We know that gamma ray explosions happen randomly all over the sky (It's like a lottery: a ticket for each square degree)
You see a FLASH! and then there's not another till about a day has gone by (But that depends upon detector sensitivity)
In just a moment they spew energy worth (That's pretty fast)
A value we can't even fathom on Earth (It's really vast!) 
But just what's giving rise to gamma ray sparked skies?
Is it the death cry of a massive star or black hole birth? (Or both, or both? or both!)

Swiftly swirling, gravity twirling
Neutron stars about to collide
Off in a galaxy so far away
Catastrophic interplay
A roller coaster gamma ray ride
Superbright explosion then
Never to repeat again
How are we supposed to know?
How about a telescope rotation
Swiftly onto the location
Of its panchromatic afterglow?

In just a moment gamma ray bursts reach a peak and swiftly fade from view (It's like a beacon shining clear across the Universe)
But they leave embers in the longer wavelengths fading for a day or two (It's exponential -- it decays forever)
To solve this space age mystery is why (We wanna know)
We want to catch a thousand bursts on the fly (What makes' em go?)
Their X-ray light disperse unlock the Universe
Measure their distance from their redshift mark their spot on the sky (They're where? They're here! They're there! They're everywhere!)

Swiftly swirling, gravity twirling
Neutron stars about to collide
Off in a galaxy so far away
Catastrophic interplay
A roller coaster gamma ray ride
Superbright explosion then
Never to repeat again
How are we supposed to know?
Swift is the satellite that swings
Onto those brightly bursting things
To grab the multiwavelength answer to what makes them glow

It's like a lottery - a ticket for each square degree
It's like a beacon shining clear across the Universe
Swift is the satellite that swiftly swings all over the sky
Swift is designed to catch a burst of gamma rays on the fly
Detectors

High-Energy Emission

Compactness Problem
Detection physics for γ-rays
Pair Production in Coulomb Field

\[ \gamma + e^- \rightarrow e^+ + e^- + e^- \]

\[ \gamma + \text{nucleus} \rightarrow e^+ + e^- + \text{nucleus}' \]

http://besch2.physik.uni-siegen.de/~depac/DePAC/DePAC_tutorial_database/grupen_istanbul/n_bild40.jpg
Mass attenuation coefficients for sodium iodide. The 'Compton total' attenuation coefficient \( \sigma/\rho = \sigma_a/\rho + \sigma_p/\rho \) is shown explicitly. (From Evans, R. D., op. cit.)

photoelectric

Compton

pair production
Attenuation of photons in the atmosphere

Attenuation of photons in the 1972 COSPAR International Reference Atmosphere with $1/e$ absorption length plotted as a function of energy and altitude or atmospheric depth.
Relative importance of the three major types of electromagnetic interactions. The lines show the values of $Z$ and $h\nu$ for which the two neighboring effects are just equal. (Evans, R. D., *The Atomic Nucleus*, McGraw-Hill, 1955, with permission.)
Fig. 1. Energy level diagram for a typical inorganic scintillator.

also, BGO (Bi$_4$Ge$_4$O$_{12}$) - without “activator”

~10^{-3} doping
Thallium
NaI(Tl)

~4000 Å
Fig. 3.1  Emission spectra of NaI(Tl), BGO and CdWO₄, scaled on maximum emission intensity.

Fig. 3.3  Temperature dependence of the scintillation yield of NaI(Tl), CsI(Na), CsI(Tl) and BGO.

Fig. 4.1  Schematic of a photomultiplier tube.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>NaI(Tl)</th>
<th>CsI(Tl)</th>
<th>CsI(Na)</th>
<th>BGO</th>
<th>Ge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scintillation efficiency relative to NaI(Tl)</td>
<td>100%</td>
<td>45%</td>
<td>85%</td>
<td>10%</td>
<td>–</td>
</tr>
<tr>
<td>Typical energy resolution (FWHM in keV) at 662 keV</td>
<td>50</td>
<td>60</td>
<td>60</td>
<td>90</td>
<td>2</td>
</tr>
<tr>
<td>Light decay constant (μs)</td>
<td>0.23</td>
<td>1.0</td>
<td>0.63</td>
<td>0.30</td>
<td>2*</td>
</tr>
<tr>
<td>Afterglow (after 3 ms)</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>0.1%</td>
<td>–</td>
</tr>
<tr>
<td>Hygroscopicity</td>
<td>high</td>
<td>low</td>
<td>high</td>
<td>none</td>
<td>–</td>
</tr>
<tr>
<td>Britteness</td>
<td>high</td>
<td>low</td>
<td>low</td>
<td>low</td>
<td>–</td>
</tr>
<tr>
<td>Density (g cm$^{-3}$)</td>
<td>3.67</td>
<td>4.51</td>
<td>4.51</td>
<td>7.13</td>
<td>5.36</td>
</tr>
<tr>
<td>Gamma-ray attenuation length (1/e)</td>
<td>1.77 mm</td>
<td>0.9 mm</td>
<td>0.9 mm</td>
<td>0.4 mm</td>
<td>3.5 mm</td>
</tr>
<tr>
<td>at 100 keV</td>
<td>4.5 cm</td>
<td>3.3 cm</td>
<td>3.3 cm</td>
<td>2.0 cm</td>
<td>2.9 cm</td>
</tr>
<tr>
<td>at 1 MeV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$K$ edge of high-Z element (keV)</td>
<td>33</td>
<td>36</td>
<td>36</td>
<td>91</td>
<td>11</td>
</tr>
</tbody>
</table>

*Many of these data are from the 1984 Harshaw Radiation Detectors Catalog (1984).

*Absolute scintillation efficiency of NaI(Tl) is 0.13. Efficiency is the ratio of the energy in the light output in the wavelength band of a PMT response to the energy of the incident gamma ray. The numbers for the wavelength band of a photodiode are considerably different (see Section 3.3.1).

*Typical charge collection time for a large coaxial Ge detector. Values range from < 1 μs to several microseconds depending on detector size.
Energy Resolution $(\Delta E/E) \sim 10$

Fig. 4.4 Example of a pulse height spectrum of 662 keV gamma rays absorbed in a photodiode scintillation detector equipped with an 18x18x25 mm$^3$ CsI(Tl) scintillation crystal.
CCDs

Many photoelectrons

\[ E_{\gamma}/\text{Si band gap energy} = 1\text{MeV}/1\text{eV} \approx 1000 \]

# of electrons \( \propto \) incident energy

Energy resolution \( (\Delta E/E) \sim 40 - 100 \)

Read out chips quickly (cosmic ray noise)

time resolution set by read time
Determining Spectra

Measured science spectra only as good as your response matrix $R[i,j]$
Response matrix only as good as your calibrations
“Forward Folding”
Response to a power law with $N_{\text{phot}} \propto E^{-1}$

http://www.bo.iasf.cnr.it/~amati/tesi
Continuum

Briggs 1995 “Low-Energy Spectral Features in GRBs”
[astro-ph/9610144]
FIG. 4. To illustrate the dependence of the deconvolved photon points on the model for a model containing a line, two deconvolutions of the same data are shown. For the top curve, a continuum model is assumed, while for the bottom curve (shifted downward by $\times 2.5$), an additive Gaussian line is also included in the model. The data are that of the line candidate in GRB 940703—for count data and models see ref. (9).
Fig. 1.—Example of a spectral fit. The GRB model (eq. [1]) was fitted to the average spectrum of 1B 911127. The low-energy spectral index is \( \alpha = -0.968 \pm 0.022 \), the high-energy spectral index \( \beta = -2.427 \pm 0.07 \), and the break energy \( E_0 = 149.5 \pm 2.1 \). With 100 degrees of freedom, \( \chi^2 = 121.58 \).

\[ N(E) = A \left( \frac{E}{100 \text{ keV}} \right)^{\alpha} \exp \left( - \frac{E}{E_0} \right), \]

\[ = A \left[ \frac{(\alpha - \beta)E_0}{100 \text{ keV}} \right]^{\alpha - \beta} \exp \left( \beta - \alpha \left( \frac{E}{100 \text{ keV}} \right) \right), \]

\[ (\alpha - \beta)E_0 \geq E, \]

\[ (\alpha - \beta)E_0 \leq E, \]  

which we call the GRB model. This model was constructed so that it and its derivative are continuous. This functional form reproduces the common description of burst continuum with \( \alpha \sim -1 \) and \( \beta \sim -2 \). In addition, many standard spectral shapes can be represented by this model: single power law \( (E_0 = \infty) \), photon exponential \( (\alpha = 0, \beta = -\infty) \), and energy exponential (often referred to as optically thin thermal bremsstrahlung without the Gaunt factor: \( \alpha = -1, \beta = -\infty \)). We stress that we use this functional form as a characterization of the spectrum without implying any direct relation to the underlying physical processes. For example, although \( E_0 \) plays the role of the temperature in thermal spectral forms and is therefore often called the “temperature,” it probably does not correspond to a physical temperature, since bursts are unlikely to involve thermal processes (Harding 1991).
Evidence for 2 classes of bursts
X-ray Flashes and X-ray Rich GRBs

XRFs recognized by soft X-ray excess in BeppoSAX by Jan Heise et al. (but probably seen in Ginga)

about 1/3 of HETE-2 bursts are XRFs
Are There MeV Gamma-Ray Bursts?

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3. ITP, UCSB, Santa Barbara, U.S.A.

It is often stated that gamma-ray bursts (GRBs) have typical energies of several hundred keV, where the typical energy may be characterized by the hardness $H$, the photon energy corresponding to the peak of $\nu F_\nu$. Among the 54 BATSE bursts analyzed by Band et. al. more than half have $100\text{keV} < H < 400\text{keV}$. Is the narrow range of $H$ a real feature of GRBs or is it due to an observational bias? We consider the possibility that bursts of a given bolometric luminosity occur with a distribution: $p(H)\,d\log H \propto H^{\gamma}\,d\log H$. We model the detection efficiency of BATSE as a function of $H$ and calculate the expected distribution of $H$ in the observed sample for various values of $\gamma$. The Band sample shows a paucity of soft (X-ray) bursts, which may be real. However, because the detection efficiency of BATSE falls steeply with increasing $H$, the paucity of hard bursts need not be real. We find that the observed sample is consistent with a distribution above $H = 100\text{keV}$ with $\gamma \approx 0$ (constant numbers of GRBs per decade of hardness) or even $\gamma = 0.5$ (increasing numbers with increasing hardness). Thus, we suggest that a large population of unobserved hard gamma-ray bursts may exist. It is important to extend the present analysis to a larger sample of BATSE bursts and to include the OSSE and COMPTEL limits. If the full sample is consistent with $\gamma \geq 0$, then it would be interesting to look for MeV bursts in the future.
Determining Location

(apart from the timing/IPN technique)
1. “Collimation”

restrict field of view of detectors
2. Cross detector fluxes

- BATSE had 8 LAD
- each gives relative cos $\theta$ to burst

Locations of $\sim$few degrees (covariances of DRM and position)
Coded Mask Imaging

Fig. 1. The basic steps involved in coded aperture imaging are shown above. In an attempt to obtain a higher SNR, a multiple-pinhole aperture is used to form many overlapping images of the object. The resulting recorded picture must be decoded, using either a digital or optical method. The resulting reconstruction is of higher quality than that obtained by using a simple pinhole.

Fig. 4. This coded aperture arrangement employs only the basic \( r \) by \( s \) pattern for the aperture and has the disadvantage that the detector must be large enough to contain the image from the full field of view.

Fig. 5. A 40 \( \times \) 40 random array. As shown in Fig. 6, the uniformly redundant array is superior to the random array because of its ideal system point-spread function.
Compactness Problem
Considered a high energy test photon traversing through a shell of photons given that ~1 GeV photons were detected
Fig. 1. The minimum bulk Lorentz factor $\Gamma_{\text{MIN}}$ for three EGRET GRBs, as obtained from the pair production condition $\tau_{\gamma\gamma}(\varepsilon_t) = 1$ in Eq. (1). Here $\varepsilon_t$ is the maximum energy detected by EGRET (listed in ref. 11). Results are shown for two different source distances, (a) $D = 100\,\text{kpc}$ and (b) $D = 1\,\text{Gpc}$, with the expansion opening half-angle always being $\Theta_\beta = 90^\circ$. 