Are GRB jets magnetically-dominated, or baryon-rich, or lepton-rich?

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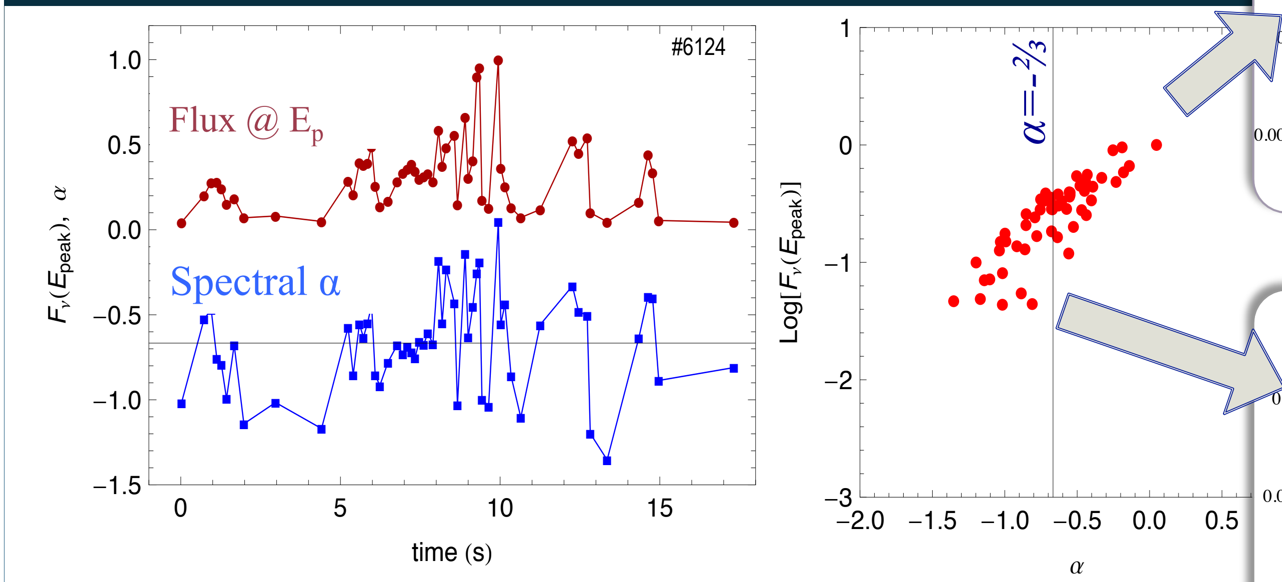
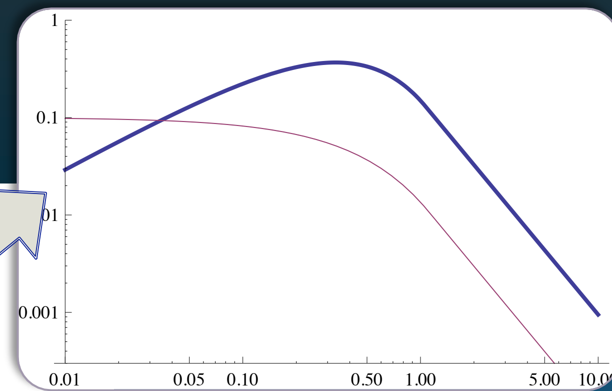
S. Pothapragada
S. Reynolds (KU)

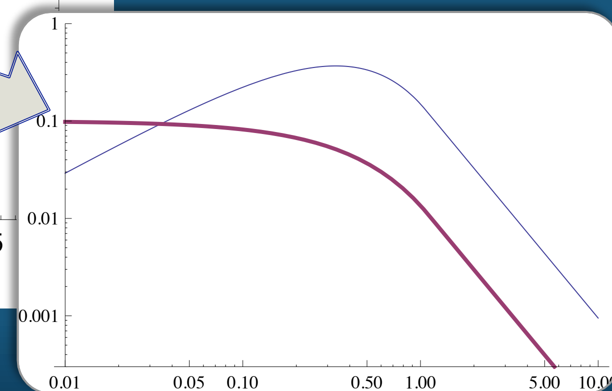
GRB spectral variability

Spectra are harder at larger fluxes

for $P(\nu) \sim \nu^{1+\alpha}$ below spectral peak

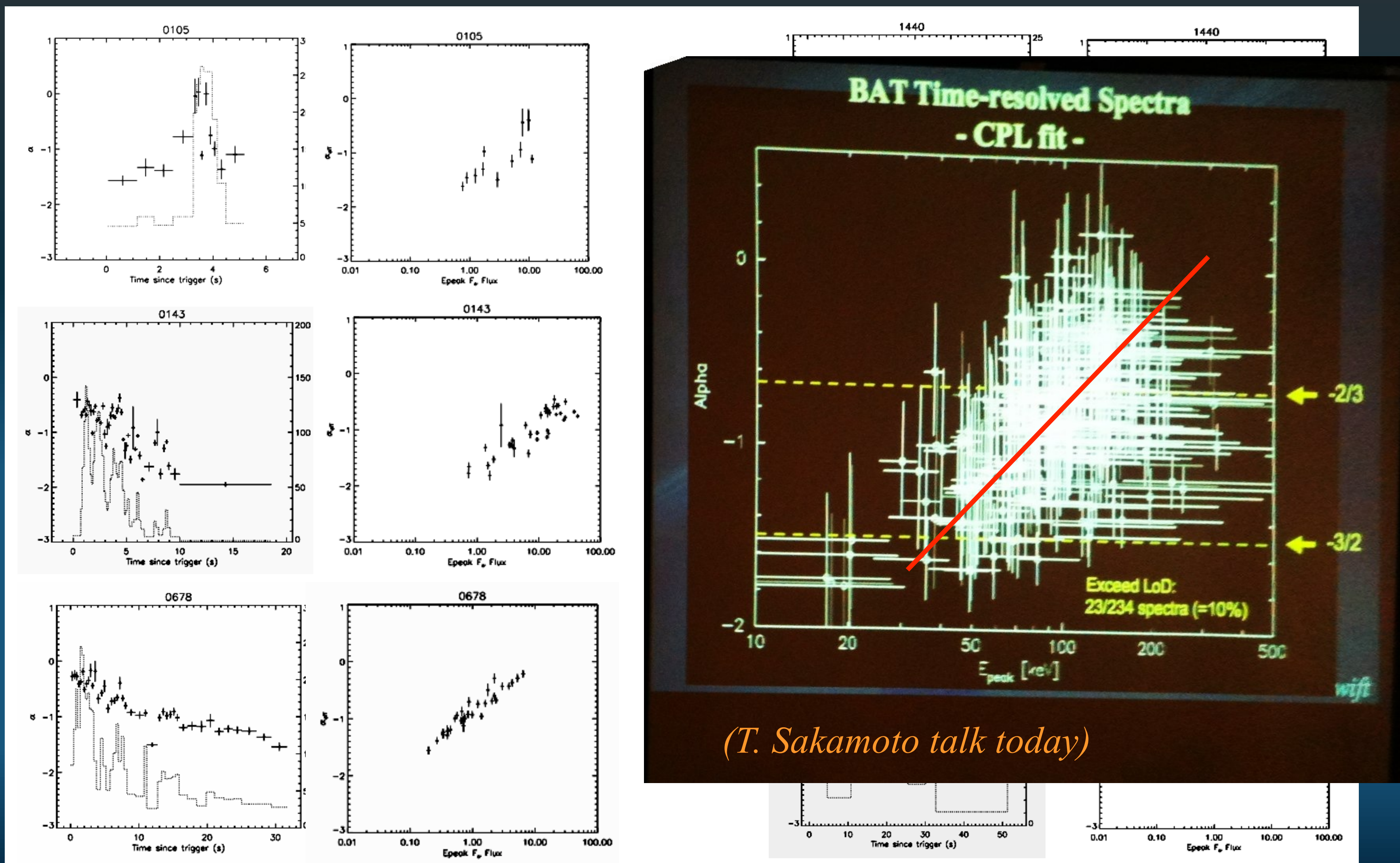






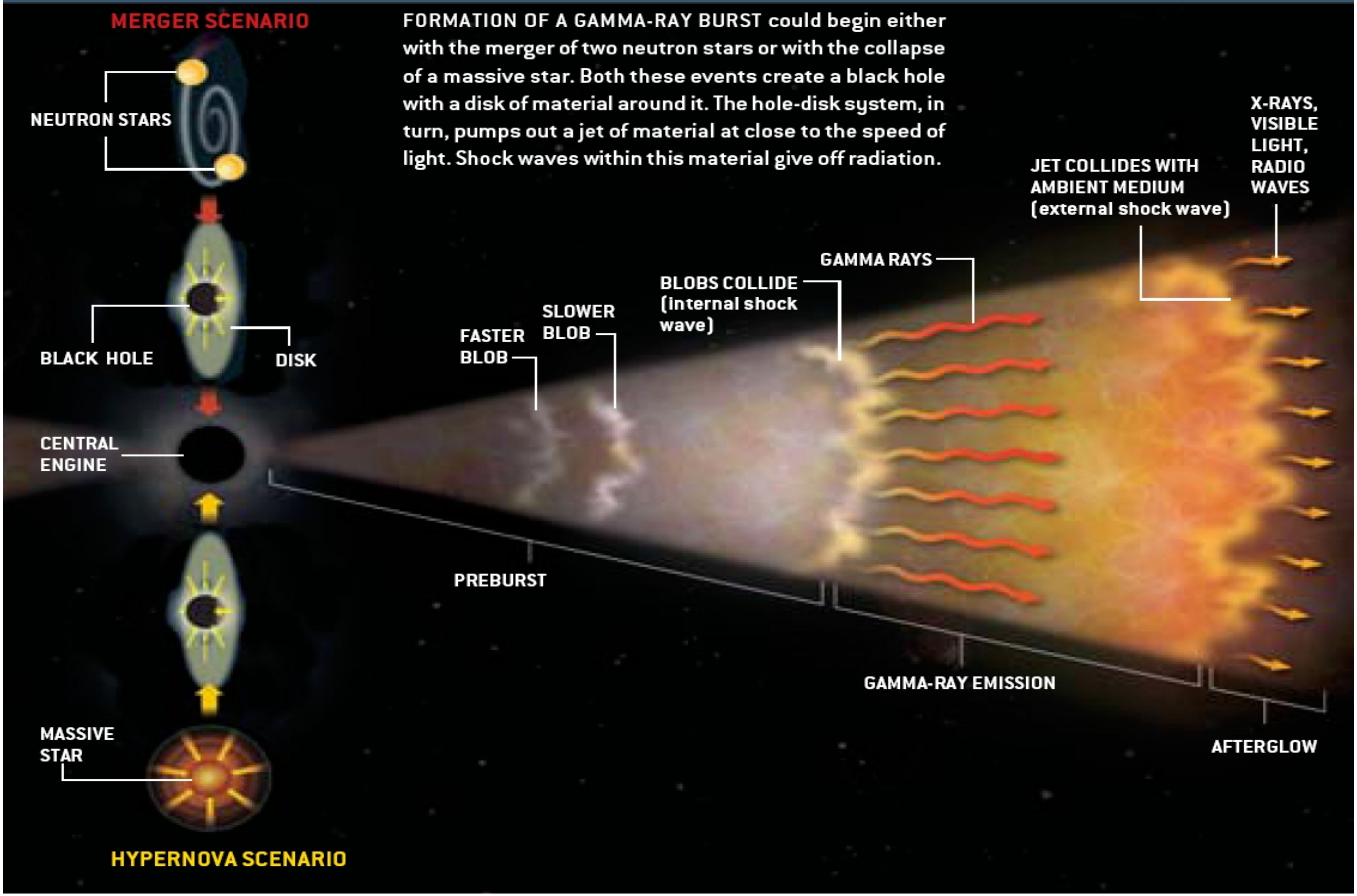
25% of GRBs exhibit this correlation

Rapid spectral variability

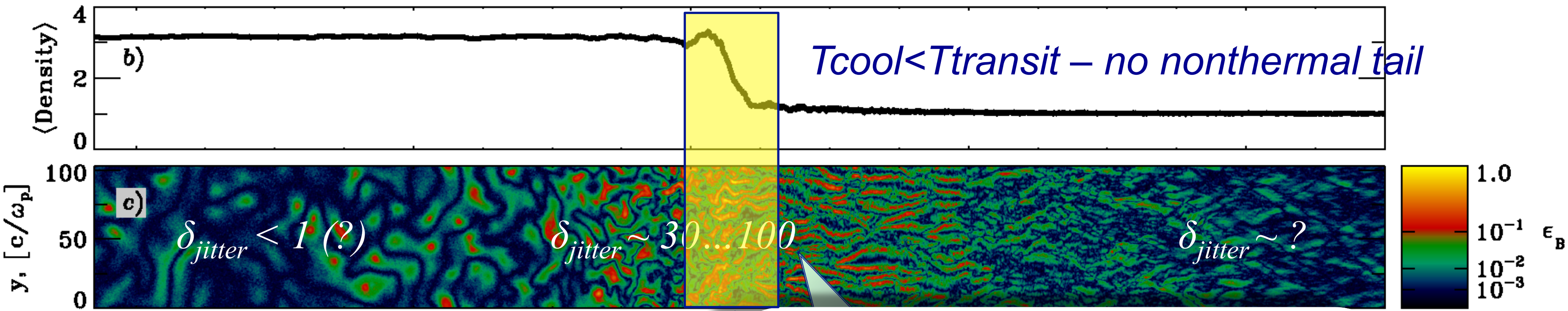


(Kaneko, et al. ApJS 2006; PhD thesis)

Baryonic shock model



Weibel in shocks

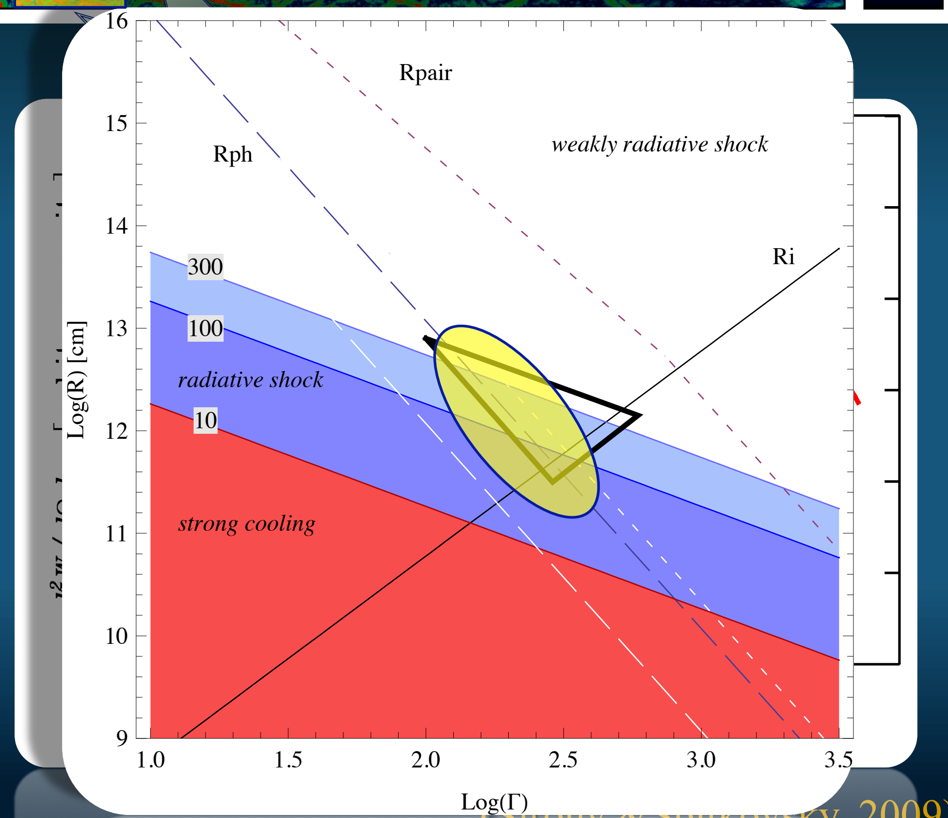


$\delta_{jitter} \sim eB\lambda/mc^2 \sim 6\ B_{Gauss}\ \lambda_{meter}$

→downstream:
'aged', isotropic turbulence

→diagnostics: δ_{jitt} → λ → n

(Medvedev & Spitkovsky, 2009)



(Sironi & Spitkovsky, 2009)

A grand challenge

Shock PIC simulations → shocks are the synch-like *“standard-spectral-shape” sources* (unless IC or optical depth included talks by Diagne, Pe’er,…)

Real GRB spectra → variable & often inconsistent with synchrotron

- PIC simulations are not yet adequate:
  - too short, too small box (foreshock emission, CR feedback)
  - ambient field (whistlers)
- GRBs are *not* due to shocks:
  - Collisional dissipation, optical depth effects (e.g., *Beloborodov talk*)
  - Poynting-flux-driven (magnetically-dominated) outflow

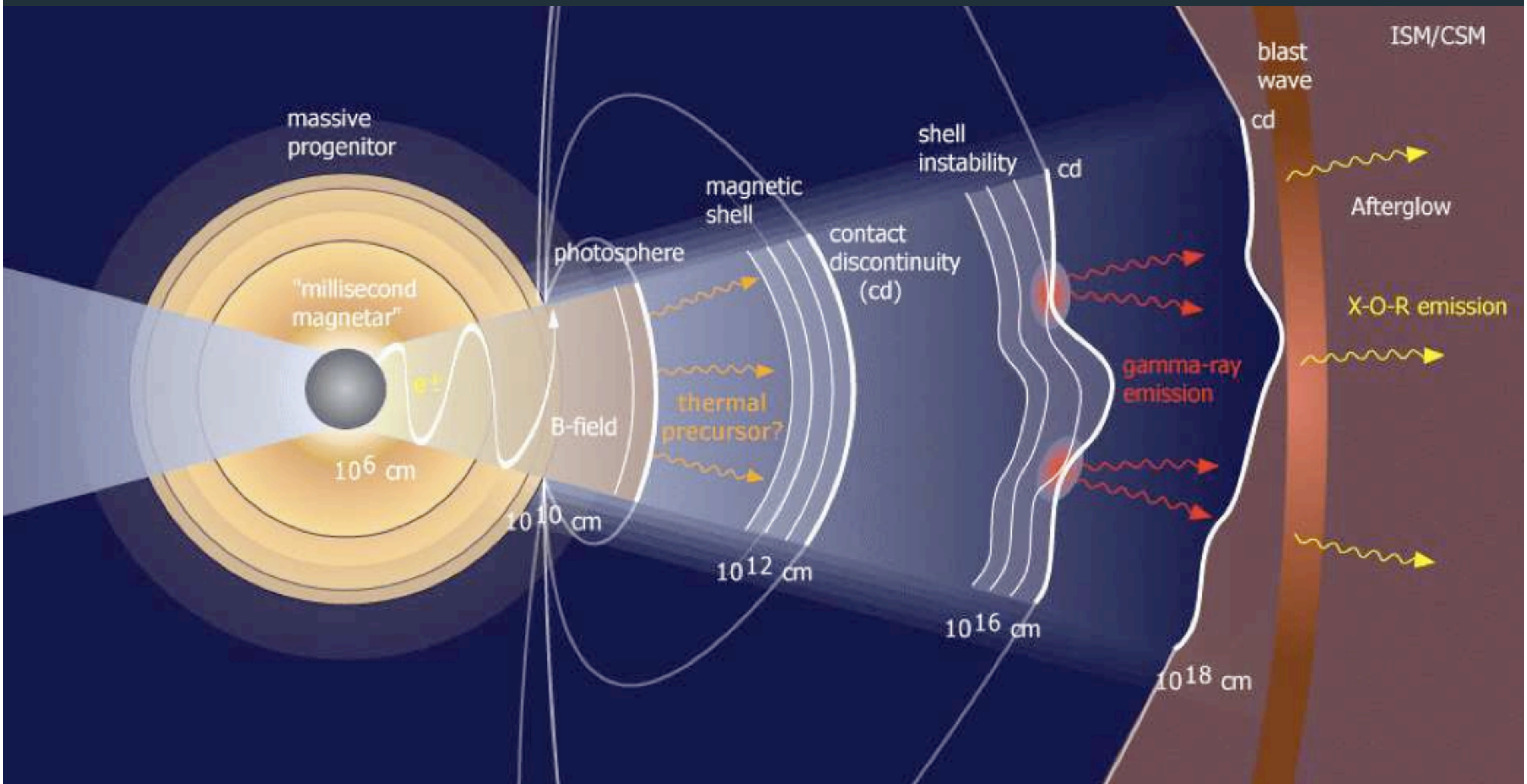
    ➔ *Reconnection*

Baryonic ejecta

- Dissipates energy and radiates via shocks
- Shocks are steady-state structures:
  - little or no emission variability
  - little or no radiation anisotropy
- Emit synch-like (and possibly flat) spectra:
  - no “synch-violating” spectra
  - need additional physics (self-absorption,???)

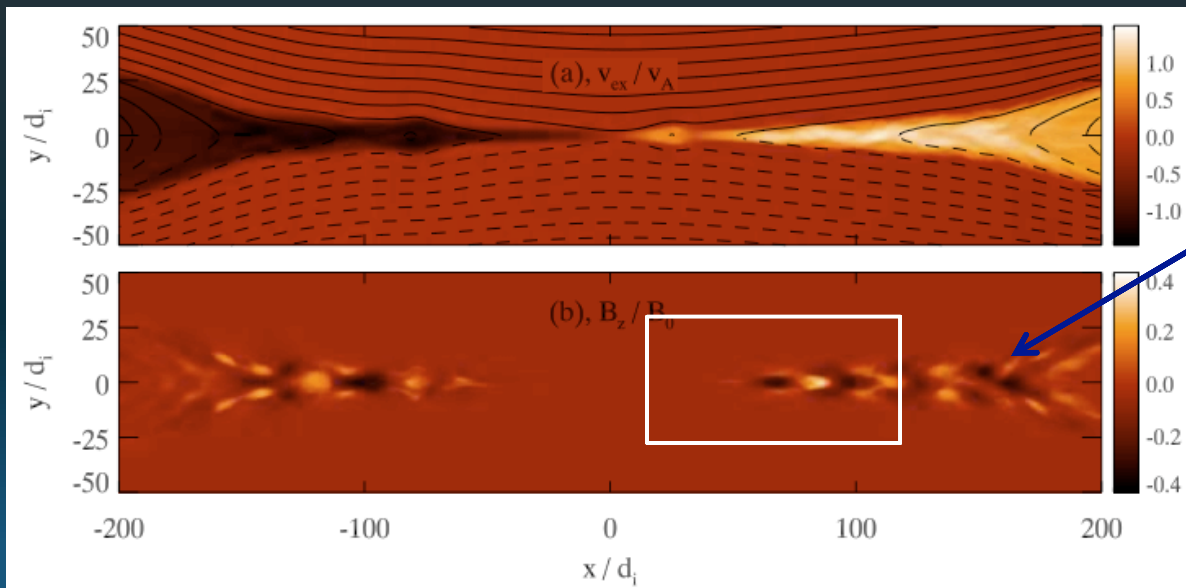
-- alternatives needed --

Magnetically-dominated ejecta



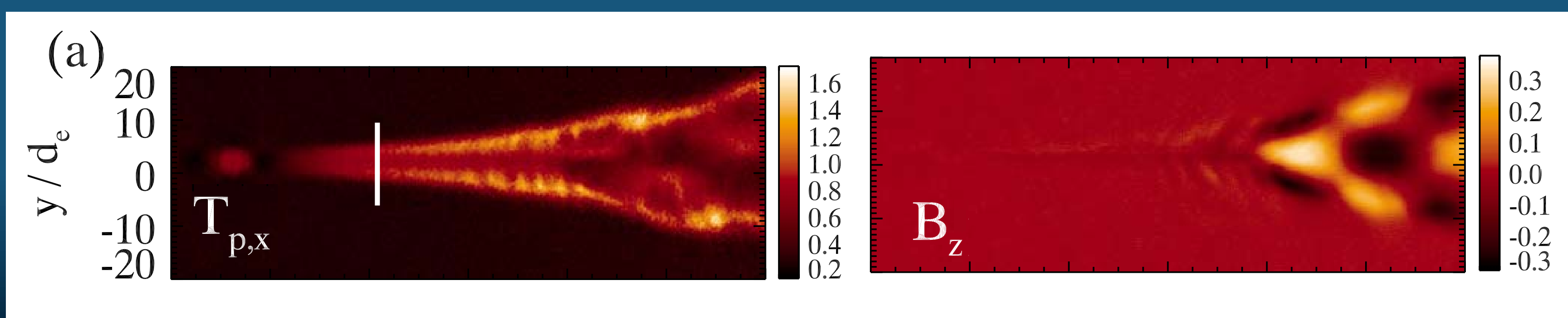
(Lyutikov & Blandford 2003)

Reconnection (e^+e^-)

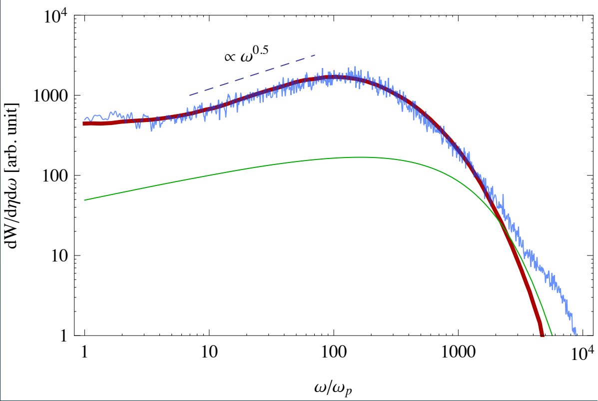


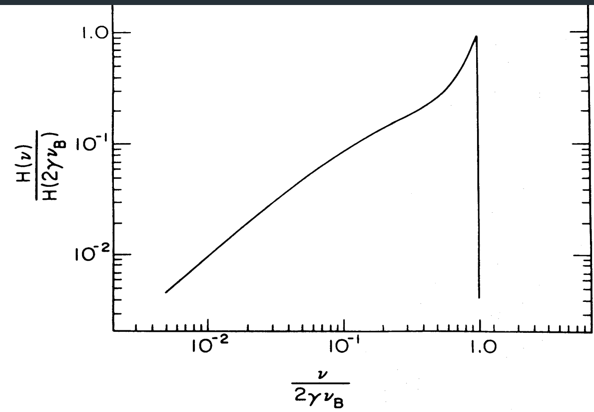
Weibel fields

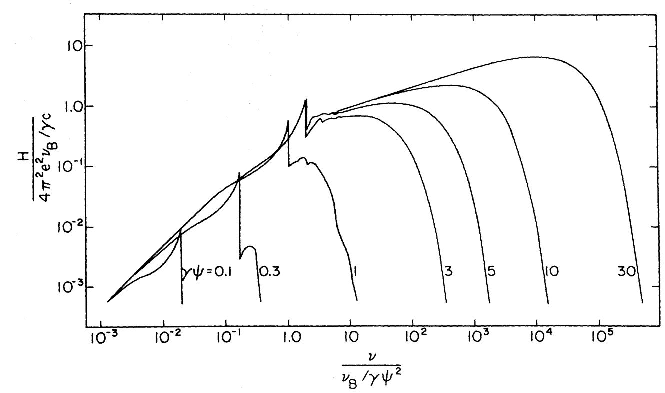
Relativistic & non-relativistic reconnection in e^+e^- pair plasma (Swisdak, Liu, J. Drake, ApJ, 2008, 2009; Zenitani & Hesse, PoP, 2008)

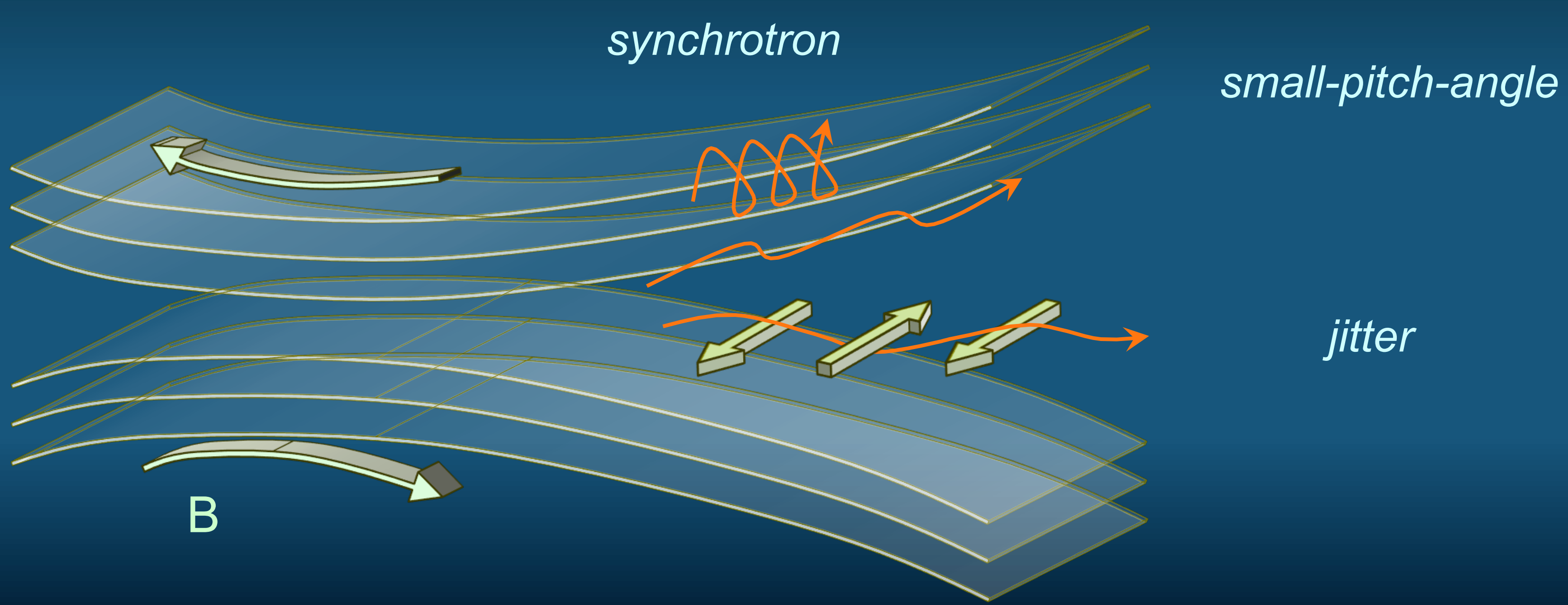


Radiation from reconnection



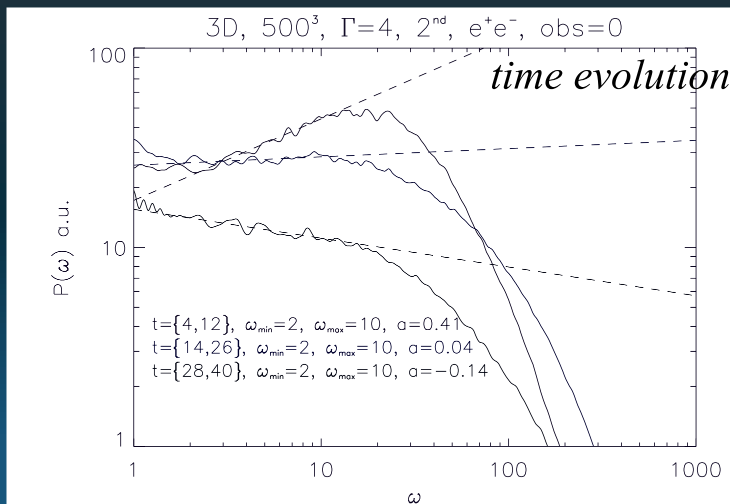


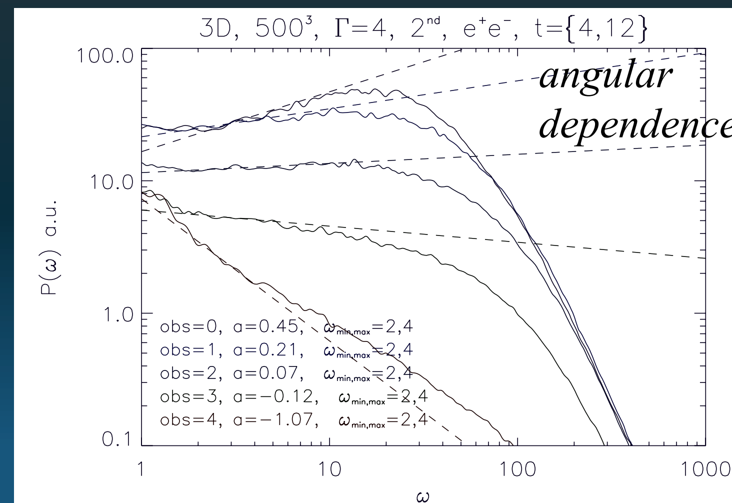


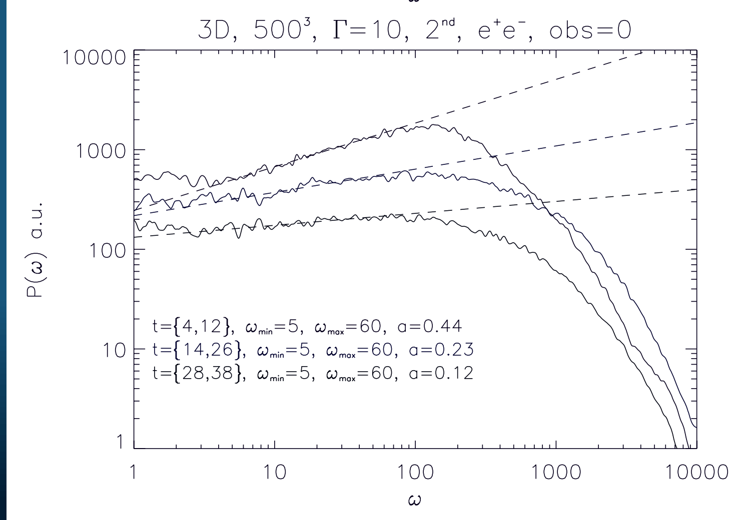


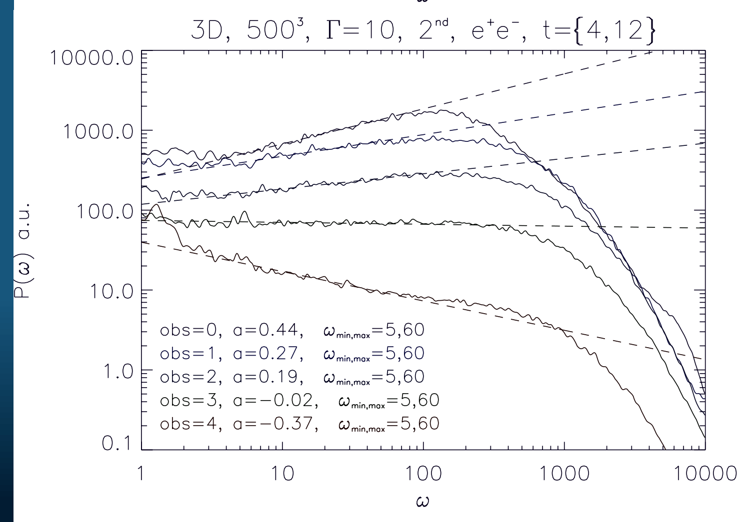
Radiation during Weibel instability

PIC 3D e^+e^- simulations (Frederiksen, Haugboelle, Nordlund, Medvedev, ApJL, 2010)
Radiation is obtained self-consistently in situ, “on the flight” from the same particles









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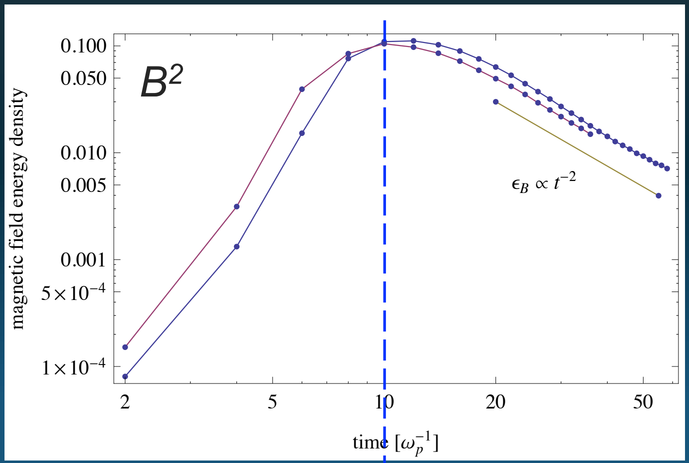
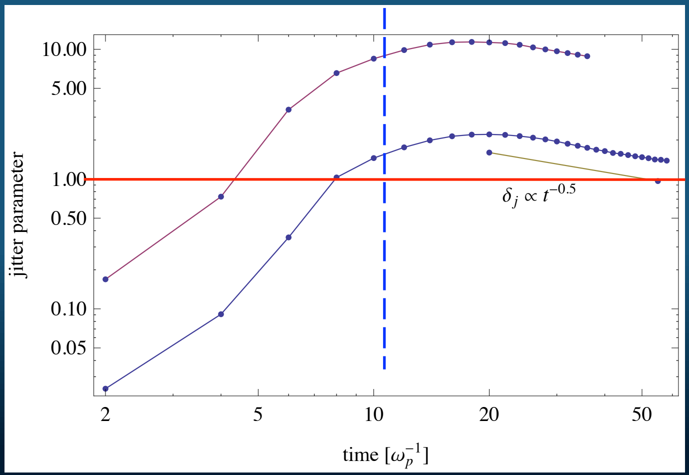
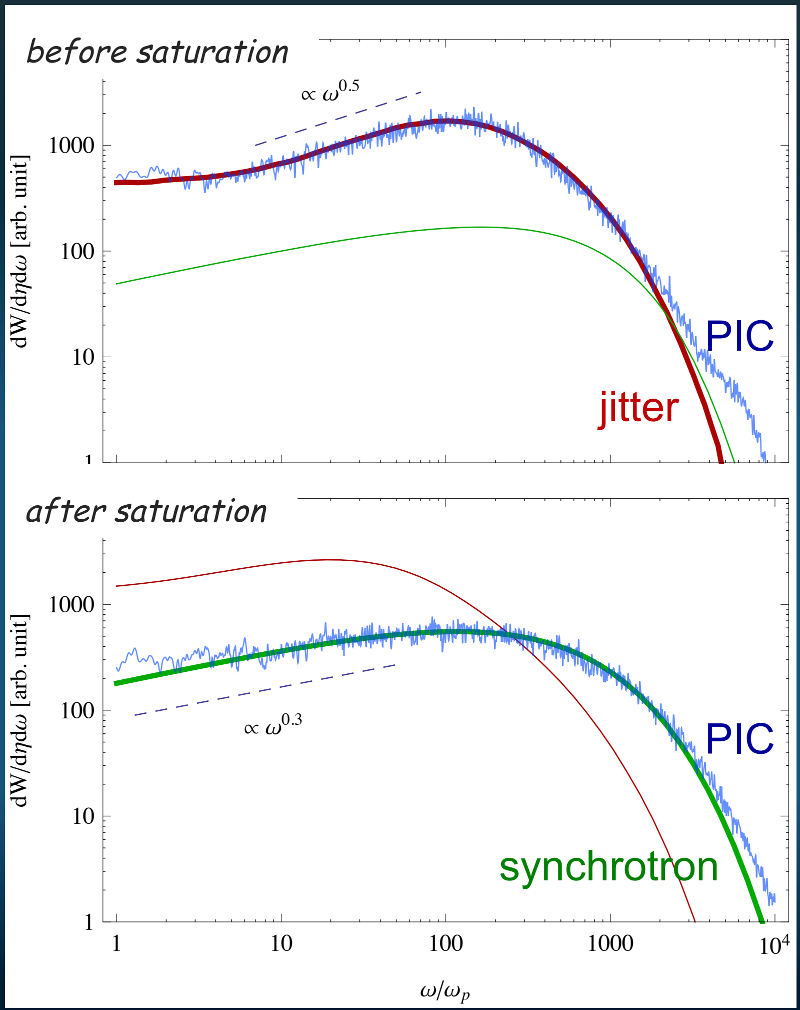
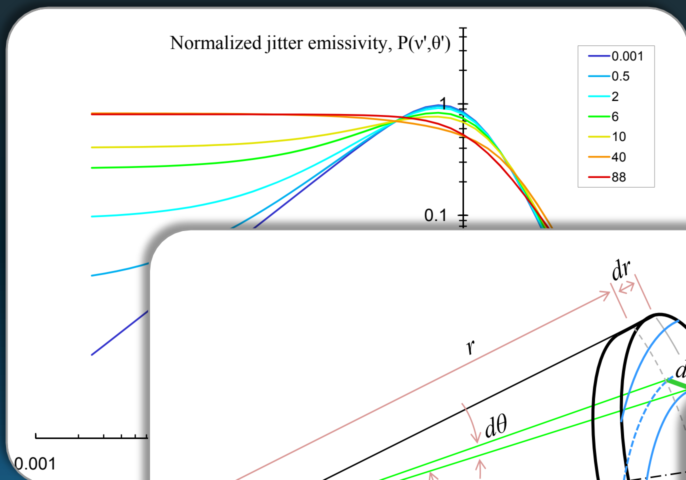






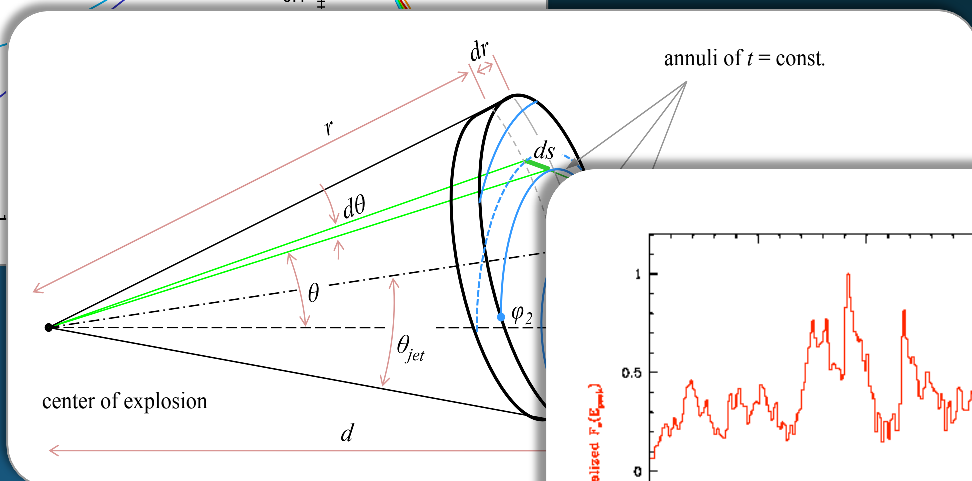
Modeling

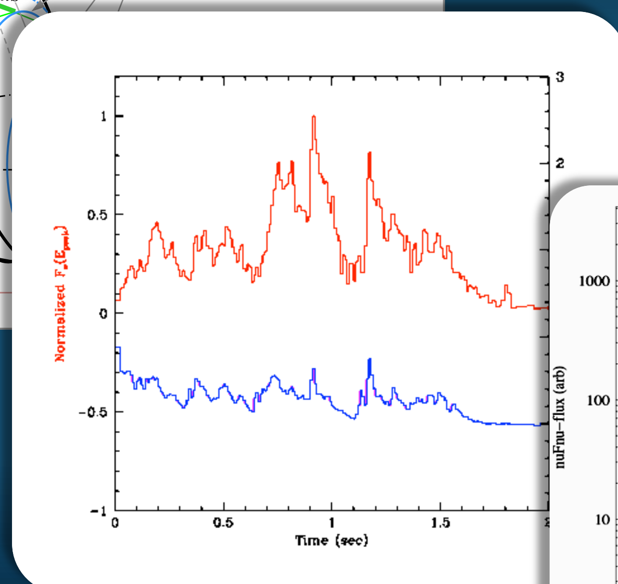
***Intrinsic anisotropy** of co-moving spectra*

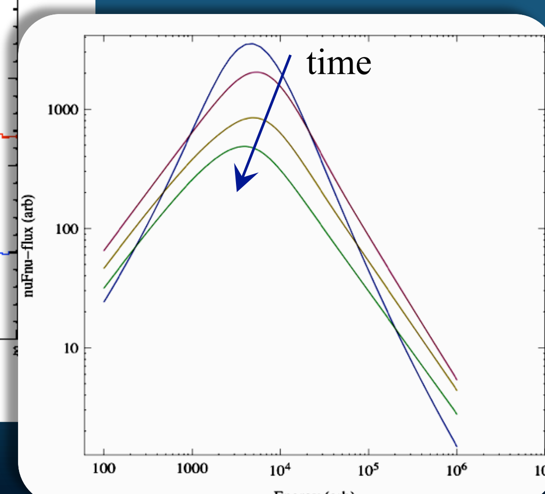


Relativistic kinematics:

time-dependent aberration
& Doppler boost







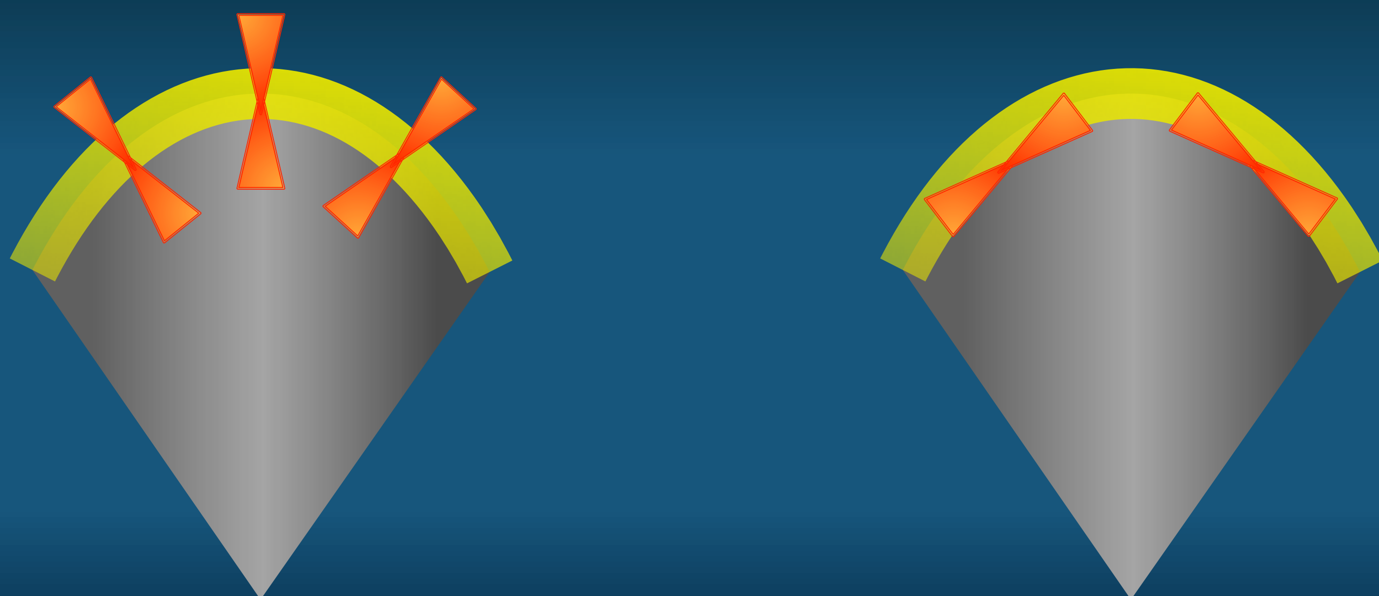
Resulting light-curves:

bolometric flux
& hardness evolution

(Medvedev, et al, ApJ 2009)

Clue on B-field orientation in GRB jet

Assume magnetic field dominated jet; radiation is produced in reconnection.
Consider radial field (due to Contact Discont. instability) and
poloidal field (large-scale jet field)



Clue on B-field orientation in GRB jet

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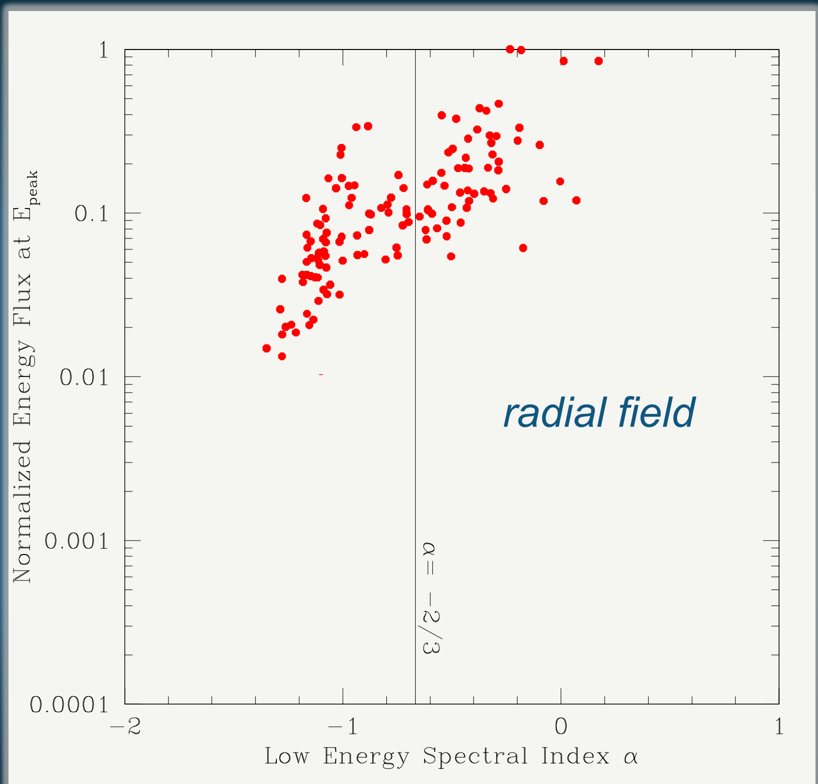
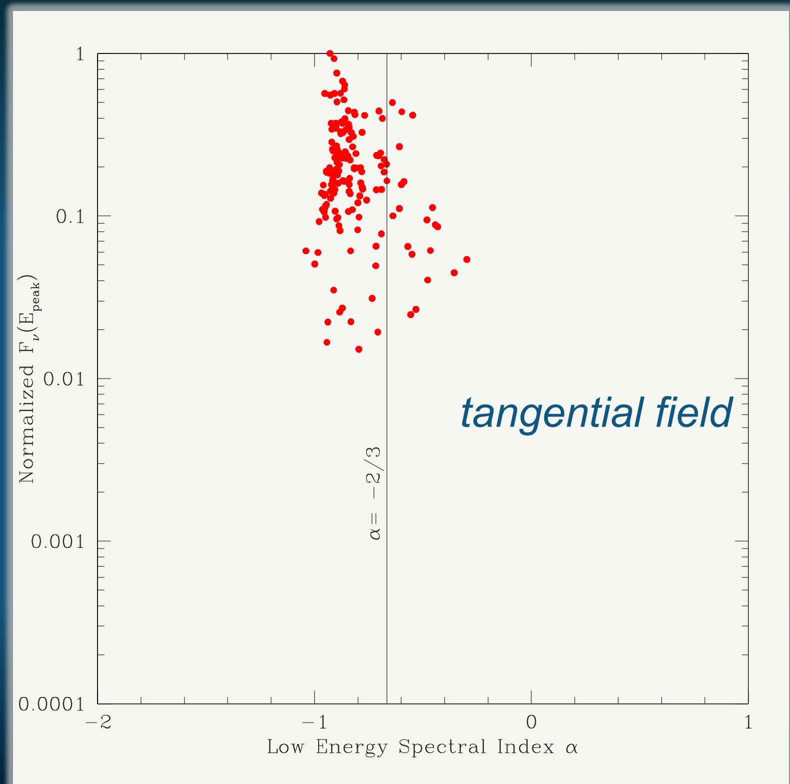
tangential field configuration model is at odds with most observations





Conclusions

Paradigm shift:

- Emissivity is intrinsically anisotropic (angle-dependent)
- Emissivity can also be time-dependent
- Geometry is a major factor:
  - global jet geometry → spectral variability
  - jet-in-a-jet orientation → diversity of GRBs

Spectrally variable GRBs

→ not consistent with optically thin shock model (baryonic and/or leptonic)

→ indicative of magnetic reconnection (Poynting flux dominated jets)

α *>-2/3 non-*synchrotron spectra are *jitter* and/or *small-pitch-angle*.

→ models with variable optical thickness (& thermal+PL) need more studies

Low or no spectral evolution GRBs

→ can be from shocks

→ flat, $\alpha \sim -1$, *jitter spectra* – leptonic jets preferred

→ synchrotron-like – baryonic ejecta preferred