Ryo Tsutsui, JGRG 22(2012)111305

"Measuring distance with gamma-ray bursts"

RESCEU SYMPOSIUM ON

GENERAL RELATIVITY AND GRAVITATION

JGRG 22

November 12-16 2012

Koshiba Hall, The University of Tokyo, Hongo, Tokyo, Japan

Distance measurement with (long) gamma-ray bursts

- Ryo Tsutsui (RESCEU)
  on behalf of GRB Cosmology Project
  and Hi-Z GUNDAM Project

JGRG22 2012/11/13

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- Brief introduction of gamma-ray bursts
- previous works and problems for distance measurements with gamma-ray bursts
- Their improvements and future prospects

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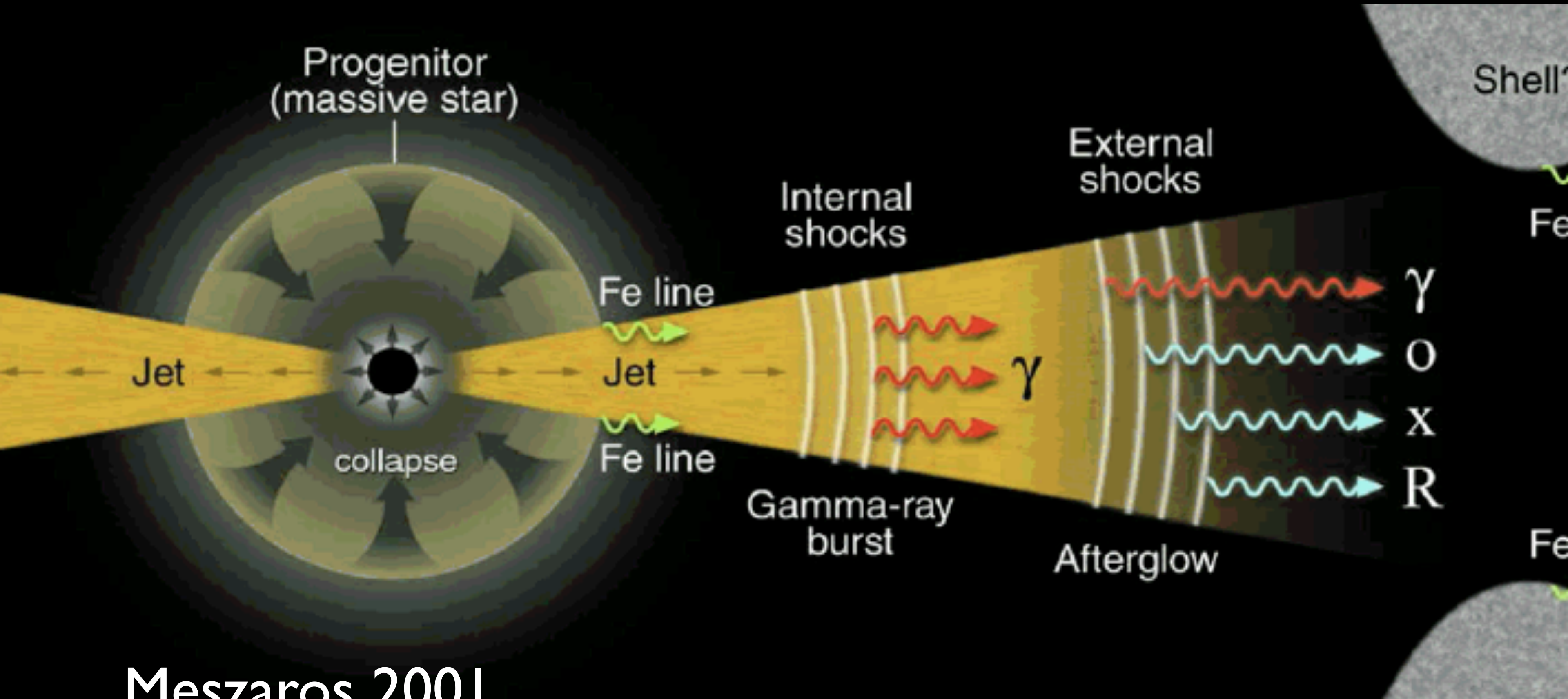
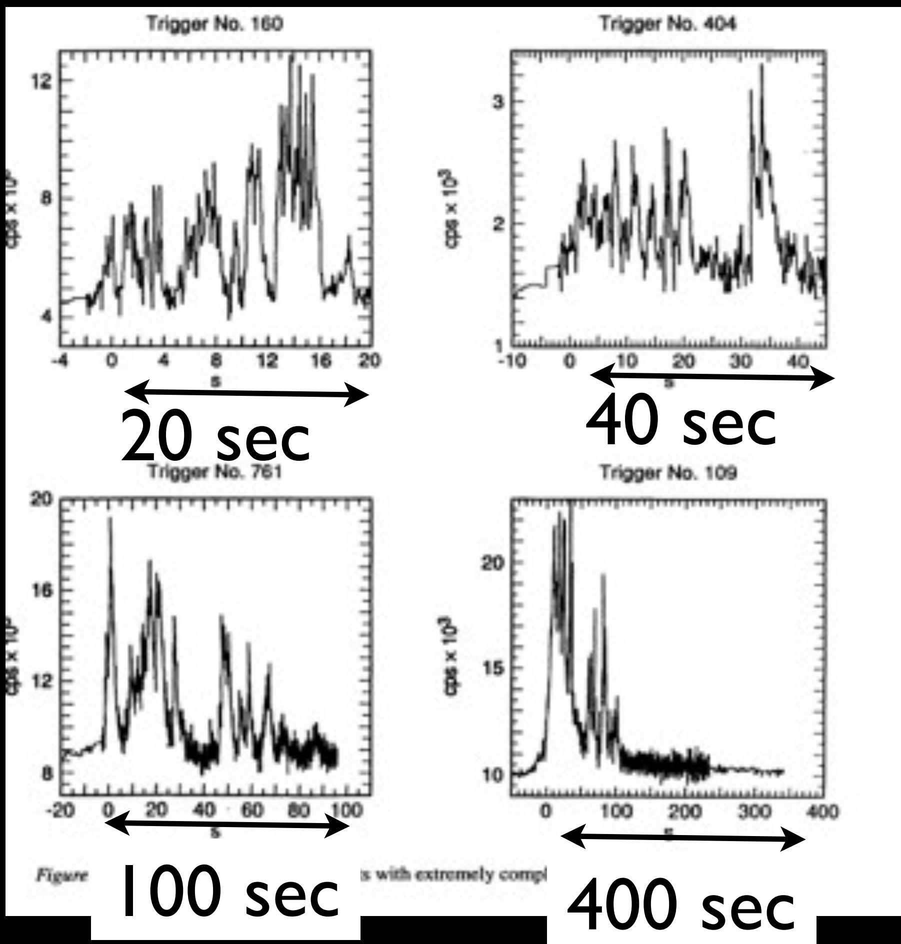
The simplest picture of long gamma-ray bursts



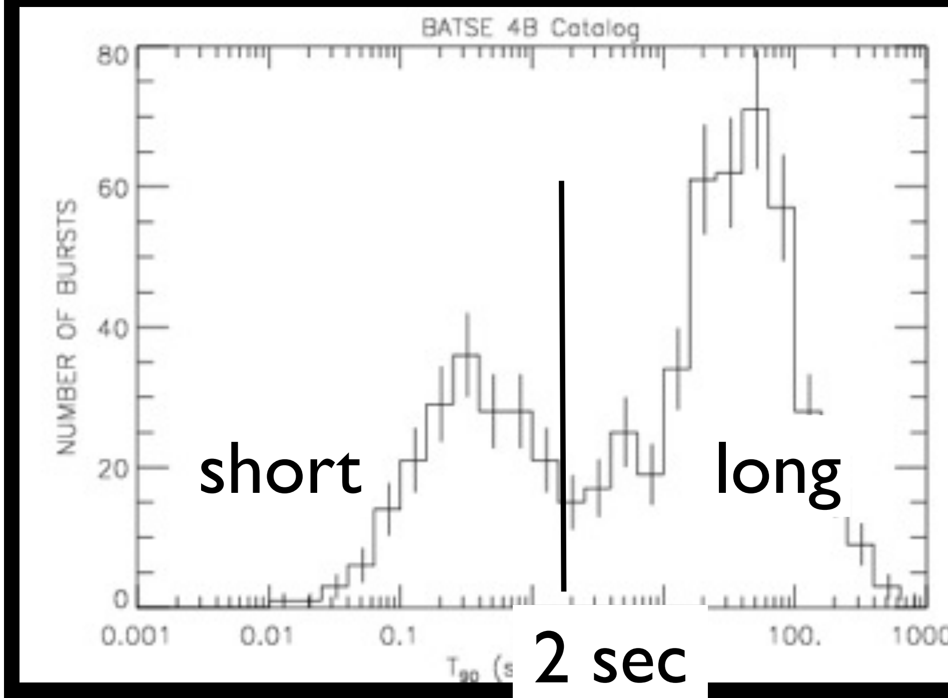
Meszaros 2001

- Energy release form central engine
- Radiation from relativistic jet Lorents factor ~ 100
- interaction between shell and interstellar medium

Time scale of GRBs

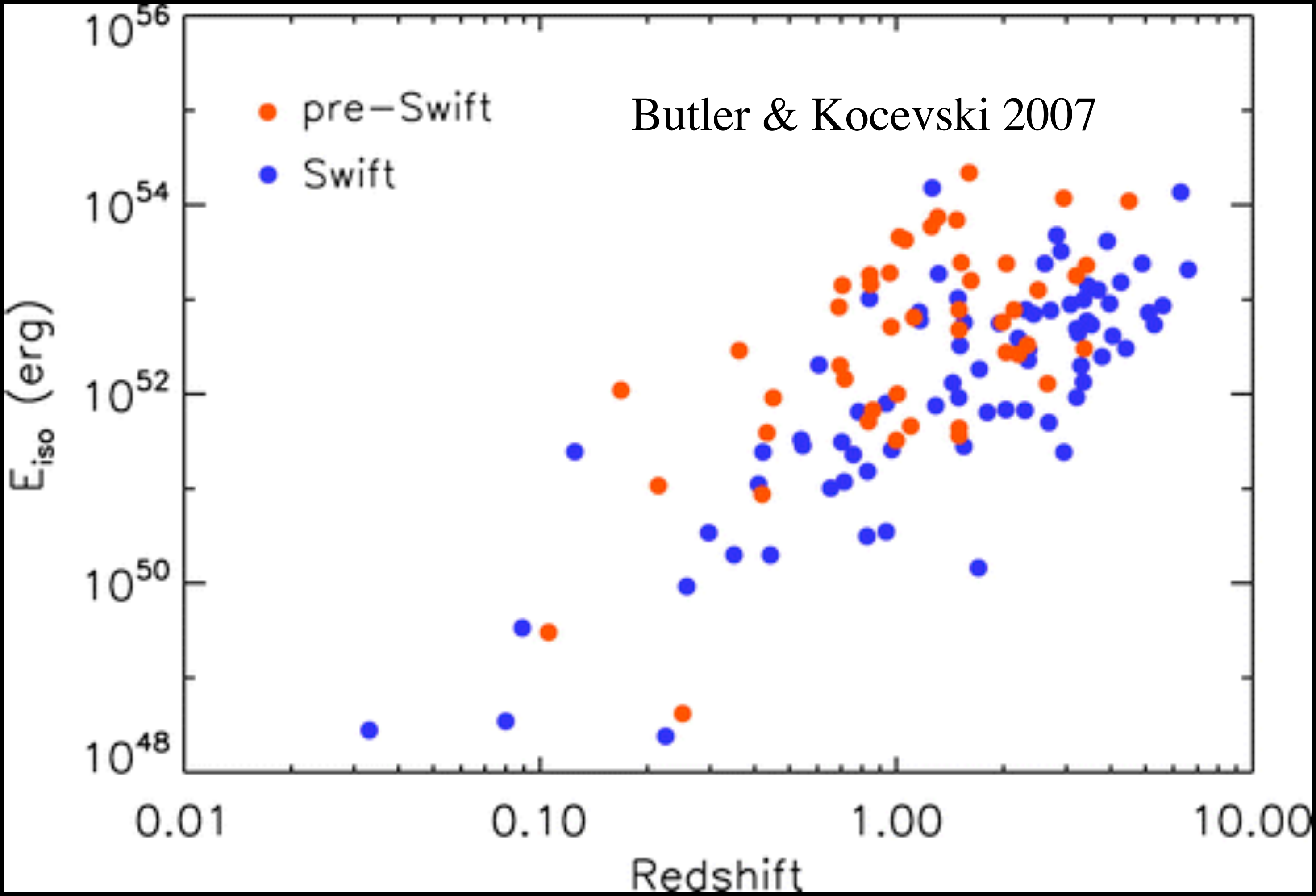


Complex time profile

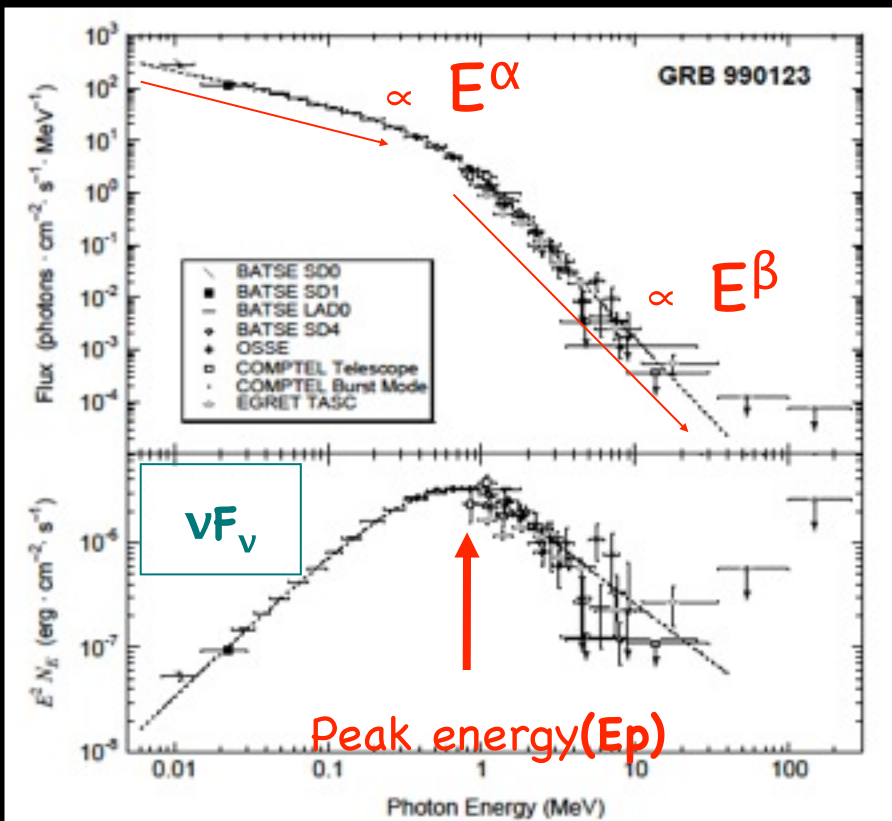


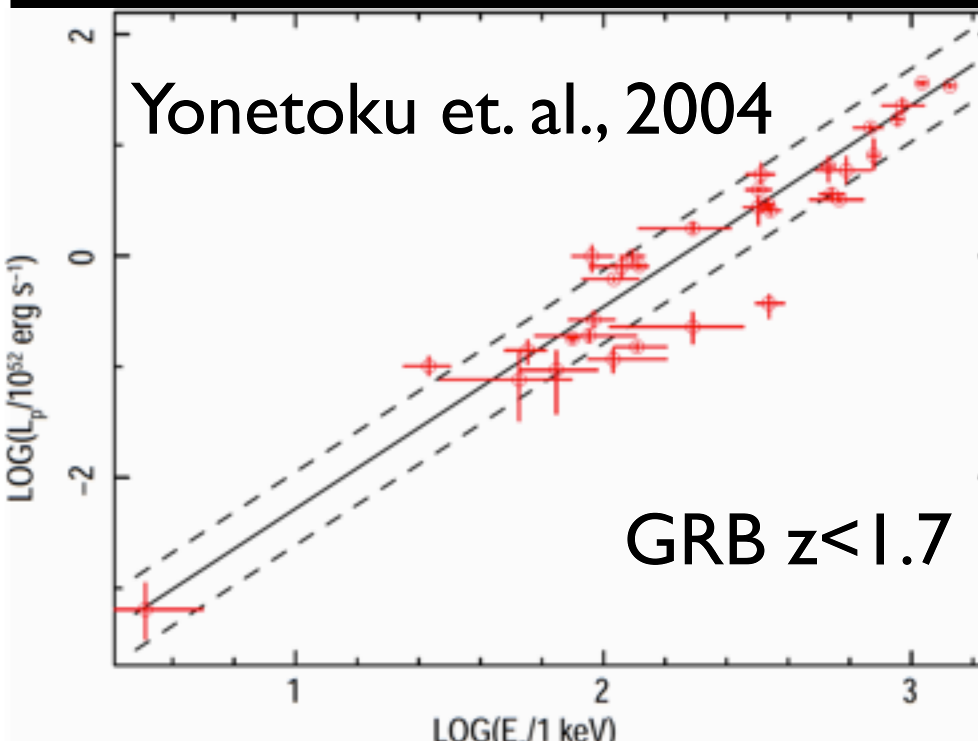
Two population
Long: core collapse
Short: merger?

Energy and distance of GRBs



Spectra - Luminosity correlation





GRBs are "standardizable candles"

Luminosity of objects in the sky

Sun 10^{33} erg/s

Type Ia Supernovae 10^{43} erg/s

Gamma ray bursts 10^{53} erg/s

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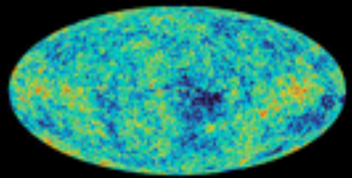
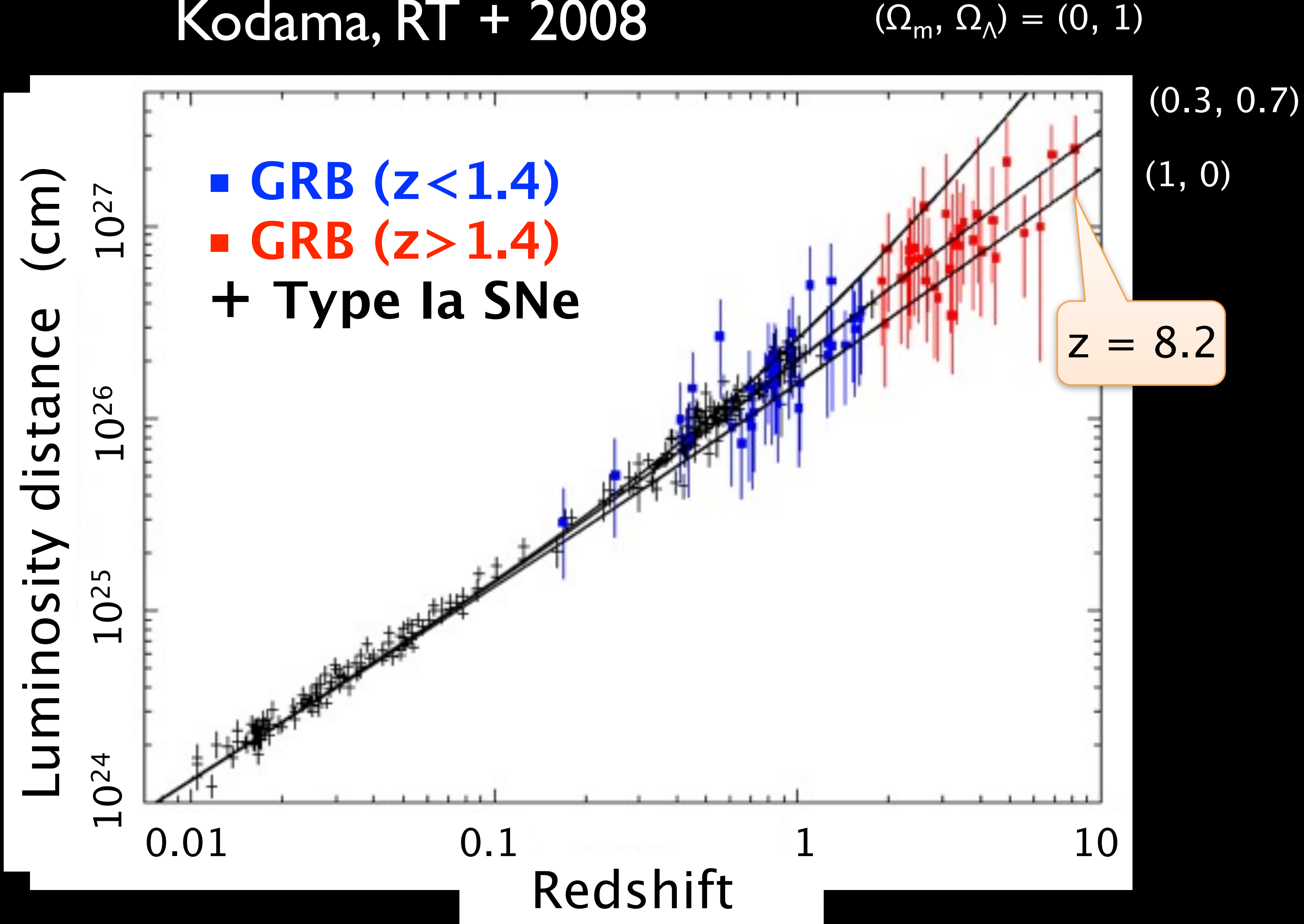
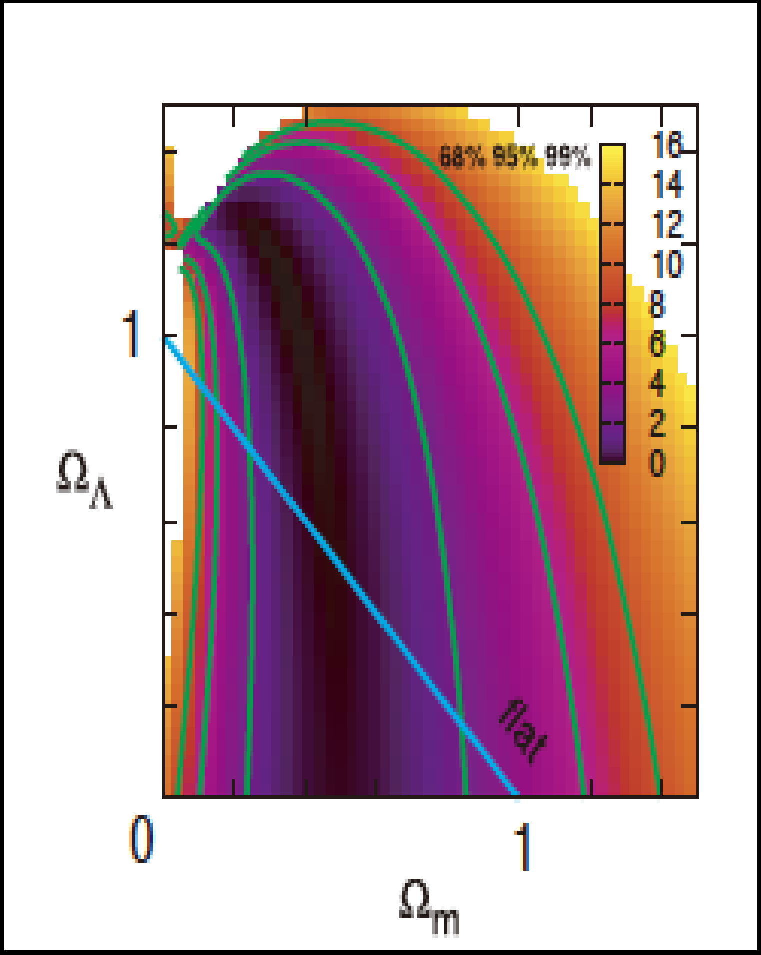
Distance measurement with GRBs

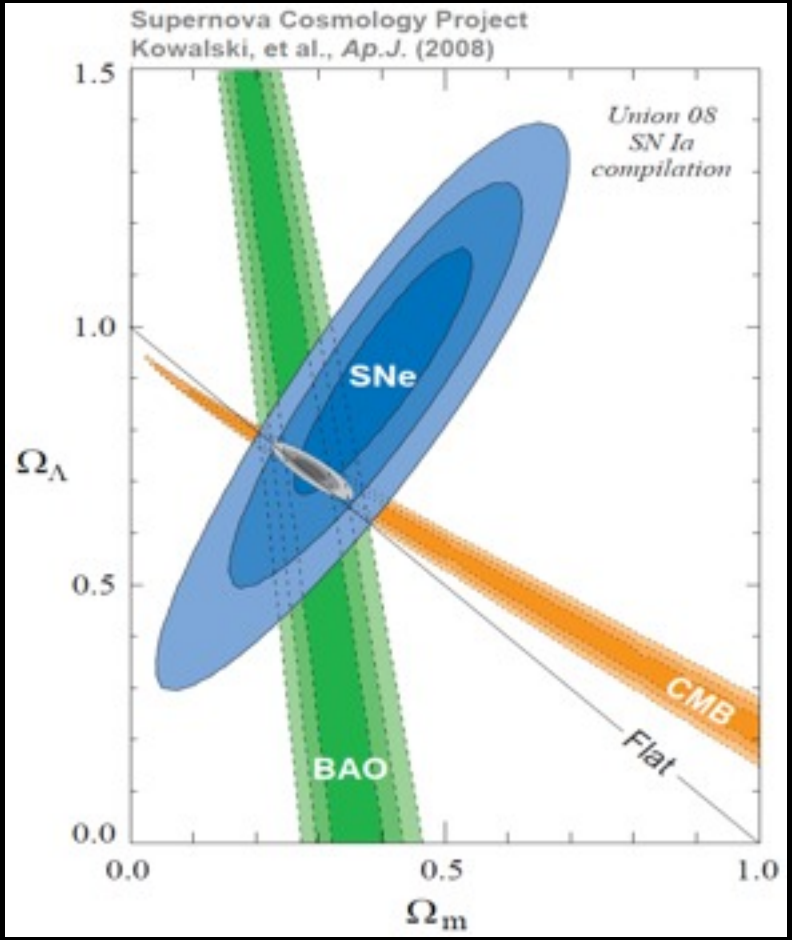


Kodama, RT + 2008

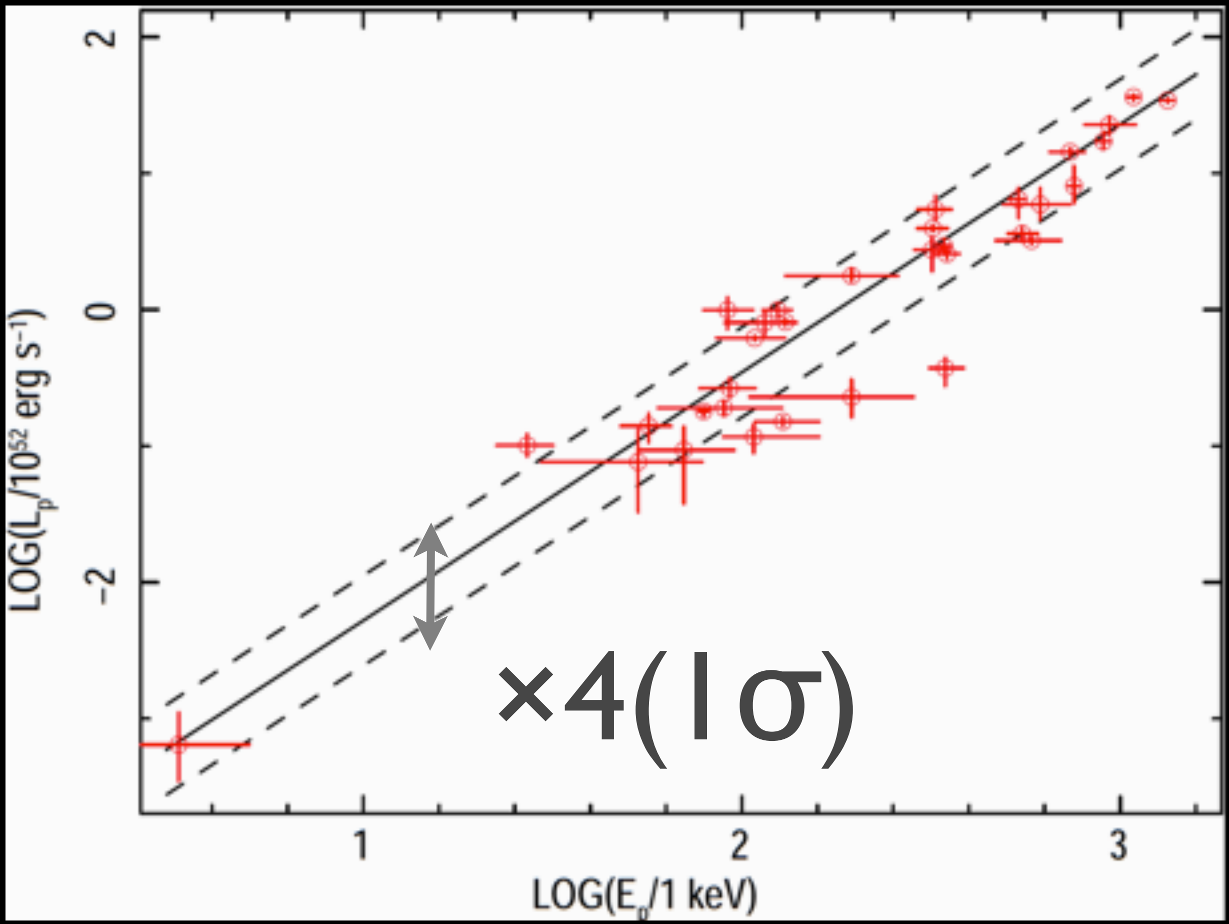


Kodama, RT + 2008



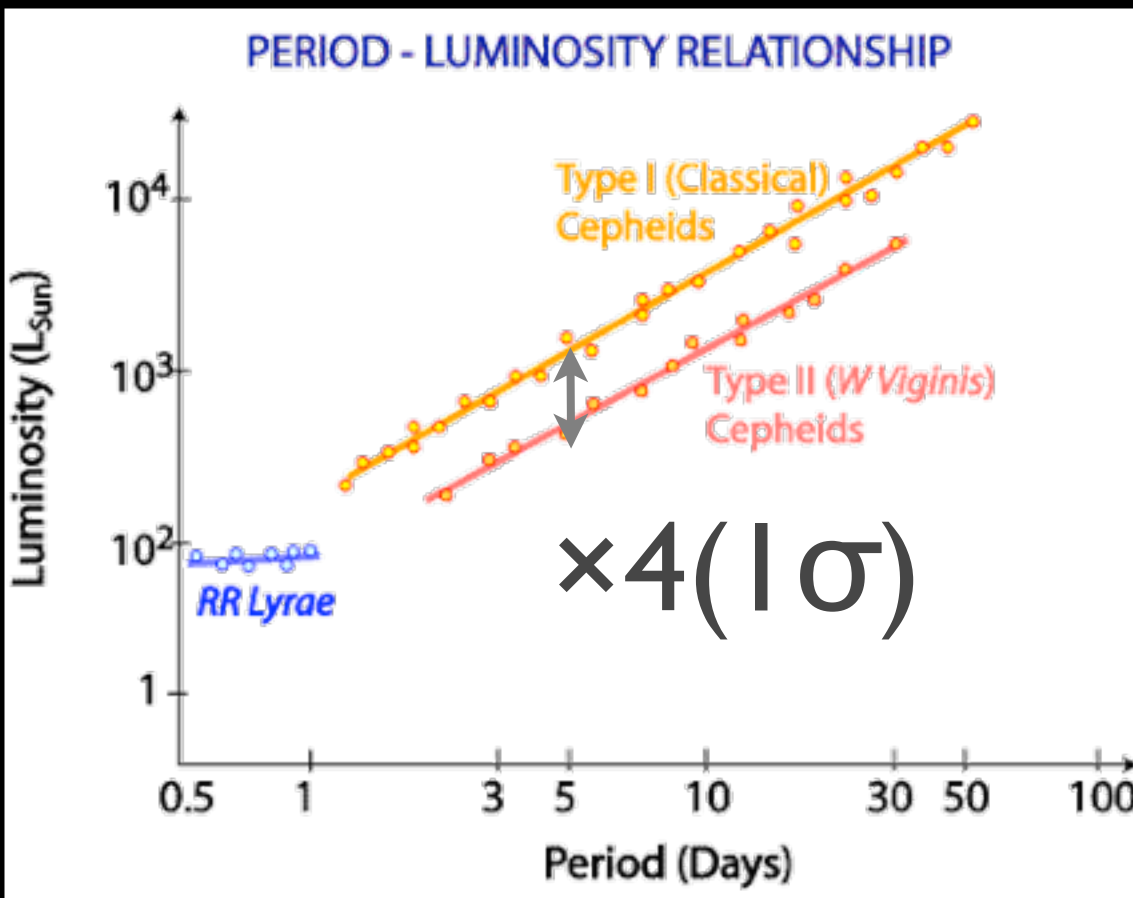


Major origin of error



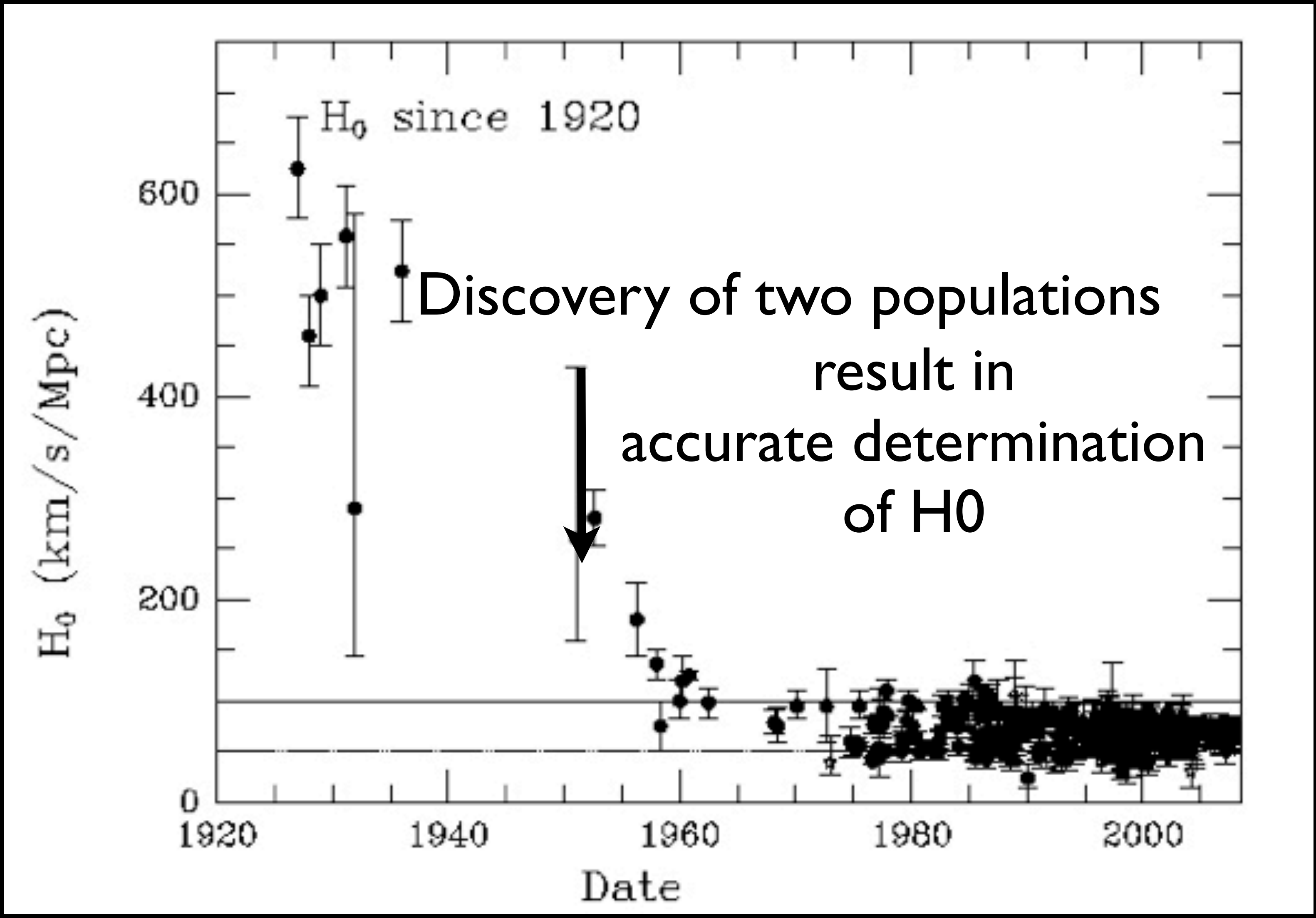
The upper dashed line is 4 times brighter than the lower one.
This means that we have two times uncertainty in distance measurement with Ep-Lp relation.

What means "Four times"

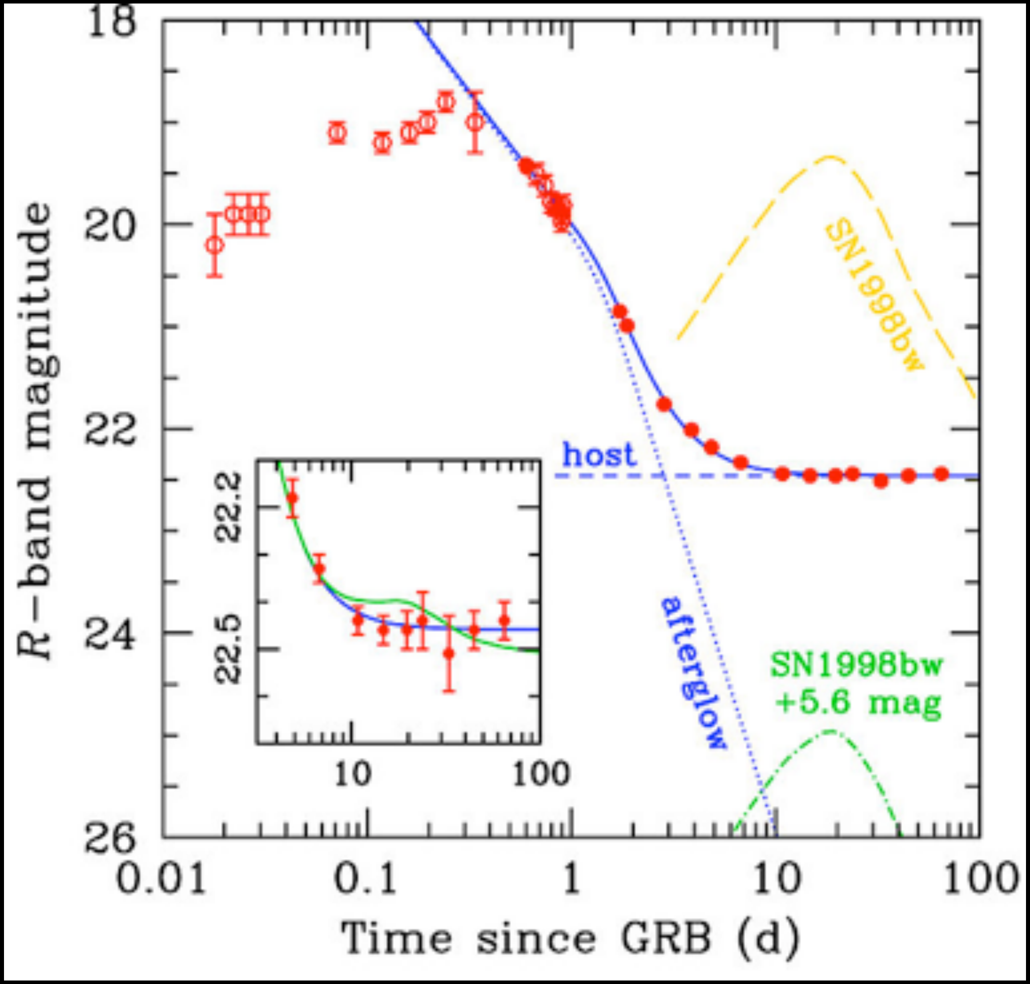


The difference between two P-L relations for Cepheid is comparable with dispersion of the Ep-Lp relation for long GRBs.

Result of the classification of Cepheid variable

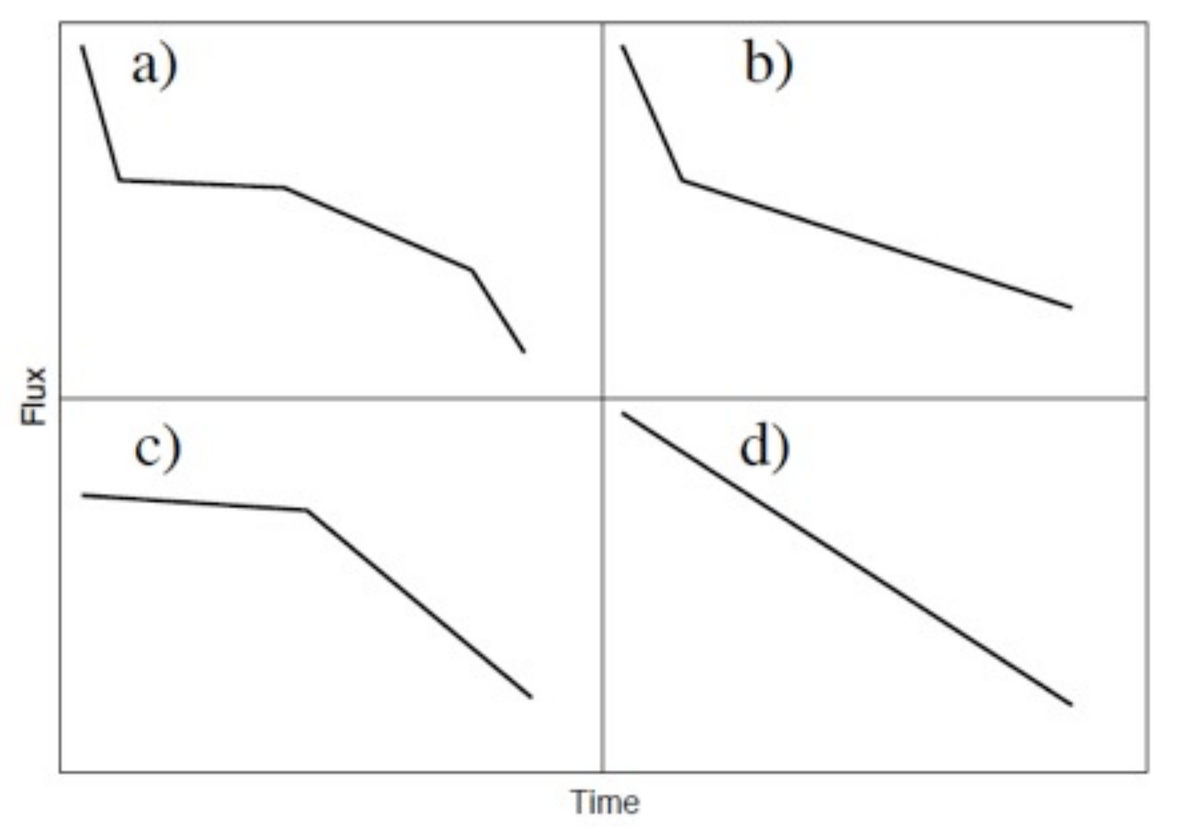


Clues for the existence of sub-classes of long GRBs I



Some long GRB are associated with Type Ic SN, but some does not. These events may result in sub structure in the Ep-Lp relation.

Clues for the existence of sub-classes for long GRBs II



The most difficult problem which GRB study is facing.
This suggests that there are some populations of long GRB.

Diversity of X-ray AG light curve ($t \sim 100\text{-}10^6$ sec)

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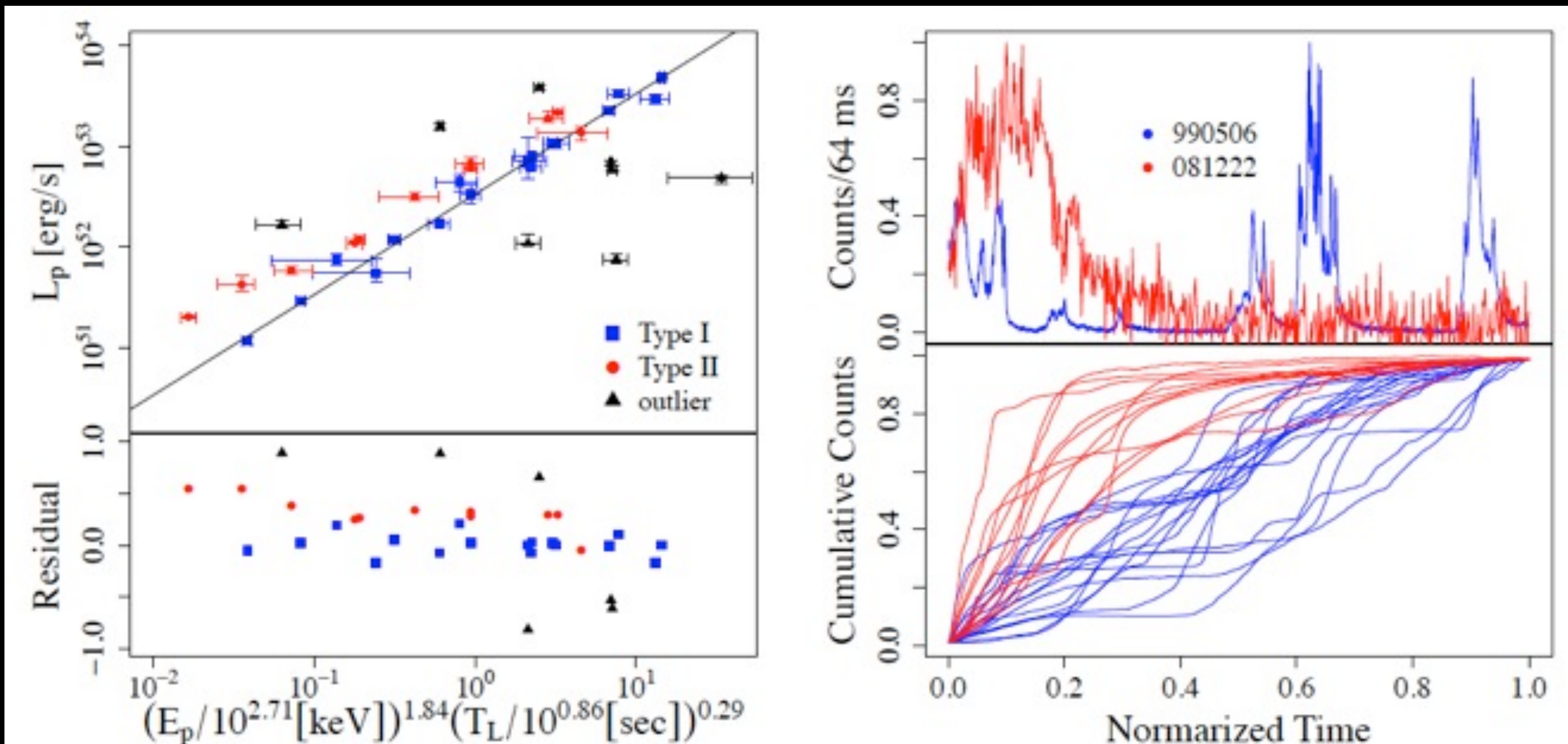
Toward accurate candles

- The use of accurate data.
- Redefinition of Lp in GRB rest frame time.
- The use of robust statistics and outlier rejection
- The second parameter : $T_L = E_{iso}/L_p$

Yonetoku, RT, + PASJ, 2010
RT, + PASJ, 2011

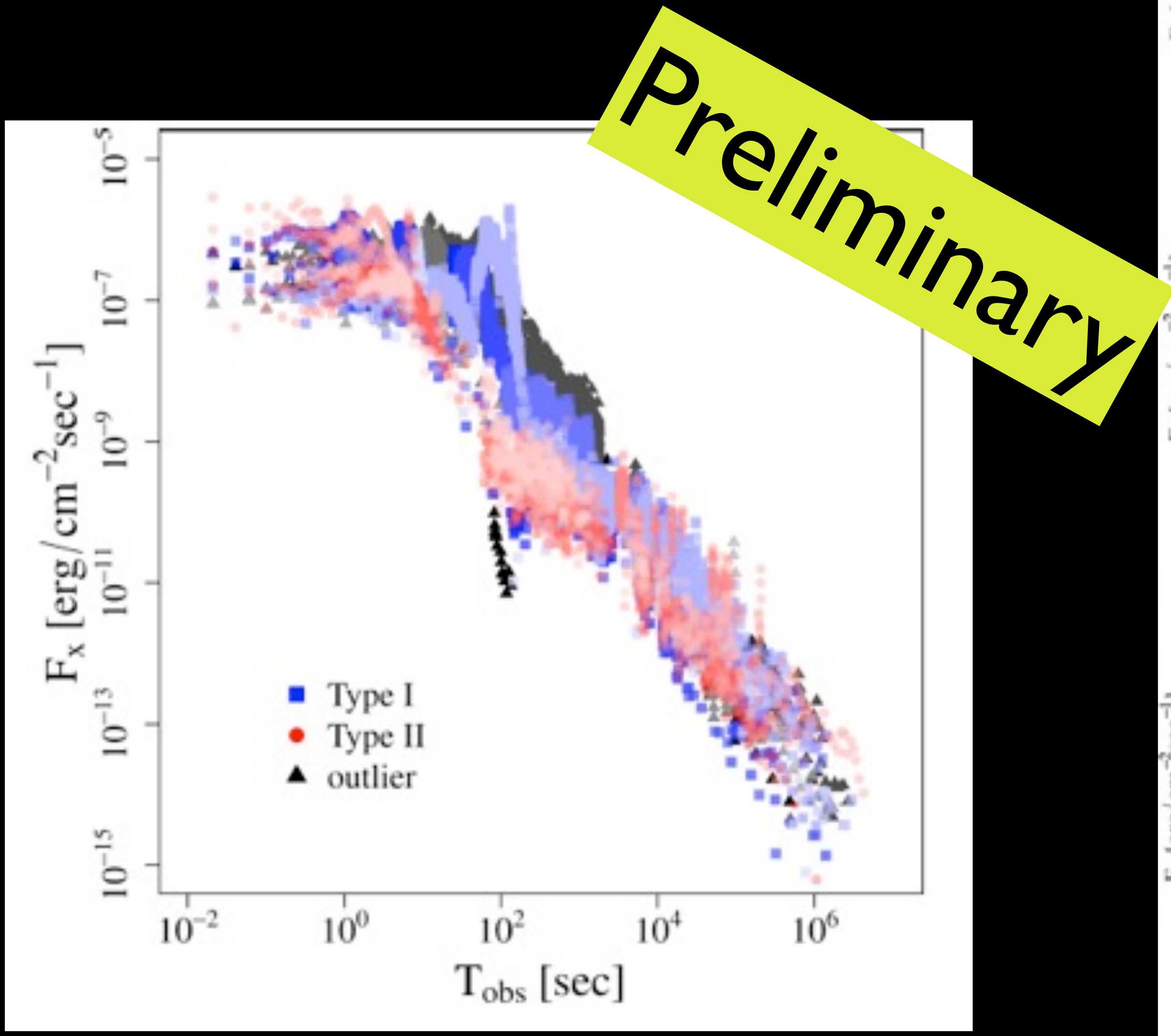
Two separate populations of long GRBs

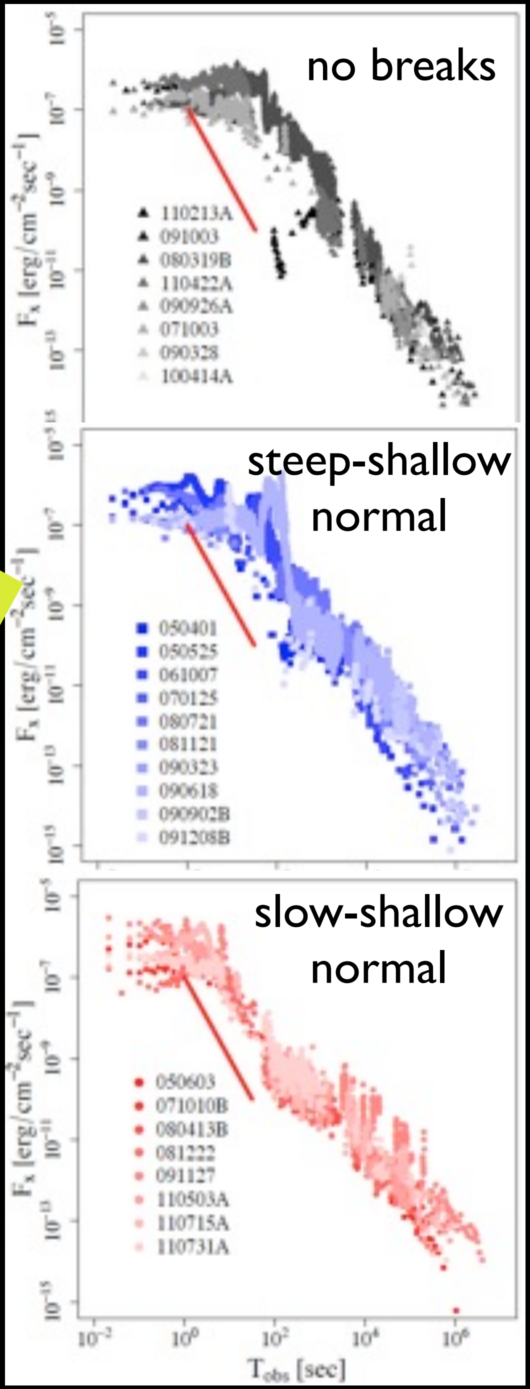
RT. PASJ in press



$T_L = E_{iso}/L_p$

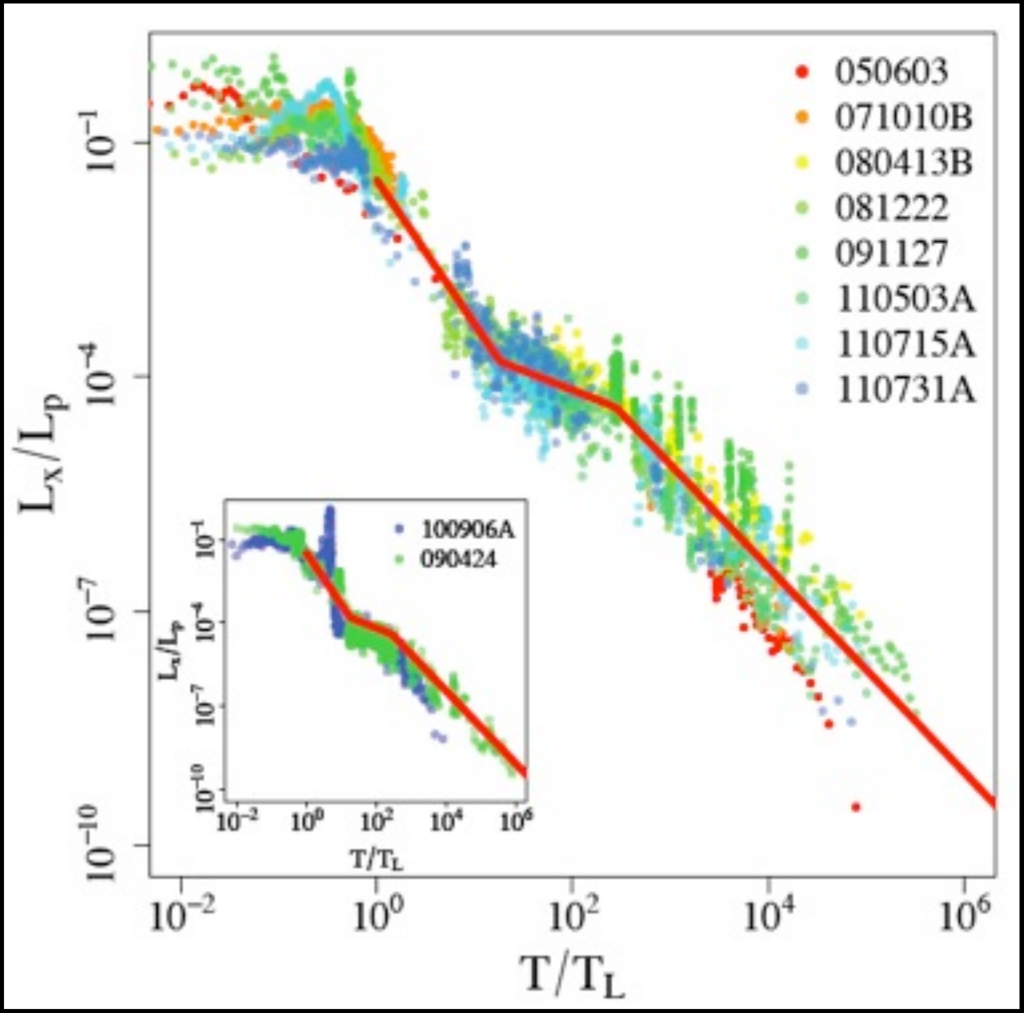
Prompt-afterglow connection





A new scaling law of Type II long GRBs

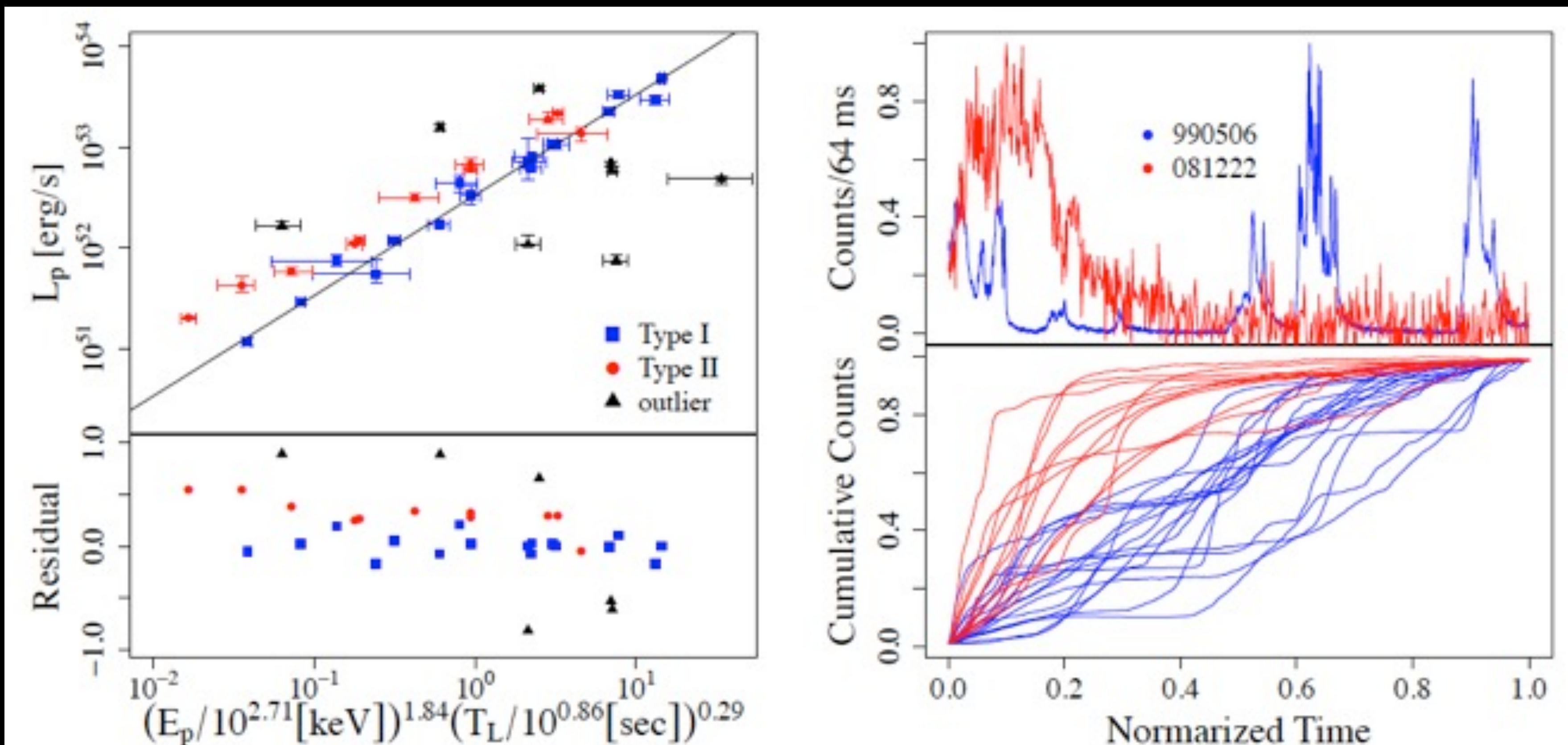
Preliminary



Division into sub classes reveals a beautiful scaling law of Type II long GRBs. This relation implies a universal mechanism which governing both of prompt and afterglow emissions.

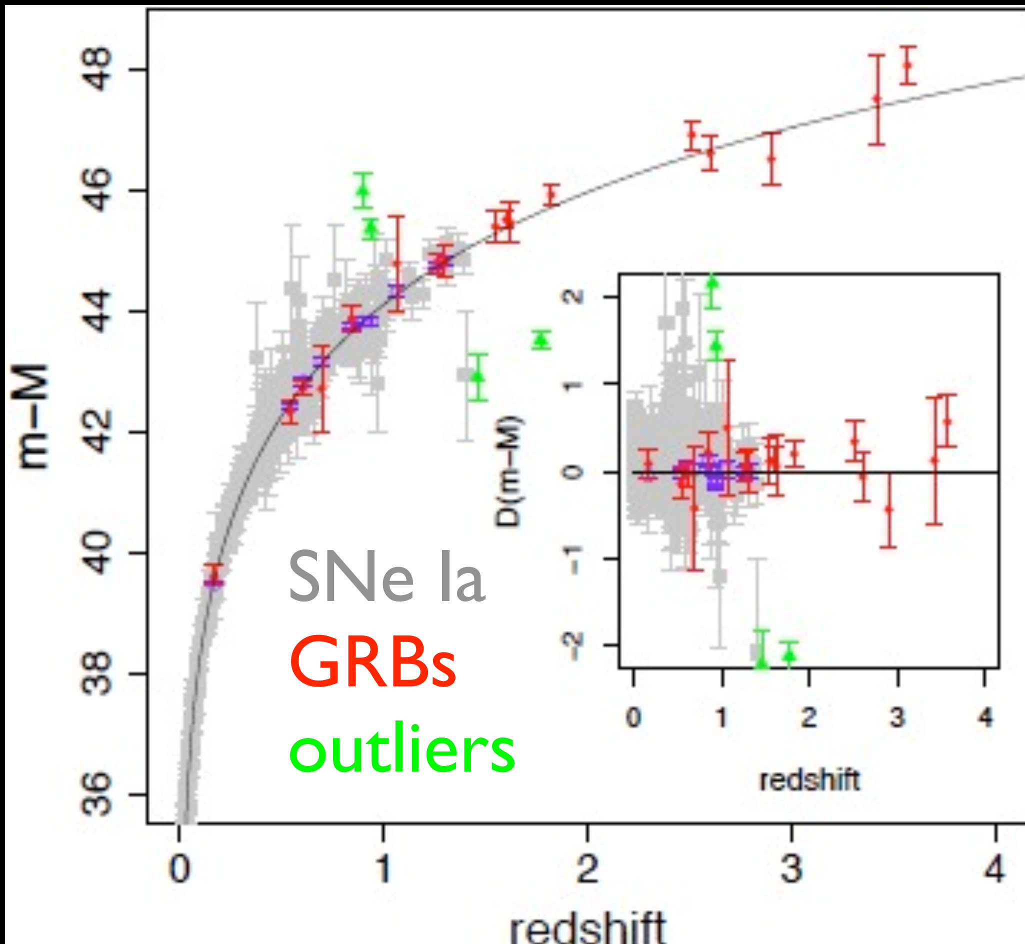
Two separate populations of long GRBs

RT. PASJ in press



$T_L = E_{iso}/L_p$

Hubble diagram for Type I long GRBs



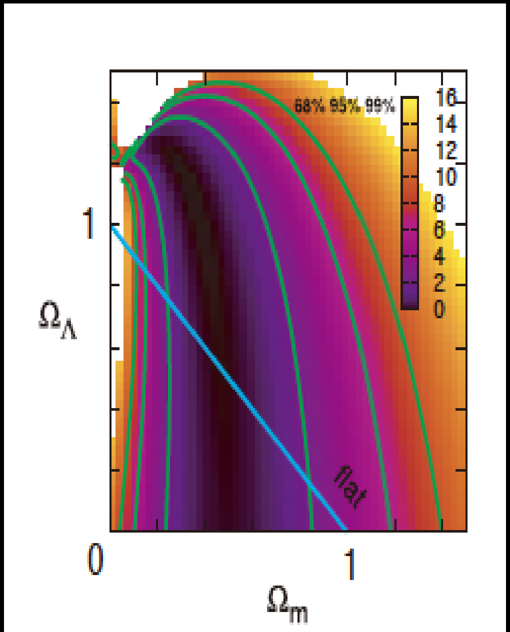
$(\Omega_m, \Omega_\Lambda) = (0, 1)$

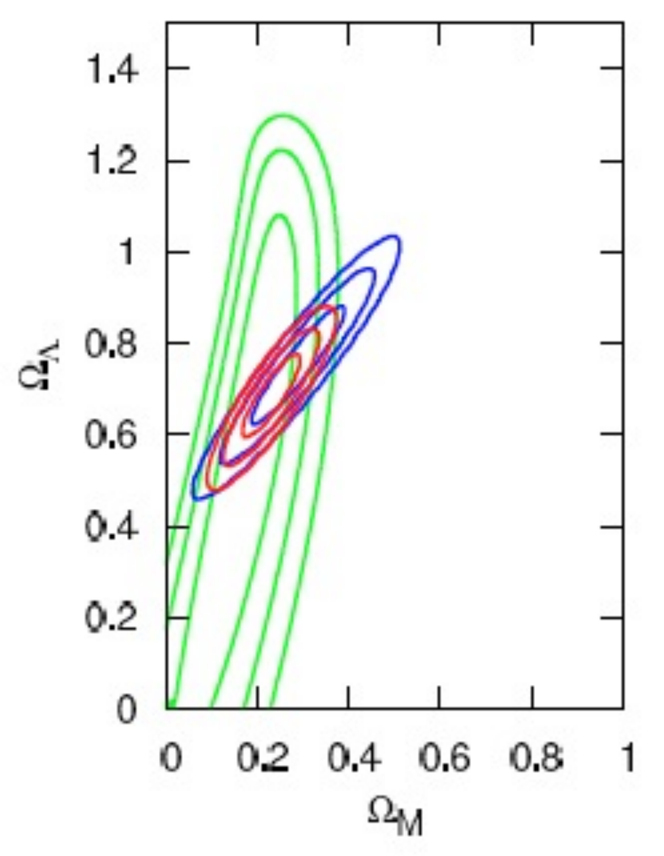
$$\bar{\sigma}_{\mu,\mathrm{GRBs}} = 0.31$$

$$\bar{\sigma}_{\mu,\mathrm{SNeIa}} = 0.26$$

The error of LGRBs becomes as small as those of SNe Ia.

Constraint from Type I long GRBs

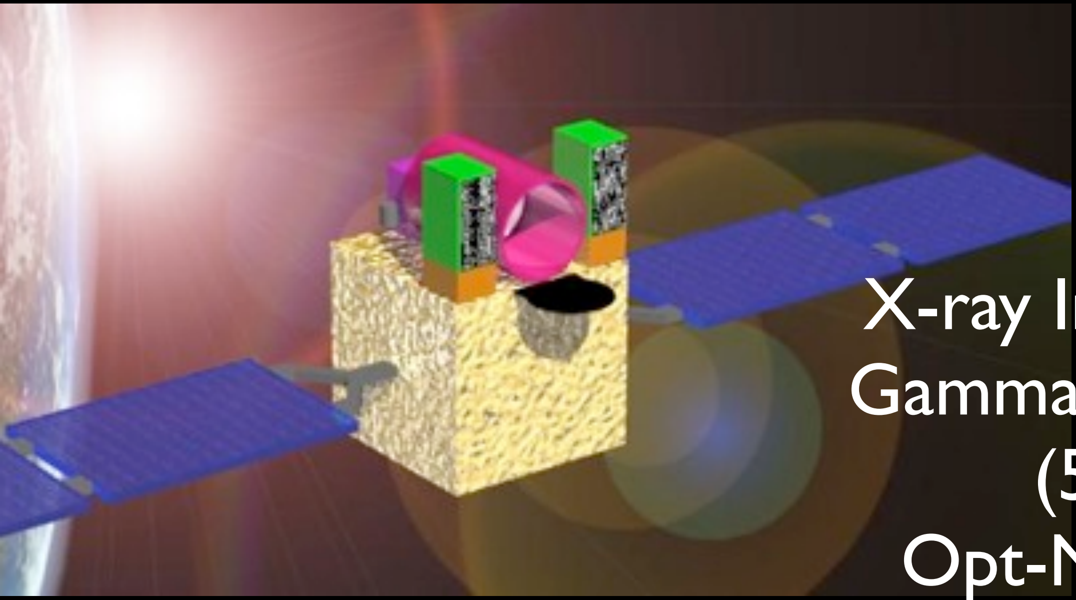




	Ω_M	Ω_Λ	χ^2/d.o.f
9 LGRBs (flat)	0.22 ± 0.04	-	5.09/7
557 SNe Ia (non-flat)	0.29 ± 0.10	0.76 ± 0.13	542.1/555
Combined (non-flat)	0.23 ± 0.06	0.68 ± 0.08	548.3/564

Future mission

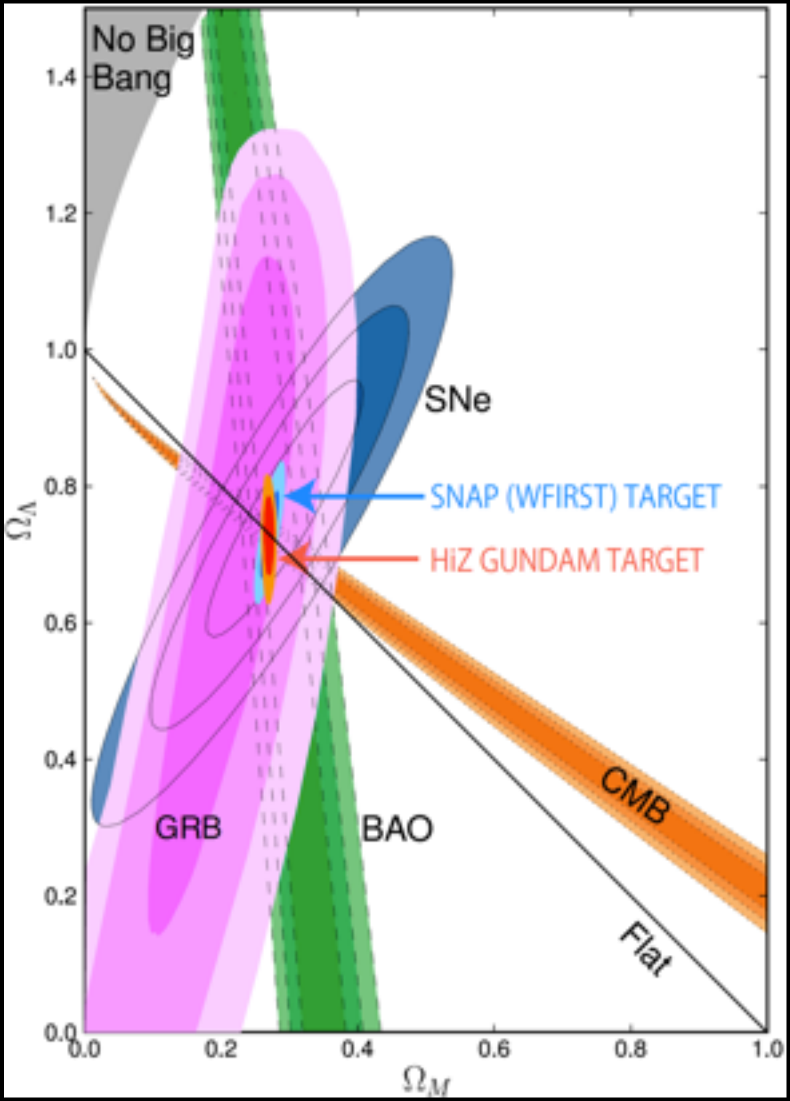
HiZ-GUNDAM (High-z Gamma-ray bursts for Unraveling the Dark Ages Mission)



X-ray Imager (4-100keV)
Gamma-ray spectrometer
(50-1000keV)
Opt-NearIR Telescope
(0.3-1.7μm)

80 events/year (40 events for cosmology?)

Hubble diagram for Type I long GRBs



$\sigma_{\Omega m} \sim 0.01$ for 100 Type I long GRBs.

GUNDAM @ ODAIBA

Hi-Z GUNDAM Project has nothing to do with a famous japanese animation GUMDAM

If you go to Odedo-onsen by subway and monorail,
you can find big gundam from monorail.

Summary

- We have found sub classes of long GRBs.
- Division into two classes drastically improve accuracy of distance measurement.

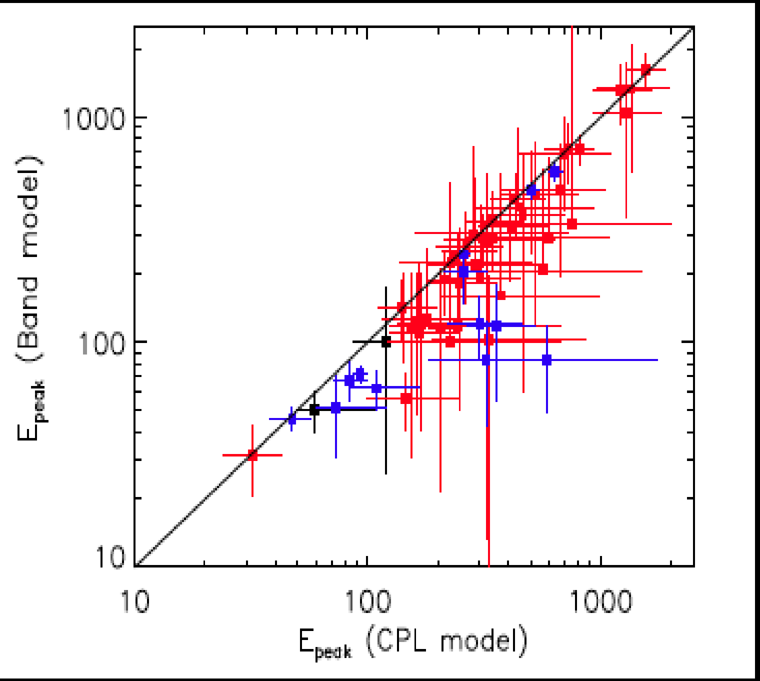
Two distinct spectral model

BAND model

$$f_{\mathrm{BAND}}(E) = \begin{cases} A\left(\frac{E}{100}\right)^{\alpha} \exp\left[-\frac{E(2+\alpha)}{E_{\mathrm{peak}}}\right], & E < E_c, \\ A\left[\frac{(\alpha-\beta)E_{\mathrm{peak}}}{100(2+\alpha)}\right]^{\alpha-\beta} \exp(\beta-\alpha)\left(\frac{E}{100}\right)^{\beta}, & E \geq E_c, \end{cases}$$

Cut off power law model

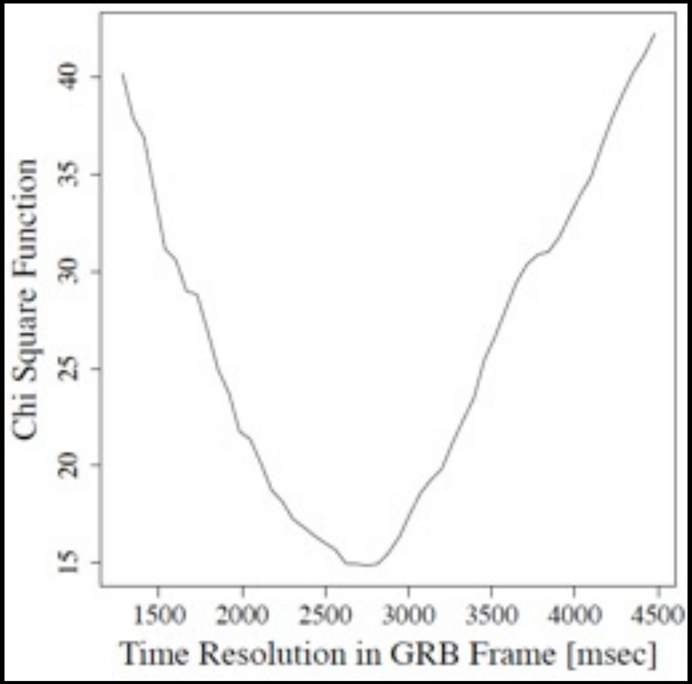
$$f_{\mathrm{COMP}}(E) = A\left(\frac{E}{E_{\mathrm{piv}}}\right)^{\alpha} \exp\left[-\frac{E(2+\alpha)}{E_{\mathrm{peak}}}\right].$$



CPL Ep is alway higher than Band Ep

How to define Lp

I sec in observer frame
→2.7 sec in GRB rest fram



τ ≈ 2.7 sec is the best resolution for Lp