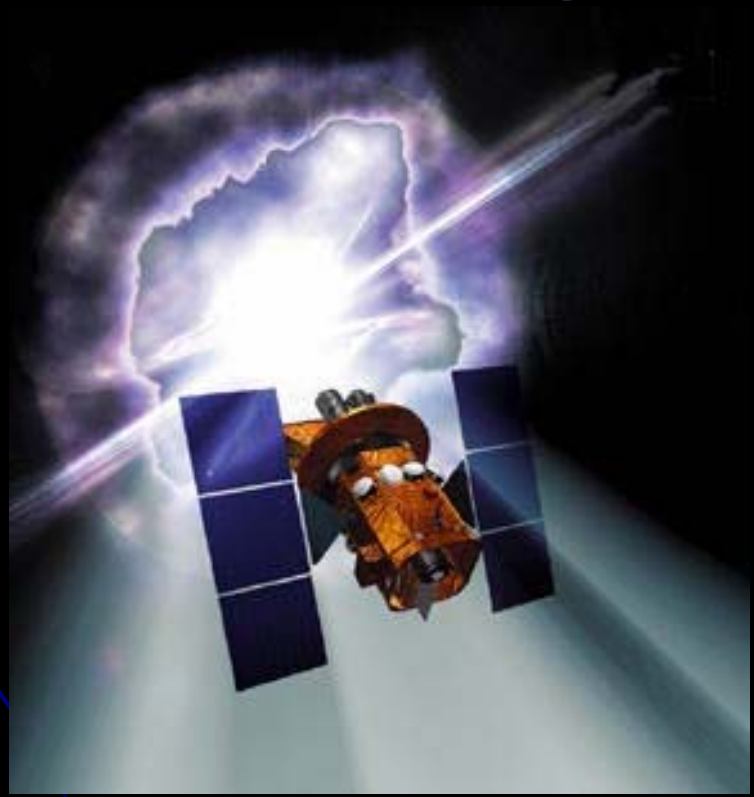
UNIVERSITY of GLASGOW

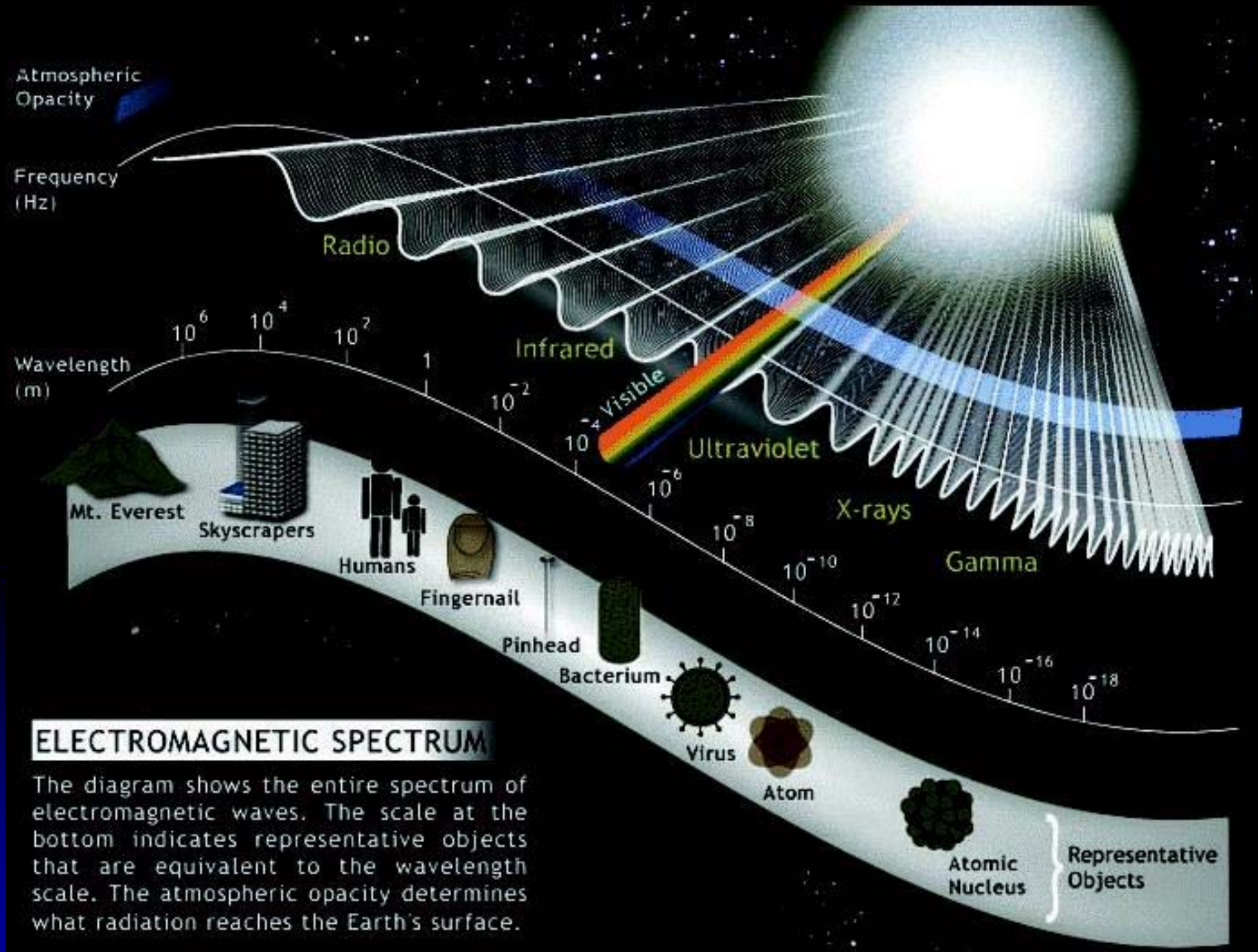
Gamma Ray Bursts



Fiona Speirits, Dept. of Physics and Astronomy

GRBs – The furthest away and most energetic events since the BIG BANG!

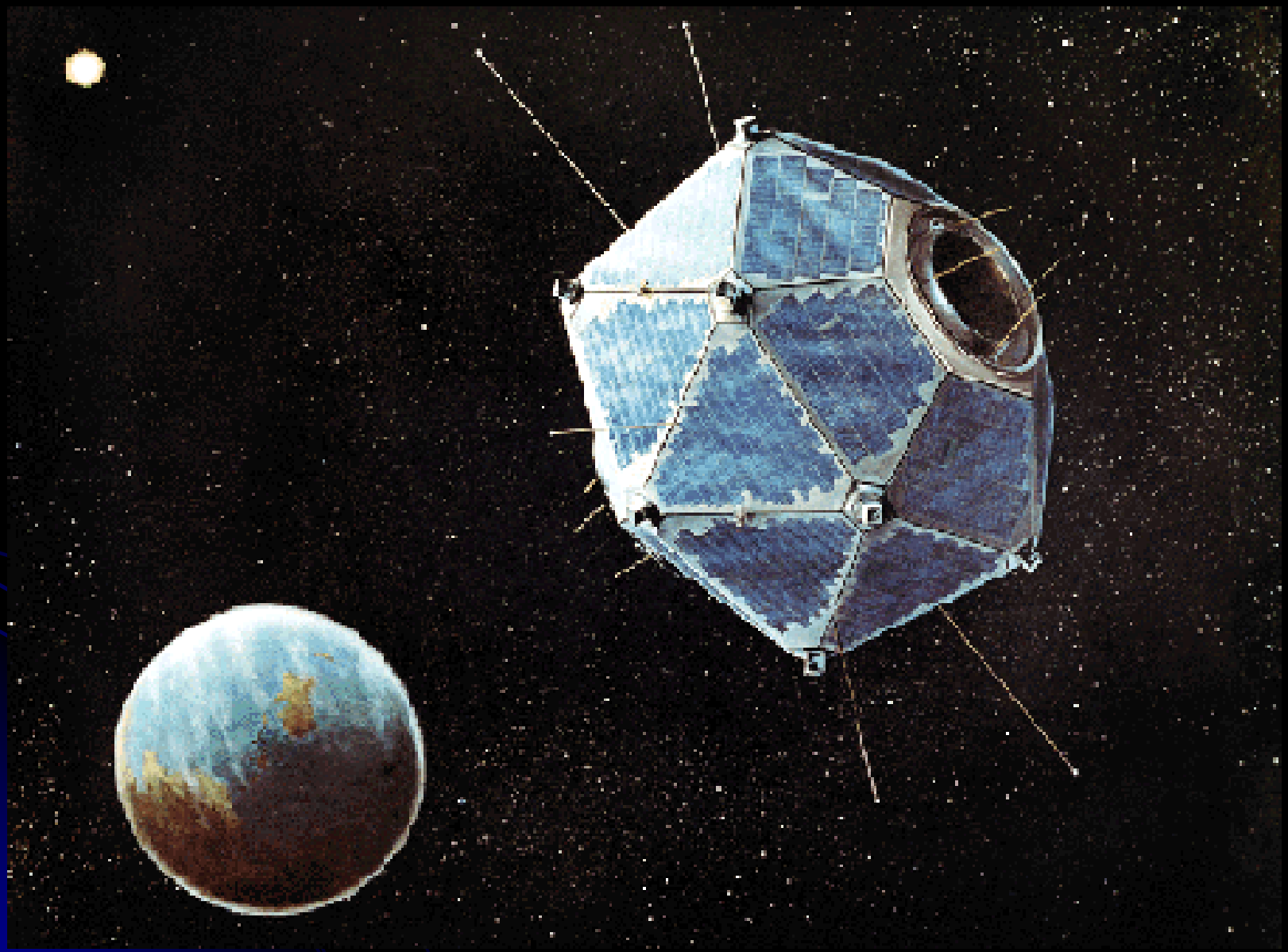
- Discovery and history of exploration
- How do we study them today?
- What actually are GRBs?!
- What can we learn from them?



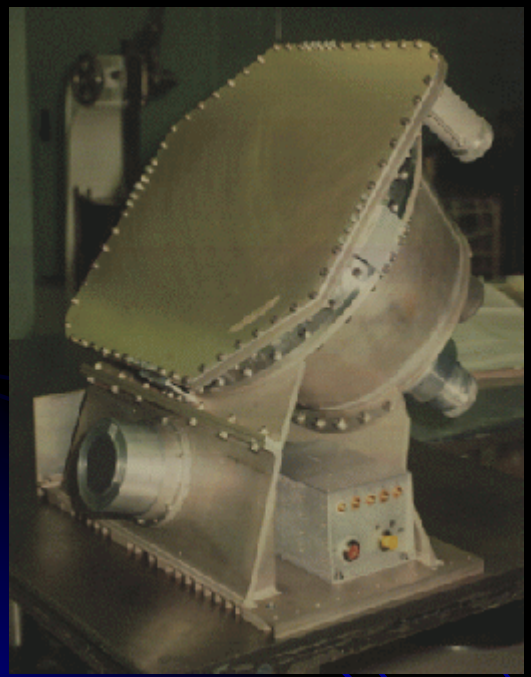
ELECTROMAGNETIC SPECTRUM

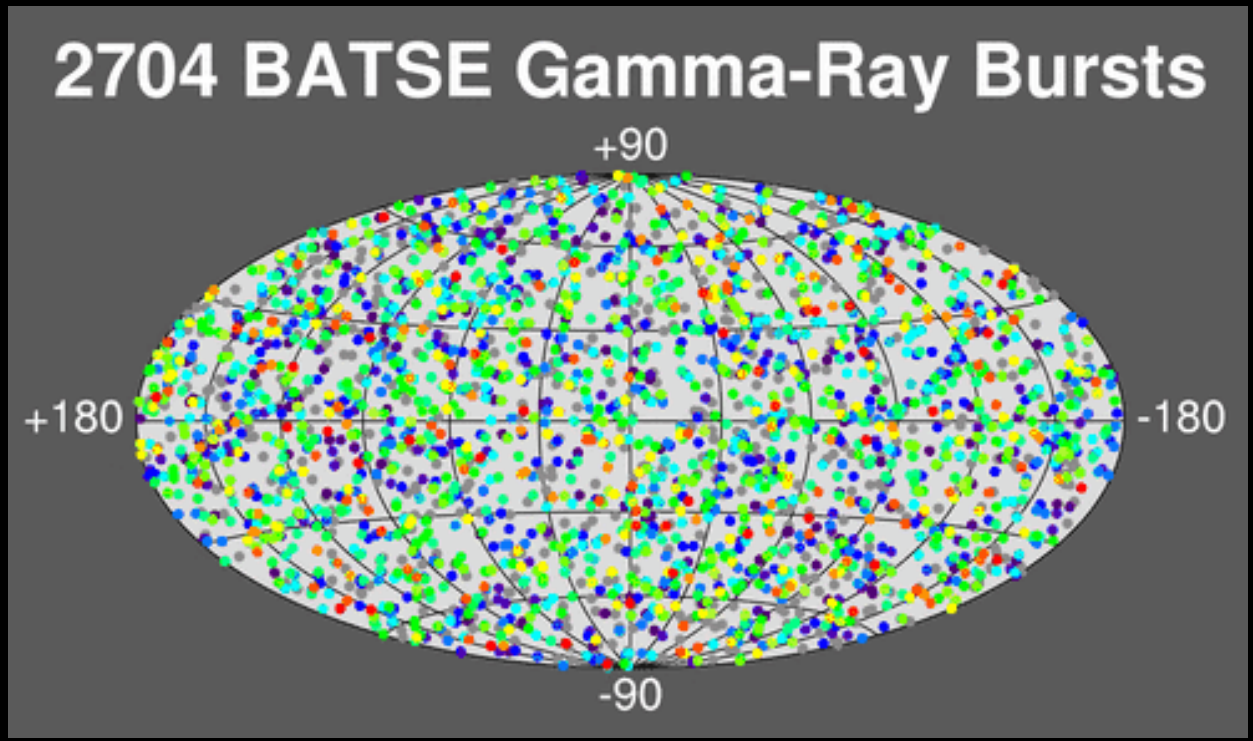
The diagram shows the entire spectrum of electromagnetic waves. The scale at the bottom indicates representative objects that are equivalent to the wavelength scale. The atmospheric opacity determines what radiation reaches the Earth's surface.

Vela



Burst And Transient Source Experiment (Batse)





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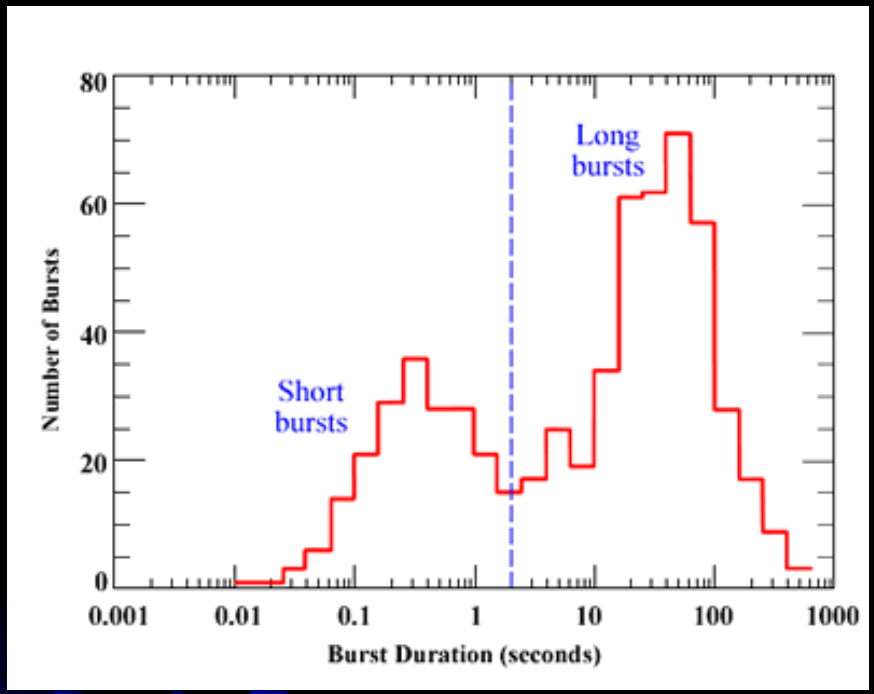

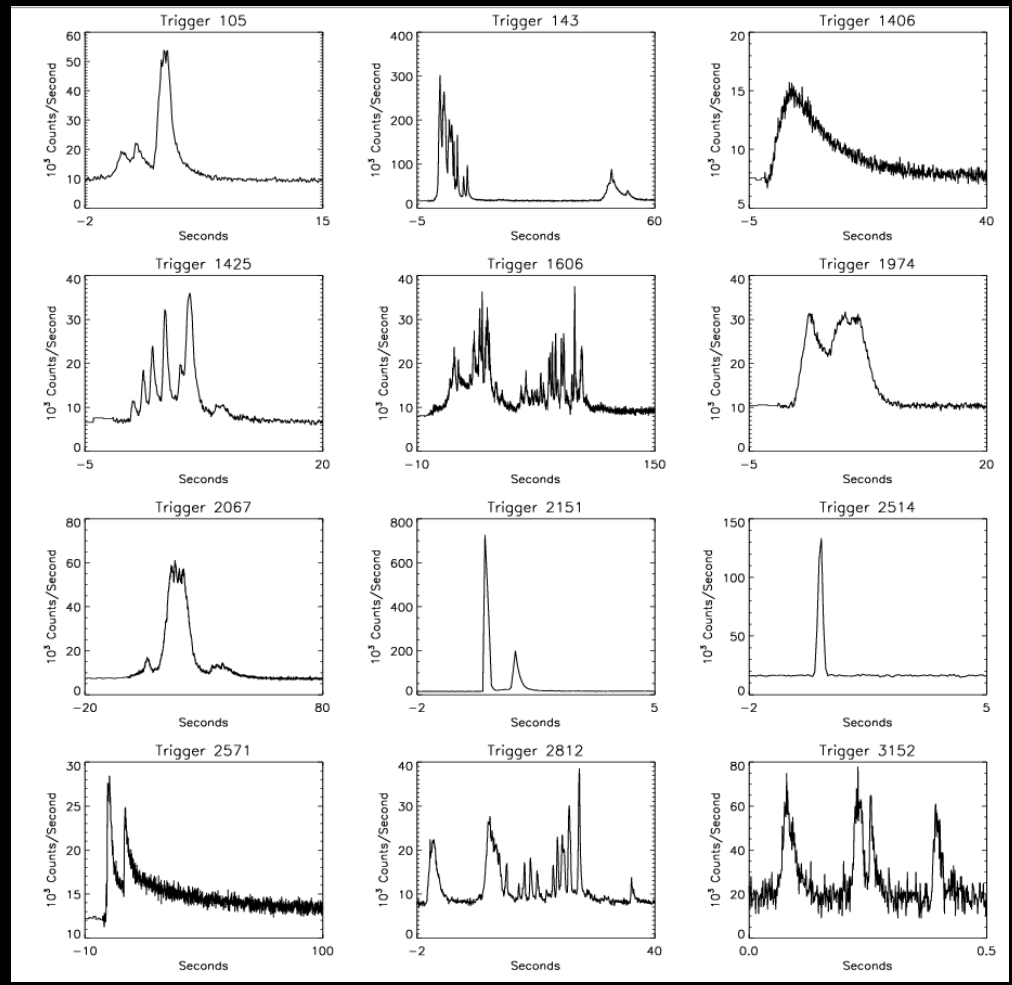

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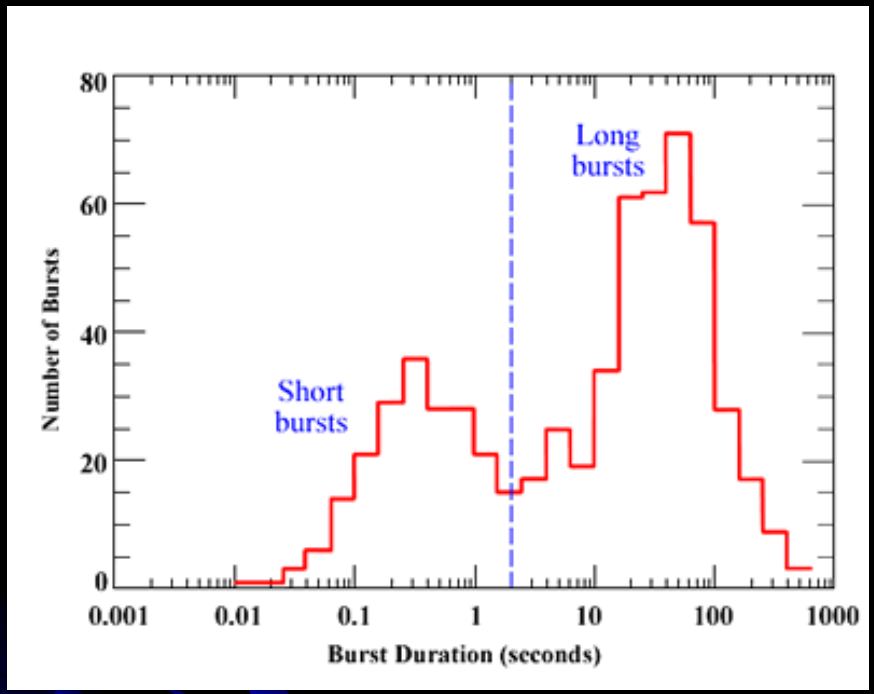
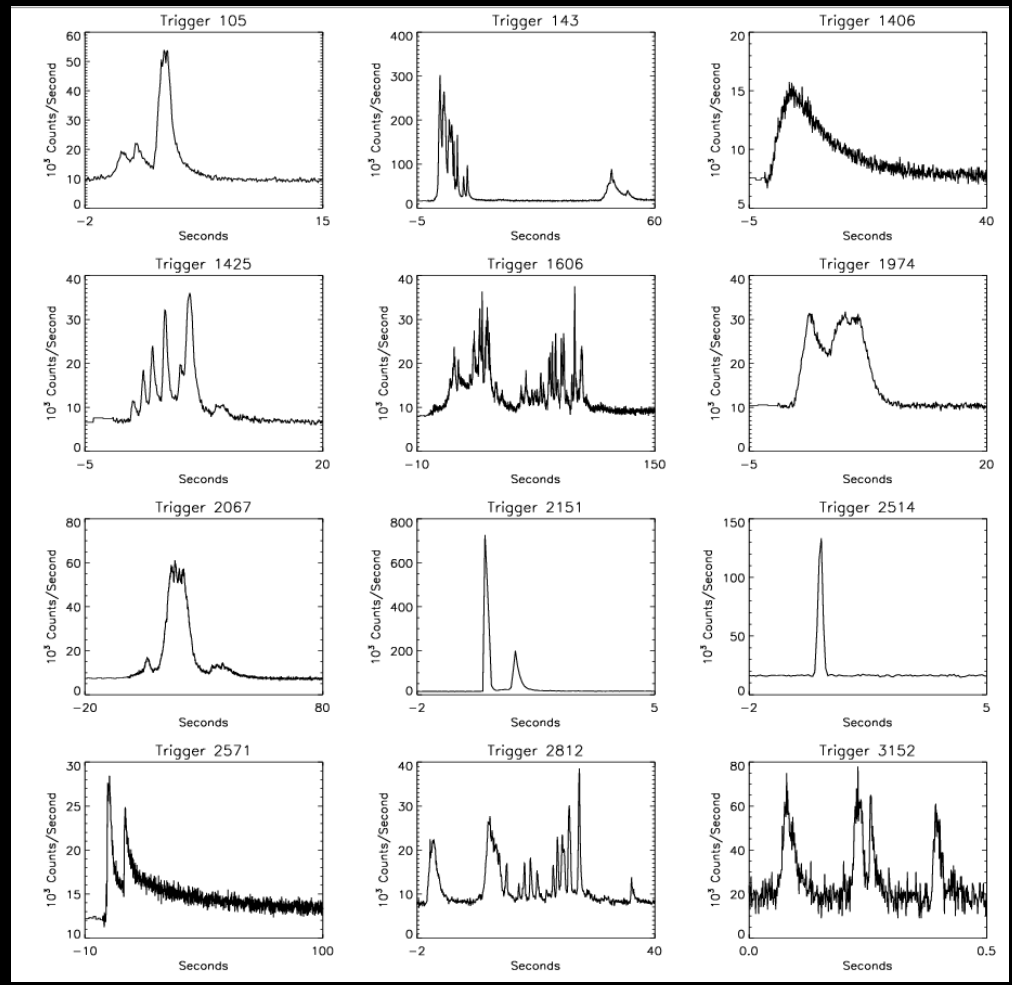


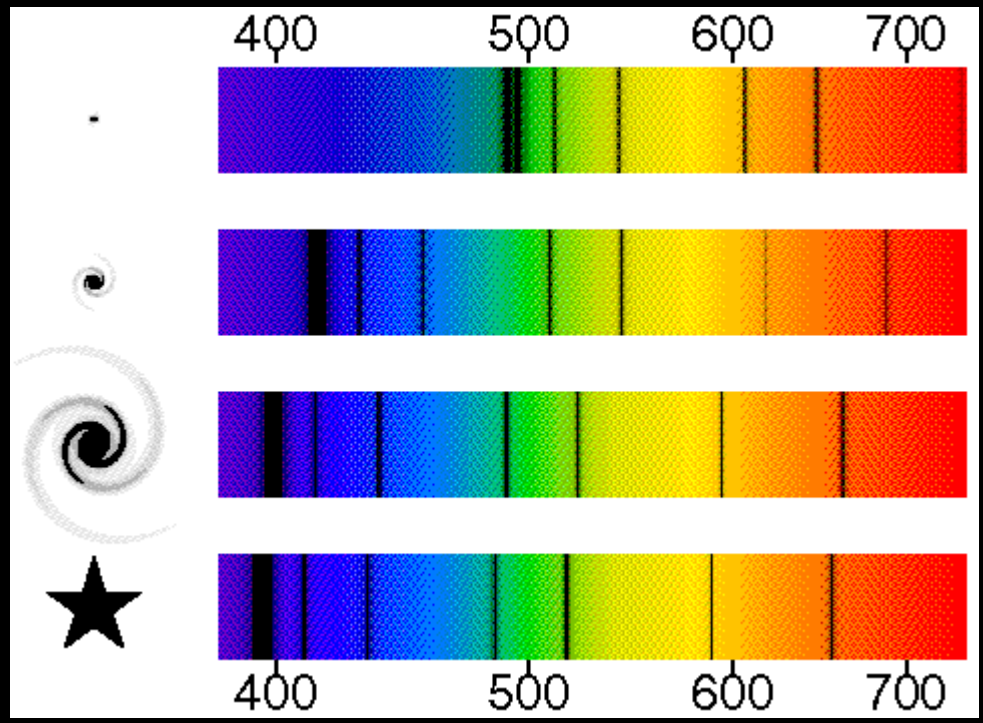


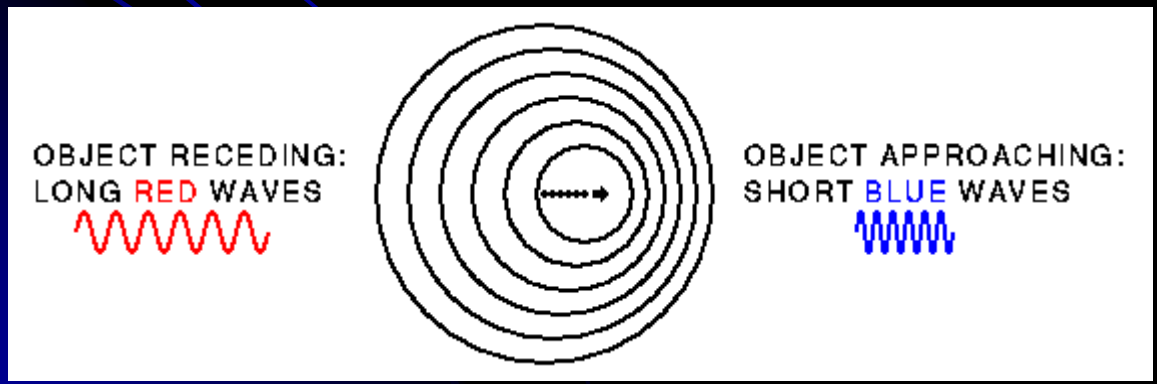
2 options:

1. GRB sources located in an extended Galactic Halo

2. GRBs are cosmological events

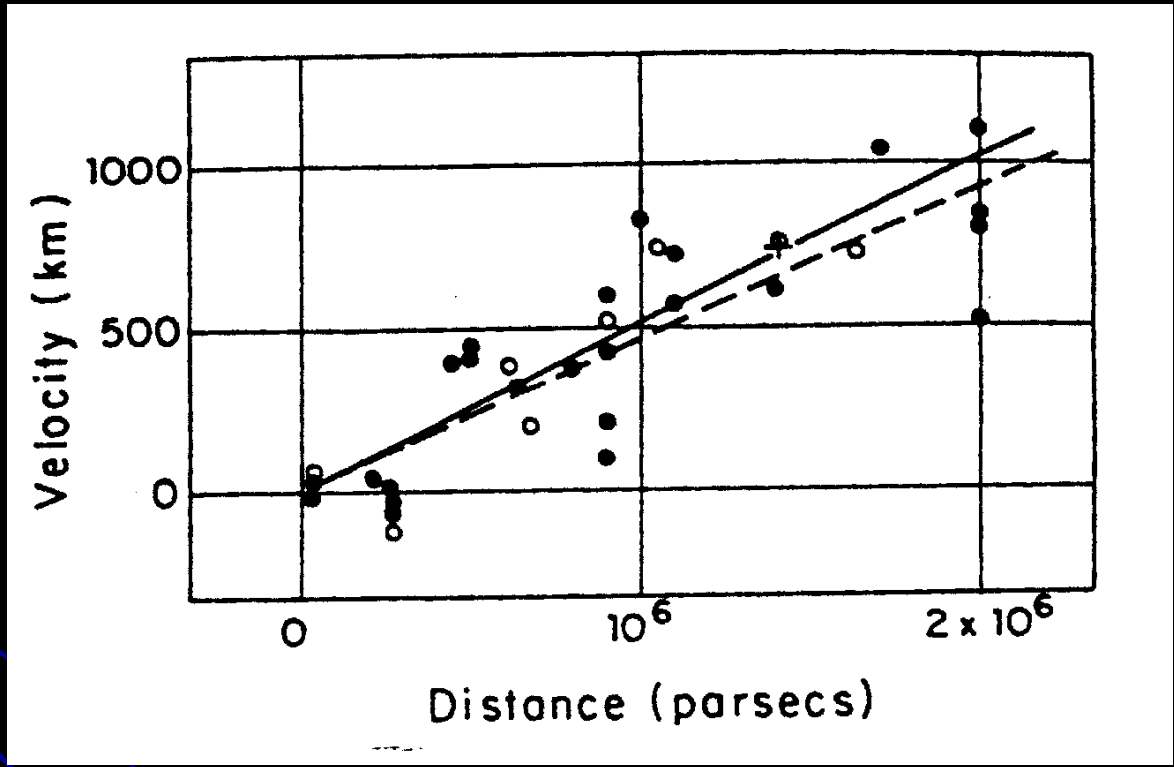
Redshift, Distance & The Expanding Universe





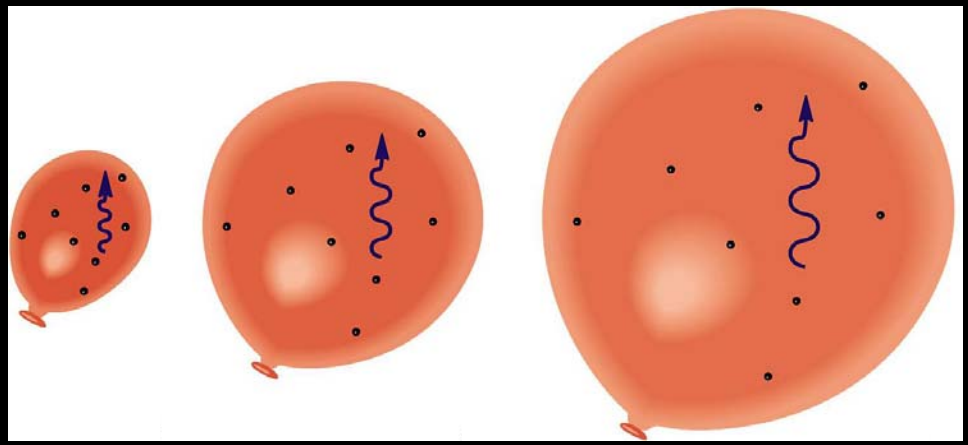
$$\frac{\Delta\lambda}{\lambda} \approx \frac{v}{c}$$

Redshift, Distance & The Expanding Universe

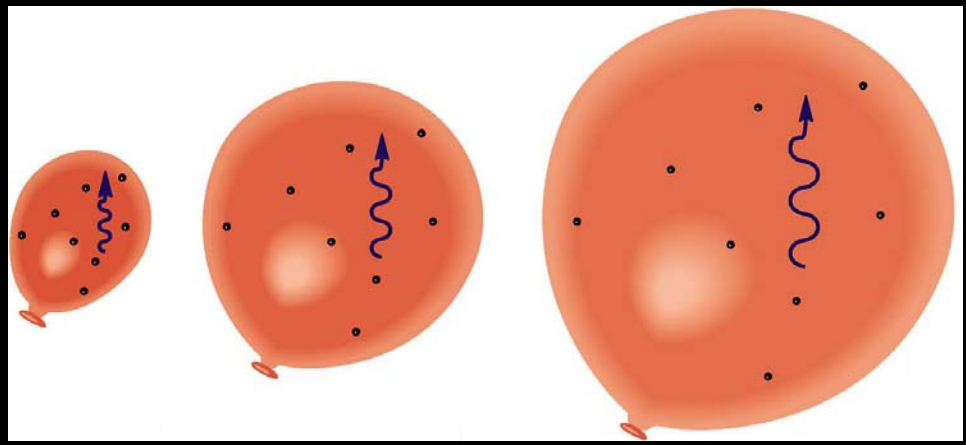


Hubble's Law $v = H \times d$

Cosmological Redshift



Cosmological Redshift



Enter values, hit a button

71 H_o
0.27 $Omega_M$
3 z
Open Flat
0.73 $Omega_{vac}$
General

Open sets $Omega_{vac} = 0$ giving an open Universe [if you entered $Omega_M < 1$]
Flat sets $Omega_{vac} = 1-Omega_M$ giving a flat Universe.
General uses the $Omega_{vac}$ that you entered.

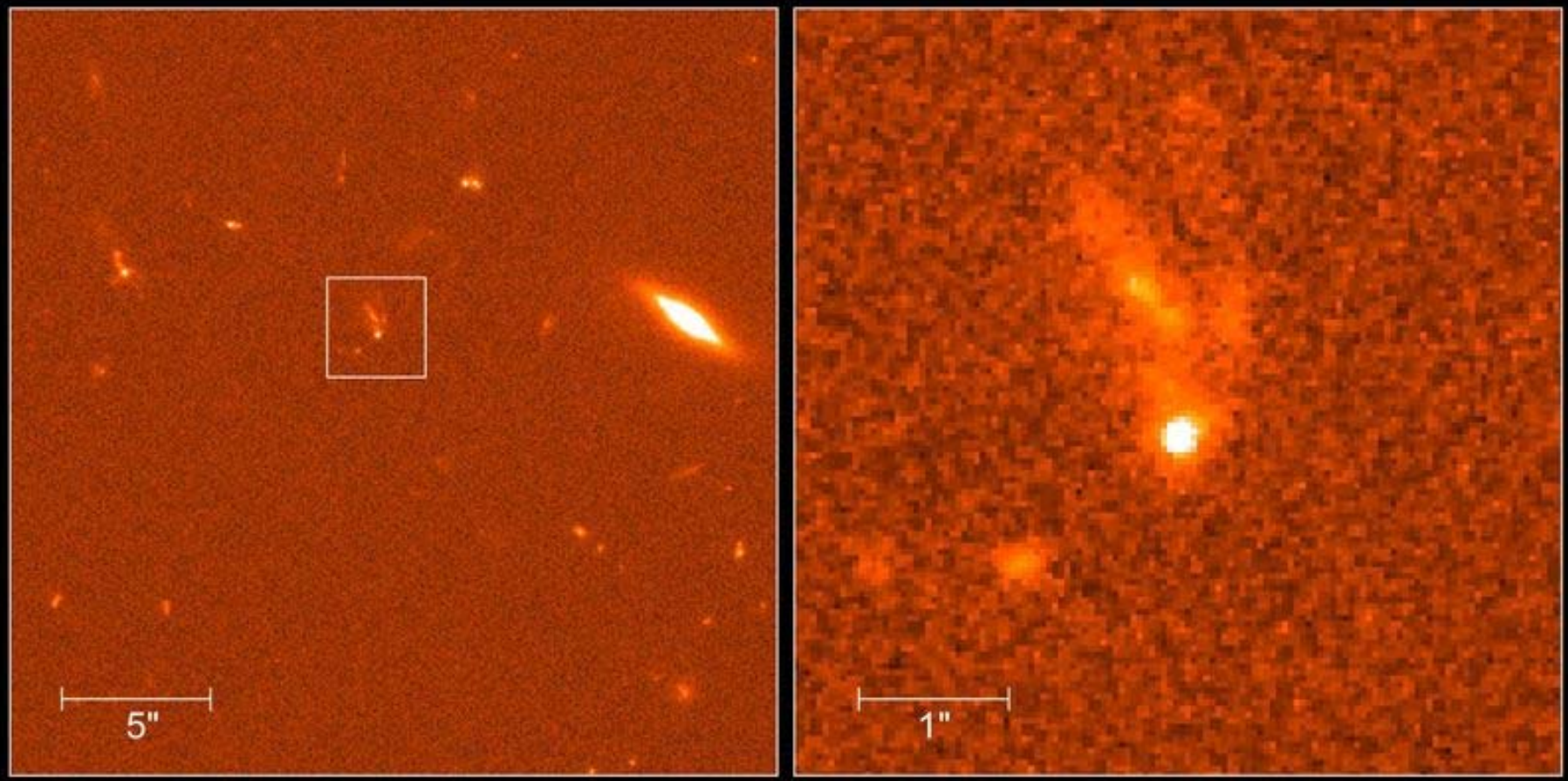
For $H_o = 71$, $Omega_M = 0.270$, $Omega_{vac} = 0.730$, $z = 3.000$

- It is now 13.666 Gyr since the Big Bang.
- The age at redshift z was 2.190 Gyr.
- The light travel time was 11.476 Gyr.
- The comoving radial distance, which goes into Hubble's law, is 6460.6 Mpc
- The comoving volume within redshift z is 1129.524 Gpc^3.
- The angular size distance D_A is 1615.1 Mpc or 5.2678 Gly.
- This gives a scale of 7.830 kpc/".
- The luminosity distance D_L is 25841.7 Mpc or 84.285 Gly.

1 Gly = 1,000,000,000 light years or $9.461*10^{26}$ cm.
1 Gyr = 1,000,000,000 years.
1 Mpc = 1,000,000 parsecs = $3.08568*10^{24}$ cm, or 3,261,566 light years.

http://www.astro.ucla.edu/~wright/CosmoCalc.html

Optical Counterparts



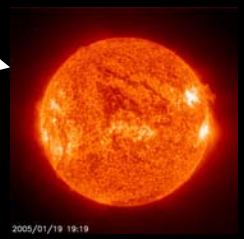
Gamma Ray Burst GRB990123
Hubble Space Telescope • STIS

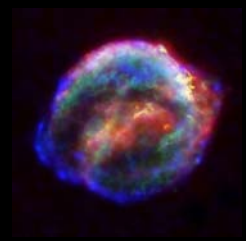
PRC99-09 • STScI OPO • A. Fruchter (STScI) and NASA

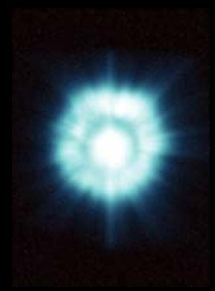
Conclusion...

GRBs must be Extragalactic

Typical Scales



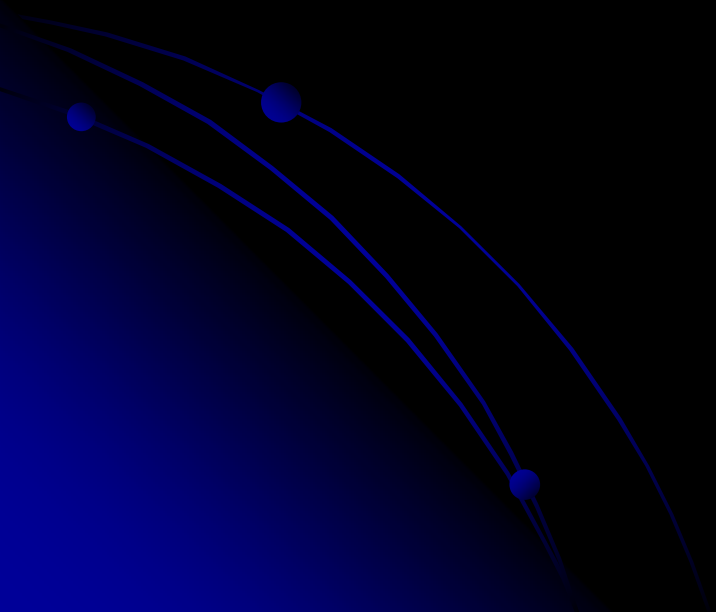




Earth - Moon

~ 385 000 km

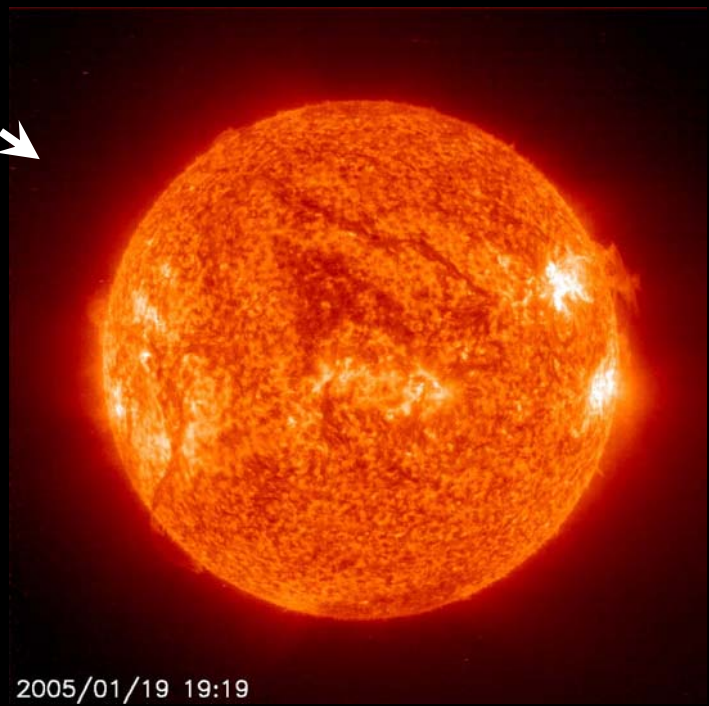
t_l ~ 1 second



EARTH - SUN

~ 150 000 000 km

t_l ~ 8 minutes



EARTH - ALPHA CENTAURI

$\sim 4 \times 10^{13}$ km = 1.3 pc

$t_l \sim 4.3$ years

Earth - Nearest Galaxy

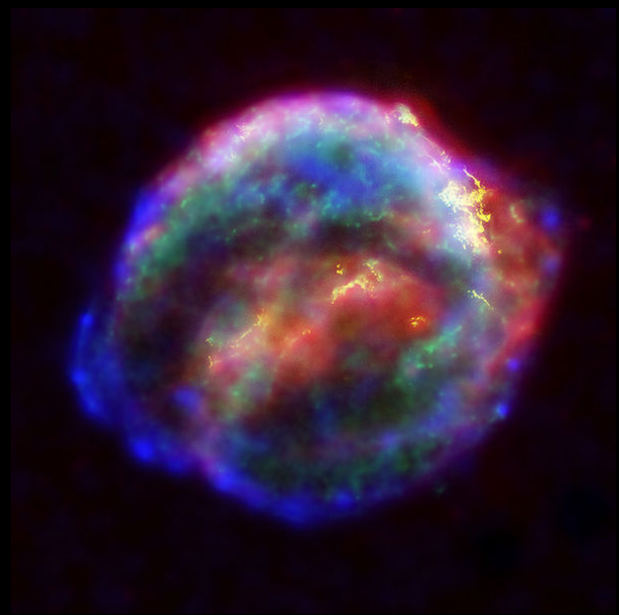
~ 0.77 Mpc

t_l ~ 2.5 million years

EARTH - FURTHEST SUPERNOVA

~ 3 Gpc

t_l ~ 9.8 billion years



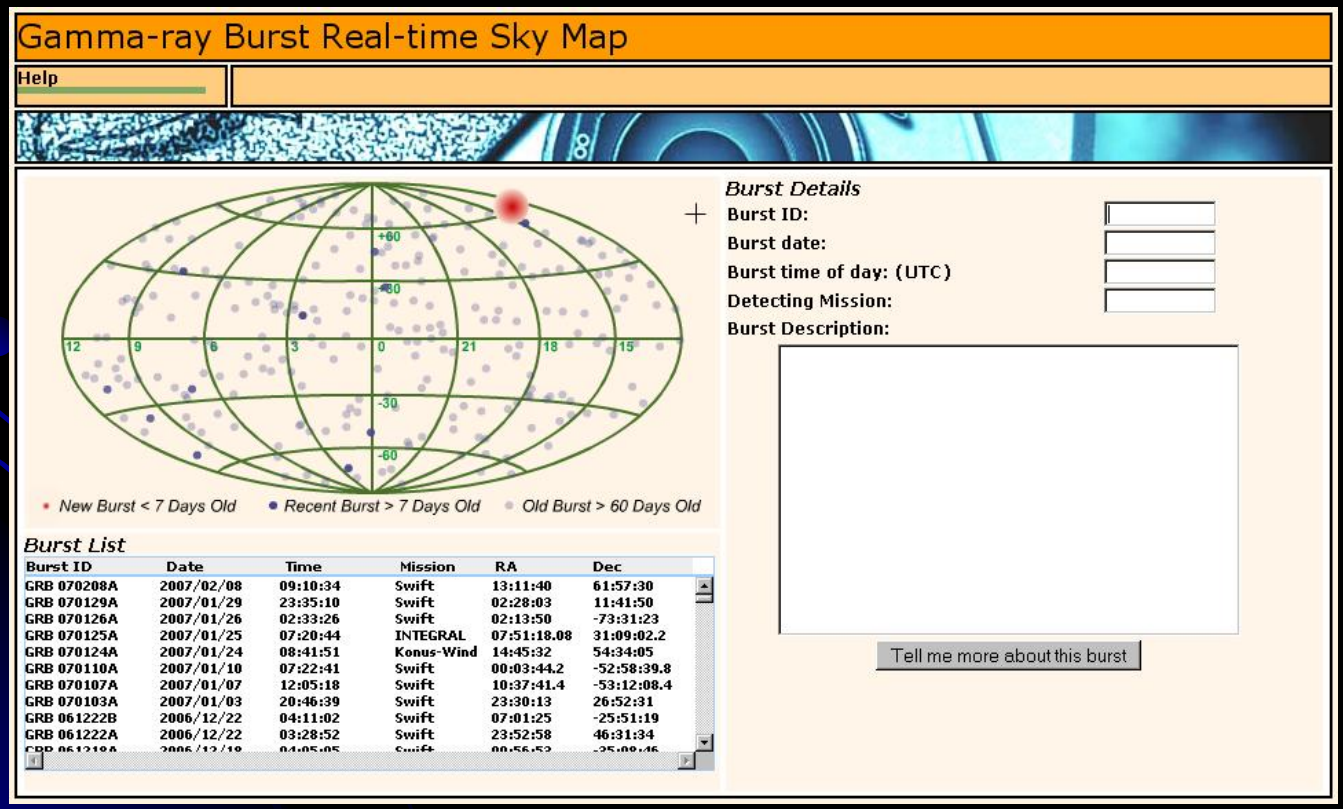
EARTH - FURTHEST GRB

~ 4 Gpc

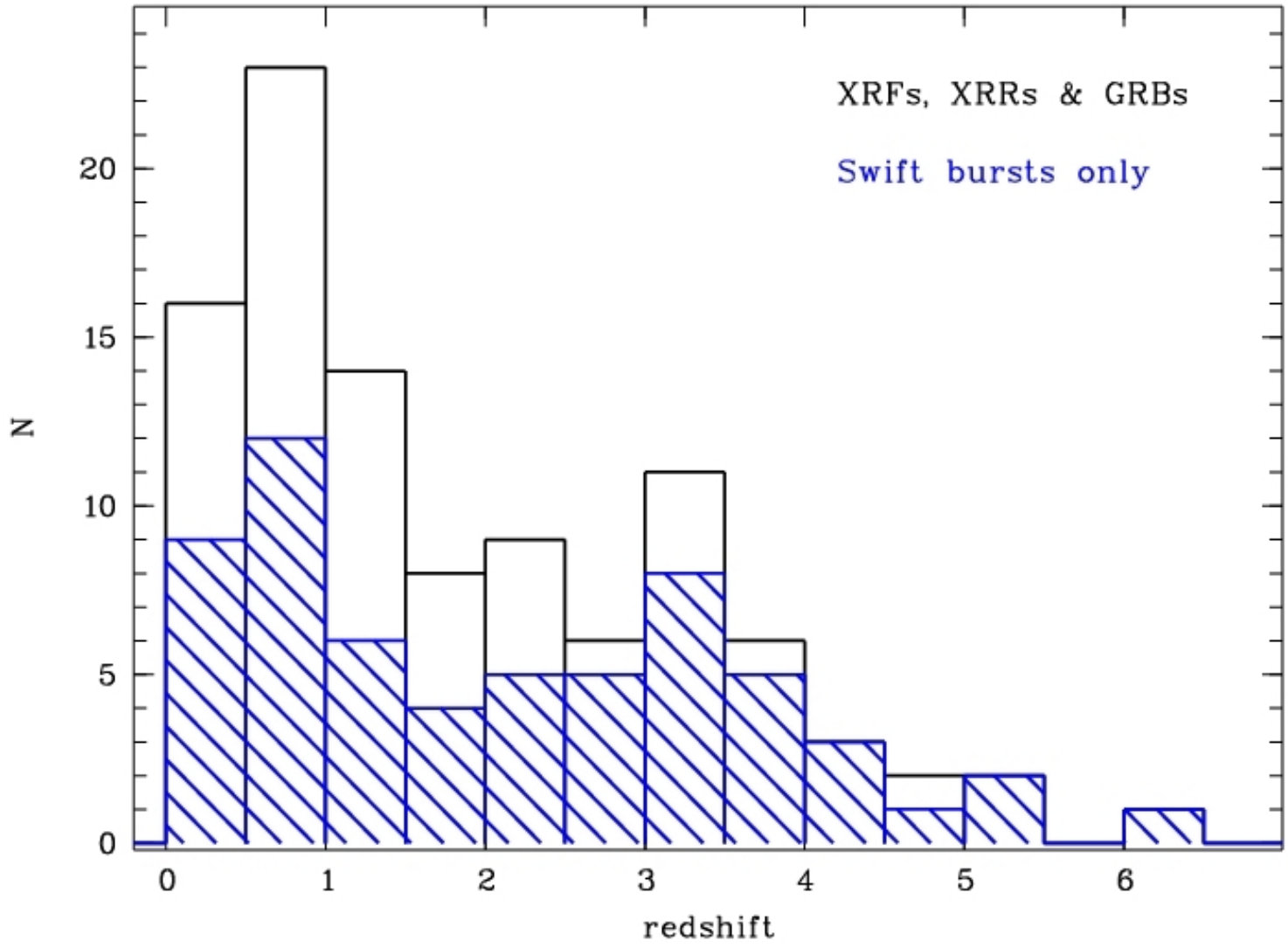
t_l ~ 13 billion years

SWIFT – http://swift.gsfc.nasa.gov

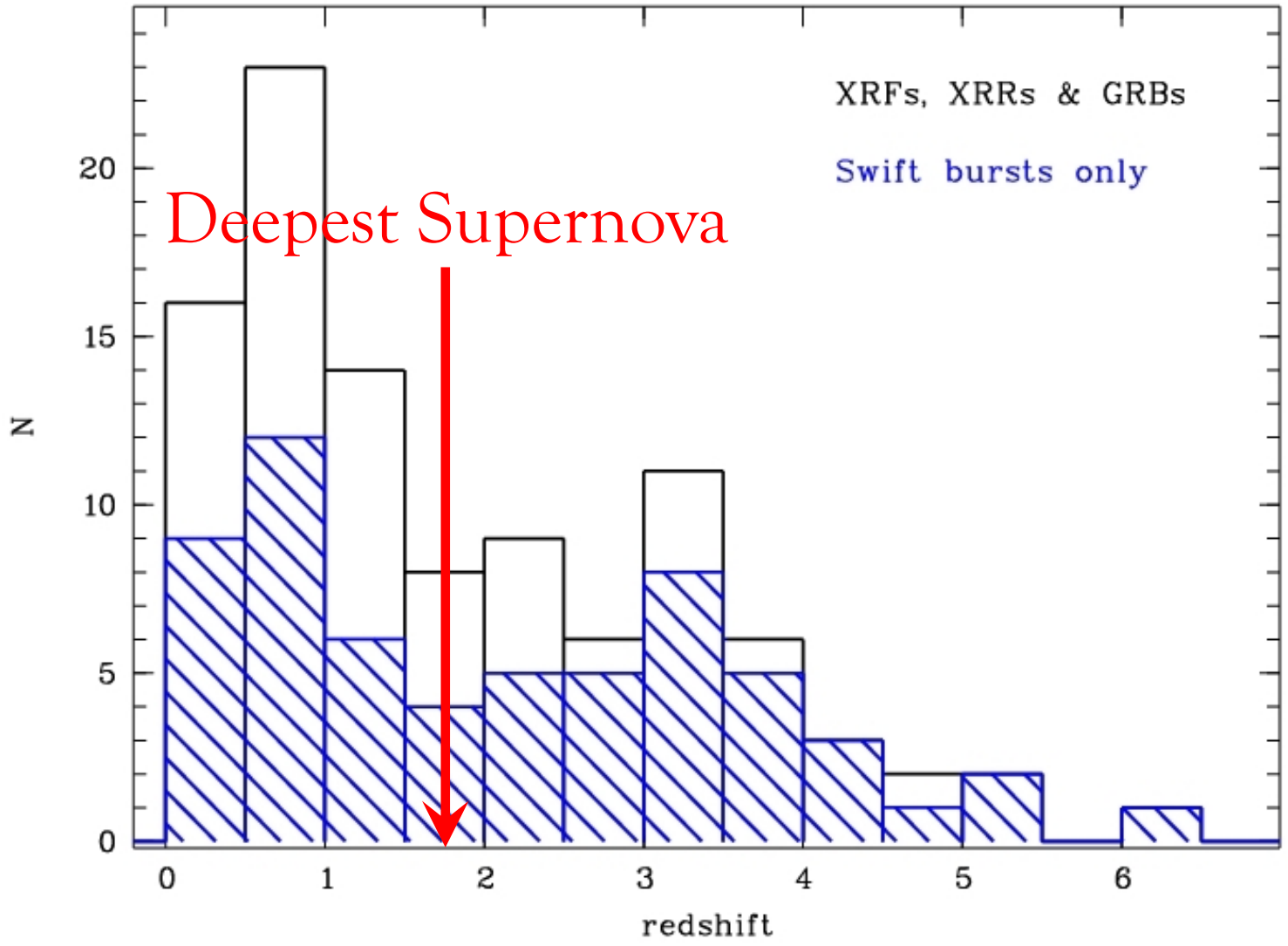
- Launched 2004
- Detection rate around a few GRBs per week
- Highest redshift z=6.3



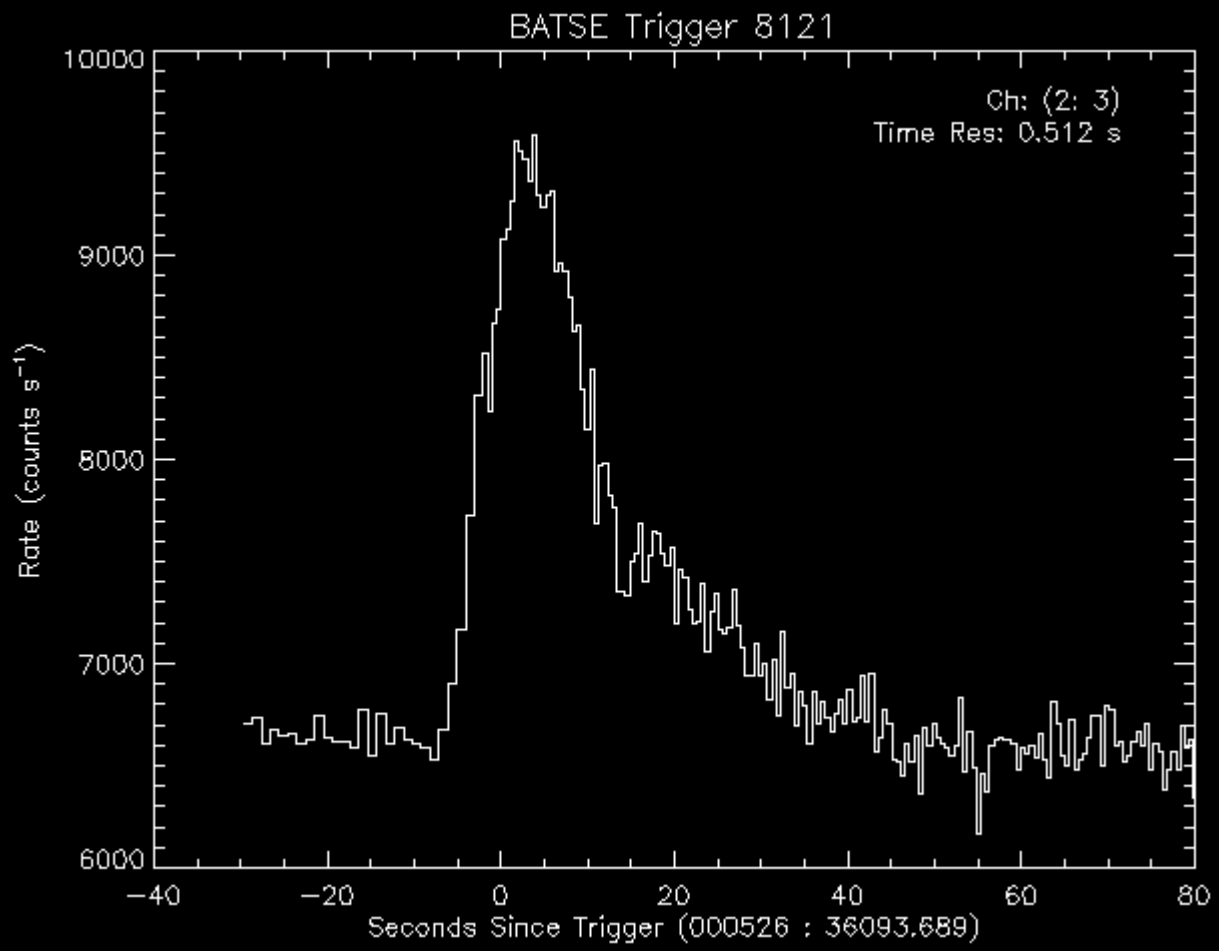
Swift


XRFs, XRRs & GRBs
Swift bursts only
N
redshift
0
5
10
15
20
0
1
2
3
4
5
6

Swift

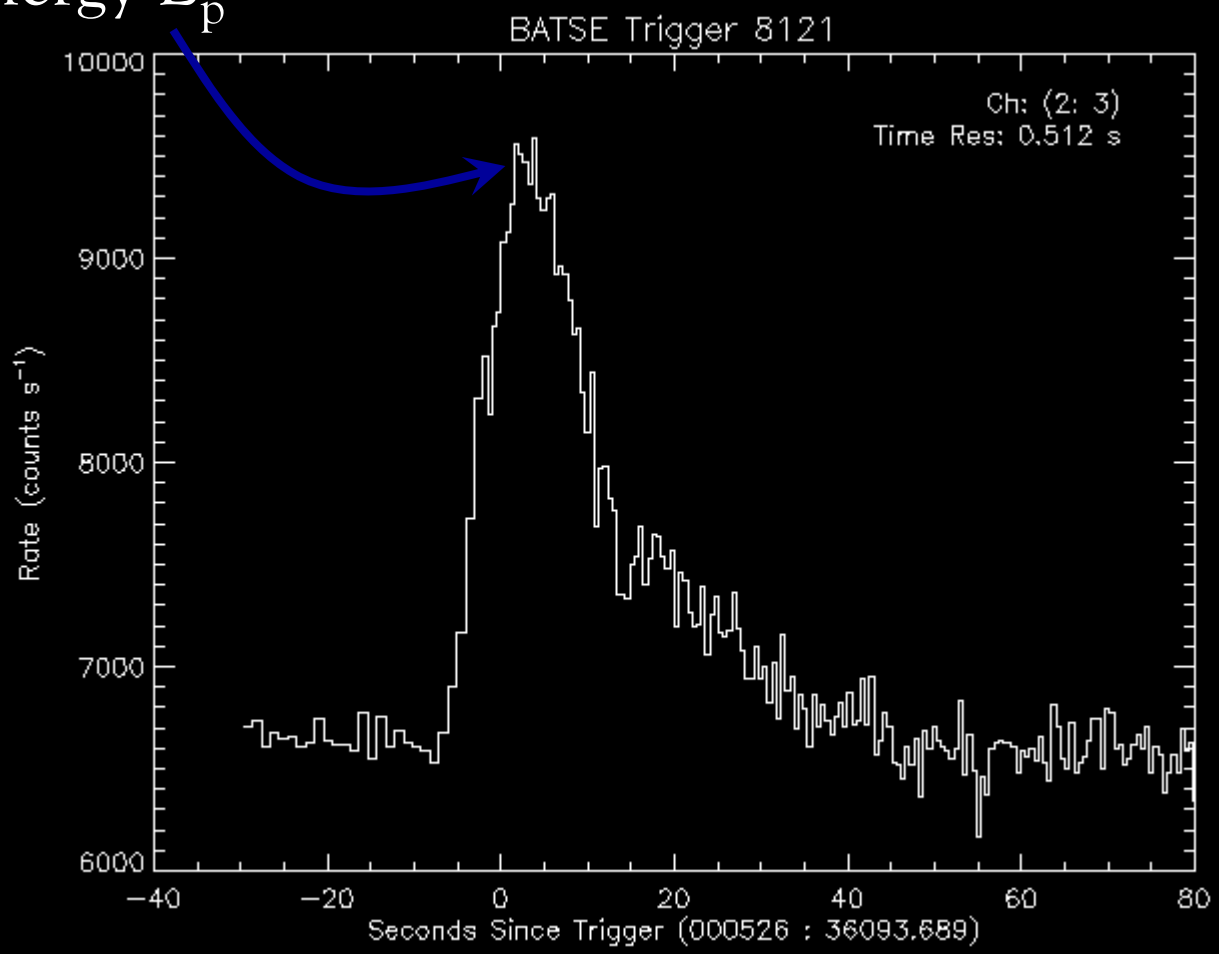

XRFs, XRRs & GRBs
Swift bursts only
Deepest Supernova
N
redshift
0
5
10
15
20
0
1
2
3
4
5
6

GRB PROPERTIES



GRB PROPERTIES

peak energy E_p



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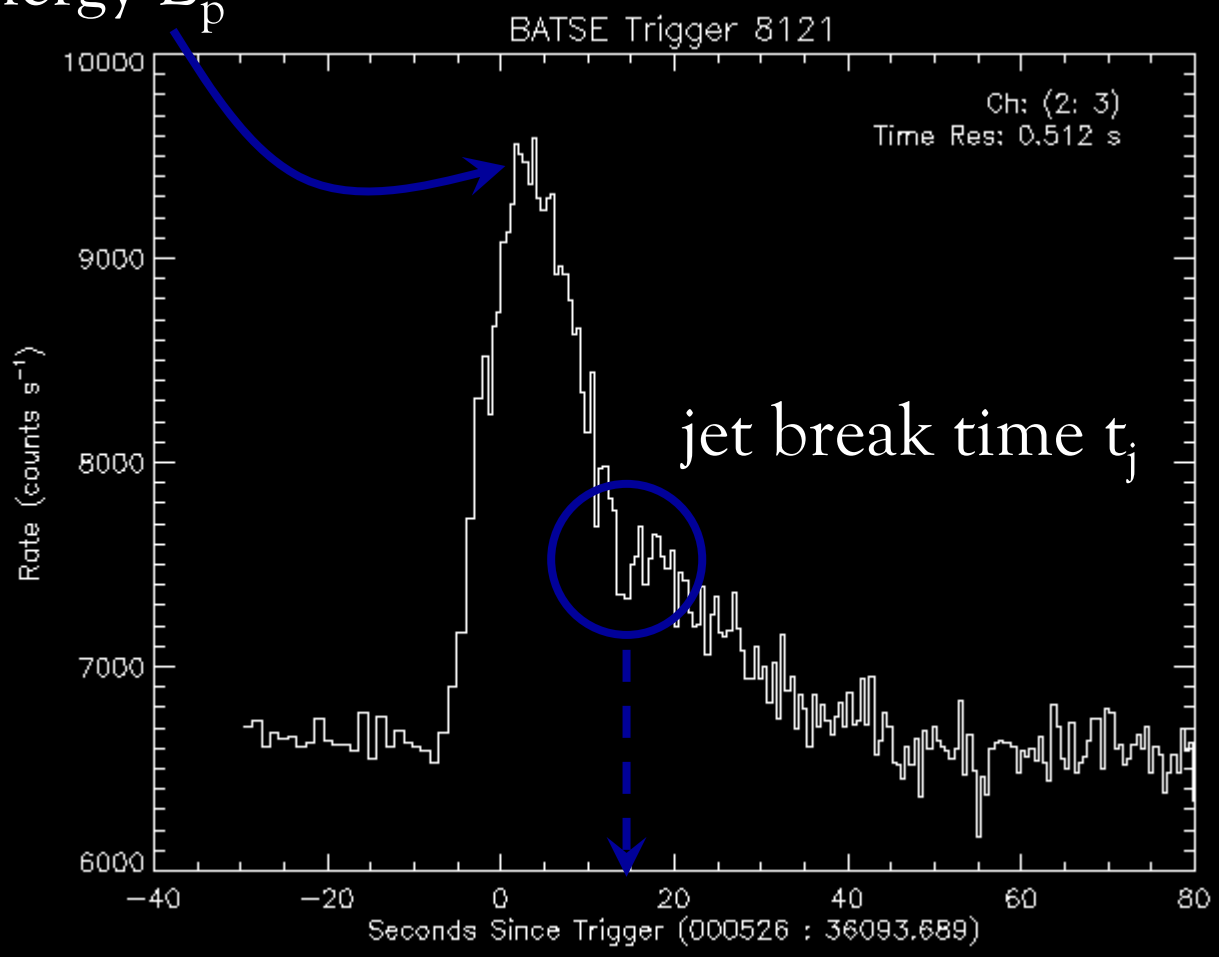
peak energy E_p

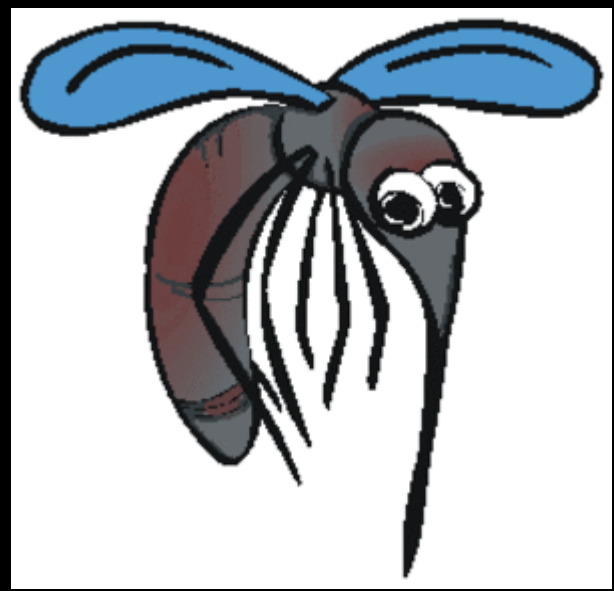


jet break time t_j

GRB PROPERTIES

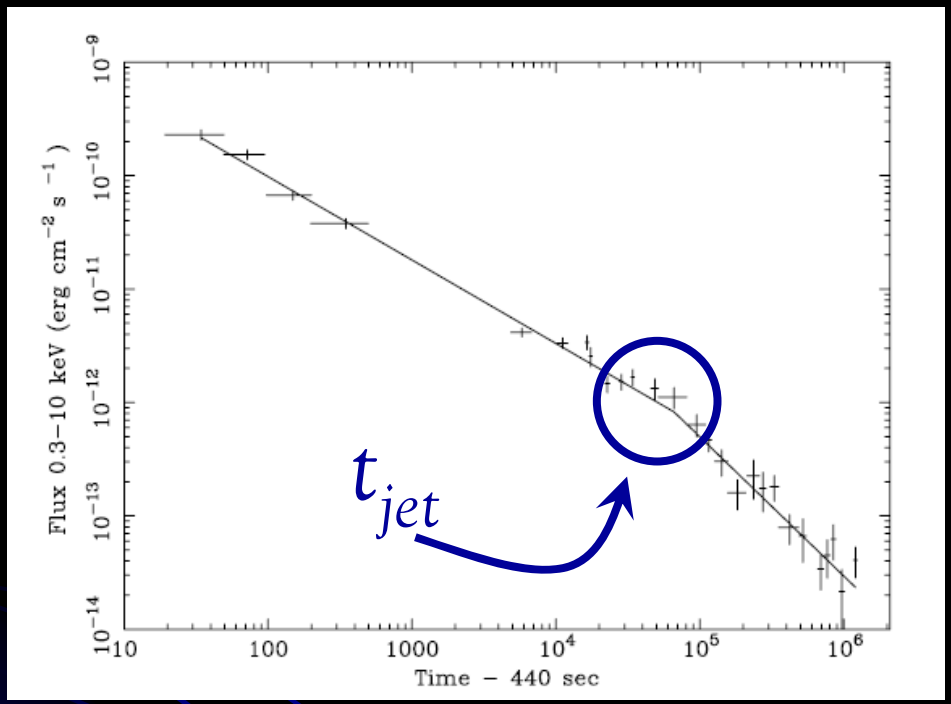
Typical peak energy: 10^{52} ergs

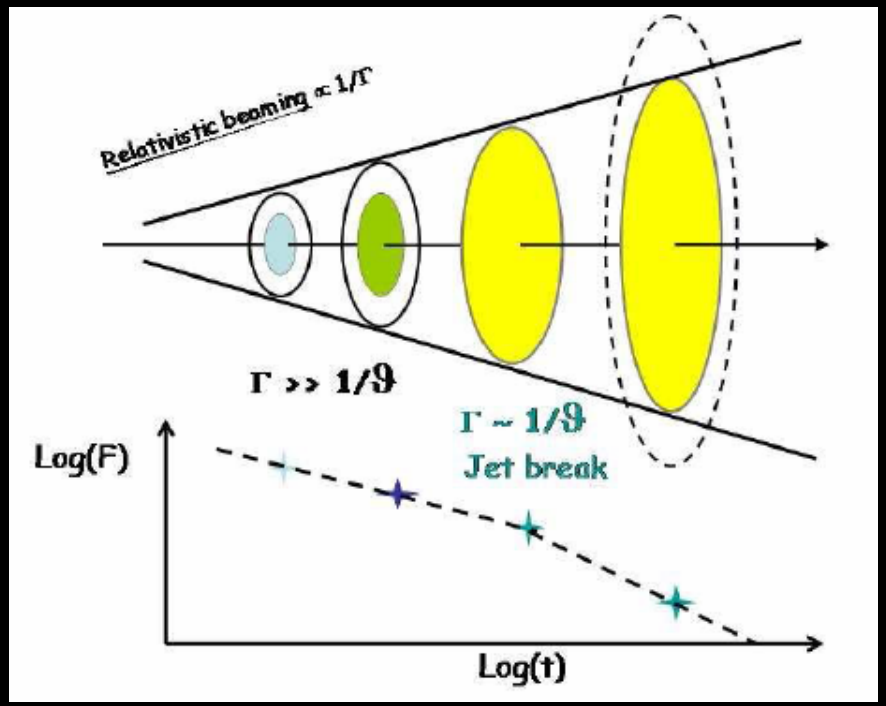
1 erg = 10^{-7} J
= energy of a flying mosquito



How many light bulbs is that...?!

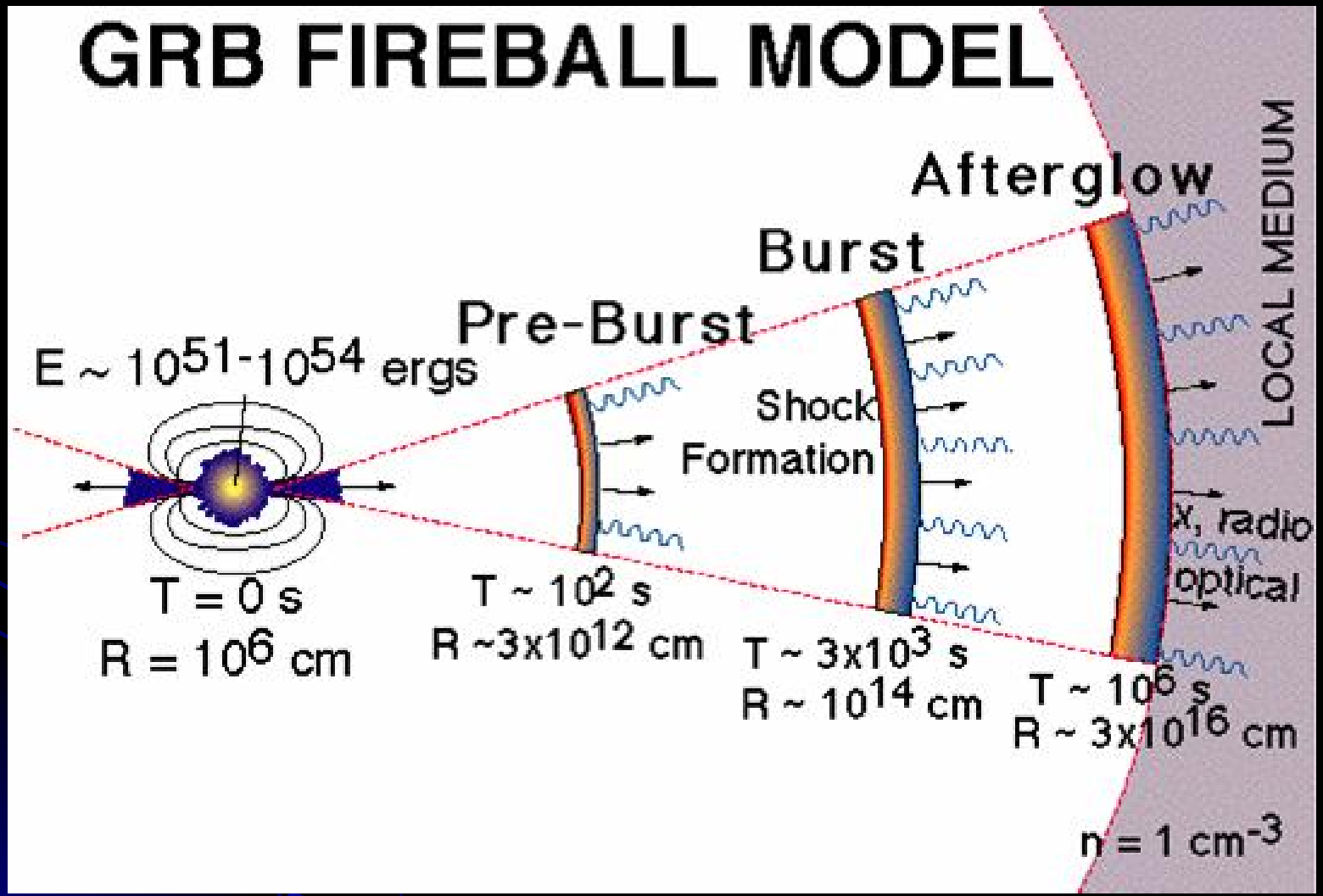
GRB PROPERTIES



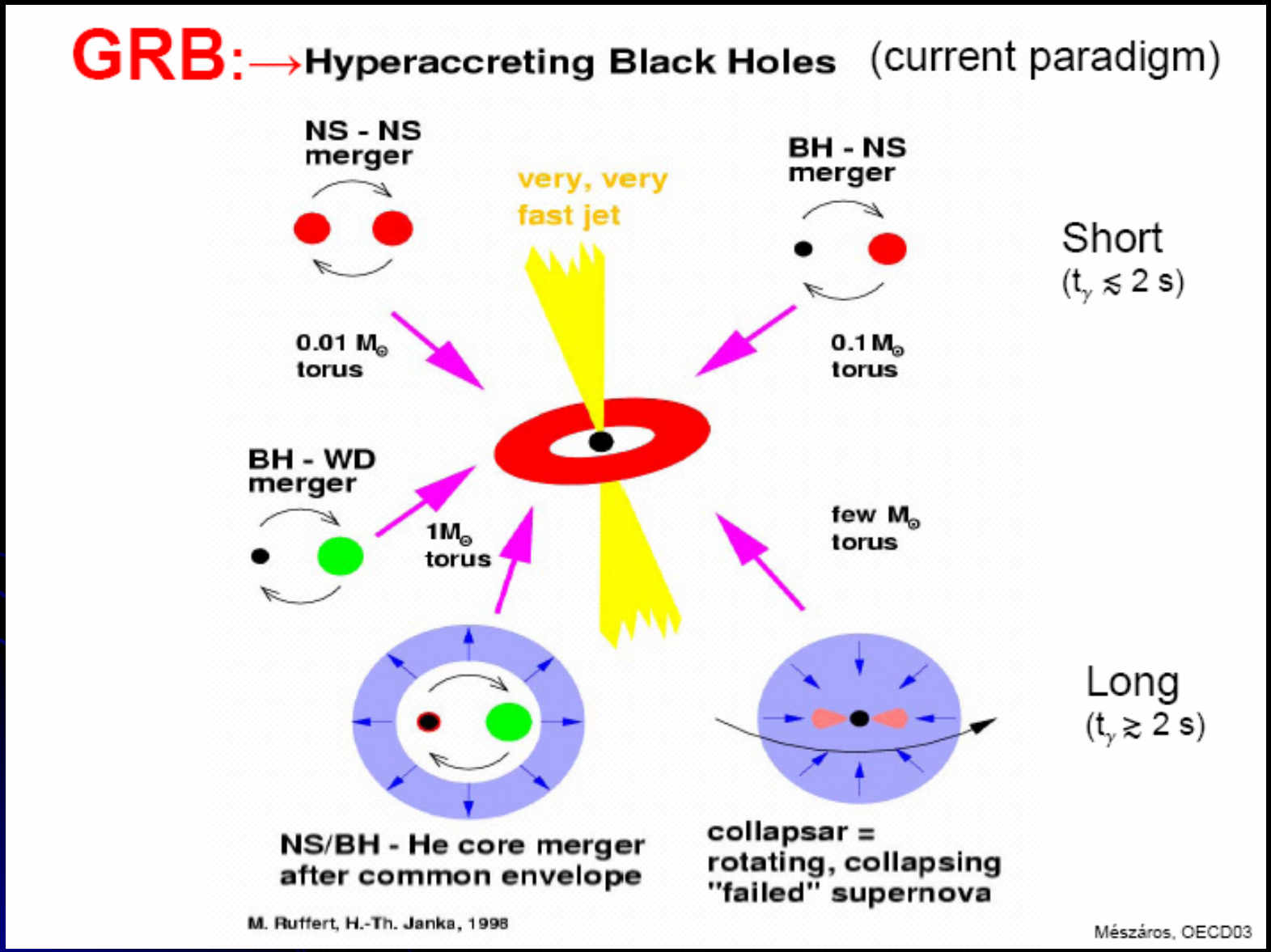


Jet break time allows us to calculate the opening angle of the highly relativistic cone-shaped outflow

GRB MODEL


GRB FIREBALL MODEL
Afterglow
Burst
Pre-Burst
LOCAL MEDIUM
E ~ 10^51-10^54 ergs
Shock
Formation
x, radio
optical
T = 0 s
R = 10^6 cm
T ~ 10^2 s
R ~3x10^12 cm
T ~ 3x10^3 s
R ~ 10^14 cm
T ~ 10^6 s
R ~ 3x10^16 cm
n = 1 cm^-3

What Causes GRBs?



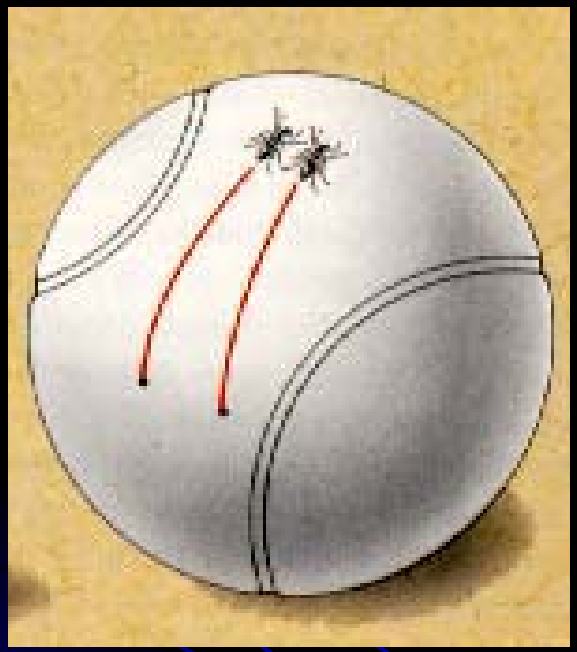
GRB – SUPERNOVA LINK

But what's the use of GRBs and Supernovae...?

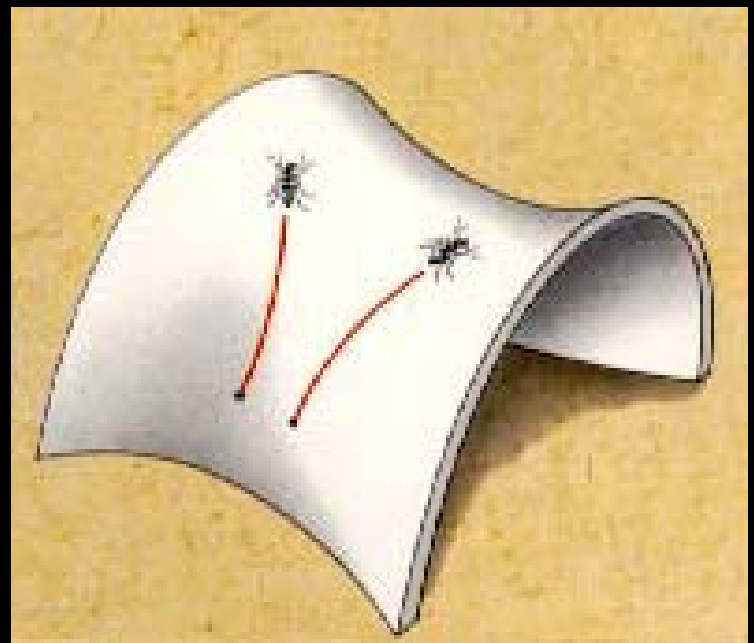
GRB – SUPERNOVA LINK

They can be used to probe the shape and fate of the Universe

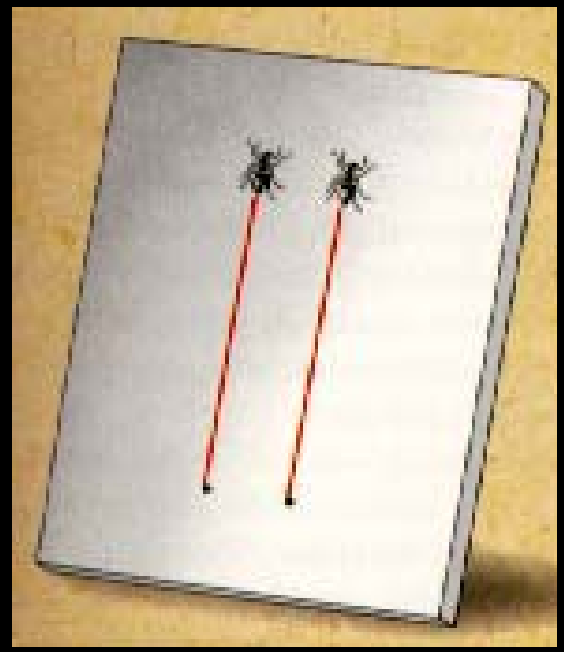
The Shape Of The Universe



Closed

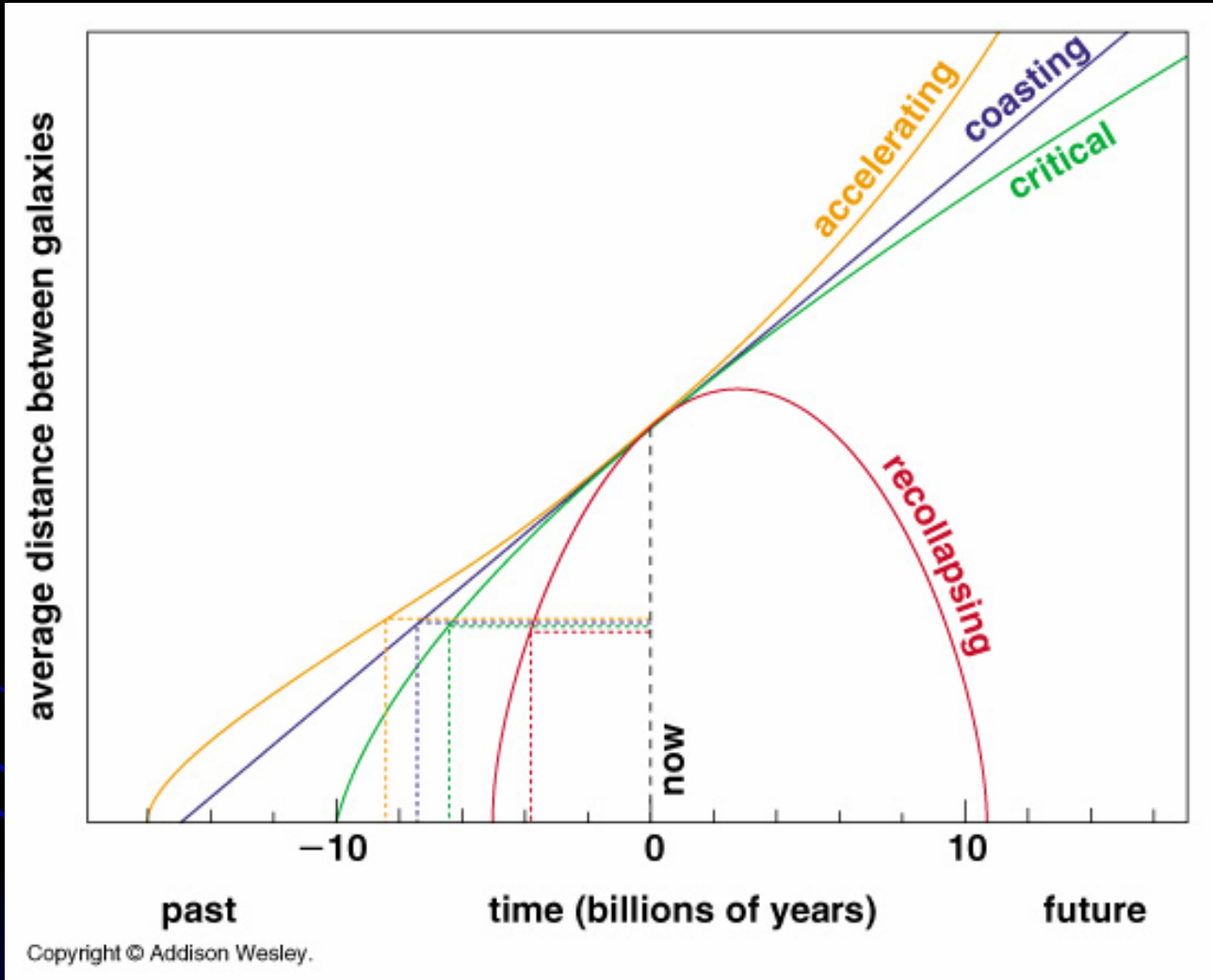


Open

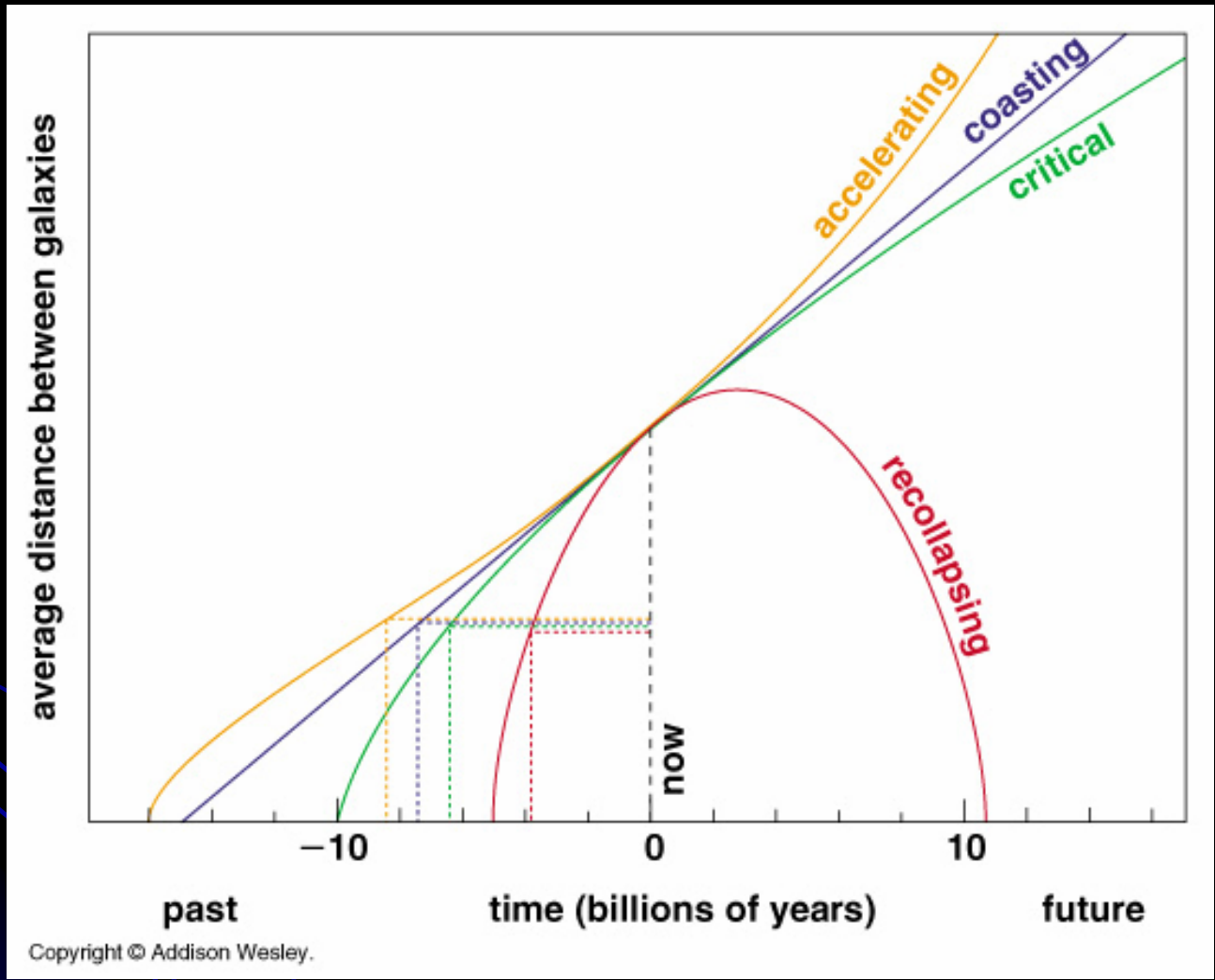


Flat

The Fate Of The Universe

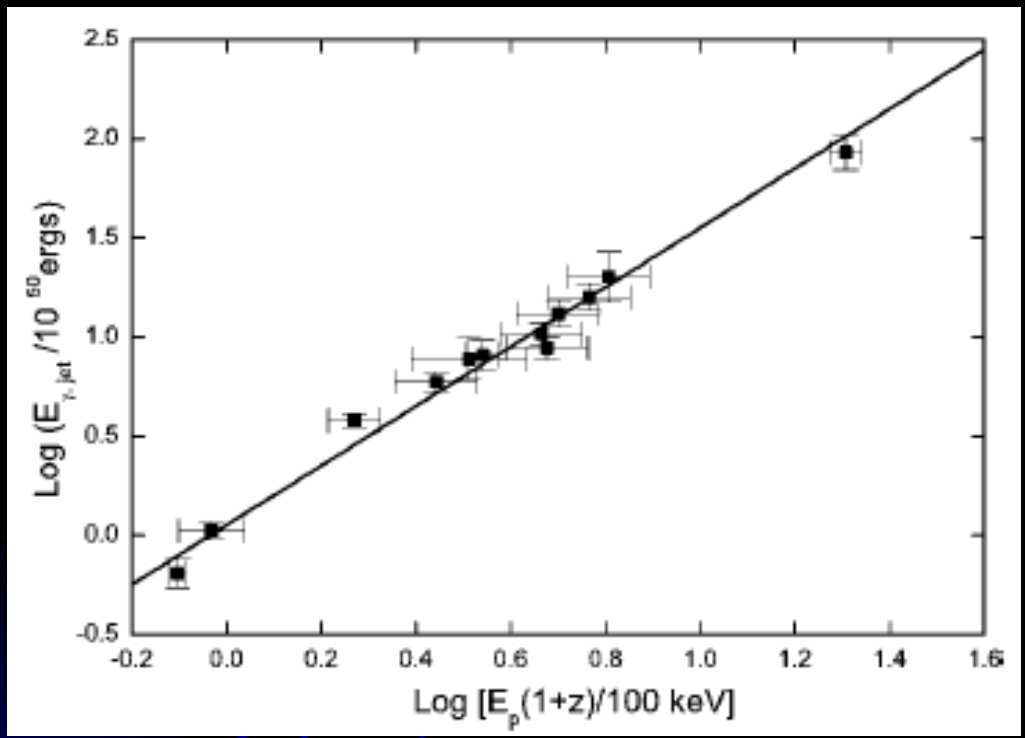


The Fate Of The Universe



How can GRBs help?

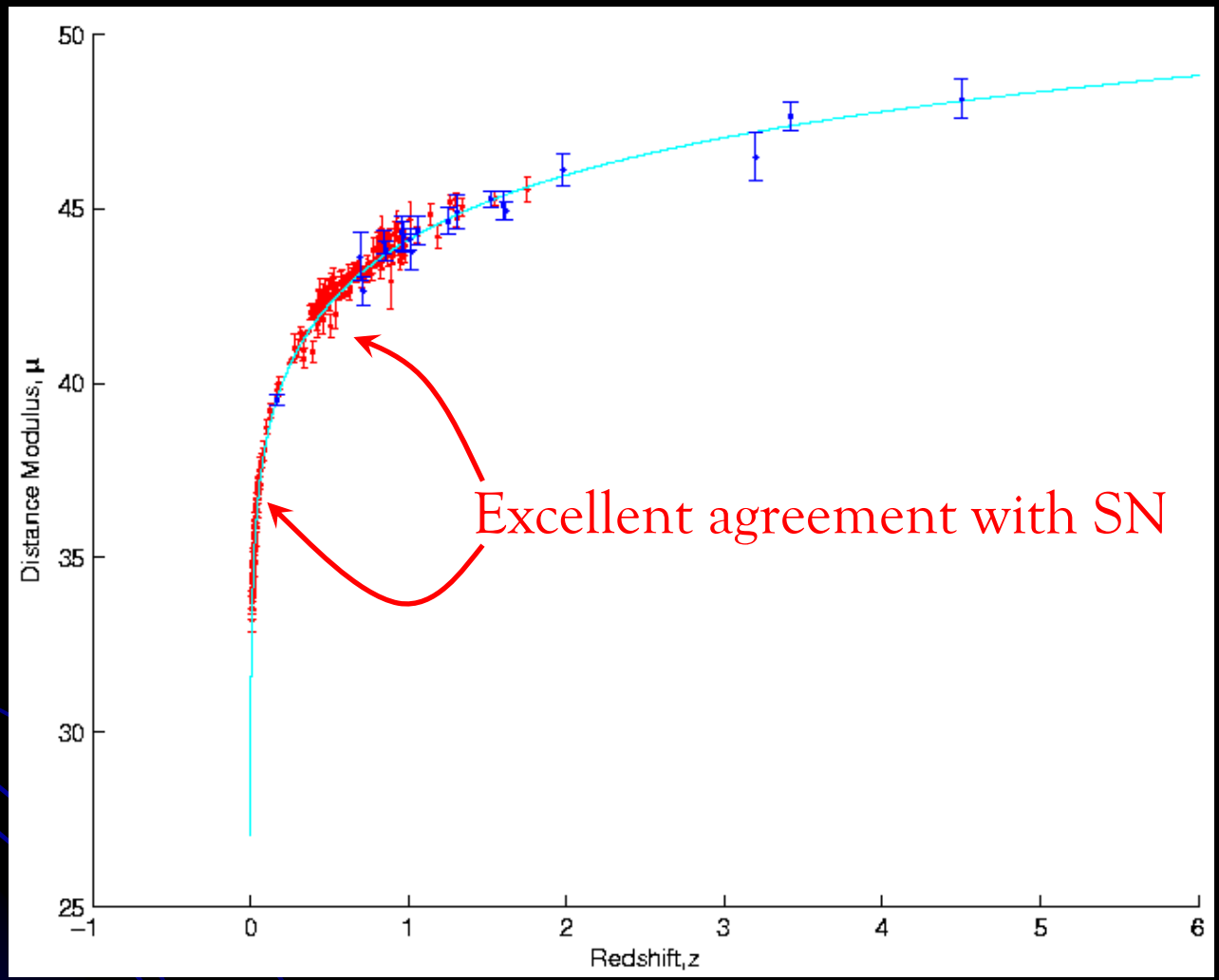
GRBs AS STANDARD CANDLES



The 'Ghirlanda' Relation

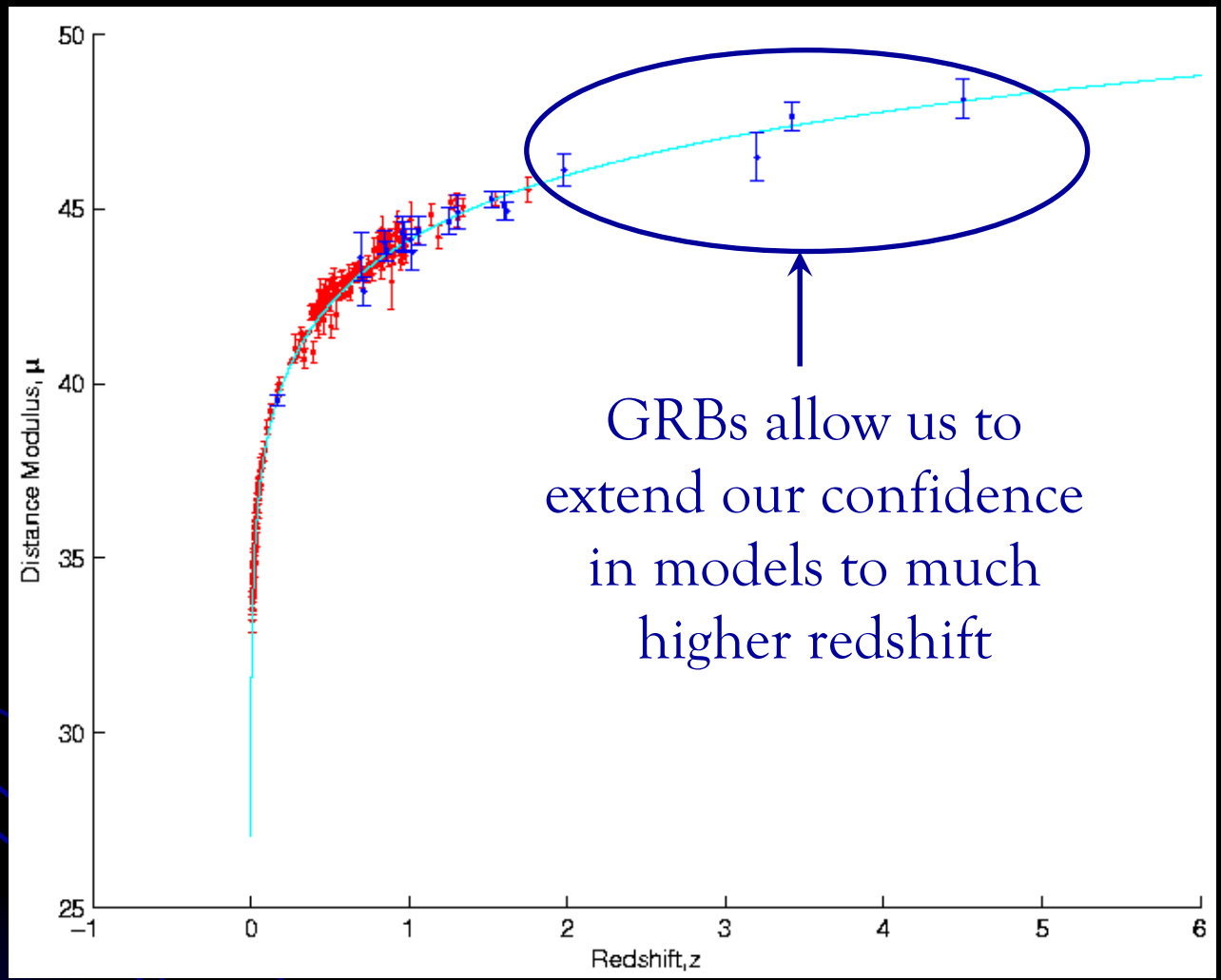
Recent work has identified potential properties of GRBs that may allow them to be used as standard candles

Observational Data



Hubble Diagram for SN and GRBs

Observational Data



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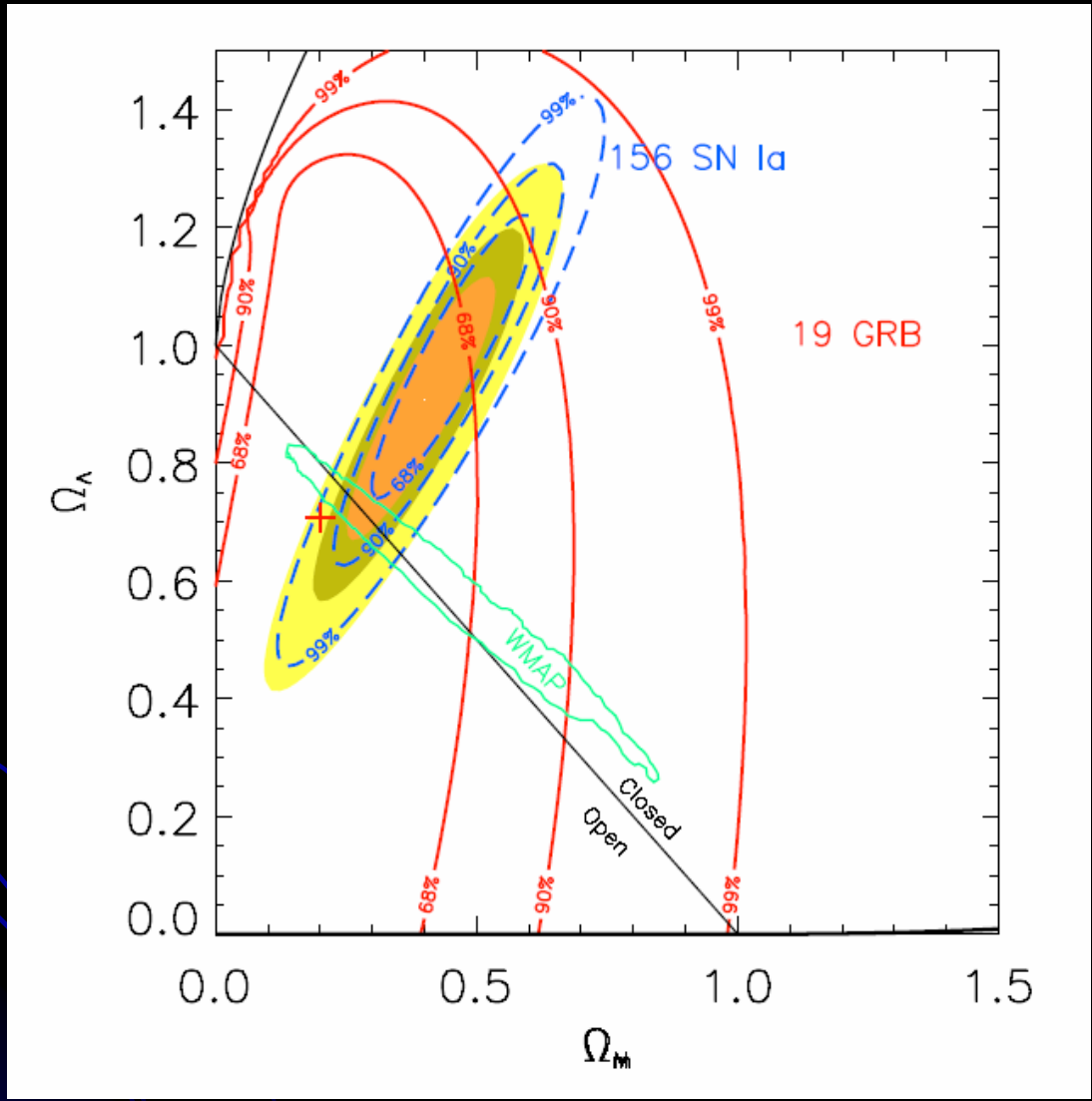
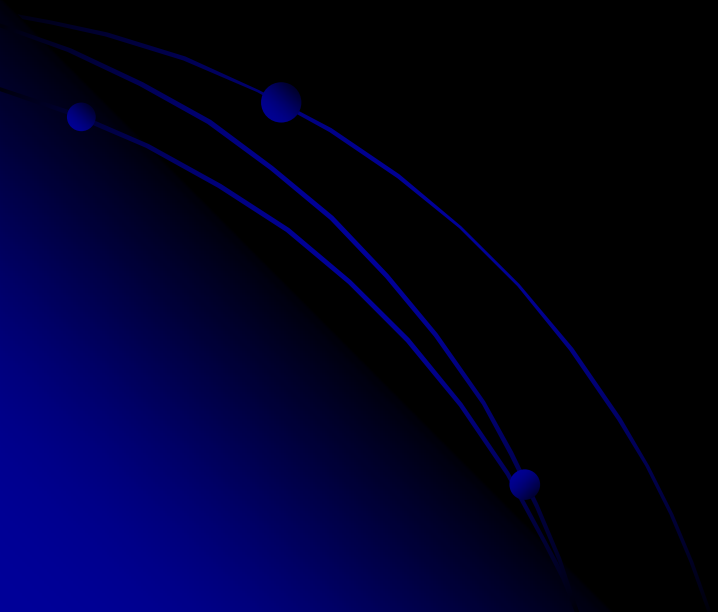


Problems With GRBs As Standard Candles

- GRBs are detected very frequently but accurate enough data only available for a very few sources



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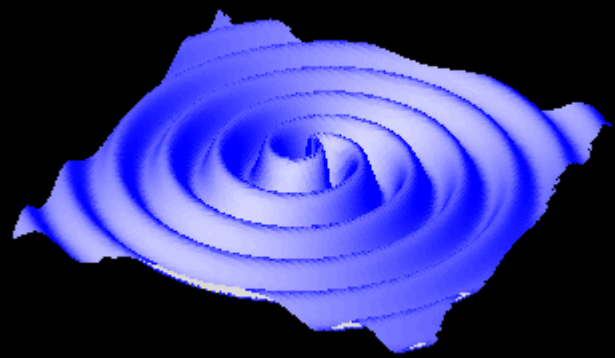
- GRBs are detected very frequently but accurate enough data only available for a very few sources
- Very new field – progenitors not fully understood
- Researchers may be guilty of looking for patterns where they don't actually exist
- But!! Very vibrant research field with great potential!

GRBs And Gravitational Waves

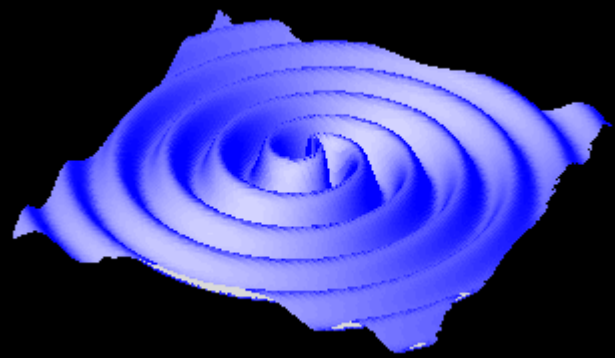
- Gravitational wave sources include inspiral mergers and formation of black holes...



GRBs And Gravitational Waves

- Gravitational wave sources include inspiral mergers and formation of black holes...

- GRBs should be the perfect candidate!



GRBs And Gravitational Waves

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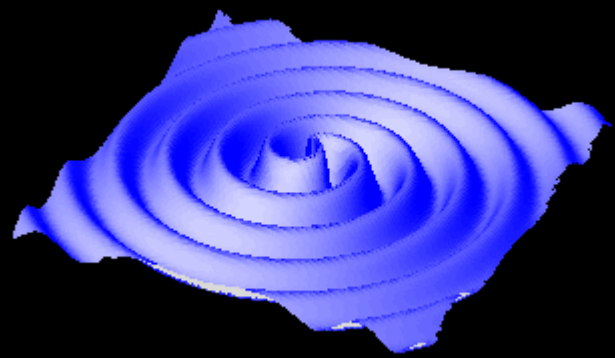
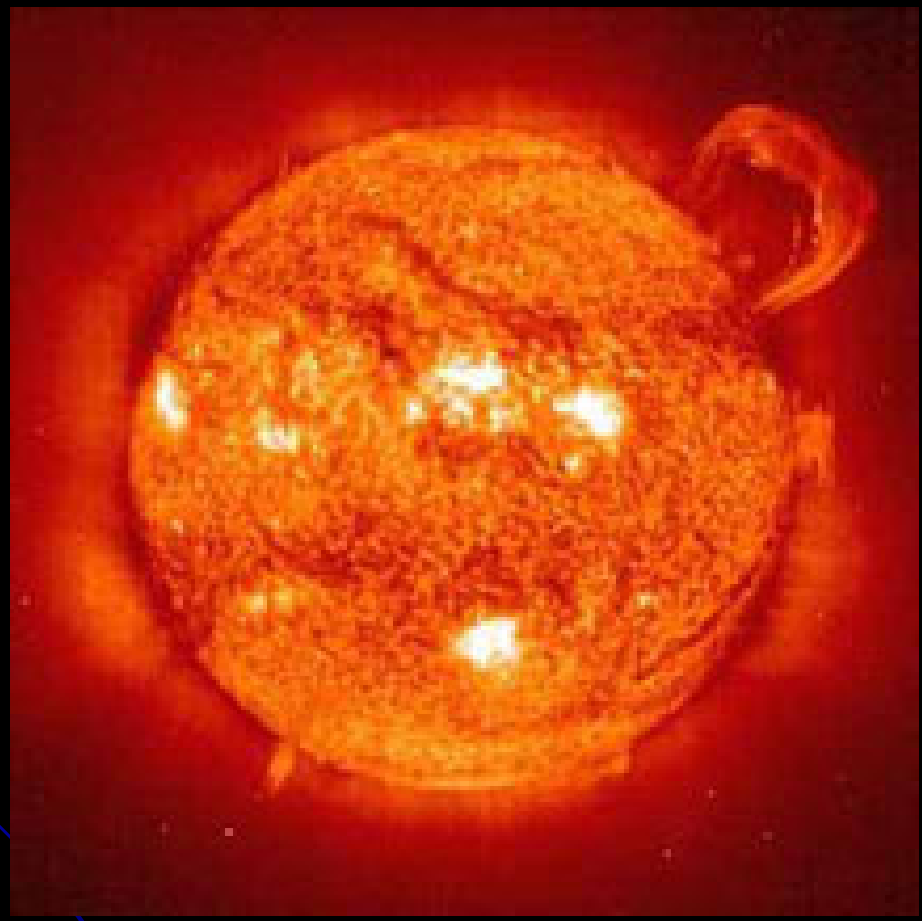


- GRBs should be the perfect candidate!

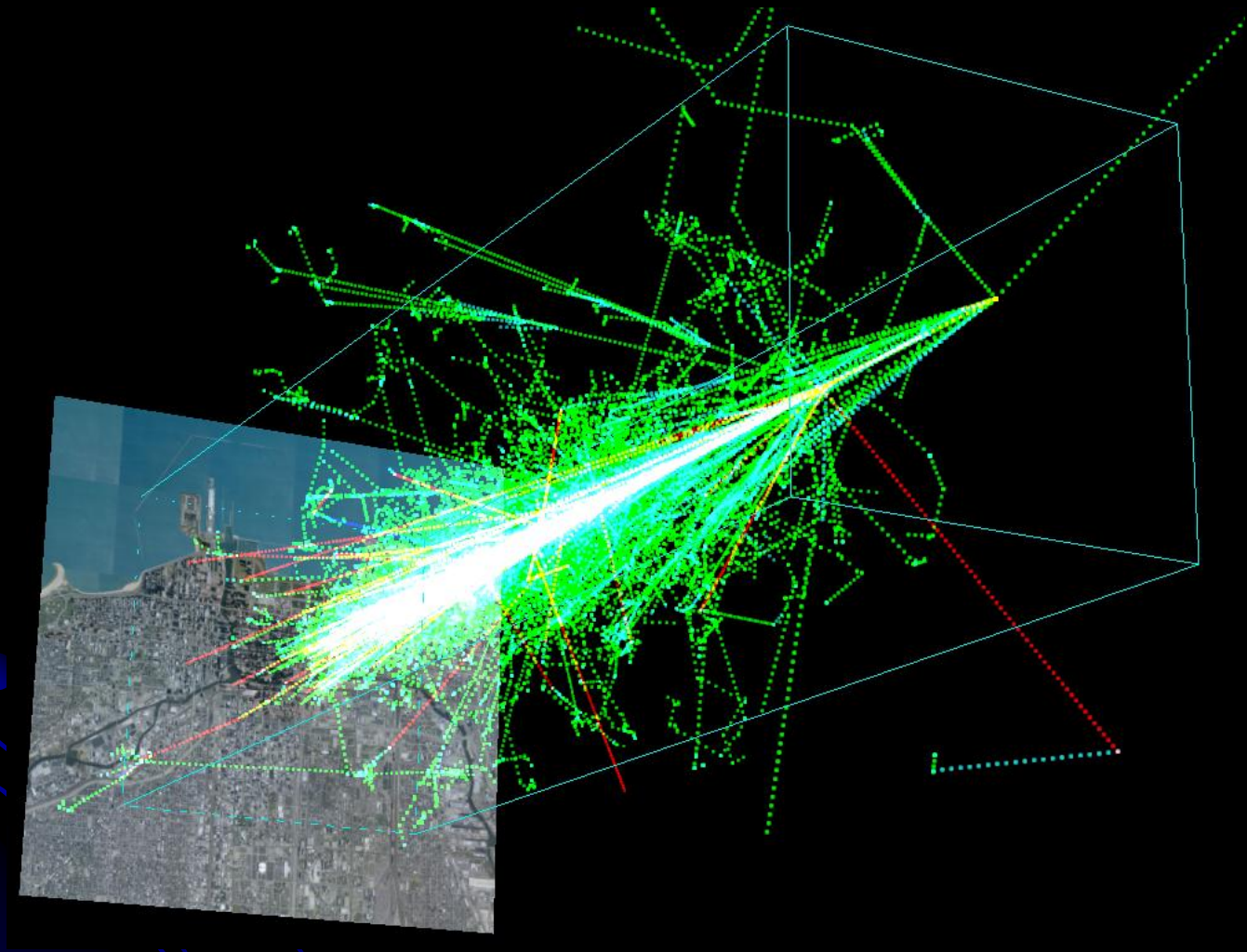
- ...although large distances are a disadvantage

Other Gamma Ray Sources



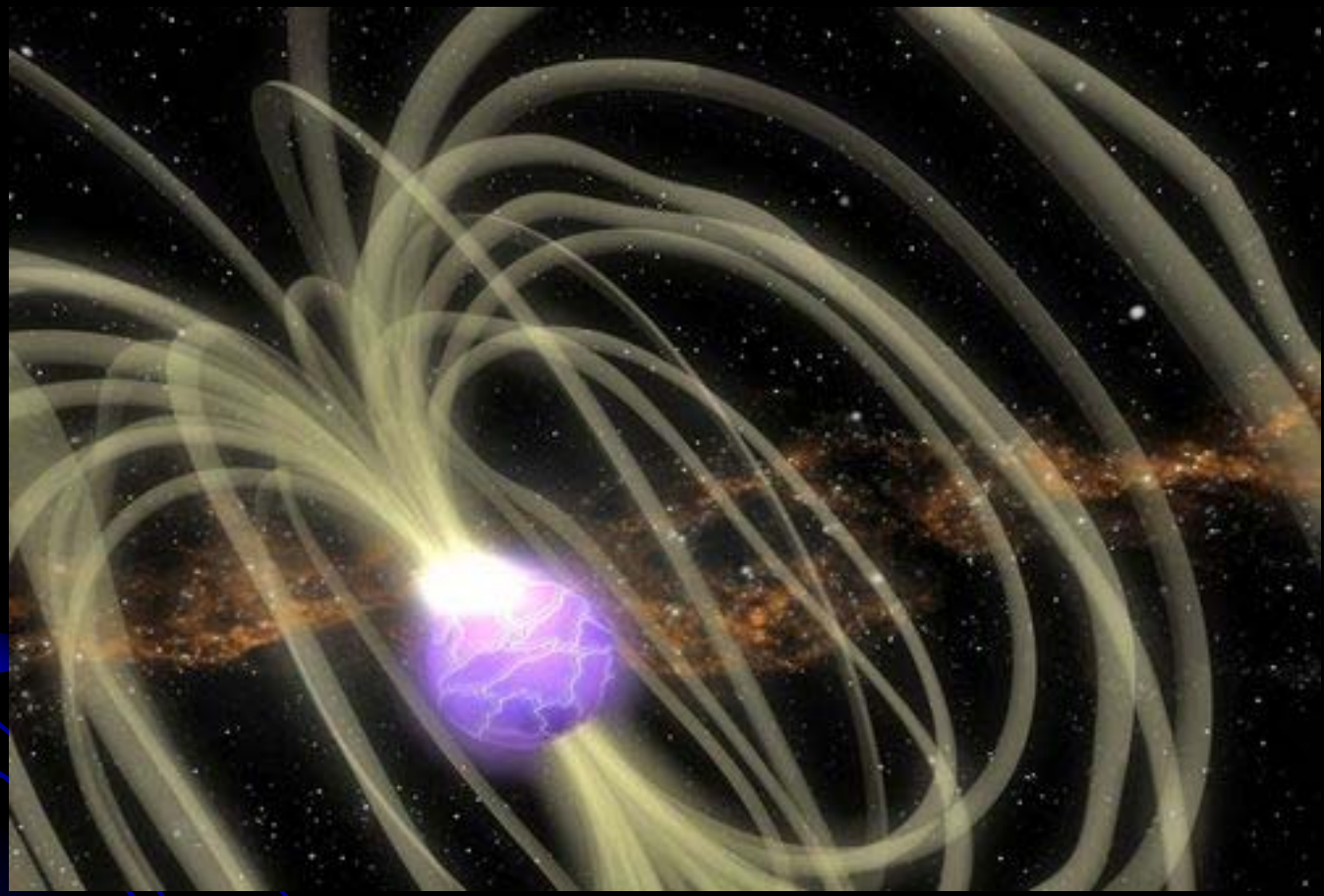
Solar flares

Other Gamma Ray Sources



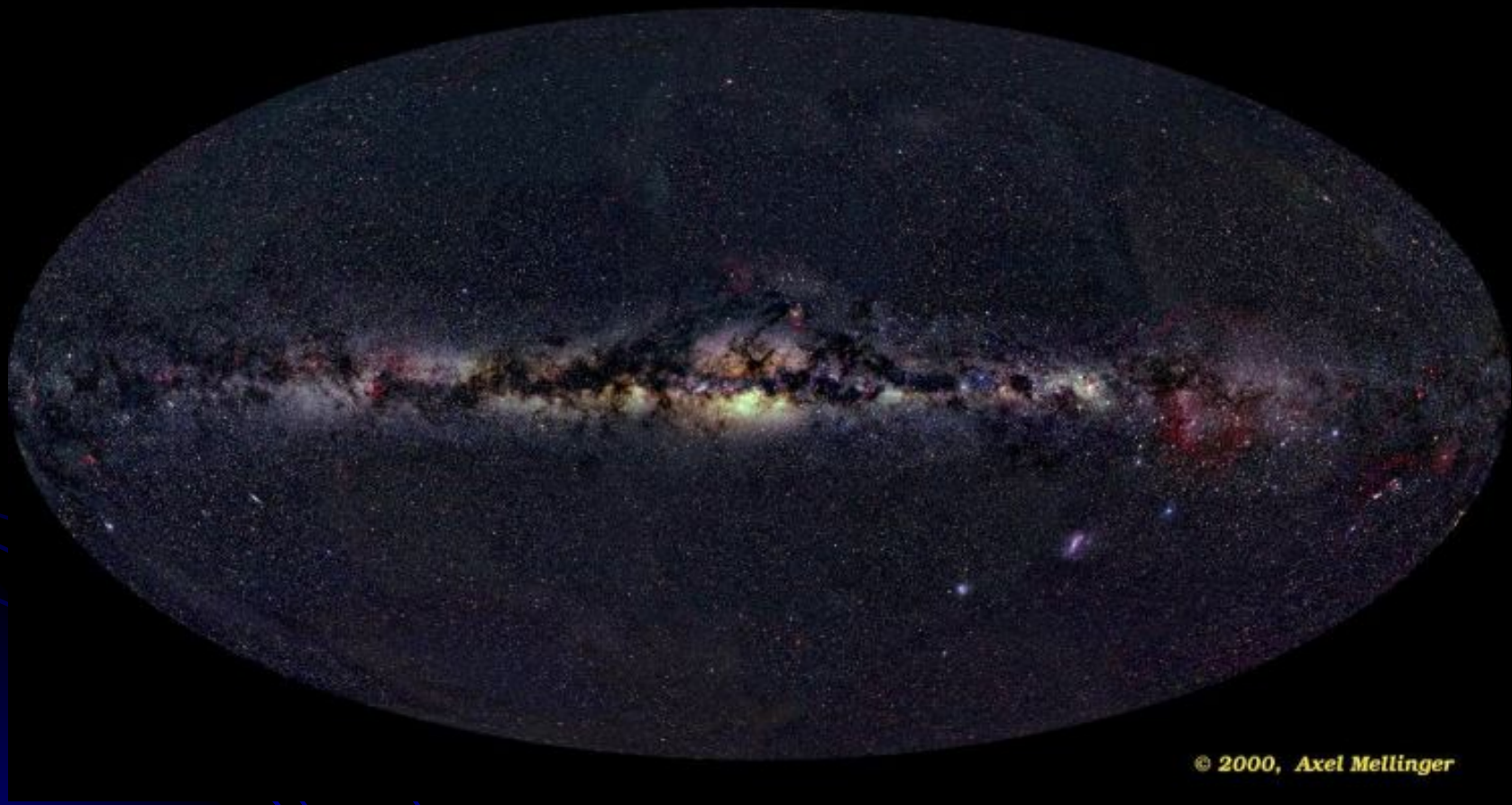
Cosmic rays interacting with the Earth's atmosphere

Other Gamma Ray Sources



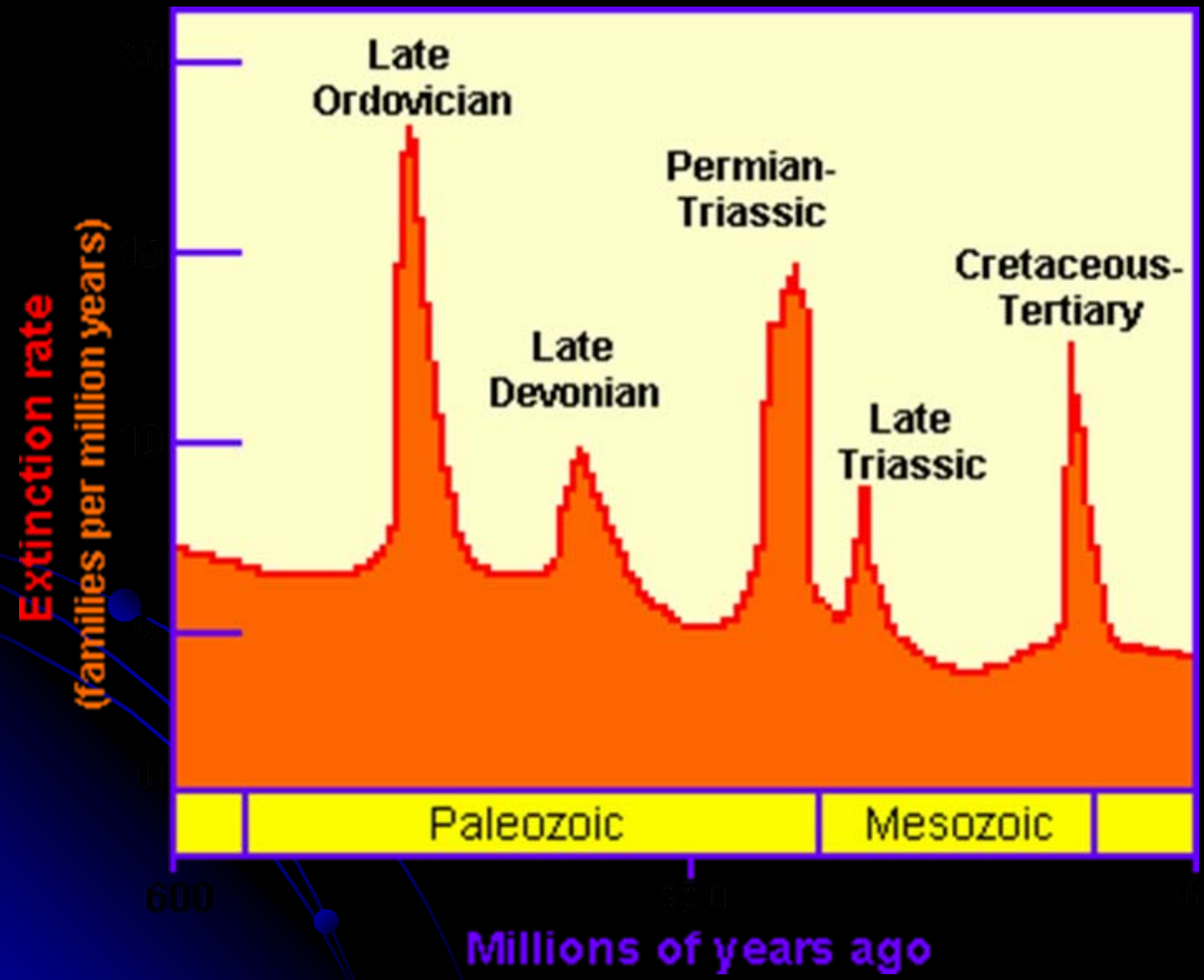
Magnetars – Neutron stars with exceptionally strong magnetic fields

Closer To Home...

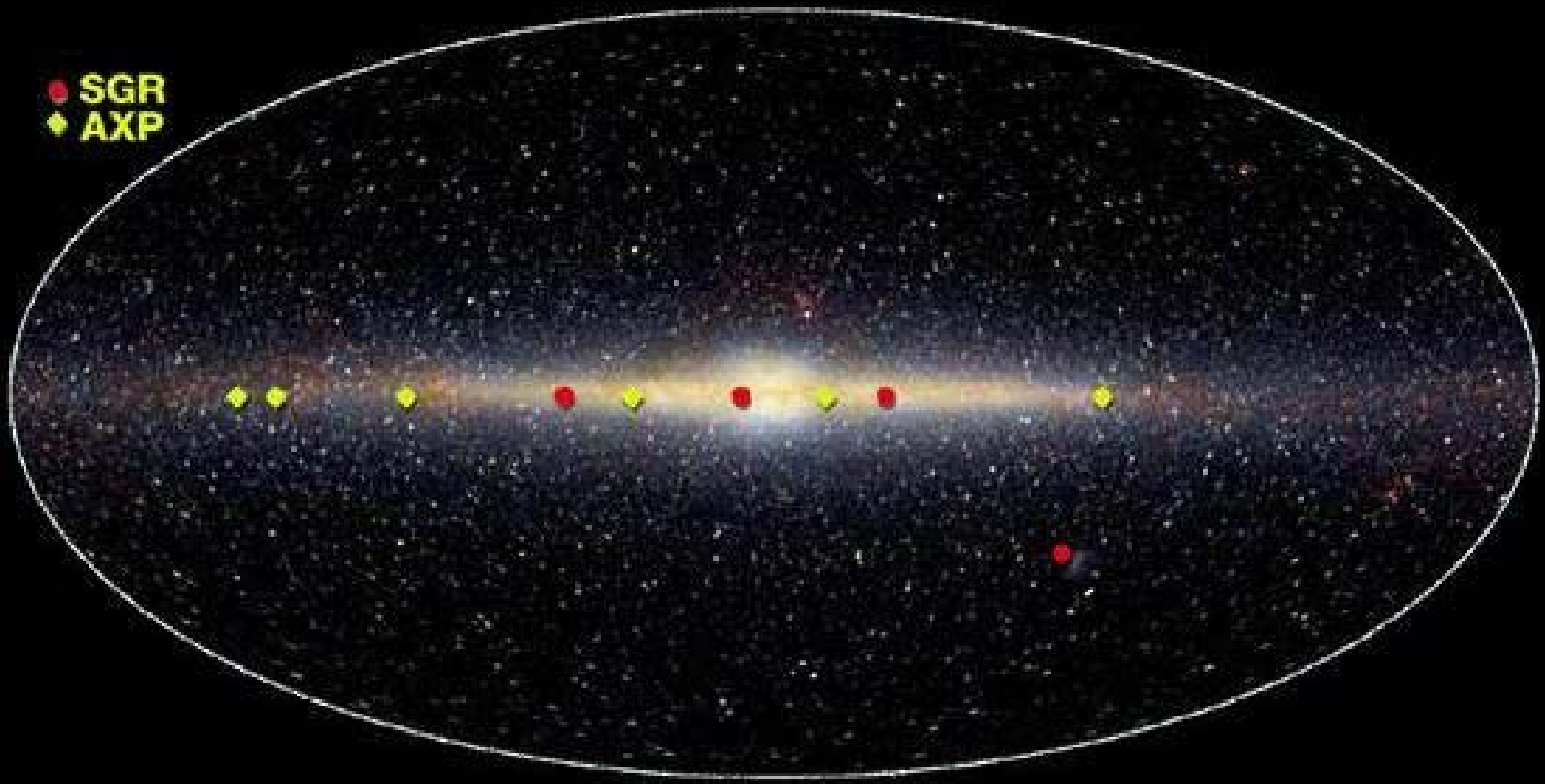


What if a GRB went off in our galaxy...?!

Closer To Home...



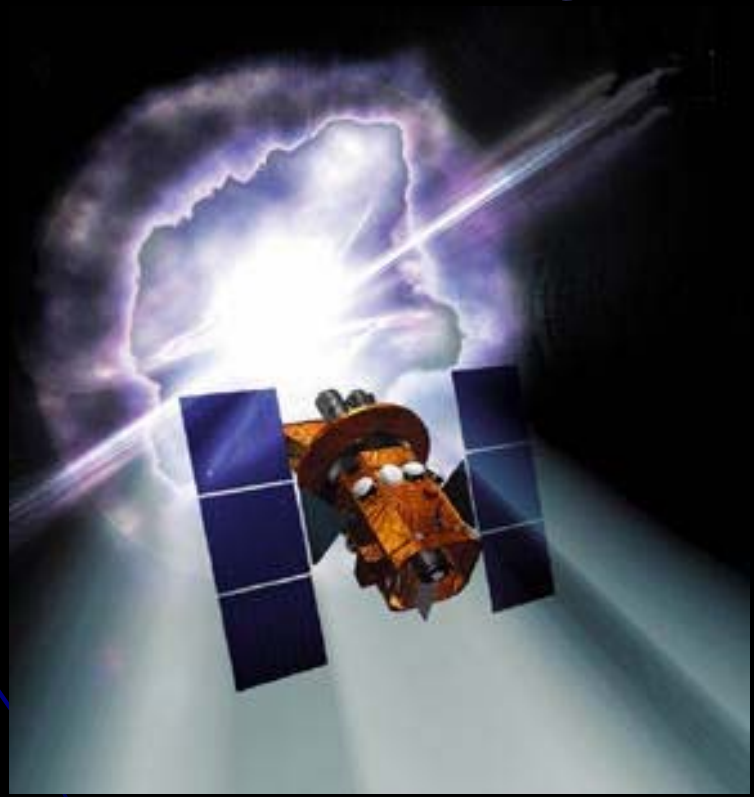
Closer To Home...



Soft Gamma Repeaters

UNIVERSITY of GLASGOW

Gamma Ray Bursts



Fiona Speirits, Dept. of Physics and Astronomy