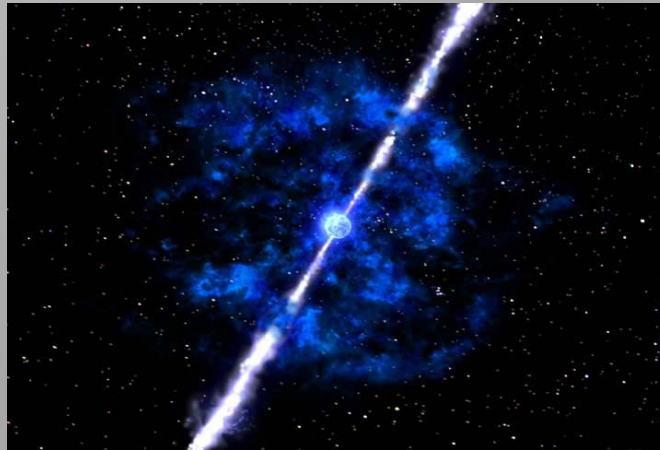


# *Are Gamma-Ray Bursts Cosmological Standard Candles?*



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*Department of Physics*  
*Michigan Technological University*  
*April 2009*

# Outline

- ✓ *A brief history of time & the Universe*
- ✓ *Introduction to Astrophysical notions & definitions*
- ✓ *Gamma-Ray Bursts (GRBs)*
- ✓ *GRBs as probes of the early universe*
- ✓ *Are GRBs real standard candles?*
  - *Shahmoradi & Nemiroff, The possible impact of GRB detectors on cosmological standard candles, **MNRAS***
  - *Shahmoradi & Nemiroff, Correlation of Gamma-Ray Burst Hardness and the spectral peak energy, **MNRAS Letters***

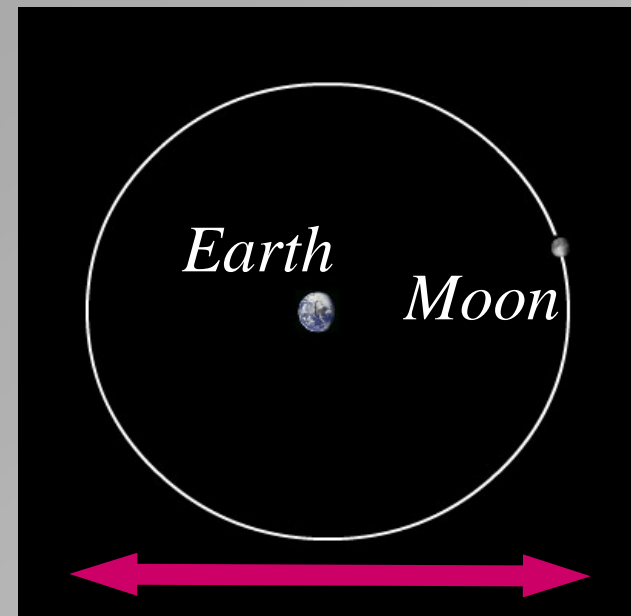
## *Edwin Hubble, Astronomer, 1925*

- ✓ *The Universe is unimaginably huge*
- ✓ *The Universe is expanding*
  - ✓ *It had a beginning 13.7 billion years ago*
- ✓ *The visible size of the universe:*

*13.7 billion light years*

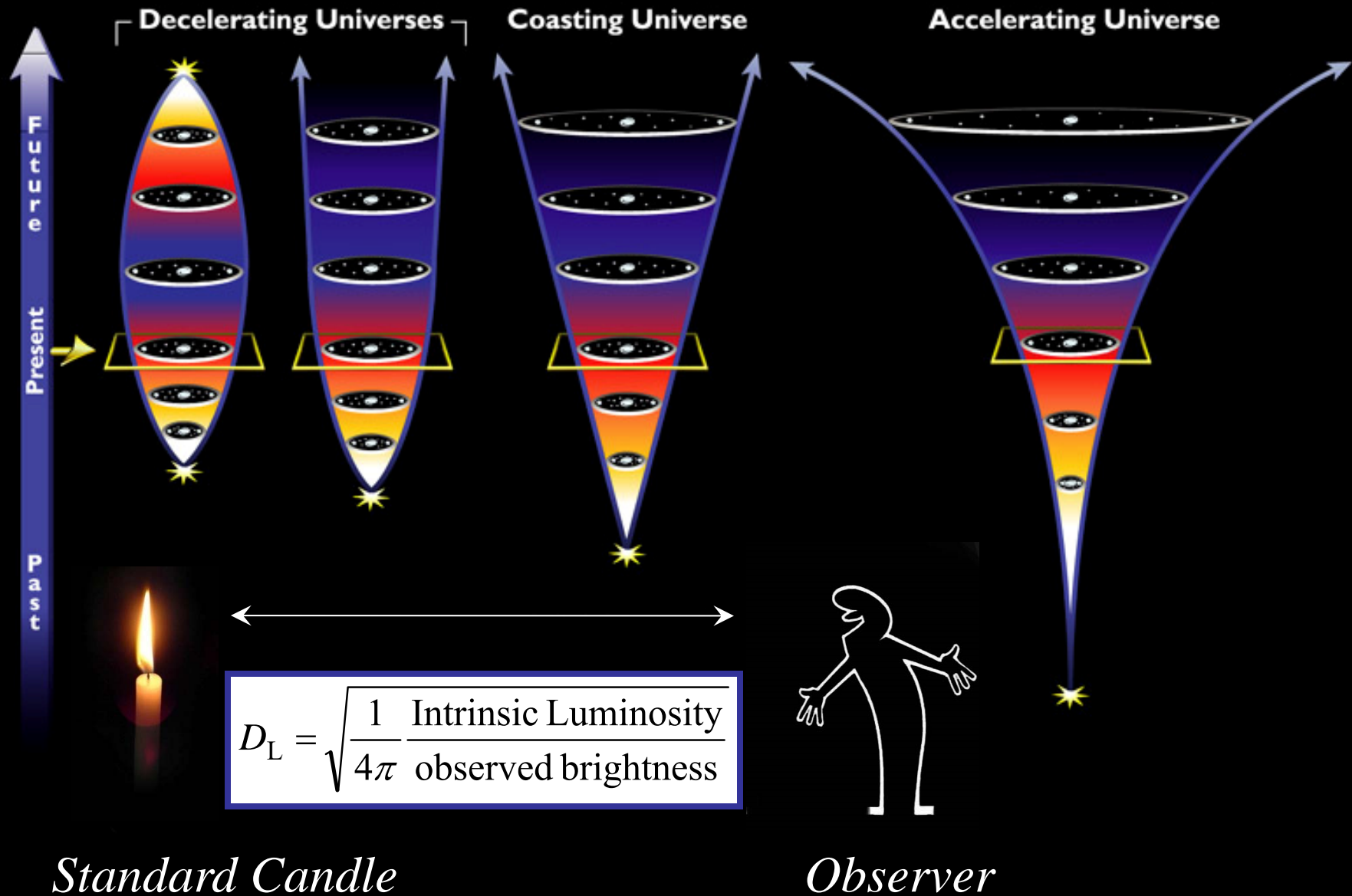
*or*

$$1.3 \times 10^{26} m$$

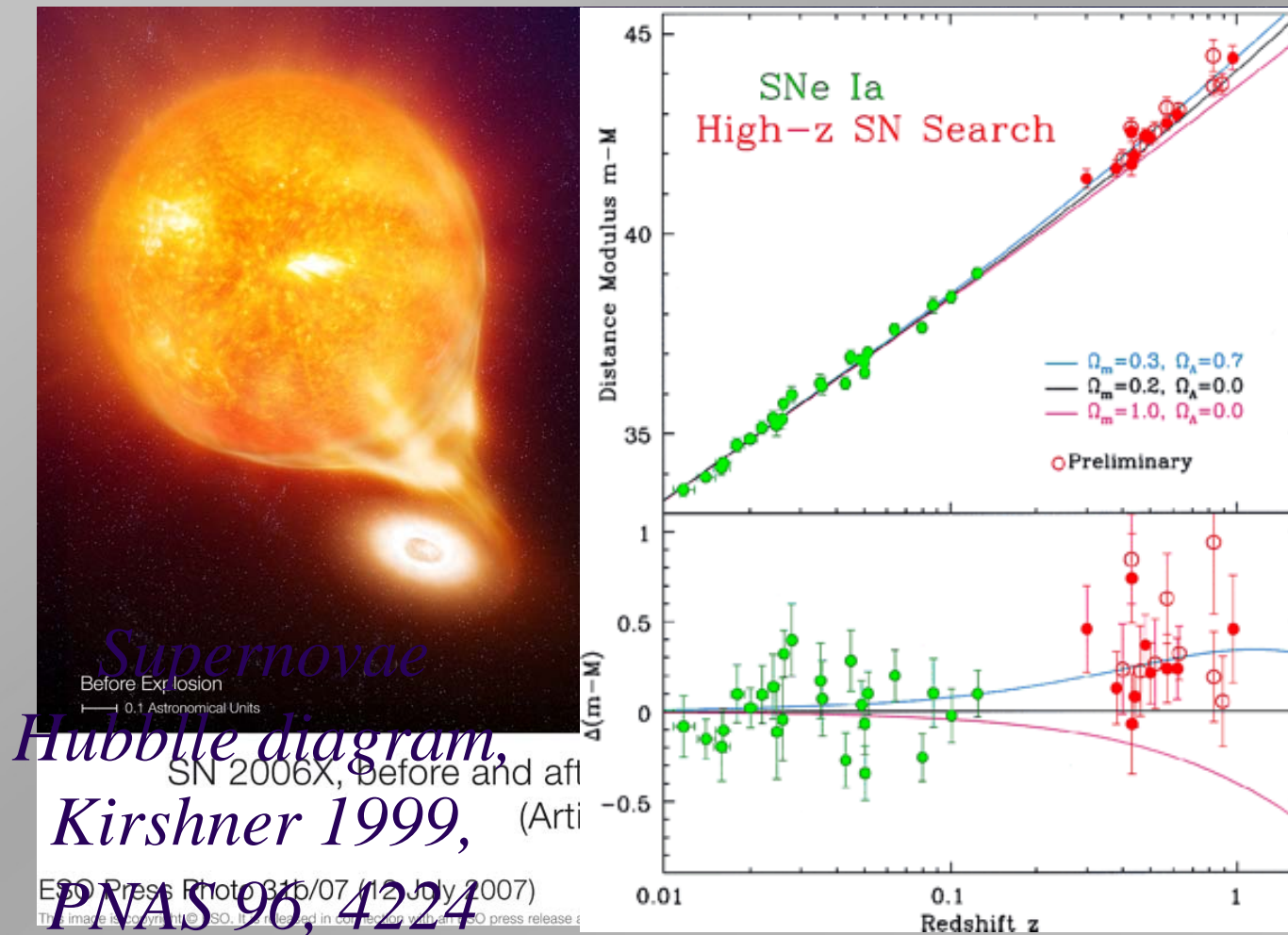


*2 light seconds*

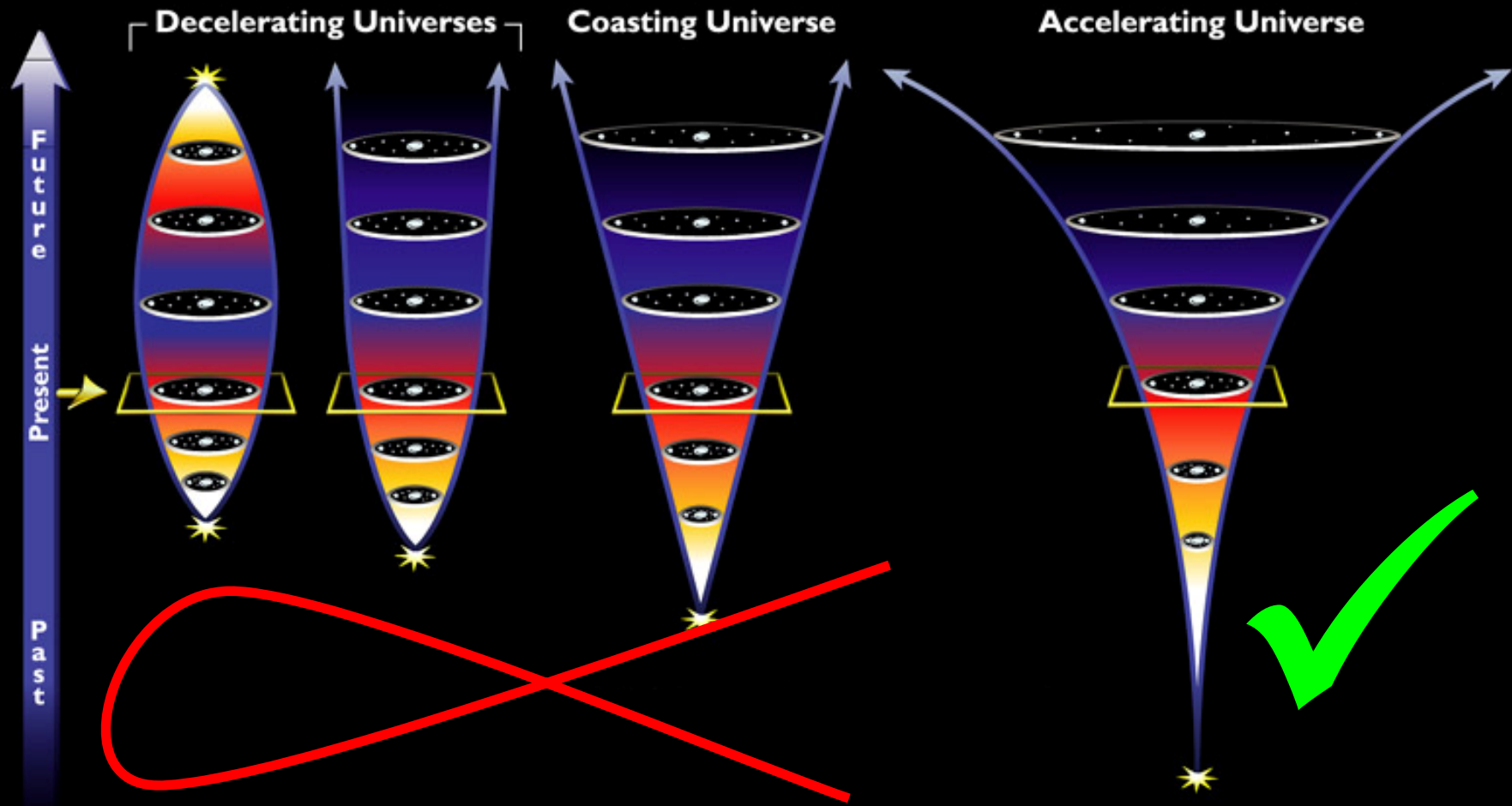
# Possible Models of the Expanding Universe



# Type-Ia Supernovae as Cosmological Standard Candles



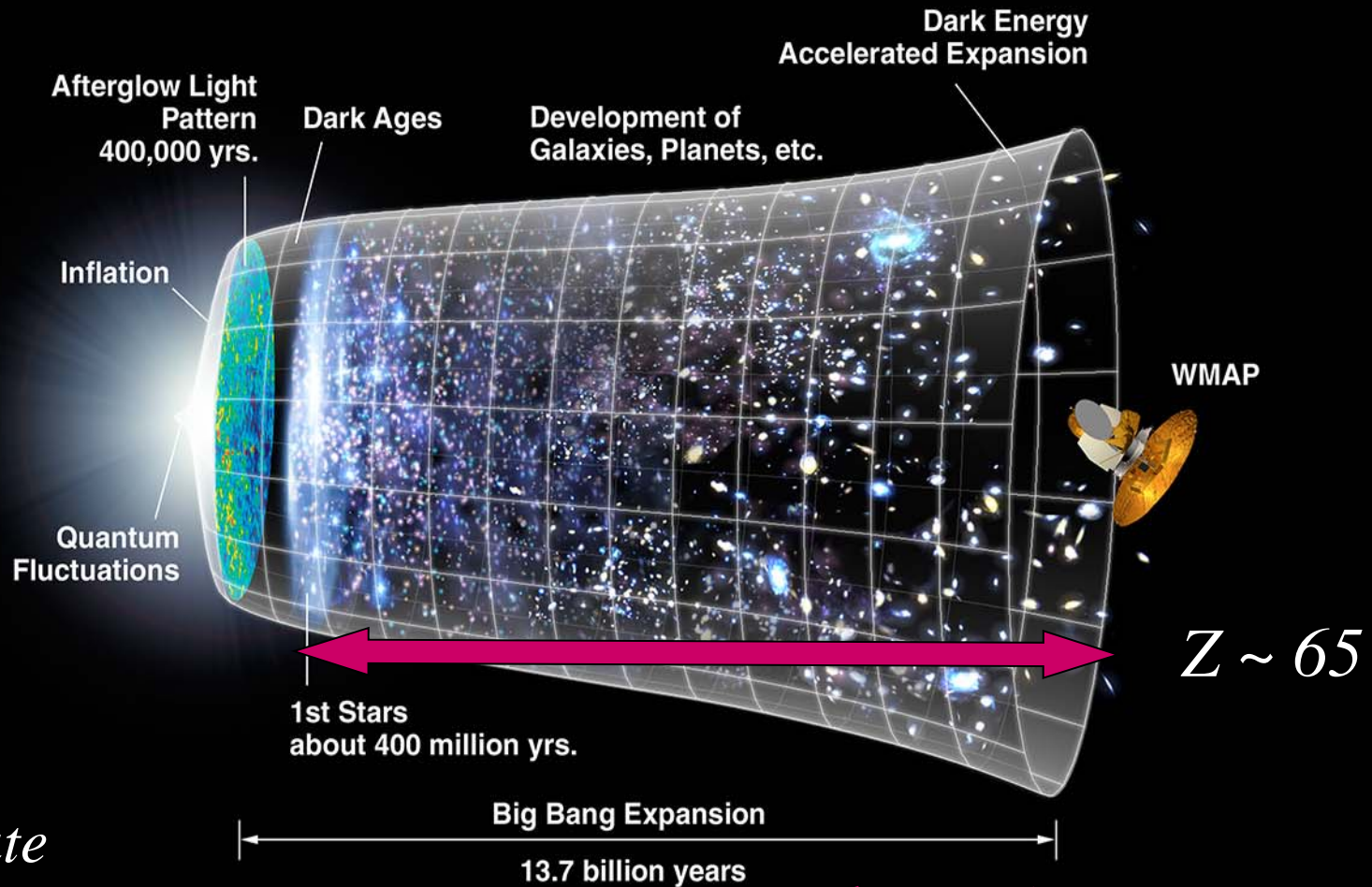
## Possible Models of the Expanding Universe



*Expansion Rate  $> 0$*



# *How to constrain the expansion rate of the universe?*



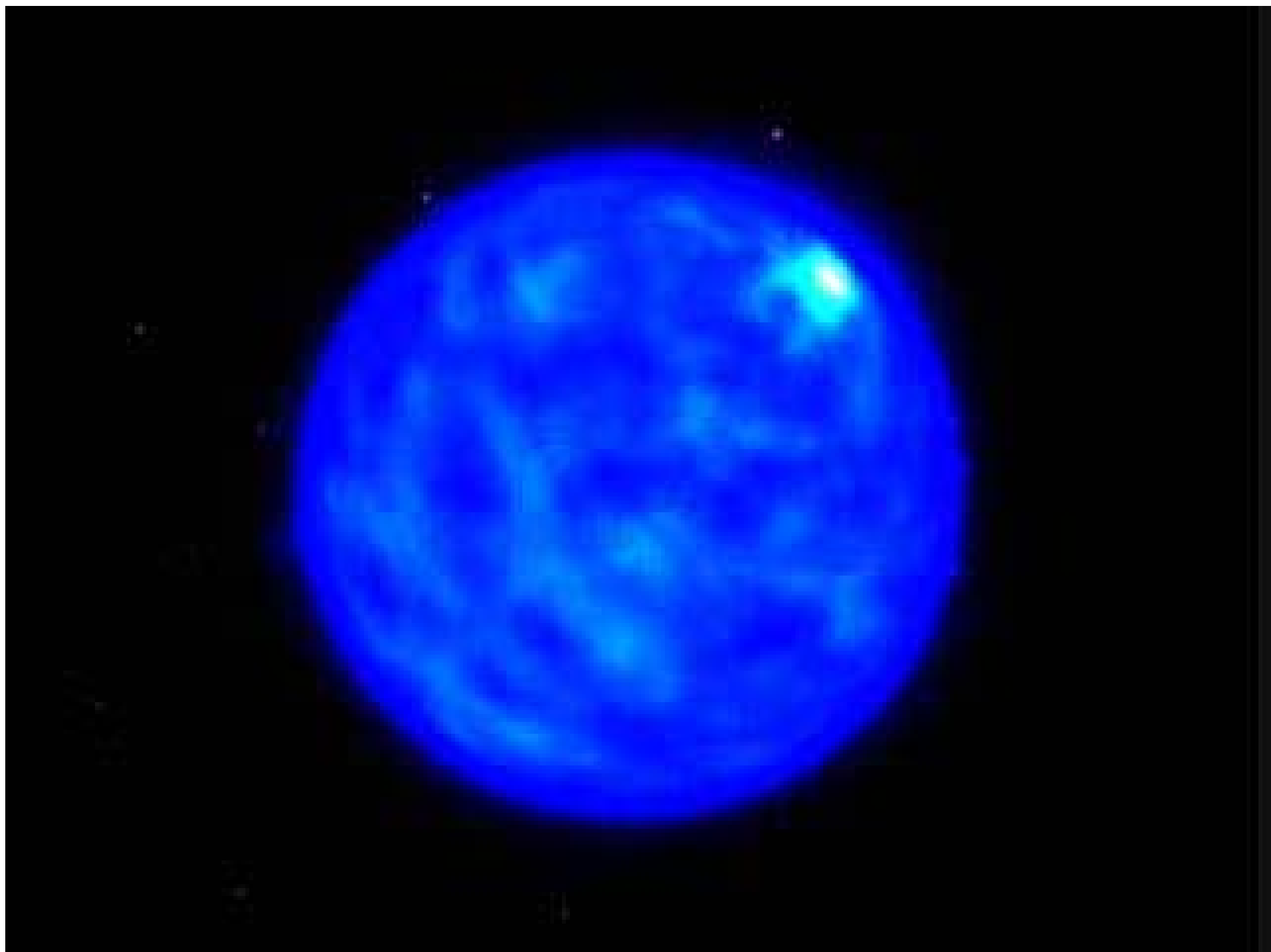
*Candidate  
Standard Candle:  
Gamma-Ray Bursts (GRBs)*

*Supernovae projects:  $Z < 1.7$*

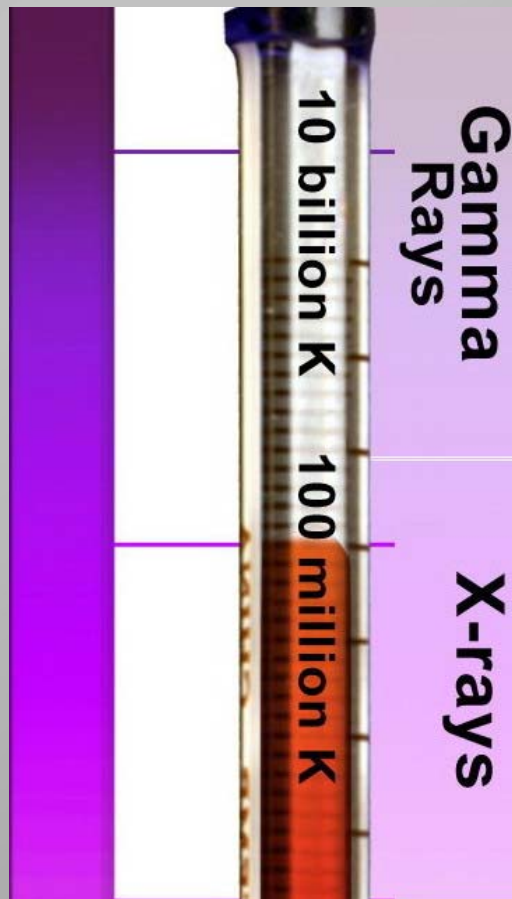
# *Gamma-Ray Bursts*

- ✓ *discovered by Vela nuclear test detection satellite (1960s) , Top-Secret project before the collapse of USSR*
- ✓ *possibly related to the death of super-massive stars*
- ✓ *the most powerful explosions in the Universe*
- ✓ *energy release:  $10^{47}$  ergs –  $10^{55}$  ergs*
- ✓ *energy range: 1 KeV - 10 MeV (Gamma Ray)*
  - ✓ *energy range of the Sun: 1 – 2 eV*
- ✓ *duration: 10 ms - >1000 s*

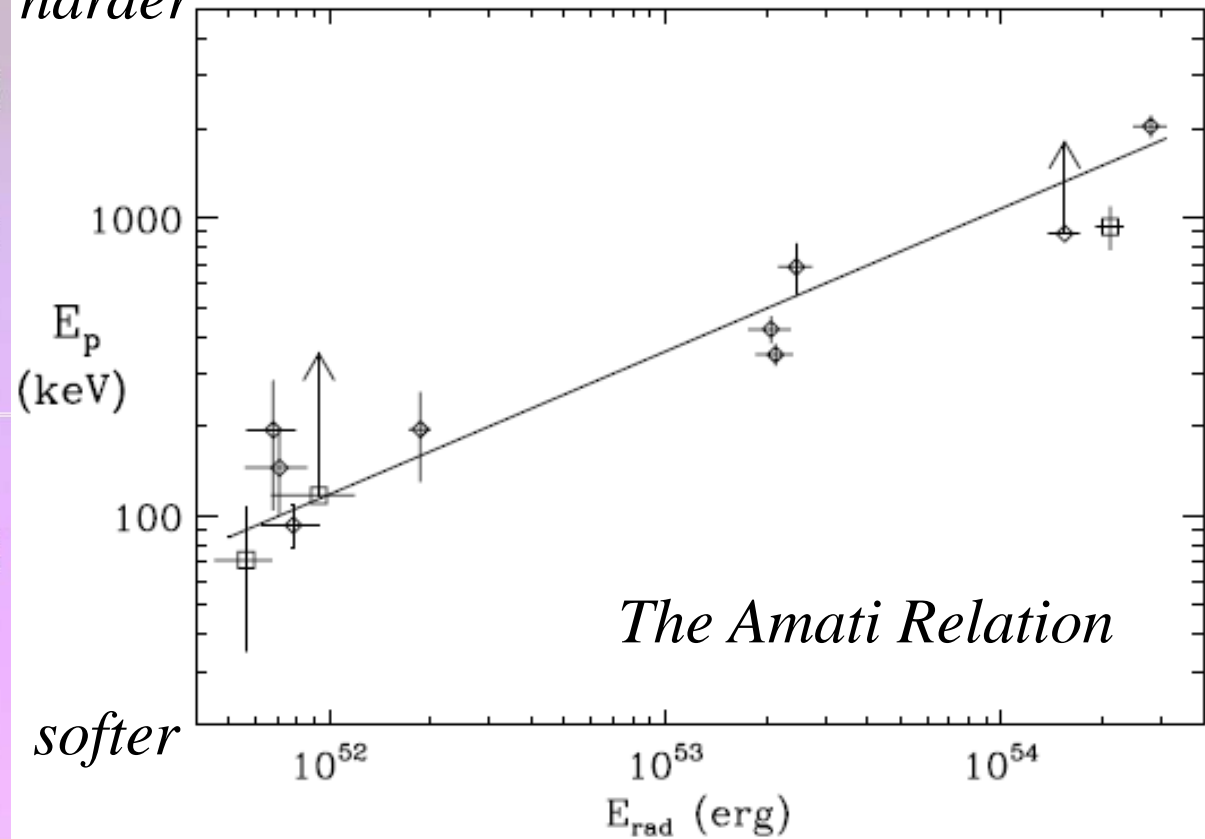




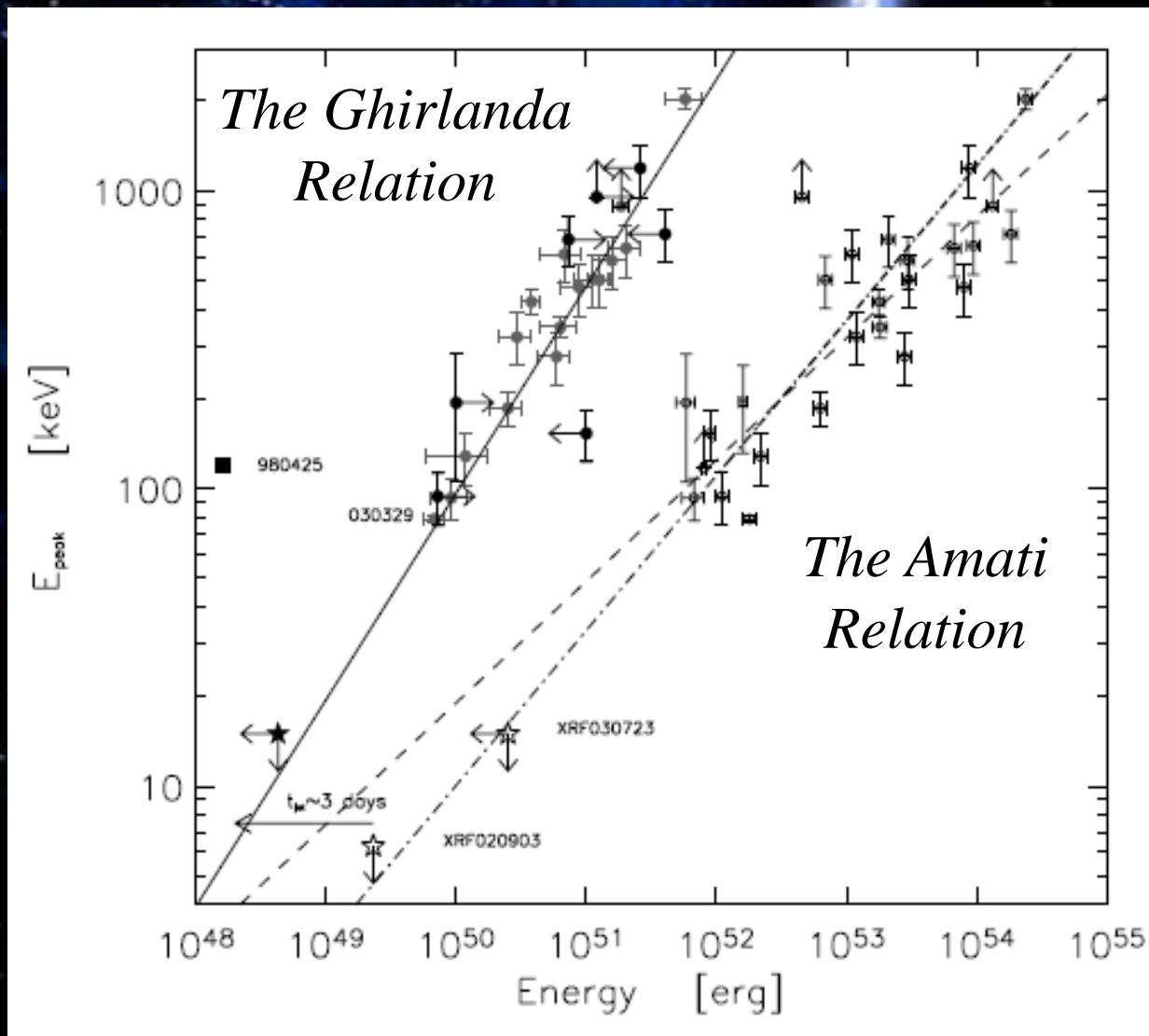
# Amati (2002)



*harder*



# Ghirlanda (2004)



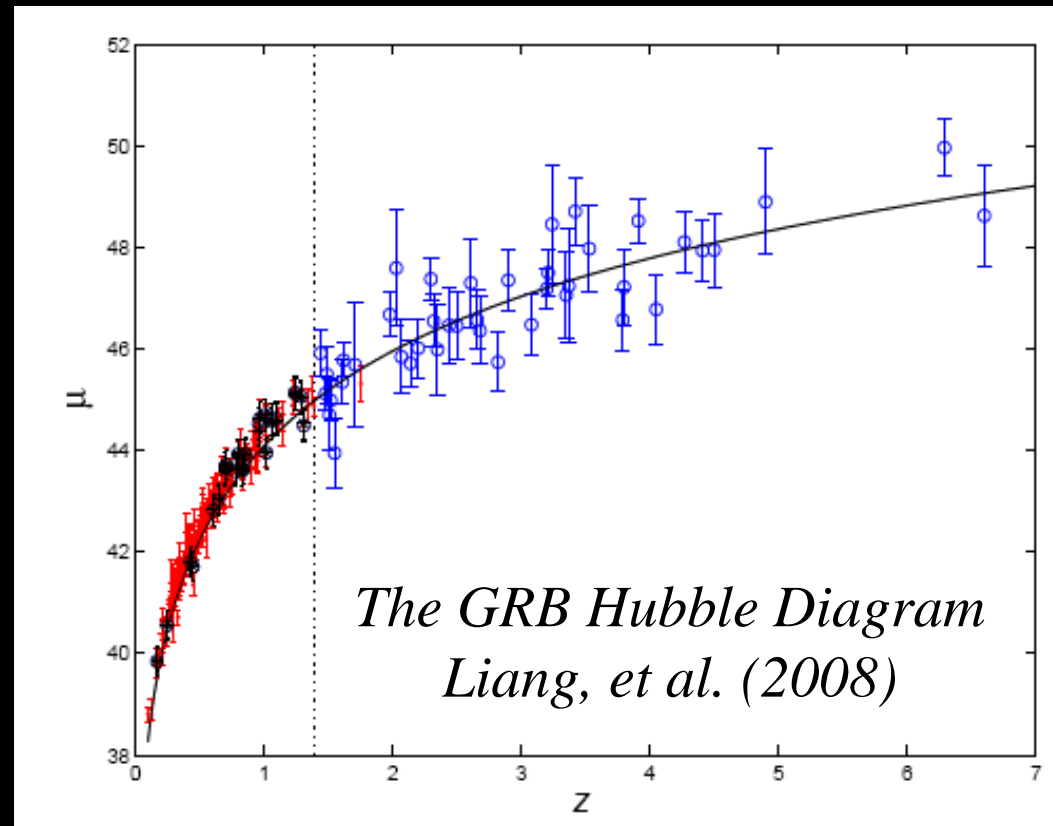


$$D_{L, \text{Obs}} = \sqrt{\frac{1}{4\pi} \frac{E_{\text{iso}}(E_{p, \text{int}})}{S_{\text{bol}}}}$$



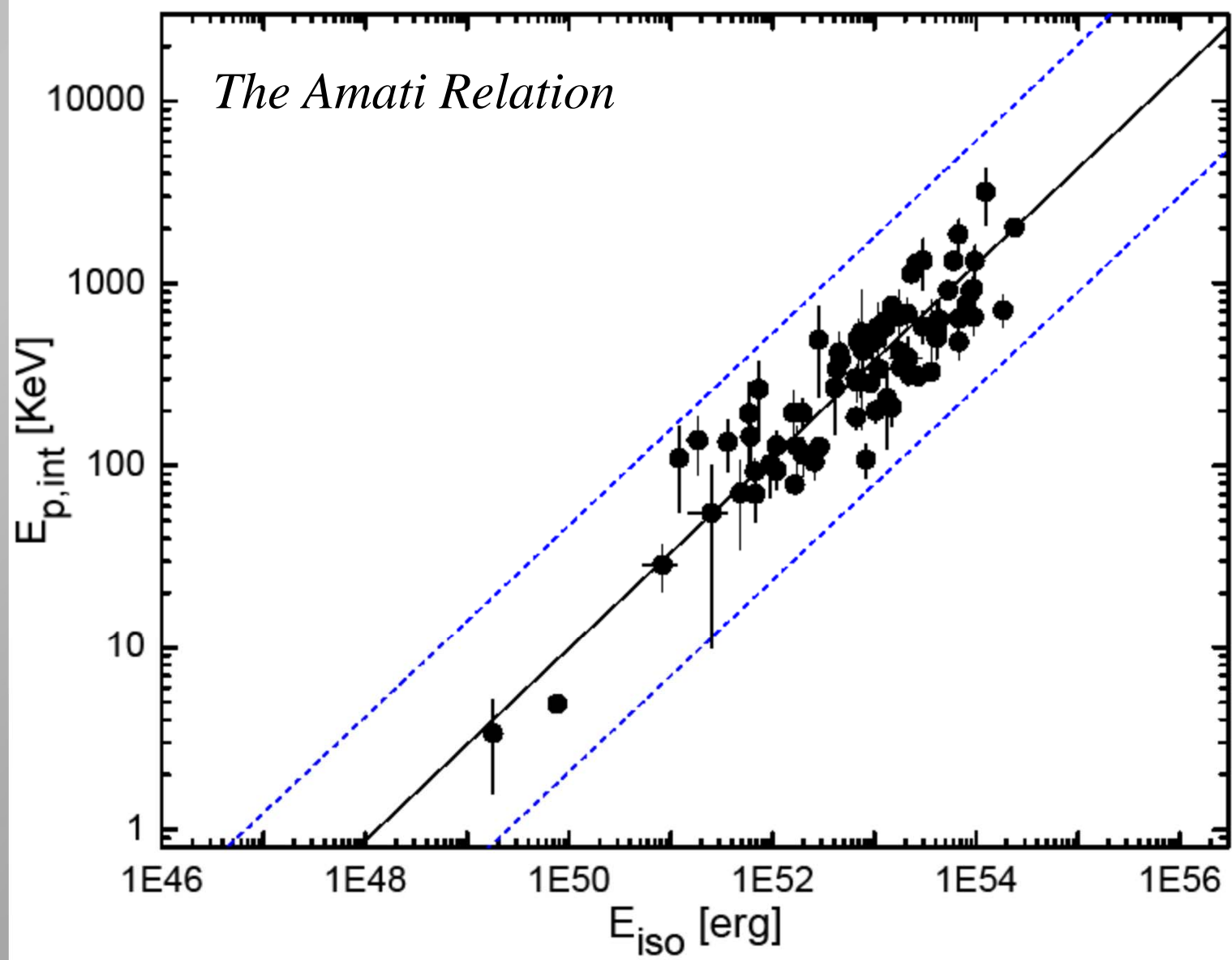
*Standard Candle*

*Observer*

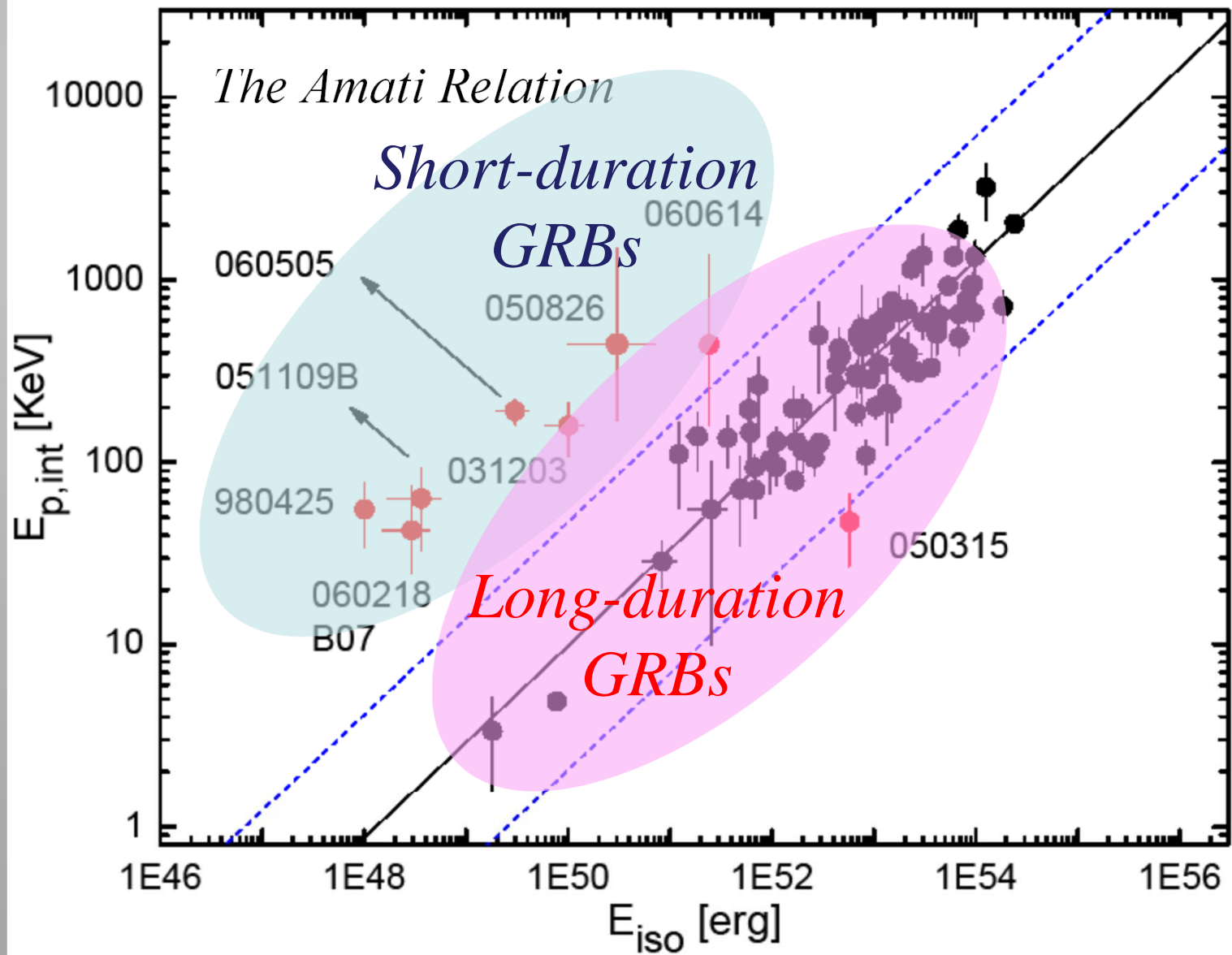


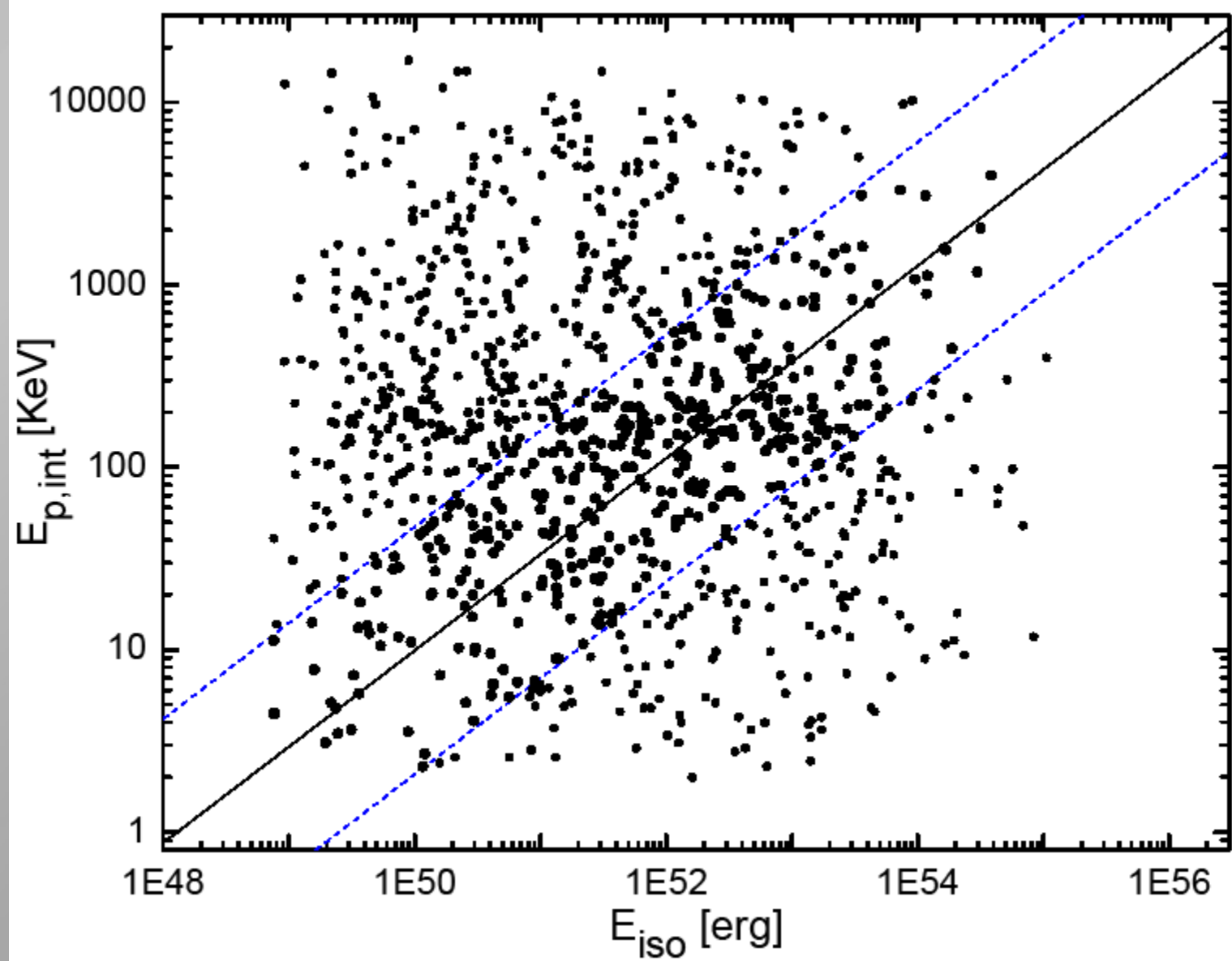
# *Problems with GRB relations*

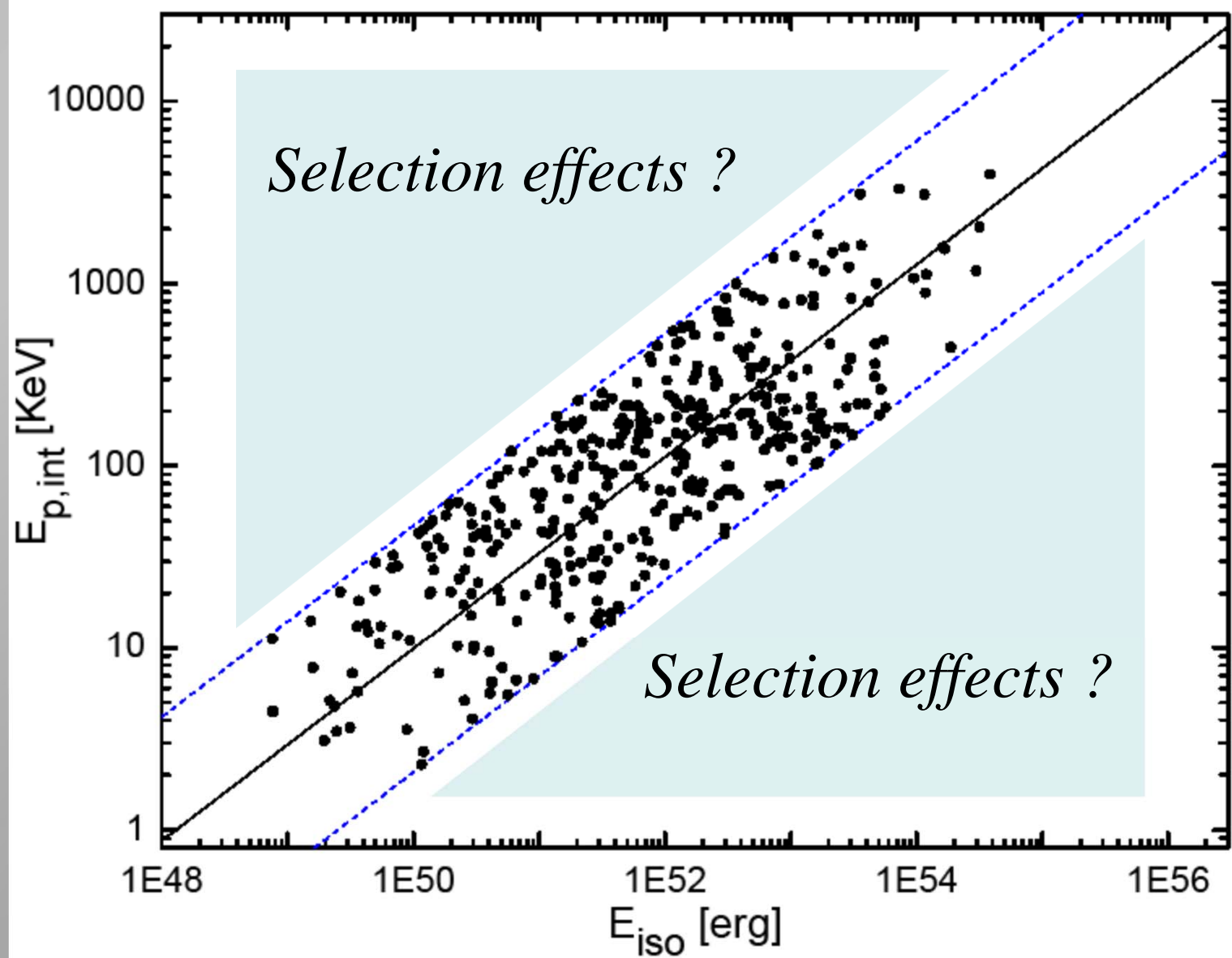
- ✓ *no physical basis for GRB relations to date*
- ✓ *frequent number of outliers to these relations*
  - ✓ *All authors have overlooked outliers to these relations in their GRB Hubble diagrams.*











## *Identifying the selection effects*

- ✓ *E<sub>peak</sub> determination of all GRBs detected so far.*
- ✓ *almost impossible through spectral analysis of GRBs*

*A new method to determine E<sub>peak</sub>*

*Shahmoradi & Nemiroff, 2009, MNRAS letters*

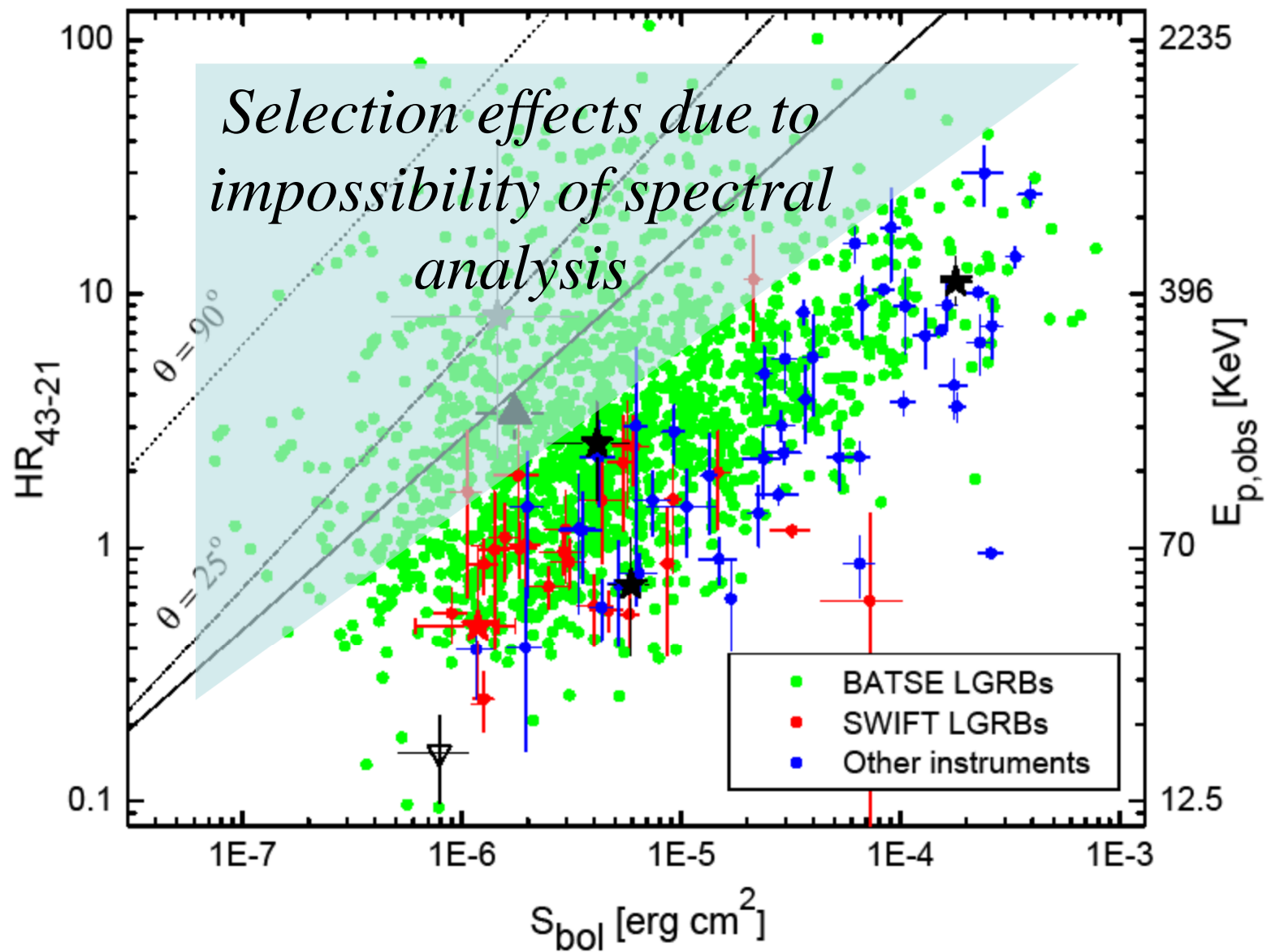
*Brightness (S)*

*Red*      *25 - 50 keV*  
*Yellow*    *50 - 100 keV*  
*Green*     *100 - 300 keV*  
*Blue*      *> 300 keV*

$$HR_{43-21} = \frac{S_{\text{Blue}} + S_{\text{Green}}}{S_{\text{Yellow}} + S_{\text{Red}}}$$

*time*

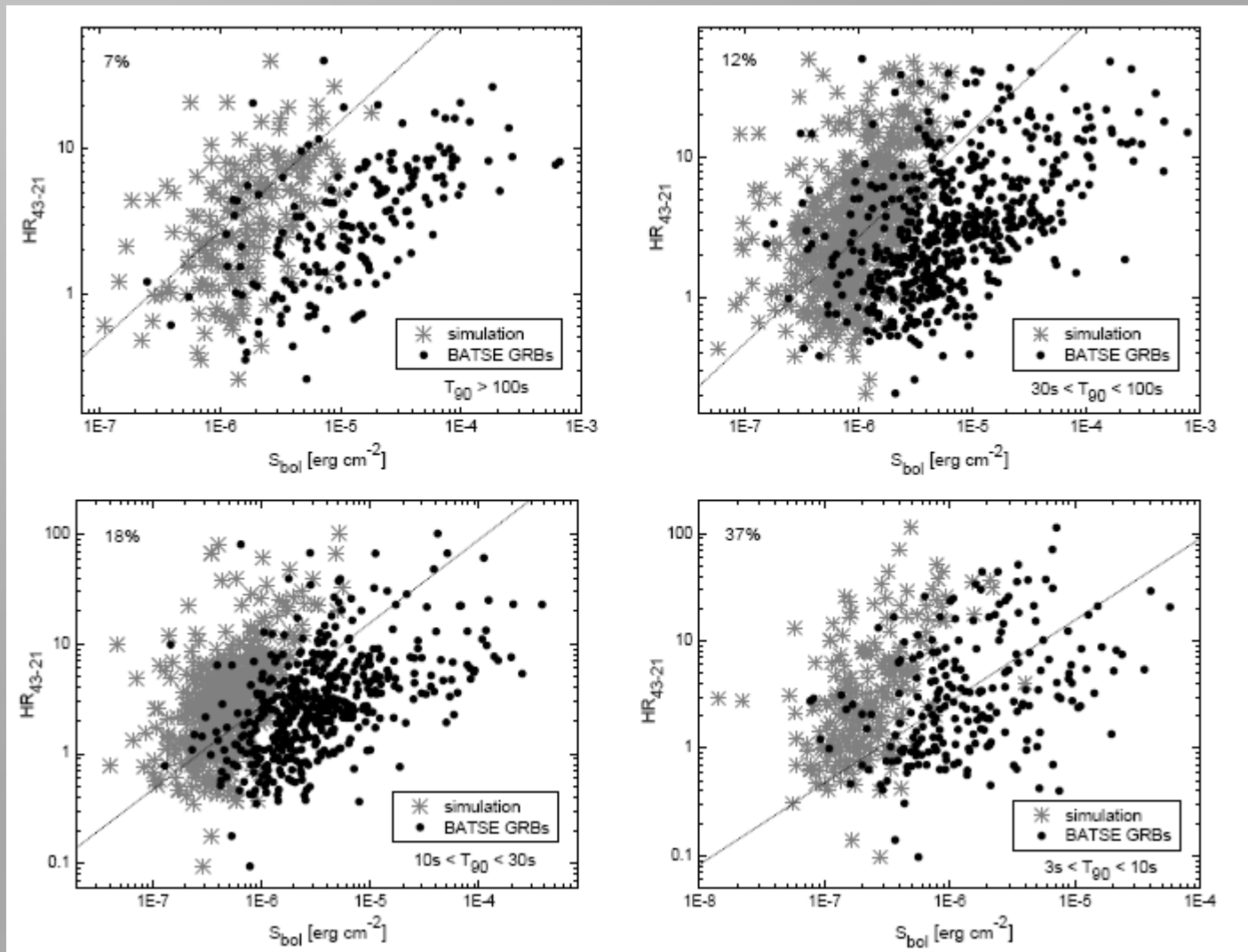


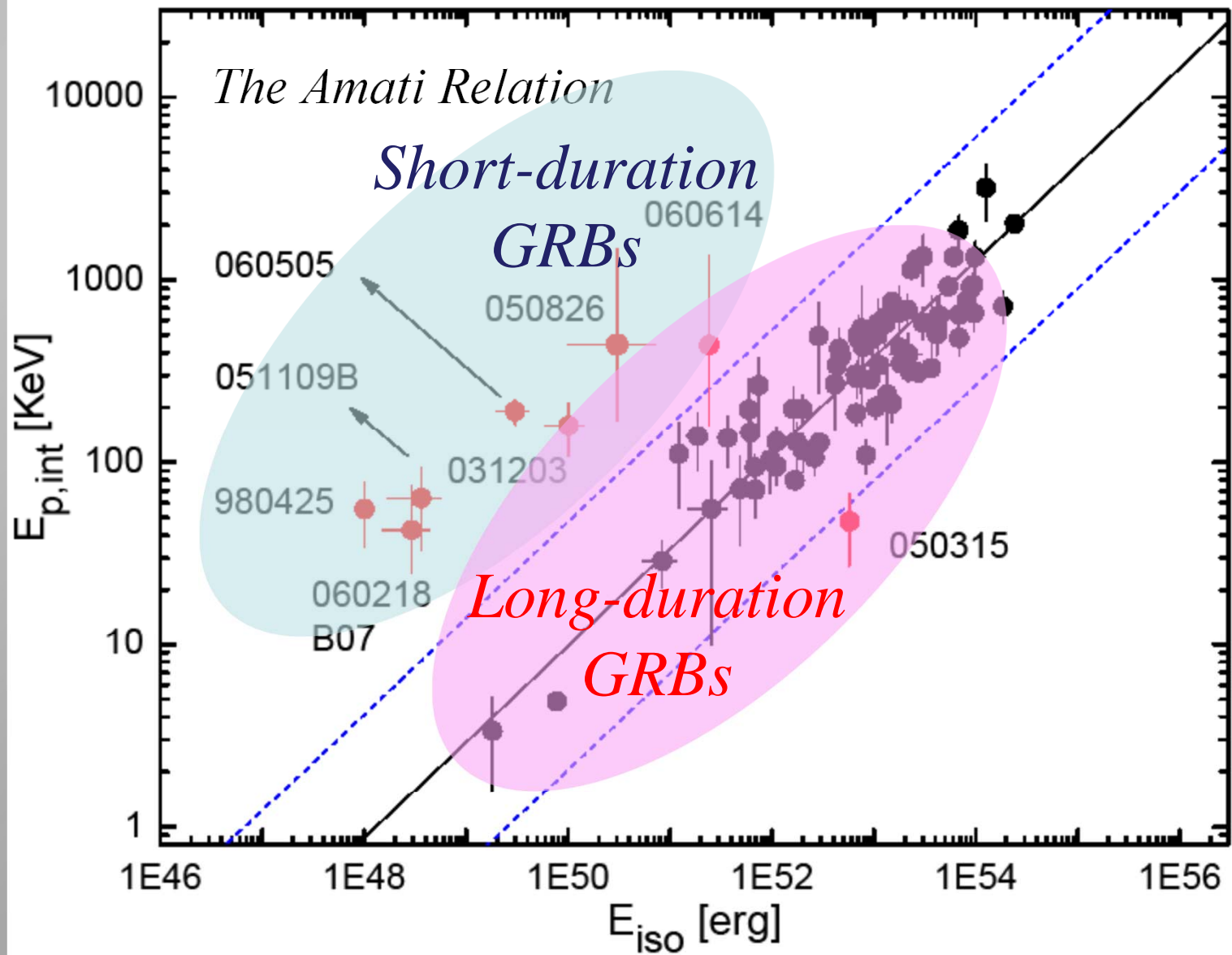


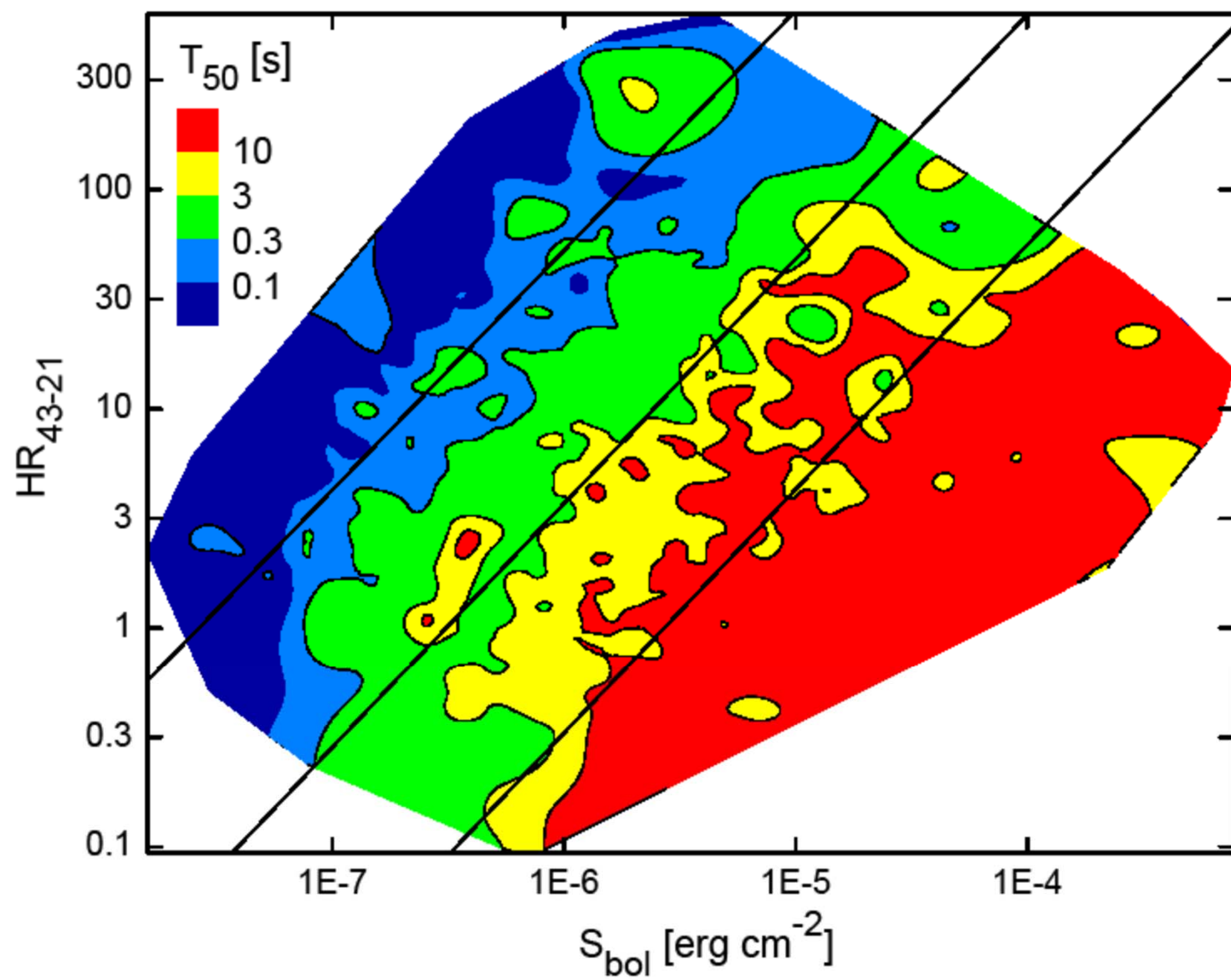


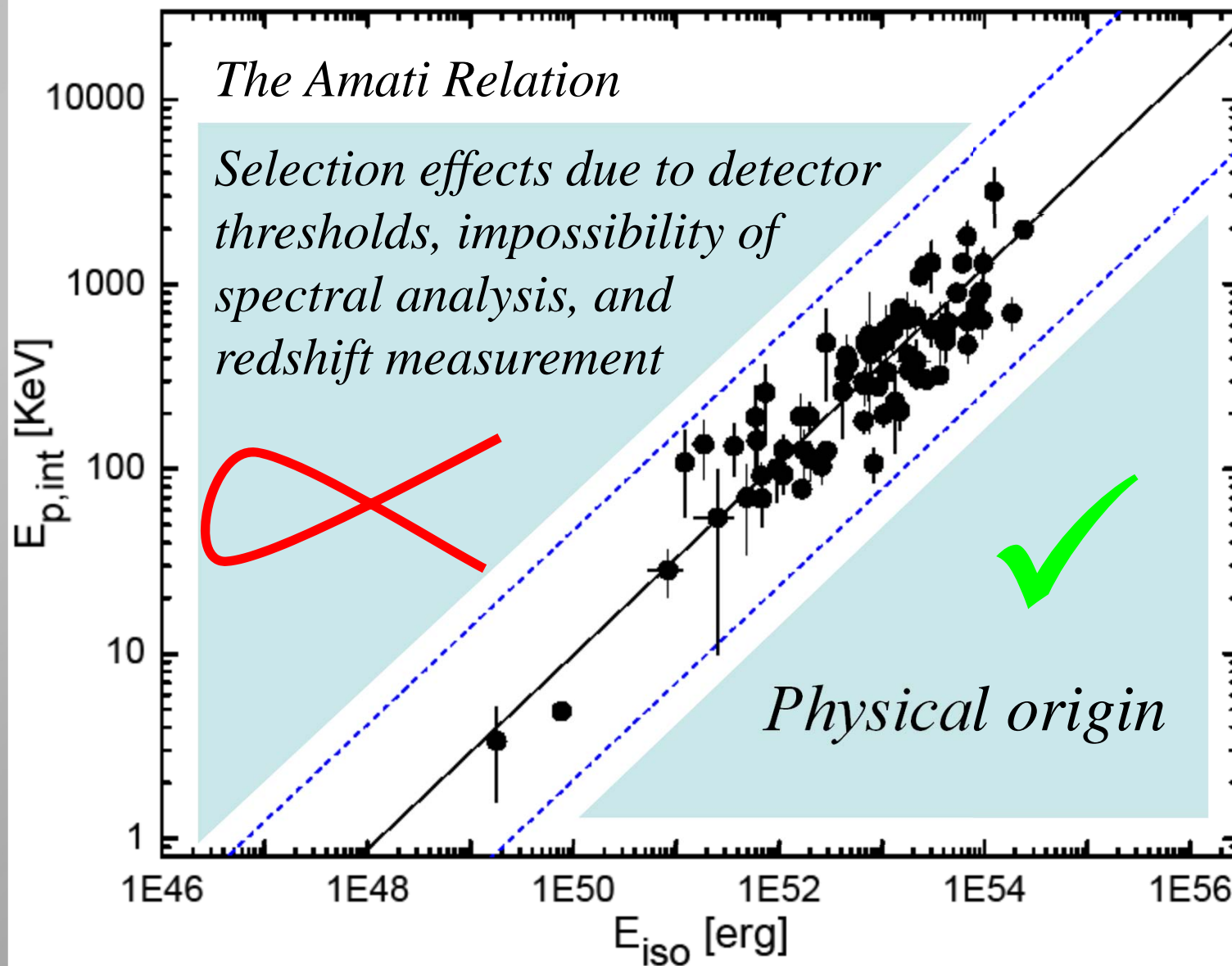
# *Selection Effects due to GRB Detectors?*

✓ *BATSE (1990-2000)*









✓ *Shahmoradi & Nemiroff, 2009, MNRAS*

## *Summary*

- ✓ *Gamma-Ray Bursts are the most powerful events of the Universe, possibly related to the death of super-massive stars.*
- ✓ *GRBs are expected to be detectable out to  $z \sim 65$ .*
- ✓ *Several correlations among the spectral parameters of GRBs have been proposed, such as the Amati, Ghirlanda relations.*
- ✓ *Numerous attempts has been made by different authors to use these relations to construct the Hubble diagram*
- ✓ *The result of our analyses, however, provide the first direct evidence that the Amati & Ghirlanda relations do not have physical origins and to our estimates, these relations hold as inequalities.*

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  journal={Monthly Notices of the Royal Astronomical Society},  
  volume={451},  
  number={1},  
  pages={126--143},  
  year={2015},  
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  title={On the similarities of the prompt gamma-ray emissions in Short and Long Gamma-Ray Bursts},  
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  title={What Causes GRB Time Dilation?},  
  author={Nemiroff, Robert and Shahmoradi, Amir},  
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  organization={AIP}  
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  title={How Real detector thresholds create false standard candles},  
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  pages={425--427},  
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  author={Nemiroff, Robert J and Shahmoradi, A},  
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  volume={42},  
  pages={228},  
  year={2010}  
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  author={Shahmoradi, Amir and Nemiroff, Robert J},  
  journal={Monthly Notices of the Royal Astronomical Society},  
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  volume={740},  
  year={2011}  
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  title={The possible impact of gamma-ray burst detector thresholds on cosmological standard  
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  author={Shahmoradi, A and Nemiroff, RJ},  
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  number={3},  
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  title={Classification and Energetics of Cosmological Gamma-Ray Bursts},  
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