Gamma-Ray Bursts

The accidental discovery and their current mysteries

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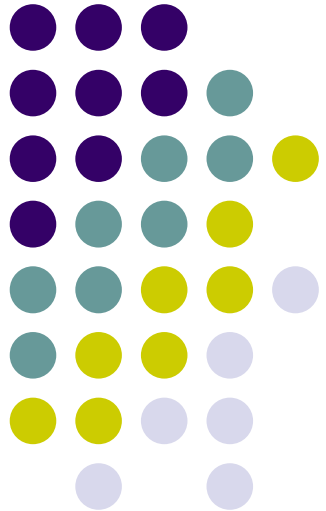
24-11-2006



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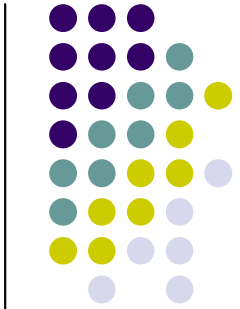
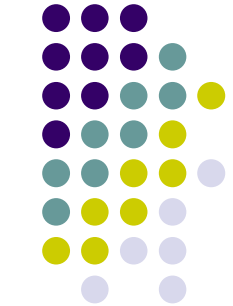


- Introduction; history
- Where do GRBs originate?
- What is a GRB?
  - energetics of GRBs
  - classification
- What causes them; progenitors
  - models
  - evidence
- Summary

History



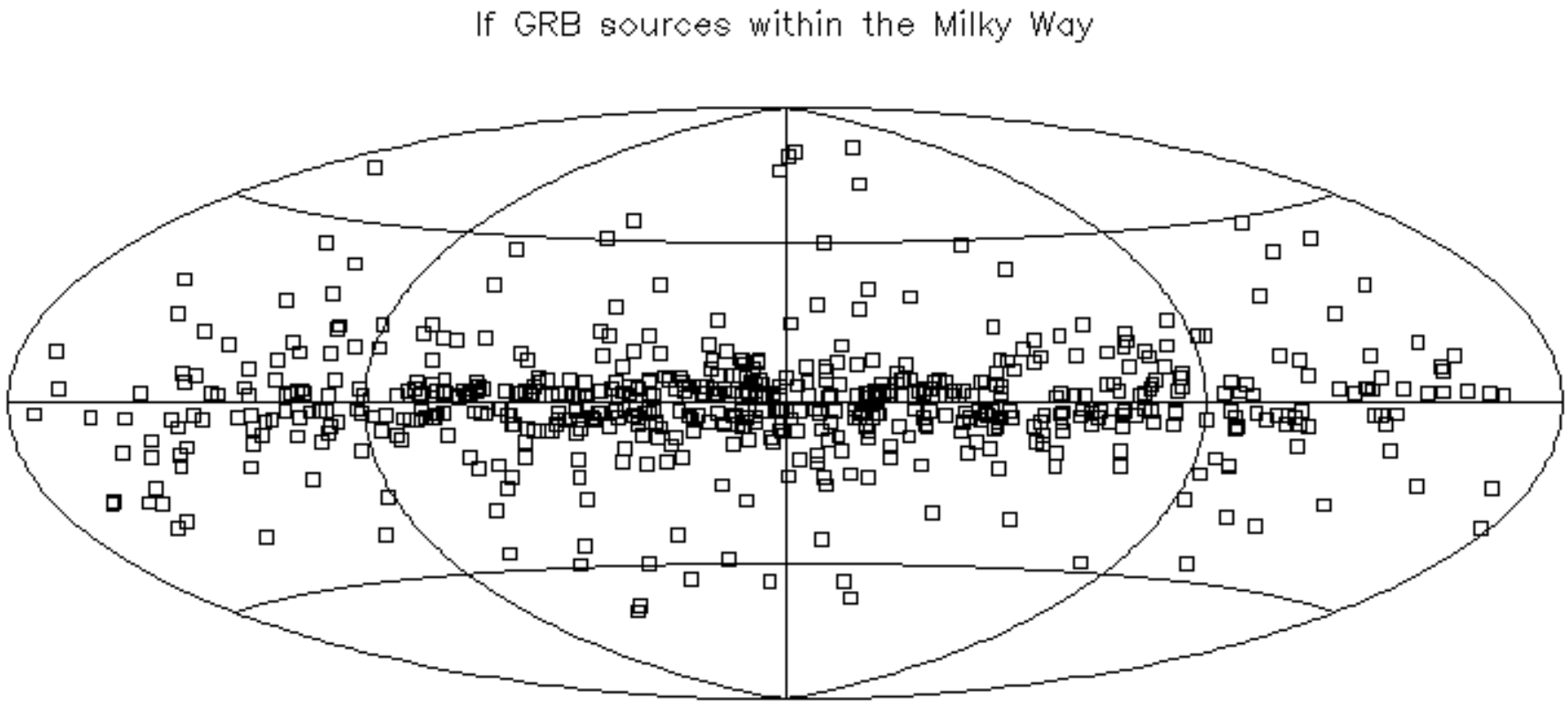
- 1963: Vela satellites launched to look for nuclear explosions
- Nuclear explosions create gamma-rays
- Evidence for short bursts not due to nuclear reactions
- 1973: Results finally published

Where do they originate?

- Accurate position could not be found
- Not from our solar system
- Three possibilities:
  - in the disk of the Milky Way
  - diffuse halo around the Milky Way
  - distant galaxies

- GRO satellite with BATSE could find the location

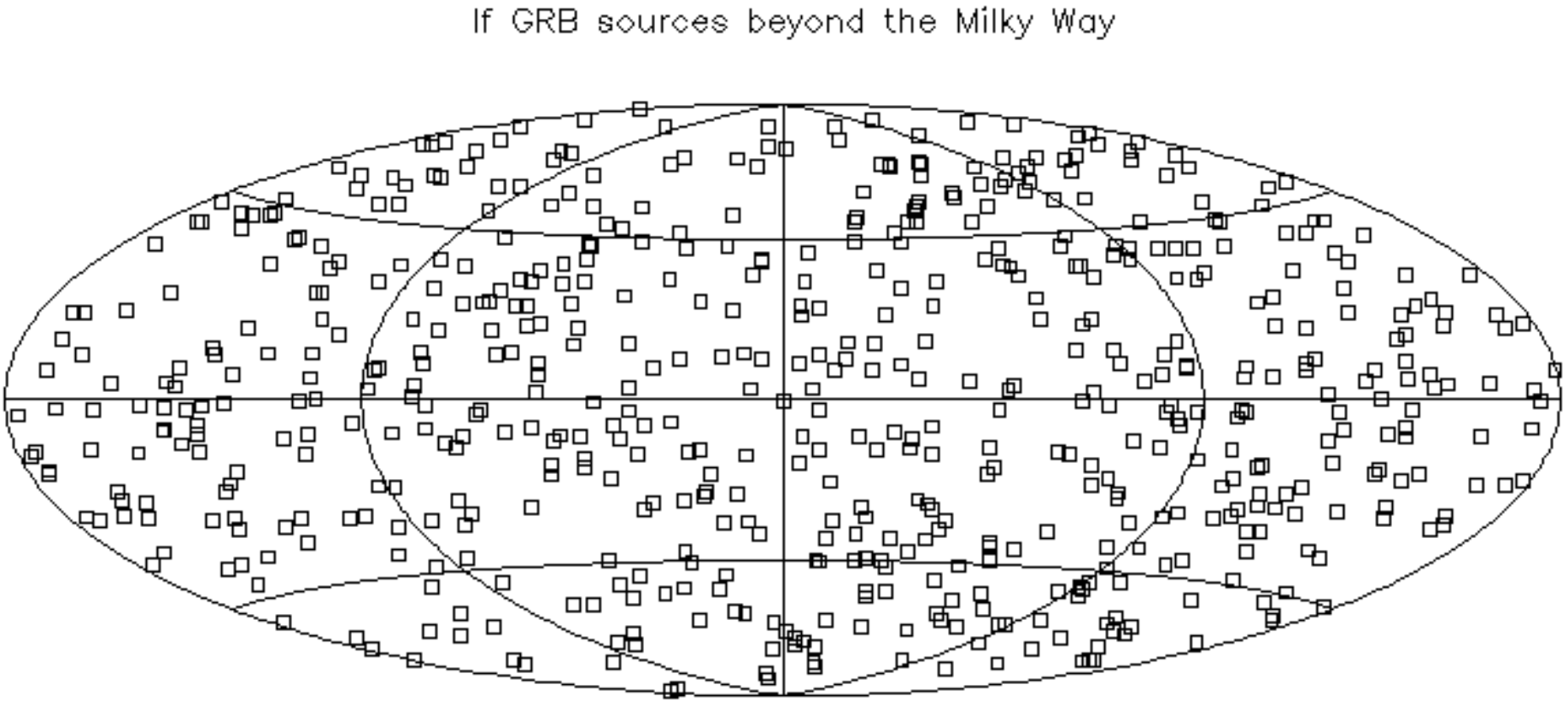
Milky Way



- Probably found in the disk, concentrated at the buldge

http://spiff.rit.edu/classes/phys240/lectures/grb_his/grb_his.html

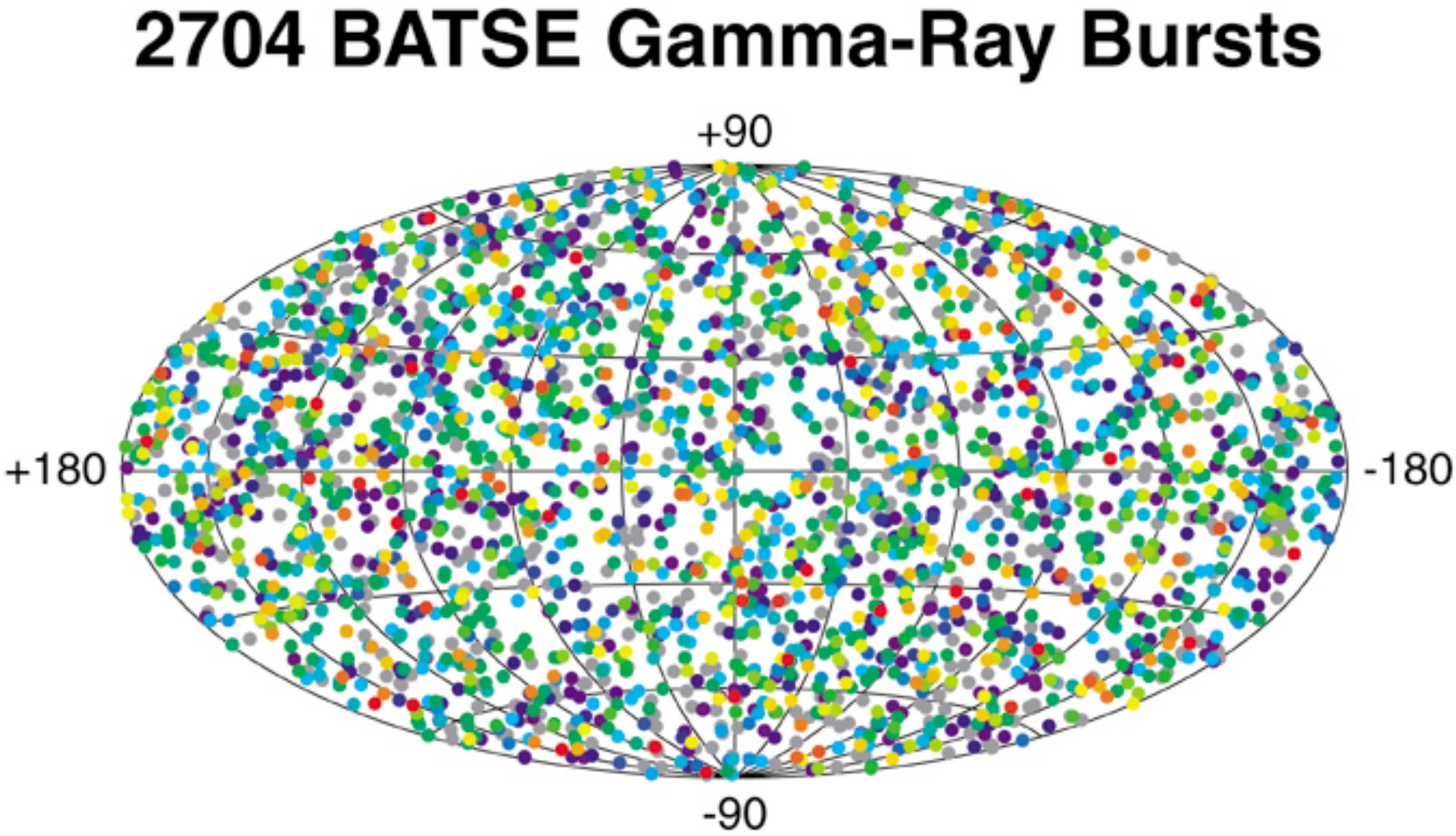
Halo/Distant galaxies



- Isotropic distribution

http://spiff.rit.edu/classes/phys240/lectures/grb_his/grb_his.html

BATSE distribution



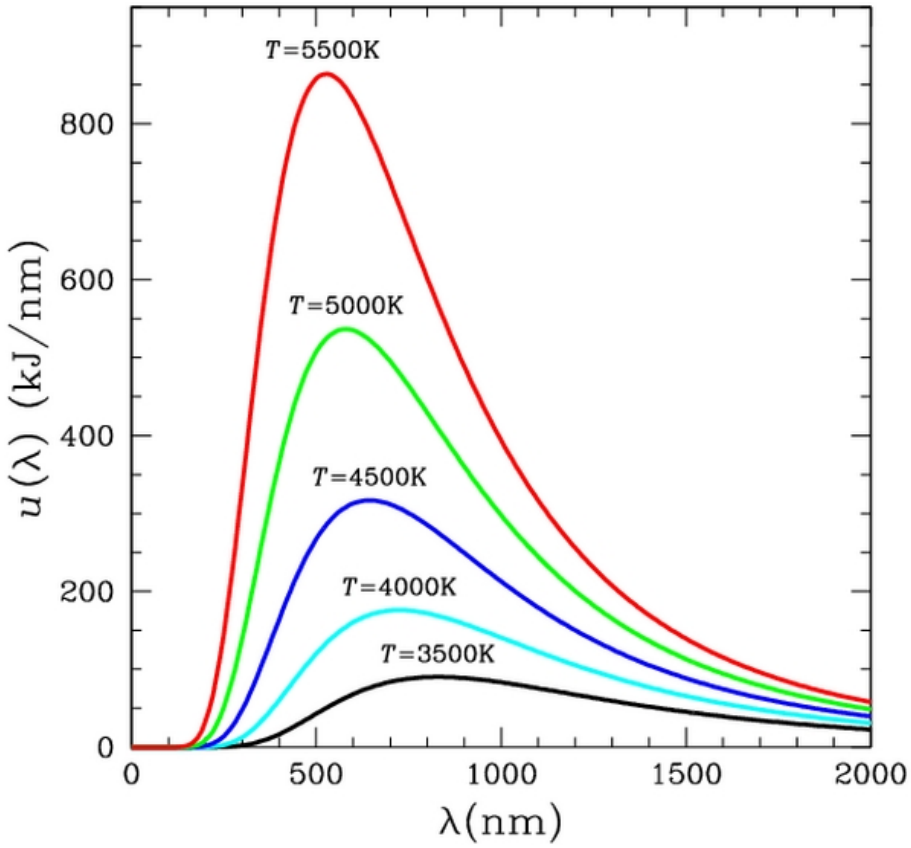
http://cossc.gsfc.nasa.gov/docs/cgro/images/batse/BATSE_2704.jpg

Where do they originate?

- GRBs originate in distant galaxies:
  - afterglow emissions associated with distant galaxies
  - typical redshift of 1.0 (8 billion ly)
  - most distant GRB; 12.3 billion ly

What are GRBs?

- Lasting a few milliseconds to several minutes
- Most luminous events since Big Bang
- Detected once a day
- GRBs are more than explosions of gamma rays



- Wien's law: $\lambda_{\max} = \frac{k}{T}$

http://en.wikipedia.org/wiki/Image:Bbs.jpg

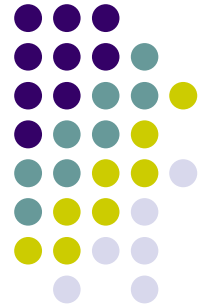
Energetics of GRBs

- Gamma-rays can be produced:
  - in nuclear explosions
  - when relativistic particles collide with low energy photons $E = h\nu = hc/\lambda$

- If the explosion is uniform, energy release is:
  - 10^{47} J
  - solar mass converted into energy

    - This is not possible!

Energetics of GRBs



- Energy release is along a narrow jet
- Opening angle varies greatly
- True energy release is constant at 10^{44} J
  - comparable to a supernova

- Consequence: we can't see all the GRBs
  - 500 occur a day

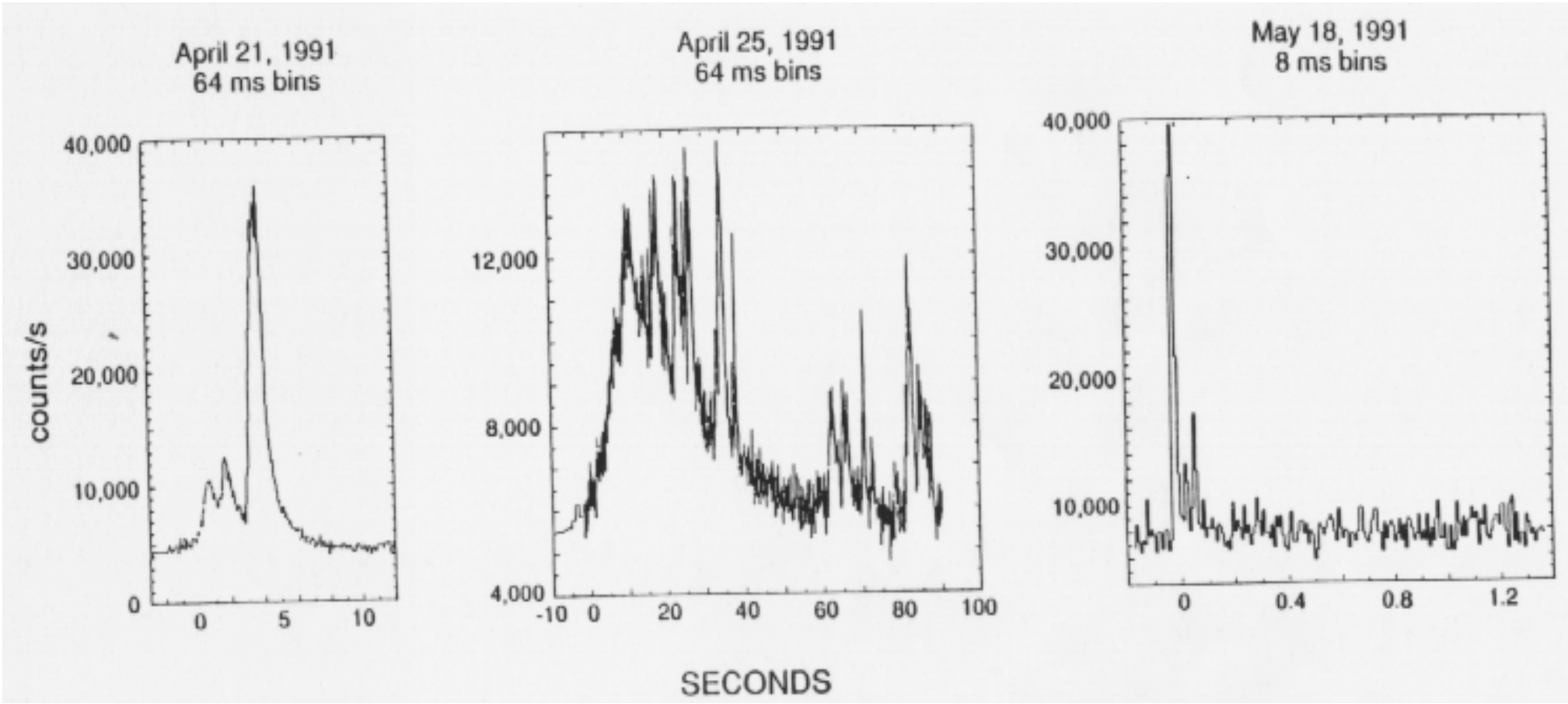
Classification

- Short-duration bursts
  - few milliseconds to 2 seconds
- Long-duration bursts
  - 2 seconds to several minutes

- Spectra
  - short bursts have a ‘harder’ spectra
  - evolve differently over time

- Different sources!

Spectra of GRB



http://aether.lbl.gov/www/projects/neutrino/grb/burst_duration.html

Progenitors of long bursts

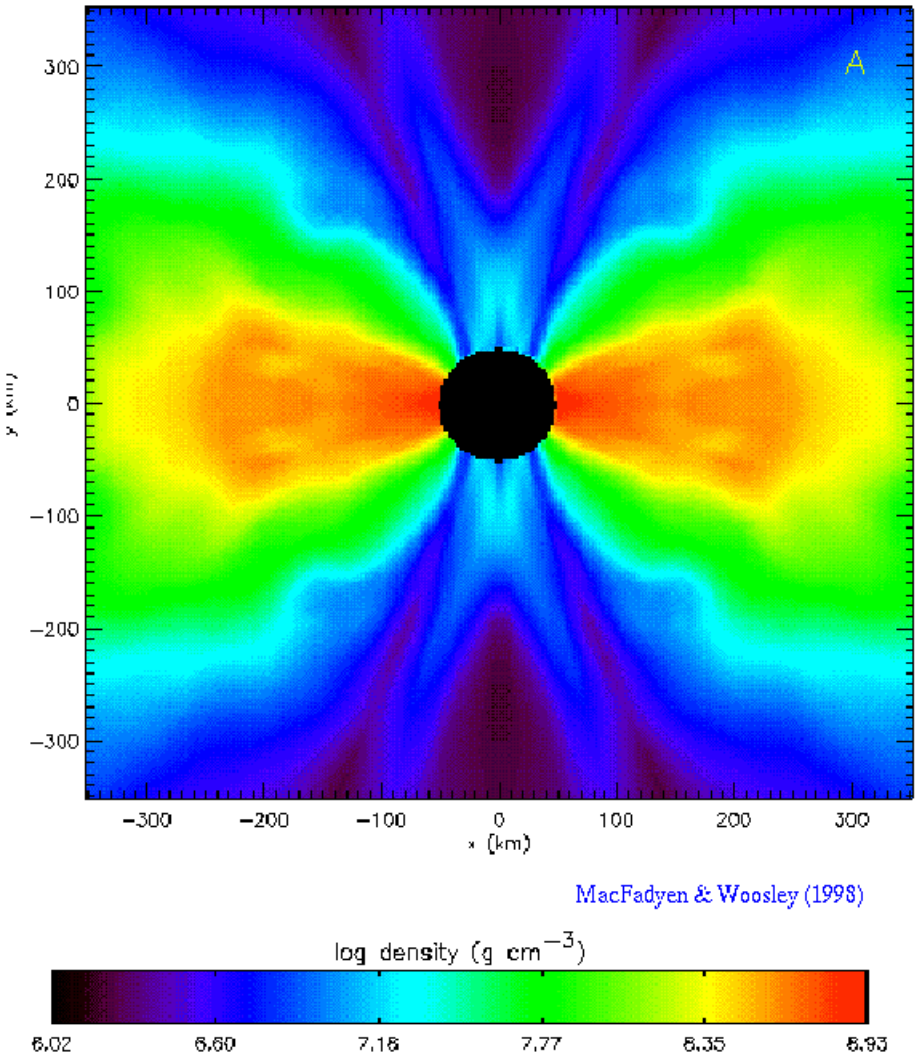
- More information about long bursts
- Needed to find an “afterglow”
- 1997: BeppoSAX finds afterglow associated with distant galaxy

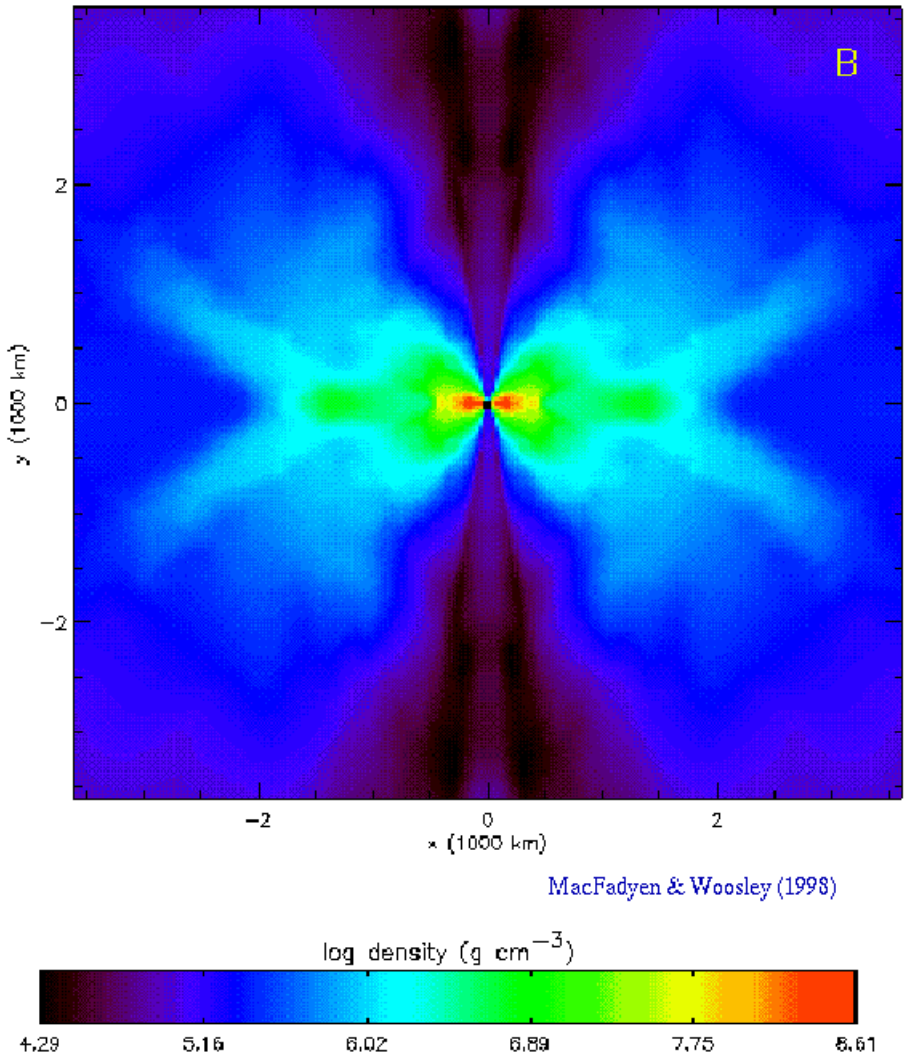
- Progenitor: Collapsar or hypernova
  - collapse of the core of a hypernova

Hypernova/Collapsar model

- Caused by Wolf-Rayet star
- Core collaspes
- Black hole forms inside
- Accretion disk forms around the black hole
  - Angular momentum of the infalling matter

Accretion disk

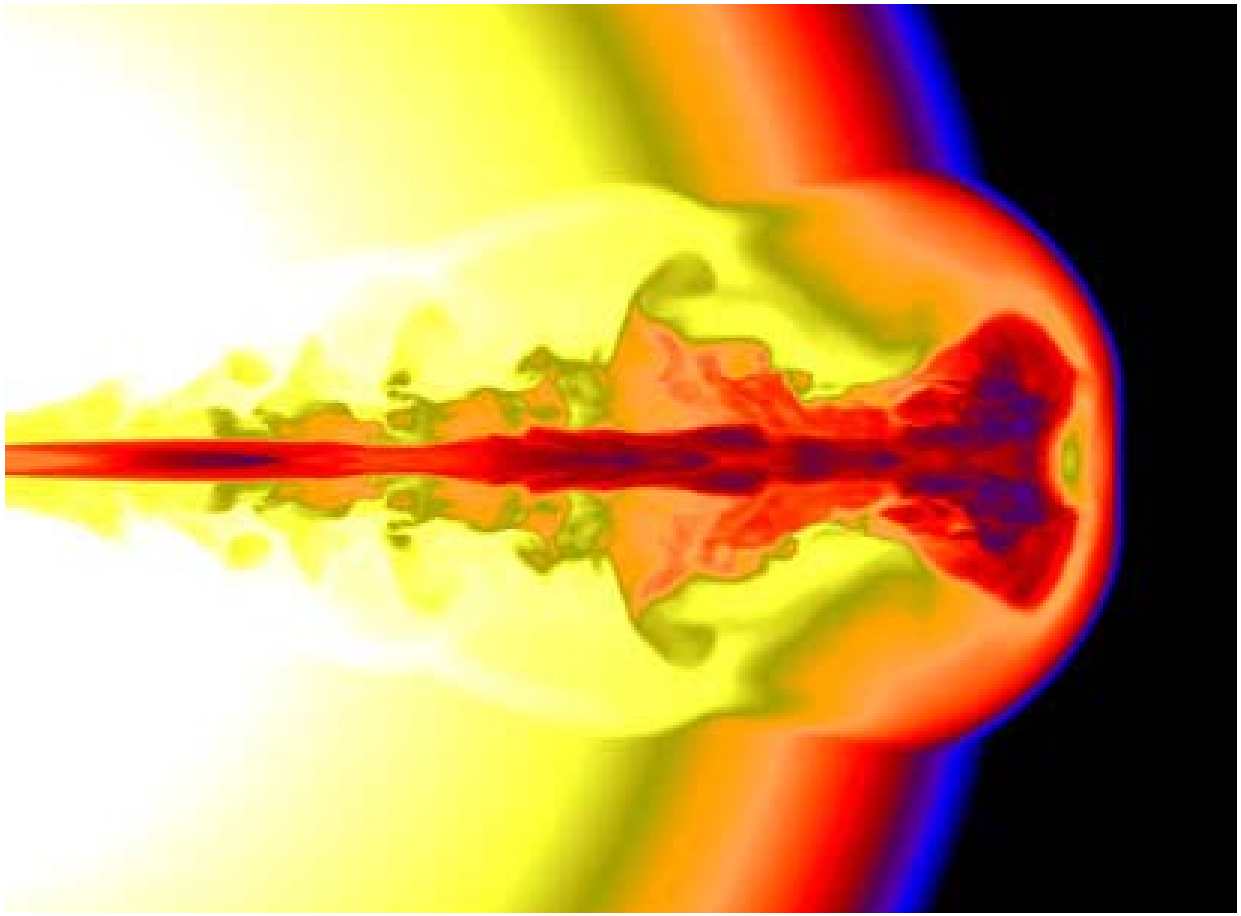


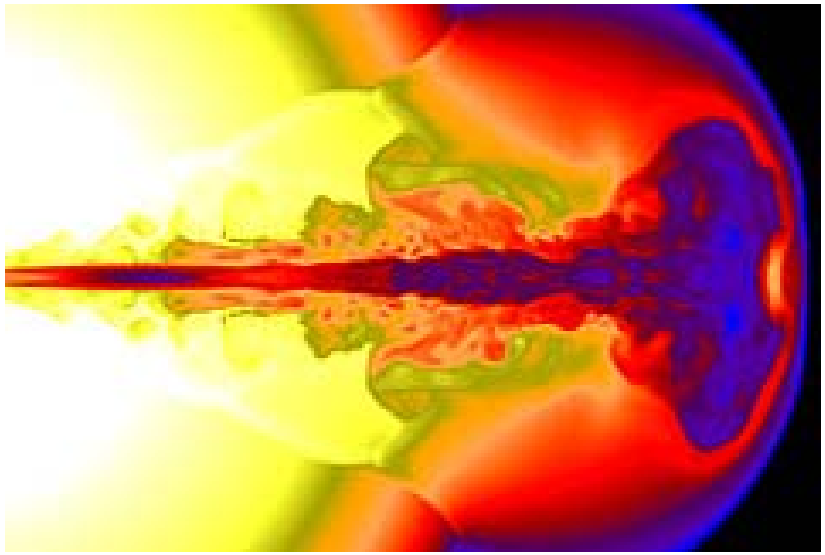


http://www.ucolick.org/~andrew/

The jet

- A pair of jets gets driven out from the rotation axis
  - neutrino annihilation or magnetic forces can deposit energy over the disk poles
  - energy comes into contact with matter falling inward
  - matter gets heated up
  - expands in the direction with the lowest resistance





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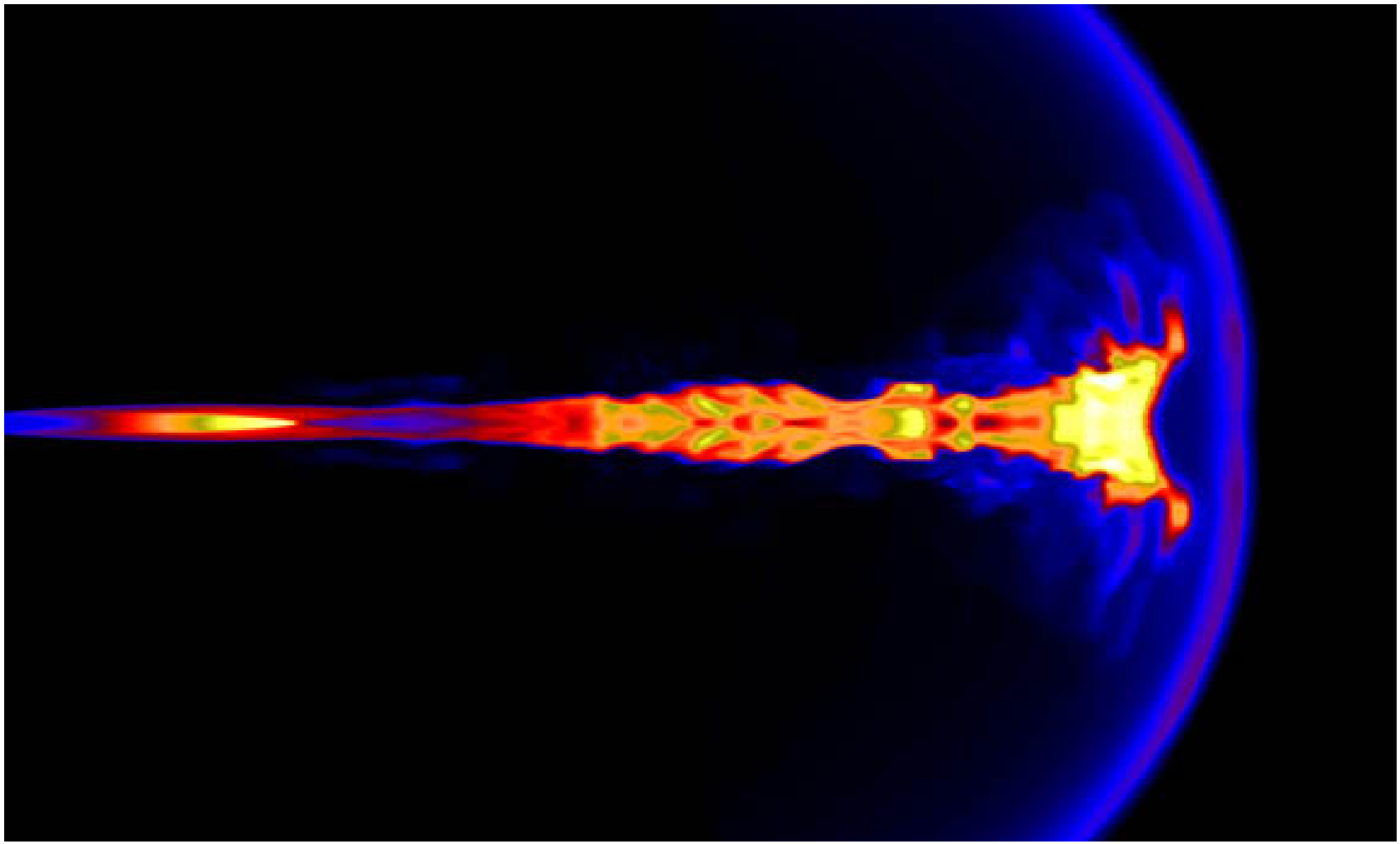
Gamma-ray burst

- Producting of gamma rays
  - collision between jet and matter
  - internal collisions in jet

- Jet accelerates as density decreases
- Stellar material collides with interstellar gas
  - this excites new emmisions: “afterglow”
    - can last for days or weeks

Gamma-ray burst



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Collapsar Model

Evidence

- Found in systems with abundant star formation
  - spiral arms of spiral galaxies
  - irregular galaxies
    - massive stars evolve and die rapidly
- Occures more in younger galaxies
  - more star formation
- Detection of supernova almost immediately after GRB

GRB 030329

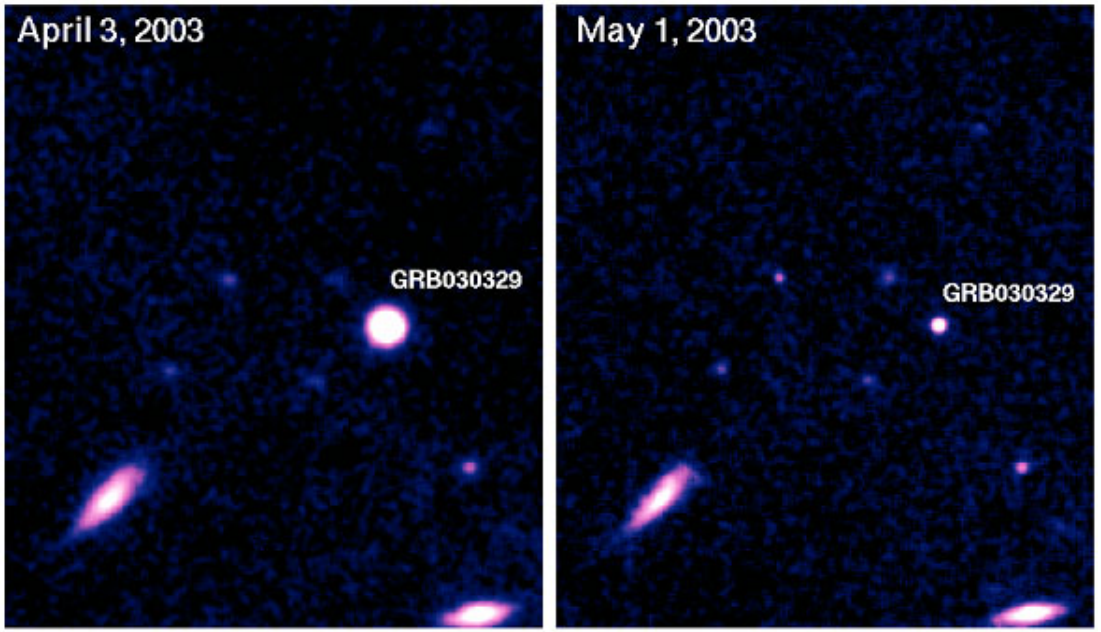
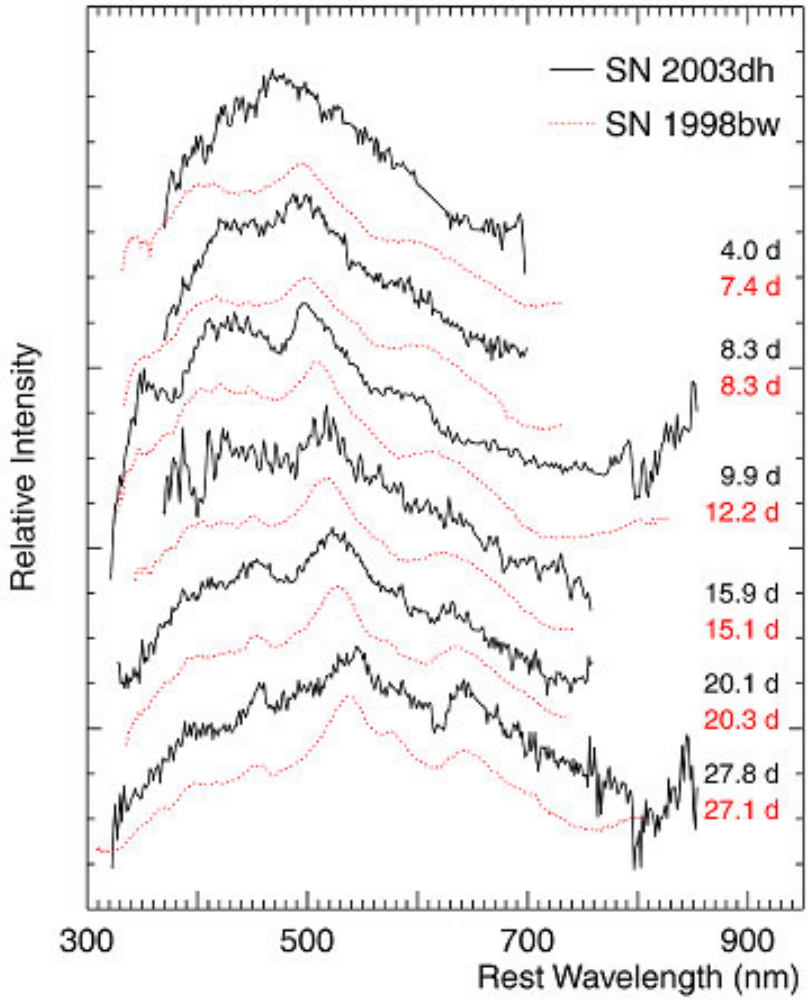


Image of Afterglow of GRB 030329
(VLT + FORS)

ESO PR Photo 17a/03 (18 June 2003)



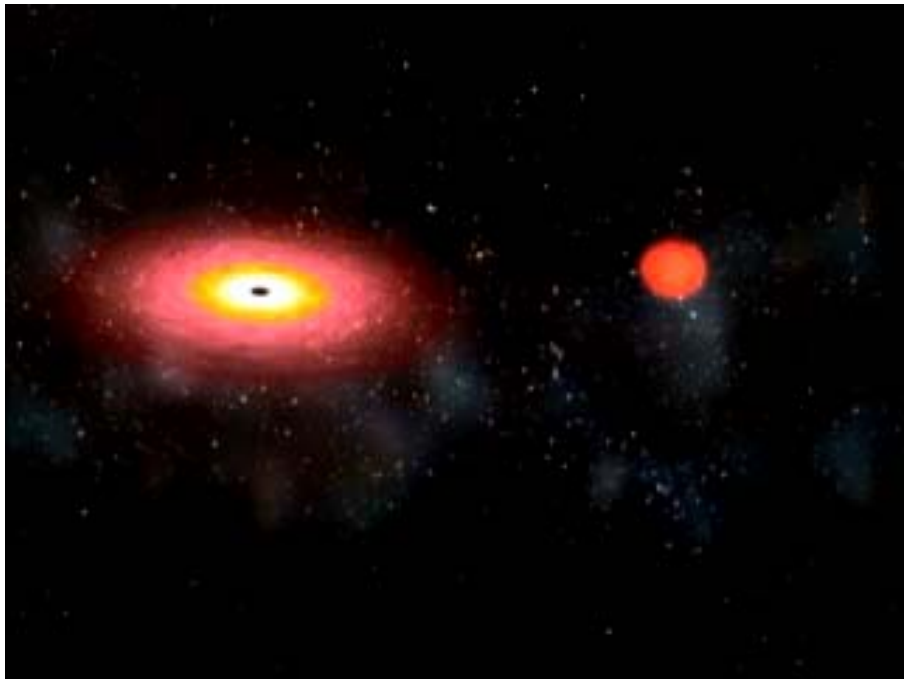
Visual Spectra of Hypernova in GRB 030329
(VLT + FORS)

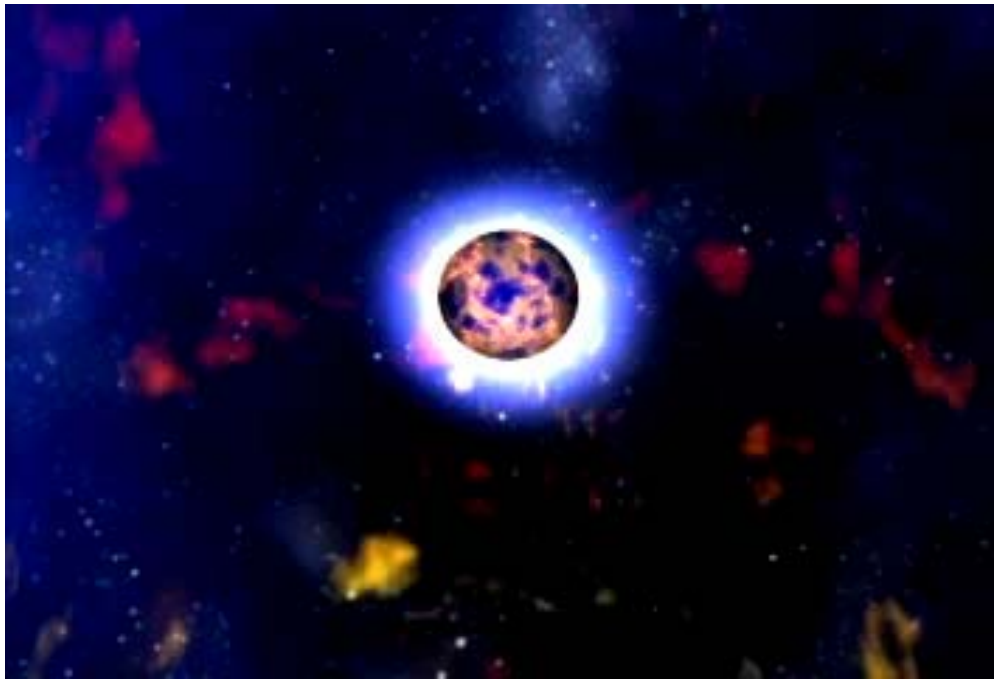
ESO PR Photo 17b/03 (18 June 2003)

Progenitors of short bursts

- 2005: Swift captured afterglow
  - GRB lasted 30 milliseconds
- Possible progenitors:
  - neutron star – neutron star merger
  - neutron star – black hole merger
- Binaries spiral together due to energy loss
- Over in a few seconds

Merger simulations

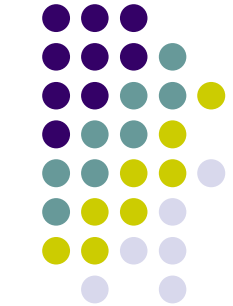




http://www.nasa.gov/vision/universe/watchtheskies/short_burst.html

http://www.nasa.gov/mission_pages/swift/bursts/short_burst_oct5.html

Evidence



- Associated with old galaxies
  - no star formation
- Located at the edge of the host galaxy
  - neutron star formation ‘kicks’ the binary out
- Nearer than long bursts
  - older galaxies
    - these binaries need time to evolve

Summary

- Explosion of gamma-rays
- Followed by an afterglow
- Beamed in jet
- Long bursts
  - t > 2 seconds
  - core collapse of a hypernova
- Short bursts
  - t < 2 seconds
  - N+N or N+BH merger
- Birth of black hole

Questions?