The photospheric origin of the Yonetoku relation in gamma-ray bursts

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Collaborators

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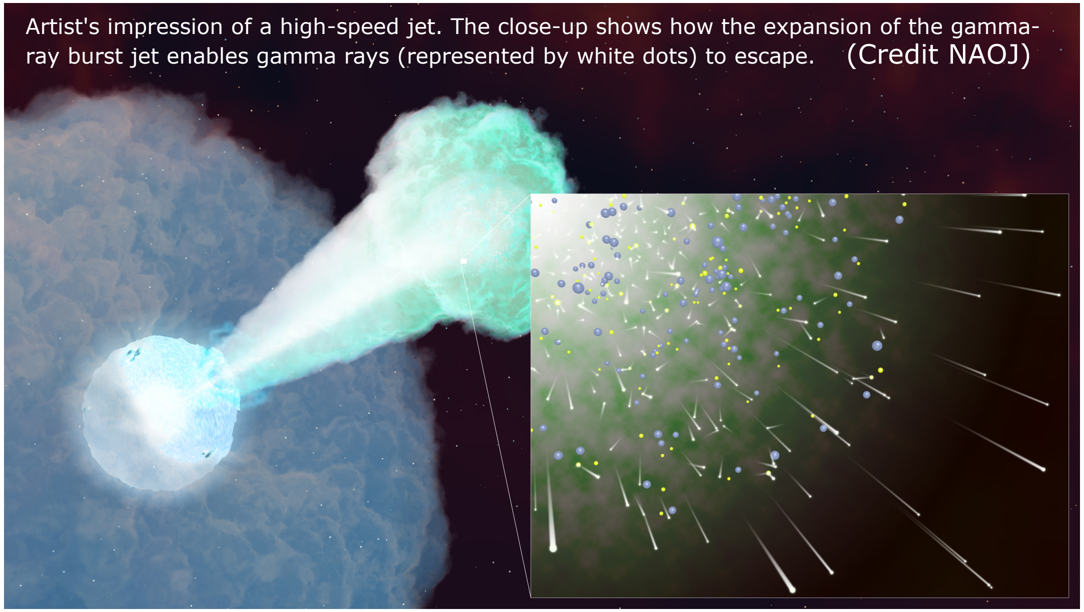
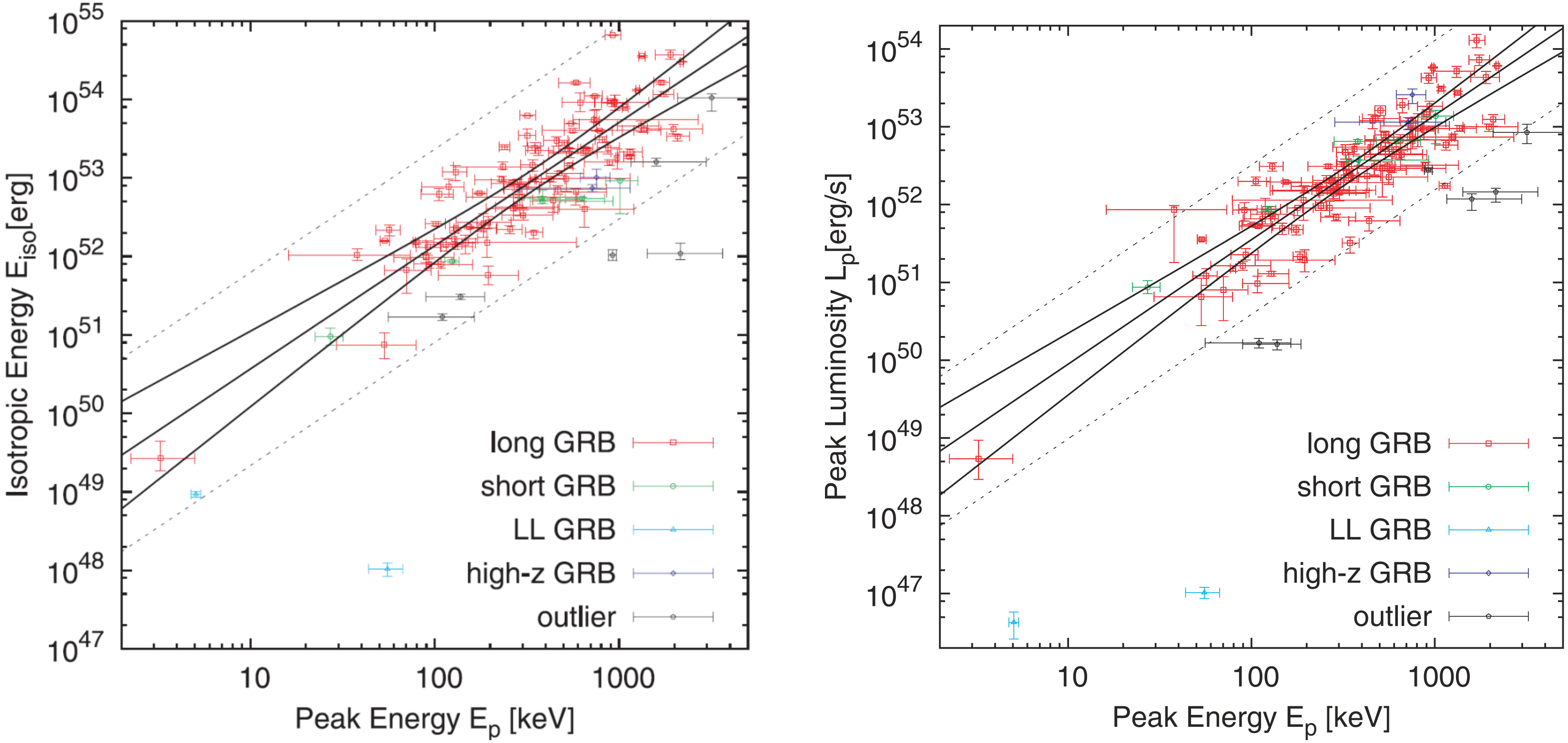
Ito et al. 2019, NatCo, 10, 1504



@ Ioffe Workshop on GRBs and other transient sources: 25 Years of Konus-Wind Experiment 2019/9/9

Tight correlation between $E_p - E_{iso}$, $E_p - L_p$

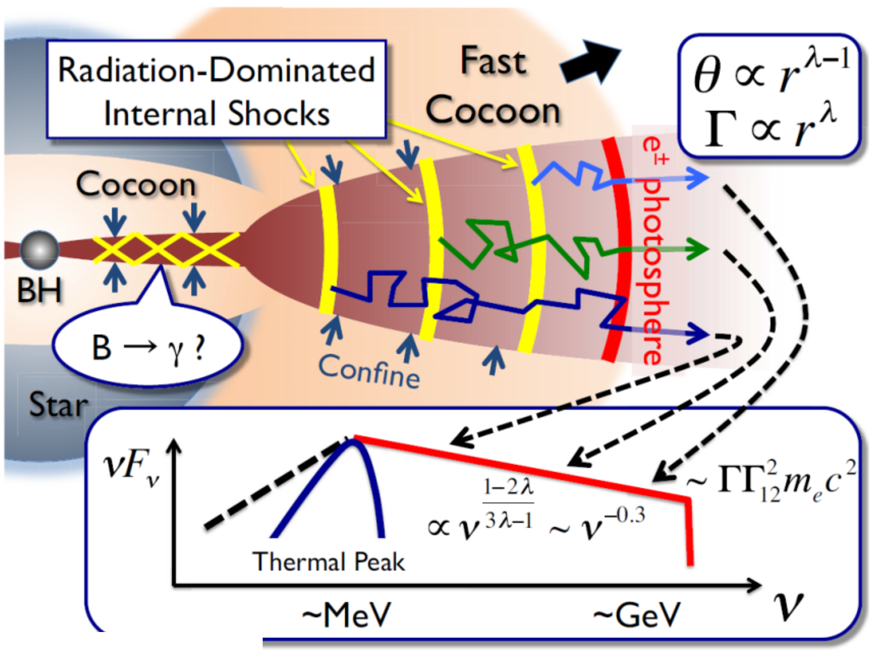
Amati + 2002;2006 Yonetoku + 2004 ; 2010



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; Begue + 2013; 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, Gottlieb+2019

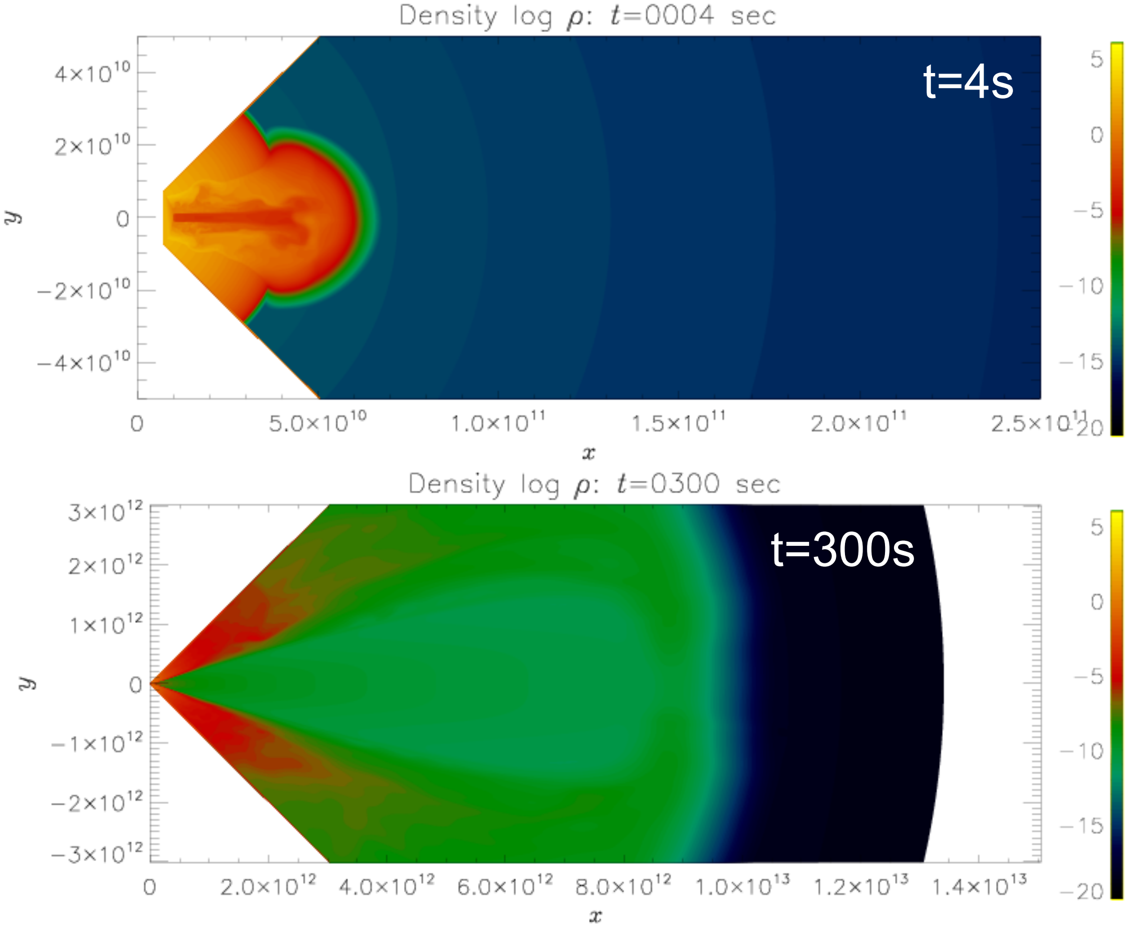
This Study

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

See also Lazzati 2016, Parsotan & Lazzatil 2018, Parsotan, Lopez-Camara, Lazzati 2018

3D relativisitic hydrodymaical simulation

Calculation of relativistic jet breaking out of massive progenitor star



Progenitor star

16TI (Woosley & Heger 2006)

$M_* \sim 14 M_{sun}$

$R_* \sim 4 \times 10^{10}$ cm

Jet parameter

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

$\theta_j = 5^\circ$

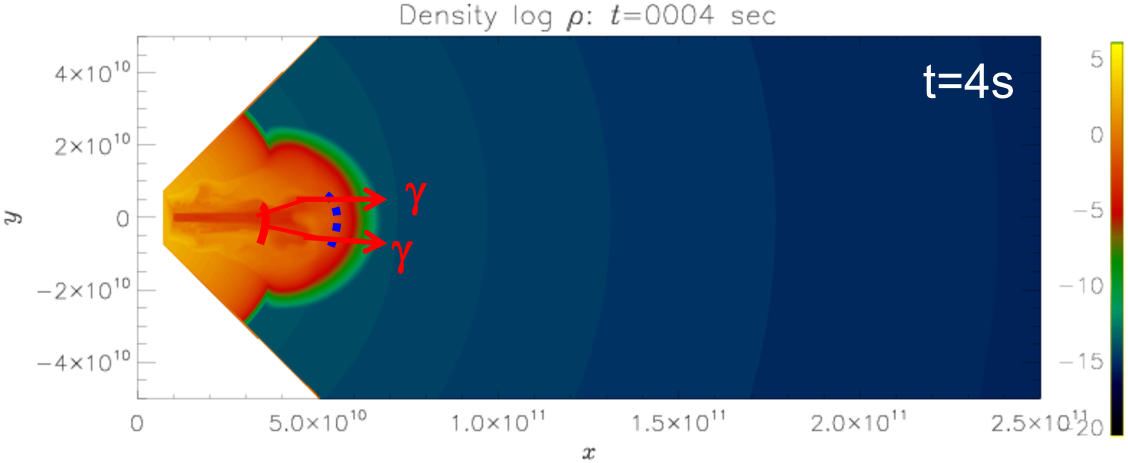
$\Gamma_j = 5$

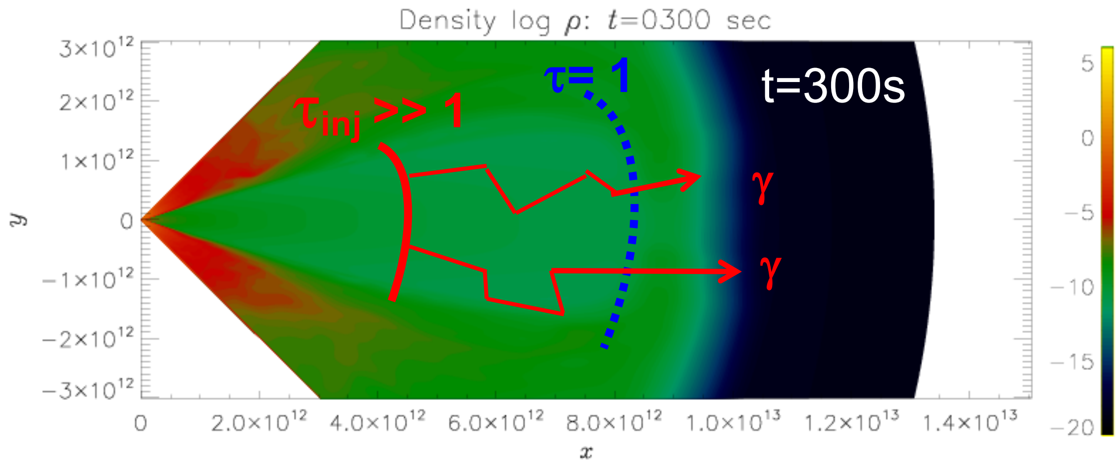
$\Gamma h = 500, 900$

3 models with different power

3D relativisitic hydrodymaical simulation

Calculation of relativistic jet breaking out of massive progenitor star





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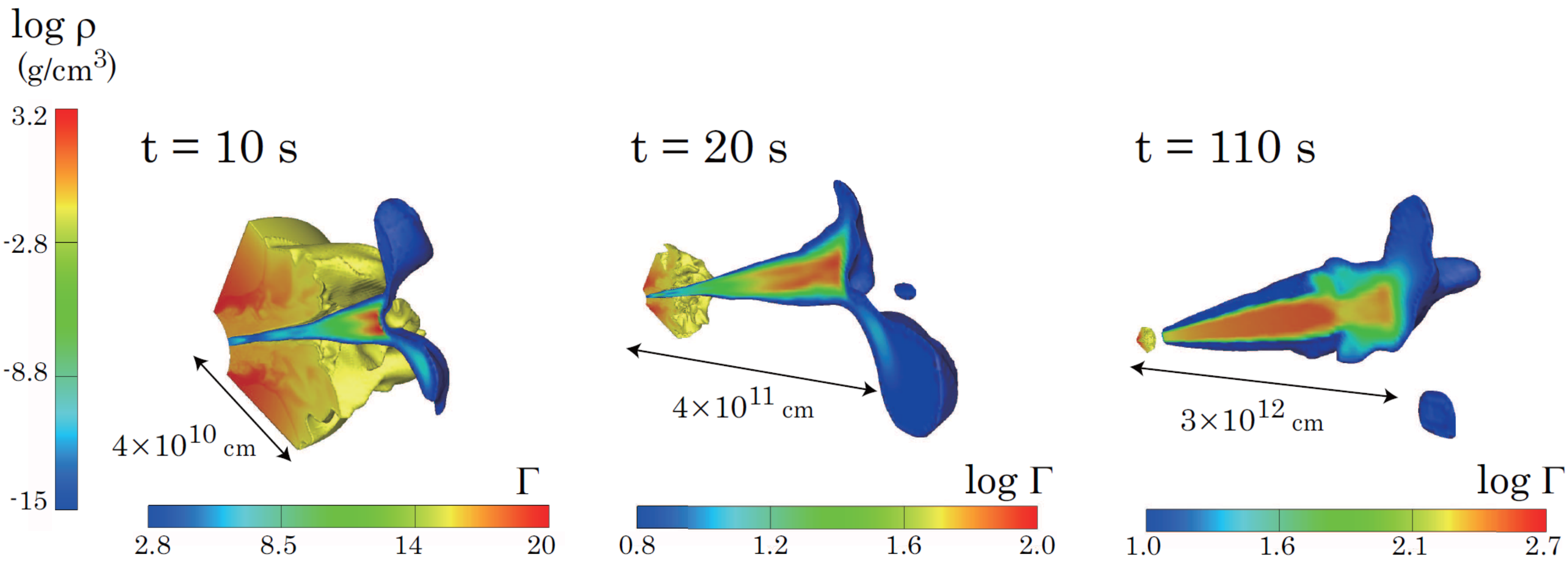
3 models with different power

Radiative transfer calculation

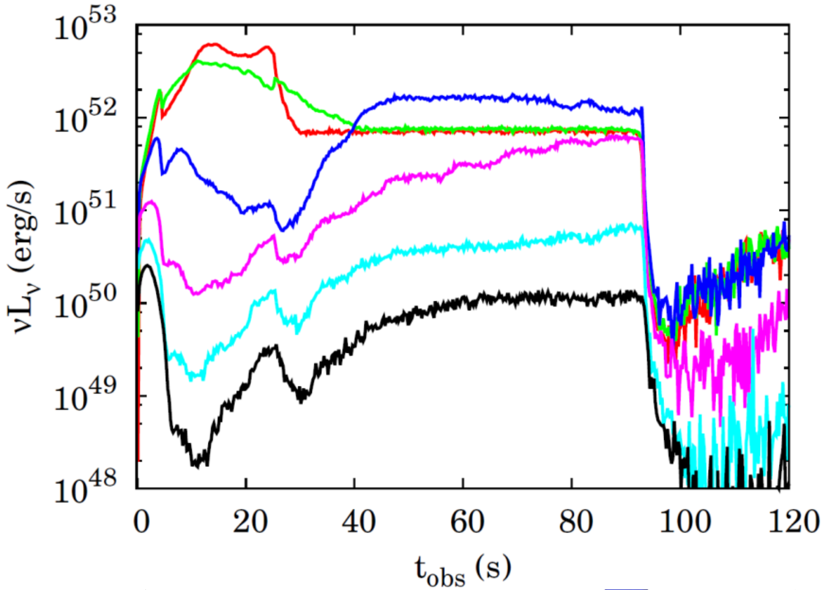
Propagation of photons are calculated until they reach optically thin region

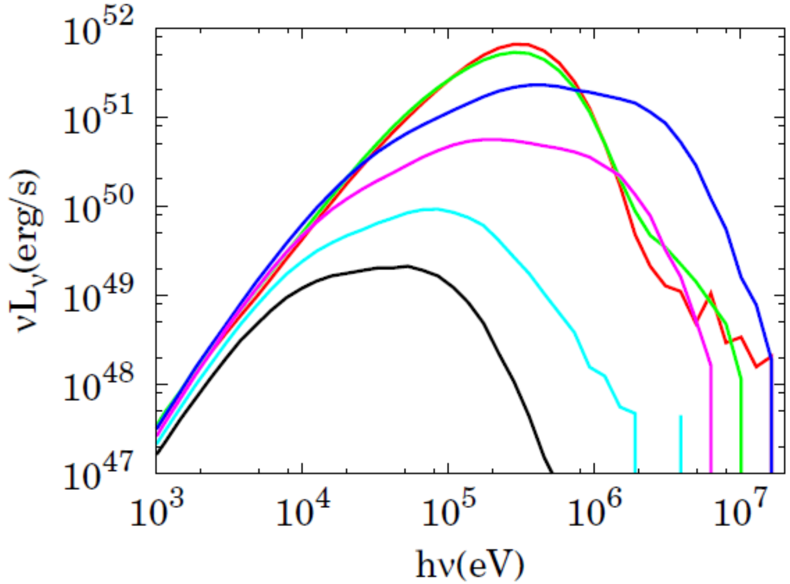
fiducial model $L_j = 10^{50}$ erg/s

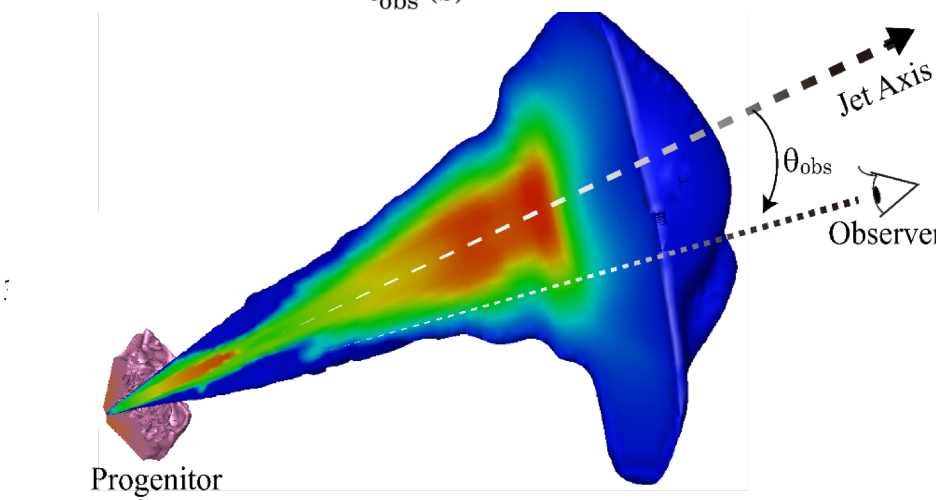


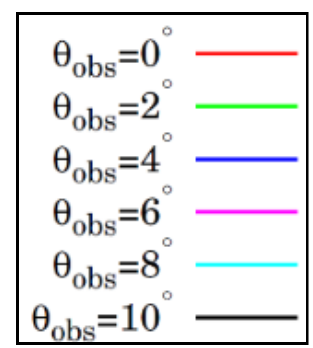
Ito + 2015

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









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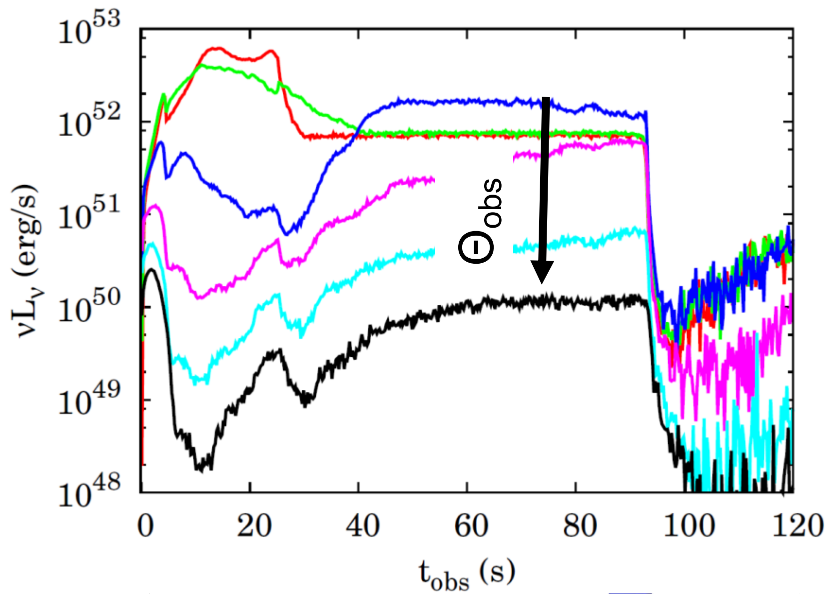
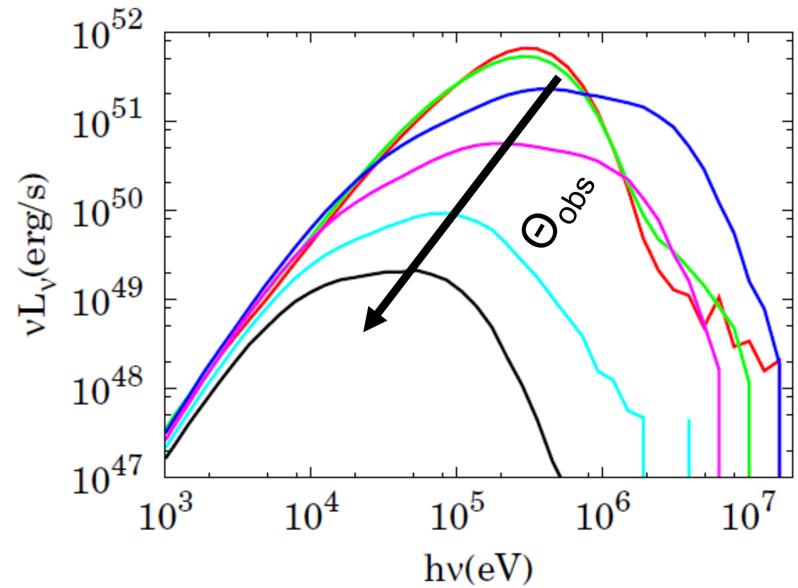
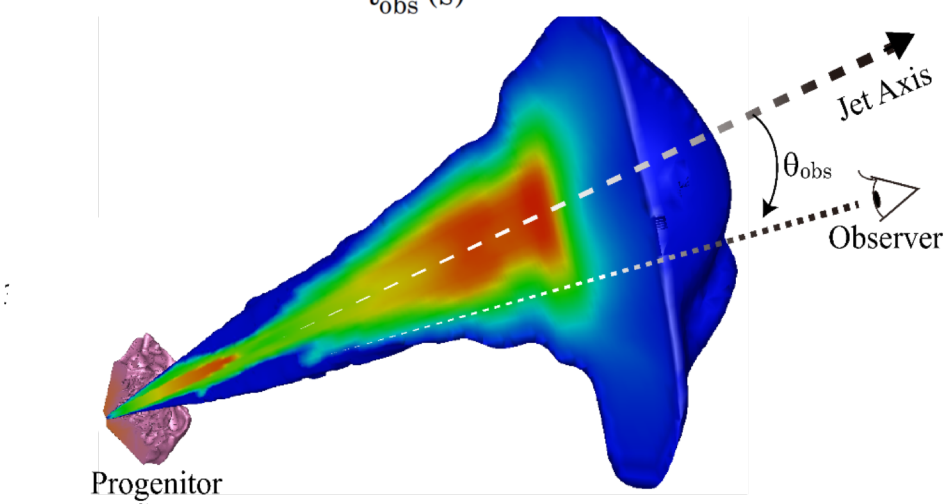
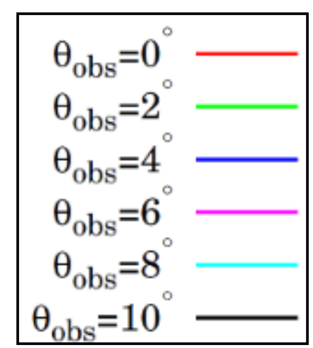


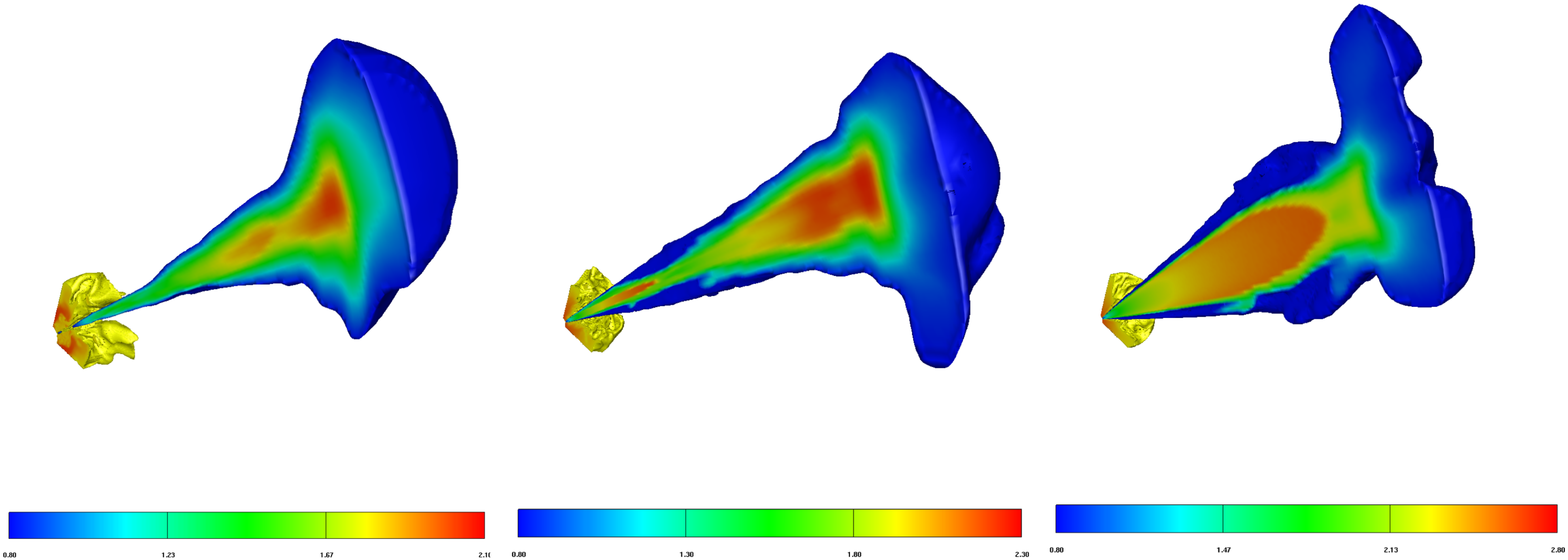






E_p & L_p decline as Θ_{obs} increases

Dependence on jet power



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

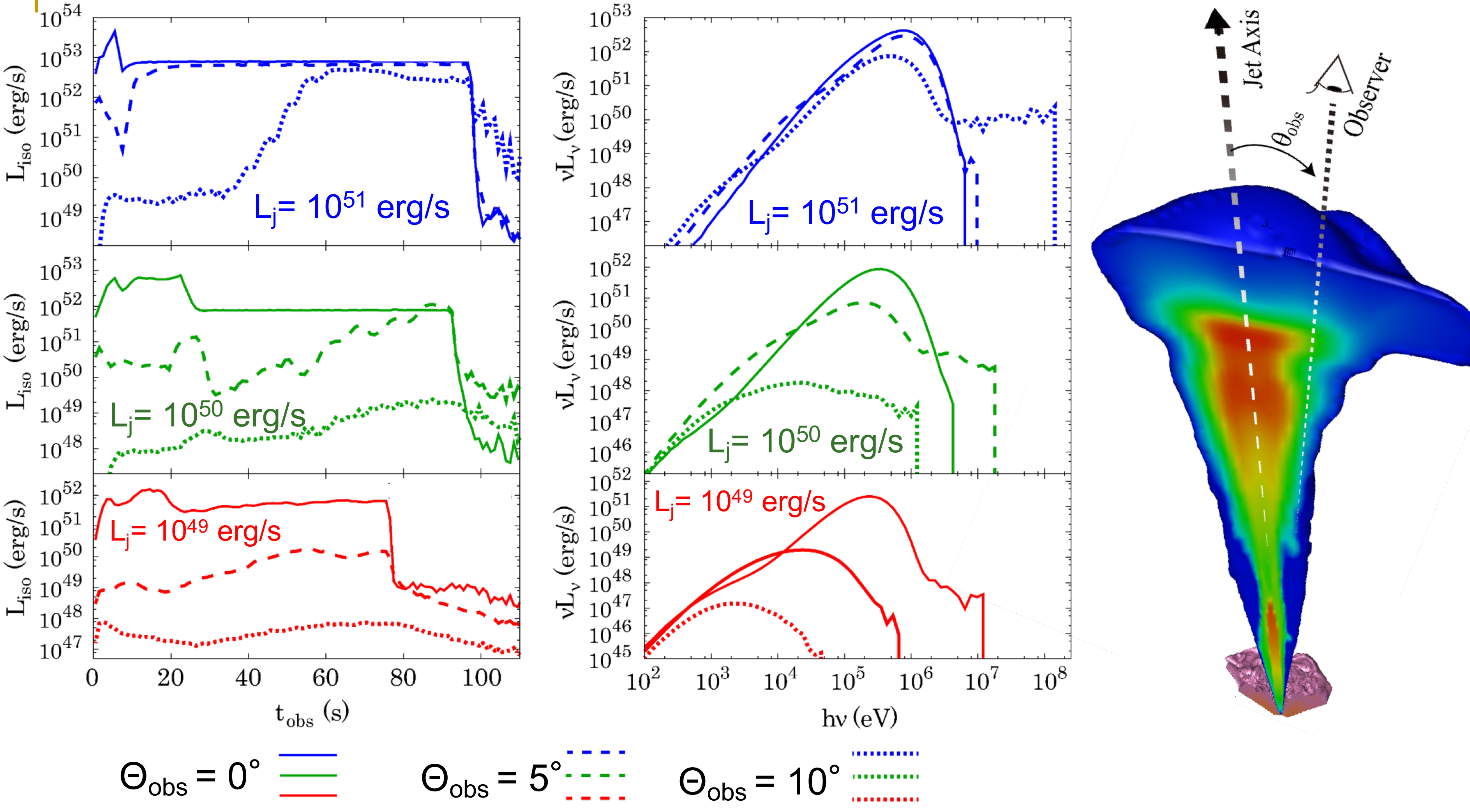
$L_j = 10^{50}$ erg/s

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

t=40s

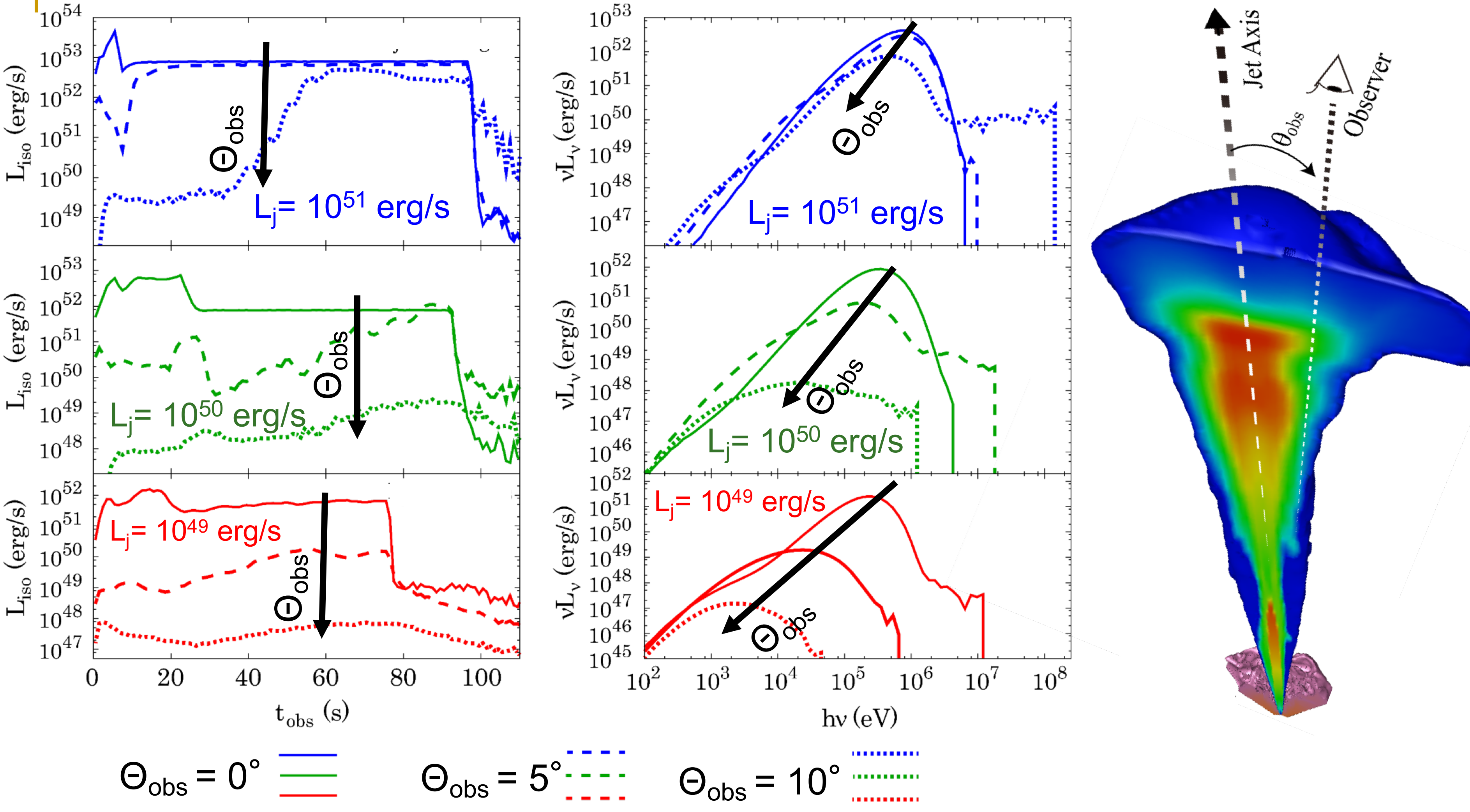
Ito + 2019

Dependence on jet power



L_p & E_p are systematically higher for higher L_j

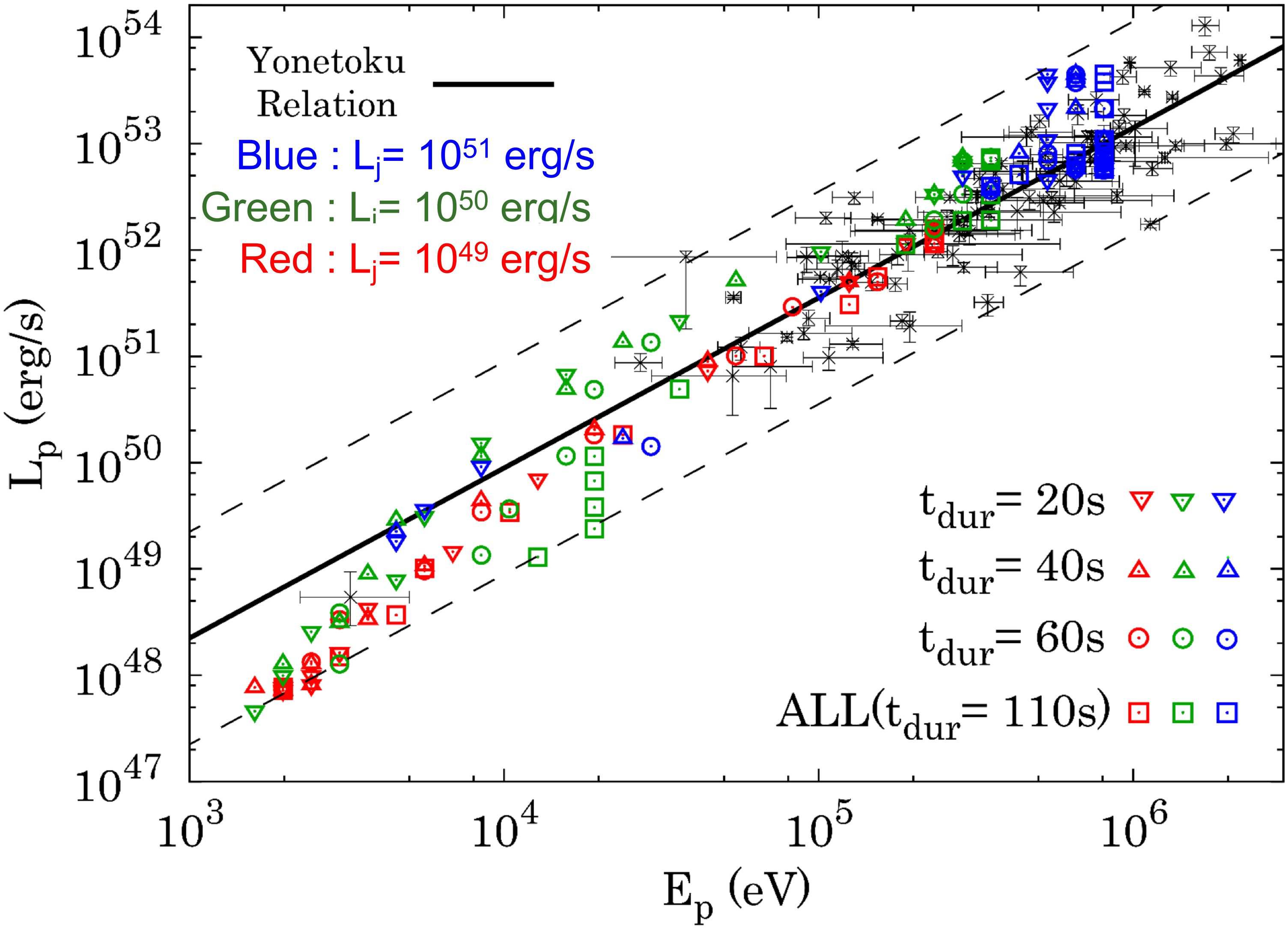
Dependence on jet power



E_p & L_p decline as Θ_{obs} increases

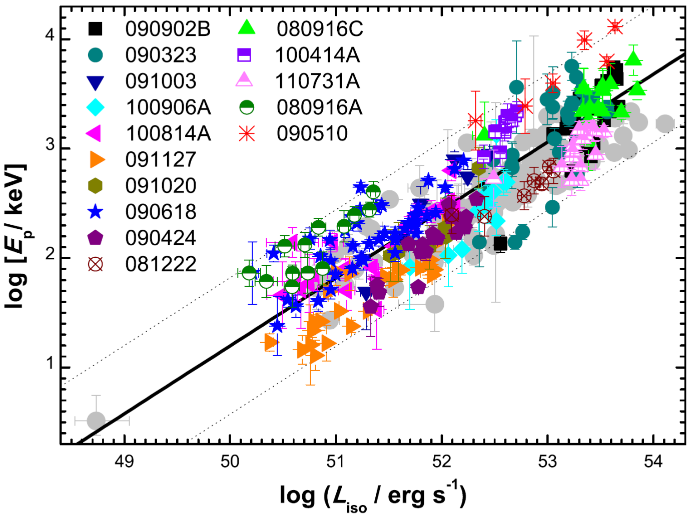
lateral structure of jet induces the viewing angle dependence

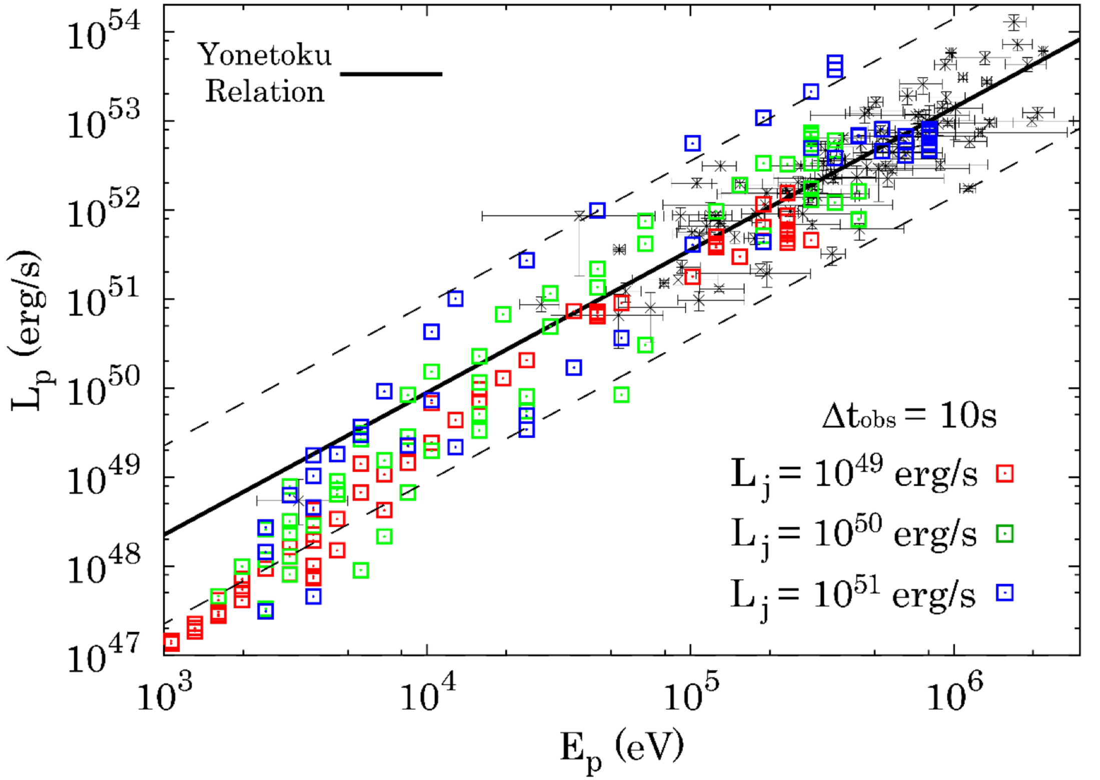
Yonetoku relation



Remarkable match with observations

Time resolved Yonetoku relation



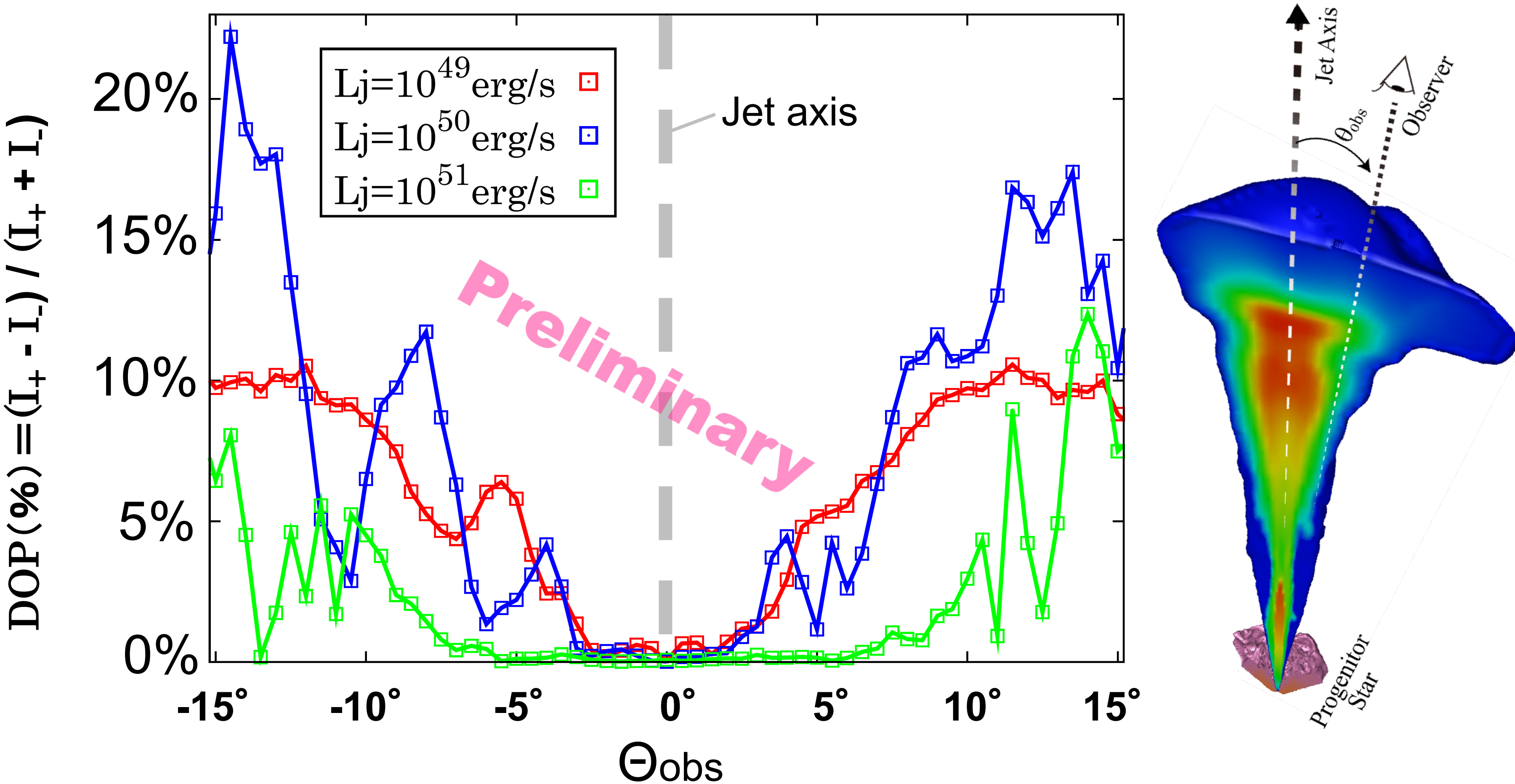


Lu + 2012
15 GRBs with time resolved
Ep and redshift

Yonetoku Relation holds *regardless* of the time interval

photospheric emission as dominant radiation process

polarization



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

Ito + 2019, 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 & L_p
- This relation holds *regardless* of the jet power
- Support to photospheric emission as a dominant radiation mechanism for GRBs
- Prediction of high polarization at large viewing angle