Fermi Probes of Shock Environs in Gamma-Ray Bursts and Blazars

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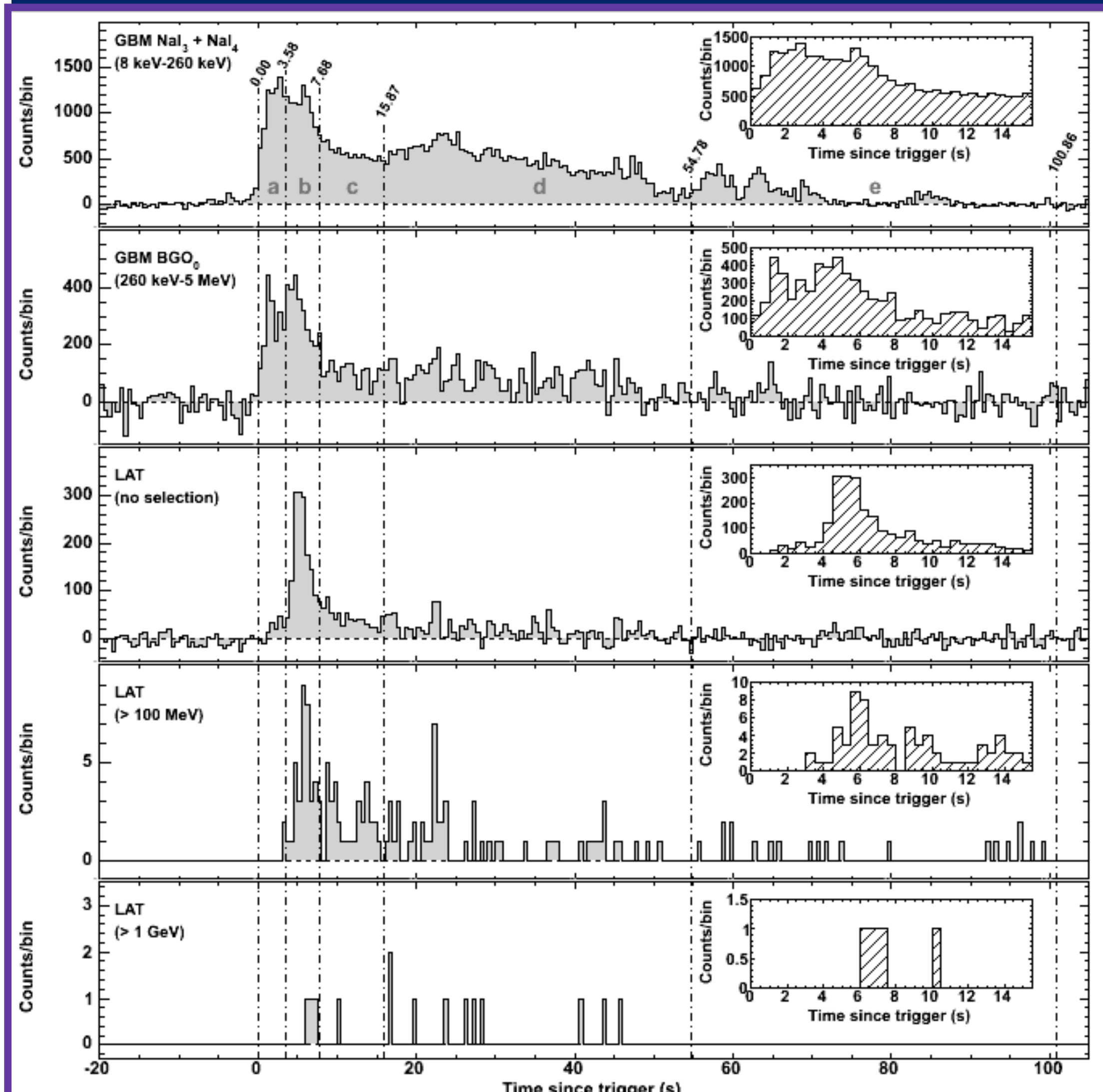
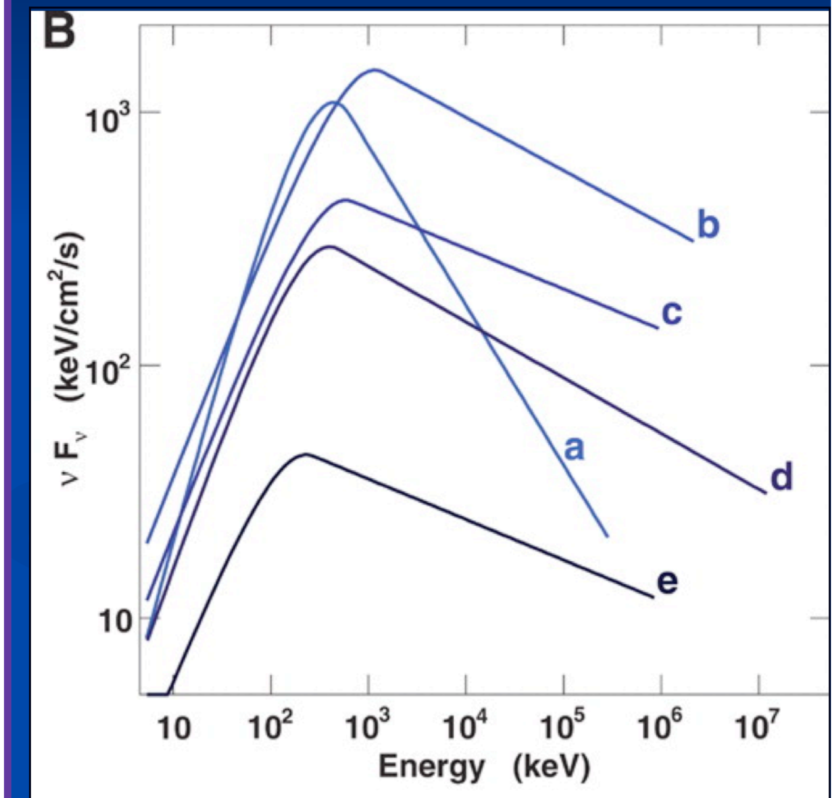
Fermi GRB 080916c
Temporal and Spectral Evolution



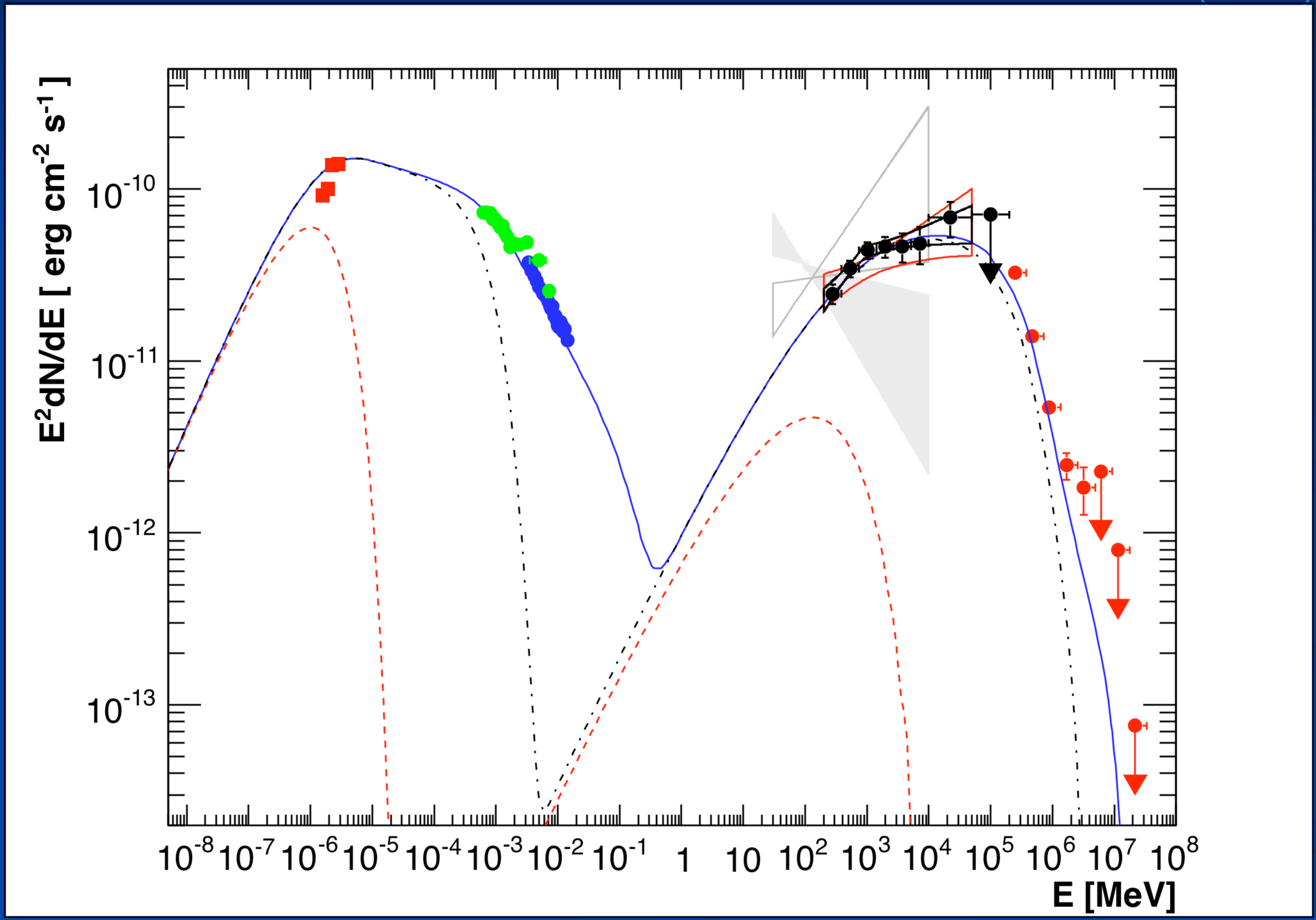


- Science (2009): Abdo et al.

Multi-wavelength Low-state SED: *Fermi*-LAT Blazar PKS 2155-304

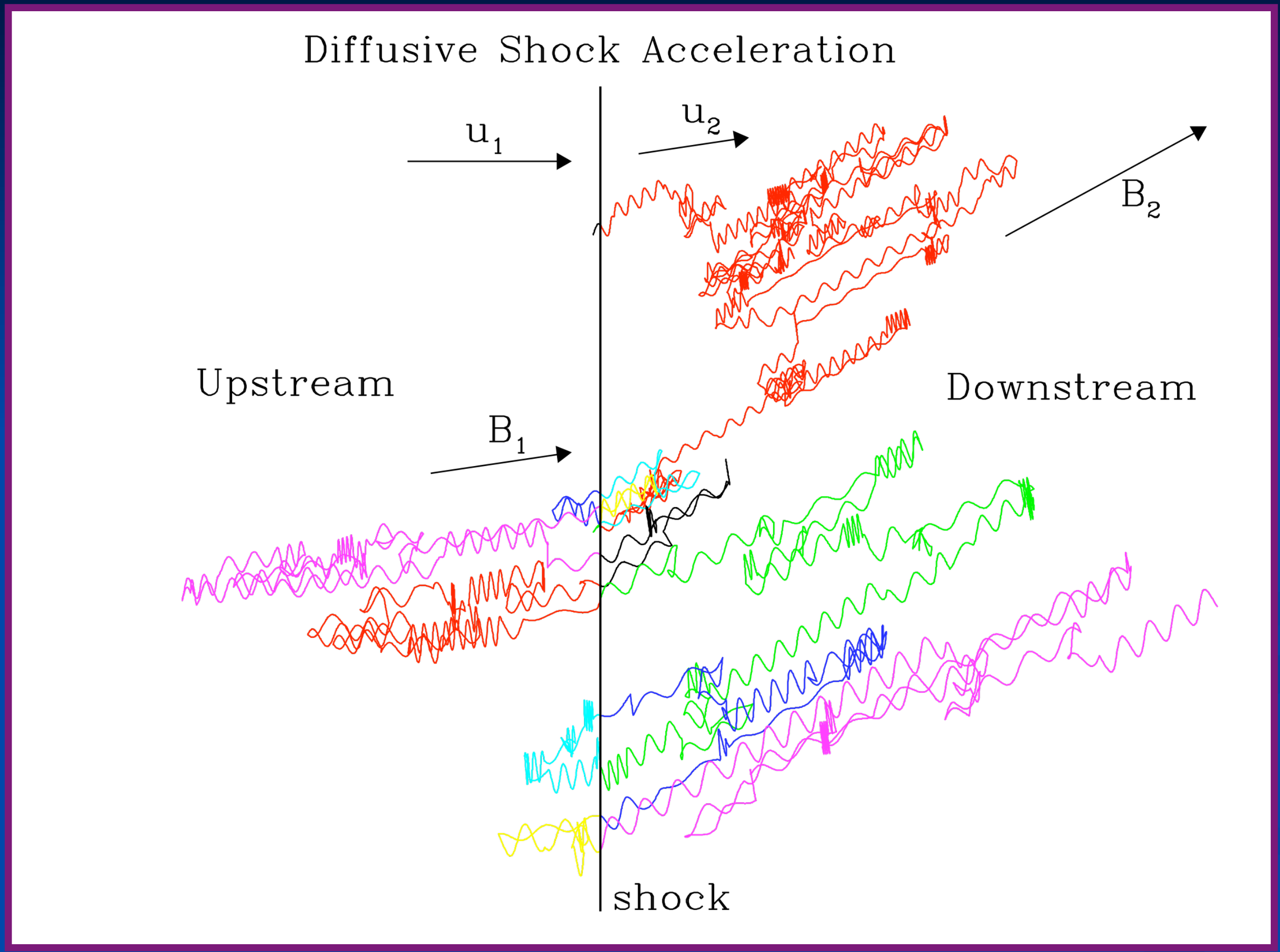
z=0.116

Abdo et al. (2009)



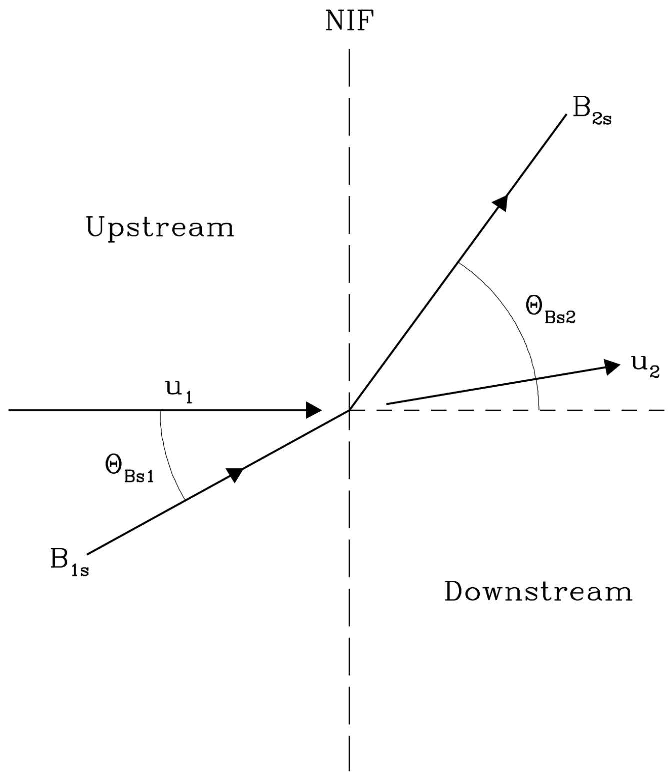
HBLs vs. FSRQs; breaks in LAT-band complicate things – e.g. 3C 454.3

Monte Carlo Simulation Particle Trajectories

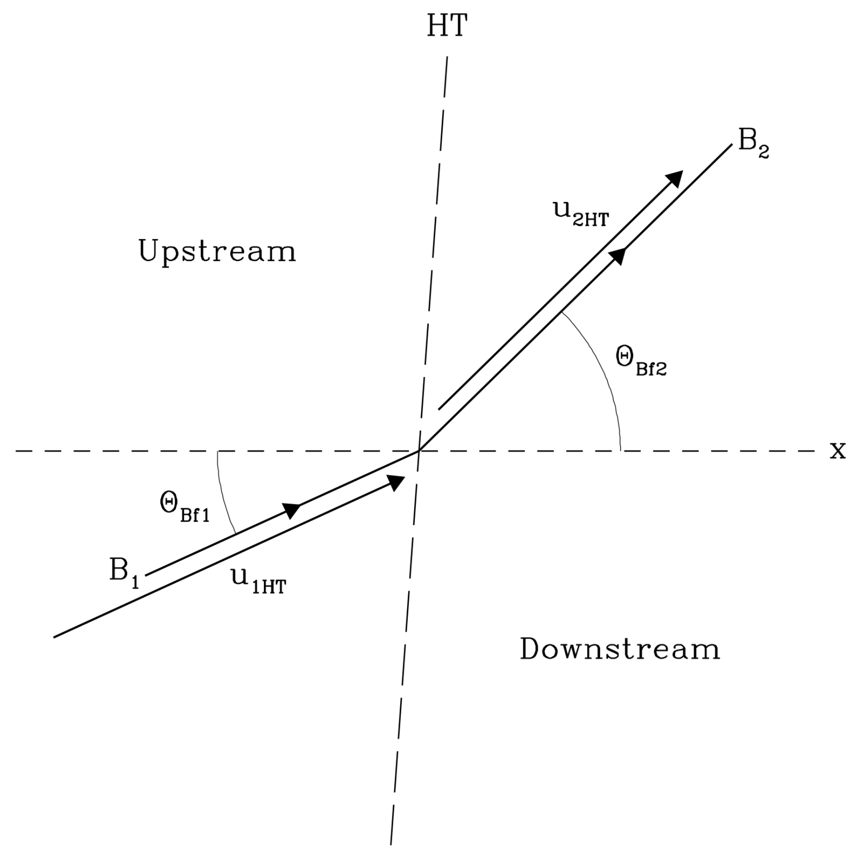


- Gyration in B-fields and diffusive transport modeled by a Monte Carlo technique; color-coded in Figure according to fluid frame energy.
- Shock crossings produce net energy gains (evident in the increase of gyroradii) according to principle of first-order Fermi mechanism.

Oblique Shock Geometry



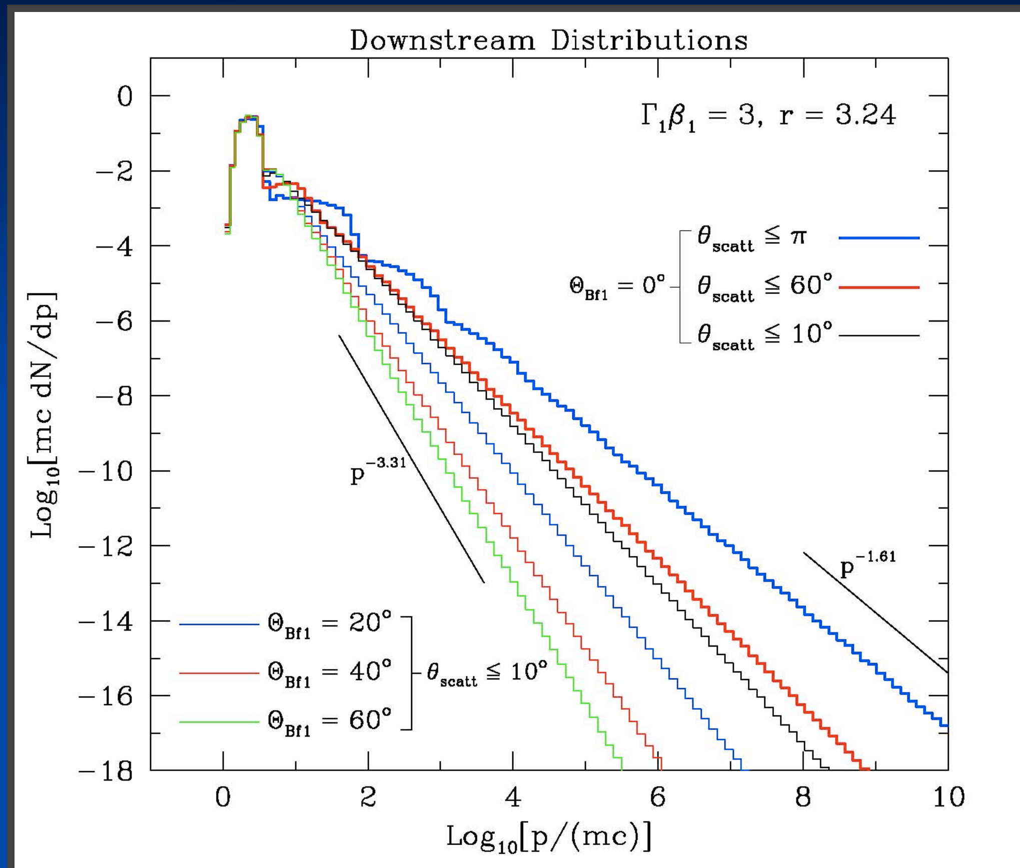
Normal Incidence Frame (NIF)



de Hoffmann-Teller frame (HT)

Spectral Dependence on Field Obliquity

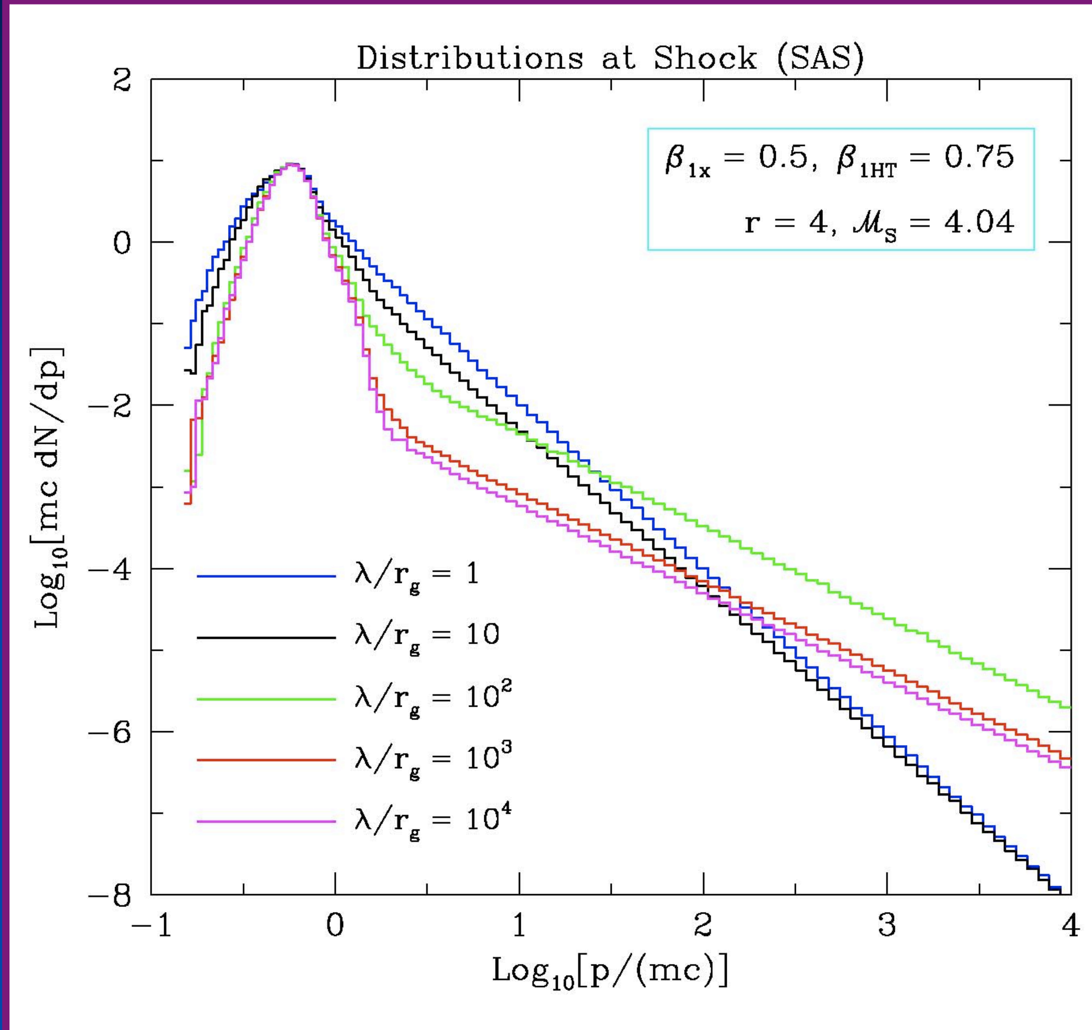
Superluminal cases ->



- Increasing upstream B-field obliquity and/or ratio of mean free path to gyroradius steepens the continuum (e.g. Bednarz & Ostrowski 1998; Ellison & Double 2004; Summerlin & Baring 2010 [in prep]; Kirk & Heavens 1989).

Shock Acceleration Injection Efficiencies

- Complete particle spectra in the limit of small angle scattering (SAS: pitch angle diffusion: PAD) range considerably;
- In cases of strong cross field diffusion, the index is around two and the injection is efficient;
- Gyro-orbit simulations for $\lambda/r_g \rightarrow \infty$ that give flat power-law indices are poor injectors – this becomes far more extreme as HT frame speed approaches c.

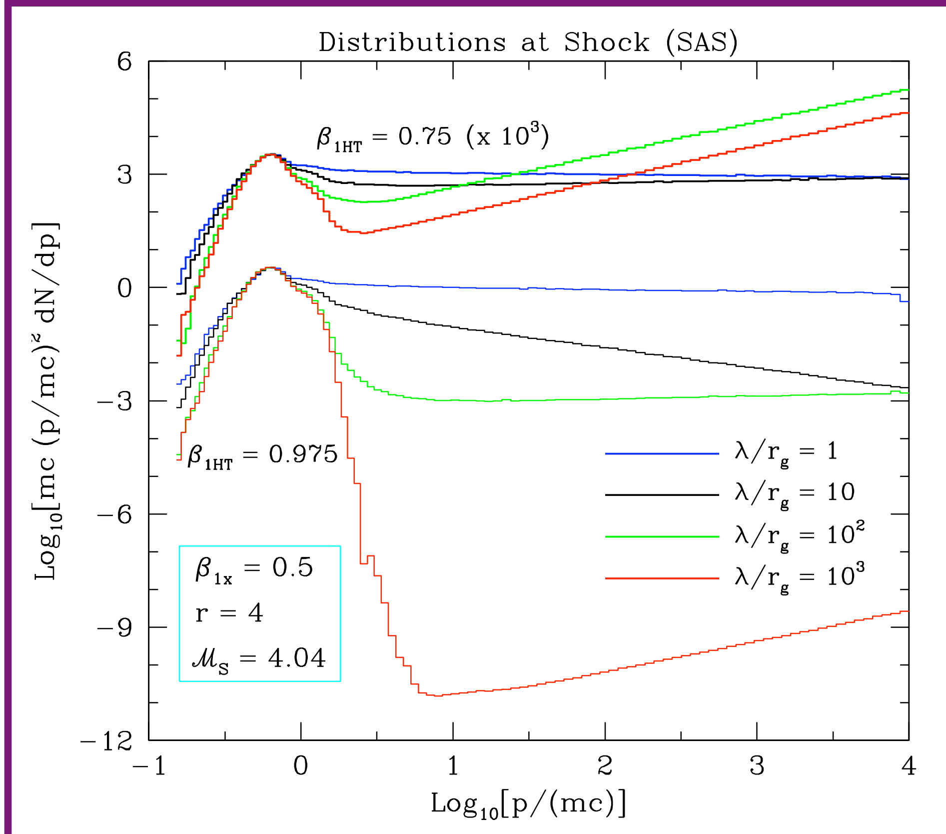


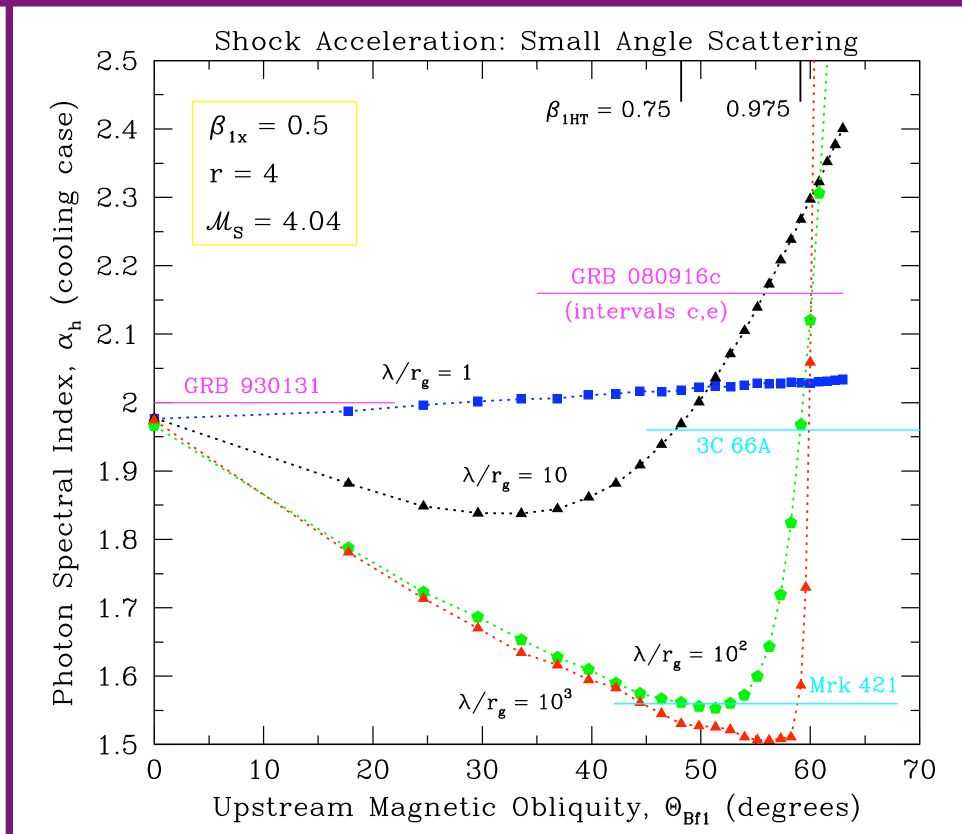
Baring & Summerlin 2010, in prep.

Connecting to Source Gamma-ray Observations

- Model coupling between particle acceleration index σ for $dn/dp \propto p^{-\sigma}$ and observed photon index β ($dn_\gamma/d\varepsilon_\gamma \propto \varepsilon_\gamma^{-\beta}$) depends on whether in situ cooling is efficient or not.
- Three main possibilities for GRBs and blazars:
  - Uncooled synchrotron or IC/SSC: $\beta=(\sigma+1)/2 \Rightarrow \sigma=2\beta-1$
  - Strongly-cooled synchrotron or IC/SSC: $\beta=(\sigma+2)/2 \Rightarrow \sigma=2\beta-2$
  - Uncooled hadronic emission: $\beta\sim\sigma$
- => Great diagnostics potential in *Fermi* era!
- E.g. for GRBs when $2<\beta<2.2$, then $2<\sigma<2.4$ in strongly-cooling scenarios => *subluminal/mildly-superluminal* shocks, perhaps with strong turbulence.
- Several LAT blazars may require *subluminal* shocks.

Shock Acceleration Spectra and Indices





- **Cooled** GRB and blazar scenarios require either strong turbulence, or **subluminal shocks**;
- For **uncooled** GRB/blazar synchrotron/IC/SSC emission picture, **superluminal shock regime is preferred**.

Conclusions

- **Shock acceleration particle indices depend on several parameters: field obliquity, the scattering strength or level of MHD turbulence, amount of diffusion across B;**
  - **=> there is no canonical spectral index.**
- **So, GRB and blazar spectra are intimately connected to detailed shock parameters =>*Fermi* role for gamma-ray spectral diagnostics for leptonic and hadronic models.**
- **Index parameter space dichotomizes into sub-luminal (flat) and super-luminal (steep) regimes.**
- **Cooling models: GRB β indices suggest acceleration in subluminal or mildly-superluminal shocks; several LAT-TeV blazars indicate subluminal acceleration regimes.**
- **Non-cooled models: both GRB and blazar spectra suggest acceleration in superluminal environments.**