超高エネルギーガンマ線による残光探査

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理研シンポジウム「HETEがひらくガンマ線バースト観測新時代」 1999/6/7－9

EGRET GRB observations

- 5 bursts: fluence >15% of BATSE
  High-energy long tail exists
  A 18 GeV event after 5400sec (GRB940217, Chance prob. 5×10^{-6})
- Average spectrum:
  flat!

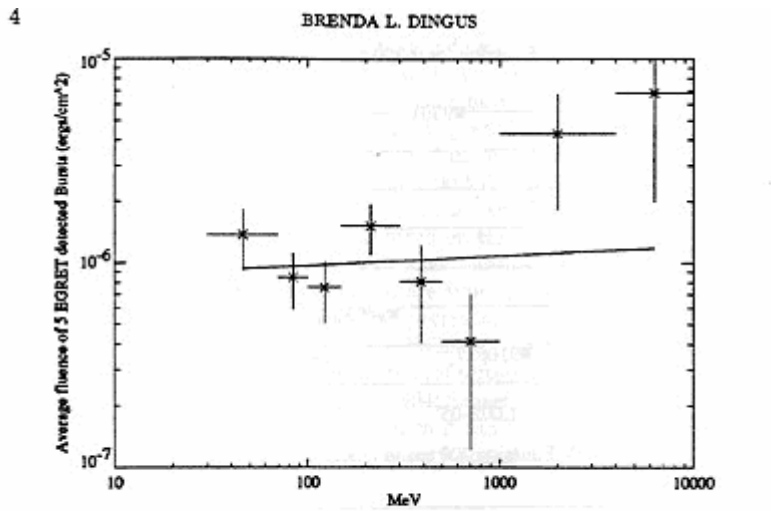


Fig. 2. Average spectrum of high energy emission within 200 seconds of BATSE trigger of GRB940301, GRB940217, GRB930131, GRB910601, GRB940503. A power law fit to all the data points is shown and has an index of -0.05 ± 0.25 or 1.95 ± 0.25 differential photon spectral index.

Expected GRB rate

- Mannheim, Hartmann and Funk (1996 ApJ467, 532)
  - Constant rate out to $z_{max}=2.1$
  - 10^{-6} bursts/year/galaxy of $7 \times 10^{50} h^{-2}$ erg

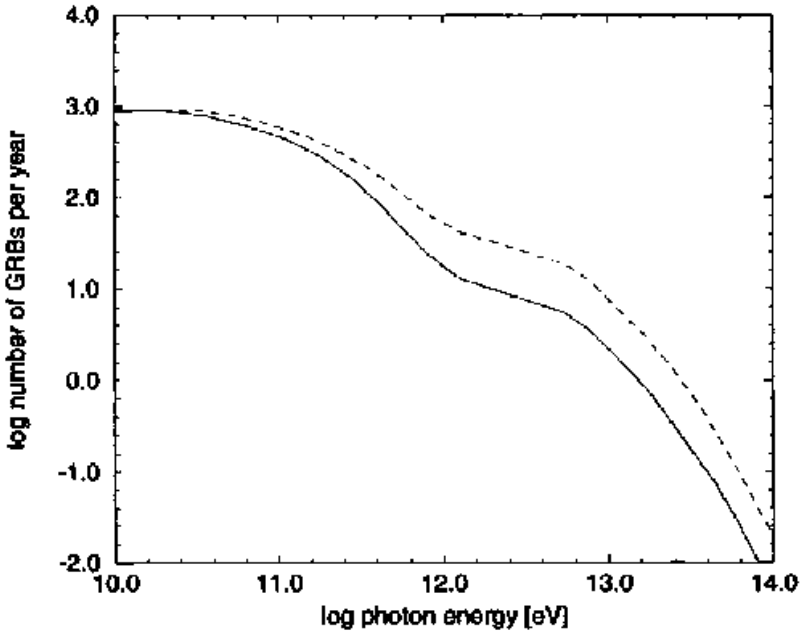
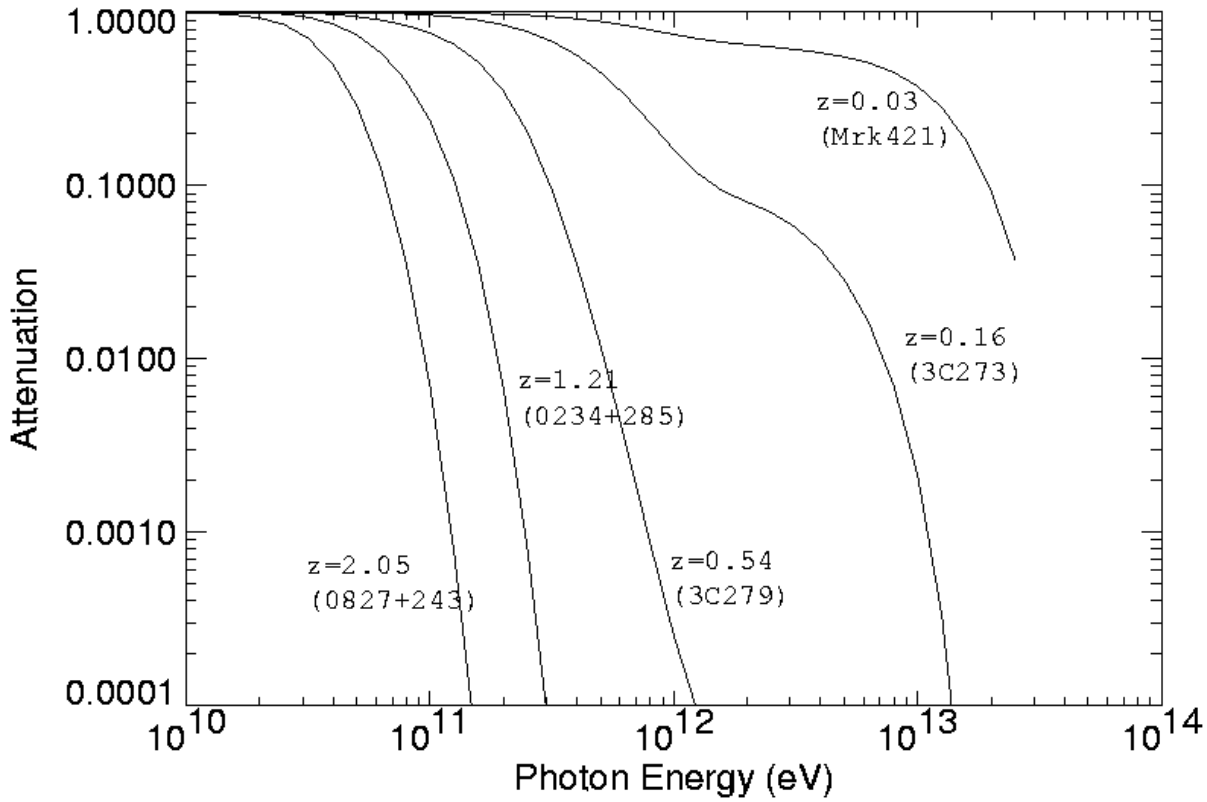


FIG. 4.—GRB rate as a function of energy threshold. *Solid line*: $h = 0.5$. *Dashed line*: $h = 1.0$.

Attenuation by IR bkgd



Totani 1999

Limiting sensitivity

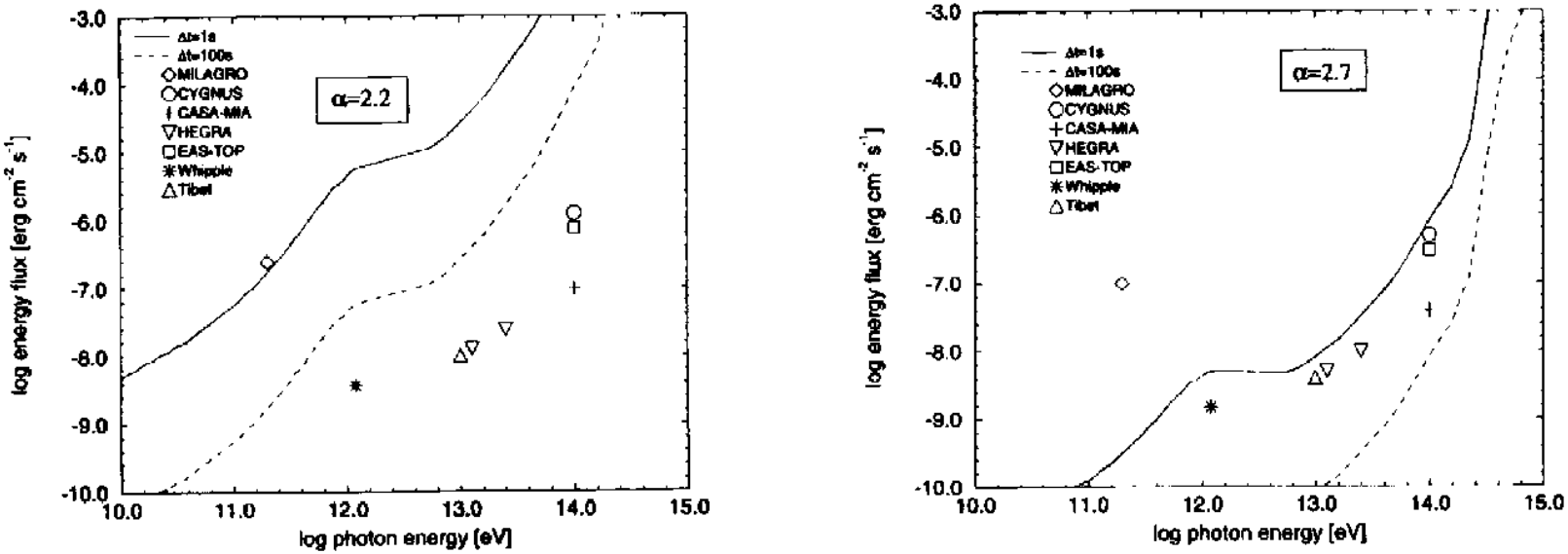


FIG. 5.—*Solid lines*: Limiting sensitivity for detection of all GRBs as a function of threshold energy assuming a high-energy tail spectral index α ($h = 0.5$). *Dashed lines*: Same for high-energy tails with extended durations relative to the BATSE bursts by a factor of 100. *Symbols*: current experimental flux limits for burst detection (typically assuming $\delta t \sim 30$ s).

Mannheim et al. 1996 ApJ467, 532

Past VHE observations

Group	Method	Energy	Result	Ref.
Tibet	Sci. array	10 TeV	6 σ for 57 bursts	AA 311 ('96) 919
AIROBICC	Ch. array	20 TeV	920925c: 2.7 σ U.L. for 3 bursts	AA 337 ('98) 43
Whipple	Imaging Ch.	250 GeV	Upper limits for 9 bursts	ApJ 479 ('97) 859

Basic parameters of Cherenkov telescopes

- Energy range: 100 GeV~10 TeV (~100 TeV for large zenith angle)
- Field-of-view: 3~4degree
- Moonless night:
  - 2 weeks or 80~100h/month(depends on season)

  Clear night: 70~80%

  ⇒ Duty factor 8~11%

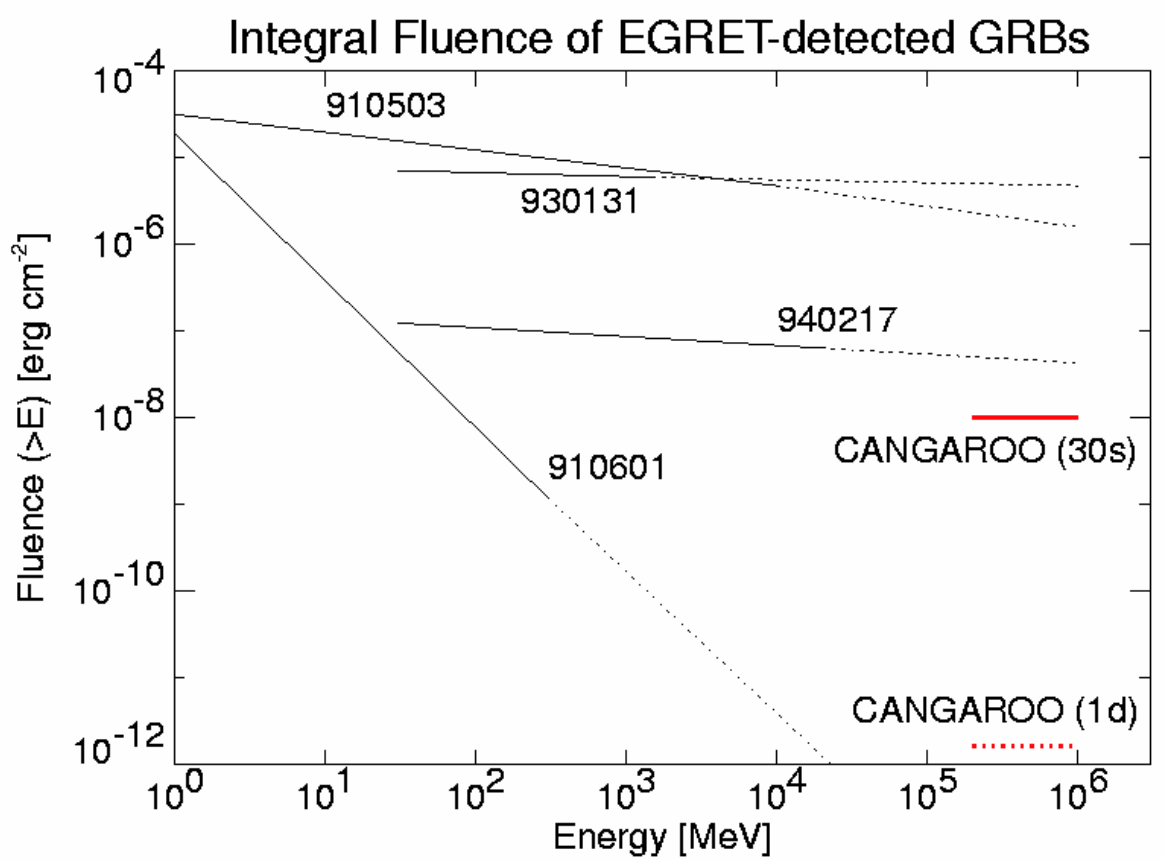
Fast follow-up observations

- Sky coverage: 7% (θ_z<30°) - 18% (<50°)
- CANGAROO-II telescope slew rate of 0.5deg/s (1.5deg/s possible)
  ⇒ pointing within 30sec for most of locations up to θ_z < 50deg
  ⇒ can catch GRBs longer than 30sec (~30% of BATSE GRBs)
- Total duty factor: 0.2~0.7%

Afterglow observations

- Clear, moonless night within one day:
  2wk/30days × (70~80)% = 1/3
- Sky coverage increase for 6 hours:
  $\theta_z = 30^o$: × 2.5
  $\theta_z = 50^o$: × 1.5
- Total duty factor: 6~9%
  (HETE trigger 30/yr ⇒ 2~3/year)

Sensitivity



CANGAROO 3.8m observations

We observed 3 BeppoSAX-detected GRBs:

- GRB970402 (14h50m, -69°19')
  Apr 4-10 (11h31m ON at θ_z=38-50°, *NO OFF*)
- GRB980326 (08h36m, -18°53')
  Mar 30-Apr 1 (4h30m ON at θ_z=15-35°, 4h46m OFF)
- GRB980425 (19h35m, -52°50')
  Apr 29-May 3 (11h31m ON at θ_z=22-30°, 9h OFF)

CANGAROO 3.8m results

- GRB970402
  Excess: 1.4σ, $F_{3\sigma}(>2.3\mathrm{TeV}) < 5.6 \times 10^{-12}\mathrm{cm}^{-2}\mathrm{s}^{-1}$
- GRB980326
  Excess: 1.5σ, $F_{3\sigma}(>2.4\mathrm{TeV}) < 9.6 \times 10^{-12}\mathrm{cm}^{-2}\mathrm{s}^{-1}$
- GRB980425
  Excess: 0.7σ, $F_{3\sigma}(>2.4\mathrm{TeV}) < 7.8 \times 10^{-12}\mathrm{cm}^{-2}\mathrm{s}^{-1}$

Broken Lorentz invariance?

- Some quantum gravity theories predicts

$$pc = E\sqrt{1 + E / E_{\mathrm{QG}}}, \quad E_{\mathrm{QG}} \geq 10^{16}\,\mathrm{GeV}$$

Amelino-Camelia et al. Nature 393 (1998) 763

- Effects:
  - VHE photons slow down: $v = c(1 - E / E_{\mathrm{QG}})$
  - Universe is transparent to:
    >10TeV photons / Multi-PeV protons

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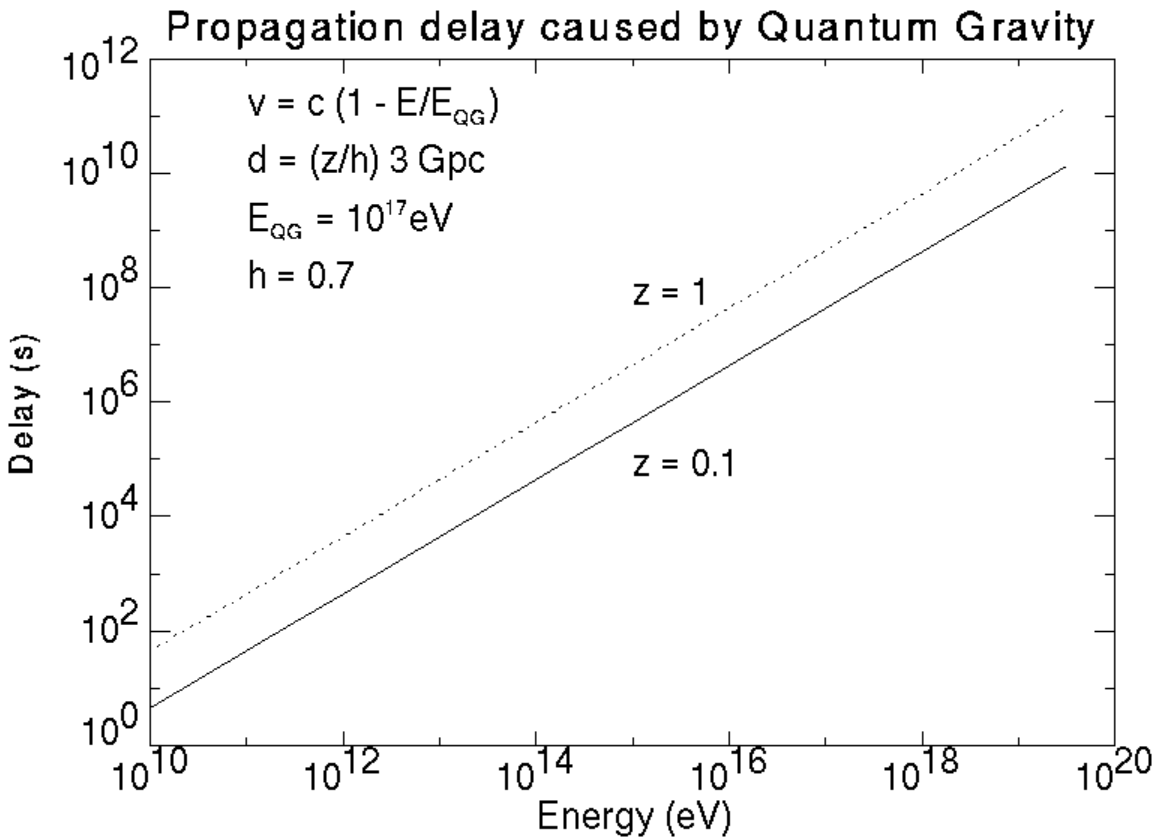
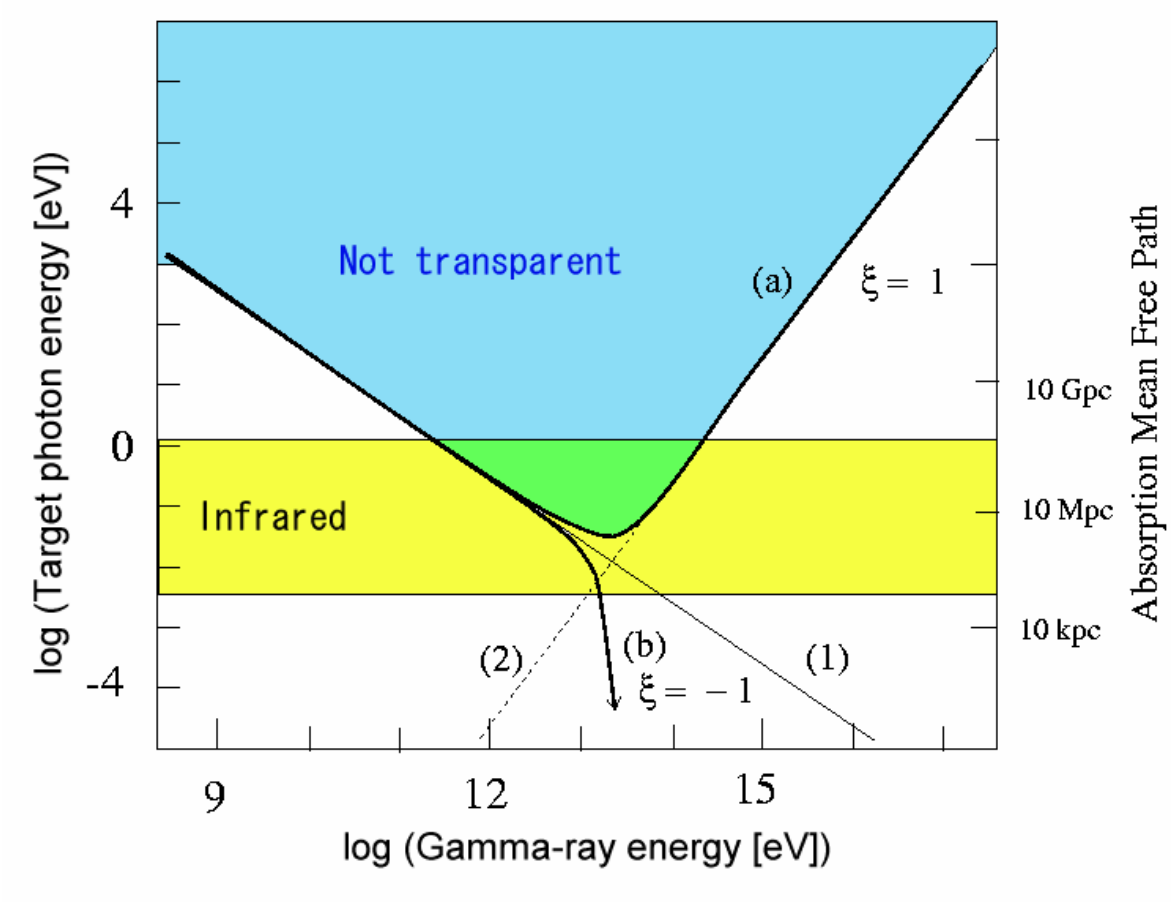
Photon propagation delay

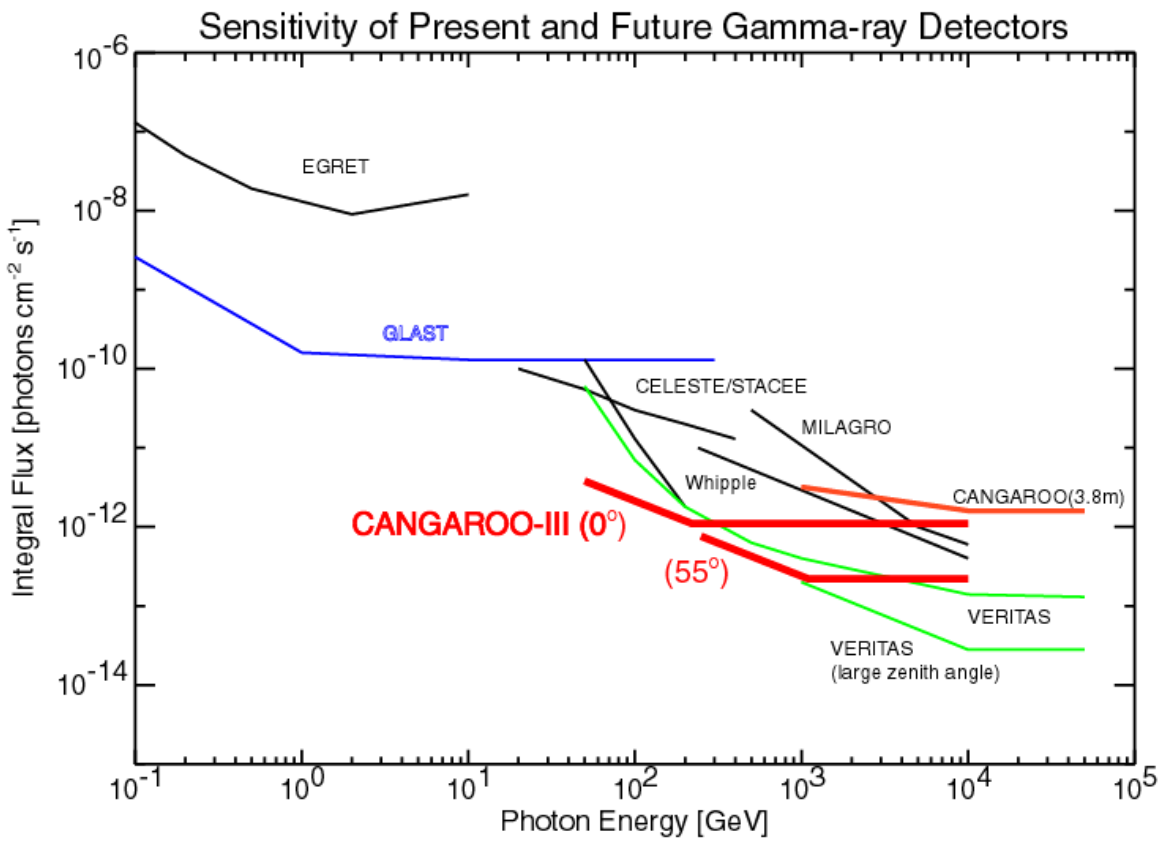


Photon transparency



T. Kifune astro-ph/9904164c

CANGAROO-III sensitivity



Summary

- GeV gamma-ray emission from GRBs:
  flat spectrum; longer duration(?)
- VHE gamma-rays from GRBs:
  Obs. in progress: impact if really found!
- Some worries...
  - Small duty factor
  - IR absorption? (Quantum gravity may prevent!)