Comparison of the Acceleration Mechanisms in Fermi Bubbles

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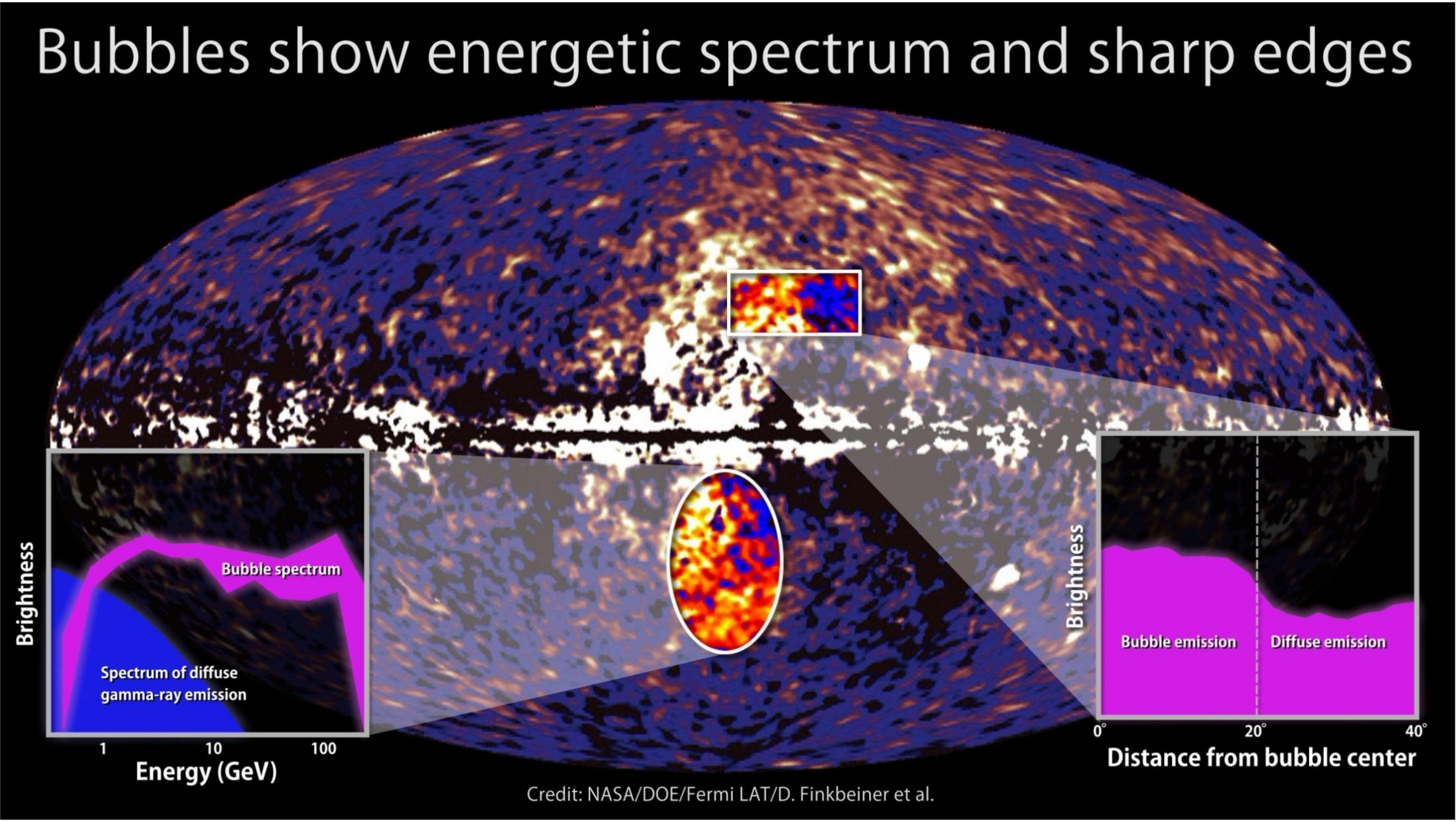
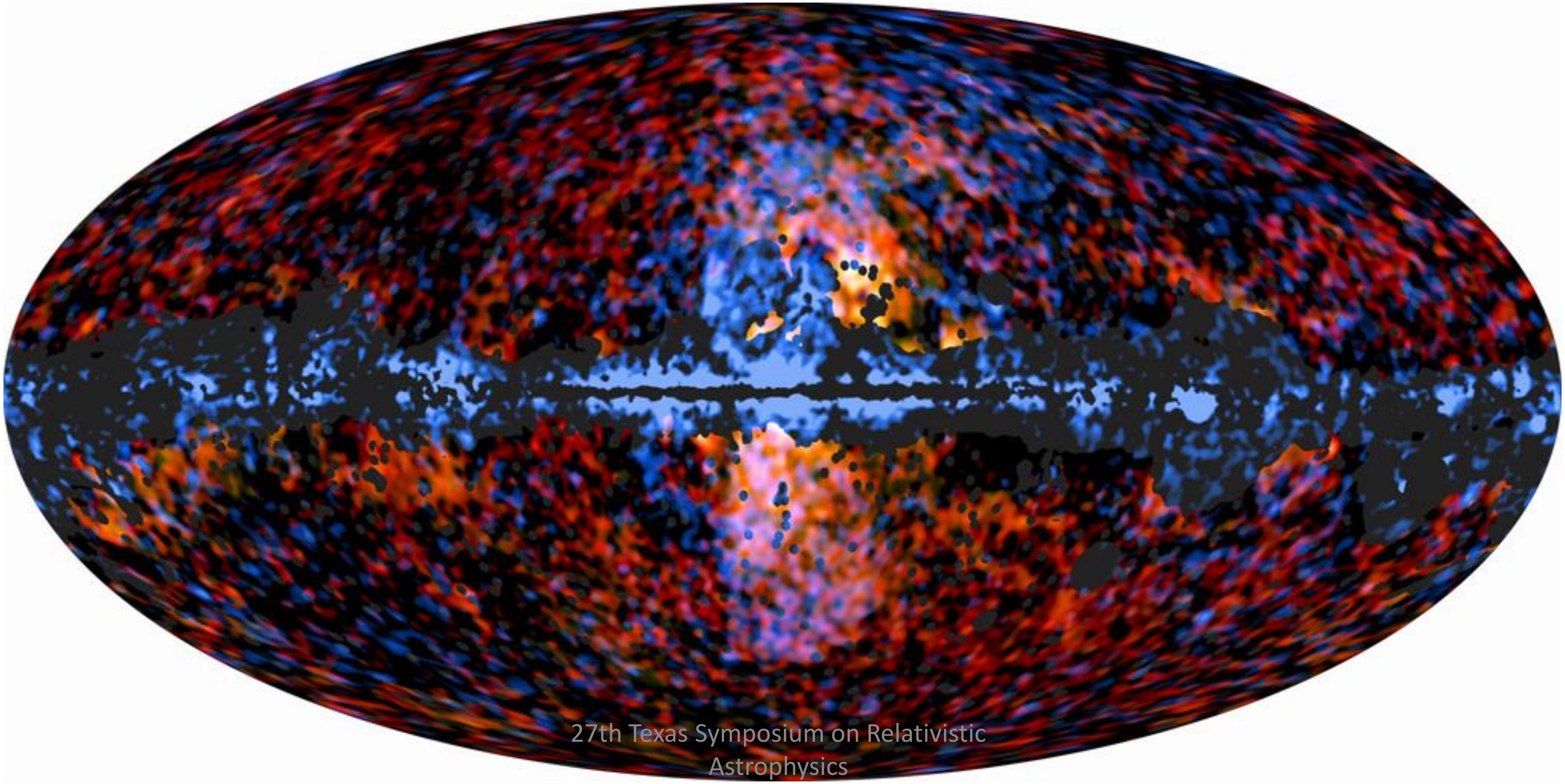
Fermi Bubbles



Dobler et al., 2010, Su et al., 2010

Counterparts: radio

- Finkbeiner 2004. “WMAP Haze”
- Planck Collab., 2012



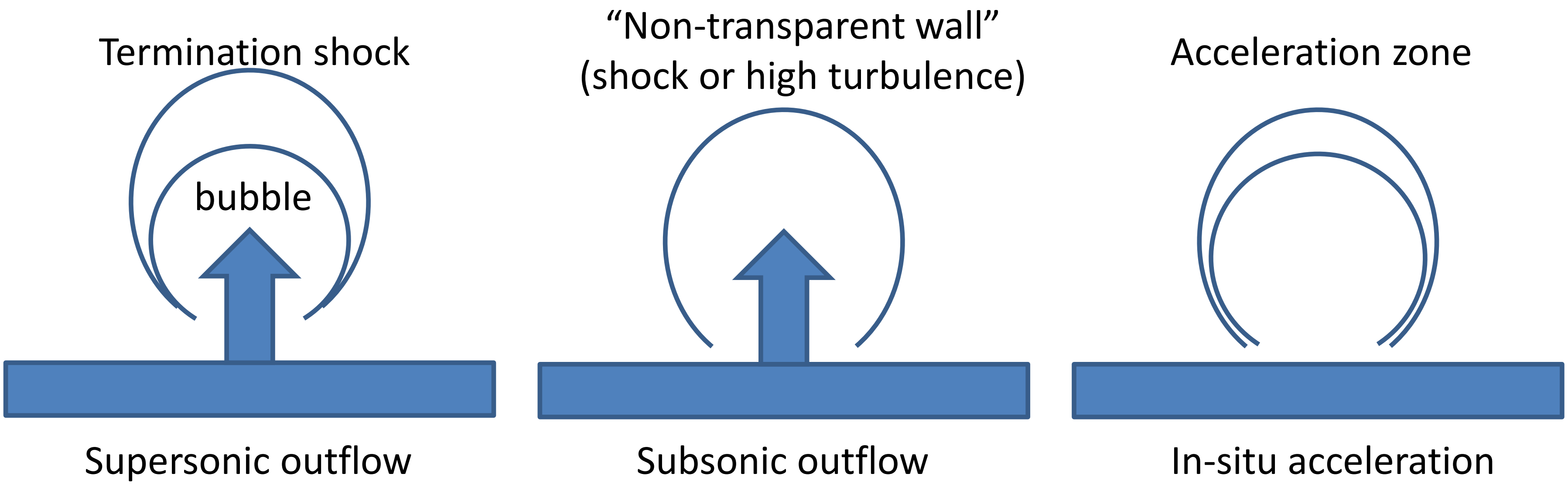
Fermi bubbles: properties

- Hard synchrotron: spectral index -2.1
- Sharp edges: shock? Low diffusion? Magnetic wall?
- Uniform brightness: concentration near the edge?
- Position: central BH-related? Starburst related?
- Probably not unique: apart from Cen A, X-Ray and radio “bubbles” in Markarian 6, Circinus
- Good corellation “radio – gamma-rays” (Dobbler, 2012) + spectral softening to high lat (Dobbler, 2012; or not? Hooper & Slatyer, 2013) – leptons?

Possible models

Hadronic	Leptonic
$p + p \rightarrow 2\gamma + e^{\pm}$	IC + synchrotron
a) Crocker & Aharonian, 2010 **Crocker, 2012** SN activity + magnetic walls **b) Istomin, 2011** Jet, “ballistic” **c) Fujita et al, 2013** Shock	**a)Su et al., 2010** Starburst or jet => giant shock **b)Guo & Mathews,2011; Yang et al., 2012** Jet + anisotropic diffusion, “ballistic” **c)Mertsch & Sarkar, 2011** Fermi-II acceleration **d)Cheng et al., 2011** Stellar captures => series of shocks
Shape – why uniform? **X-Ray emission?** **Synchrotron – secondaries if young?** **H > 50uG**	**Should be young or accelerated** **Synchrotron – young, stochastic or series**

Common points



In all cases we expect appearance of an acceleration zone: shockwave should be young (< 1 Myr), turbulence leads to stochastics

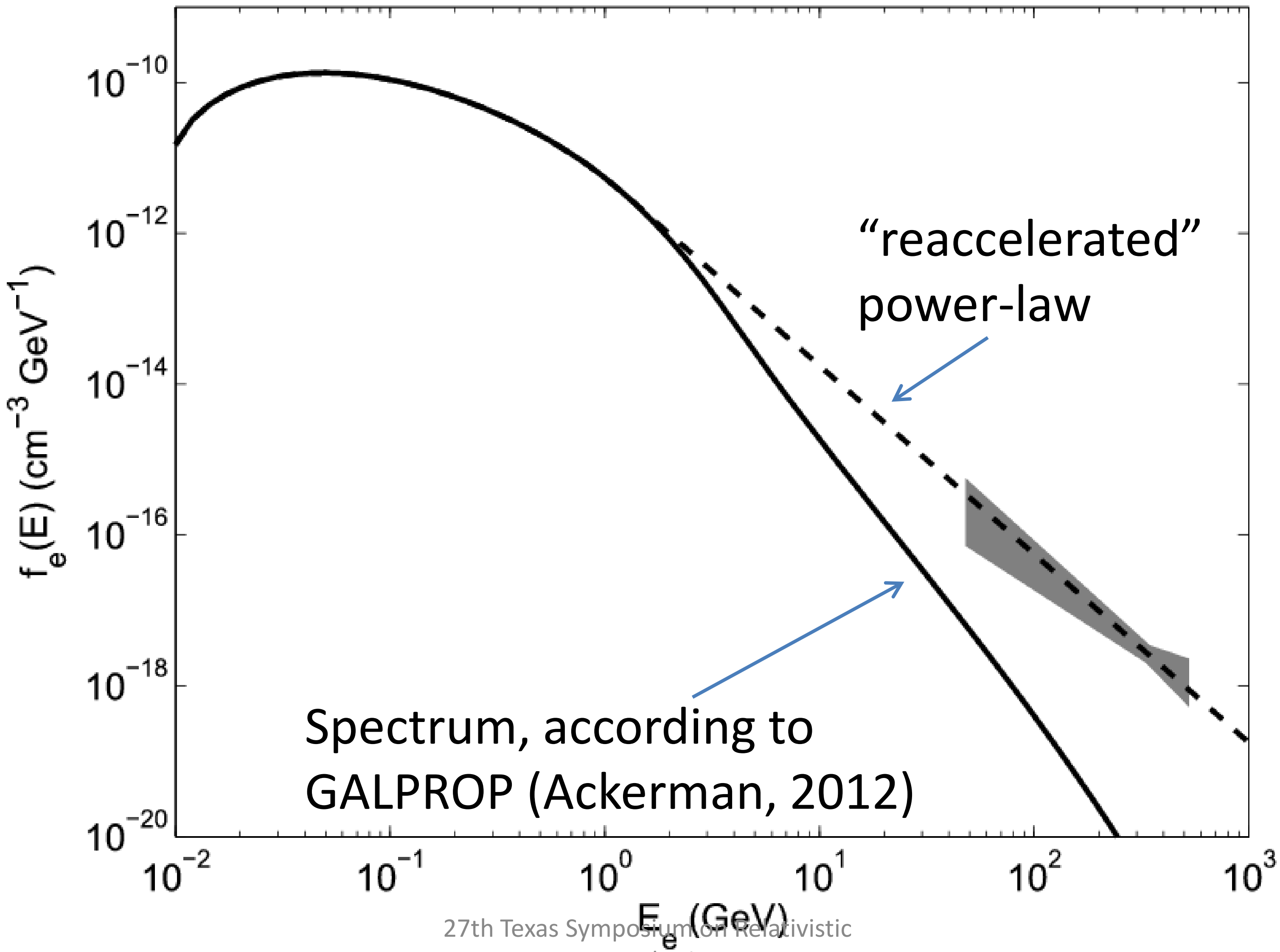
The site is giant: may affect the whole Galaxy!

(See eg. Cheng et al, 2012 – CRs above the knee)

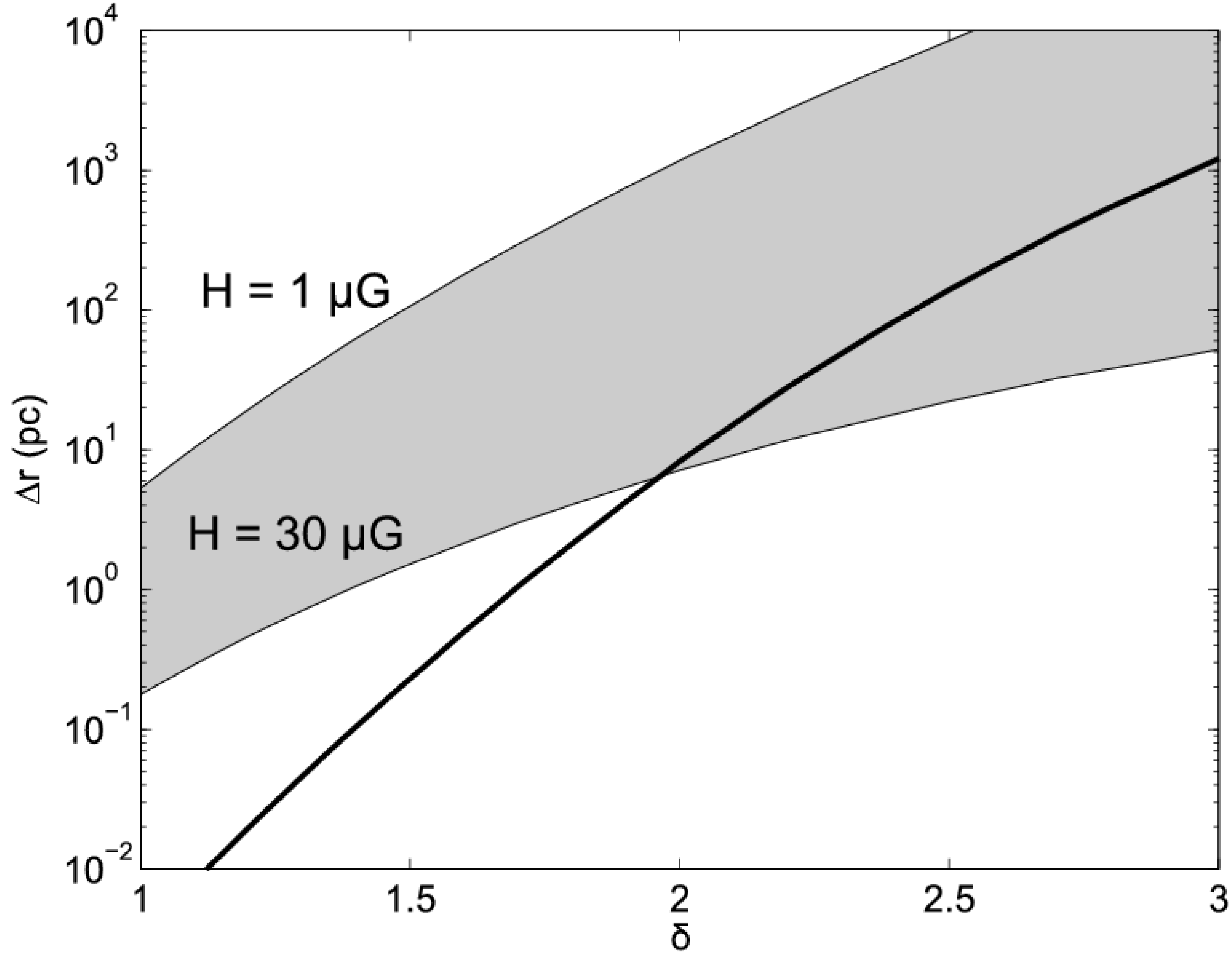
Acceleration

- From background plasma
  - Need to worry about injection
  - Can provide a lot of particles
- From pre-accelerated electrons
  - Electrons are already ‘injected’
  - More solid
  - Need to know spectrum of non-thermal electrons (GALPROP – fitted to radio and gamma-ray bkg.) OR just linear extrapolation of local spectrum

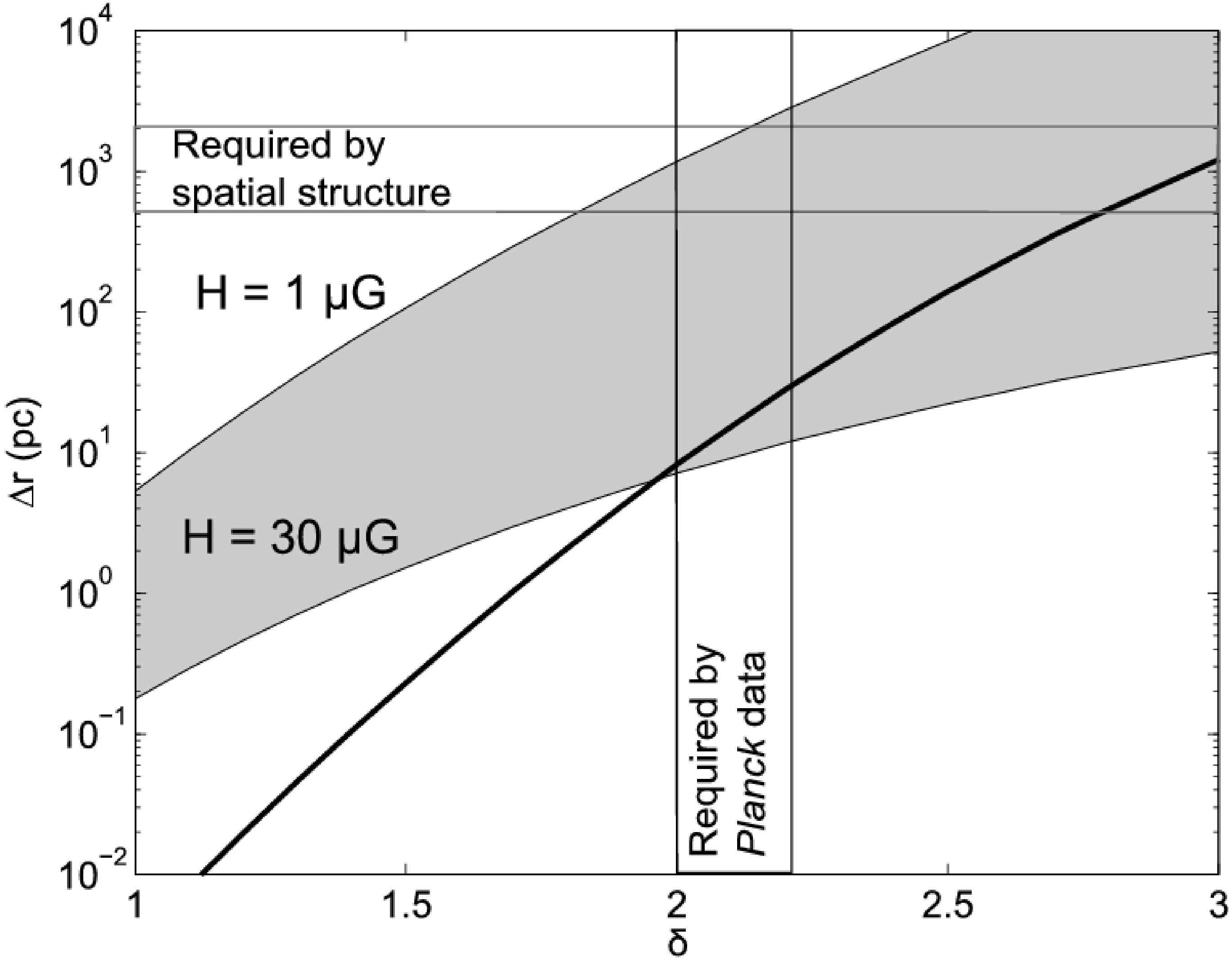
Limitations on acceleration



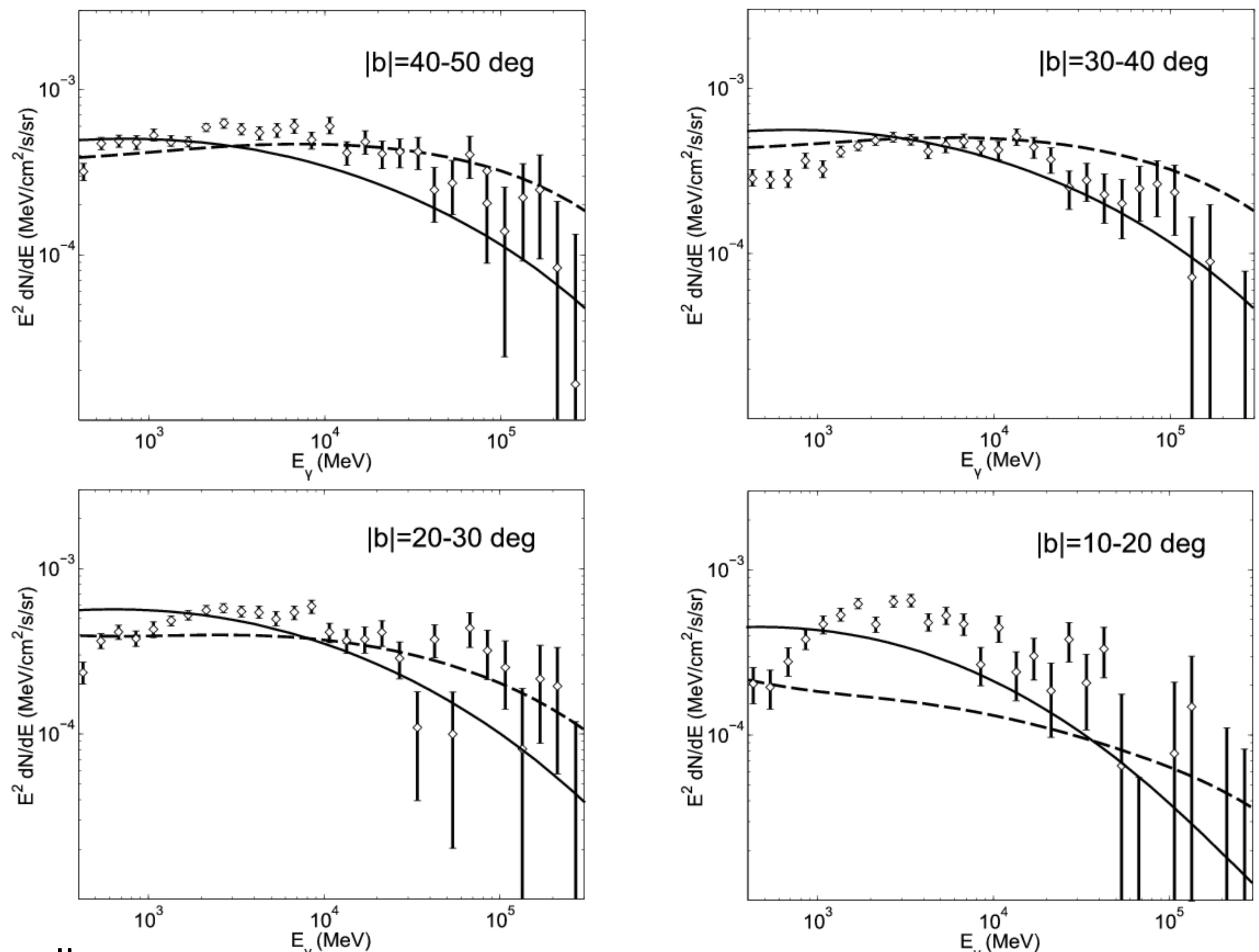
Limitations on acceleration



Limitations on acceleration



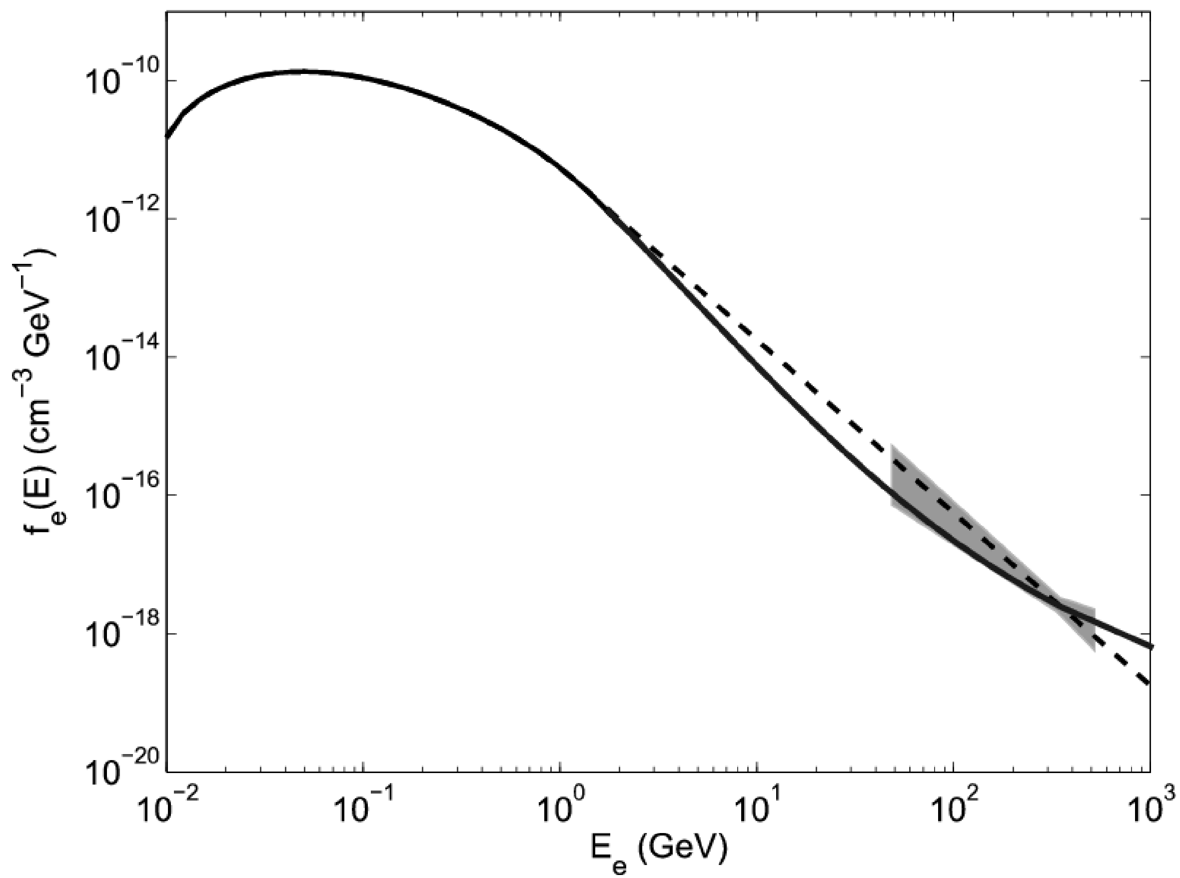
Numerical model. Stochastic acceleration



Solid – thick walls
Dashed – thin walls

Data by Hooper & Slatyer, 2013

“Concave spectrum”



- Expected in CR-modified single or multiple shocks
- Can produce spectra harder than ‘-2’

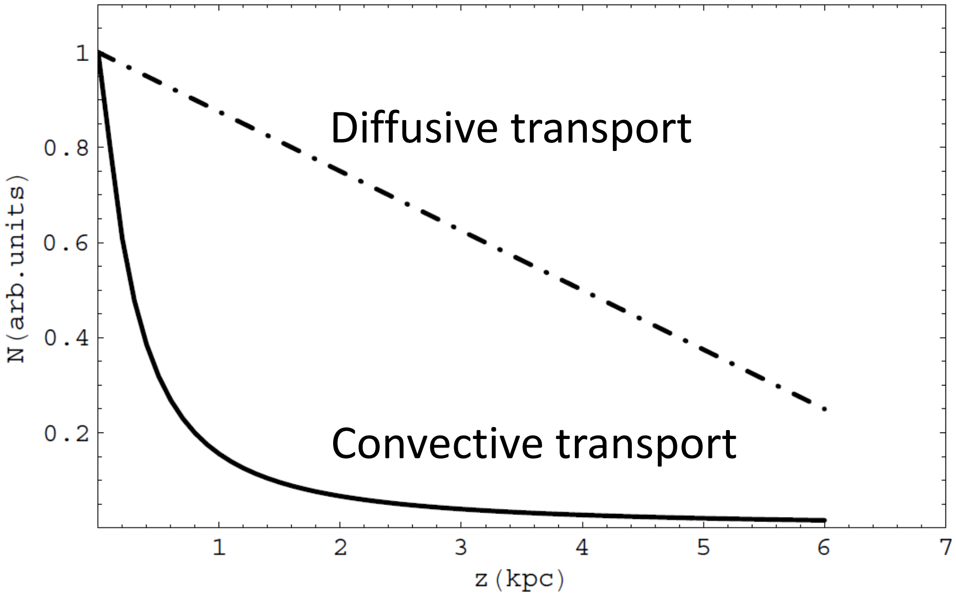
Adiabatic losses

$$-\nabla\left[D(r,z,p)\nabla f - u(r,z)f\right] + \frac{1}{p^2}\frac{\partial}{\partial p}p^2\left[\left(\frac{dp}{dt} - \frac{\nabla \mathbf{u}}{3}p\right)f - \kappa(r,z,p)\frac{\partial f}{\partial p}\right] = Q(p,r)\delta(z)$$

(see e.g. Berezinskii et al. 1990)

- Bloemen et al. 1993; Breitschwerdt et al. 2002:

$$u(z) = 3vz, \qquad v = 10^{-15}s^{-1}$$



Conclusions

- In giant structures acceleration should be carefully taken into account
- Strong shocks and stochastic acceleration are most likely excluded (diffusive transport)
- ‘Ballistic’ models – what about shocks?
- Series of weak shocks – seems fine, yet correct HD required
- Galactic wind can possibly help