Gamma-Ray Bursts

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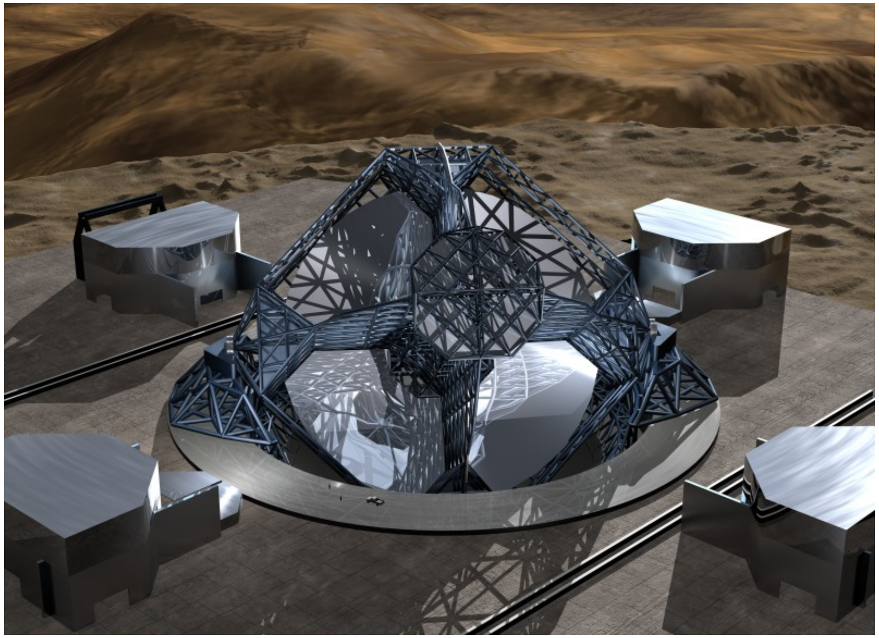
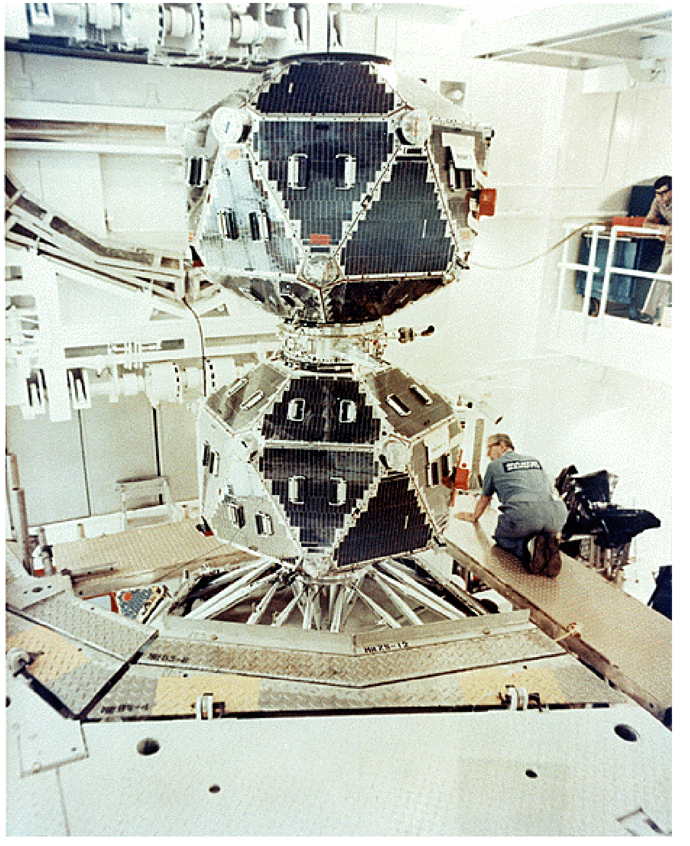
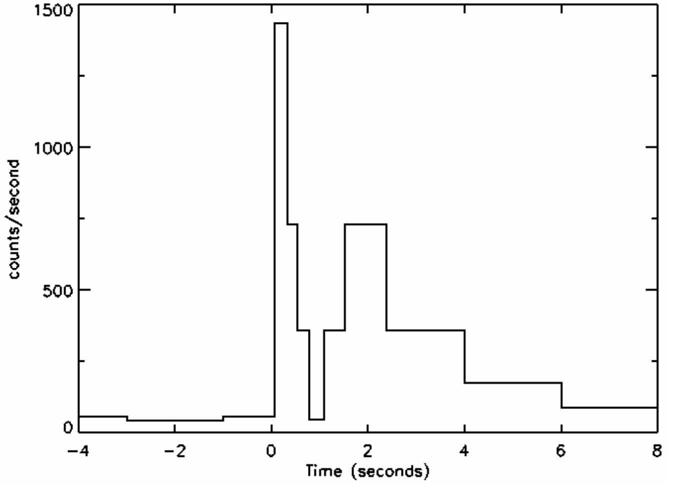


Gamma Ray Burst discovery

- 1963 - 1st pair of Vela satellites launched.
- 1965 - Ray Klebesadel starts to save data containing ‘interesting’ signals.
- 1969 - Vela 5&6 launched with better timing resolution.
- 1972 - Review of Vela data indicates that “interesting signals” do not originate from the Earth, Sun or Moon.

(Klebesadel et al., 1973; Mazets et al. 1974)



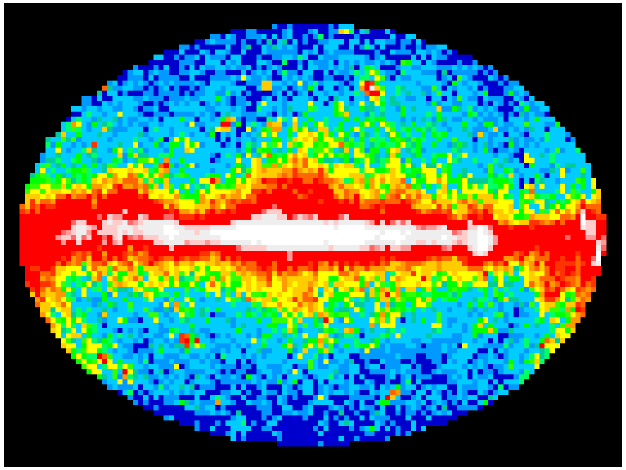


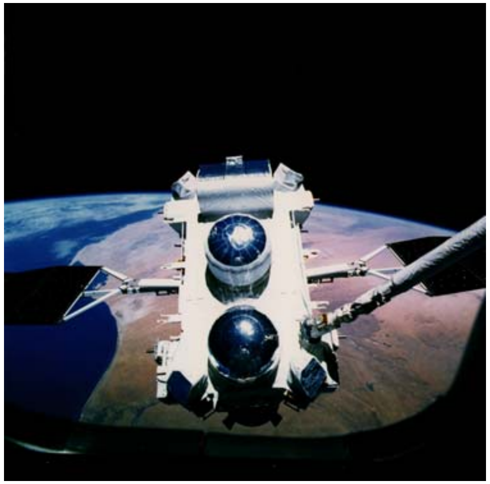
Gamma Ray Burst speculation (i.e theorists go nuts)

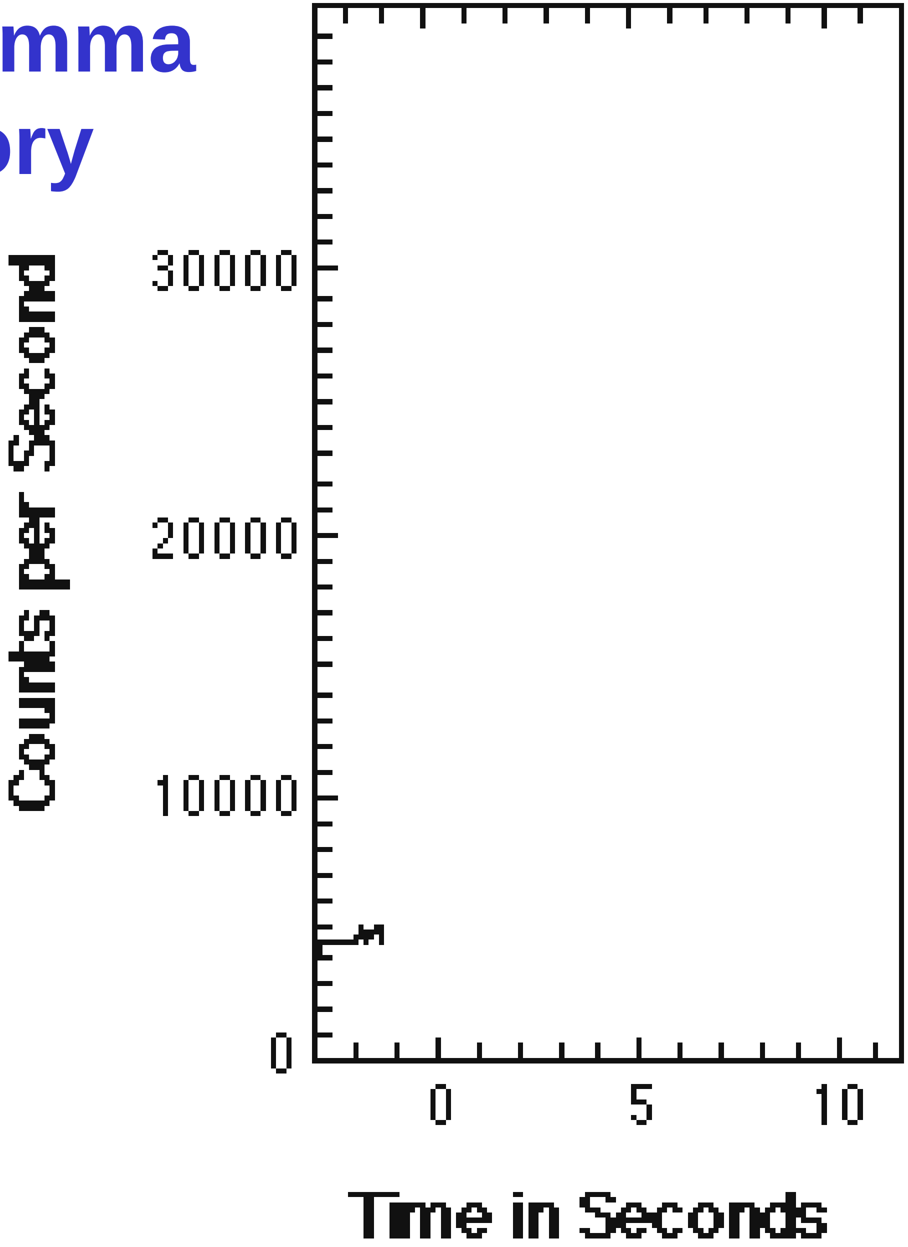
- Theoretical models published 1973-1975

“Scientists detect Alien spacecraft making jump to hyper-space”

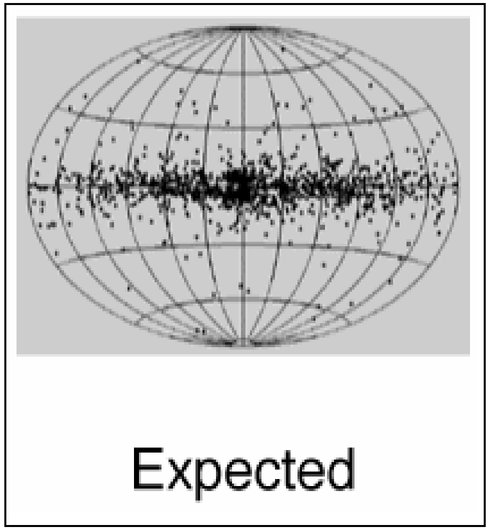
The Compton Gamma Ray Observatory

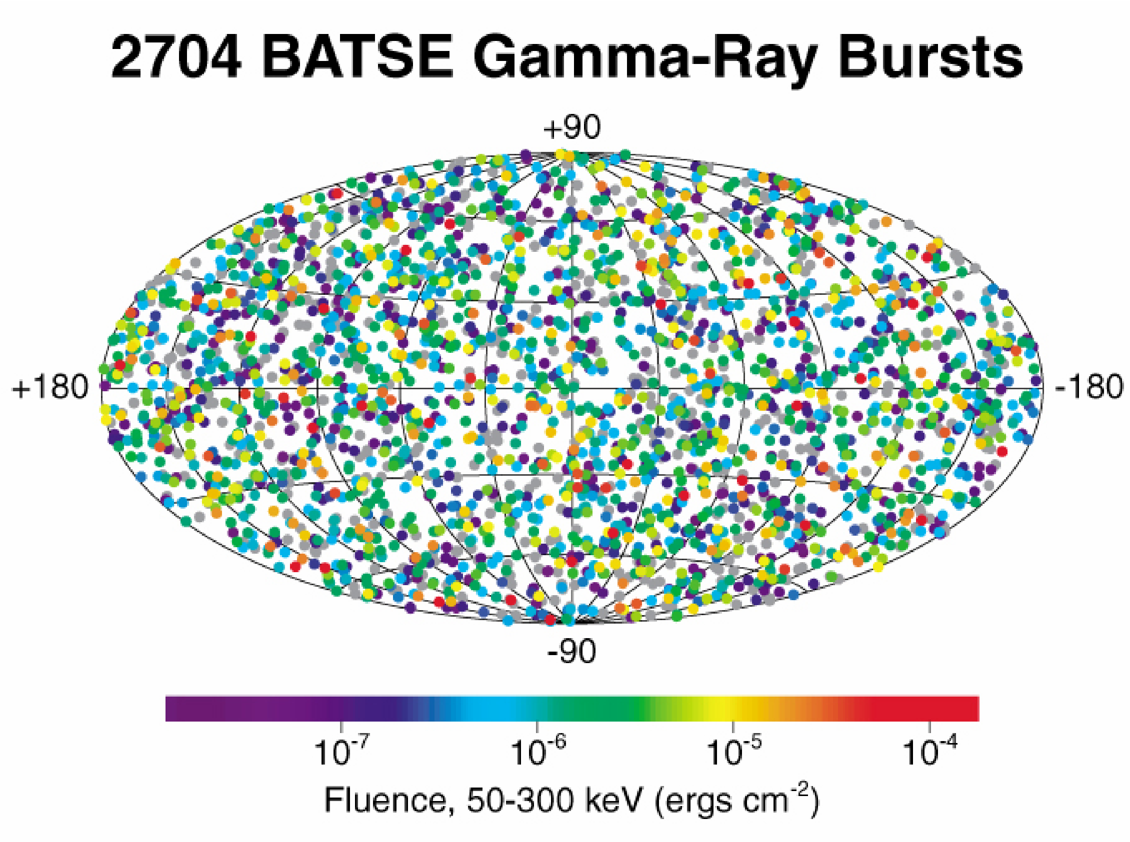






Where are they ? Compton/BATSE results





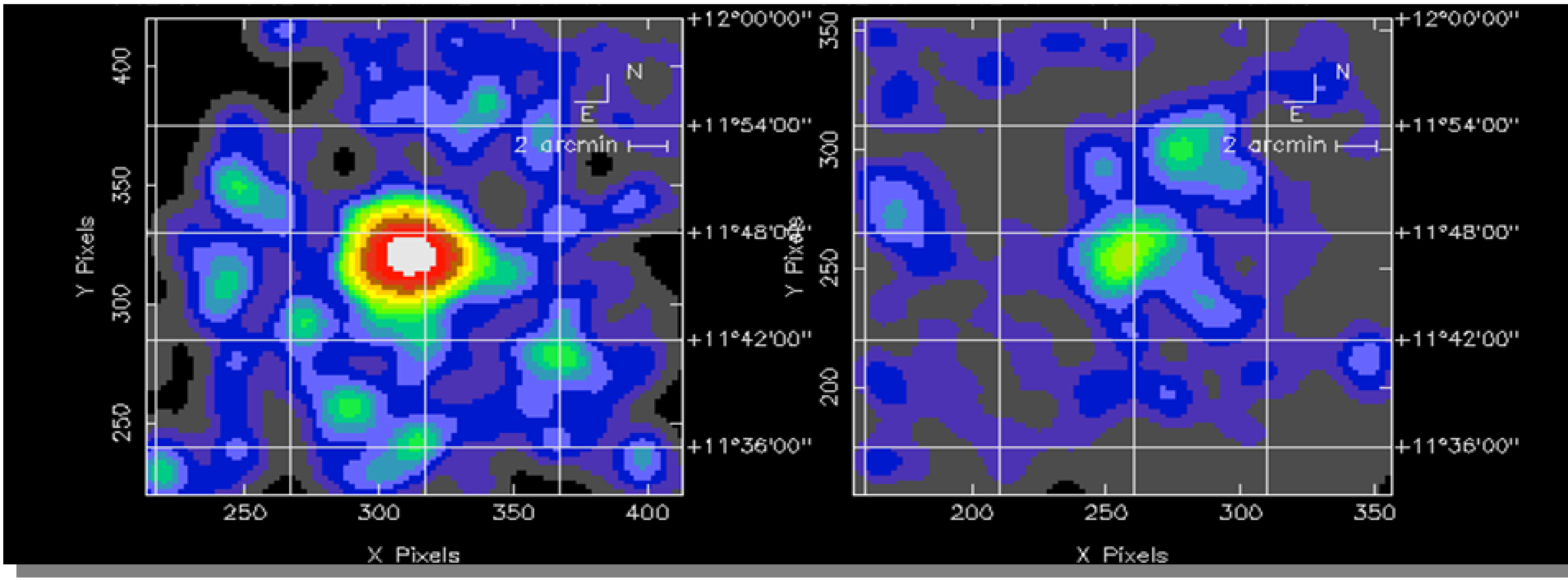
- Isotropic distribution
- Looks cosmological
- Direct measurement required...

GRB 970228: BeppoSAX Observations

X-ray and optical counterparts seen:

z=0.695 (Djorgovski et al. 1999)

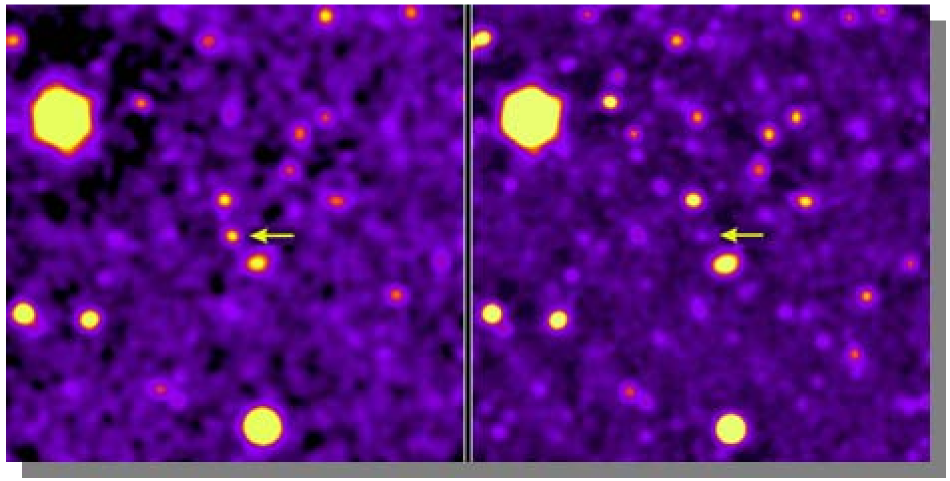
X-RAY IMAGES OF REGION CENTRED ON THE GRB



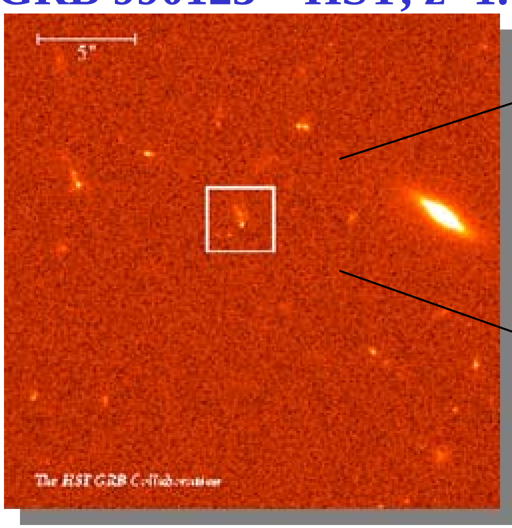
1997 February 28 **1997 March 3**

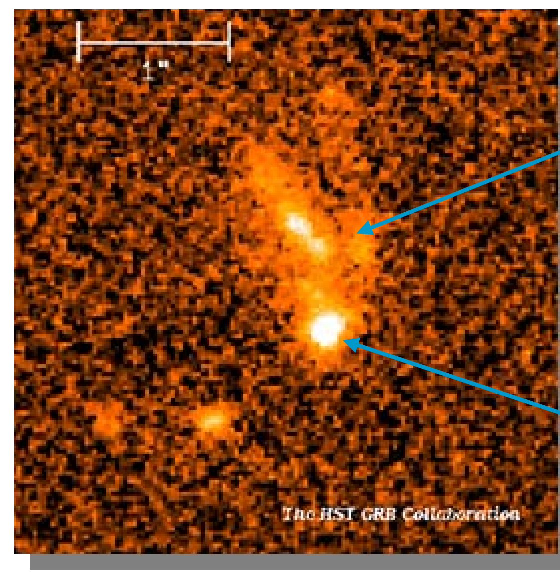
Optical Afterglows & Host Galaxies

GRB 971214 – Keck, z=3.42



GRB 990123 – HST, z=1.6





host galaxy

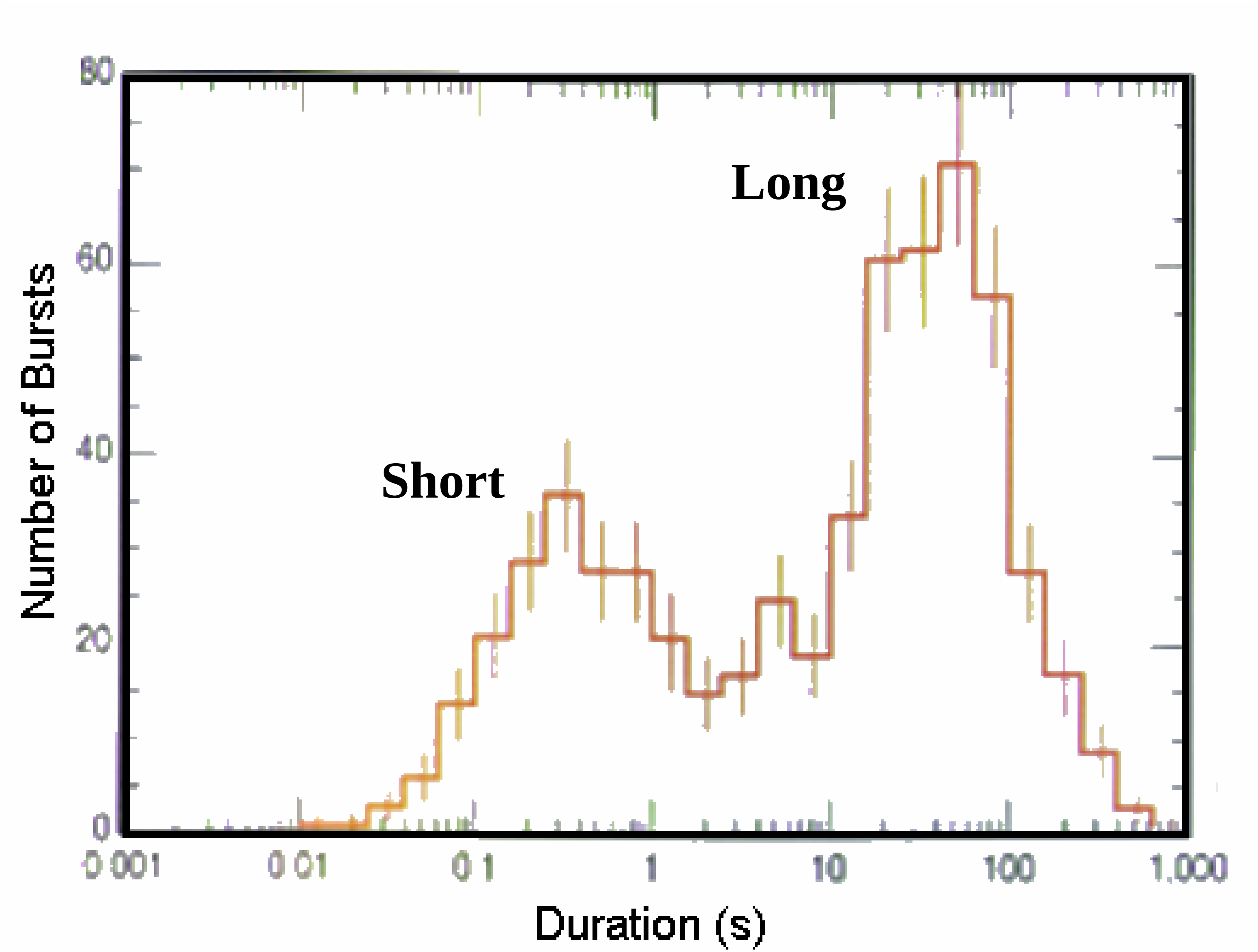
GRB

What are GRBs – best bang since the big one!

The most energetic events we know (10^{51} - 10^{52} erg, corrected for beaming).

- At the height of the burst, GRBs emit more energy in gamma rays than the rest of the Universe put together.
- GRB is ~35 magnitudes brighter than the Sun. At 1kpc a bright GRB would have m_v~ -20.
- They emit more energy in 10 seconds than our sun will emit in its entire 10 billion year lifetime.

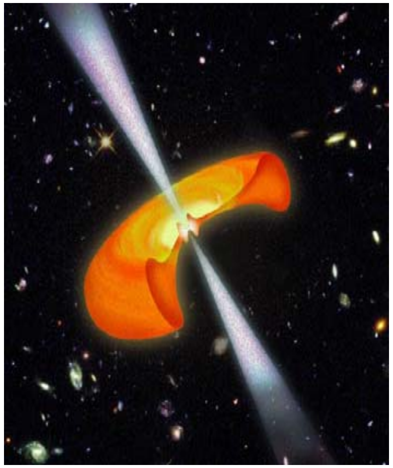
GRB Duration Distribution



Possible Models for the Progenitor

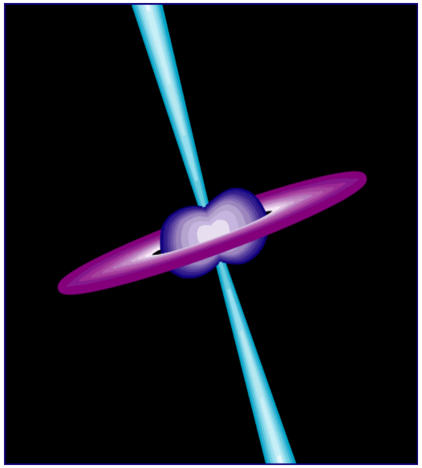
High energy (high mass), compact objects $\Rightarrow$ two leading models

collapse of giant star



Predicted γ duration ~ 10s of seconds

merging neutron star binary

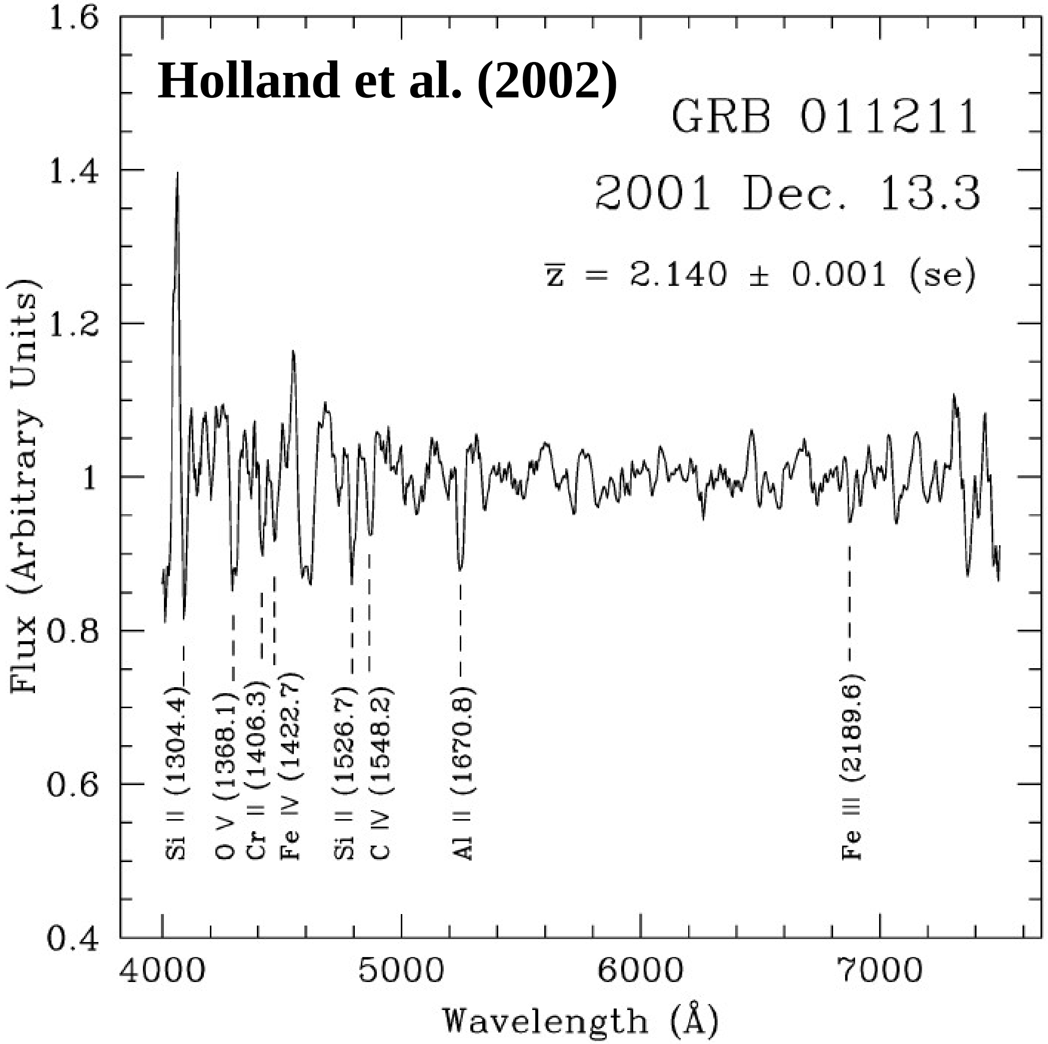


Predicted γ duration ~ seconds

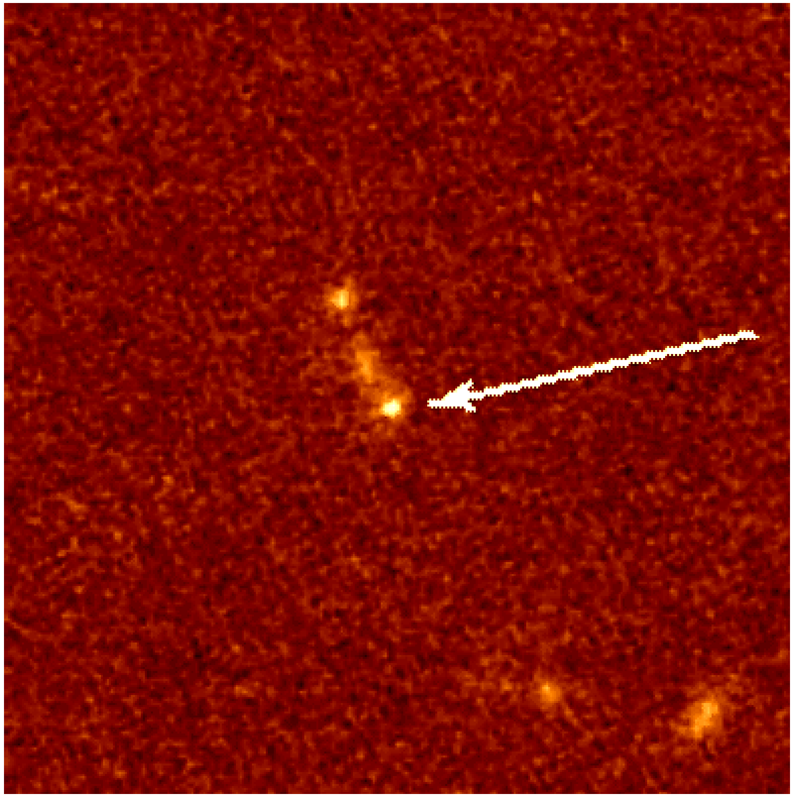
- **Both models produce an accreting black hole or a milli-second pulsar**
- **Both models have very high angular momentum**
- **Both models give beamed emission**
- **Jet internal/external shocks + interaction with surroundings ⇨afterglow**
- **The models predict different line spectra**

GRB 011211

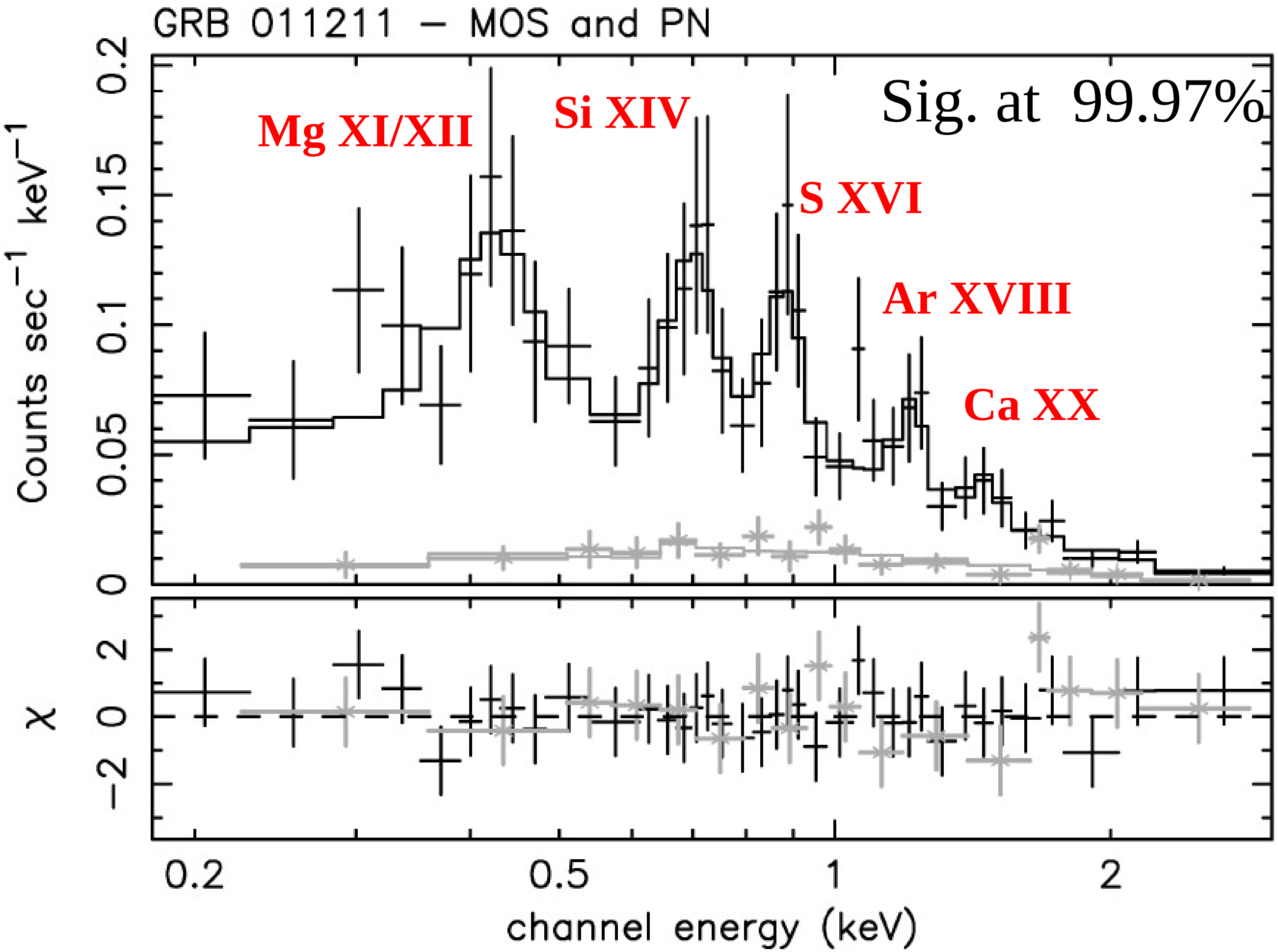
GRB Host Redshift determined as z=2.140±0.001



HST:- GRB host galaxy (Fox 2002)



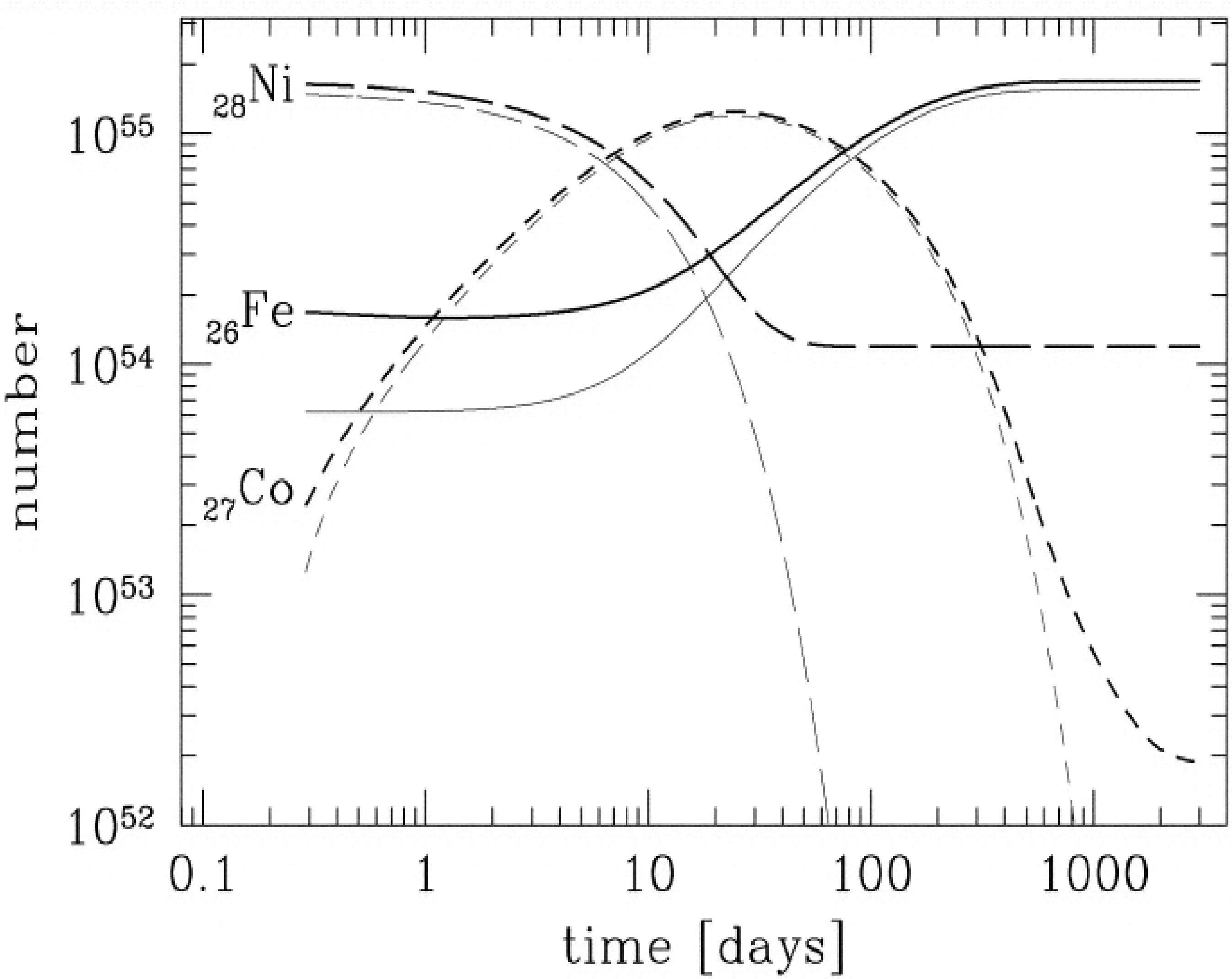
Hydrogenic lines from Mg, Si, S, Ar and Ca detected in first 10ksec x10 Solar abundances, but no iron line (<1.4 Solar) – Supernova?



Lines are blueshifted: outflow velocity = 26000 km s^{-1}

(Reeves et al., 2002, Nature, 416, 512)

Why is there no iron line in GRB 011211? Nucleosynthesis



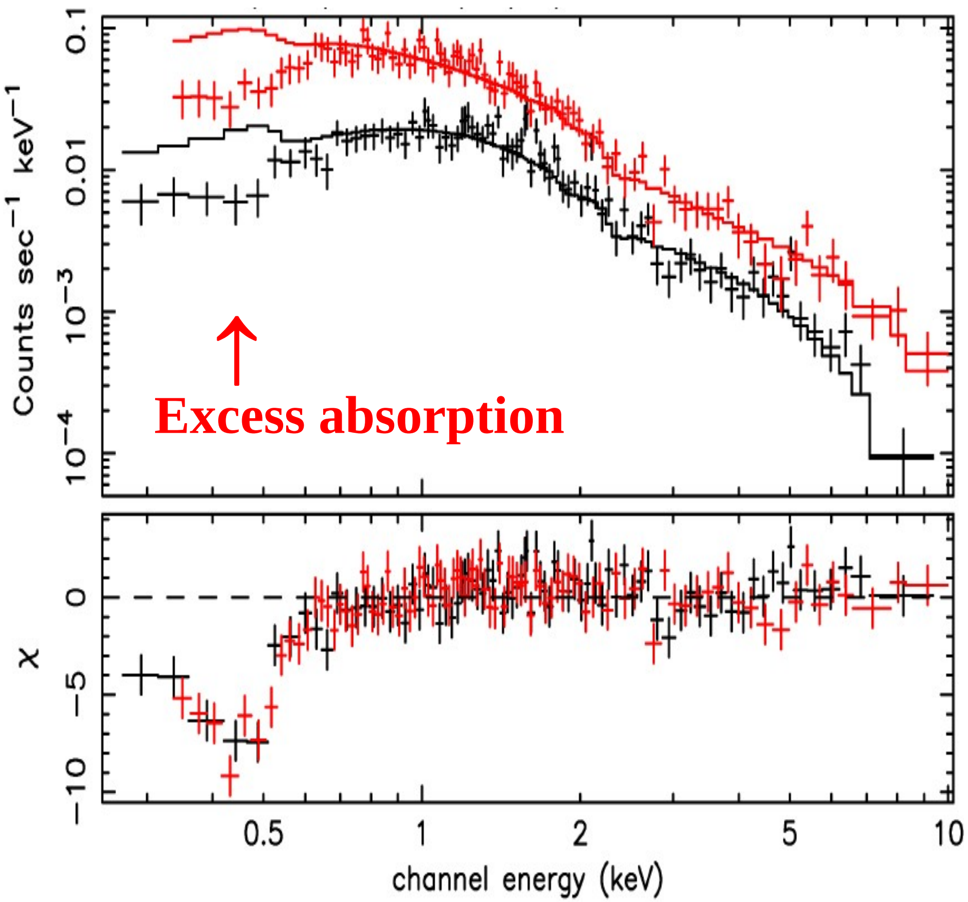
Synthesis model for a 40 solar mass progenitor star (e.g. Woosley & Weaver 1995)

Iron line only dominates after t > 100 days. Nickel line dominates at t < 10 days.

BUT – are elements made by Sne, in a torus or in the jet?

X-ray afterglow of GRB 020322 - 14.9 hr after GRB

Watson et al: 2002, A&A, 395, L41



7.8 hr observation

X-ray source fades as $t^{-1.3}$

Need intrinsic absorption.

At Z_{abs} ~ 1.8, N_H~1.3×10^{22} cm^{-2}

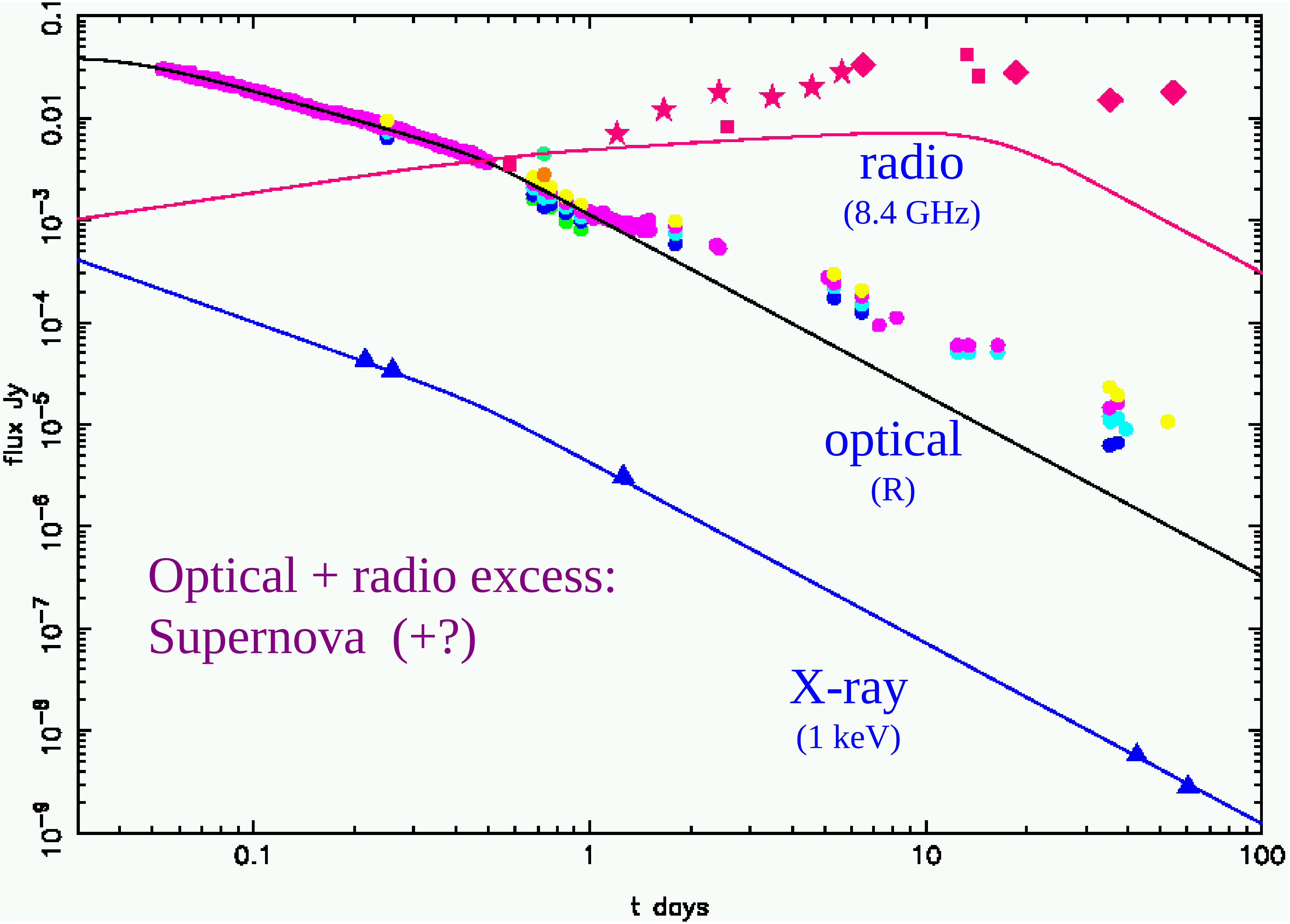
Faint, fading optical transient

No thermal emission apparent

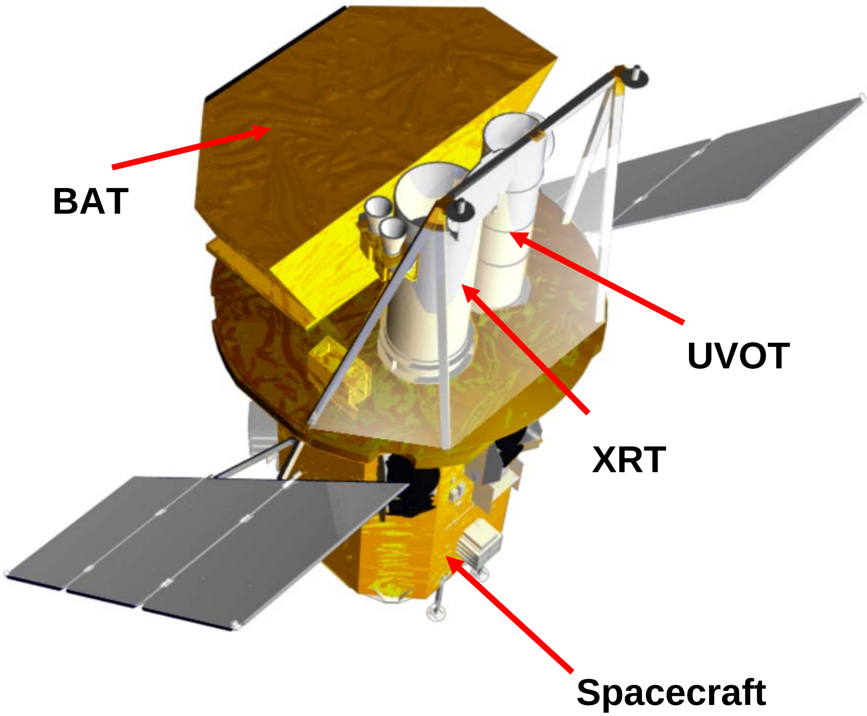
Major problem – no optical redshift!

GRB 030329 afterglow evolution

Willingale et al., 2003, MNRAS, submitted (astro-ph/0307561)



Swift – catching gamma ray bursts on the fly



- Launch in 2004
- BAT 5x sensitivity of BATSE
- X-ray telescope has a MOS CCD
- Detect ~150 GRBs/year
- Response time ~ 100 seconds

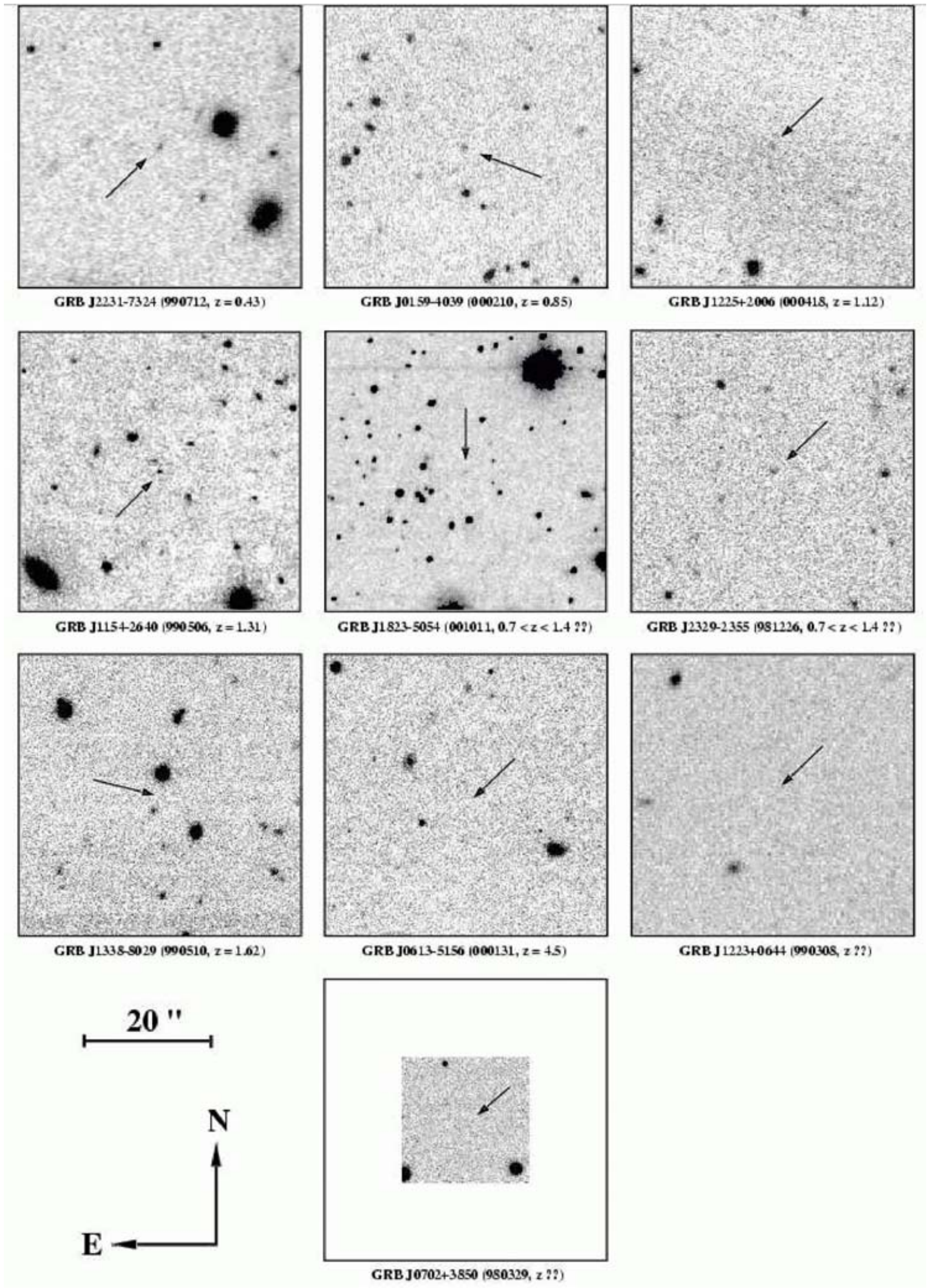
NASA
GSFC
PENNSTATE
University of Leicester
UCL MSSL
OSSERVATORIO ASTRONOMICO DI BRERA
Los Alamos NATIONAL LABORATORY
asi agenzia spaziale italiana
SwRI
SPECTRUMASTRO
SWALES AEROSPACE
Omitron Inc.
eV PRODUCTS

The immediate future of GRB research

- Swift, robotic telescopes, rapid response mode (RRM) at the VLT will revolutionize afterglow studies in 2004+.
- Early accurate location essential to get redshift (~30 known for ~200 GRBs observed since 1996)
- Swift should allow for follow-up of short and “dark” bursts and possibly some “X-ray flashes” (GRB related?).
- By ELT first-light afterglow physics may be understood.
- Progenitors may also be (partly) understood (SNe, NS+NS etc.)
- What is left…?

Need for ELT (every large telescope)

- **Rapid response observations of the afterglow (high-resolution, time-resolved spectroscopy and spectropolarimetry).**
- **Study the hosts galaxies and relation between GRBs and star formation. Typical GRB host has R~24-26.**
- **GRB host spectra and location of GRBs relative to host support idea of GRBs in star-forming galaxies.**
- **Existing samples appear bluer than high-redshift star-forming galaxies (similar to local irregulars). They may also be metal-poor hosts (Le Floc’h et al., 2003, A&A, 400, 499; Fynbo et al., 2003, A&A, 406, L63).**
- **Are current samples biased or are GRB hosts different?**



VLT/Gemini IR imaging of GRB host galaxies

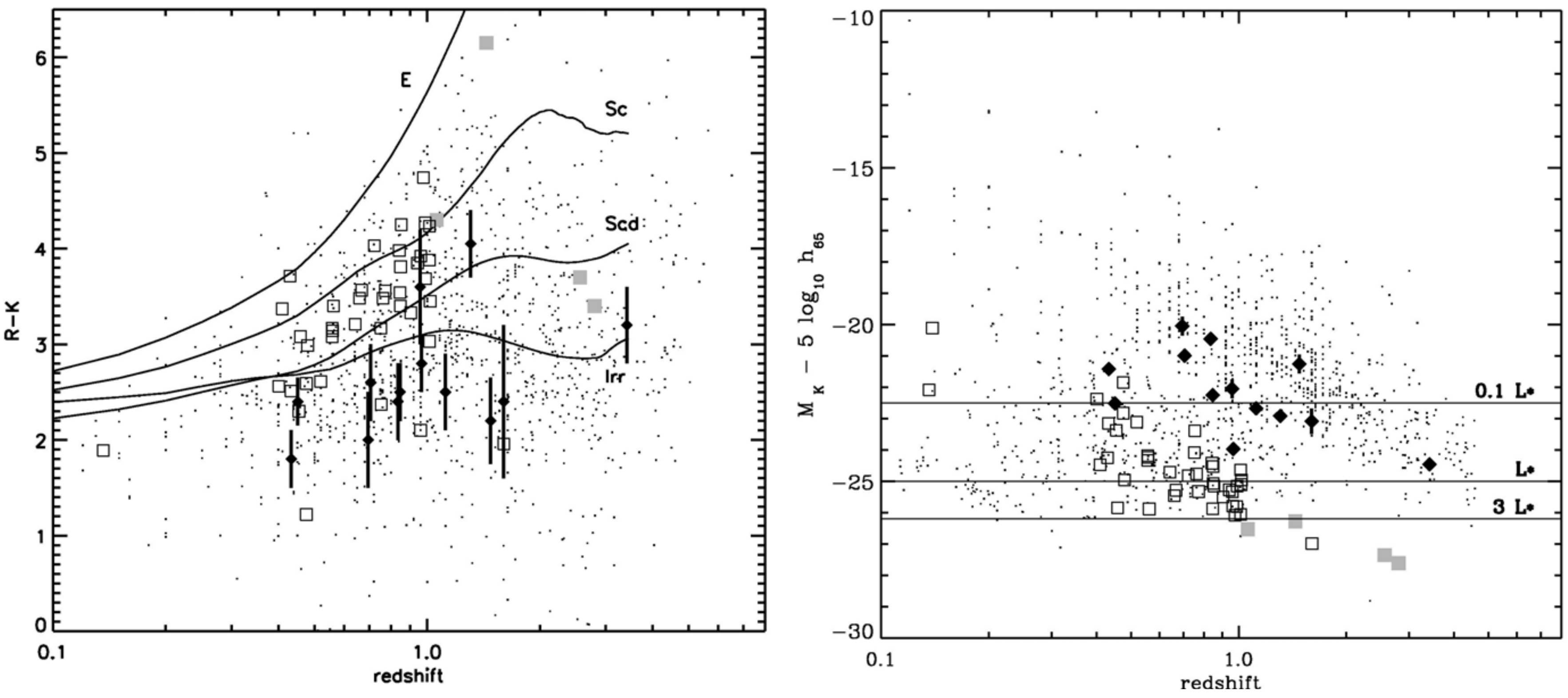
~1 hour exposures

Typical K_s~21

Le Floc'h (2003)

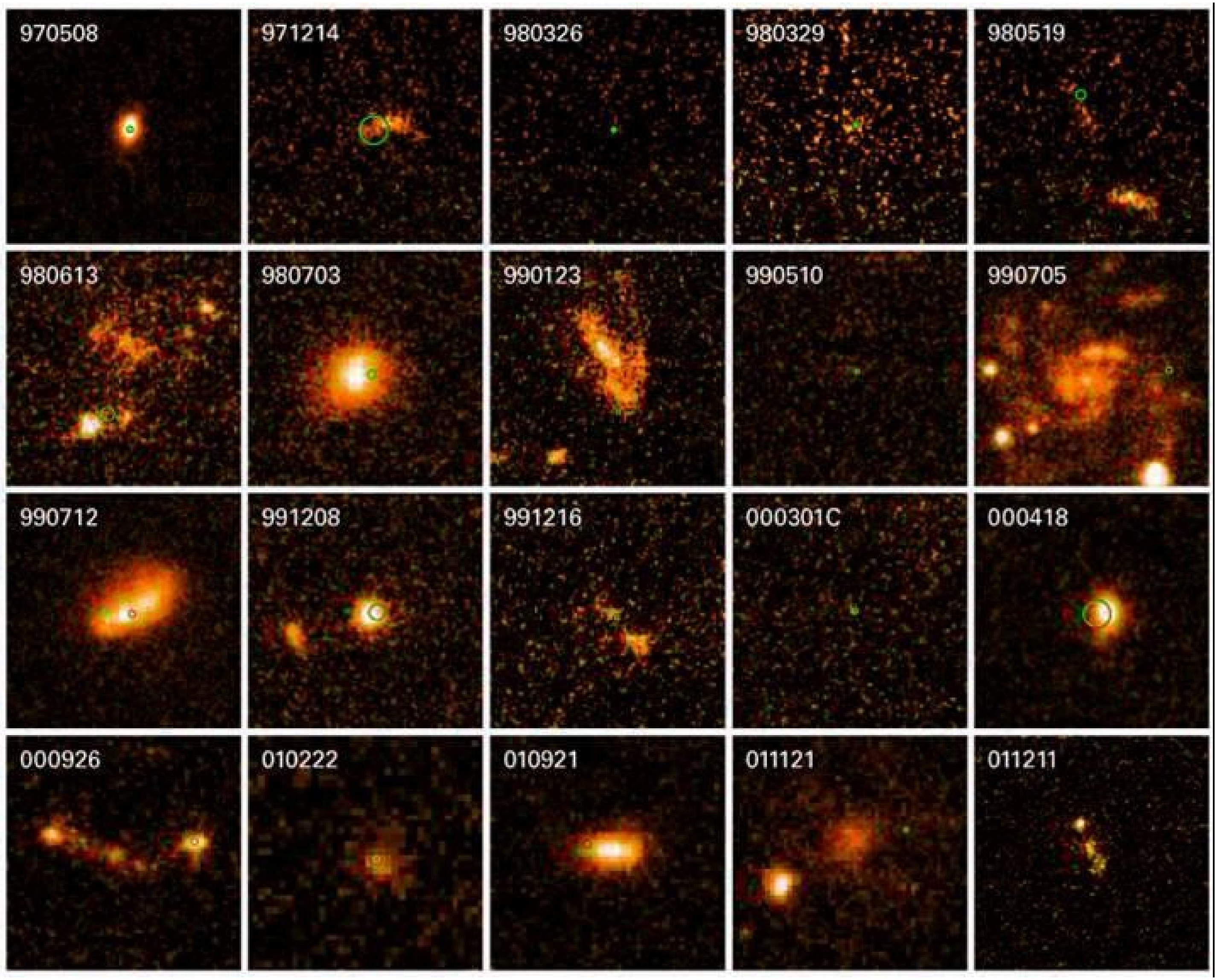
GRB host galaxy colours

(Le Floc'h et al. 2003)

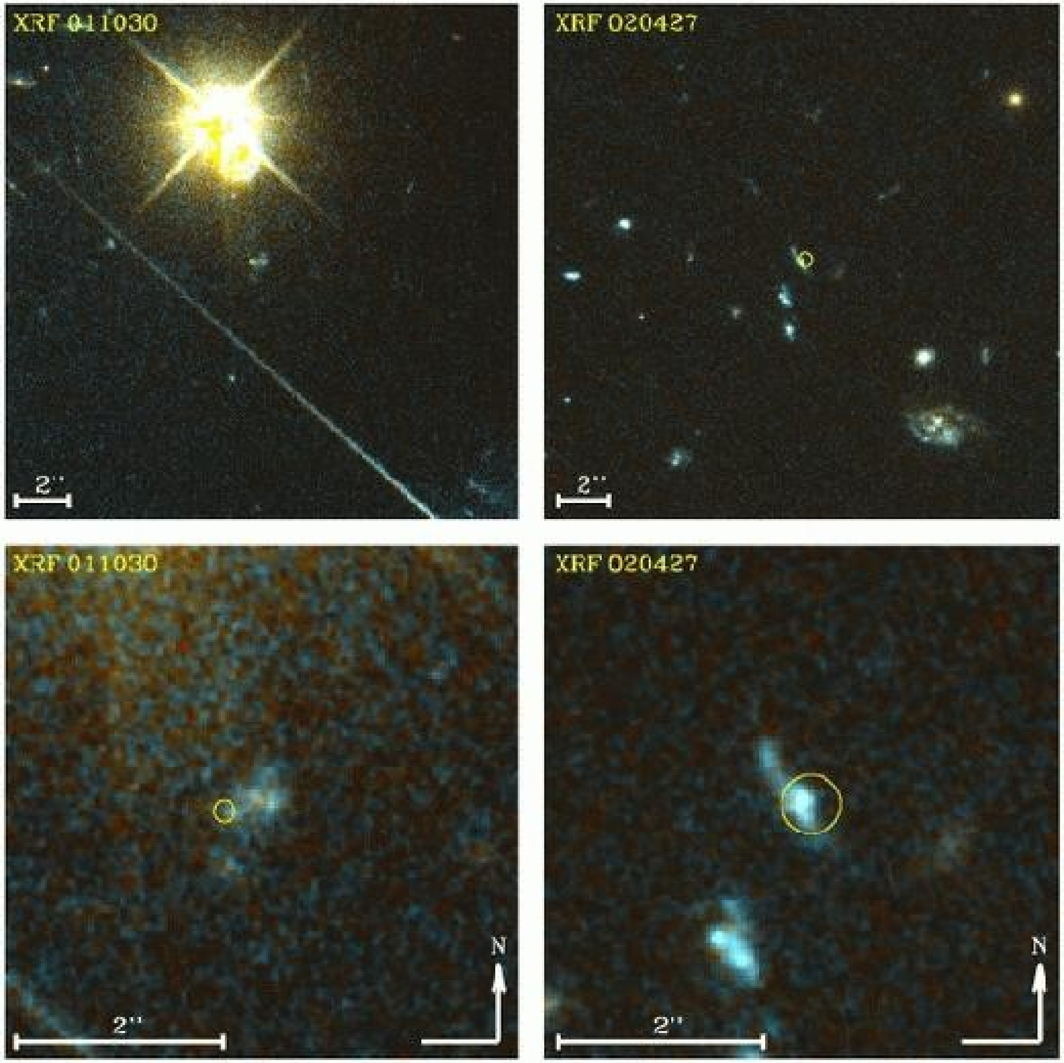


Filled diamonds are GRB hosts – appear bluer and less luminous than other star-forming galaxies observed by SCUBA or ISO

GRB host galaxies imaged by the GOSH collaboration



XRF hosts imaged by HST (Bloom et al. 2003)



ELT GRB science

- **Are GRBs tracing "normal" star formation?**
- **What is the nature of very high-redshift hosts? GRBs can be seen out to z~14-20 – use to isolate potential targets.**
- **Are GRB hosts similar to other high-redshift galaxy samples (e.g. Lyman-break galaxies, damped Lyman-α systems etc.).**
- **What is the nature of dark burst hosts?**
- **Are all SNe (or type Ic) GRBs? Anisotropic ejecta?**
- **Are GRB hosts different in terms of metallicity?**

Current GRB host studies close to limit of exisiting telescopes, even though most hosts studied to date are at redshifts <2.

<u>Need larger telescopes</u>