Photospheric Emission from Long-Duration Gamma-Ray Brusts

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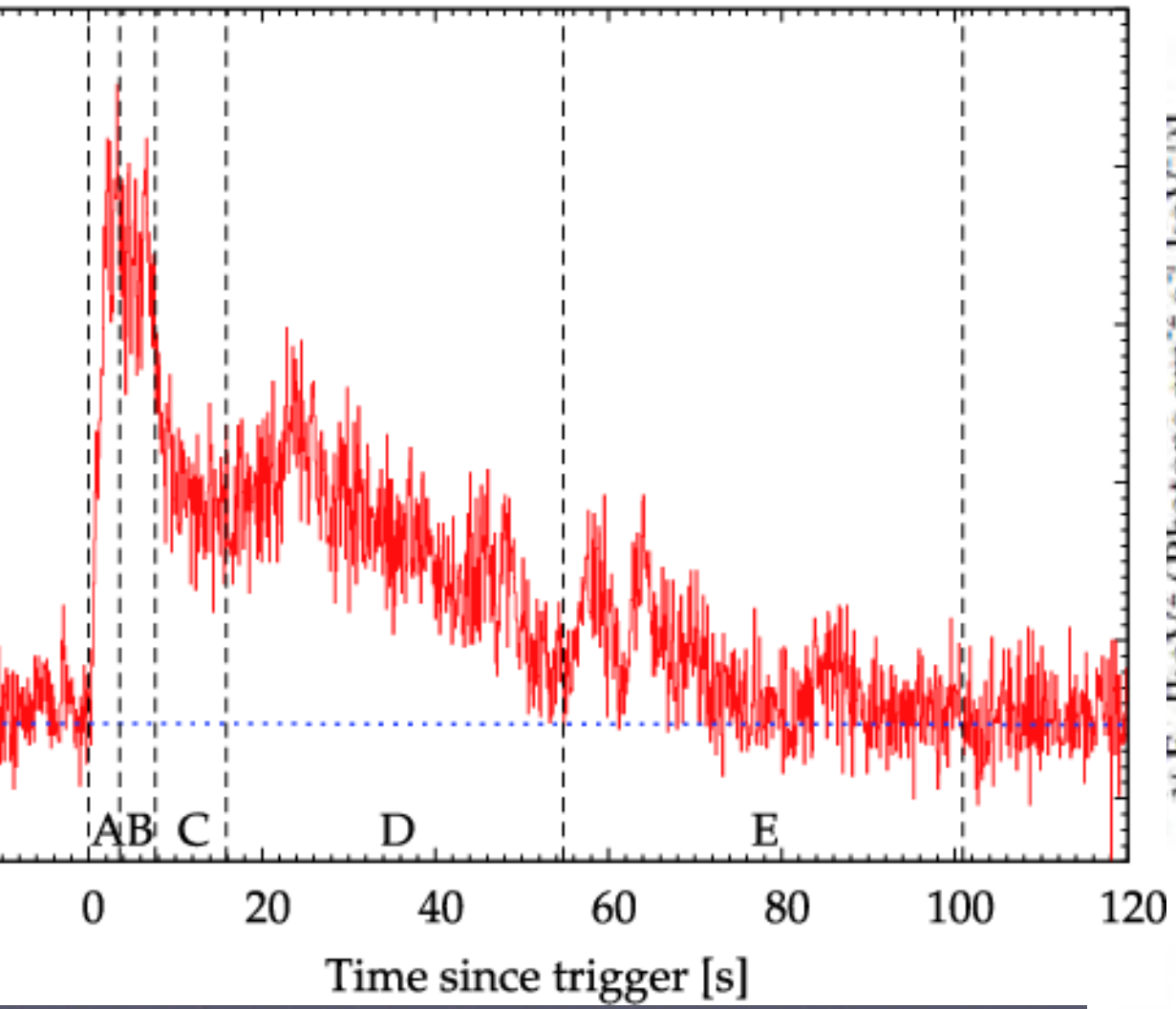
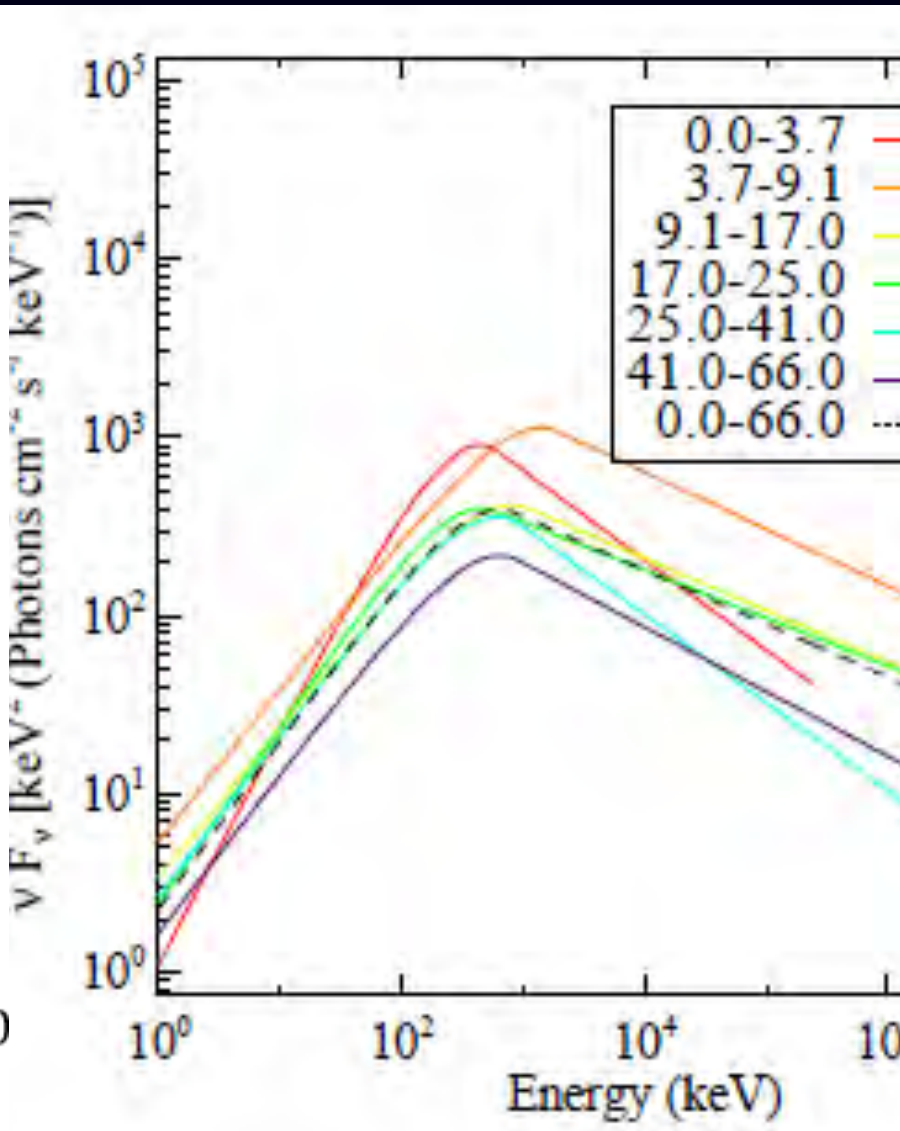
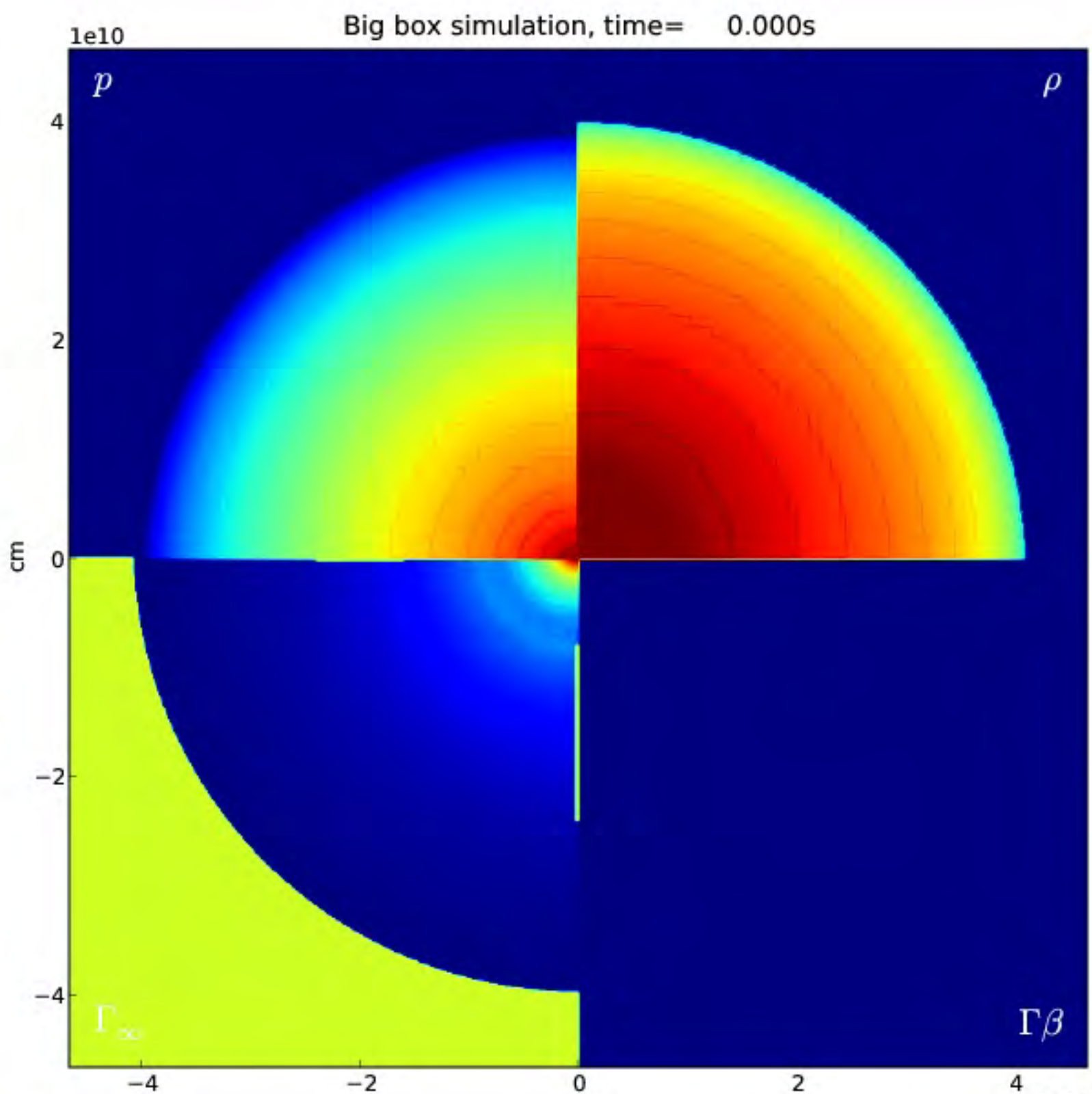
GRB Observations

GRB 080916C





GRB Simulations


Big box simulation, time= 0.000s
1e10
p
ρ
Γ_∞
$\Gamma\beta$
cm
4
2
0
−2
−4
−4
−2
0
2
4

How does a GRB make gamma-rays?

Internal Shock Model

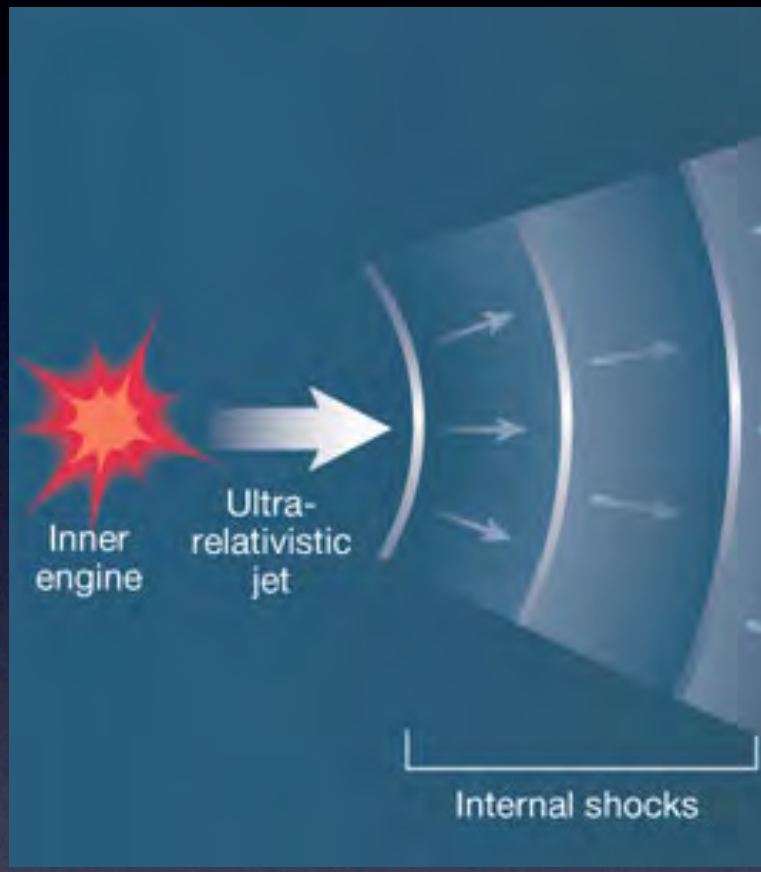
Energy injected by central engine at $10^7 - 10^8$ cm

As jet propagates, relativistic material accelerates and cools

At photosphere ($10^{12} - 10^{13}$ cm), little internal energy

Internal variation in flow leads to shocks at 10^{14}-10^{15} cm

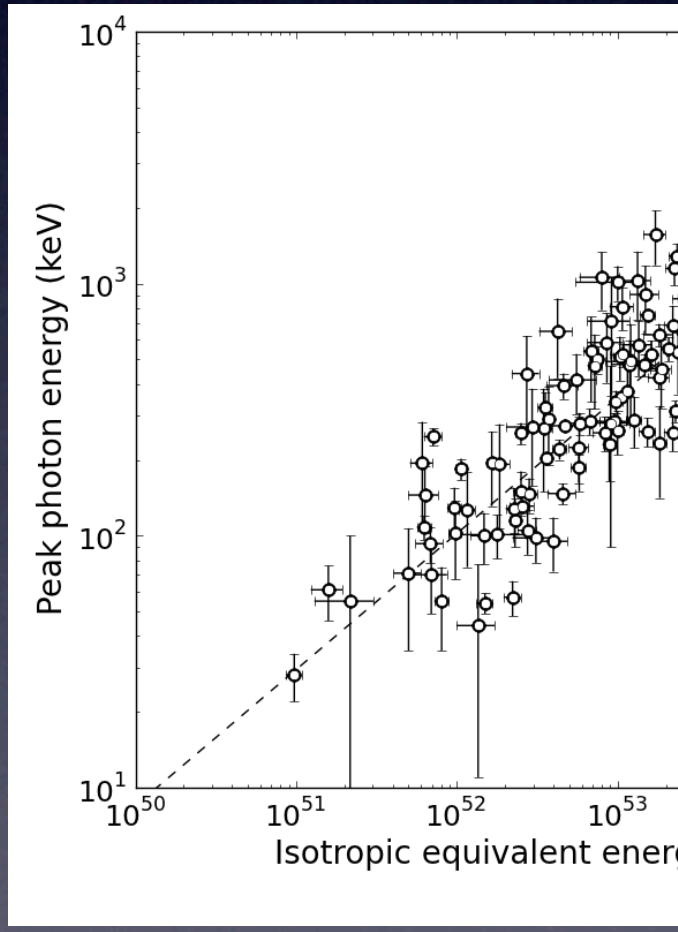
Kinetic energy converted to internal energy, synchrotron radiation produces prompt burst



Problems with Internal Shock Model

- Not very efficient
  - <10% of energy converted to gamma rays
- Also problems reproducing observed spectrum
- Problem reproducing GRB correlations

Amati Relat

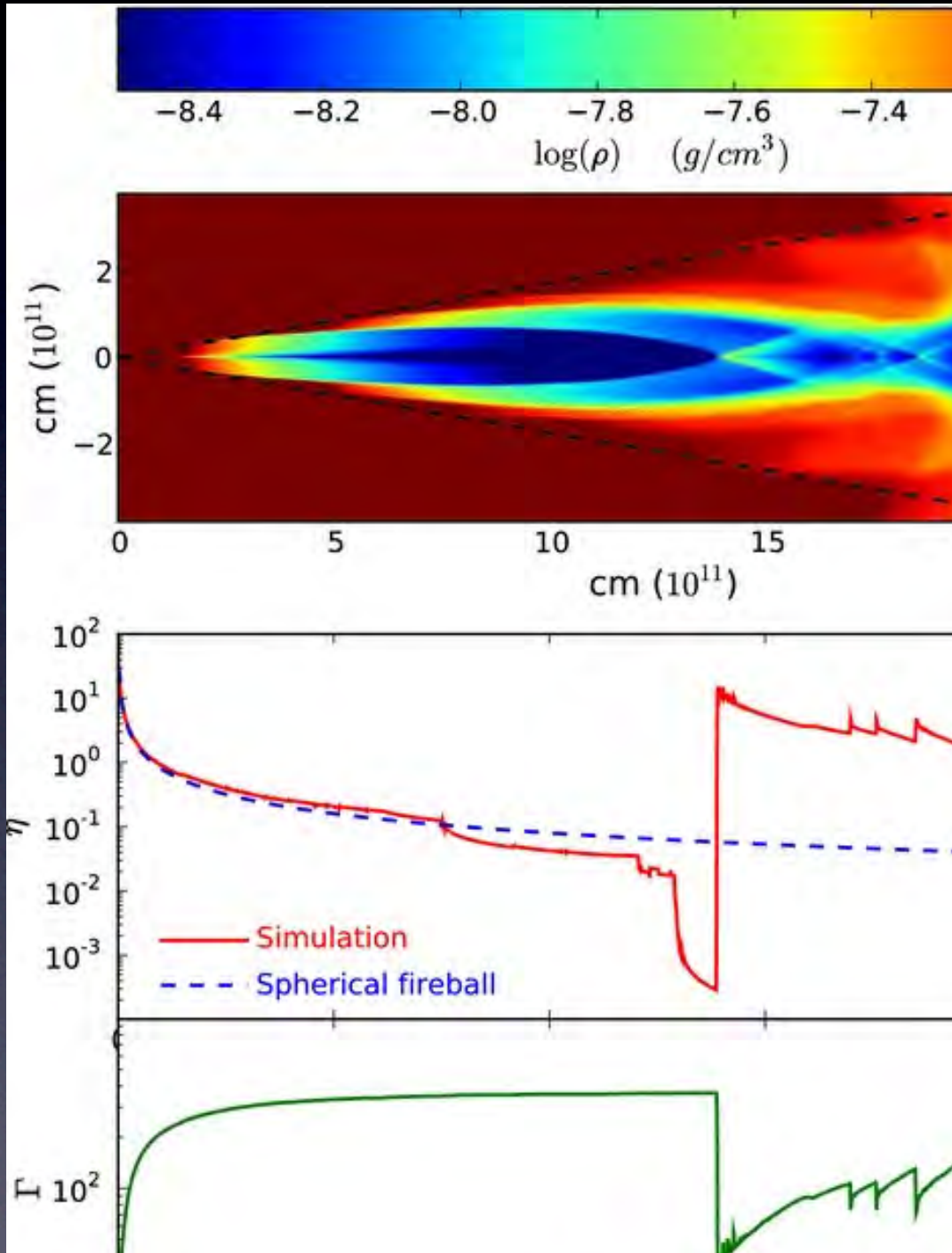


Jet Collimation

Collimation keeps the jet hot

Rather than cold material at the photosphere, internal energy ~ rest mass energy

Lorentz factor ~200, not saturated at 400



Photospheric Emission

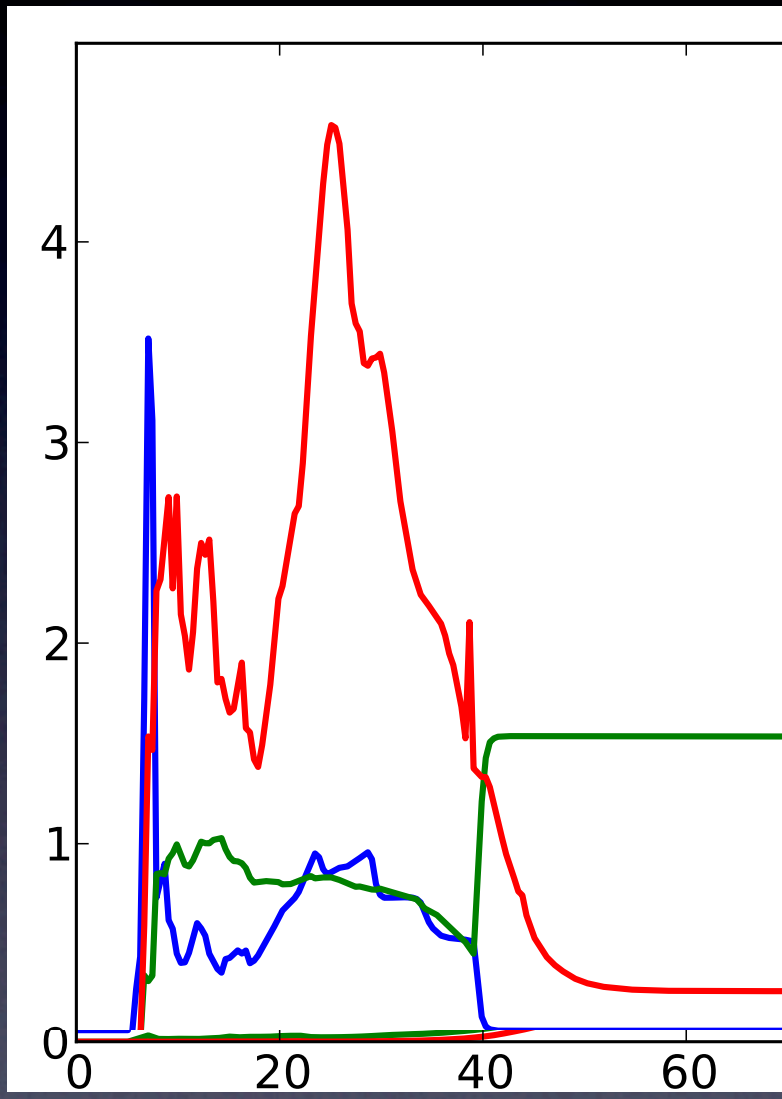
Photospheric Emission

Following Giannios (2012), peak emission frequency set where electron and radiation temperature equal

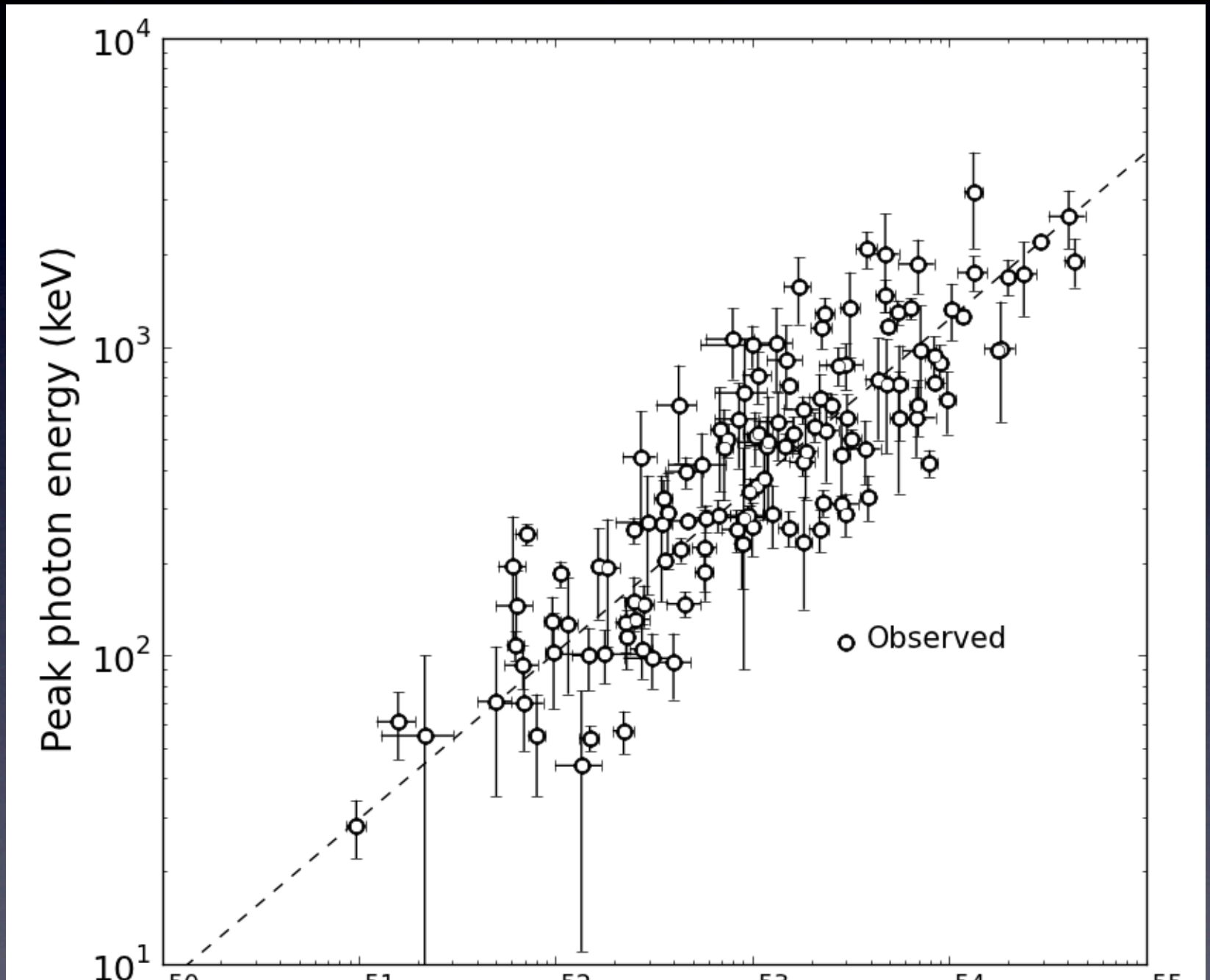
Typically, this is at $\tau \sim 50$

Red = L_{ISO} (10^{52} erg/s)

Blue = Photospheric radius (10^{12} cm)



Amati Relation



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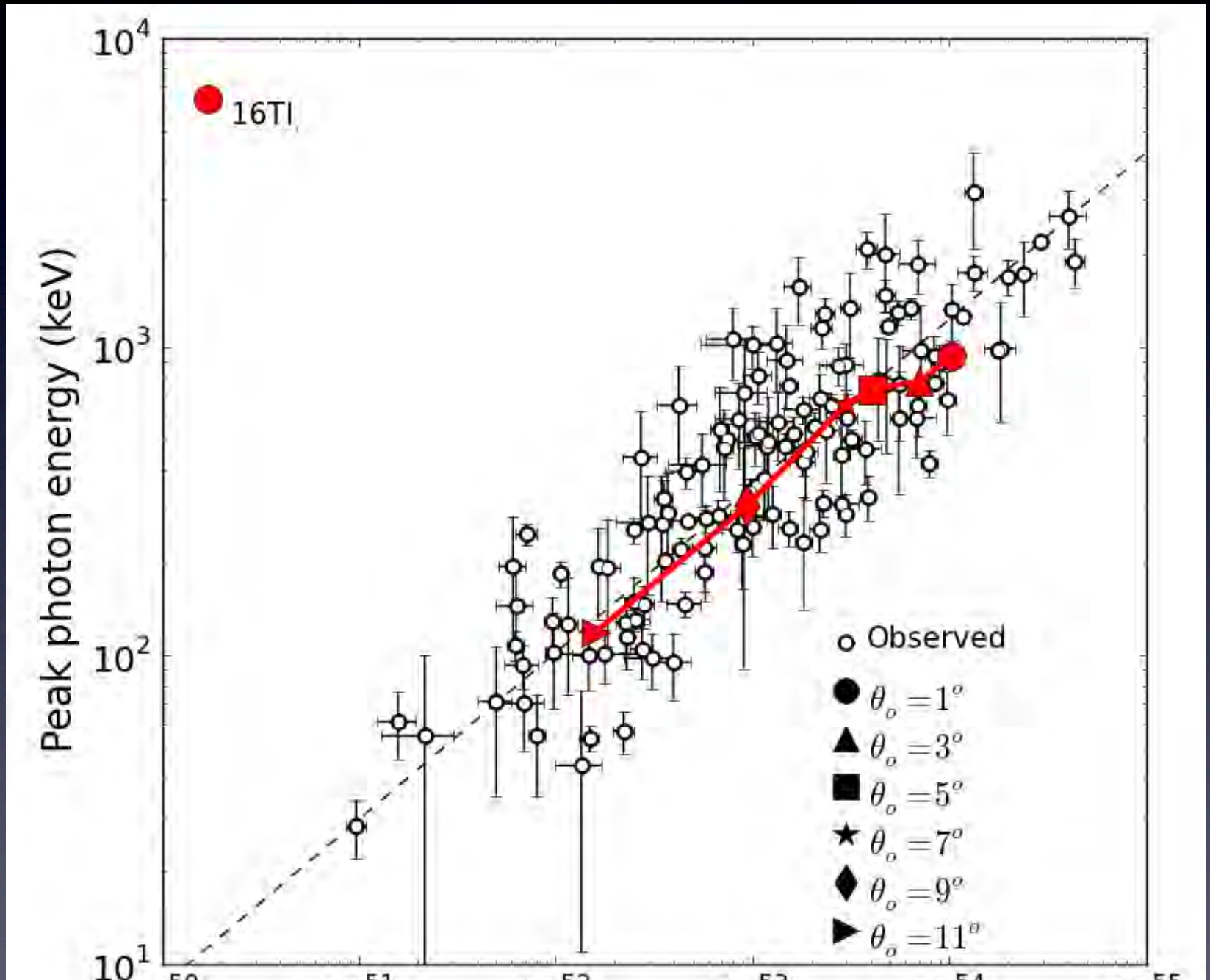

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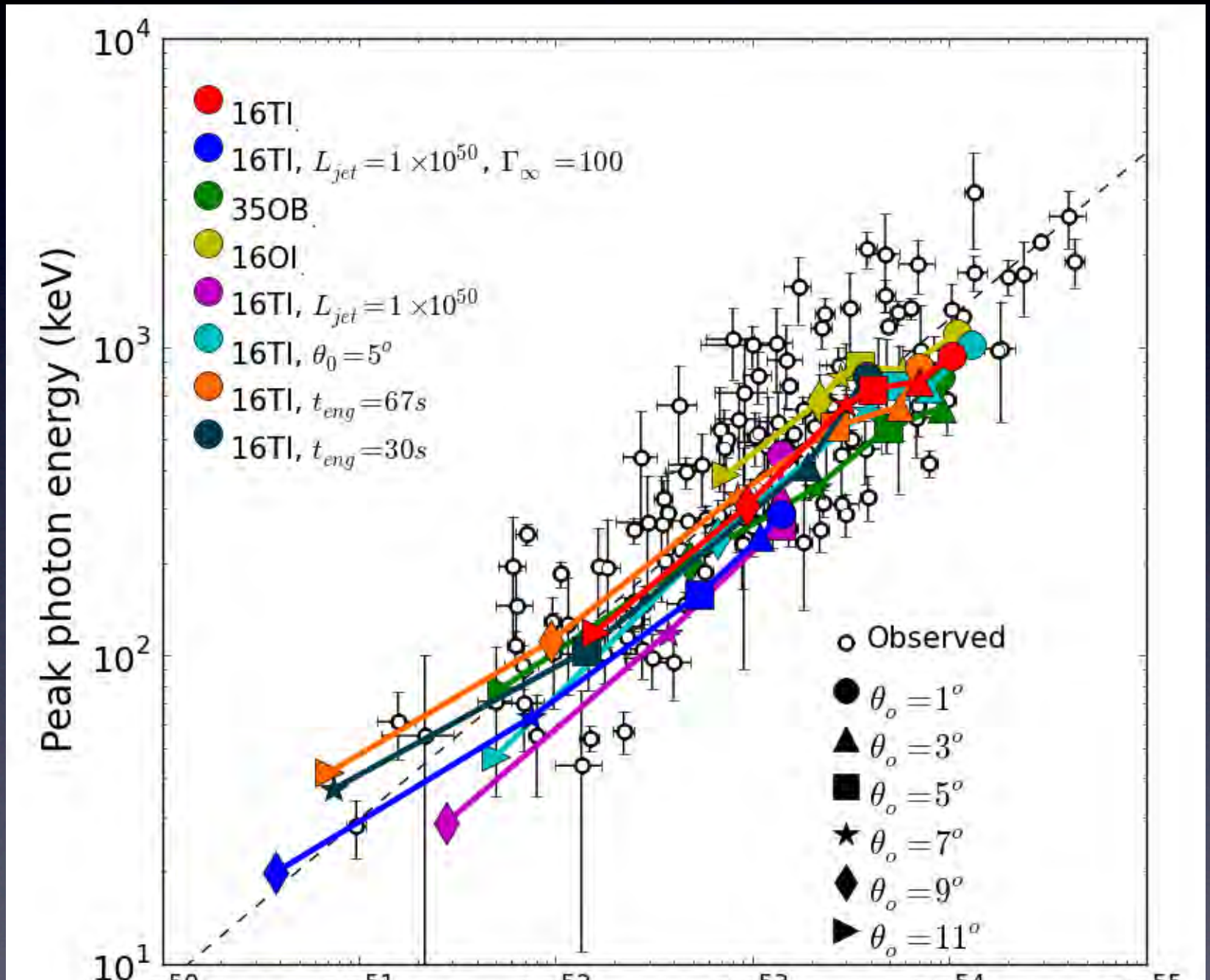
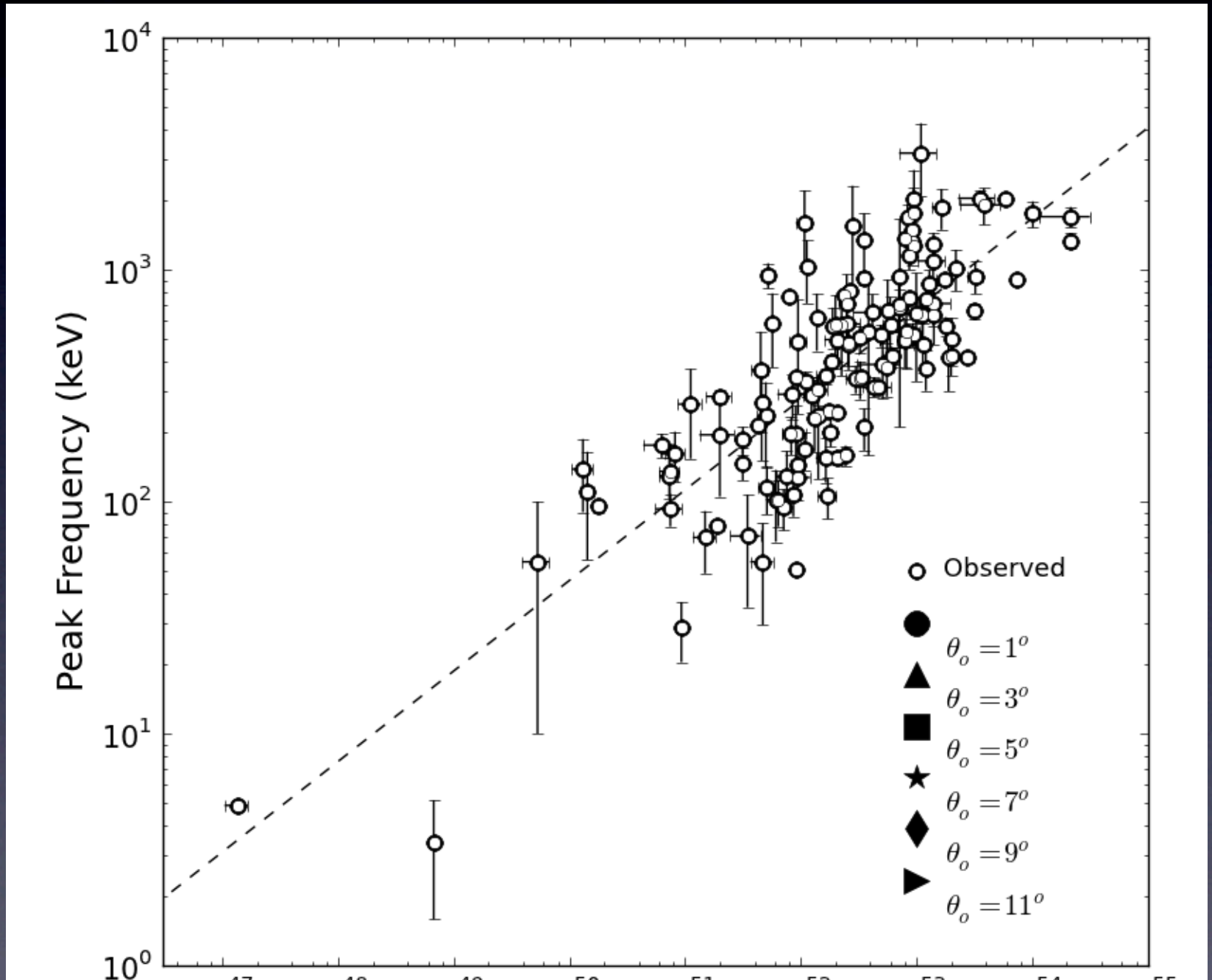
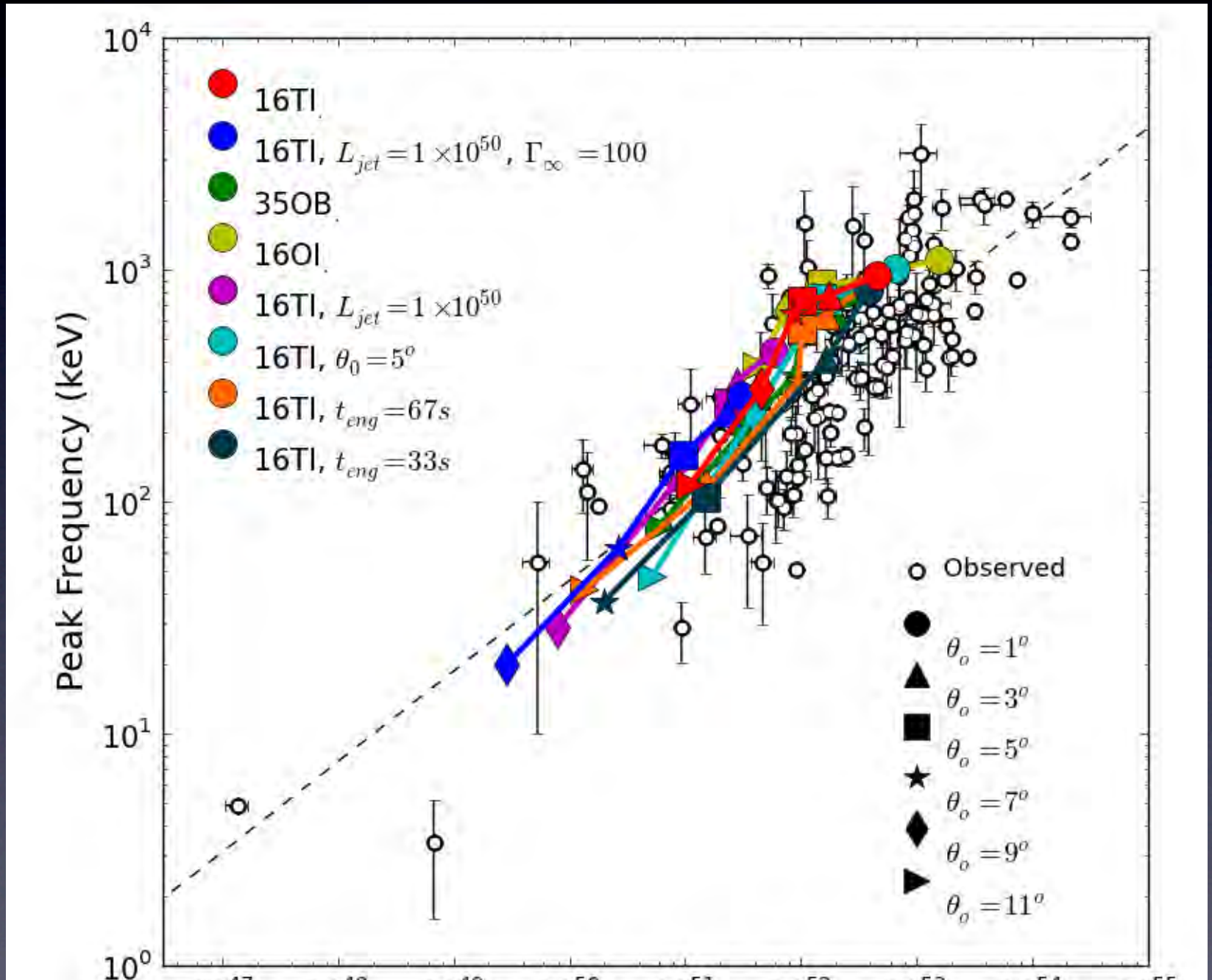


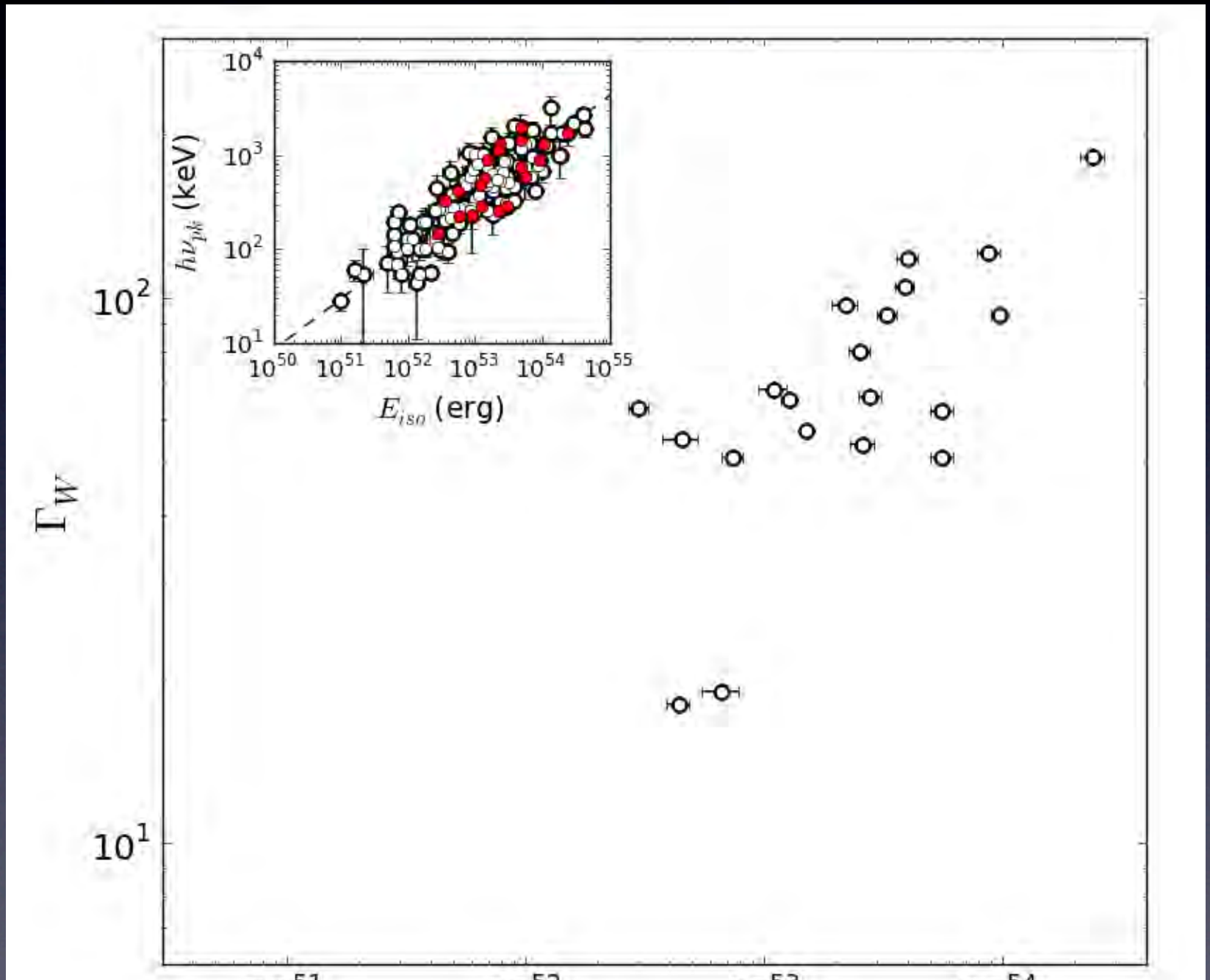
Yonetoku Relation



Yonetoku Relation



Energy vs. Velocity



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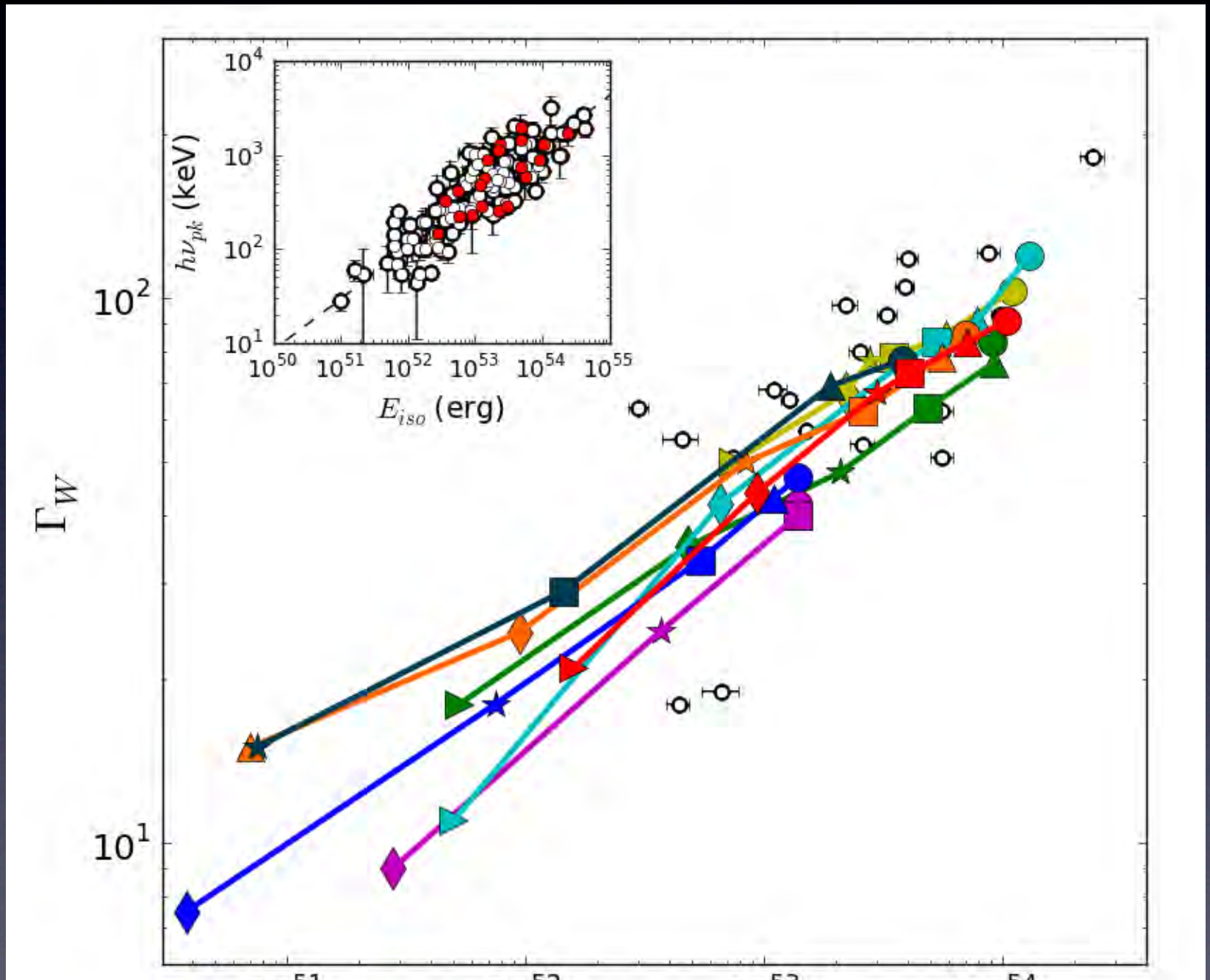
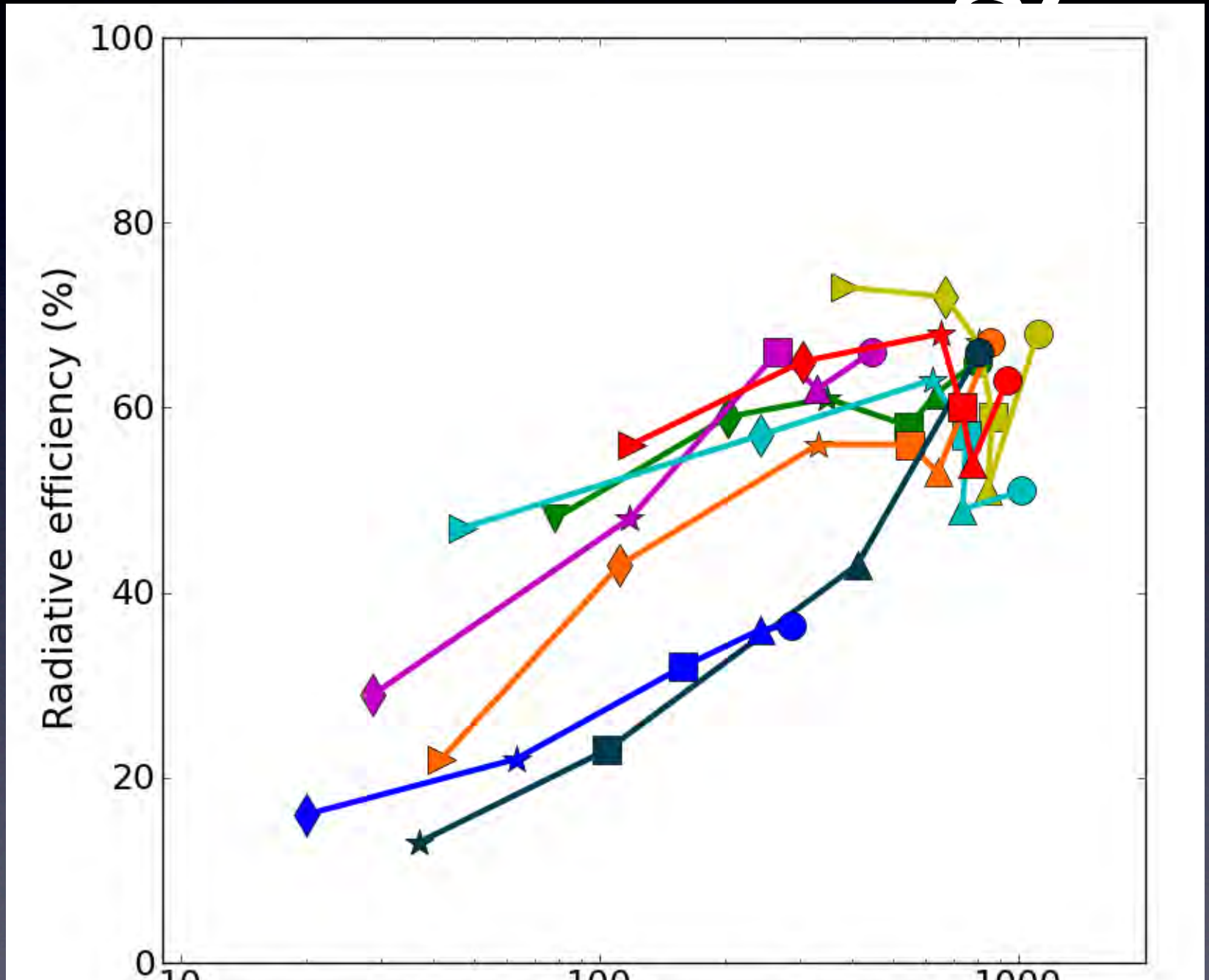


Efficiency vs. Peak Photon Energy



GRB Observations

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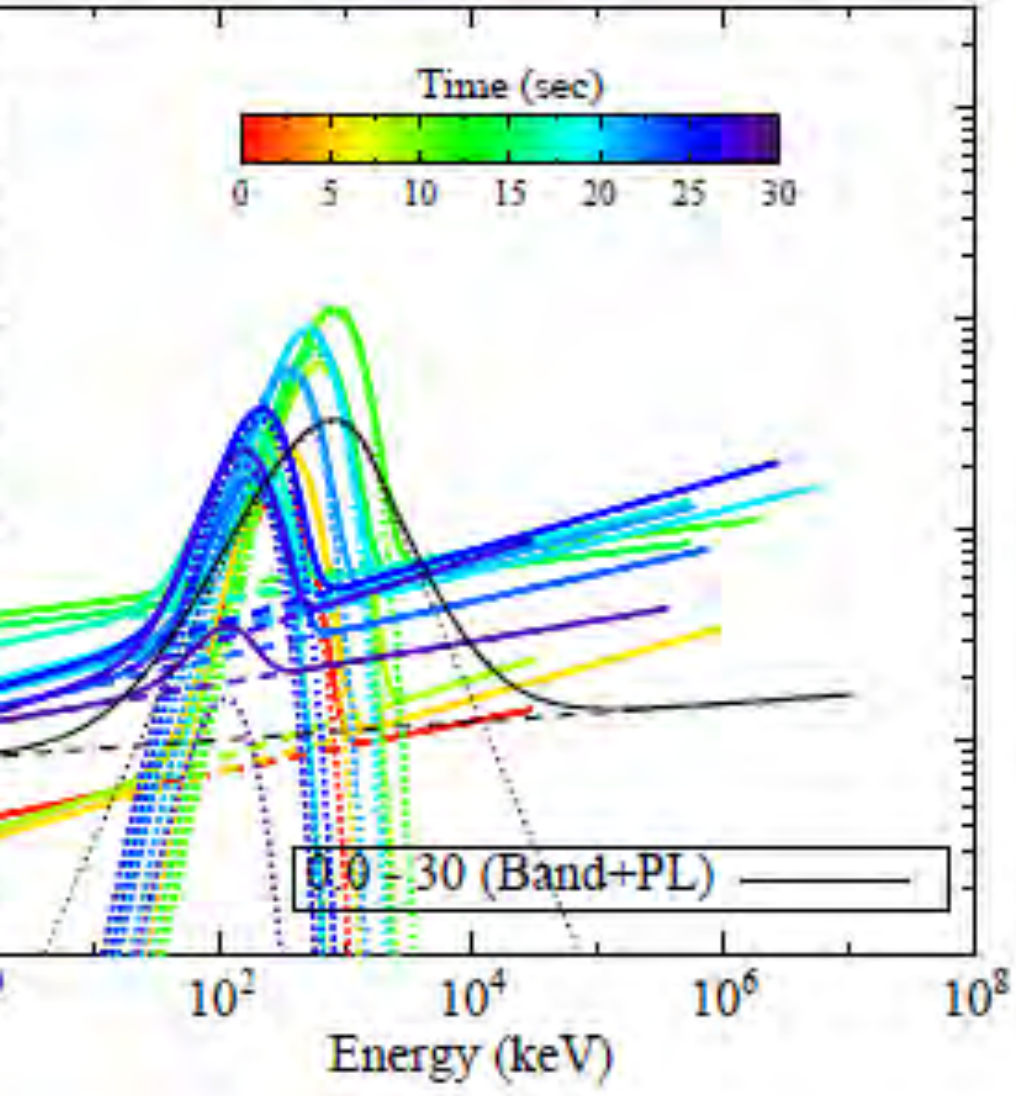

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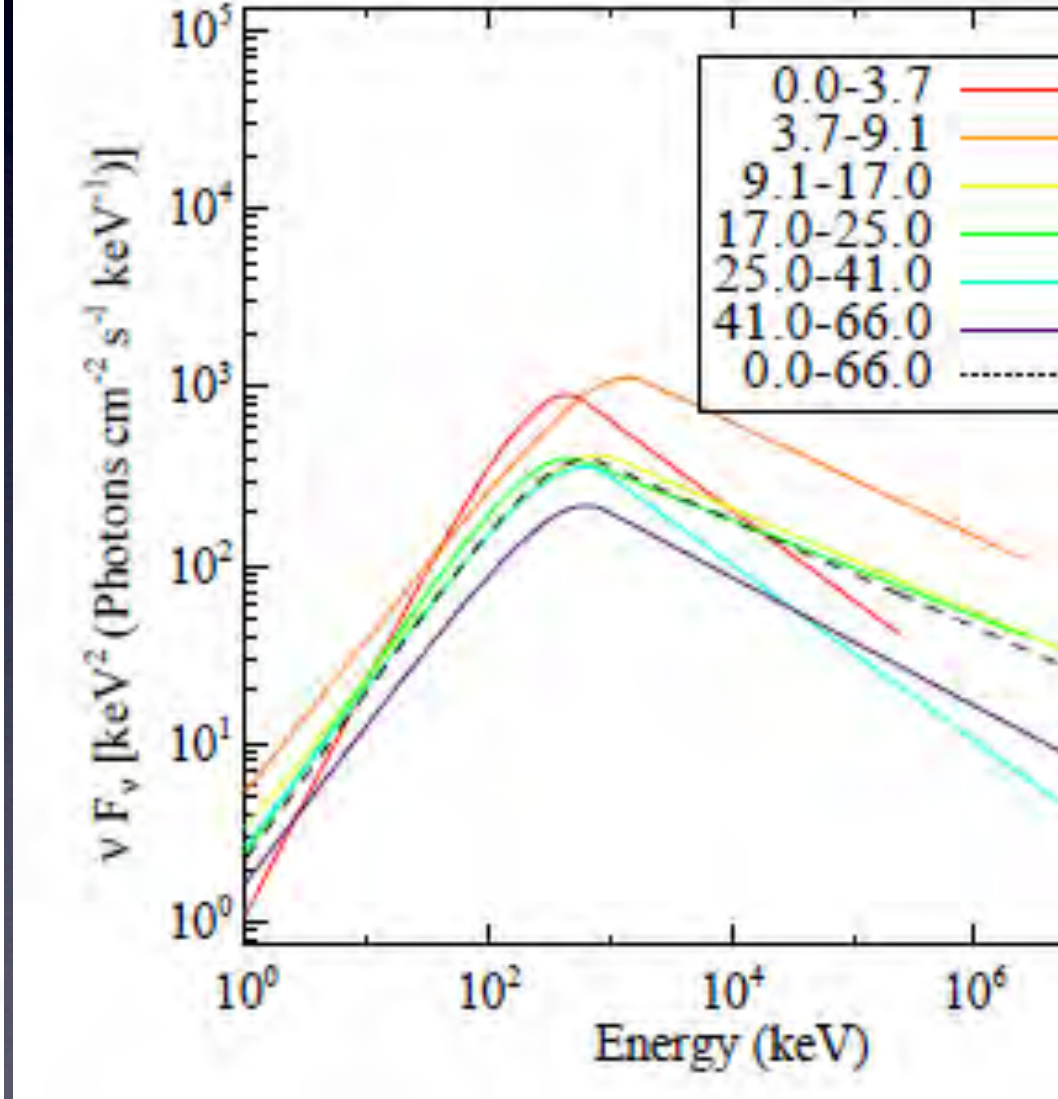
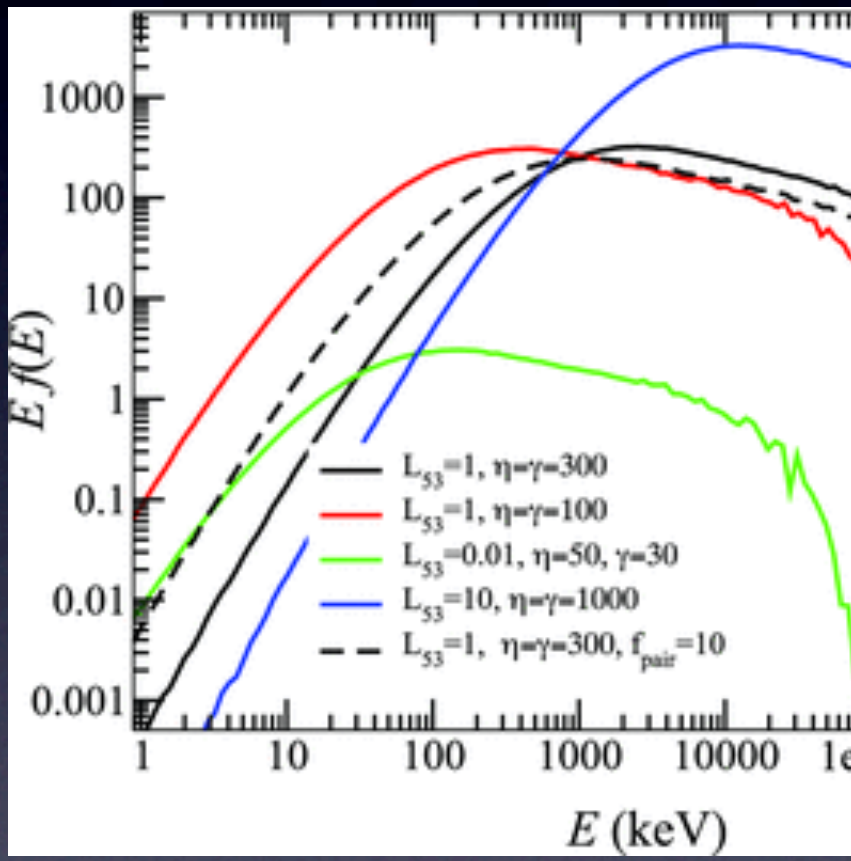


Can You Fix Photospheres?

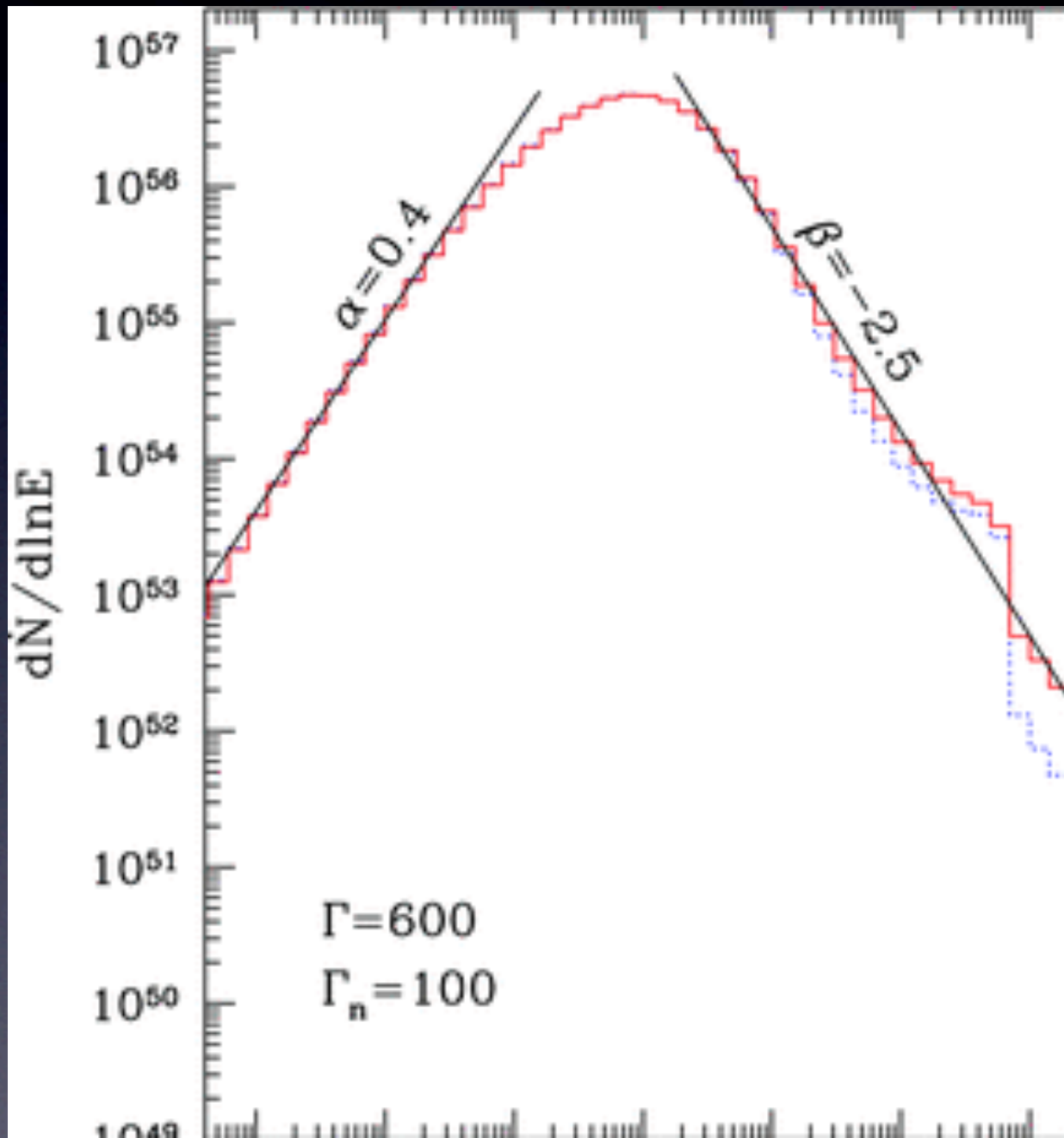
- Compton scattering of thermal photons might be able to give a power law a high energy, but difficult to extend up to GeV (Lazzati & Begelman 2010)
- Continuous dissipation produces band function spectrum at high energies



Giannios 201

Heating by Collisions

- Heating below photosphere by nuclear and Coulomb collisions
- Flatter a low energy, power law to GeV at high energy
- Also GeV neutrinos



Magnetically Dominated Jets

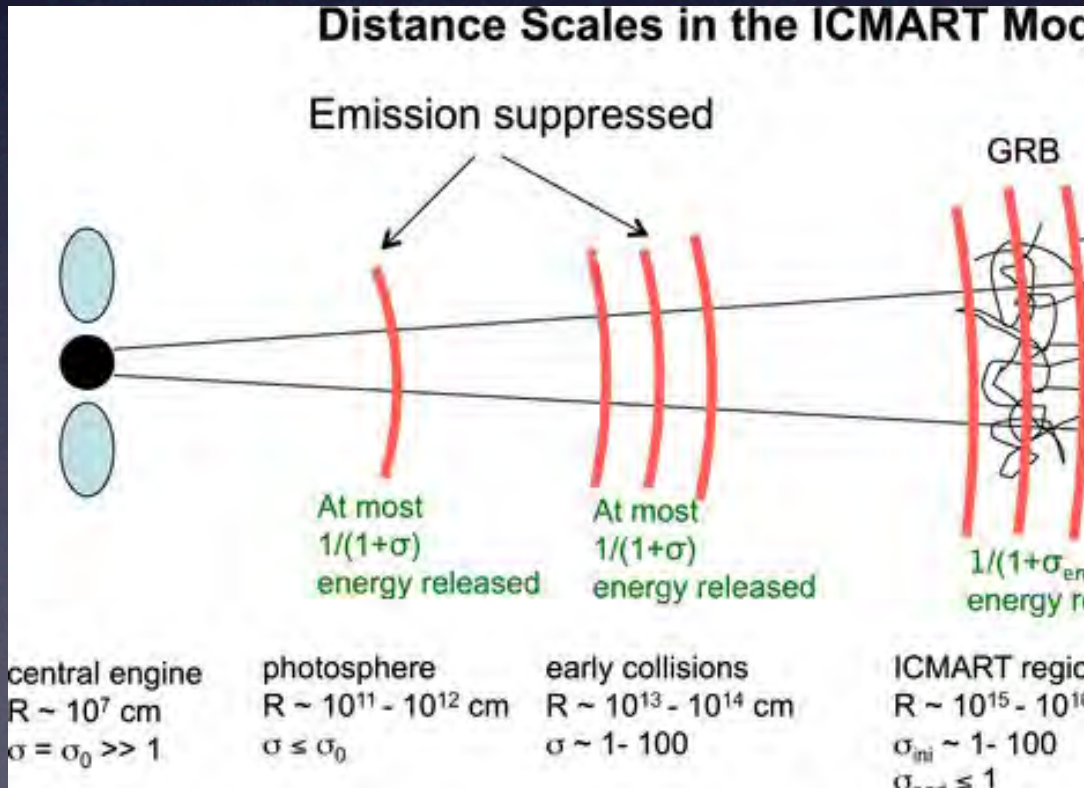
e.g. Giannios & Spruit 2005, Zhang & Yan 201

Hide photospheric emission by putting energy into magnetic field

Instabilities lead to reconnection

Convert magnetic field into particle energy

Emits synchrotron



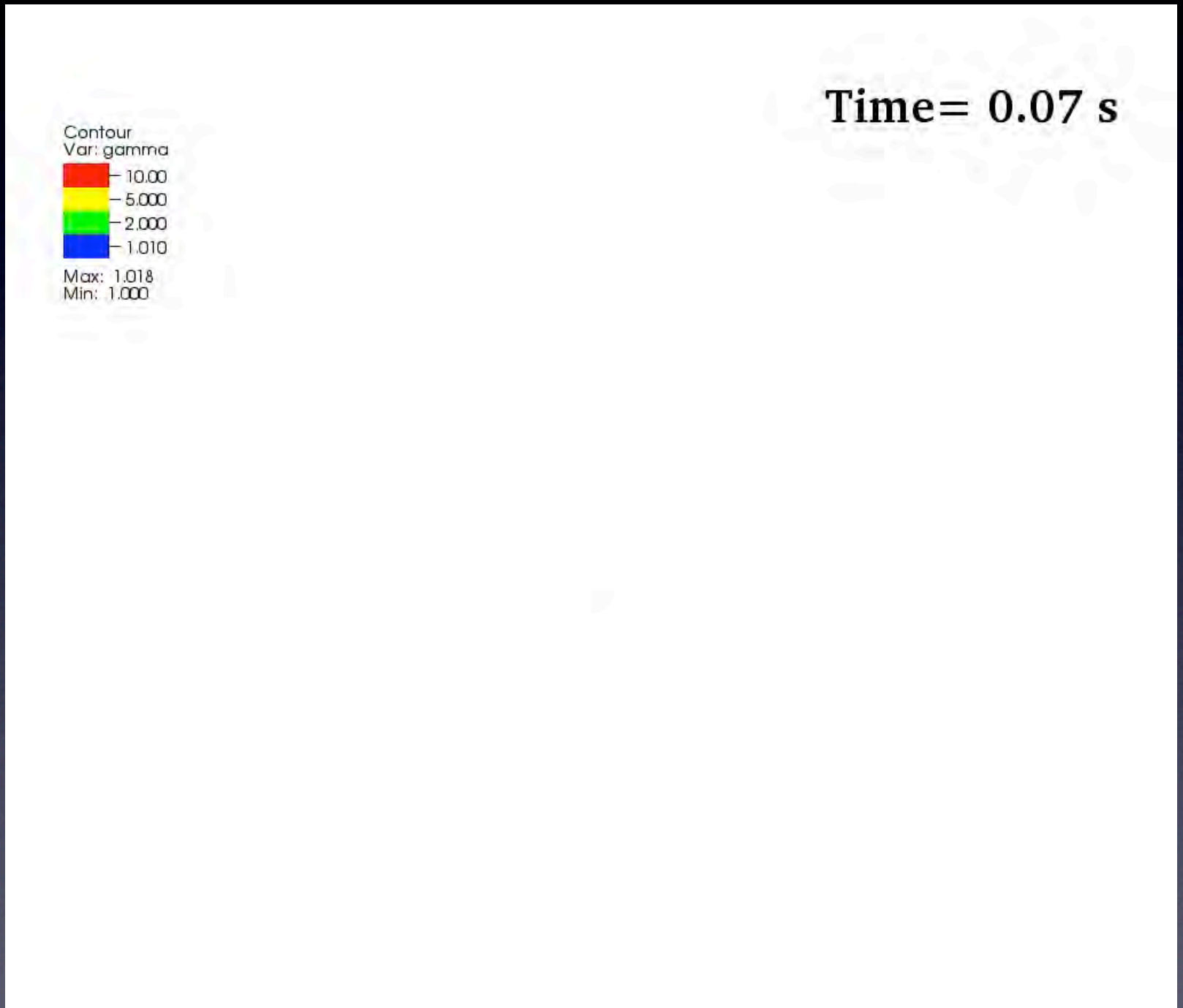
Magnetically Dominated Jets

- Needs fast reconnection
- Not certain how particles are accelerated
- Not certain if observed spectrum can be reproduced
- Not certain if correlations can be reproduced
- Should not produce GeV neutrinos

Summary

- GRBs should be dominated by photosphere
- Can naturally reproduce observed correlations
- Predicts correlation of efficiency and peak photon frequency
- Still work to be done in reproducing spectr
- Alternatives exist, but not as well develope

GRB Simulations



Problems with Photospheres

- GRBs don't look like a black body
- Need power law both below and above peak
- Black body is too steep at both ends