun's X-rays!). In addition, the high energy 'tail' in the auroral spectra is thought to be due to bremsstrahlung radiation of electrons also precipitating in Jupiter's magnetosphere close to the poles.

Investigator(s): G. Branduardi-Raymont, A. Bhardwaj, R. F. Elsner, G. R. Gladstone, G. Ramsay, P. Rodriguez, R. Soria, J. H. Waite Jr., T. E. Cravens

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

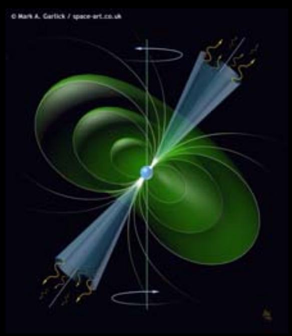


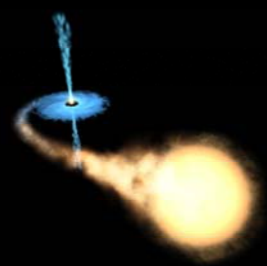


- R. Schulz, et al., 2006, A&A 448, L53

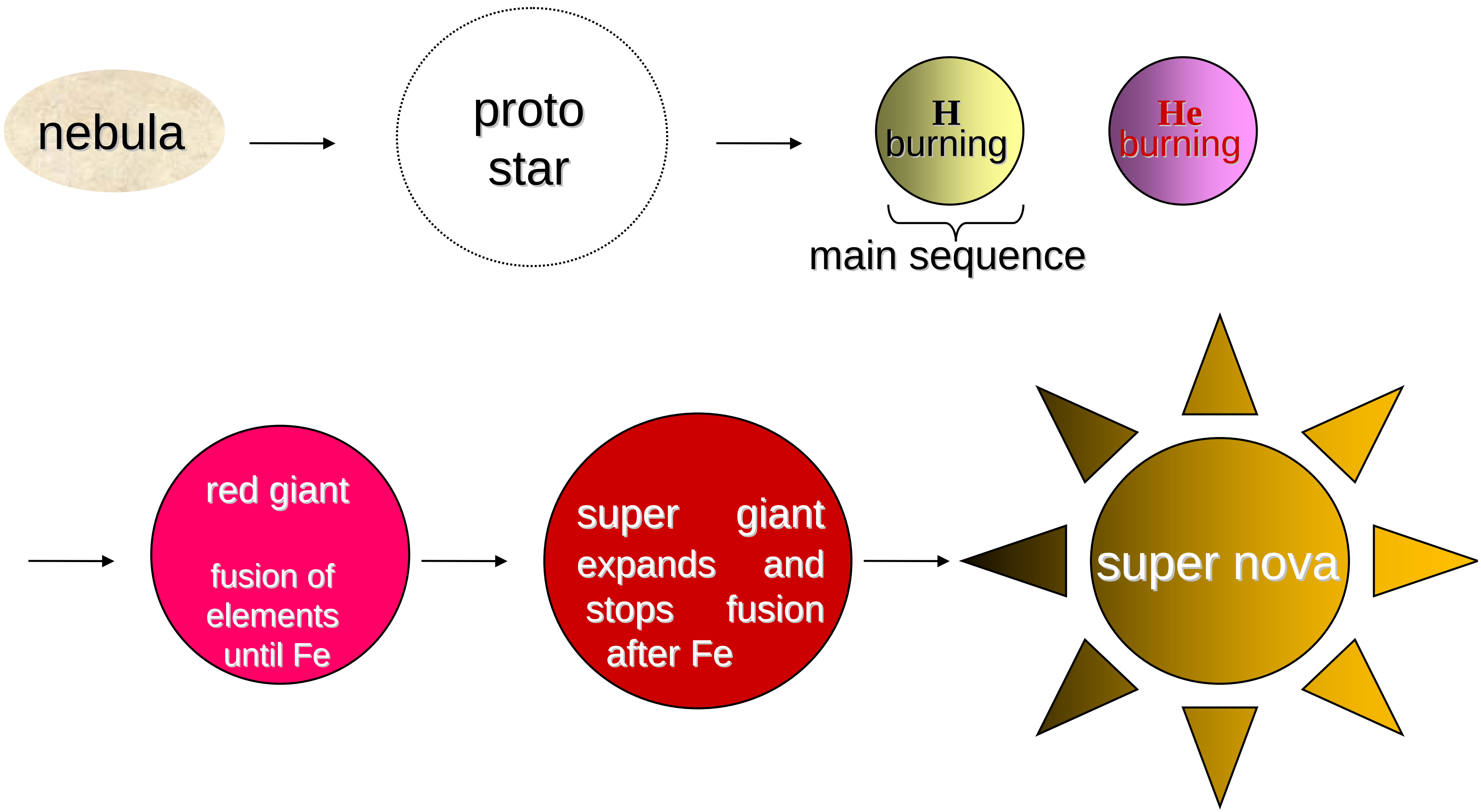
=> first detection of ice grains in material ejected from the nucleus of a comet at only 1.5 AU from the Sun

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

MK1 Right in time for the festive season, ESA's XMM-Newton X-ray observatory has discovered a huge cloud of high-temperature gas resting in a spectacular nearby star-forming region, shaped somewhat like the silhouette of Santa Claus.

An early present for astronomers, the cloud suggests that hot gas from many star-forming regions leaks into the interstellar medium.

The Orion nebula is the nearest dense star-forming region to Earth that contains stars much more massive than the Sun. XMM-Newton’s newly-discovered gas cloud is composed of winds blowing from these high-mass stars that are heated to millions of degrees as they slam into the surrounding gas.

“There is one star in particular that dominates the nebula,” says Manuel Güdel, Paul Scherrer Institut, Switzerland, who led the team that discovered the gas. The star in question is theta1 Orionis C, a giant star around 40 times mass of the Sun, with a surface temperature of 40,000°C. Güdel and his colleagues think that the violent collision between the wind from this star and the surrounding dense gas is largely responsible for the newly-discovered hot gas cloud.

The Orion nebula

The Orion nebula

The high-temperature gas fills a region of the nebula that appears to be a huge cavity in optical and infrared images. The new observations, taken with XMM-Newton’s European Photon Imaging Camera (EPIC) camera, suggest that astronomers are seeing only a particular portion of the gas. The X-rays from this portion escape absorption by patches of cold gas covering much of the front of the Orion nebula.

The surrounding pattern of absorbing clouds gives the detected gas its Santa Claus shape, with his prominent hat outlined by the northern gas bubble. In its entirety, the hot gas probably fills the whole nebula.

The team discovered it whilst conducting a survey of the young stars in the region. In the background of many of those images was a faint glow of X-rays. “The diffuse signal came up time and time again. Finally, we realized that it was something real,” says Güdel.

The Orion nebula in multiple wavelengths

The Orion nebula in multiple wavelengths

The presence of the hot gas in a fairly common nebula like Orion is surprising. Although theory has predicted such hot gas clouds, previous observations suggested that a large number of massive stars shedding winds, or supernova explosions are required. These are found in some regions of vigorous high-mass star formation, which are scattered only rarely throughout the galaxy. The new observations show that much smaller collections of high mass stars can produce hot gas as well.

There are many star-forming regions similar to the Orion nebula throughout the galaxy, so there should be a network of channels and bubbles being filled up by the hot gas leaking from these various regions. “This is another possible way to enrich the interstellar medium. You don’t have to wait for a sudden supernova to explode. You can do it with just one or two massive stars over millions of years,” says Güdel.

The Orion nebula

The Orion nebula
The team now plans to obtain new observations to determine how the gas flows out of the Orion nebula. In particular, they want to see whether it connects with a giant bubble created by supernova explosions from previous generations of massive stars.

Marcus Kirsch, 08/12/2009

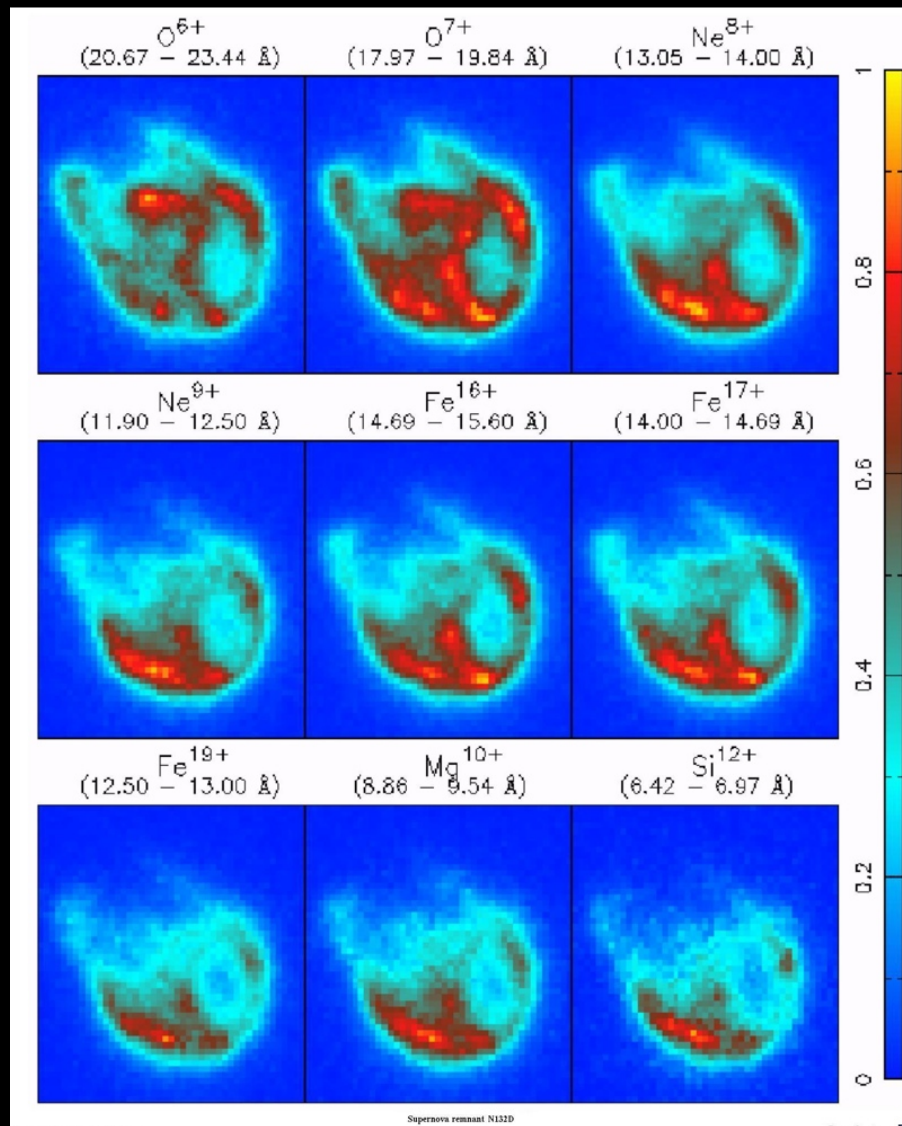
MGFK3

Super Nova Remnant N132D

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

the supernova remnant N132D in different energies

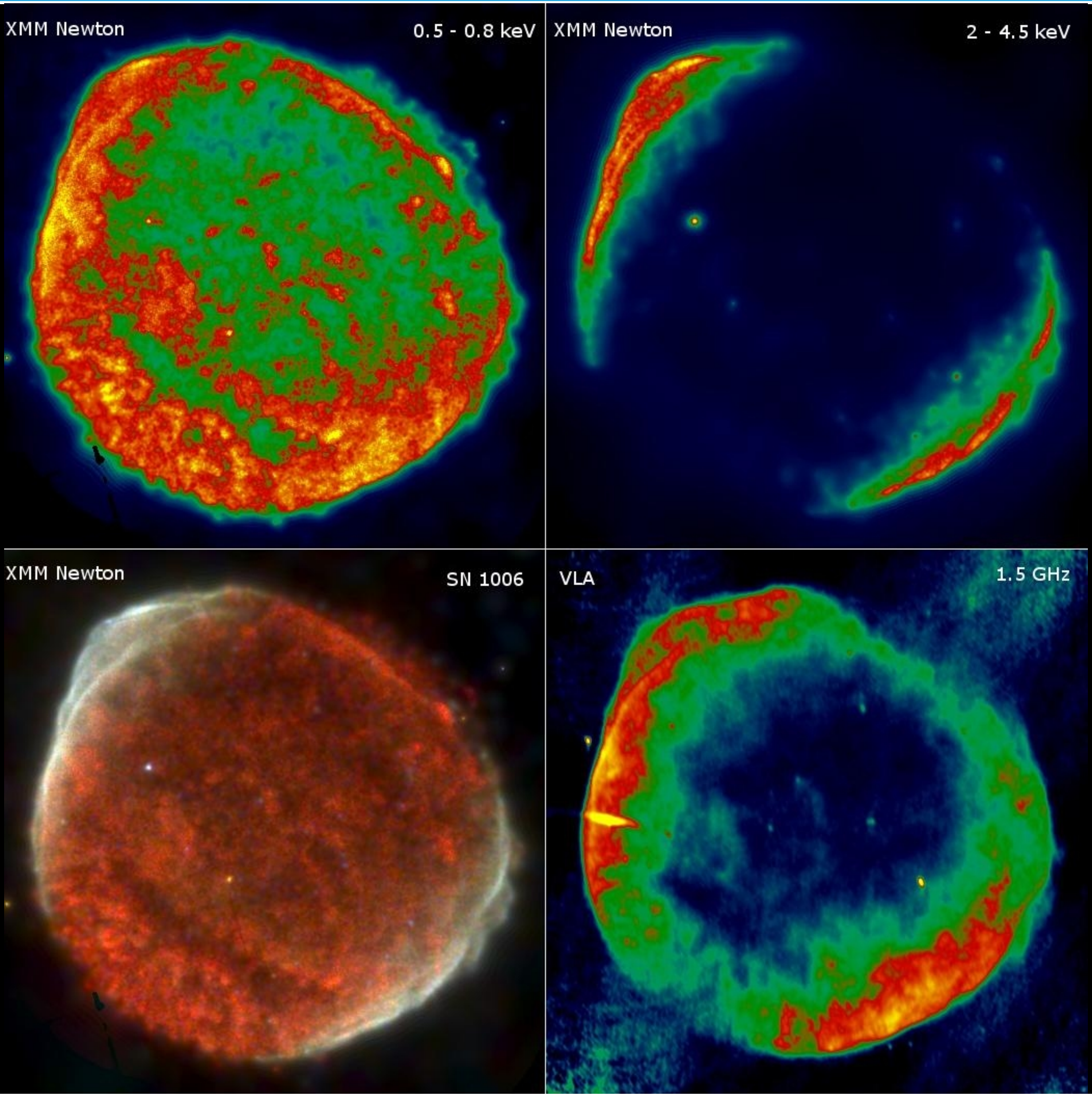
E. Behar, Columbia Univ.,



MGFK3 One of the brightest soft X-ray sources in the Large Magellanic Cloud is the supernova remnant N132D. Observations with XMM-Newton's Reflection Grating Spectrometers (RGS), complemented by images taken by the European Photon Imaging Camera (EPIC) have provided highly resolved X-ray spectra of this extended supernova remnant. In the narrow wavelength bands indicated, each EPIC-MOS image maps the distribution of nine different ions. Differences between more and less ionised regions can be noted. Oxygen rich gas is present in an area to the northeastern part of the remnant, where no other elements are emitting X-rays. This may either be relatively cold gas, or is the result of the supernova shockwave interacting with oxygen-rich stellar winds ejected before the stellar explosion.

Marcus G.F. Kirsch, 16/09/2008

SN 1006: Variations of Cosmic-ray Acceleration



R. Rothenflug et al., 2004, A&A 425, 121

Prototype of shell supernova remnants

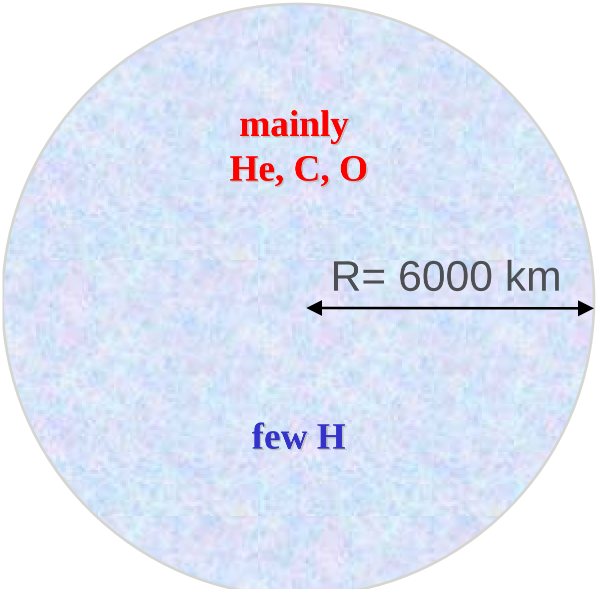
Non-thermal synchrotron emission

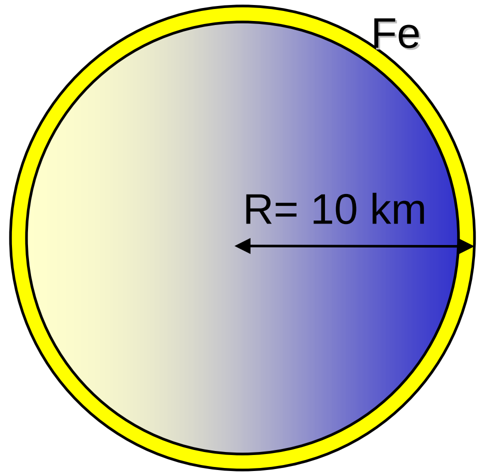
➔ The magnetic field is amplified where acceleration is efficient

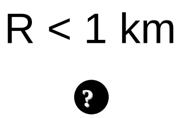
➔ Relation to the TeV emission

compact object classification

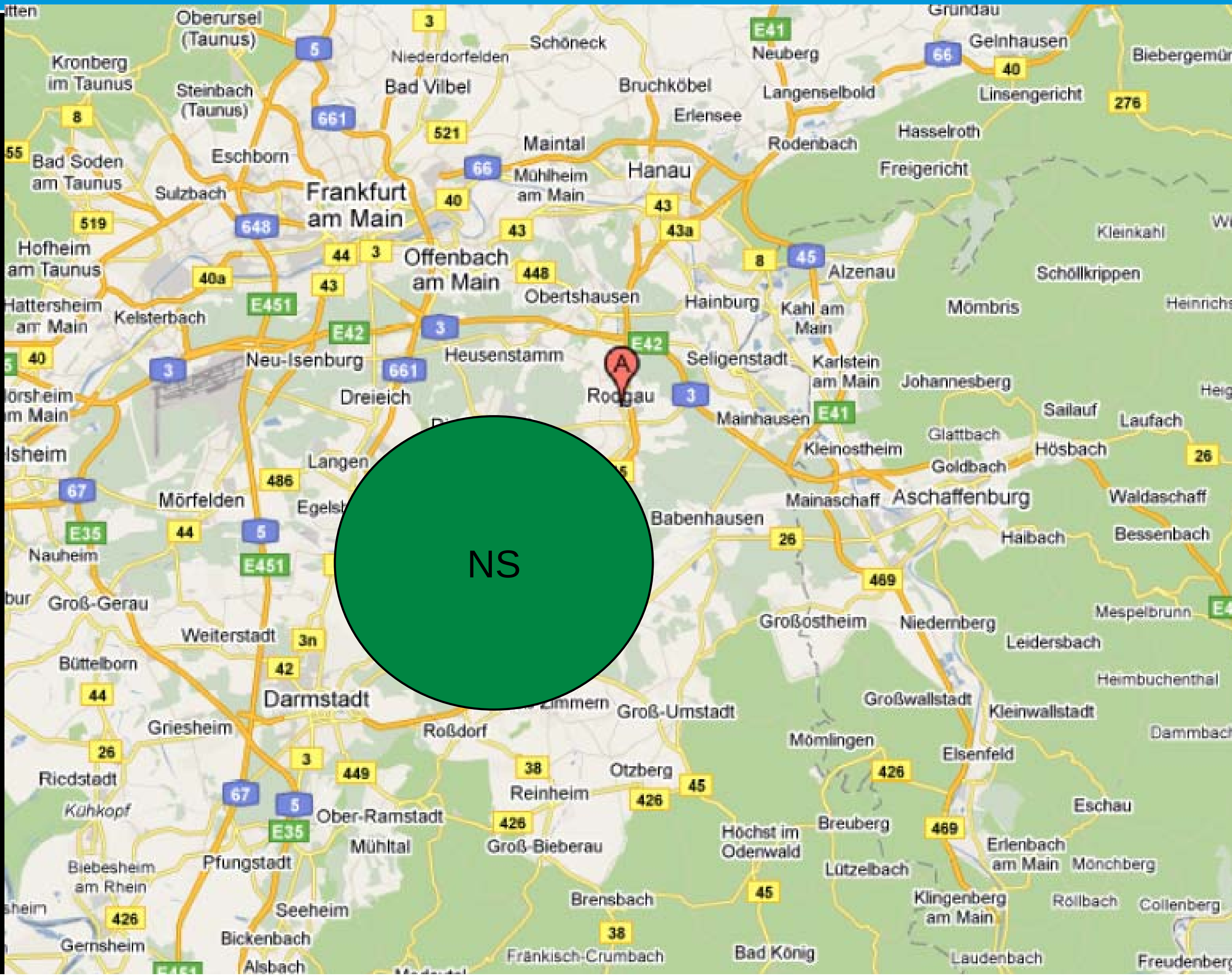
white dwarf	neutron star	black hole
$M < 1{,}4\ M_{sun}$	$1{,}4\ M_{sun} < M < 3{,}2\ M_{sun}$	$3{,}2\ M_{sun} < M$



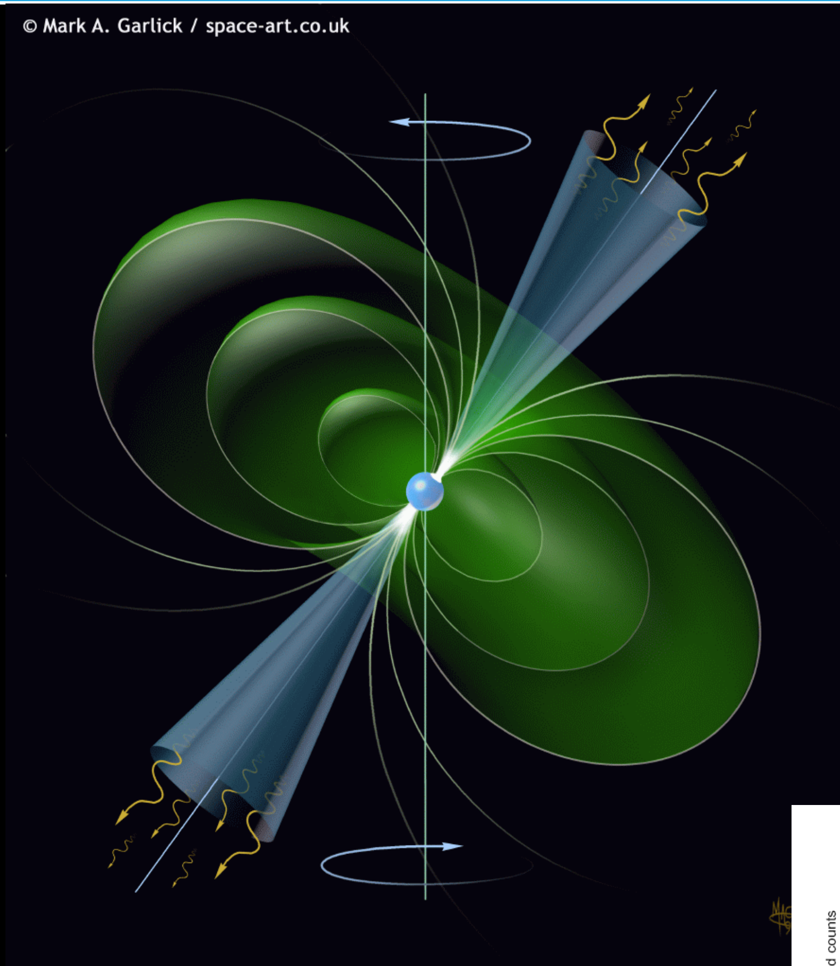




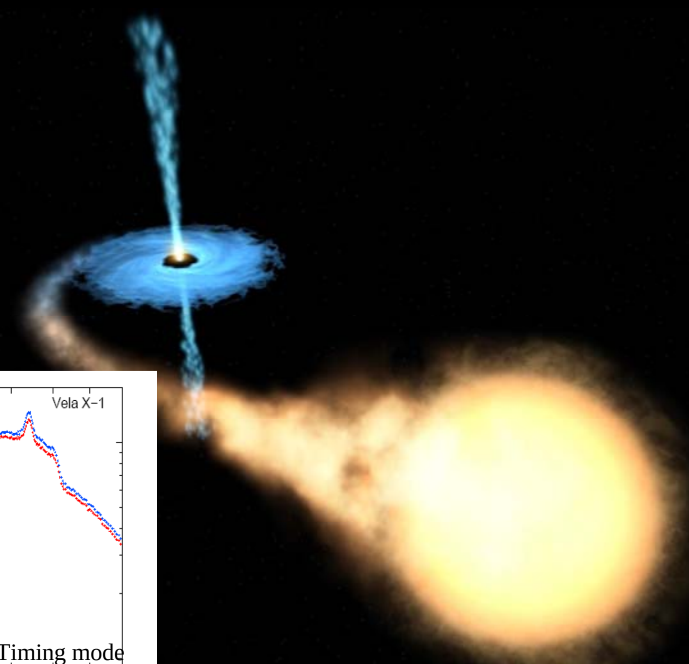
order of magnitude

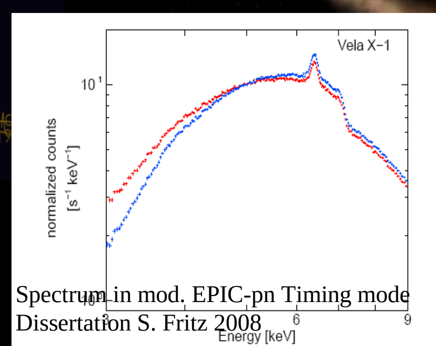


pulsars and binaries



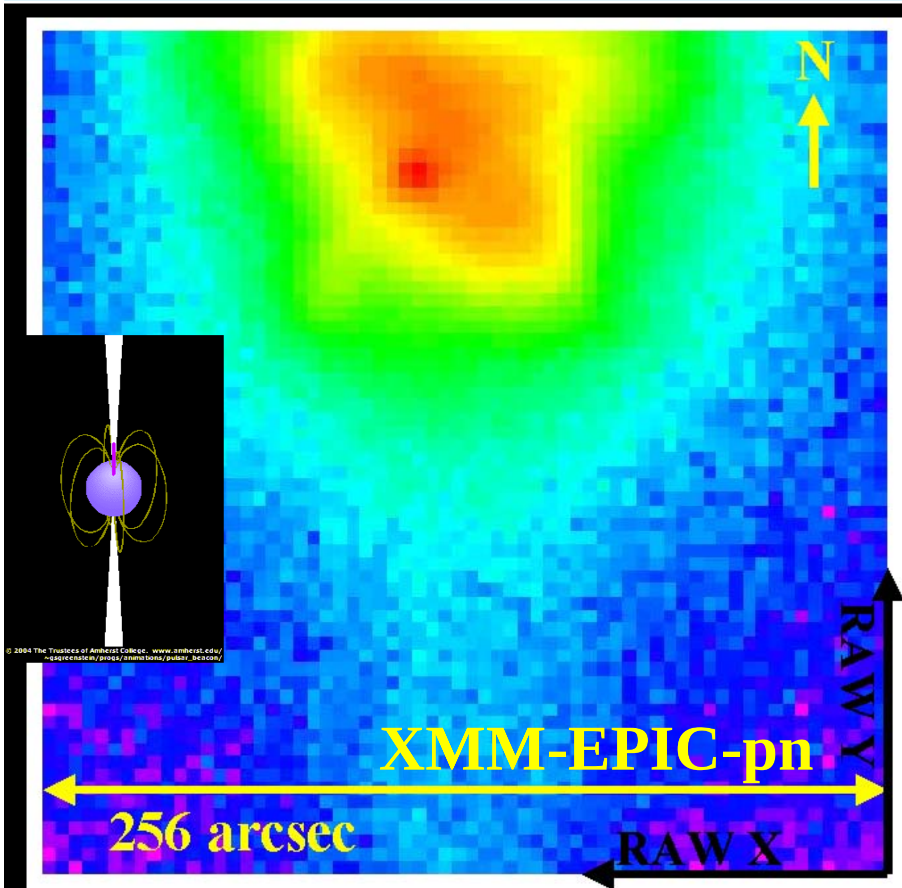
- **Pulsars:** highly magnetized rotating neutron star (compact object) that emits a beam of electromagnetic radiation, since rotational and magnetic field axes are not parallel
- **XRBs:** class of binary stars that are luminous in X-rays. X-rays are produced by matter falling from one component to the other component, which is a compact object: a white dwarf, neutron star, or black hole



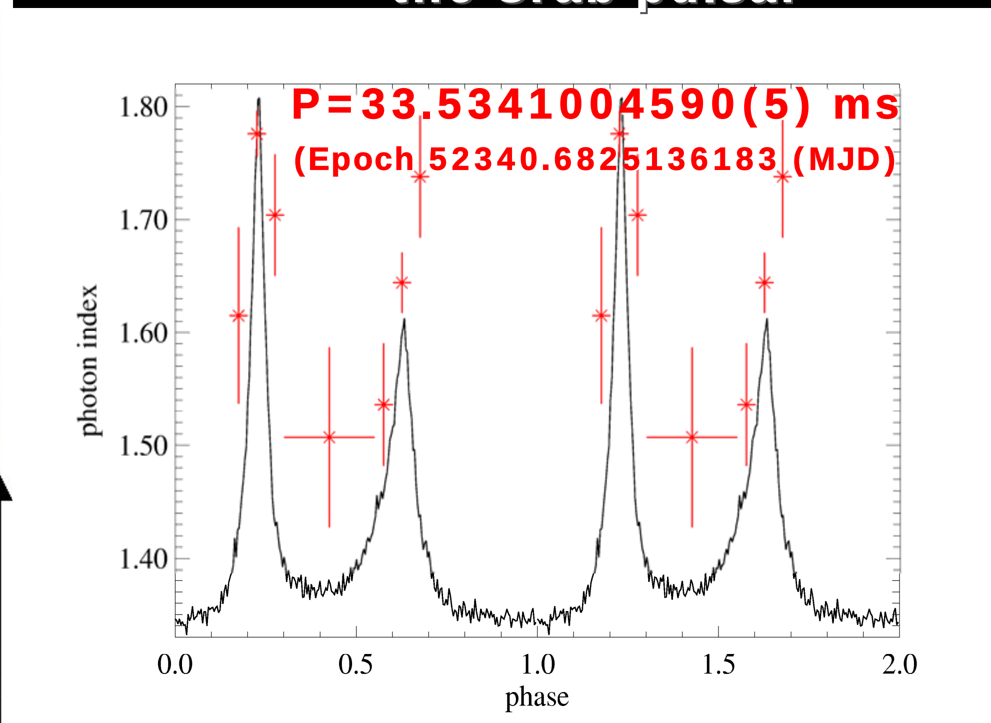


Spectrum in mod. EPIC-pn Timing mode
Dissertation S. Fritz 2008

the Crab pulsar in X-rays



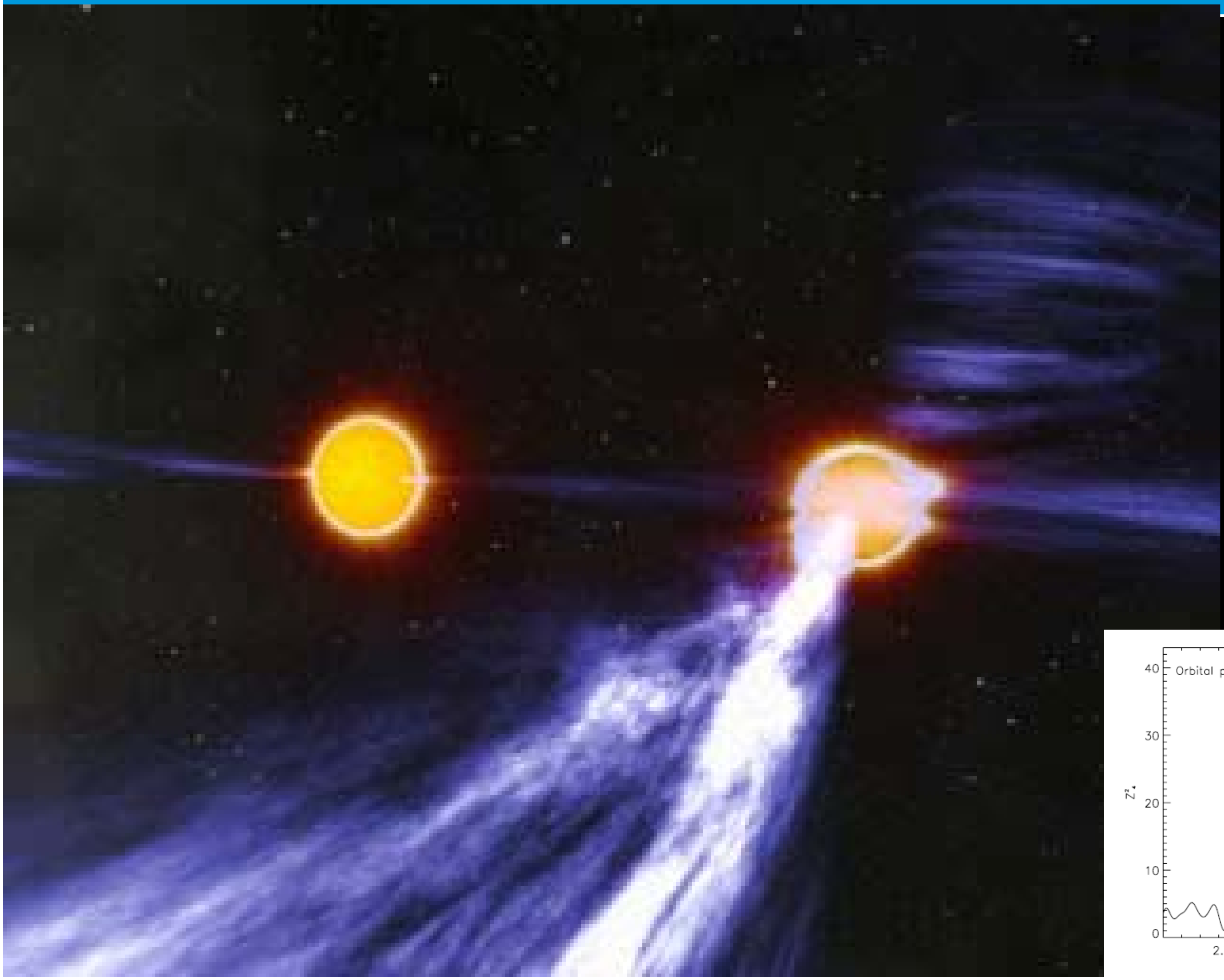
Folded light curve of the Crab pulsar



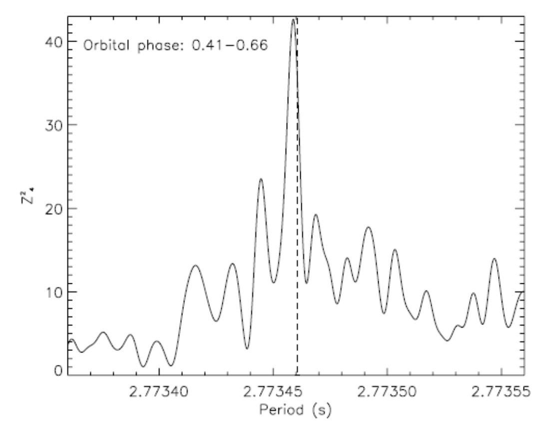
Kirsch et al. 2006, A&A 453, 173-180

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

binary pulsar system

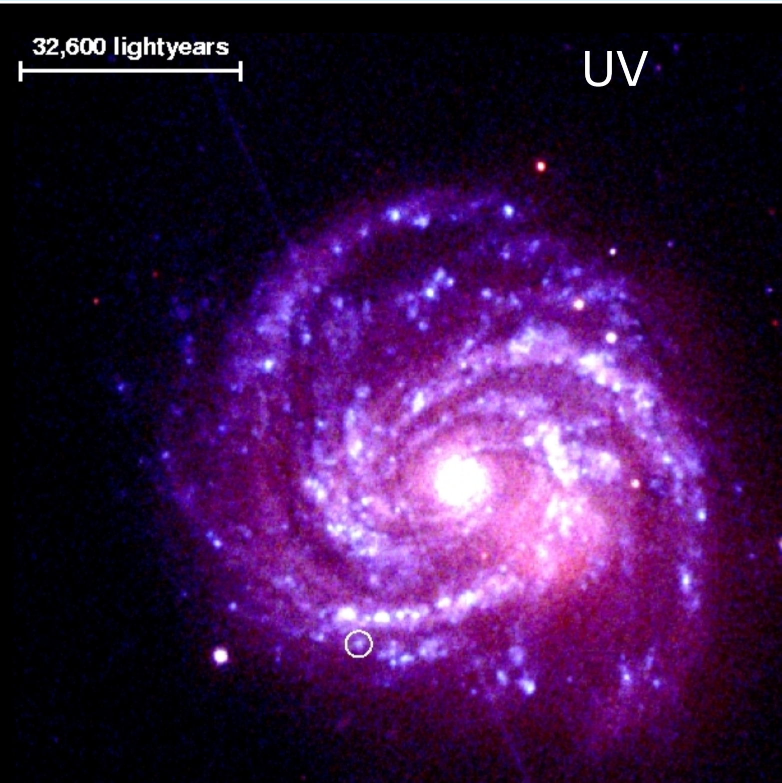


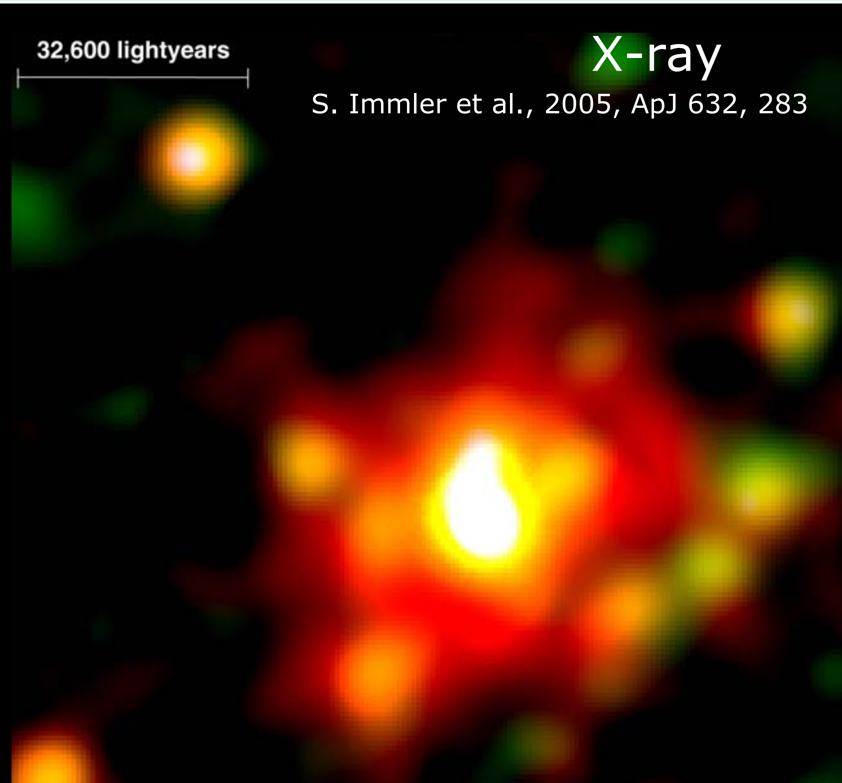
- two pulsars orbiting each other in a binary system
- PSR J0737-3039 contains a slowly-rotating 'lazy' neutron star (pulsar B) orbiting a faster and more energetic companion (pulsar A).
- A. Pellizzoni, Astrophysical Journal in May 2008.



MK2

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.

MK2 These false-colour images show the spiral galaxy M100, also known as NGC 4321, and within the galaxy the supernova SN 1979C. On the left is the image of M100 in the UV/optical, taken with XMM-Newton's Optical Monitor (OM) camera, and on the right the galaxy is shown on the same scale but imaged in the X-ray with XMM-Newton's MOS cameras. M100 is in the Virgo cluster of galaxies, 56 million light years from Earth. The overall appearance of the galaxy is strikingly different in the X-ray compared to the UV/optical. The OM image clearly 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. This particular supernova is curious because it is still just as bright in the X-ray as when it was observed by ROSAT in 1995, six years before the XMM-Newton observation. Normally objects of this type would be expected to dim significantly over time. In the OM image the false colouring was done using images taken with three fiters: the B filter (4340), the U filter (3440) and the UVW1 (2910). In the X-ray image soft (0.3-1.5 keV) X-rays are shown in red, medium (1.5-4 keV) in green and hard (4-10 keV) in blue. The hardest X-rays are emitted from the galactic core, but are not seen as pure blue because there are also medium and soft X-rays emitted from that location.

Marcus Kirsch, 08/12/2009

journey

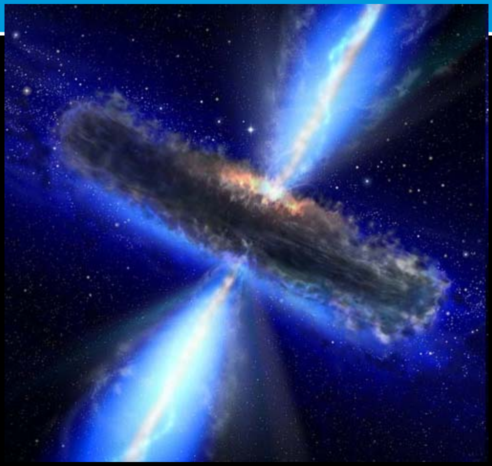

"Blazar"
Viewing down the jet
"Quasar / Seyfert 1"
Viewing at an angle to the jet
"Radio Galaxy / Seyfert 2"
Viewing at 90° from the jet
Black Hole
Accretion Disk
Torus of Neutral Gas and Dust
Radio Jet

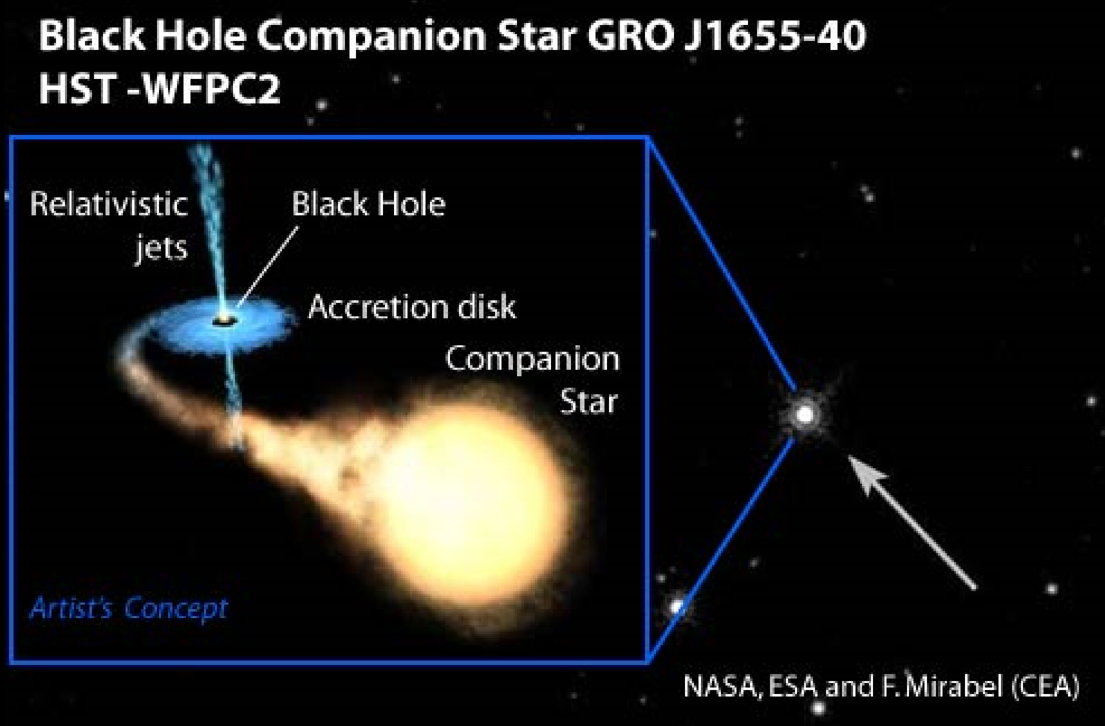
black holes

- 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

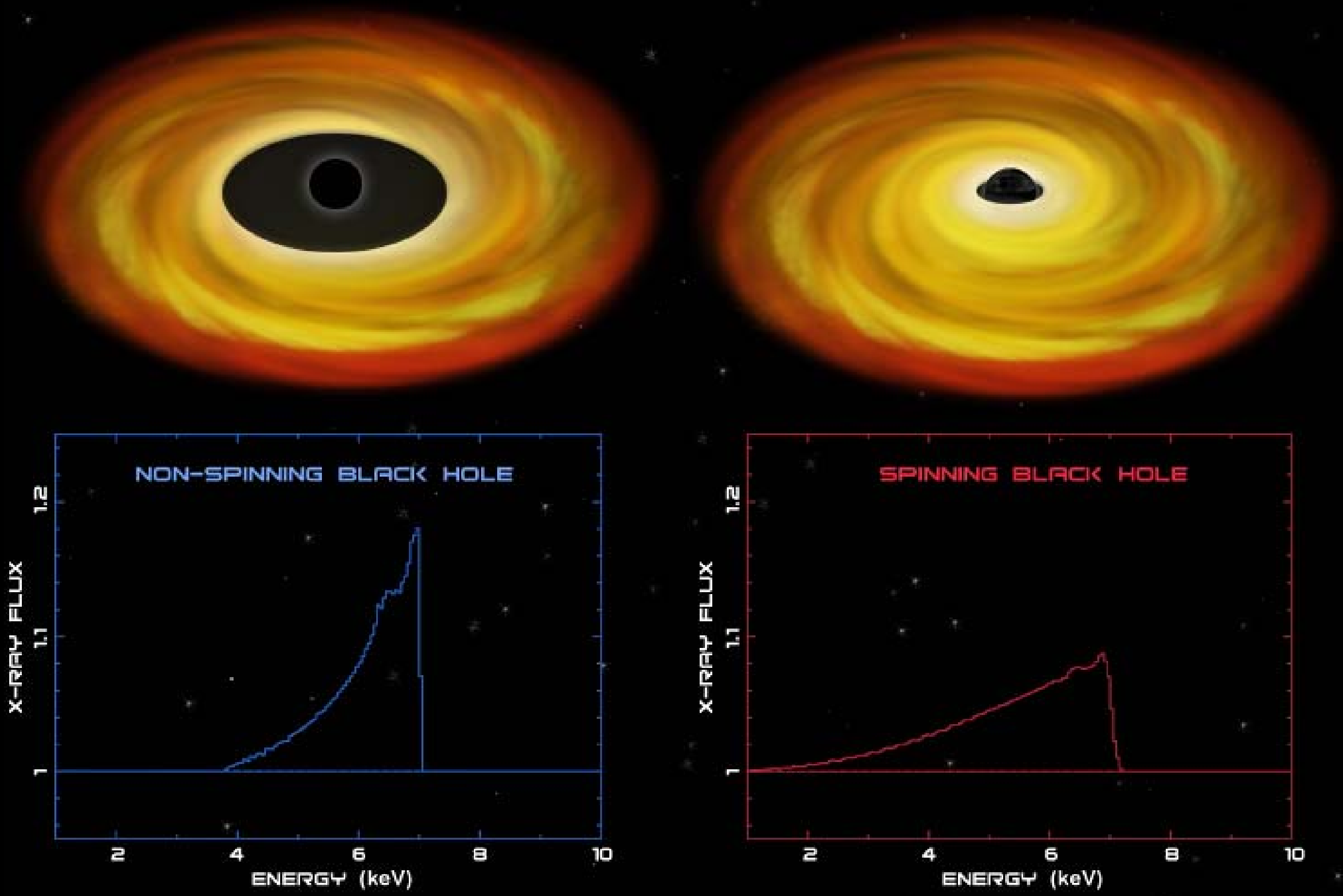




black holes – 4 types

MGFK5

- 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

MGFK5

Chandra and XMM-Newton observations of iron atoms in the hot gas orbiting 3 stellar black holes have allowed astronomers to investigate the gravitational effects and spin of these black holes. For example, as shown in the illustration, the gravity of a black hole shifts X-rays from iron atoms to lower energies, producing a strongly skewed X-ray signal.

The orbit of a particle near a black hole depends on the curvature of space around the black hole, which also depends on how fast the black hole is spinning. A spinning black hole drags space around with it and allows atoms to orbit nearer to the black hole than is possible for a non-spinning black hole. The tighter orbit means stronger gravitational effects, which means that more of the X-rays from iron atoms are shifted to lower energies.

The most detailed studies of stellar black holes to date indicate that not all black holes spin at the same rate.

Chandra data on Cygnus X-1 (similar to the lower left panel) show evidence of strong gravitational effects, with some atoms as close as 100 miles from the black hole, but no evidence of spin. XMM-Newton data from XTE J1650-500 are similar to the lower right panel and indicate that some X-rays are coming from as close as 20 miles to the black hole event horizon. This black hole must be spinning rapidly. Chandra observations of a third stellar black hole, GX 339-4, indicate that it is also spinning rapidly.

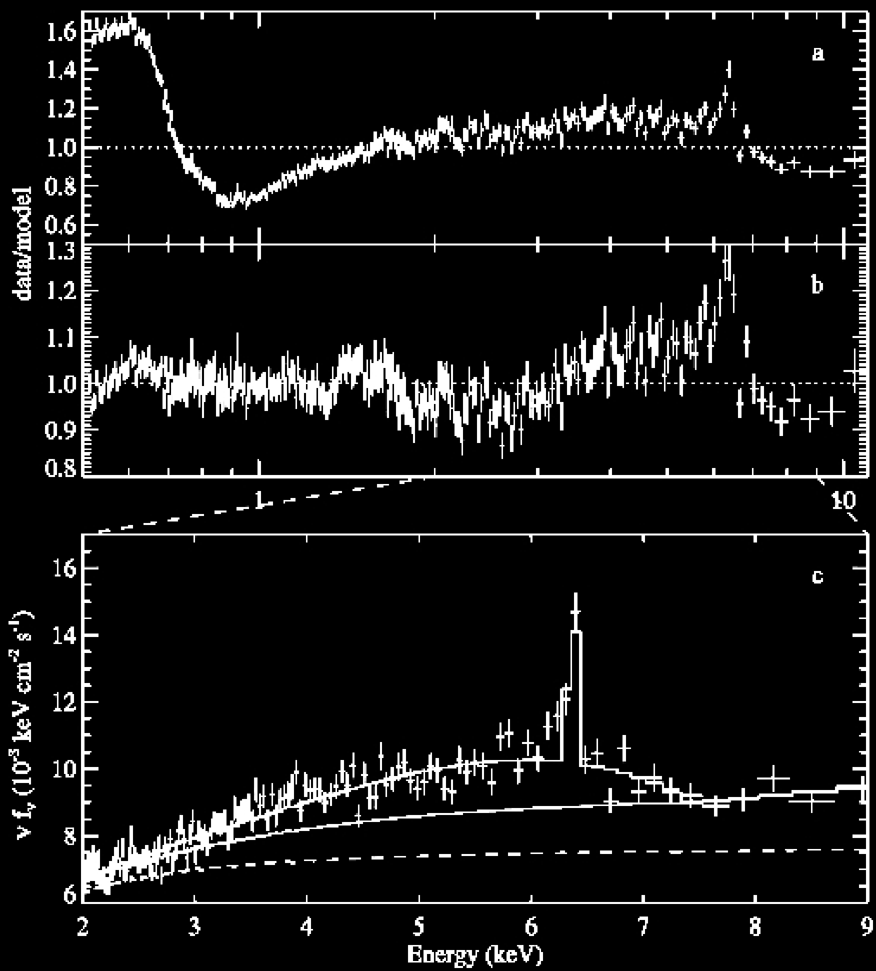
One possible explanation for the differences in spin among stellar black holes is that they are born spinning at different rates. Another is that the gas flowing into the black hole spins it up. The black holes with relatively long-lived, low-mass companions, such as XTE J1650-500 and GX 339-4, would have had a longer time to spin up than those with massive, short-lived companion stars, such as Cygnus X-1. As the spins of more black holes are measured, it should be possible to test these explanations.

http://images.google.de/imgres?imgurl=http://chandra.harvard.edu/photo/2003/bhspin/bhspin_comp.jpg&imgrefurl=http://chandra.ha

Marcus G.F. Kirsch, 23/04/2009

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

esa

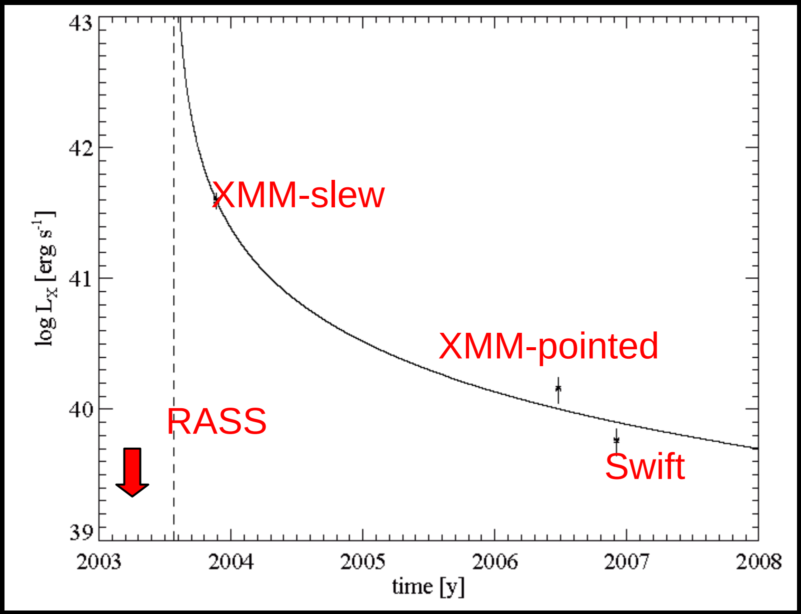


- Deep minimum' state
- Difficult to understand in any pure accretion disc model
- Extraction and dissipation of rotational energy from a spinning black hole
- J. Wilms et al., 2001, MNRAS 328, L27

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.

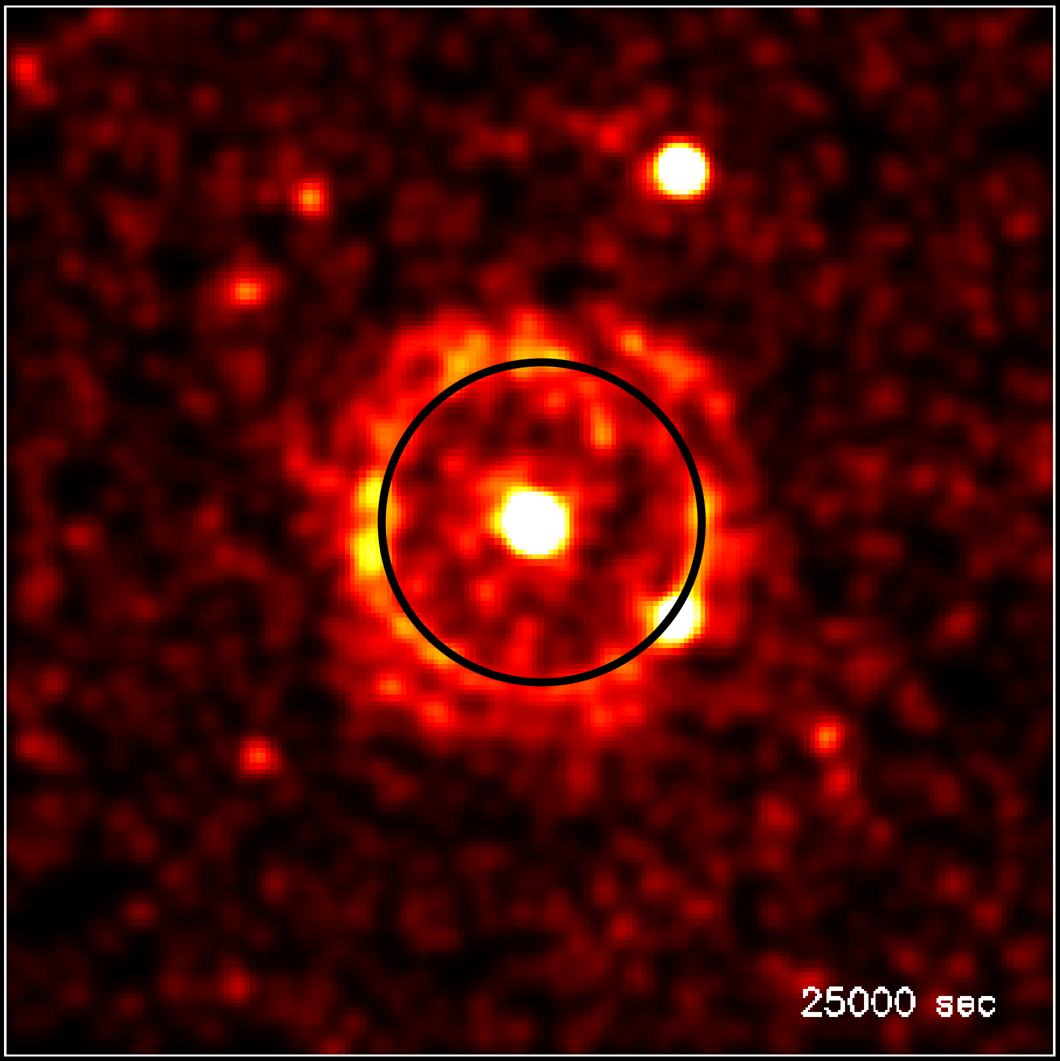
Peak in soft X-rays!

Luminosity declines as t-5/3

MGFK6

GRB 031203

GRB 031203 XMM–Newton observation



ESA, S. Vaughan (University of Leicester)

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

MGFK6 This image and animation shows GRB 032103, observed in the X-ray by XMM-Newton's MOS cameras. On December 3rd 2003 a 30-second flash of gamma rays was detected from GRB 032103 by Integral and consequently an XMM-Newton observation of the object was performed, starting 6 hours after the burst.

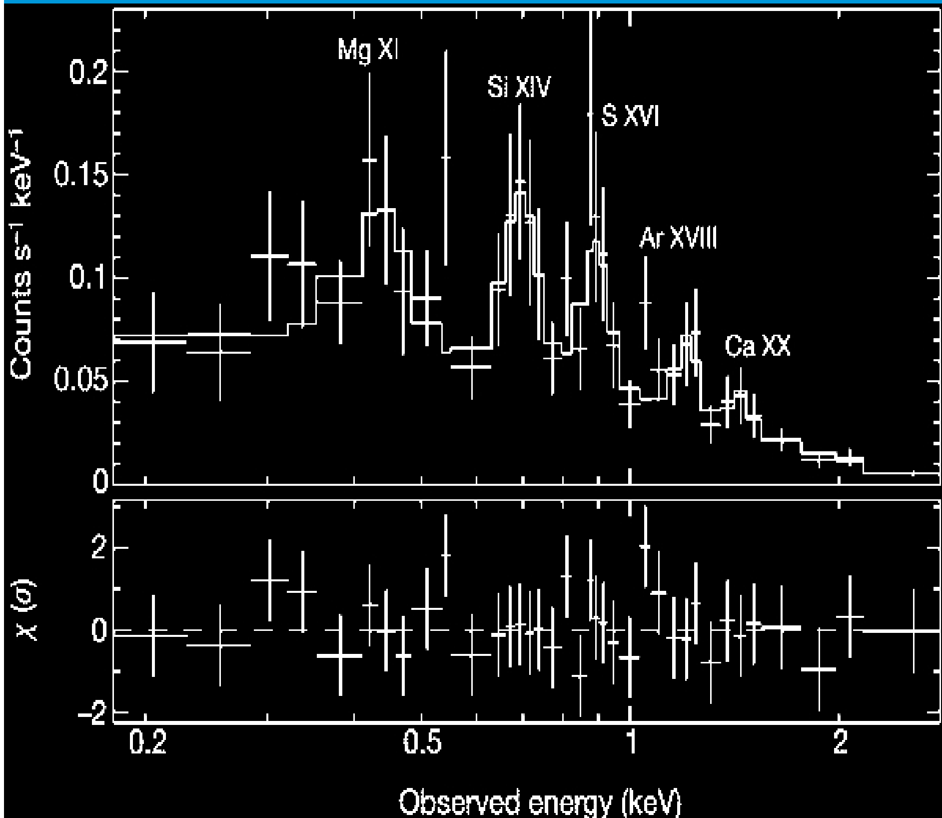
The image (top figure) and animation (bottom figure) depict photons detected in the 0.7 - 2.5 keV energy range. The data were divided into time steps, and the image and animation show how the appearance of the object changes with time. The two rings seen are concentric with the X-ray afterglow, and appear to expand outwards. They are caused by dust slabs between the observer and the GRB. The dust reflects photons from the afterglow into the line of sight of the observer. They appear to expand outwards because light scattered at a larger angle to the line of sight take longer to reach the observer, hence giving the appearance of an expanding circle. In fact, the apparent rate of expansion is a thousand times the speed of light. The two rings are caused by separate dust slabs at distances of 880 and 1390 parsecs. Expanding X-ray rings from scattering by dust grains have never been seen before, although slower-moving rings around supernovae have been observed.

Investigator(s): S. Vaughan, R. Willingale, P. T. O'Brien, J. P. Osborne, J. N. Reeves, A. J. Levan, M. G. Watson, J. A. Tedds, D. Watson, M. Santos-Lleo, P.M. Rodriguez-Pascual, N. Schartel

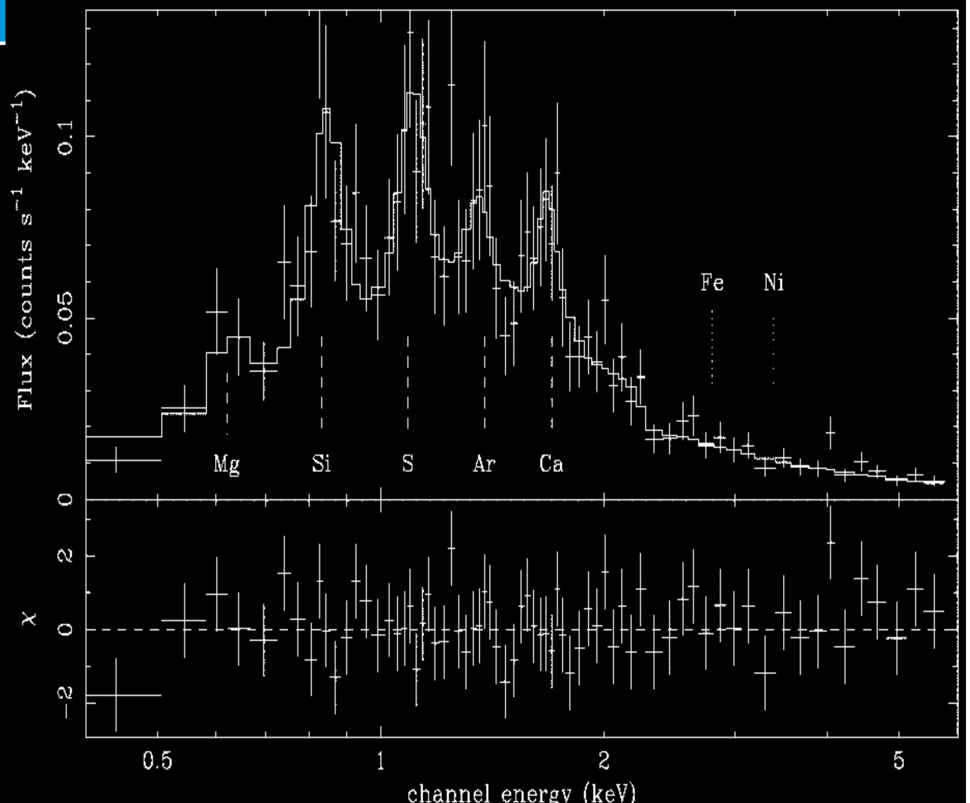
Marcus G.F. Kirsch, 16/09/2008

MGFK7

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

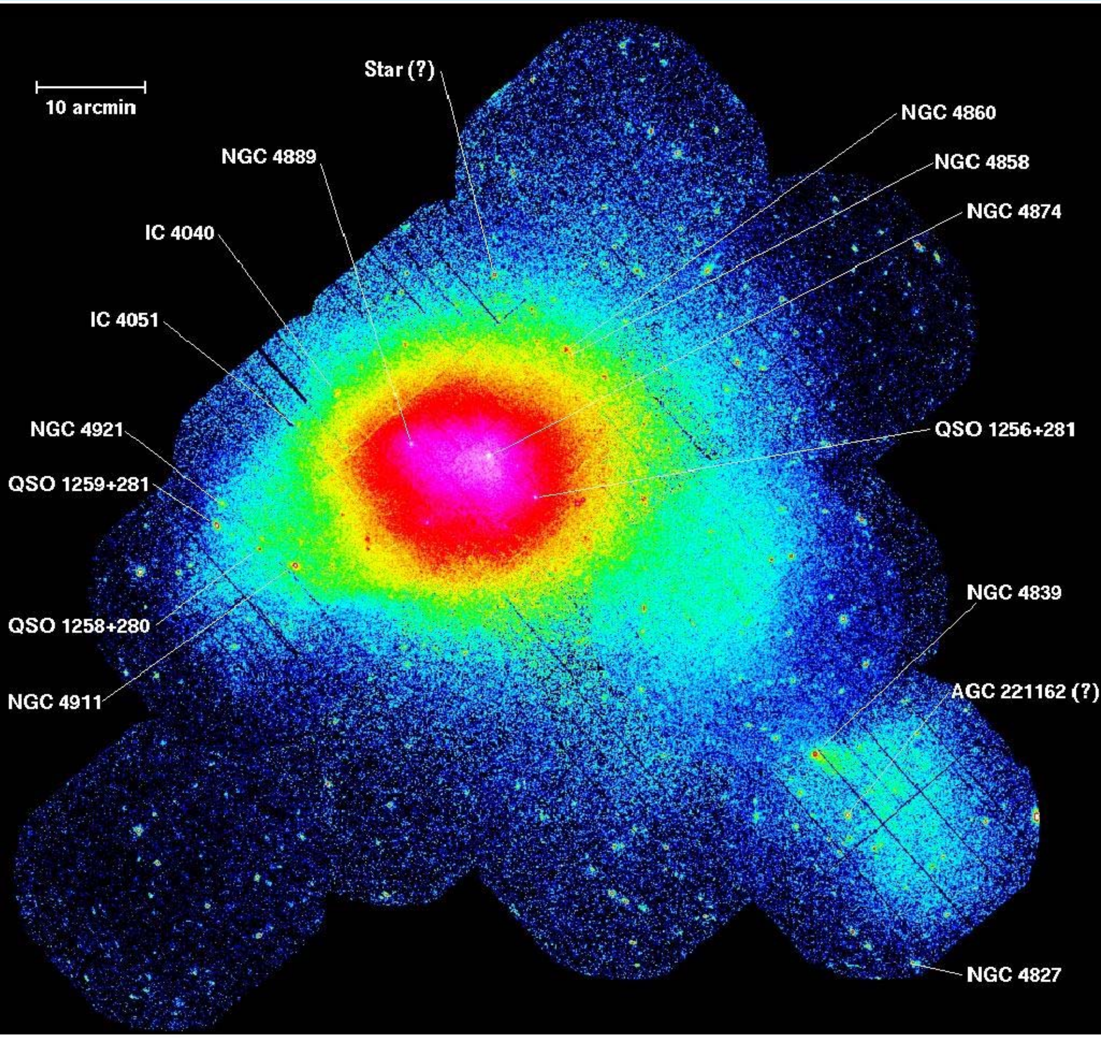
→ supernova explosion of a massive stellar progenitor precedes the GRB event and is responsible for the outflowing matter

MGFK7 The gamma-ray burst GRB011211 was first detected on 11 December 2001 at 19:09:21 UT, by the Beppo-SAX satellite; the burst duration was 270 s (making GRB011211 the longest burst observed by Beppo-SAX), with a peak flux (40-700 keV) of 5 10-8 erg cm-2 s-1. Spectroscopy of the optical afterglow revealed several absorption lines at a redshift of z = 2.141+-0.001, and R-band imaging has linked the optical transient with extended emission - the probable host galaxy - of magnitude mv = 25.0+-0.5. Assuming the absorption system arises from the GRB host galaxy, and adopting a cosmology of H0 = 75 km s-1 Mpc-1 and q0 = 0.1, implies a total equivalent isotropic energy for GRB011211 of 5 1052 erg. The observations of GRB011211 by the orbiting XMM-Newton X-ray telescope started at 06:16:56 UT on 12 December 2001, 11 hours after the initial burst. Data from the European Photon Imaging Cameras (EPIC) have been analysed, using both the MOS and pn instruments; the total observation duration is 27 ks. The time-averaged 0.2 10 keV flux, F, was 1.9 10-13 erg cm-2 s-1, decreasing with time t during the observation as F(t) proportional to t-(1.7+-0.2). The Optical Monitor detected the burst afterglow in both the visible and ultraviolet (UVW1) bands, with magnitudes of 21.12+-0.13 and 21.6+-0.3, respectively. The image shows the XMM-Newton EPIC-pn spectrum of the GRB011211 afterglow, for the first 5 ks of exposure only. The observations strongly favour models where a supernova explosion from a massive stellar progenitor precedes the burst event and is responsible for the outflowing matter.

Investigator(s): J. N. Reeves

MGFK8

Coma Cluster of Galaxies



Coma Cluster of galaxies

Image courtesy of U. Briel, MPE Garching, Germany

European Space Agency

320 Million ly

MGFK8 XMM-Newton has again observed the Coma Cluster of galaxies, with far longer exposures. Certain regions were observed for 22.6 Ksecs instead of 3.4 Ksecs originally, and with a lower proton background. Shown at the Delta Review, the new EPIC-pn image covers the 0.3 to 2.0 keV energy range and clearly discerns far more sources. The difference is striking particularly in the north/west (upper-right) corner.

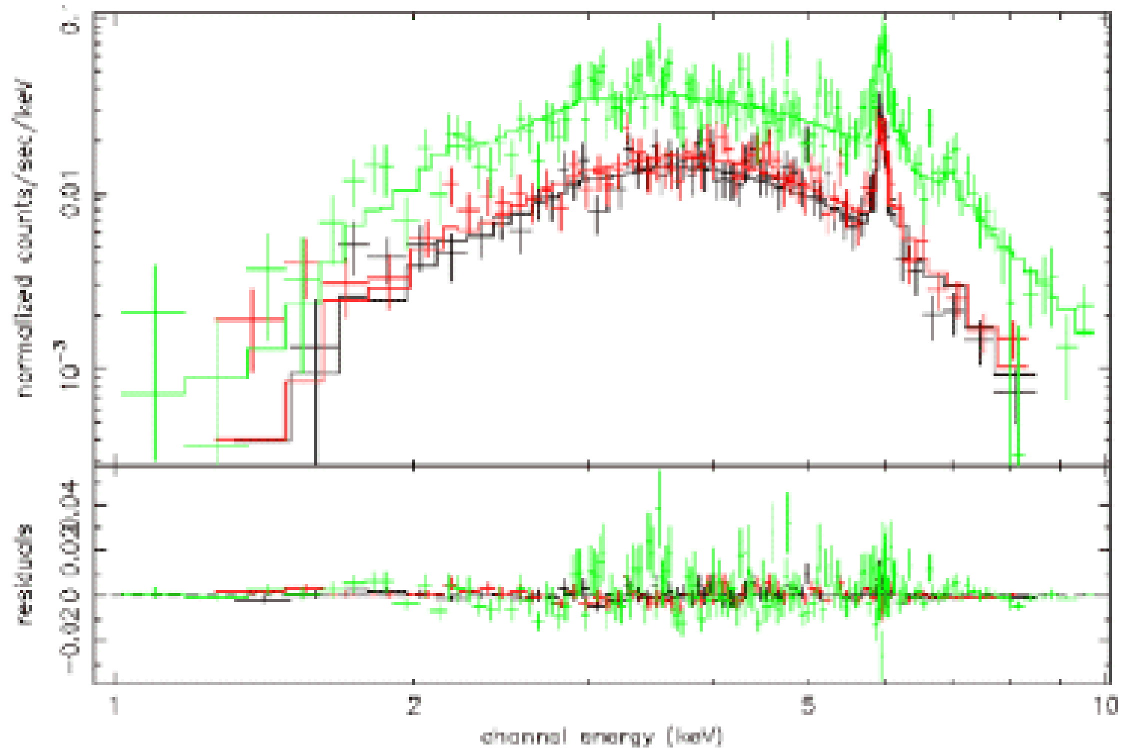
Investigator(s): U. Briel

Marcus G.F. Kirsch, 16/09/2008

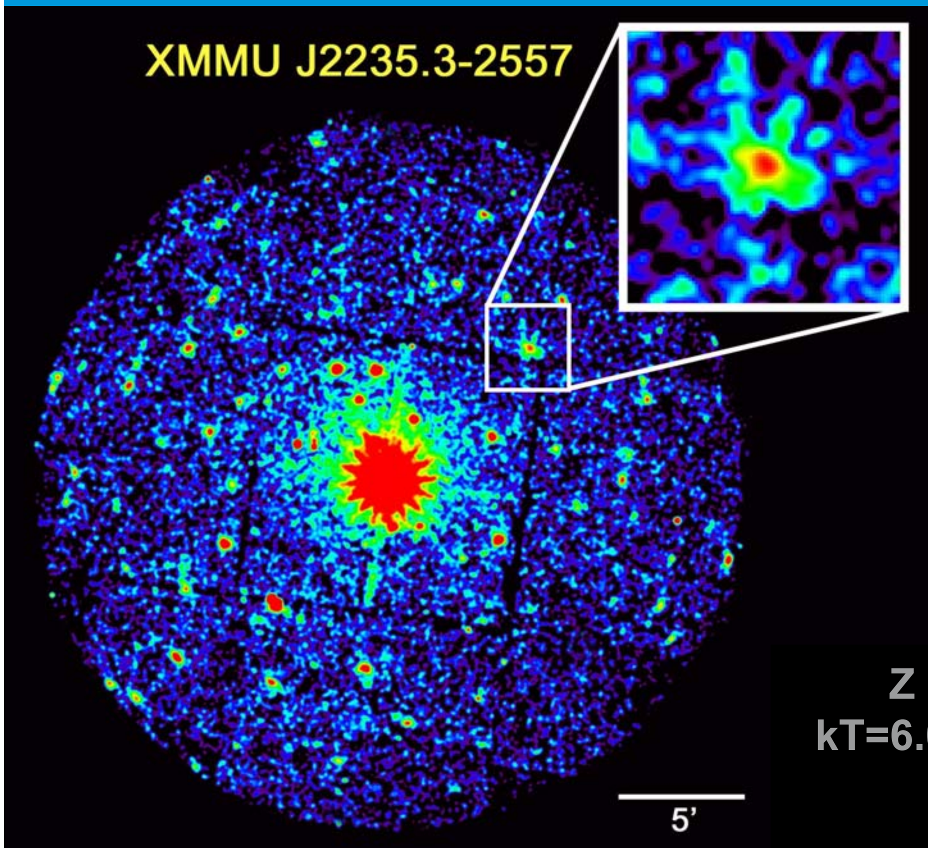
spectrum of a cluster of galaxies

- 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}

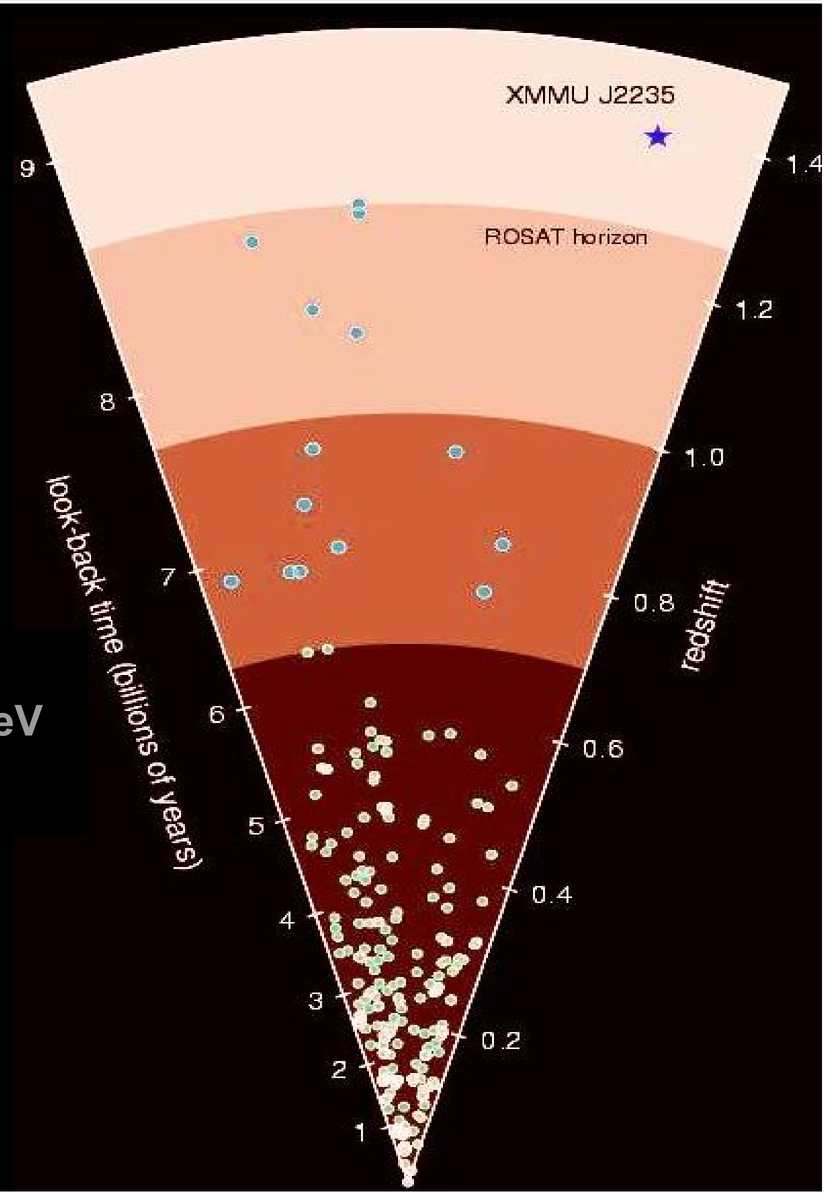
$$1 + z = \frac{\lambda_{\rm observed}}{\lambda_{\rm emitted}}$$



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

MGFK9 The image above can be displayed at full size and may be downloaded by clicking the image above.

About this Image

This image and animation shows GRB 032103, observed in the X-ray by XMM-Newton's MOS cameras. On December 3rd 2003 a 30-second flash of gamma rays was detected from GRB 032103 by Integral and consequently an XMM-Newton observation of the object was performed, starting 6 hours after the burst.

The image (top figure) and animation (bottom figure) depict photons detected in the 0.7 - 2.5 keV energy range. The data were divided into time steps, and the image and animation show how the appearance of the object changes with time. The two rings seen are concentric with the X-ray afterglow, and appear to expand outwards. They are caused by dust slabs between the observer and the GRB. The dust reflects photons from the afterglow into the line of sight of the observer. They appear to expand outwards because light scattered at a larger angle to the line of sight take longer to reach the observer, hence giving the appearance of an expanding circle. In fact, the apparent rate of expansion is a thousand times the speed of light. The two rings are caused by separate dust slabs at distances of 880 and 1390 parsecs. Expanding X-ray rings from scattering by dust grains have never been seen before, although slower-moving rings around supernovae have been observed.

Investigator(s): S. Vaughan, R. Willingale, P. T. O'Brien, J. P. Osborne, J. N. Reeves, A. J. Levan, M. G. Watson, J. A. Tedds, D. Watson, M. Santos-Lleo, P.M. Rodriguez-Pascual, N. Schartel

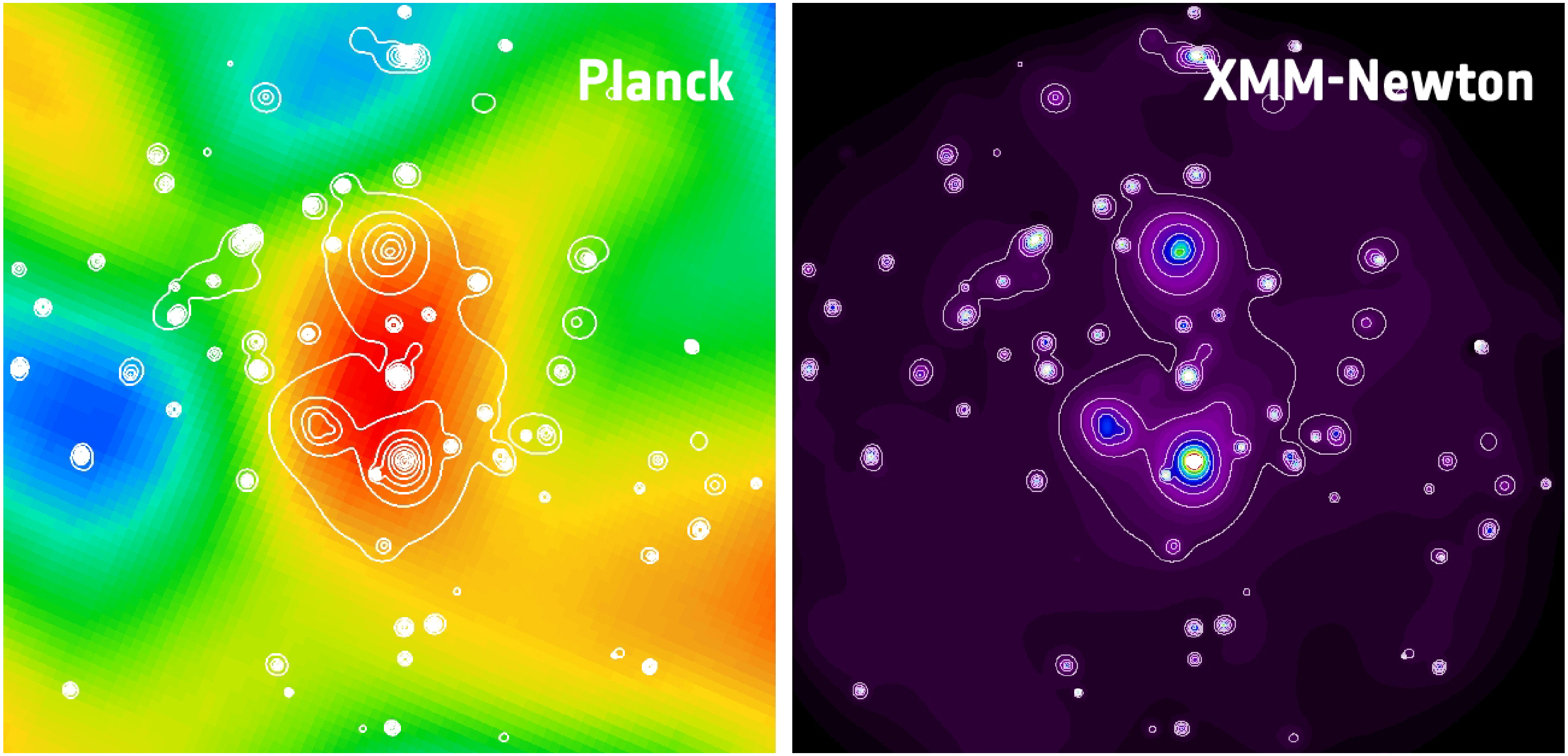
Marcus G.F. Kirsch, 16/09/2008

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

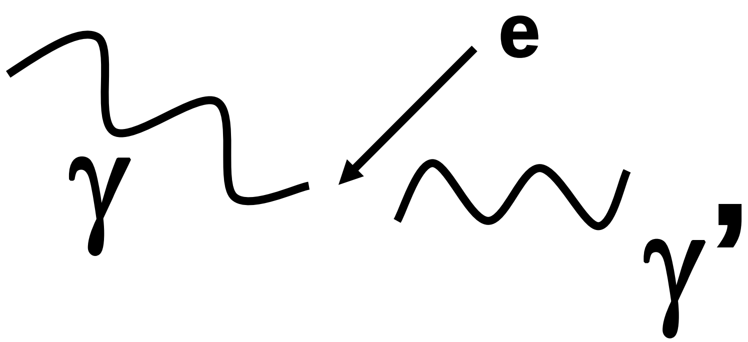
Detection of new supercluster

- 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)

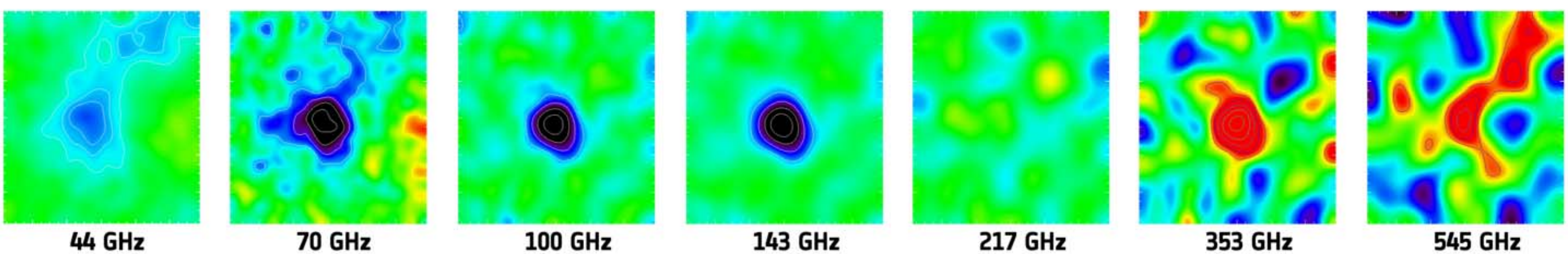


Sunyaev-Zel'dovich effect

- 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

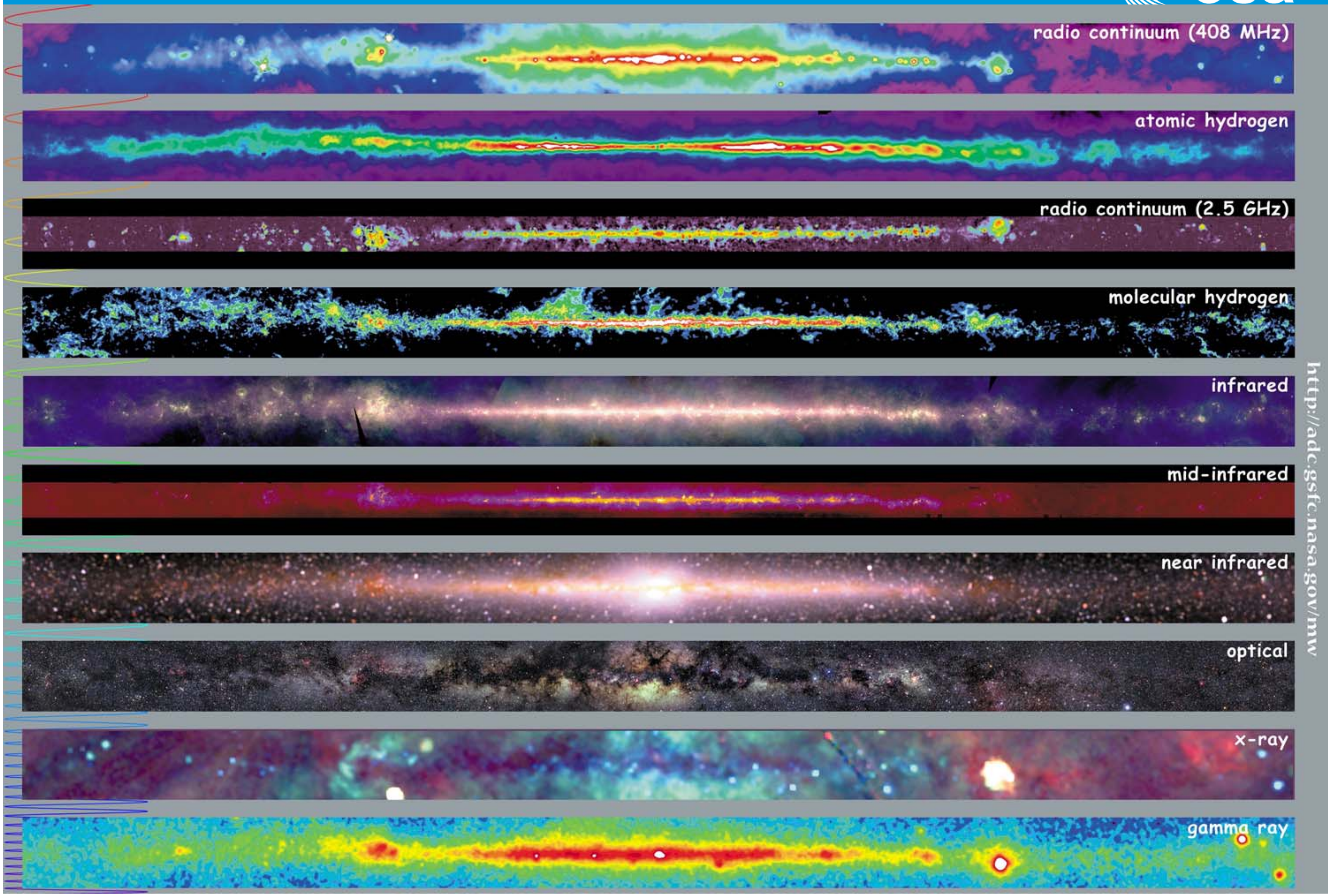


$$E_{\gamma} < E_{\gamma'}$$



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