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# Ricerca astro-nomica/fisica

Lampi di raggi Gamma

Missione Rosetta

SCOPERTA

**Comet 67P/ Churyumov-Gerasimenko**

**Period:** ≈6.5 years

**Jupiter**

**Distance from the Sun:** ≈800 million km

**Comet 1P/Halley**

**Period:** ≈76 years

**Kuiper Belt**

Reservoir of comets and other small bodies

**Distance from the Sun:** between 4.5 and 7.5 billion km

**Comet Siding Spring (C/2013 A1)**

**Estimated period** ≈millions of years

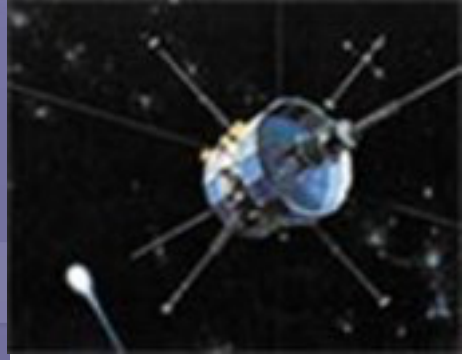
**Oort Cloud**

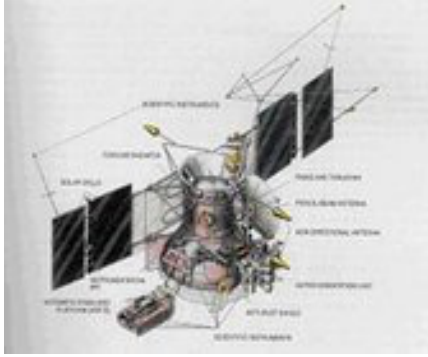
Reservoir of comets and other small bodies

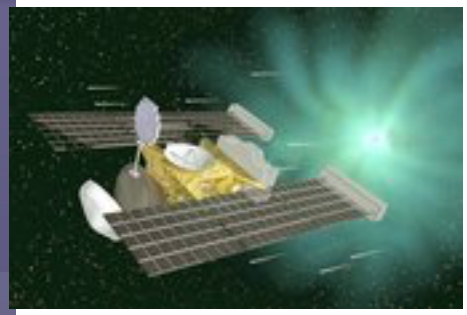
**Distance from the Sun:** trillions of km

The diagrams in this infographic are only representative and not to scale.










La ricerca per la comprensione:

1) Origine $H_20$ ?
2) Ruolo comete sulla nascita della vita sulla Terra ?

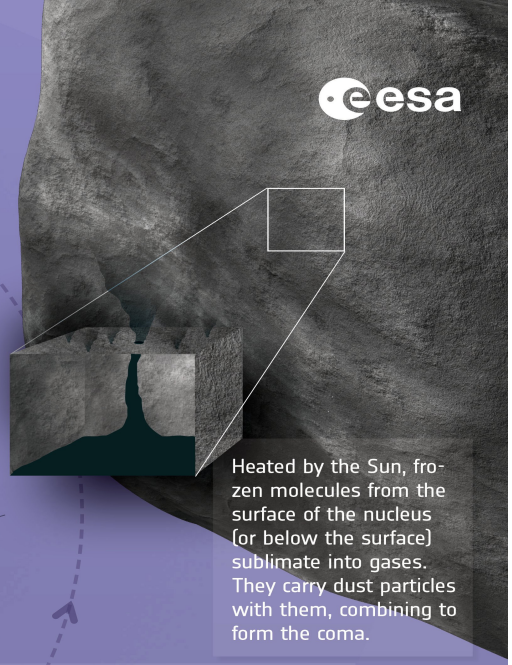
… molte altre …

3) Composizione chimica della cometa
4) Fisica dell'interazione con il vento solare
5) …

**Launch date:** 2 March 2004
Arrival at comet: 6 August 2014
Philae lander delivery: November 2014
Closest approach to Sun: 13 August 2015
**Mission end:** 31 December 2015
**Launch vehicle:** Ariane-5 G+
**Launch mass:** Orbiter: 2900 kg (including 1670 kg Propellant and 165 kg science payload);
Lander (Philae): 100 kg
**Dimensions:** Orbiter: 2.8 x 2.1 x 2.0 m with two 14 metre long solar panels

# → MEET A COMET

esa



Heated by the Sun, frozen molecules from the surface of the nucleus (or below the surface) sublimate into gases. They carry dust particles with them, combining to form the coma.

Radiation

Solar wind

**Bow shock**

The solar wind, which consists of energetic particles streaming away from the Sun, encounters the comet's coma as an obstruction along its path. This creates a shock front.

- **Diameter:** Few km to tens of km
- **Contains:**
  - Frozen molecules, including water ($H_2O$), carbon monoxide (CO), carbon dioxide ($CO_2$), methane ($CH_4$), ammonia ($NH_3$), and other inorganic and organic molecules.
  - -Dust

**Nucleus**

**Coma**

- **Diameter:** up to ≈1 million km
- **Contains:**
  - Water vapour and other gases, including carbon monoxide (CO), carbon dioxide ($CO_2$), hydrogen cyanide (HCN)
  - Dust

**Hydrogen envelope**

- **Length:** up to ≈10 million km
- **Contains:**
  - Hydrogen atoms

**Plasma tail**

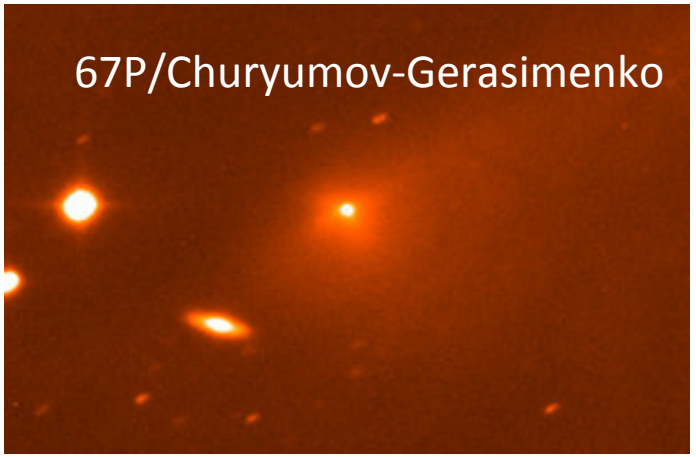
- **Length:** up to ≈100 million km

Energetic particles in the **solar wind** interact with gas molecules in the coma and transform them into ions. The magnetic field of the solar wind pushes these ions into a tail that always points opposite the Sun, in the direction of the solar wind.

**Dust tail**

- **Length:** up to ≈10 million km

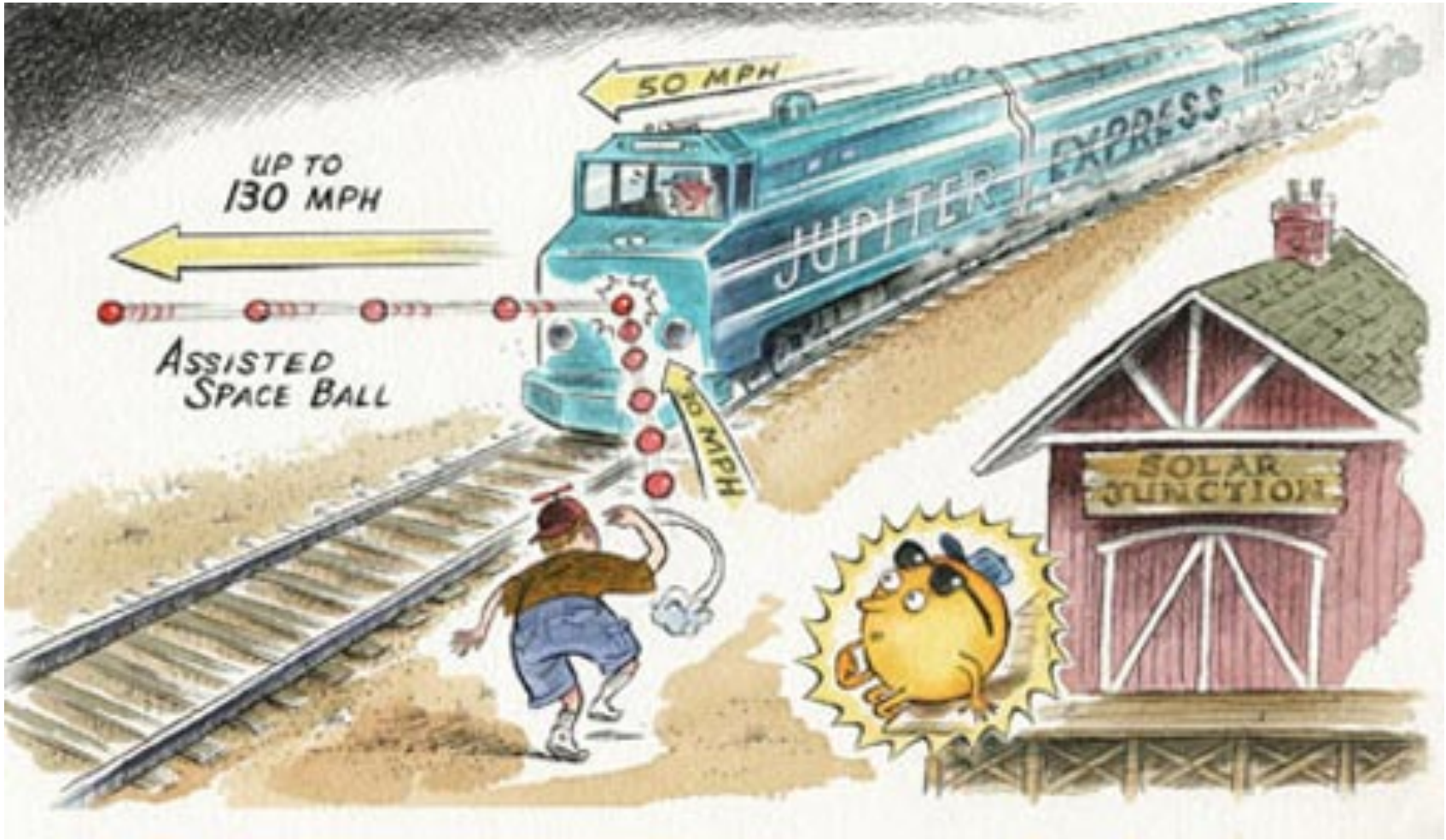
Dust particles are pushed away from the coma by the pressure of solar **radiation**, streaming out to form a broad, curved tail behind the comet's nucleus.



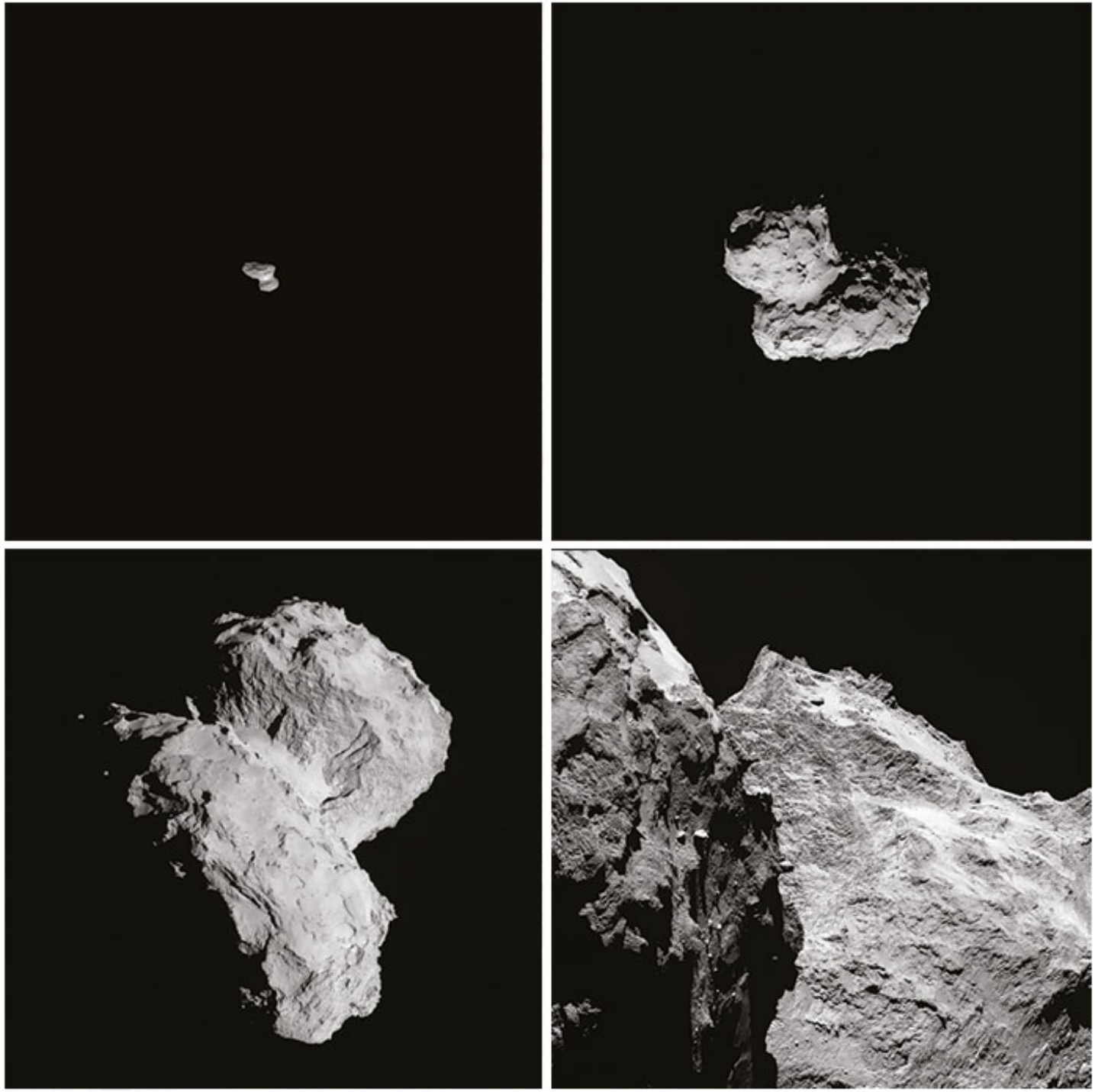

| **Comet 67P/Churyumov-Gerasimenko** | |
|---|---|
| Size of nucleus:<br>Small lobe<br>Large lobe | <br>2.5 km x 2.5 km x 2.0 km<br>4.1 km x 3.2 km x 1.3 km |
| Mass | 1013 kg |
| Volume | 25 km3 |
| Density | 0.4 g/cm3 |
| Rotation period | 12.4043 ± 0.0007 * hours |
| Spin axis | Right ascension: 69 degrees<br>Declination: 64 degrees |
| Orbital period | 6.55 years |
| Perihelion distance from Sun | 186 million km (1.243 AU) |
| Aphelion distance from Sun | 849.7 million km (5.68 AU) |
| Orbital eccentricity | 0.640 |
| Orbital inclination | 7.04 degrees |
| Water vapour production rate | 300 ml/s (June 2014)<br>1-5 l/s (July-August 2014) |
| Surface temperature | 2-5-230 K (July - August 2014) |
| Subsurface temperature | 30-160 K (August 2014) |
| Gases detected | water, carbon monoxide, carbon dioxide, ammonia, methane, methanol, sodium, magnesium |
| Dust grains | A few tens of microns to a few hundreds of microns |
| Year of discovery | 1969 |
| Discoverers | Klim Churyumov &<br>Svetlana Gerasimenko |

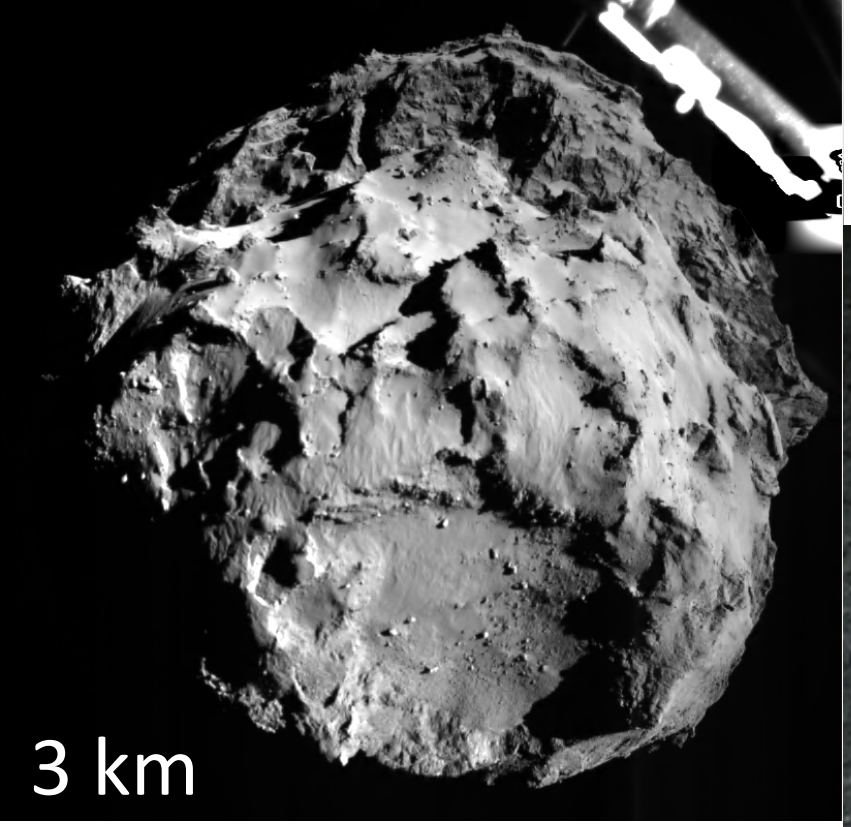
* *Reference: Mottola, S. et al. [2014]*

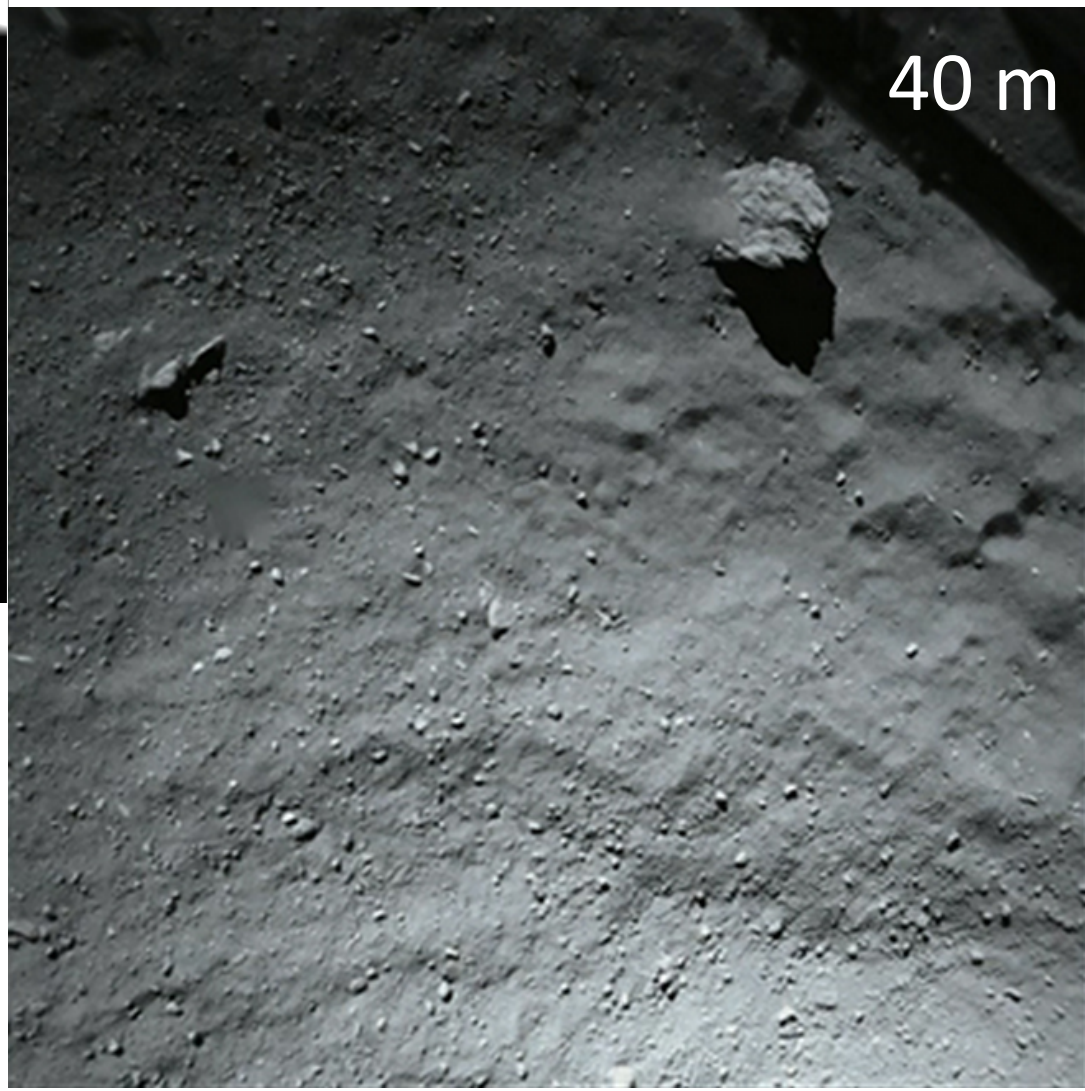
# Fionda gravitazionale




$V_f = V_i + 2U_T$ (e.g. =230 MPH)

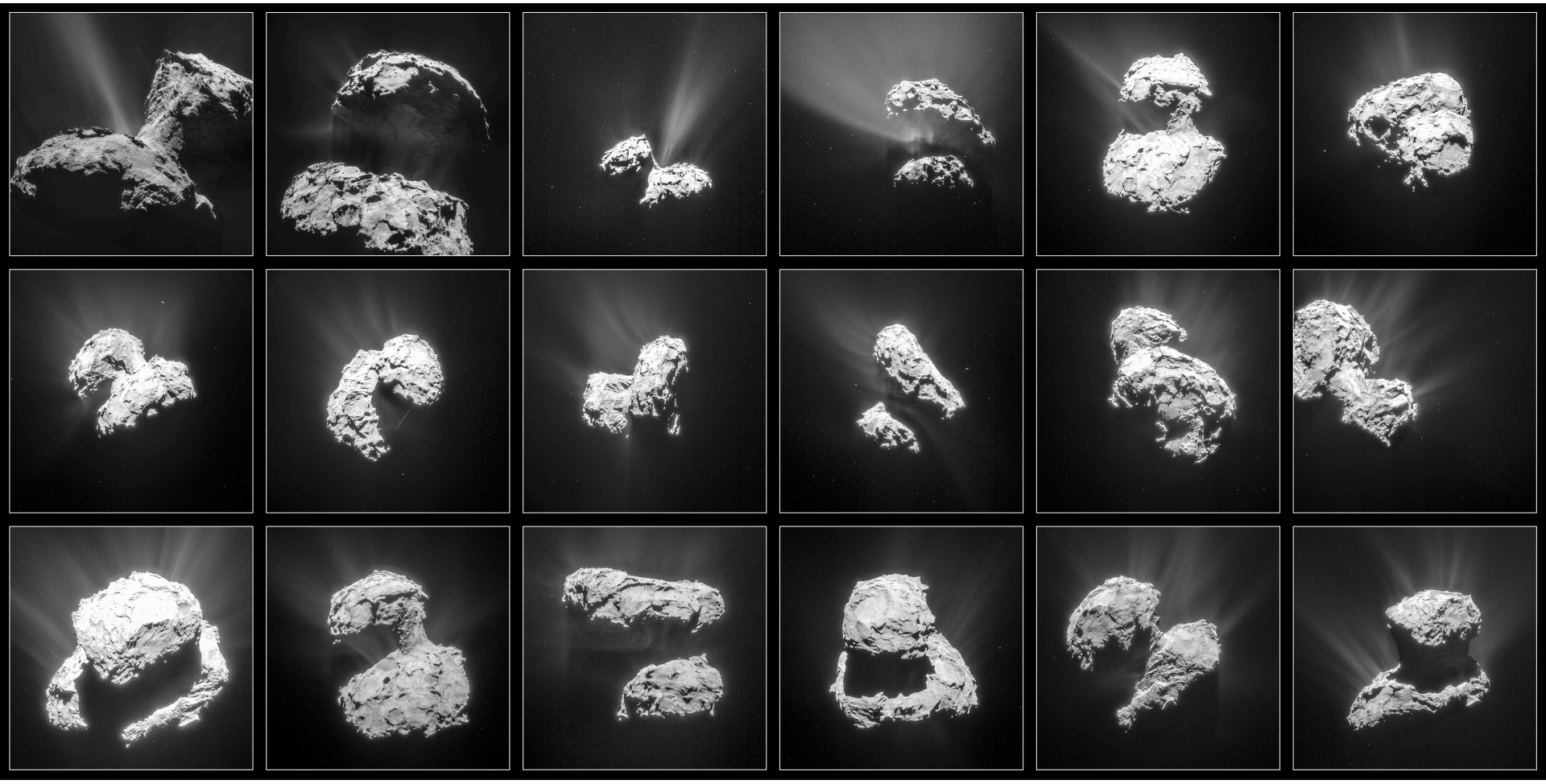




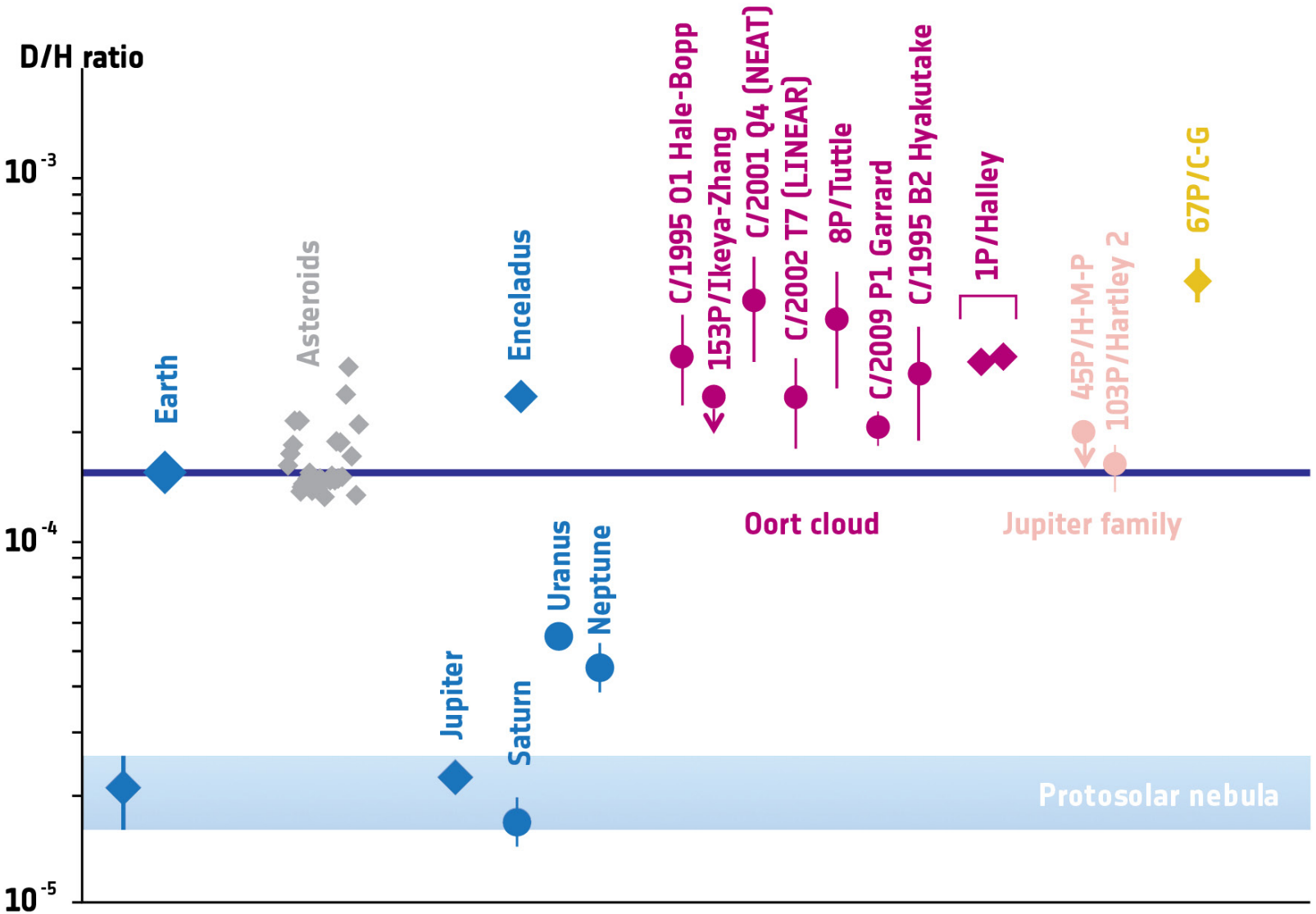




Philae

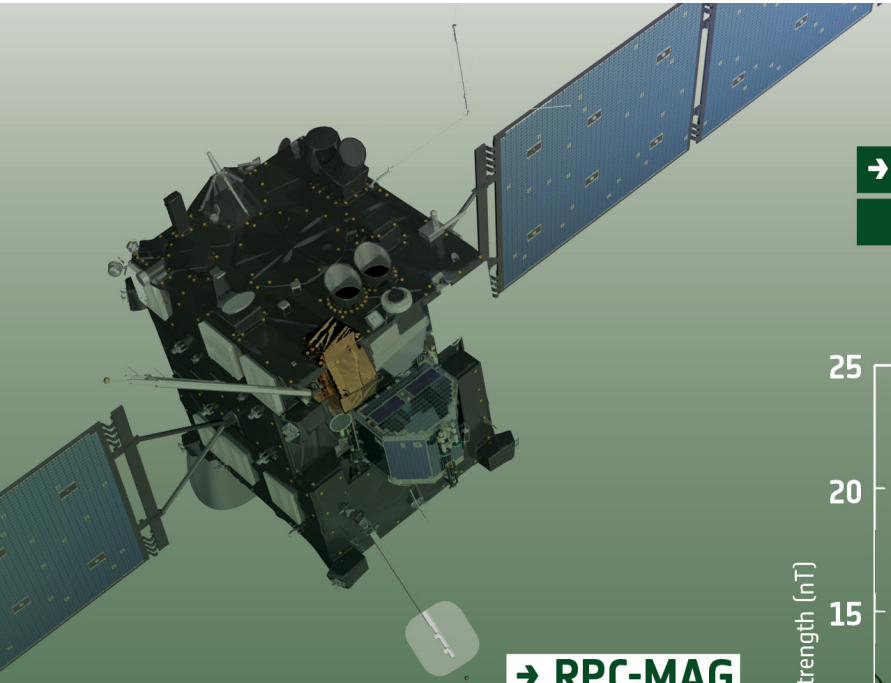
# 31 Gennaio – 25 Marzo 2015



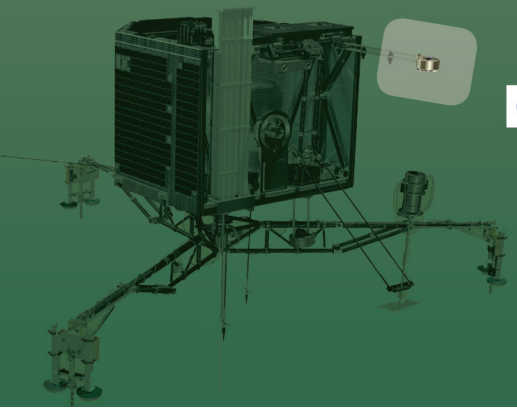
# Risultati (I): Le sorprese del Deuterio (D)



# Risultati (II): il campo magnetico non c'e'!

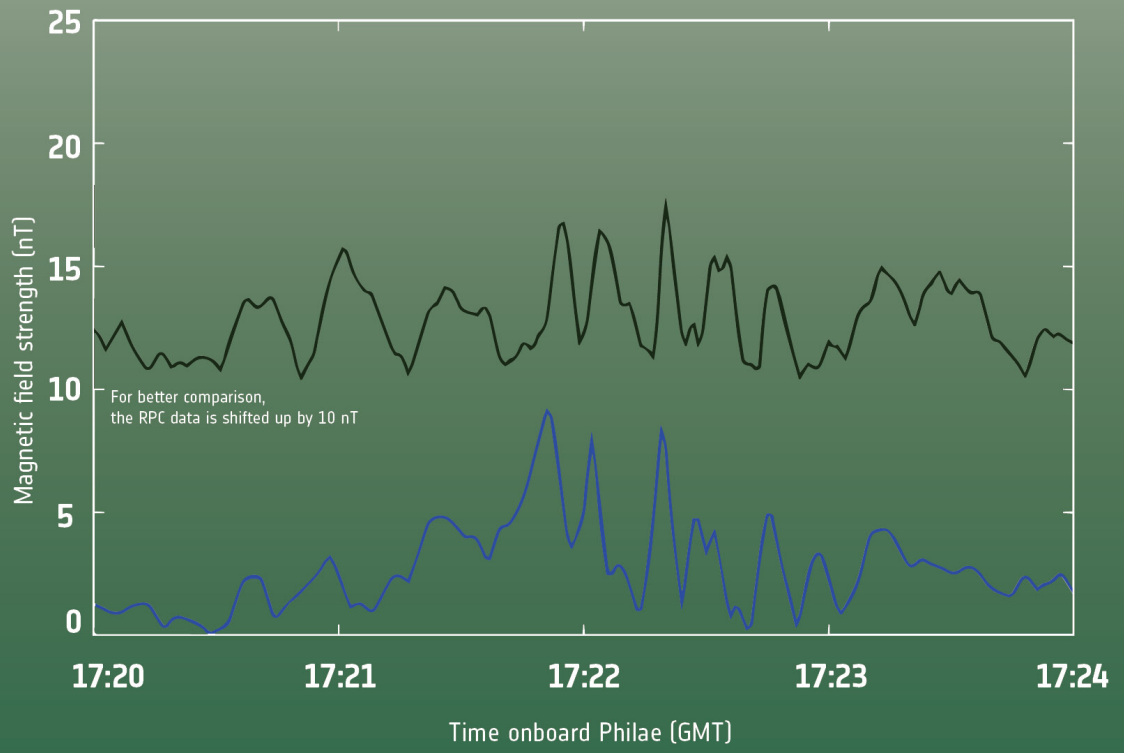


→ RPC-MAG



→ ROMAP

→ MAGNETIC FIELD MEASUREMENTS BY ROSETTA AND PHILAE JUST BEFORE SECOND TOUCHDOWN




Spacecraft : ESA/ATG medialab; Data from Auster et al (2015)

L'Orizzonte degli Eventi

## SCIENZIATI SENZA SCARPE
(ma guidati dalla curiosità)

Tommaso Maccacaro
Istituto Nazionale di Astrofisica, Milano

SERENDIPITY – Le stelle n. 112, Novembre 2012

Mi capita spesso durante un viaggio, vuoi in treno, vuoi in aereo, di scambiare due chiacchiere con chi mi sta seduto vicino. Inevitabilmente a un certo punto arriva la domanda: "E lei che lavoro fa?". Ho due possibili risposte. Se la conversazione è gradevole e mi fa piacere continuarla, rispondo che sono un astronomo; se invece interlocutori non occasionali come le persone incontrate casualmente in viaggio, dell'importanza della ricerca di base, o ricerca fondamentale, e mi rendo conto di come essa sia comunemente percepita come un'attività totalmente astratta, che non produce ritorni di utilità pratica, ma semplicemente soddisfa chi la fa. Ed è forse per questo che ho un rapporto della rete di distribuzione che ancora non esisteva. Ma questo è quanto è scaturito dalle loro ricerche. Senza quegli studi apparentemente astratti non avremmo l'energia elettrica (e tutto quanto ne consegue).
Cambiando campo della fisica, possiamo renderci conto che sono innumerevoli anche le applicazioni derivate dallo stu-

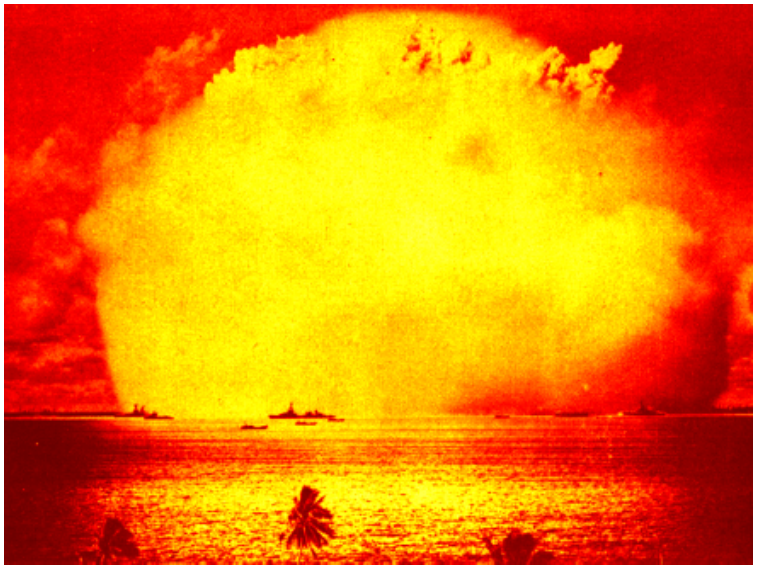
nomica/fisica

Lampi di raggi Gamma

SCOPERTA

Missione Rosetta

# History of a discovery (serendipity)



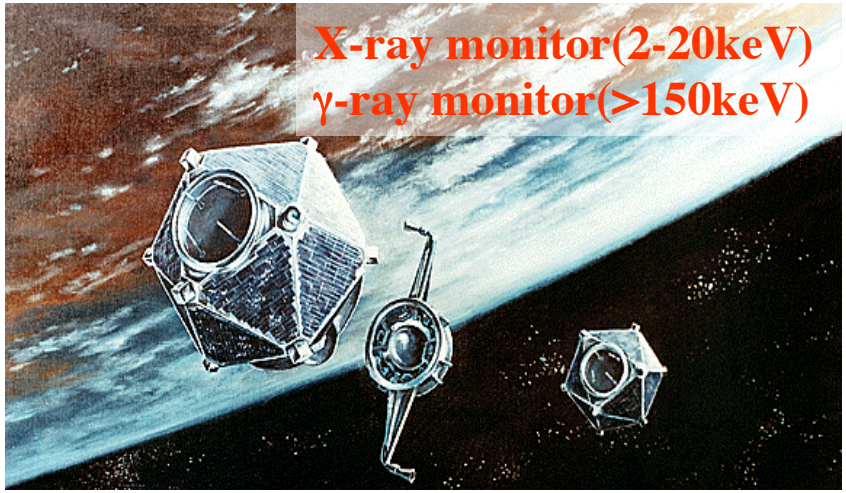

- **1954, India made the first proposal calling for an agreement to ban nuclear weapons tests.**
- **1958, the United States, the Soviet Union, and the United Kingdom began a Conference on the Discontinuance of Nuclear Tests in Geneva**
- **5 August 1963, the Partial Test Ban Treaty (PTBT) was signed in Moscow**

  " … prohibit, prevent, and abstain from carrying out nuclear weapons tests or any other nuclear explosions in the atmosphere, in outer space, under water, or in any other environment if such explosions cause radioactive debris to be present outside the territorial limits of the State that conducts an explosion."

**Verification and Compliance:** The PTBT does not provide for international verification; however, it is understood that each party may do so by its own national technical means.

US start a secret military space program to verify the compliance of the treaty

VELA (1963-65 … 1968, 1969-70)

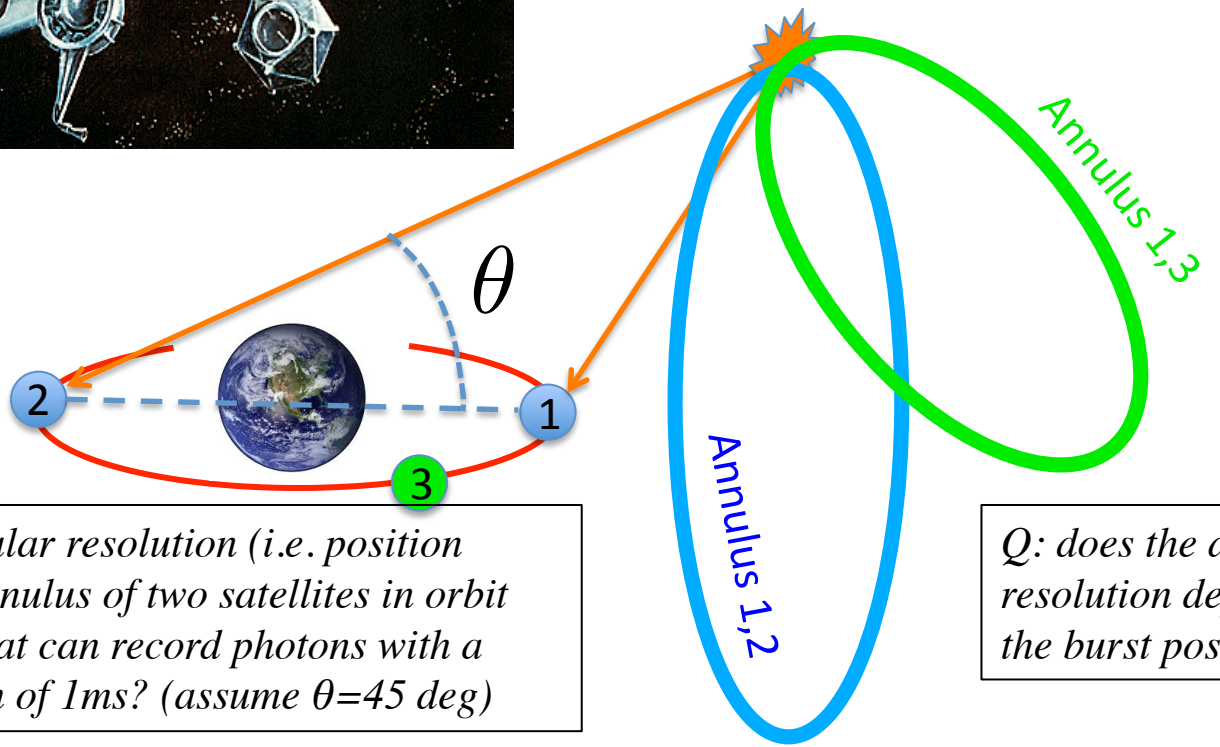



$$\delta t = t_2 - t_1 = \frac{D_{1,2} \cdot \cos\theta}{c}$$

$$\cos\theta = \frac{\delta t\, c}{D_{1,2}}$$

The solution corresponds to an annulus (1,2) whose width is determined by the temporal resolution of the satellites and their separation.

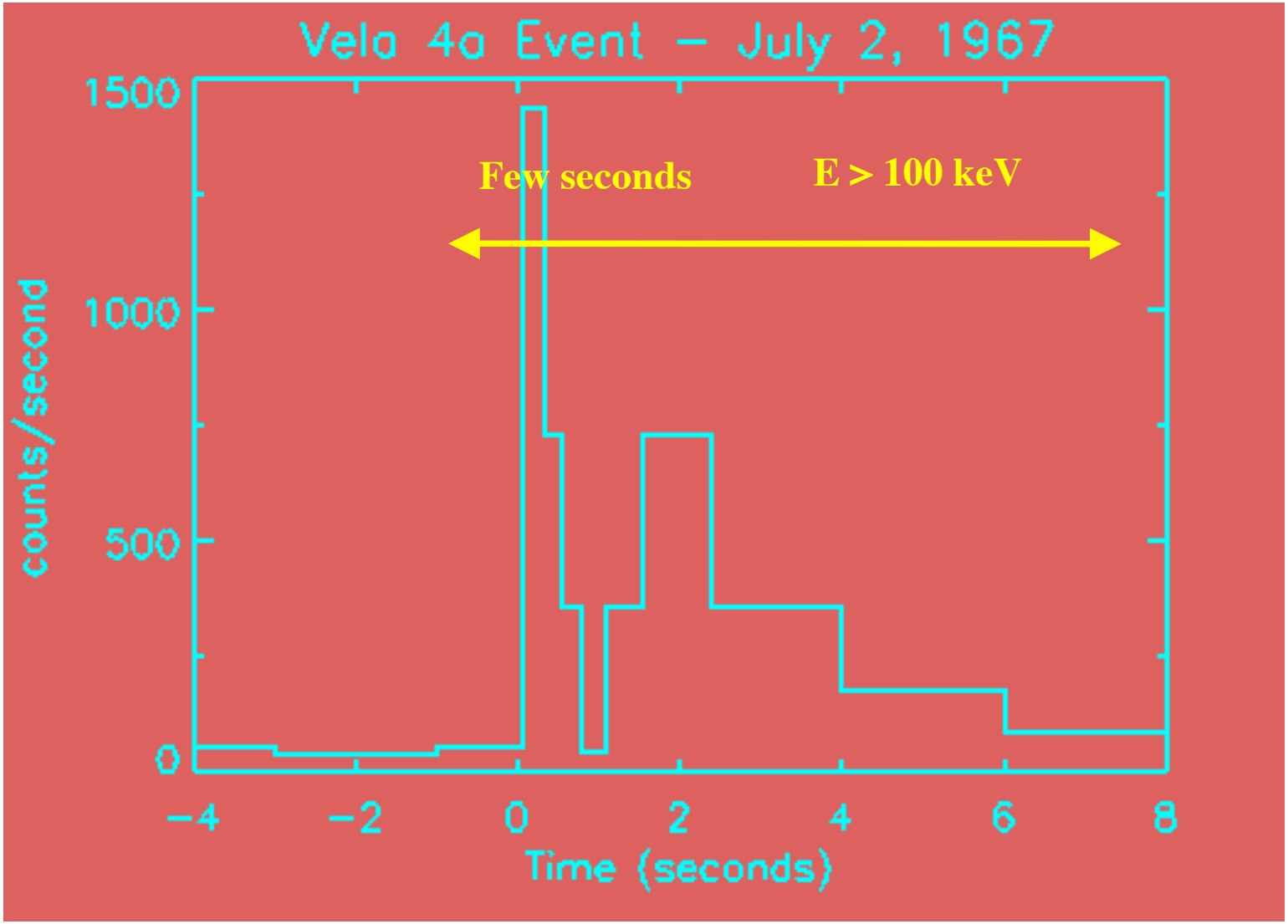
With the addition of more satellites (now IPN) the degeneracy in ϕ is reduced




*Q: what is the angular resolution (i.e. position accuracy) of the annulus of two satellites in orbit (separated by π) that can record photons with a temporal resolution of 1ms? (assume θ=45 deg)*

*Q: does the angular resolution depends on the burst position?*

# GRB 670702


Velo 4a Event – July 2, 1967
1500
1000
500
0
counts/second
Few seconds
E > 100 keV
−4
−2
0
2
4
6
8
Time (seconds)

THE ASTROPHYSICAL JOURNAL, **182**:L85–L88, 1973 June 1


# OBSERVATIONS OF GAMMA-RAY BURSTS OF COSMIC ORIGIN

RAY W. KLEBESADEL, IAN B. STRONG, AND ROY A. OLSON

University of California, Los Alamos Scientific Laboratory, Los Alamos, New Mexico
*Received 1973 March 16; revised 1973 April 2*

## ABSTRACT

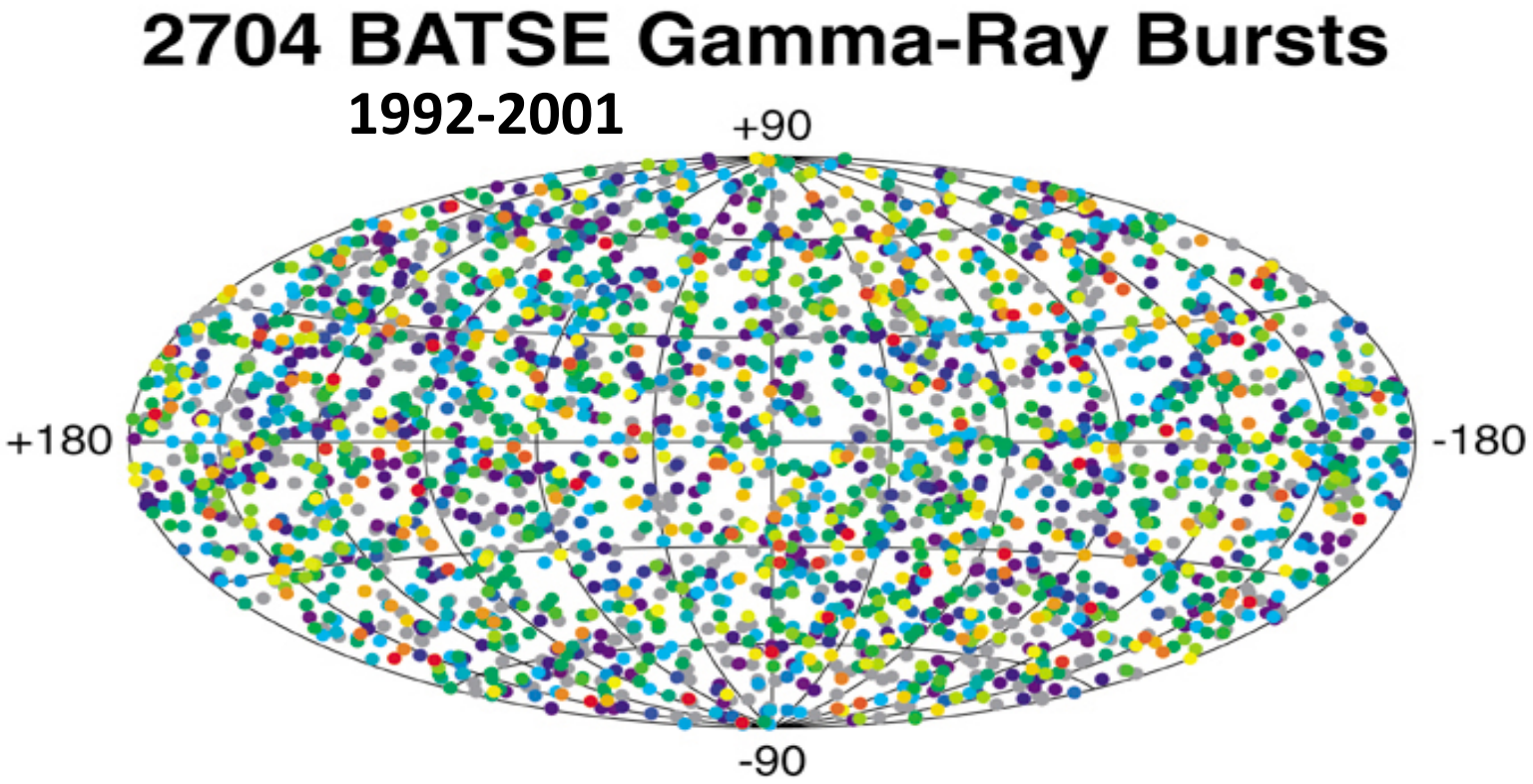
Sixteen short bursts of photons in the energy range 0.2–1.5 MeV have been observed between 1969 July and 1972 July using widely separated spacecraft. Burst durations ranged from less than 0.1 s to ~30 s, and time-integrated flux densities from $\sim 10^{-5}$ ergs cm$^{-2}$ to $\sim 2 \times 10^{-4}$ ergs cm$^{-2}$ in the energy range given. Significant time structure within bursts was observed. Directional information eliminates the Earth and Sun as sources.

*Subject headings:* gamma rays — X-rays — variable stars

## I. INTRODUCTION

On several occasions in the past we have searched the records of data from early *Vela* spacecraft for indications of gamma-ray fluxes near the times of appearance of supernovae. These searches proved uniformly fruitless. Specific predictions of gamma-ray emission during the initial stages of the development of supernovae have since been made by Colgate (1968). Also, more recent Vela spacecraft are equipped with much improved instrumentation. This encouraged a more general search, not restricted to specific time periods. The search covered data acquired with almost continuous coverage between 1969 July and 1972 July, yielding records of 16 gamma-ray bursts distributed throughout that period. Search criteria and some characteristics of the bursts are given below.

# From Vela (1960) to CGRO (1992)

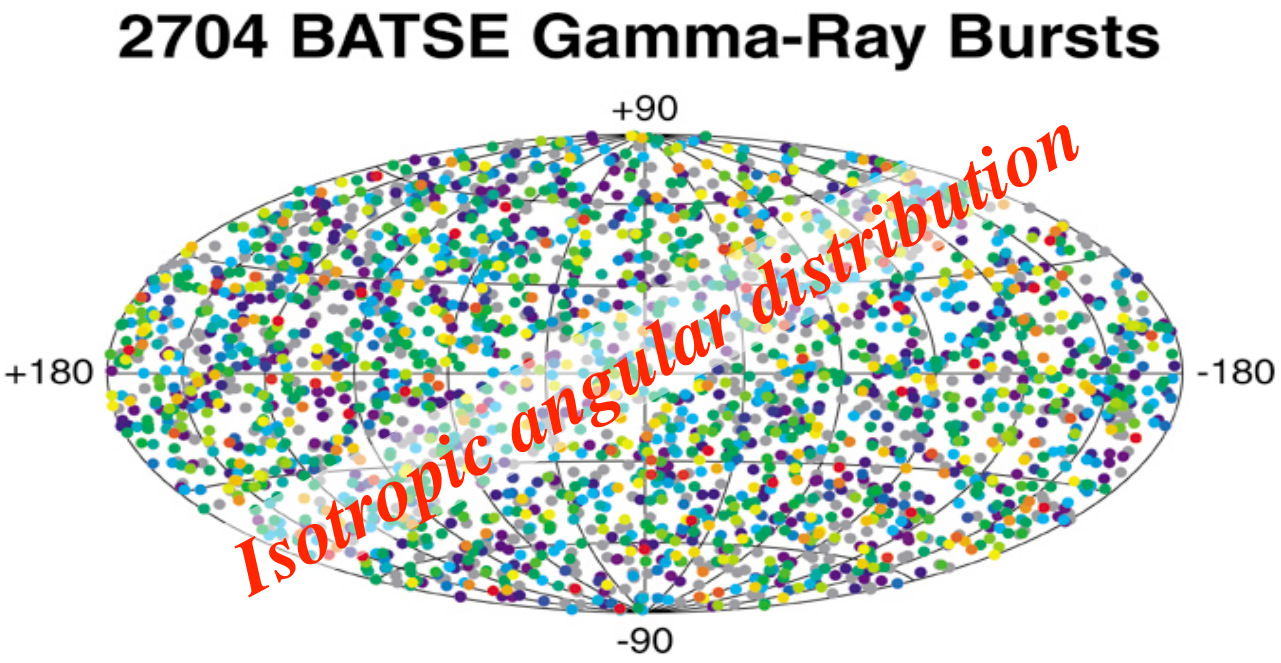



Burst And Transient Source Experiment (BATSE) on board the Compton Gamma Ray Observatory (CGRO) detects thousands of GRBs.

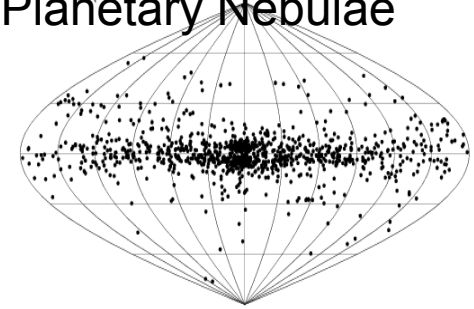
The sky distribution (here in galactic coordinates) is ISOTROPIC (independent of the burst intensity – colors)

*Q: What was the detection rate of GRBs by BATSE?*

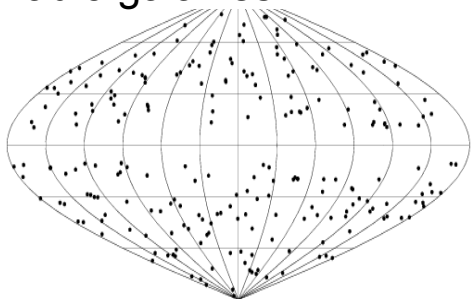
# Compare with what we know



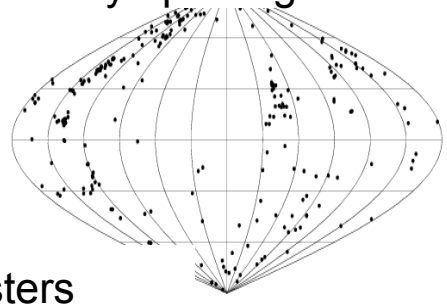

Planetary Nebulae



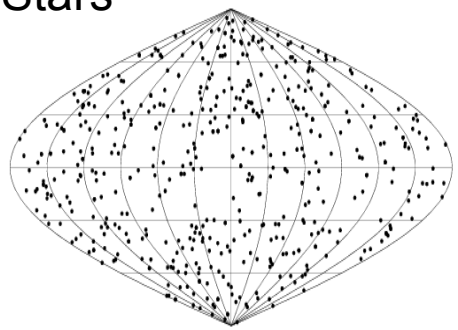
Radio galaxies



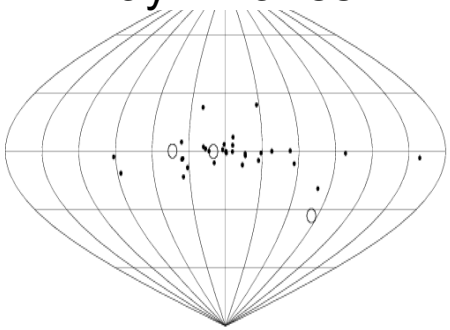
Nearby optical galaxies



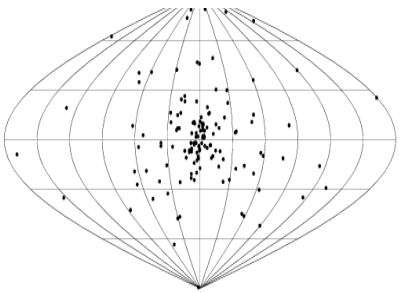
Stars



X ray Binaries

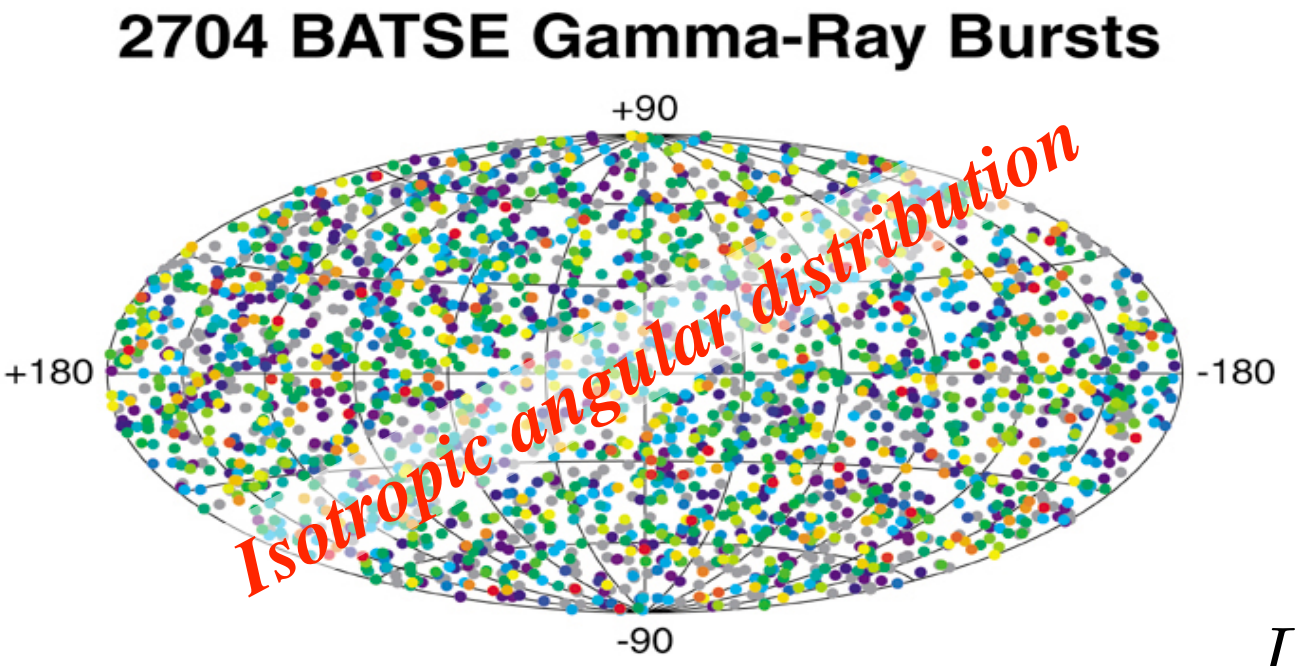


Globular clsters

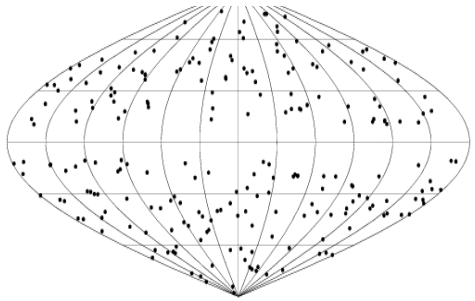


Galactic or Cosmological ?

# Compare with what we know

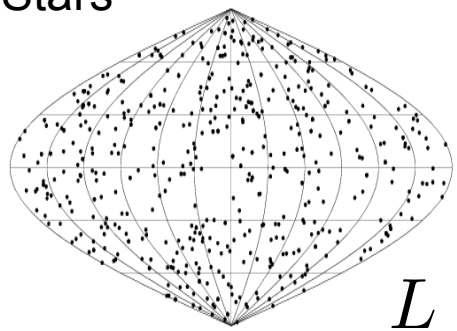



Galaxies



$$L = 10^{52}\ \mathrm{erg\,s^{-1}}$$

Stars

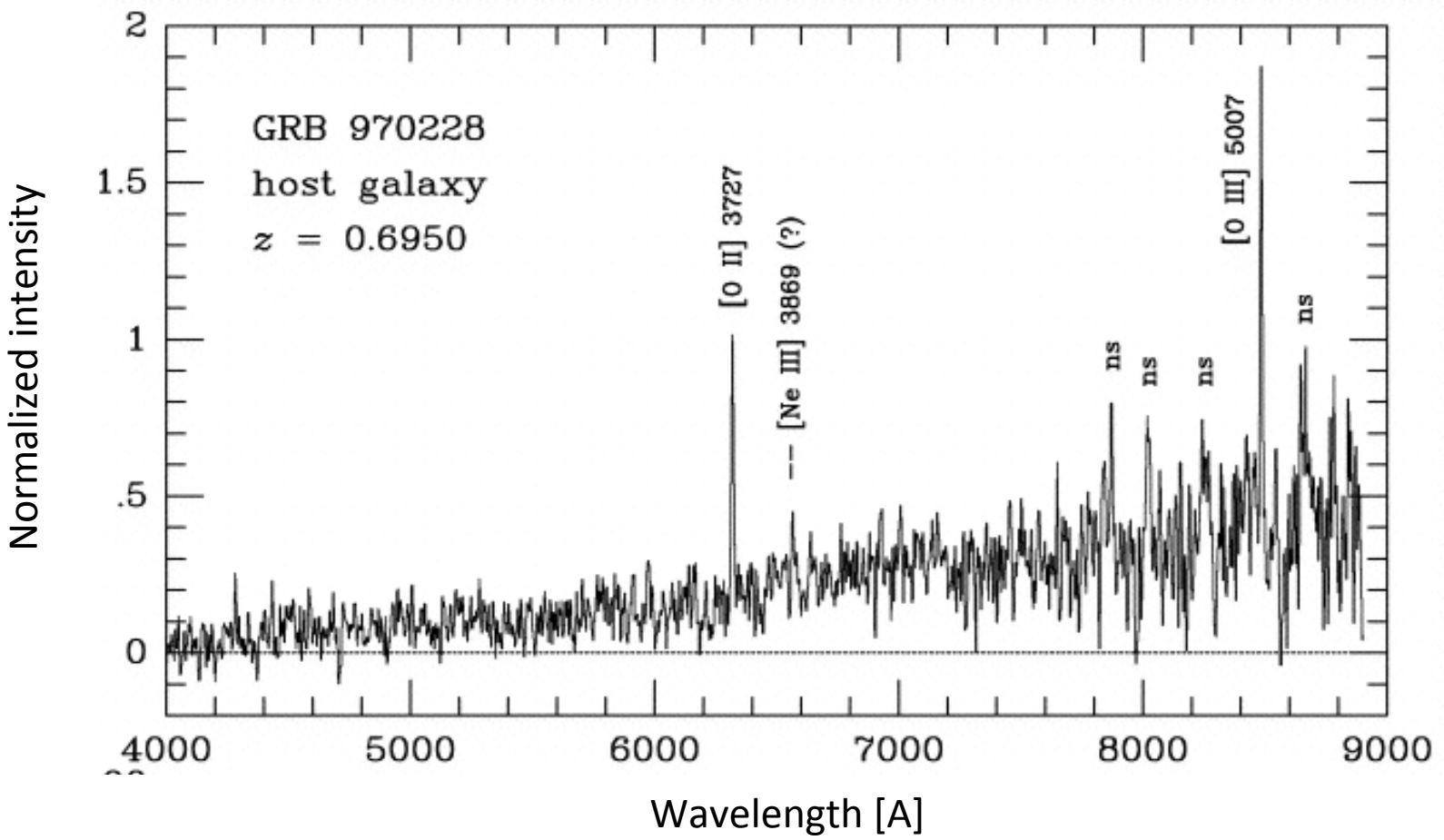


$$F = 10^{-5}\ \mathrm{erg\,cm^{-2}\,s^{-1}}$$

$$L = 2.5 \times 10^{41}\ \mathrm{erg\,s^{-1}}$$

Galactic or Cosmological ?

# > 1997 … measuring the distance of GRBs

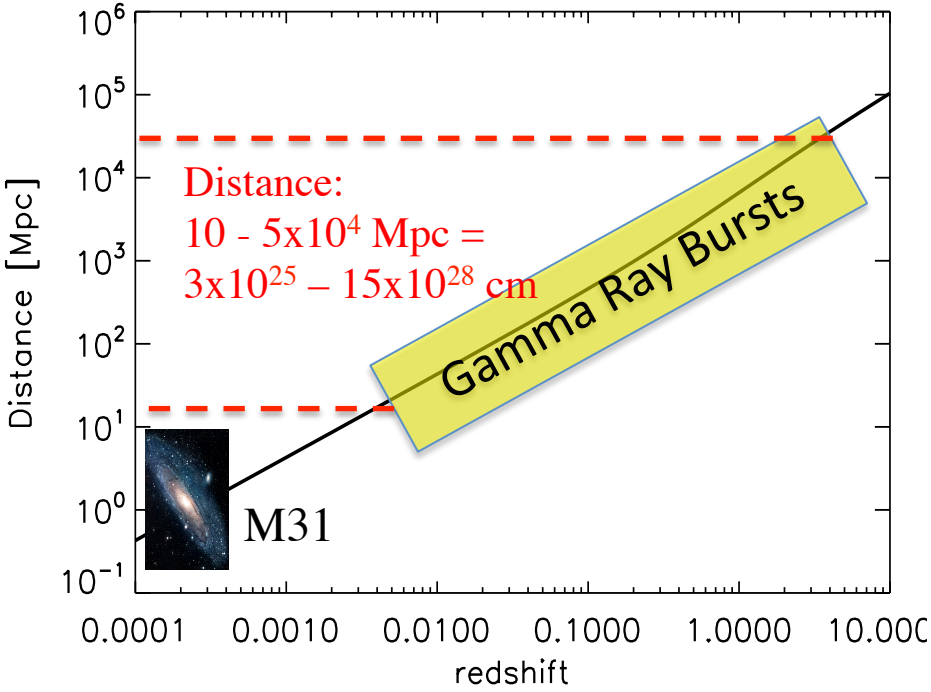


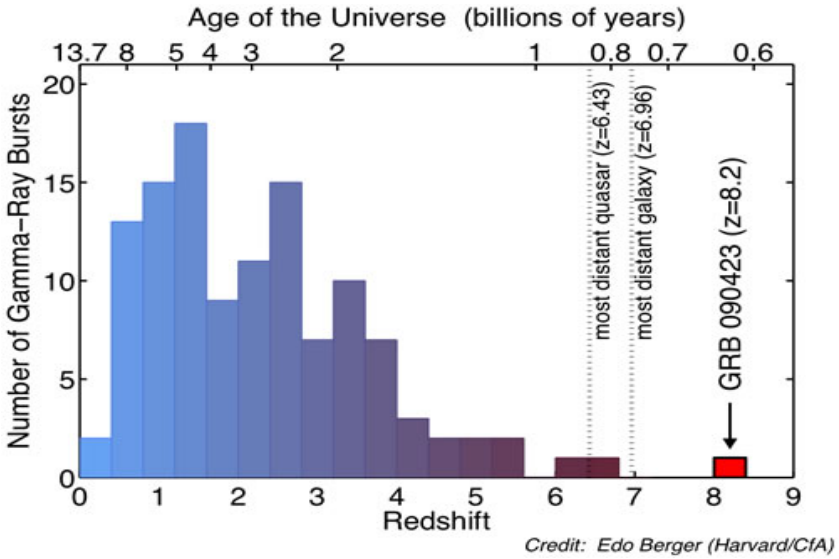

# Redshift: $z = \Delta\lambda/\lambda$

(Next year cosmology courses)

# Redshift → distance

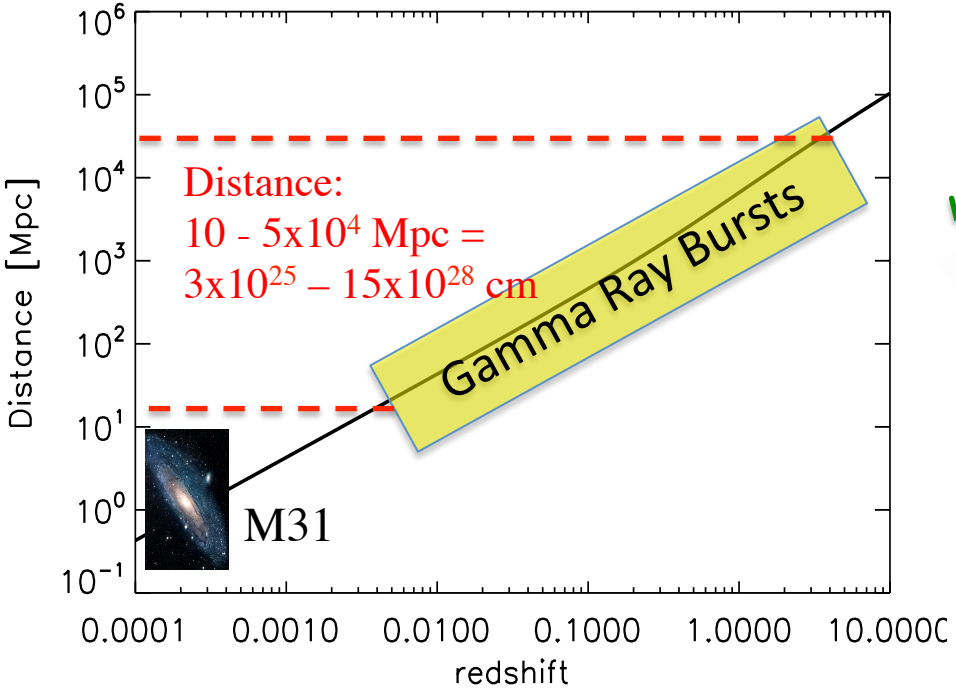
(next year cosmology courses)

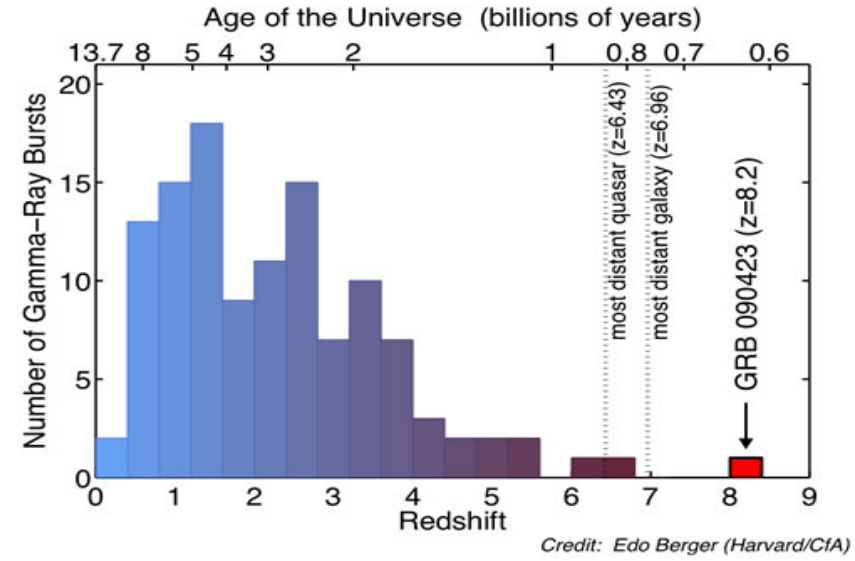


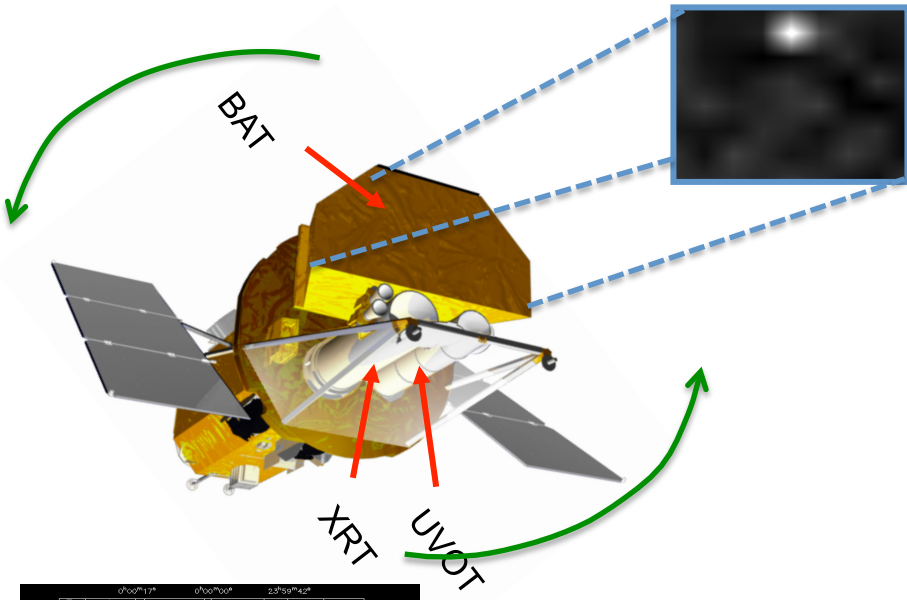
# Redshift → distance

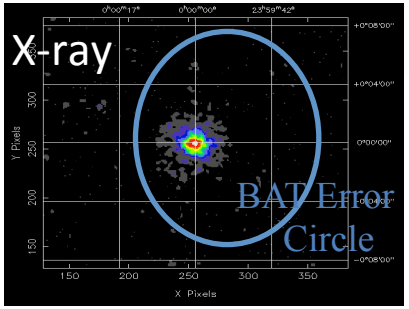
(next year cosmology courses)



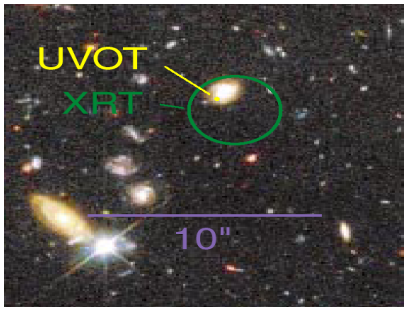




Starting in 2004 the Swift satellite allowed us to measure several redshifts (>200 today).




Swift repoints in less than 1 minute the small field of view instruments (X-ray and Optical telescope) to the position of the GRB detected by BAT




Subsequent images (separated by few minutes) identifies the transient with an accuracy of few arcseconds.

Ground-based telescopes → redshift

http://swift.gsfc.nasa.gov/docs/swift/swiftsc.html

# How much energy?

Consider a typical GRB detected by current flying instruments with a flux of $F=10^{-6}$ erg cm$^{-2}$ s$^{-1}$ with a duration of 30 s ($\gamma$-ray emission)

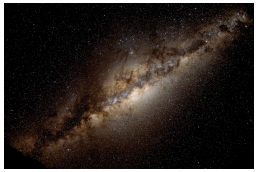
The energy of the source is: $$E = 4\pi D^2 F \cdot \frac{T}{1+z}$$

Assuming a "close by" GRB at $z_{min}$=0.01 (D = 43 Mpc – for a standard cosmology … next year) and a "distant" GRB at $z_{max}$=8 (D = 80487 Mpc) the minimum and maximum energies are:

$$E_{\odot,10^6 yr} = 10^{47}\mathrm{erg}$$

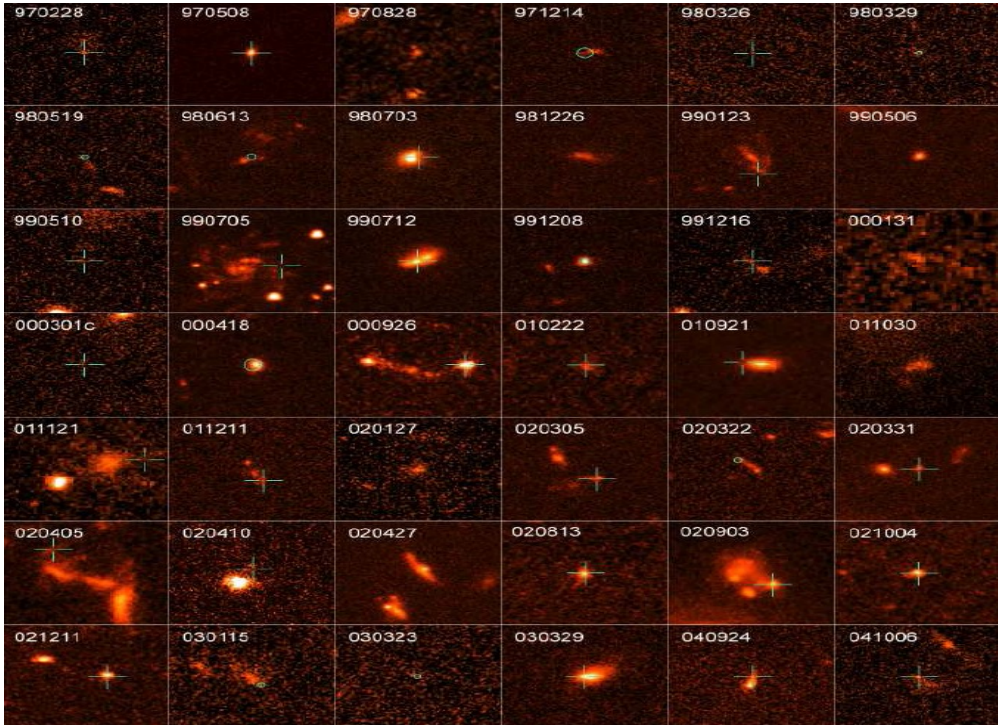
$$E_{\mathrm{min}} = 6.6 \times 10^{48}\ \mathrm{erg}$$

$$E_{MW,1yr} = 10^{51}\mathrm{erg}$$



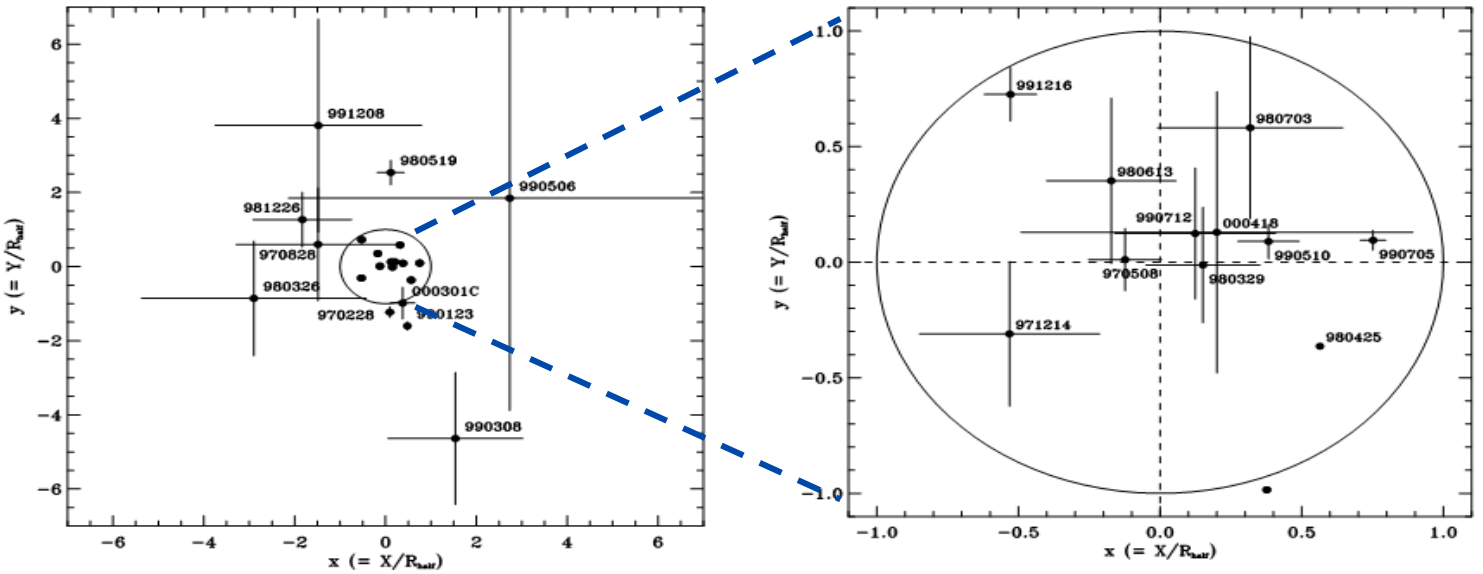
$$E_{\mathrm{max}} = 2.6 \times 10^{54}\ \mathrm{erg}$$

*Q: what is the equivalent mass?*



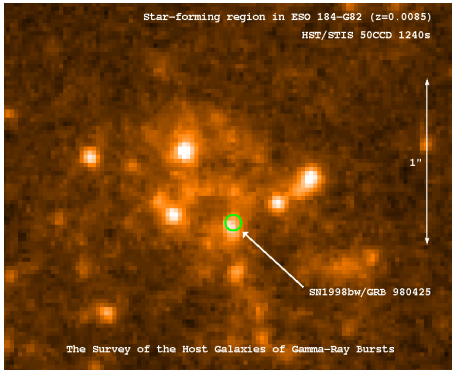

# Where are GRBs?

- They are found in galaxies ("hosts") with relatively normal star formation and different morphologies (from Irr to S)
- They trace the central regions or the star forming regions within their galaxies

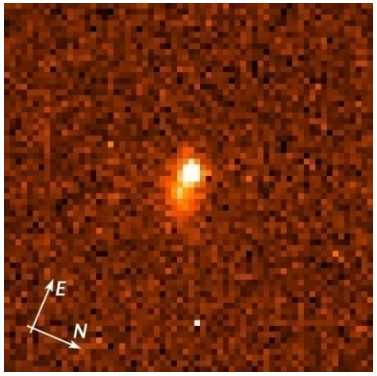


# GRBs (long duration) are associated with SN events

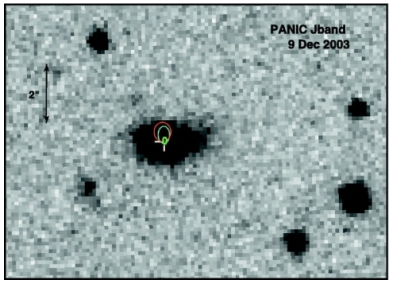
GRB 980425 (40 Mpc)



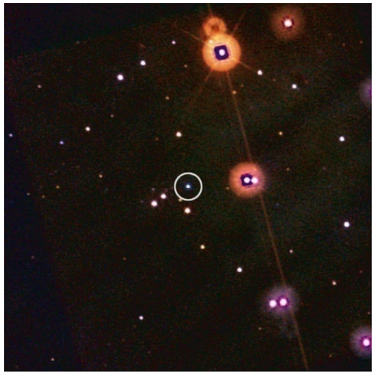

GRB 030329 (818 Mpc)




GRB 031203 (460 Mpc)




GRB 060218 (150 Mpc)

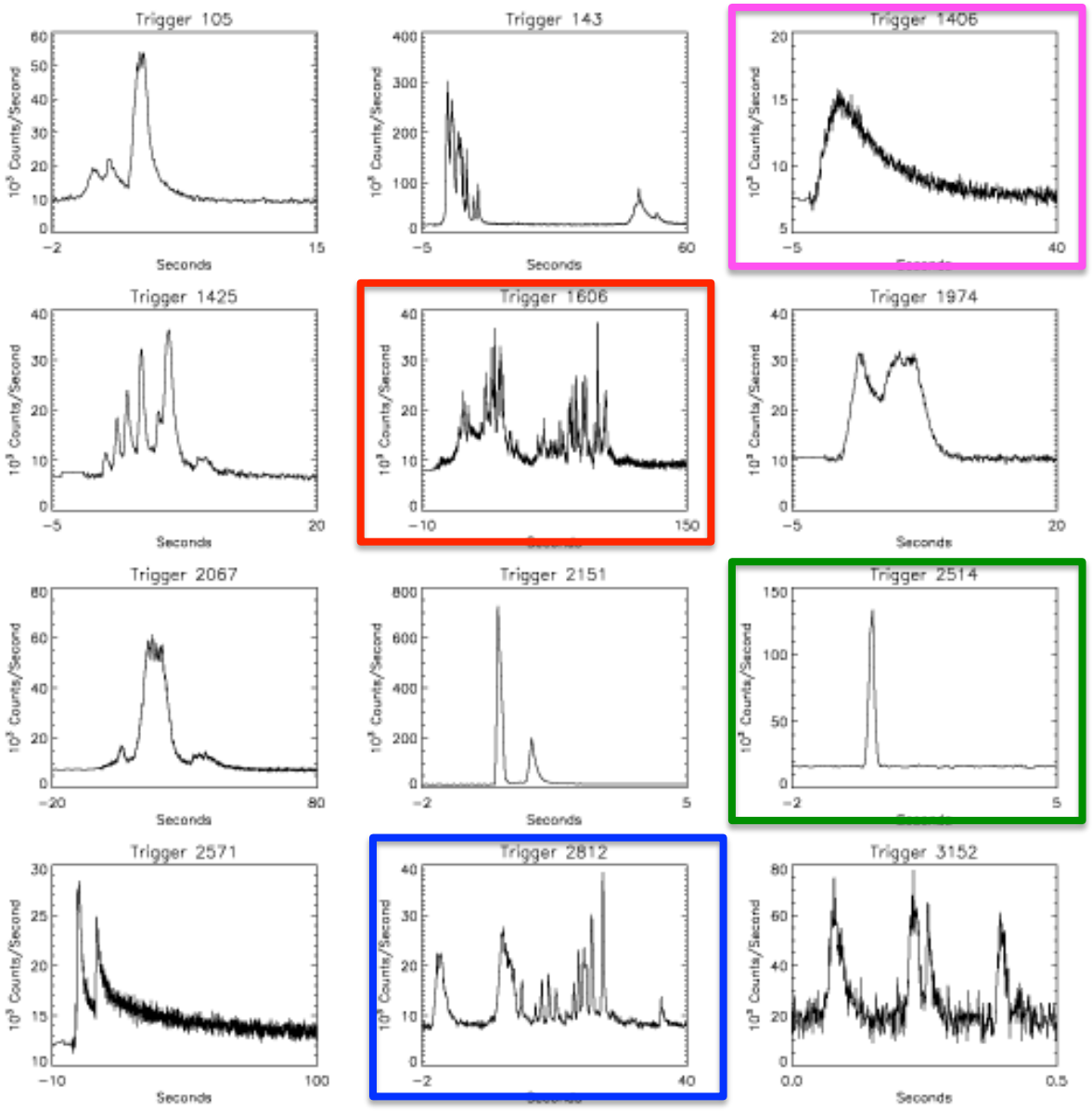


(Galama et al. 1998, Matheson et al. 2003, Malesani et al. 2004, Pian et al. 2006 … etc etc )

- Out of thousands of GRBs detected by satellites, only a dozen have been associated with SNe. [*Q: why?*]

- The SN associated with GRBs are extremely energetic: $V_{ej}$=30.000 km/s ~ 10-100 $V_{ej,II}$

# Temporal properties




What can you see ?

They appear different one from the other

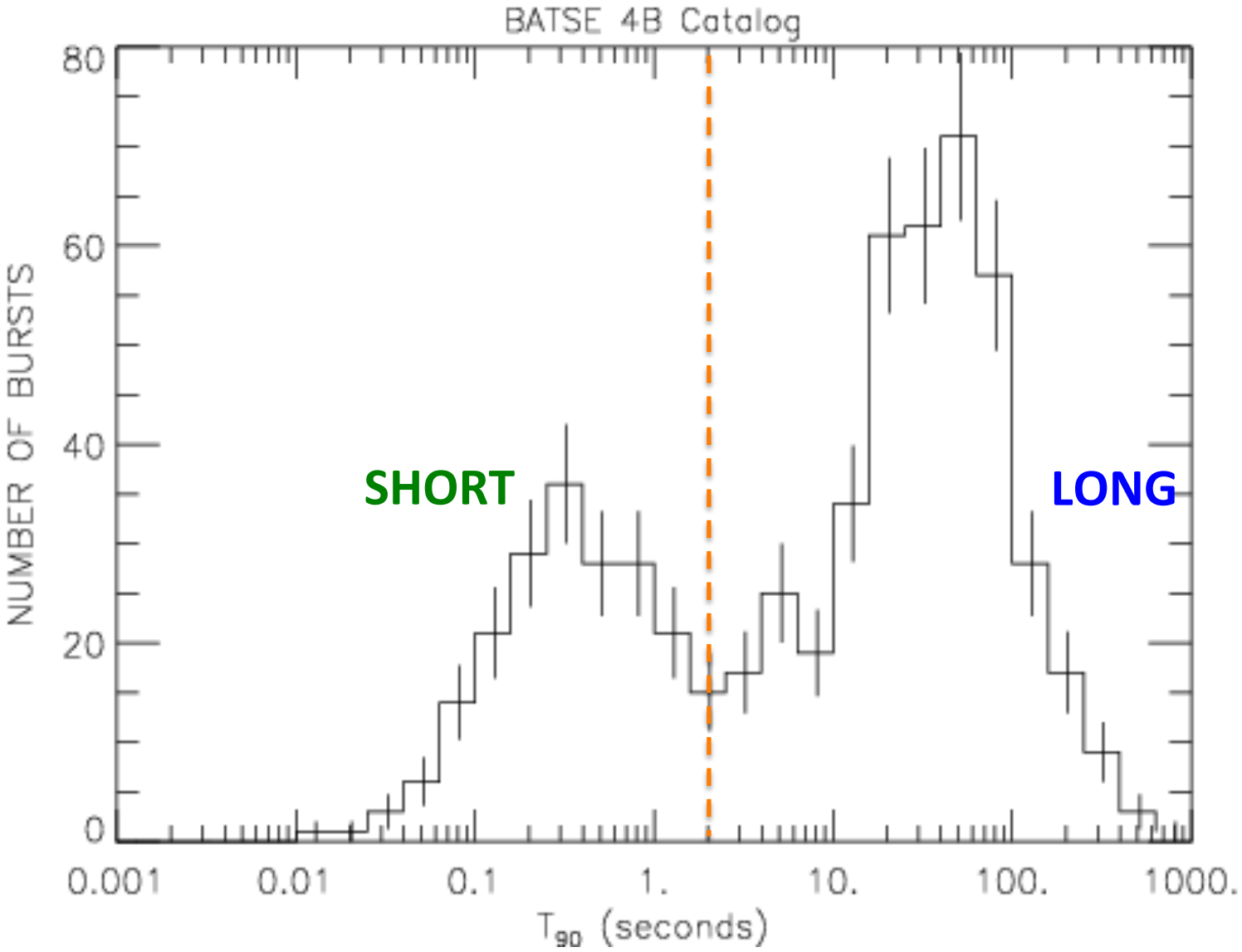
There are short and long events

There are smooth and highly variable events

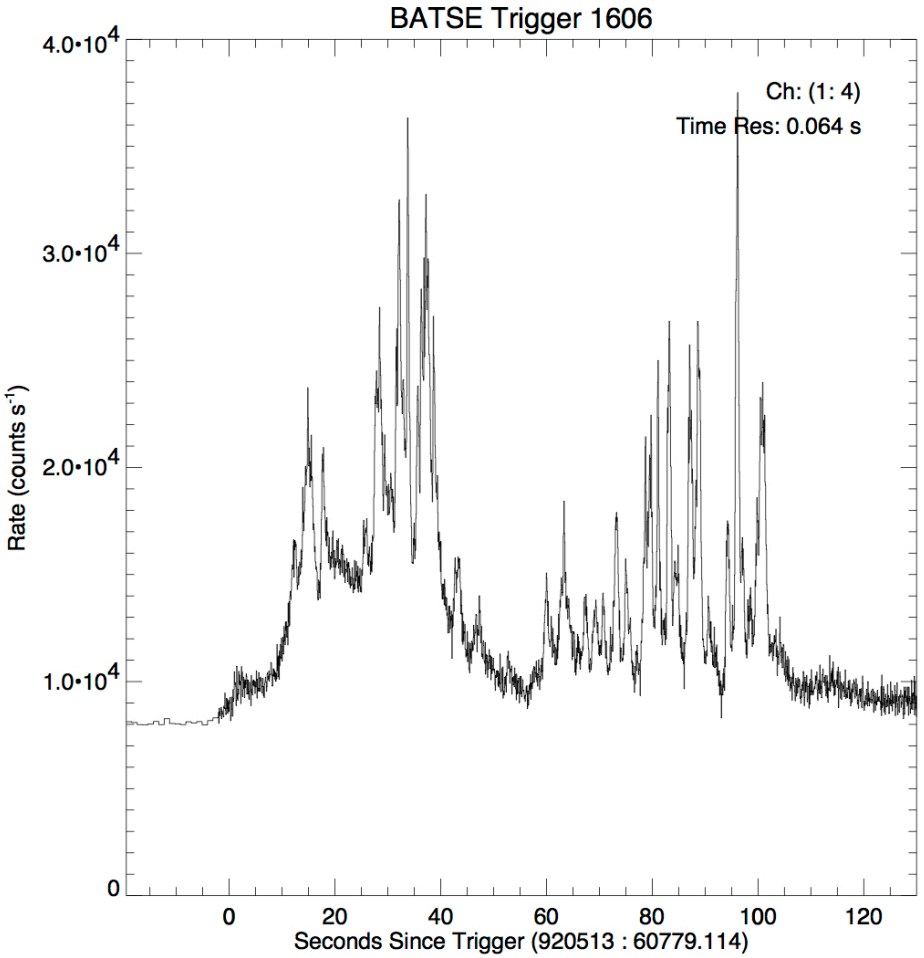
Duration

Variability

# Duration


BATSE 4B Catalog
NUMBER OF BURSTS
80
60
40
20
0
SHORT
LONG
0.001
0.01
0.1
1.
10.
100.
1000.
$T_{90}$ (seconds)

# Variability




*Q: How large is the source where radiation is produced?*

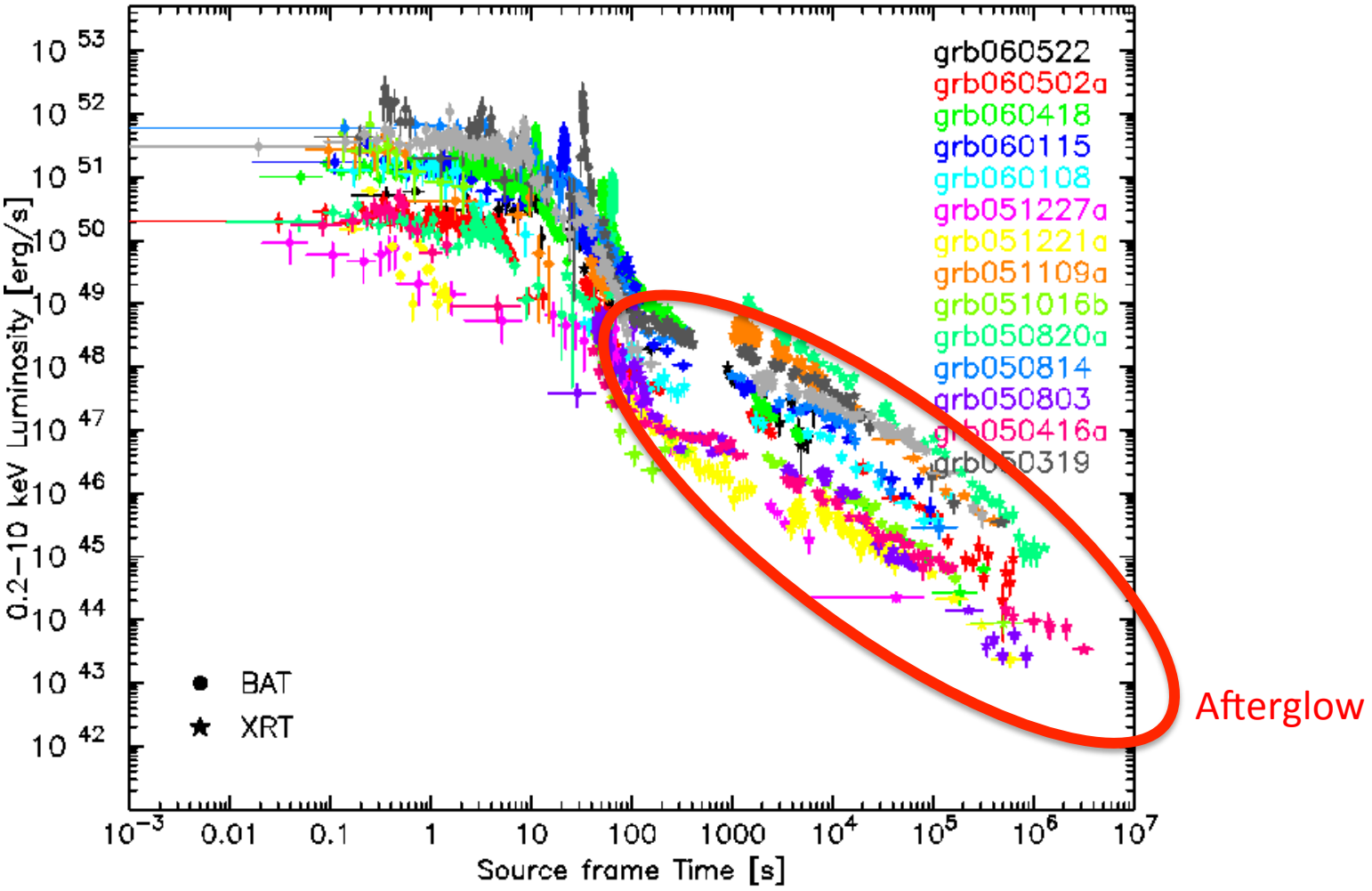
$$R = \delta t \, c$$

$$R = 3 \times 10^7 \text{ cm}$$

Typical scales of a compact object

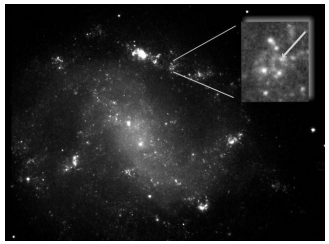
$$R_{BH} = \frac{2GM_{bh}}{c^2}$$

# The rest of the emission

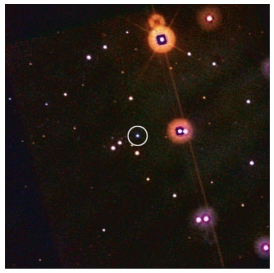



After a "prompt" (highly variable) emission the GRB electromagnetic signal is observed at lower frequencies (in the X-ray, Optical, mm, Radio bands) with a decaying L(t). This is the so-called "AFTERGLOW". The power of the emission is progressively exausted.

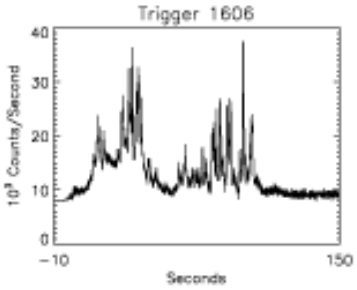
# Summary of fundamental observational facts



Cosmological sources:
$E \sim 10^{48}$-$10^{54}$ erg
Located in star forming galaxies



Associated with particularly energetic Supernovae



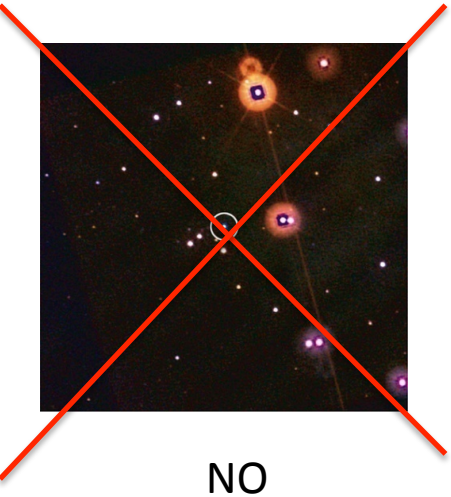

Variability → compact source

1. What makes a GRB? (i.e. what are their progenitors)

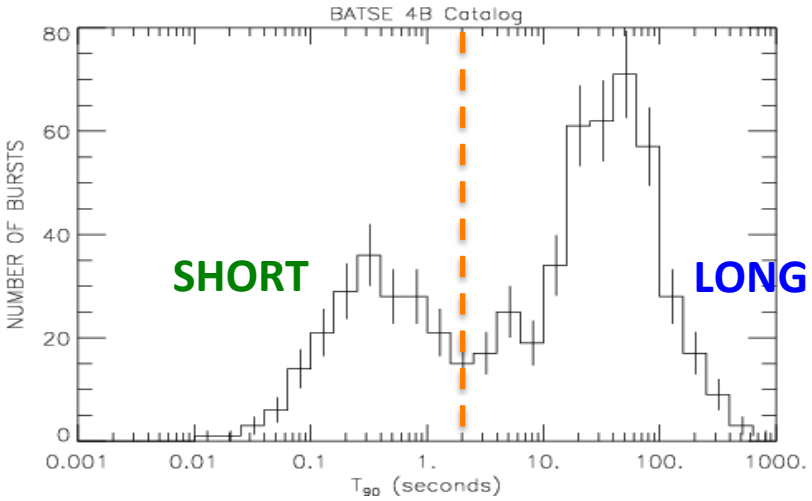
2. How the GRB produces the radiation we see? (i.e. what physics behind observational properties)

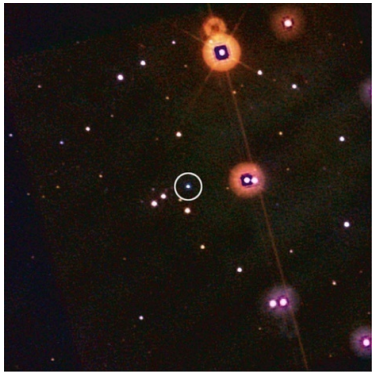
- GRBs have a stellar progenitor
- GRBs sign the birth of a black hole

# Short vs Long



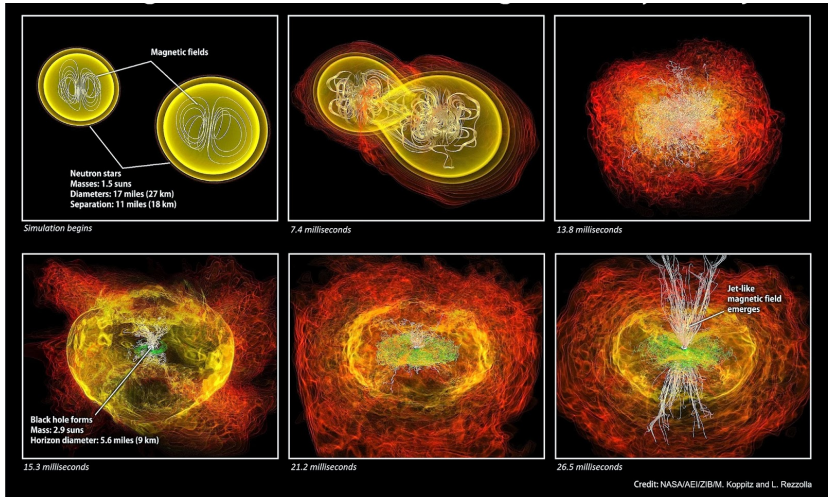
NO SUPERNOVAE



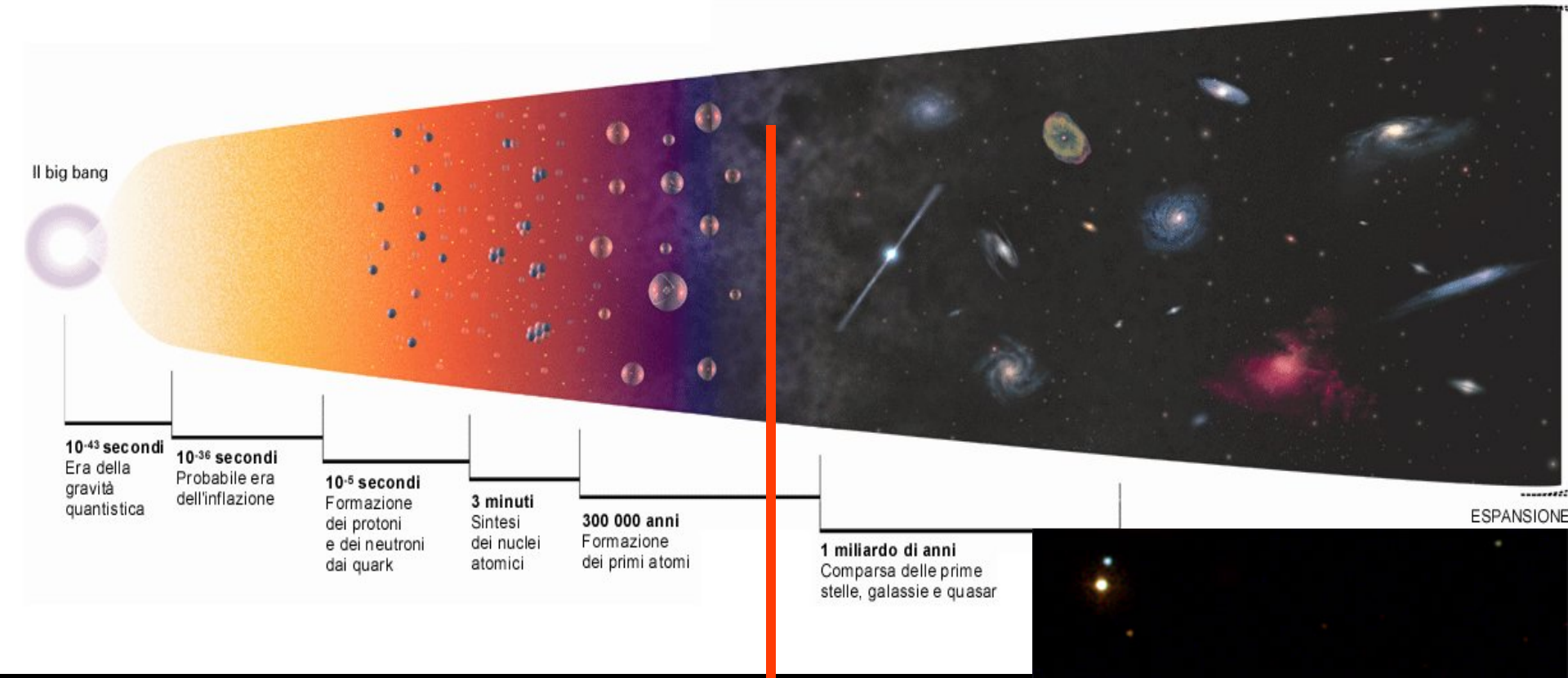



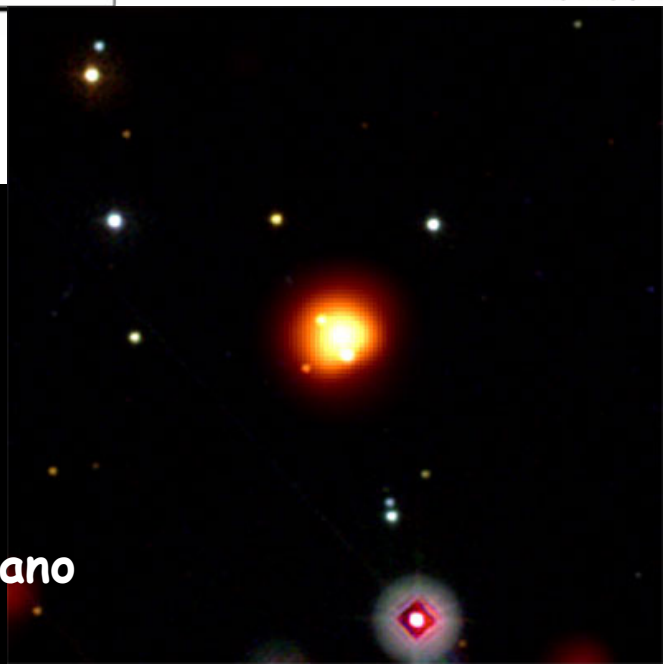
SUPERNOVAE

Several similar properties, the most striking difference is that no SN have been found in association with short GRBs → different progenitors




# GRB: testimoni dell'universo neonato



**23 Aprile 2009**

**Scoperto il GRB piu' lontano**

# Come fari per "illuminare" la storia del cosmo