Numerical Simulations of Photospheric Emission from Collapsar Jets

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Collaborators

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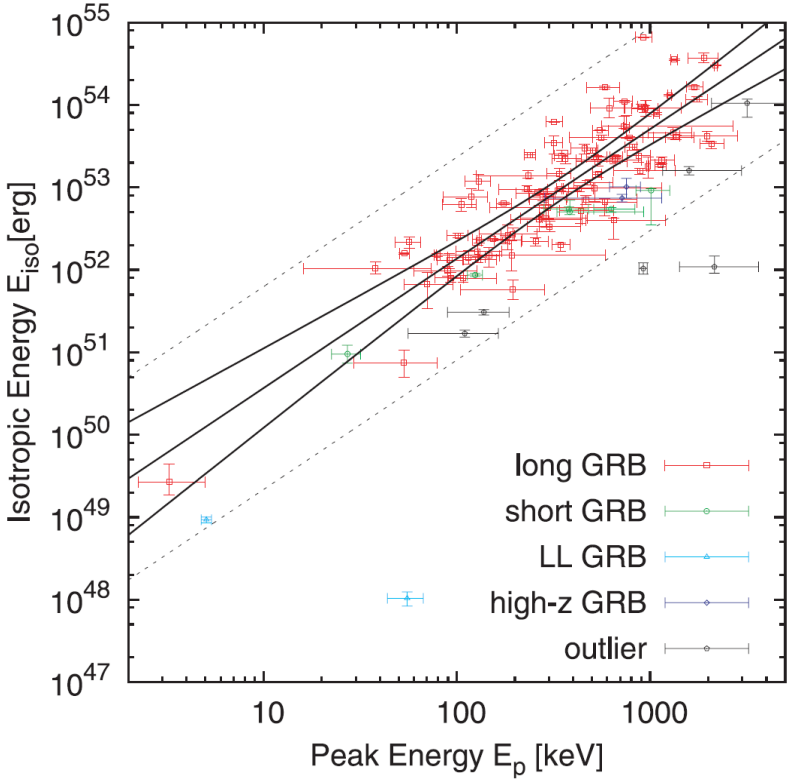
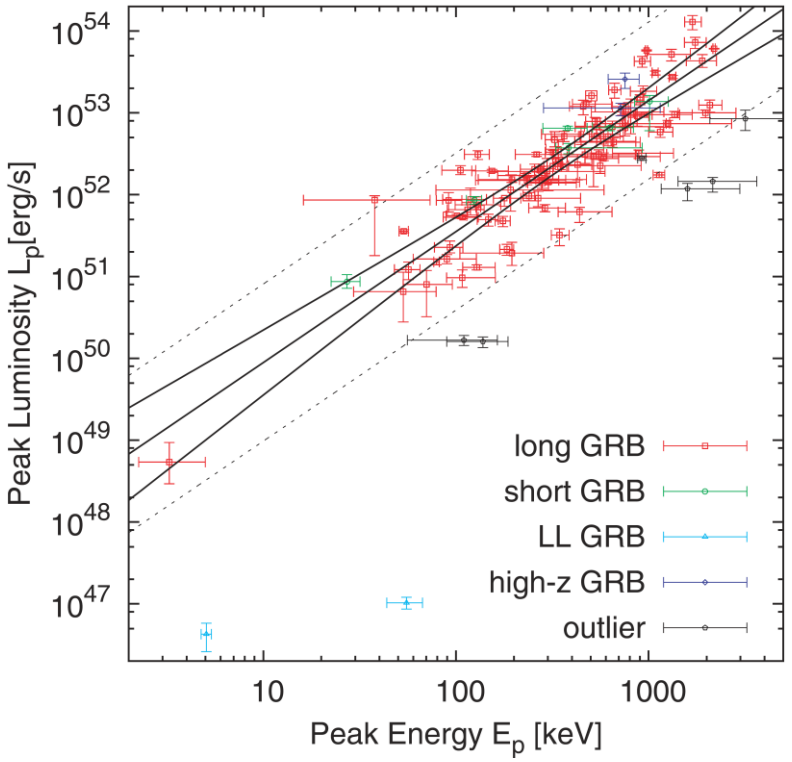
Tight correlation between E_p – E_{iso}, E_p – L_p

Amati + 2002;2006 Yonetoku + 2004 ; 2010

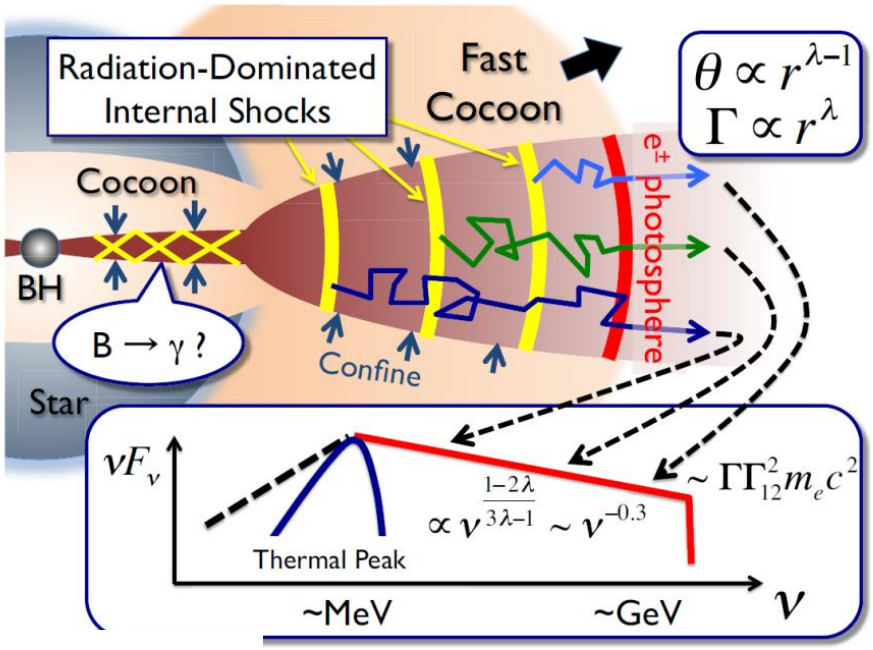




Powerful diagnostics for emission mechanism

Can photospheric emission reproduce this relation ?

Photospheric Emission in GRB jet



Ioka+2011

Dynamics of Jet and
Radiation transfer must be solved

Previous Studies

steady outflow or 1D model

Pe'er +2005,2006,2011; Giannios 2008; Beloborodov 2010,2011; Vurm+2011,2016; Lundman+2013,2014, Ito+2013,2014, Chhotray 2015

approximated treatment for radiation

Lazzati+2009,2011,2013; Mizuta+2011;Nagakura+2011; Lopez-Camara+2014

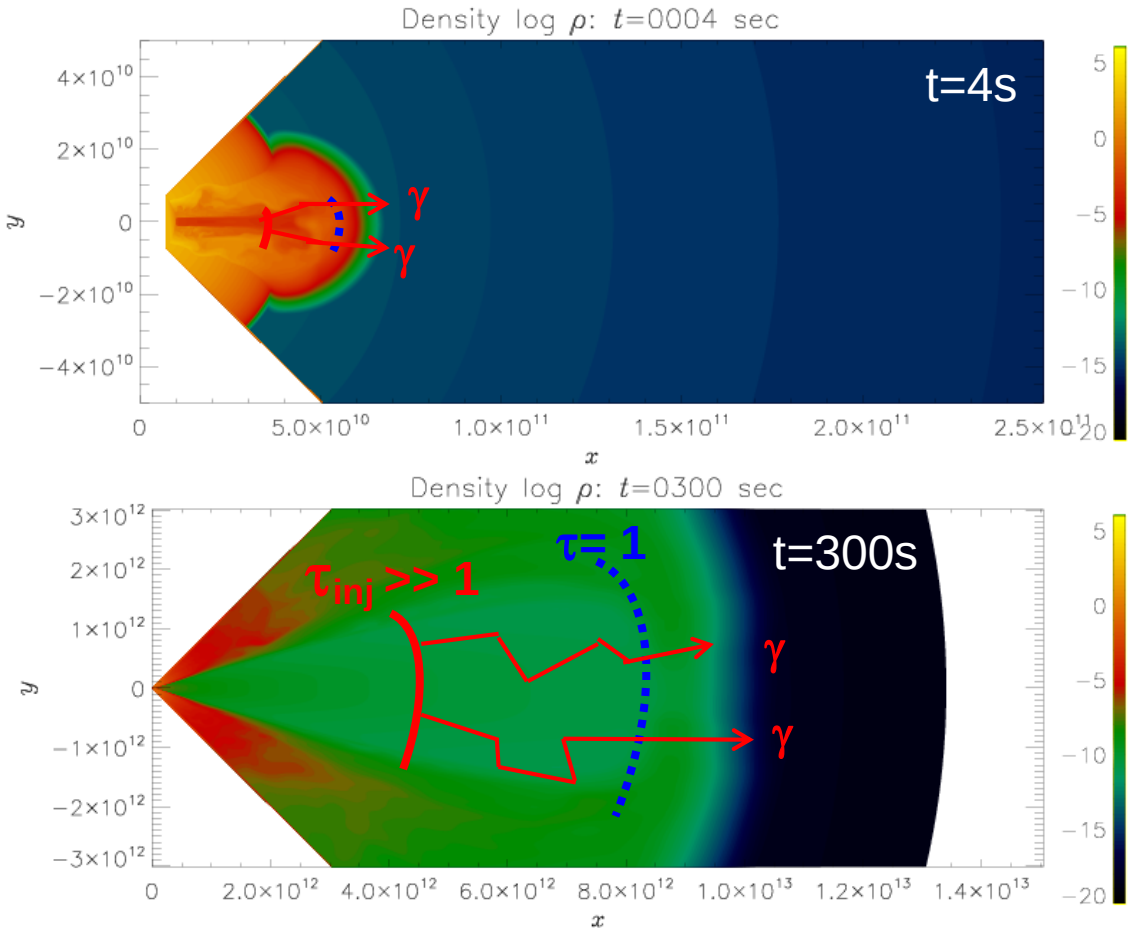
This Study

Radiation transfer calculation based on
3D hydrodynamical simulation => *Ep - Lp*

See also Lazzati 2016, Parsotan & Lazzati 2017

3D relativisitic hydrodymaical simulation

Calculation of relativistic jet breaking out of massive progenitor star



Progenitor star

16TI（Woosley & Heger 2006）

M_* ~14Msun

R_* ~ 4×10^{10} cm

Jet parameter

$L_j = 10^{49}, 10^{50}, 10^{51}$ erg/s

$\theta_j = 5°$

$\Gamma_j = 5$

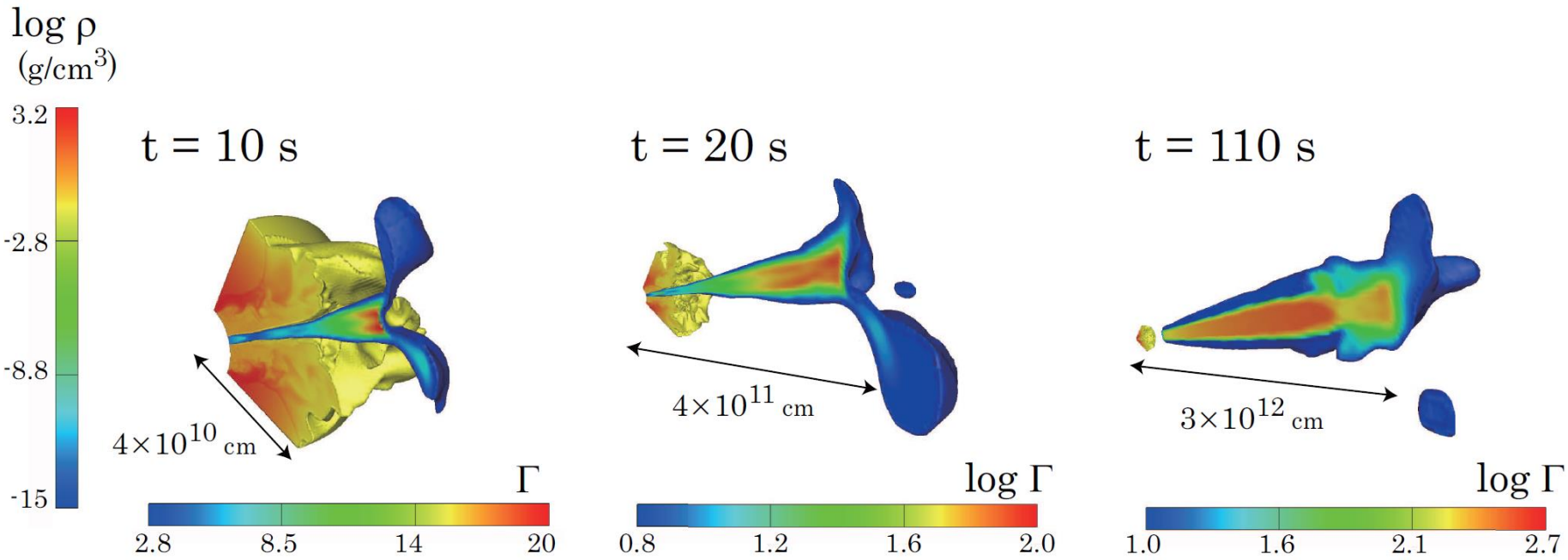
$\Gamma h = 500, 900$

3 models with different power

Radiative transfer calculation

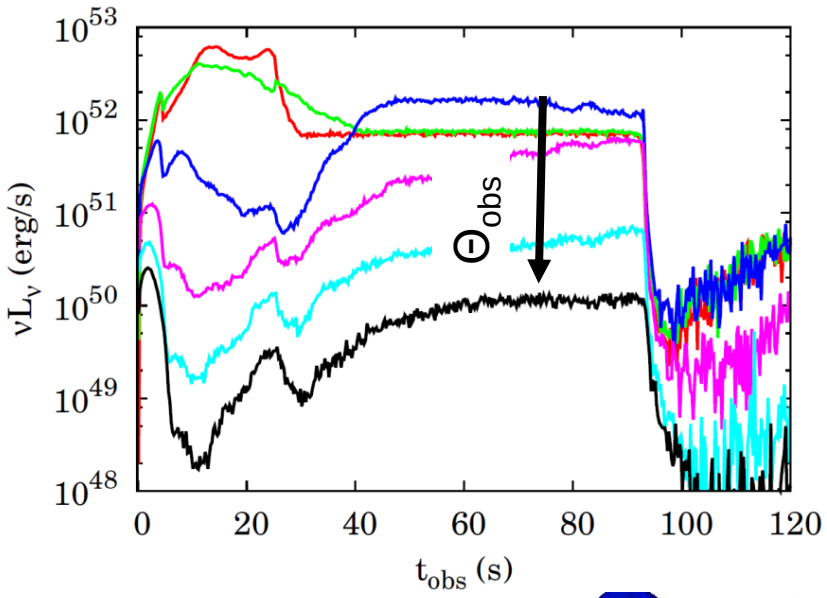
Propagation of photons are calculated until they reach optically thin region

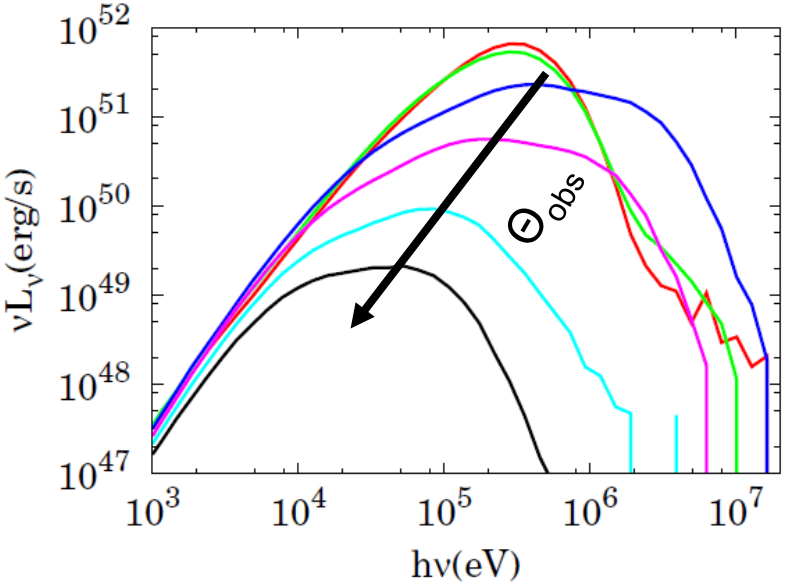
fiducial model $L_j = 10^{50}$ erg/s

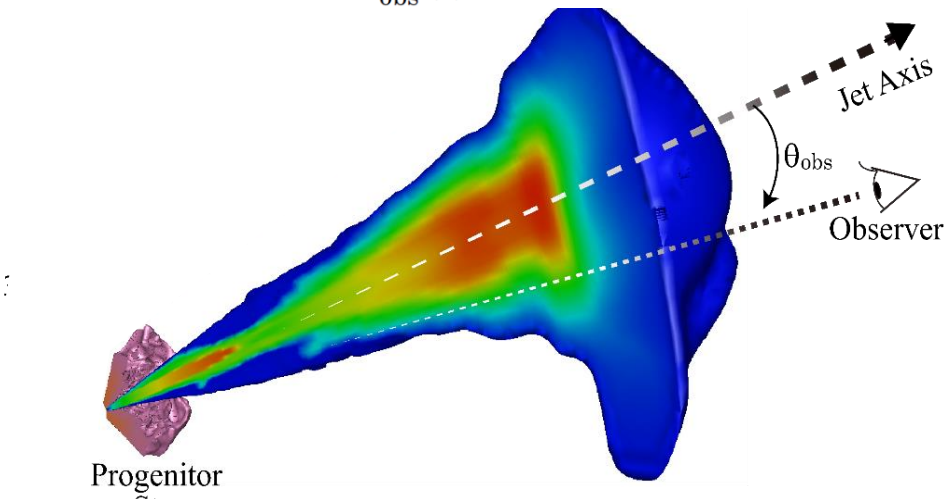


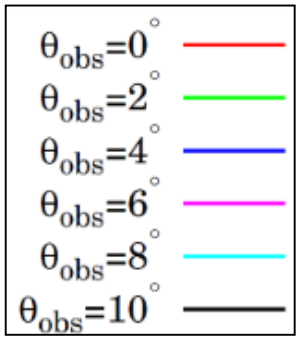
Ito + 2015

fiducial model $L_j = 10^{50}$ erg/s



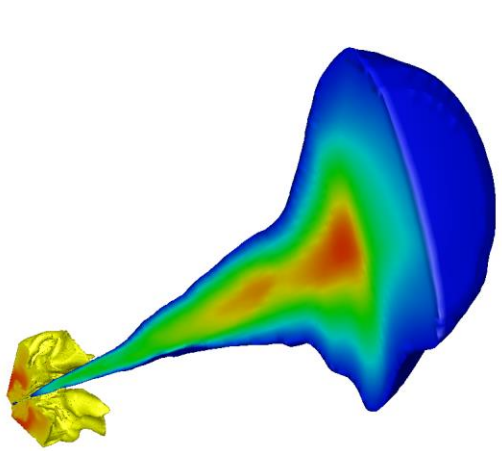


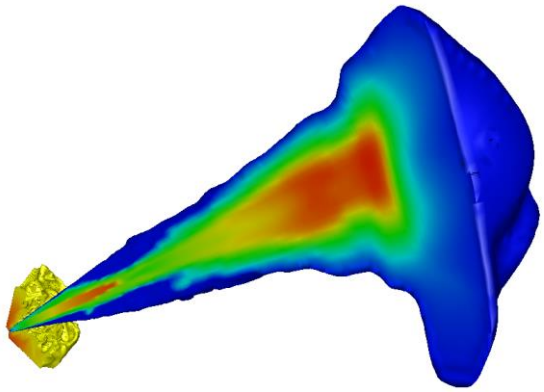


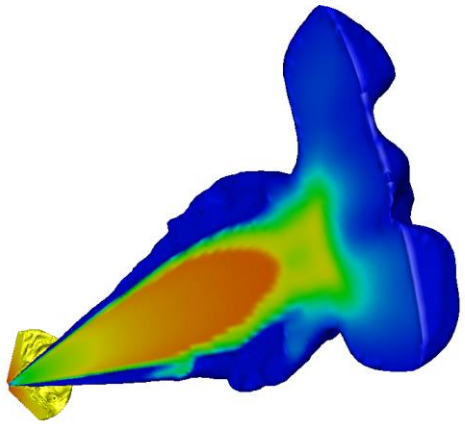


E_p & L_p decline as Θ_{obs} increases

Dependence on jet power







$L_j = 10^{49}$ erg/s

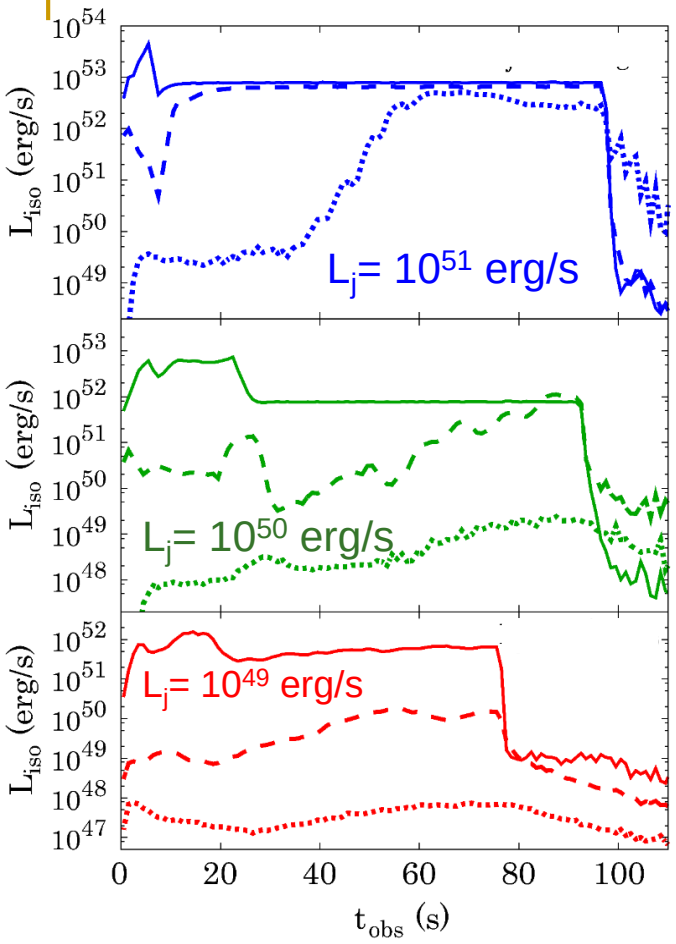
$L_j = 10^{50}$ erg/s

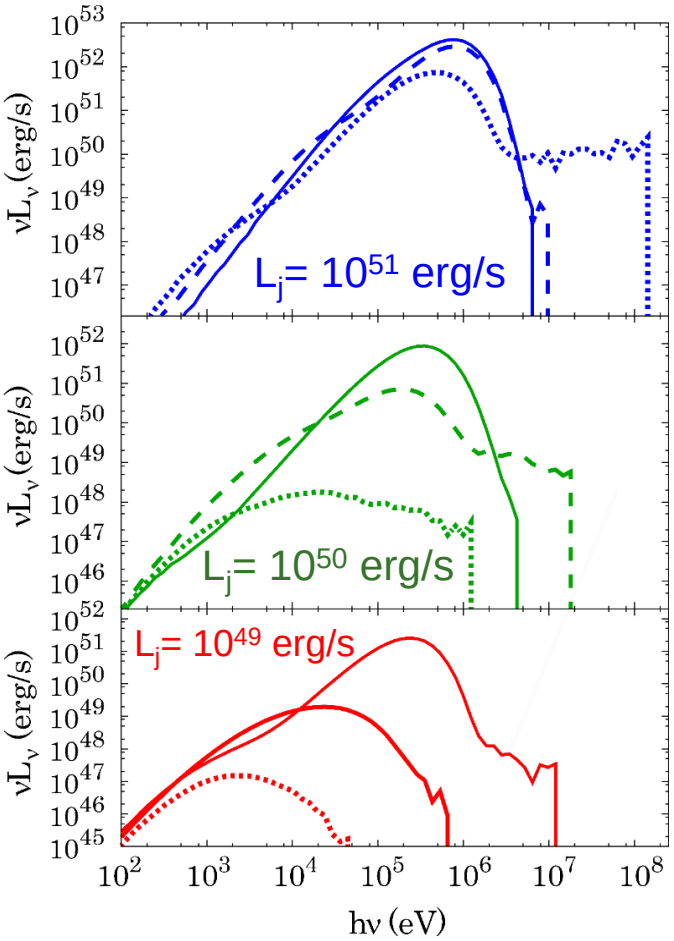
t=40s

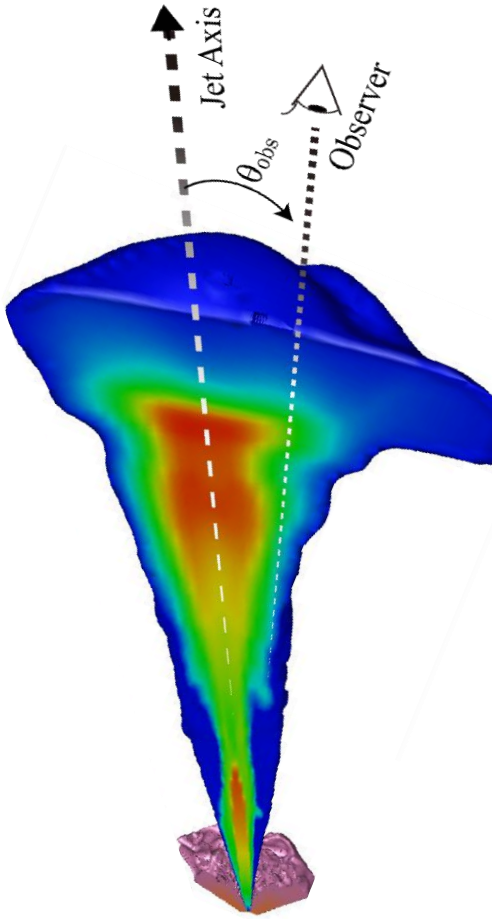
$L_j = 10^{51}$ erg/s

Ito + 2017, submitted

Dependence on jet power



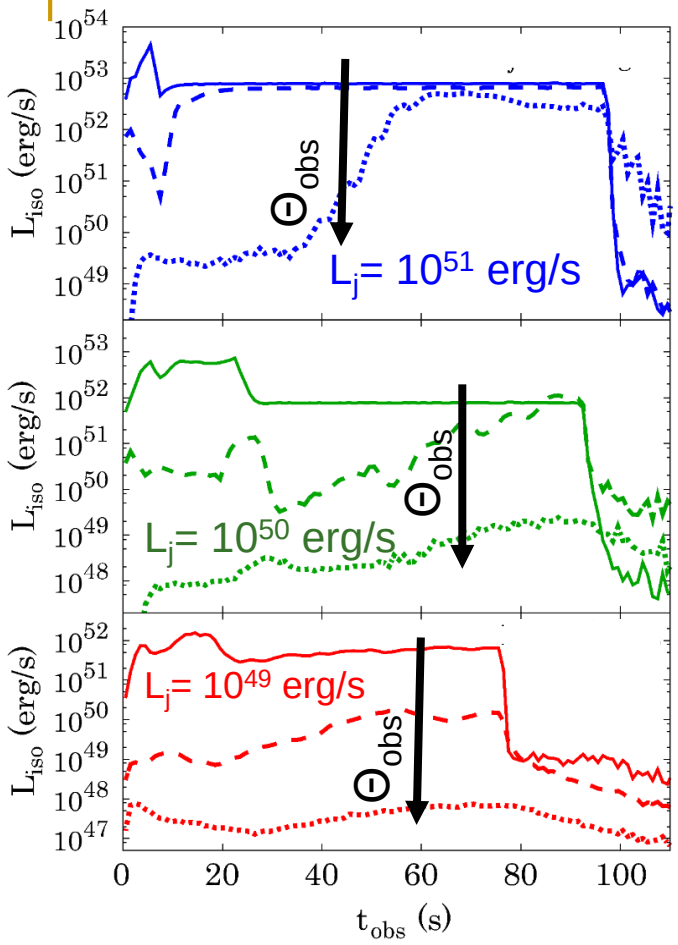


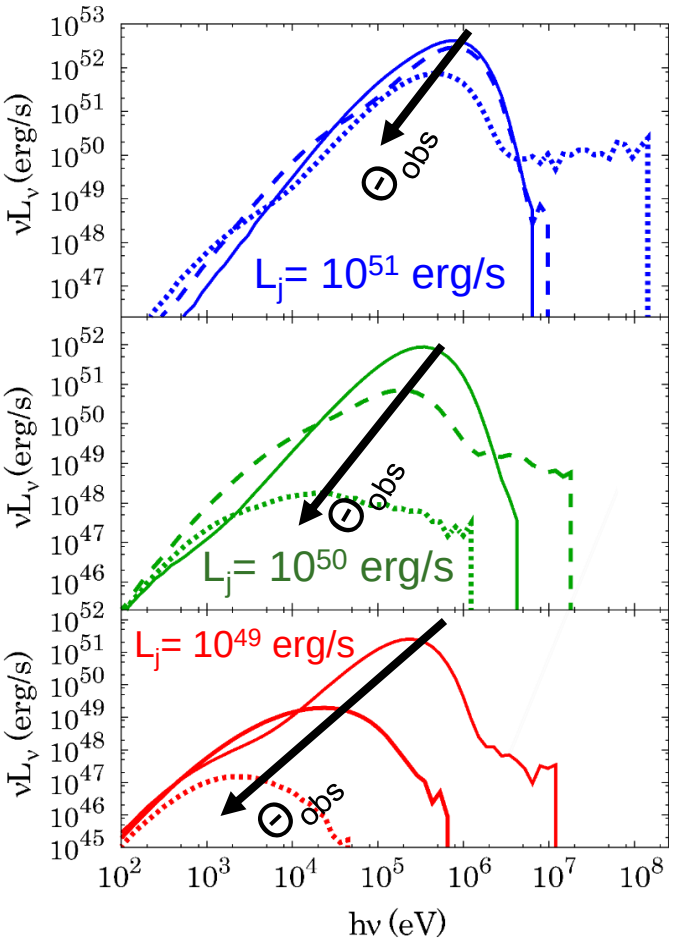


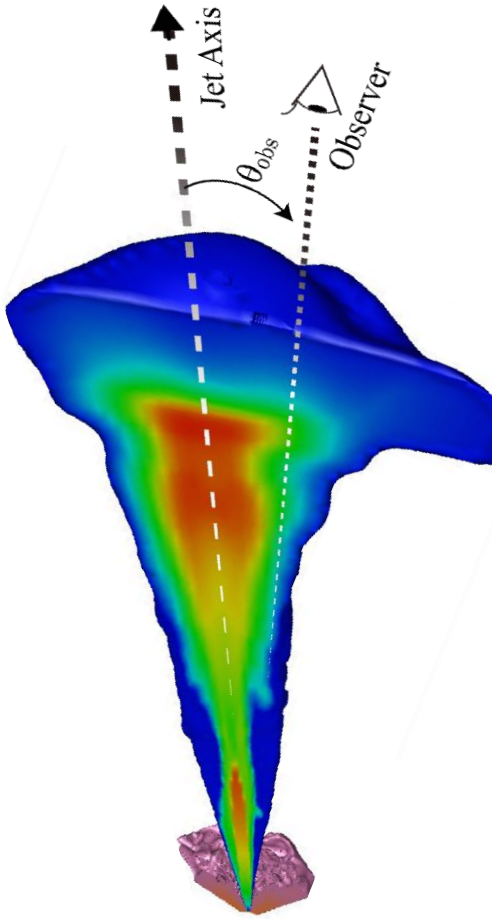
Θ_{obs} = 0° Θ_{obs} = 5° Θ_{obs} = 10°

L_p & E_p are systematically higher for higher L_j

Dependence on jet power





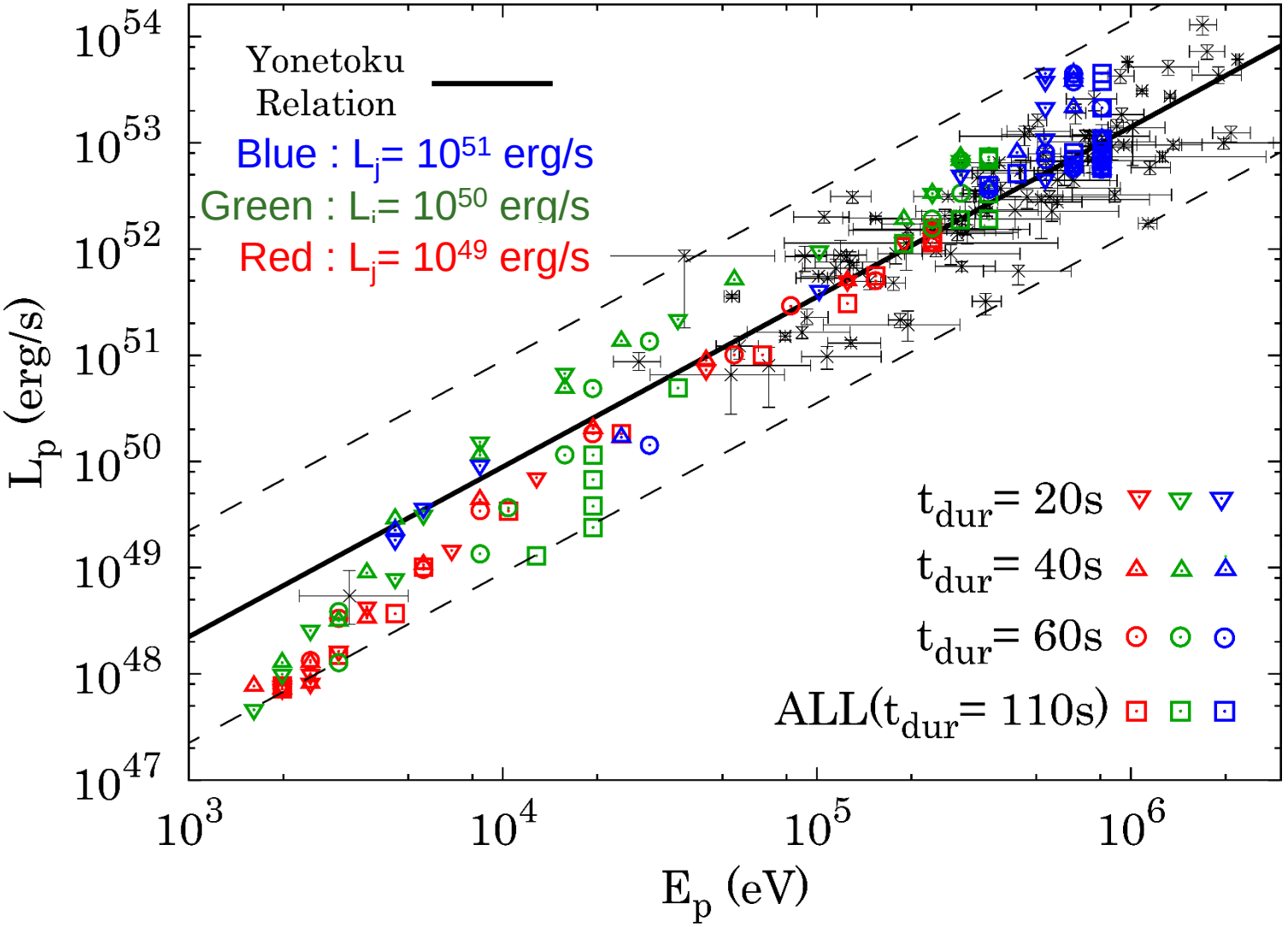


Θ_{obs} = 0° Θ_{obs} = 5° Θ_{obs} = 10°

E_p & L_p decline as Θ_{obs} increases

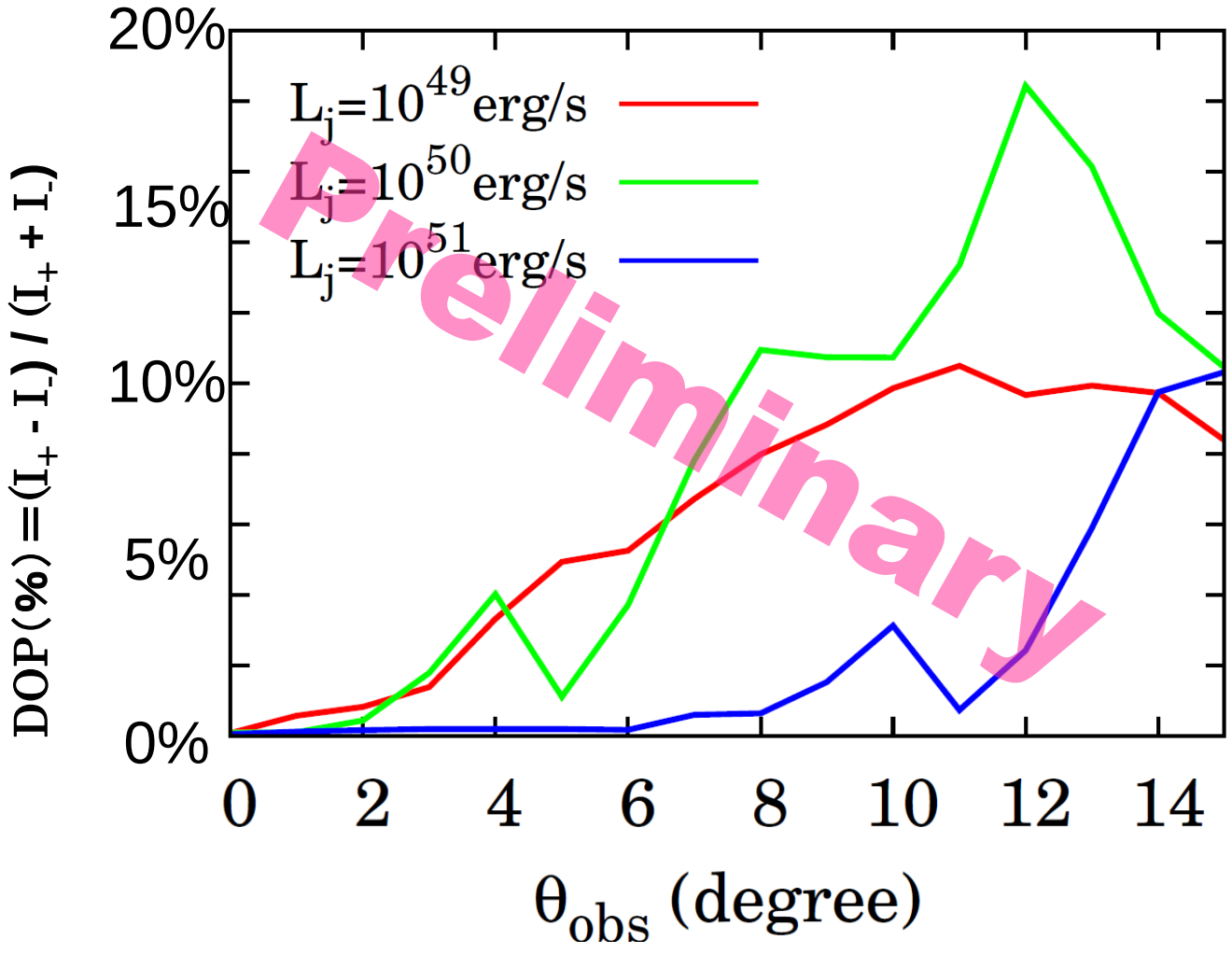
lateral structure of jet induces the viewing angle dependence

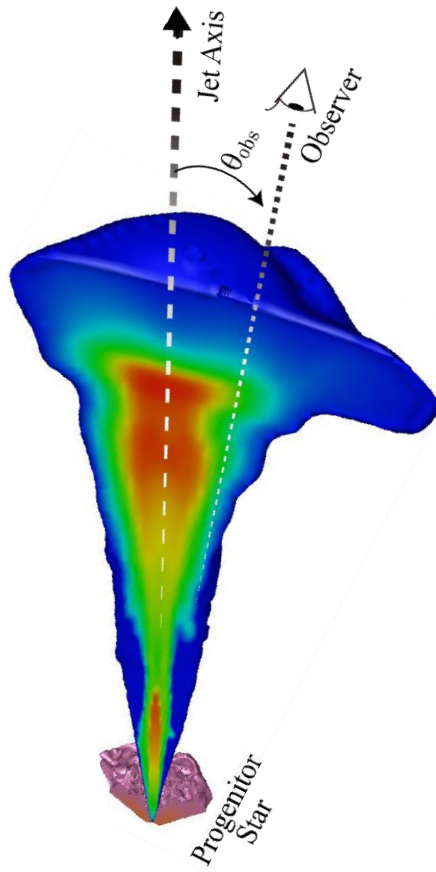
Yonetoku relation



Remarkable match with observations

polarization





High polarization (>10%) at large Θ_{obs}

Ito + 2017 in prep.

Summary

Yonetoku relation is an inherent feature of photospheric emission

Lateral structure of jet developed during propagation is an origin of the correlation between E_p & Lp

This relation holds *regardless* of the jet power

Compelling evidence of photospheric emission as a dominant radiation mechanism for GRBs

Prediction of high polarization at large viewing angle