Fermi Bubbles as probes of Galactic halo environment

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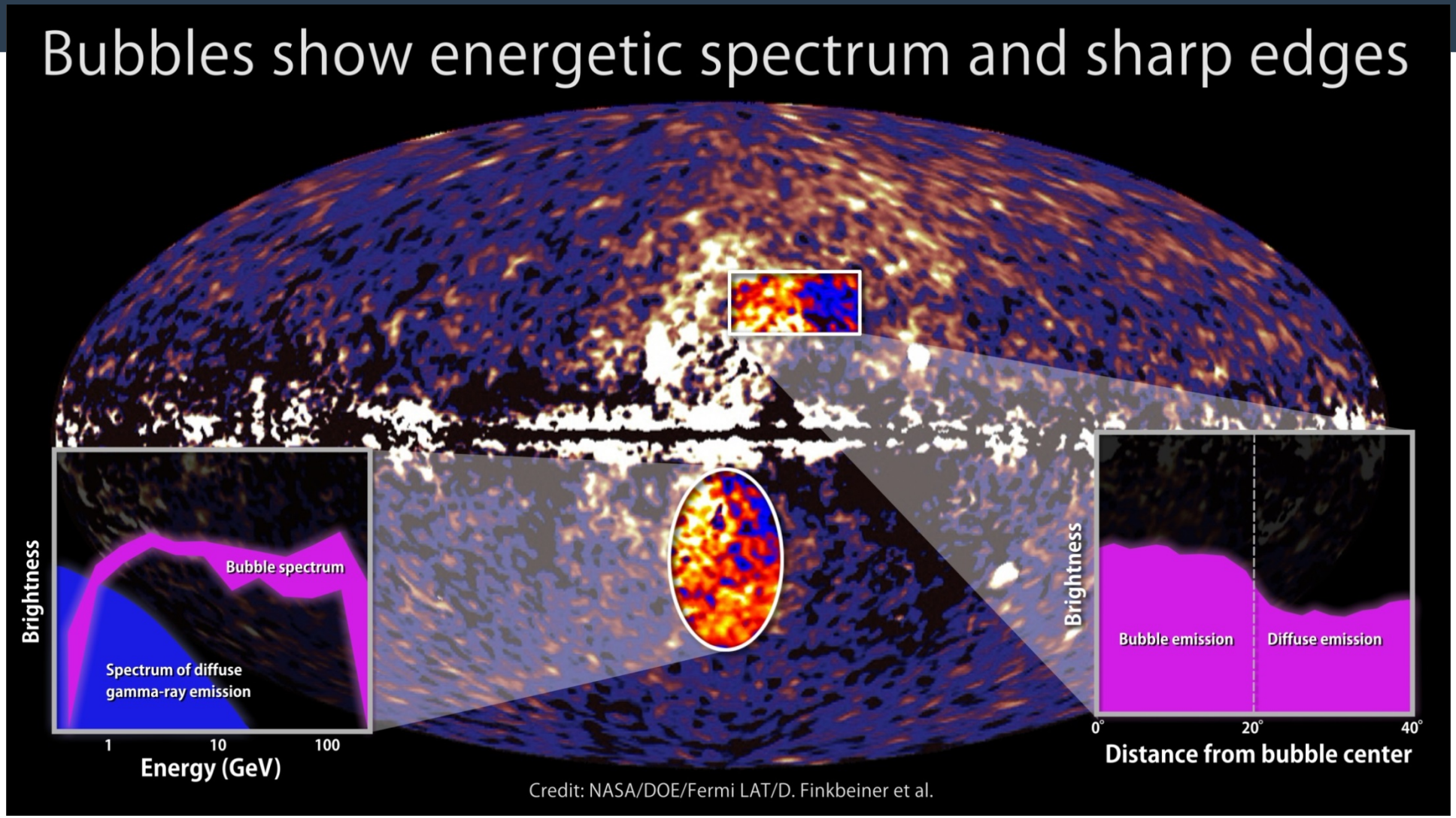
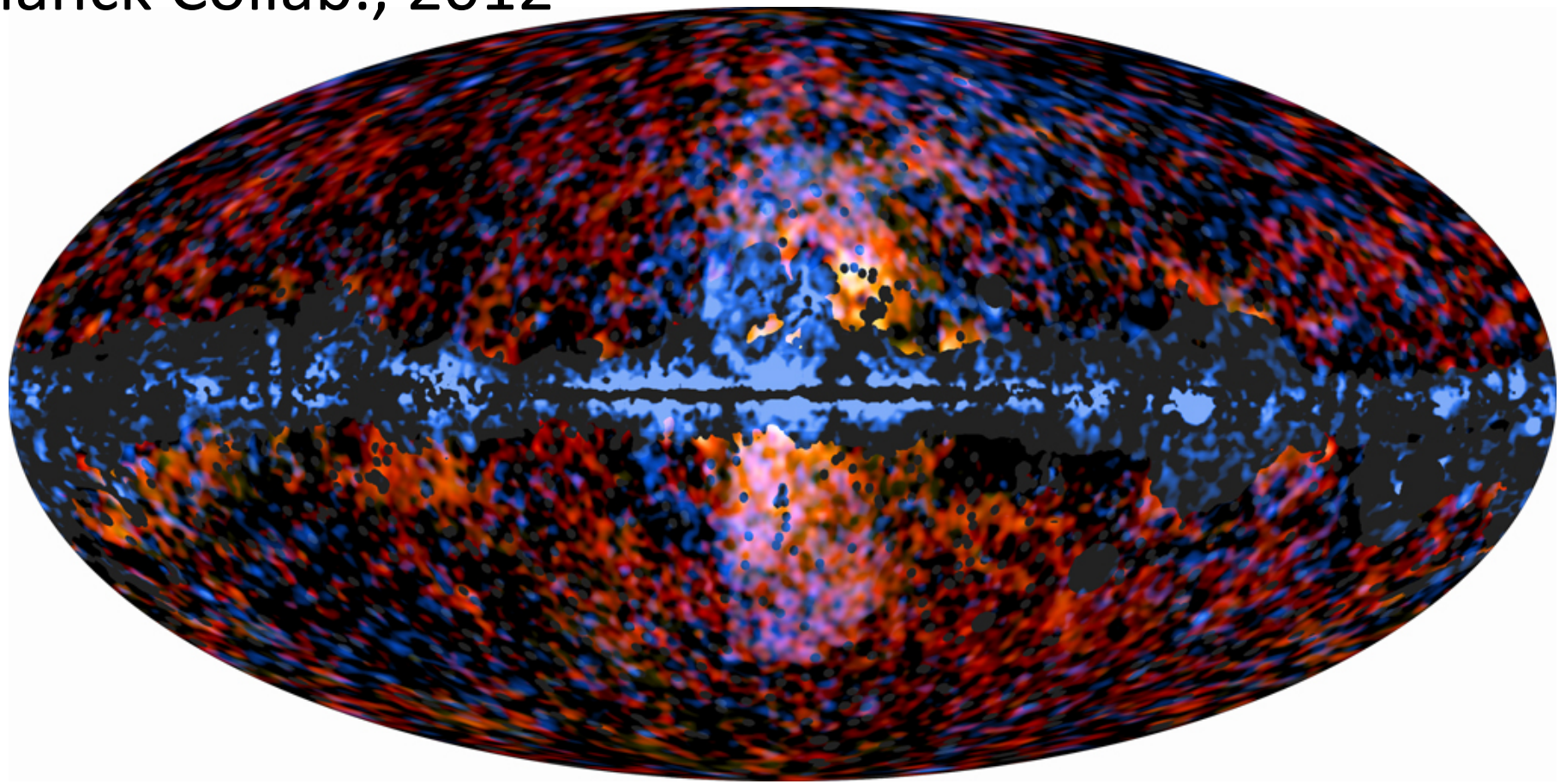
Fermi Bubbles



Dobler et al., 2010, Su et al., 2010, Ackermann et al., 2014

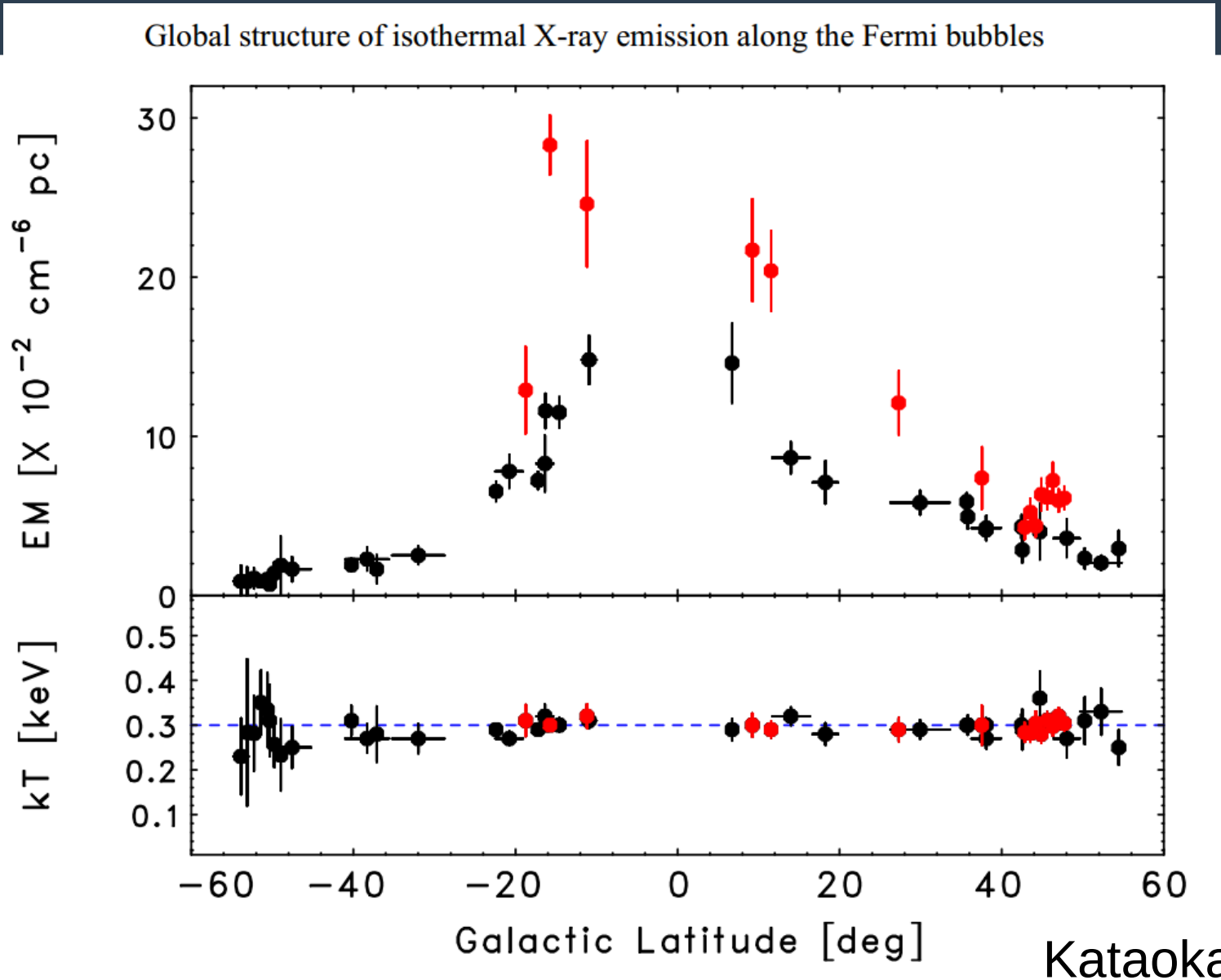
Radio counterpart

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



23 – 61 GHz: radio emission with index 0.56 ± 0.05

X-Ray counterpart



Increased density

No strong shock

Kataoka et al., 2013, 2015

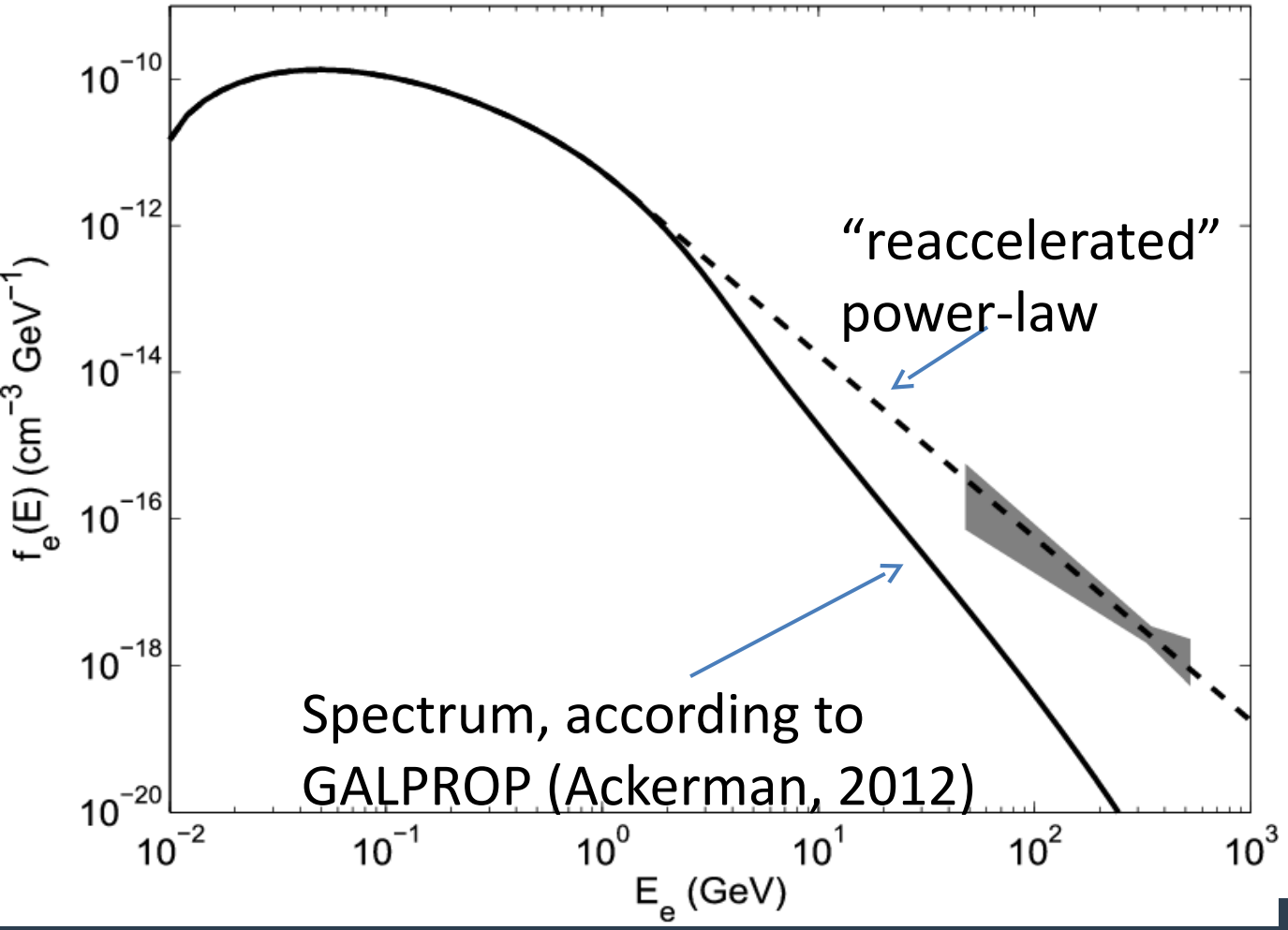
Models of Fermi bubbles

- **Leptonic**
  - Naturally explains radio+gamma-rays
  - Requires in-situ acceleration
  - Very fast outflow ruled out by X-Rays
- **Hadronic**
  - Spatial profile explained by density profile (X-Rays)
  - Requires additional component for radio
  - Requires confinement of hadrons inside the bubbles

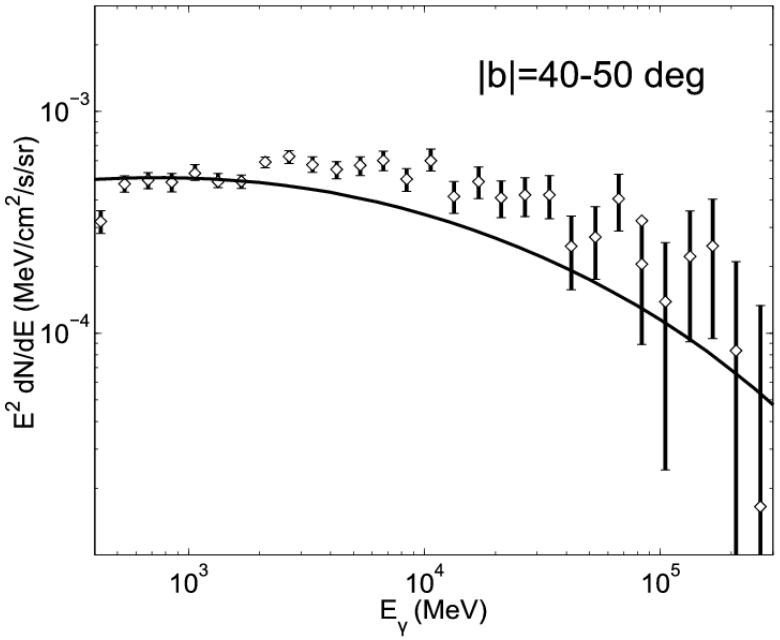
We can't choose one. But what can we say about Galactic medium?

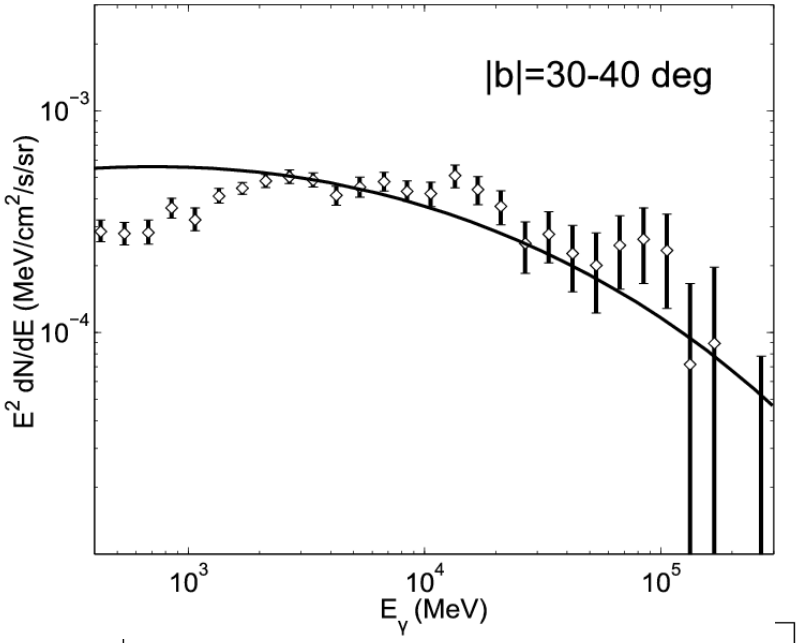
Leptonic models

- Reacceleration of GCRe is the easiest way
  (no plasma overheating, less energy, known injection)

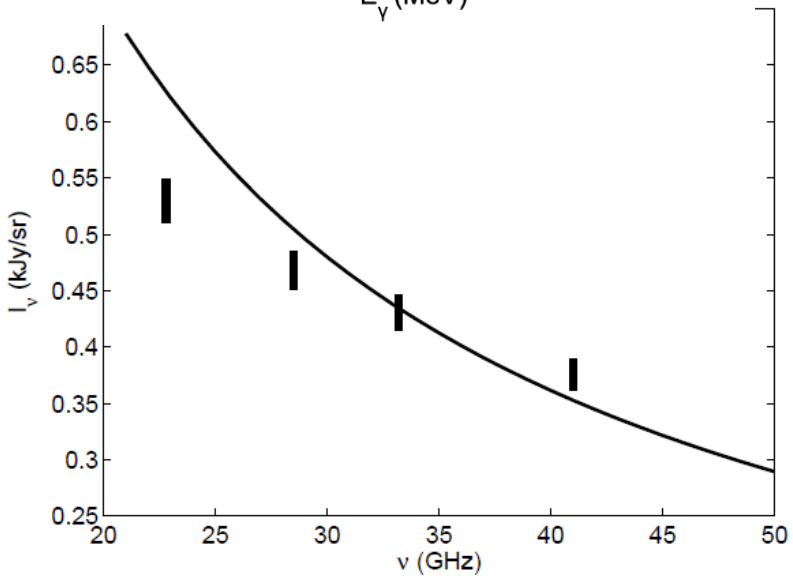


Multi-wavelength emission





- Spectrum is too steep!



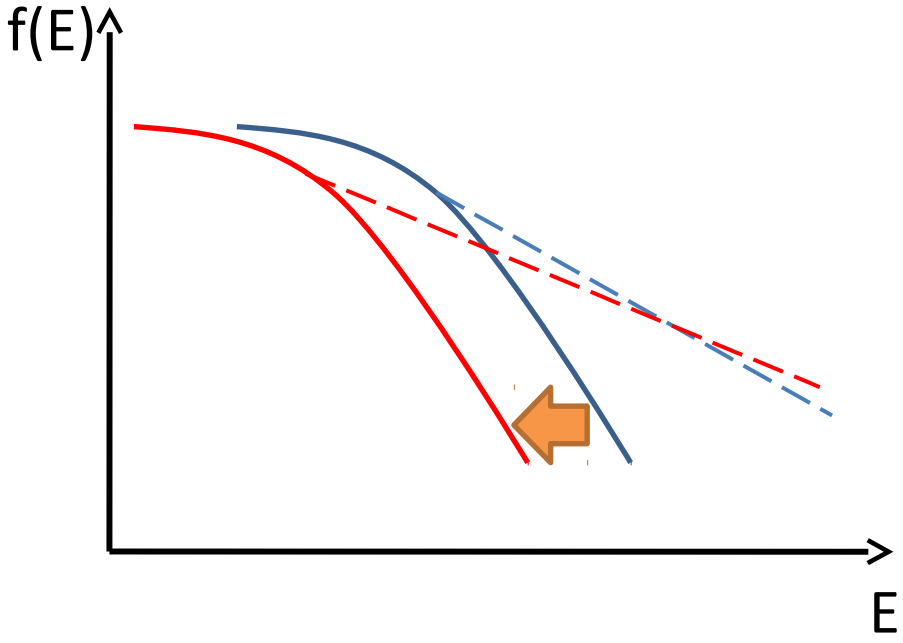
Adiabatic losses (outflow)

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

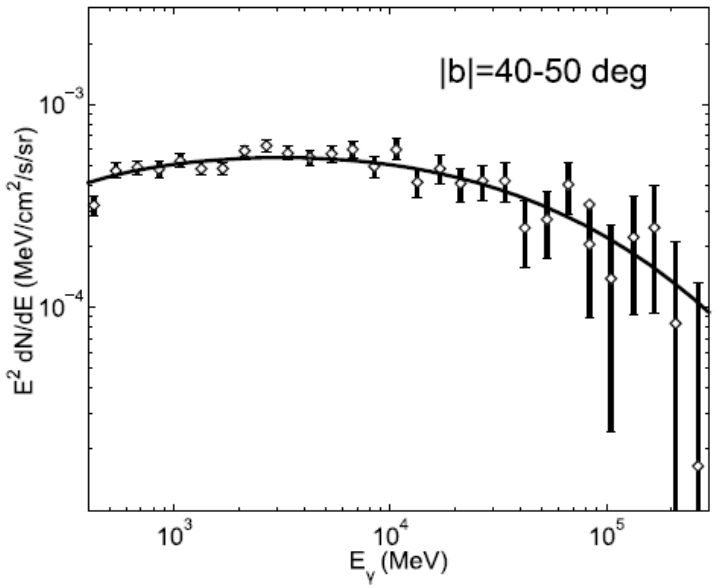
(see e.g. Berezinskii et al. 1990)

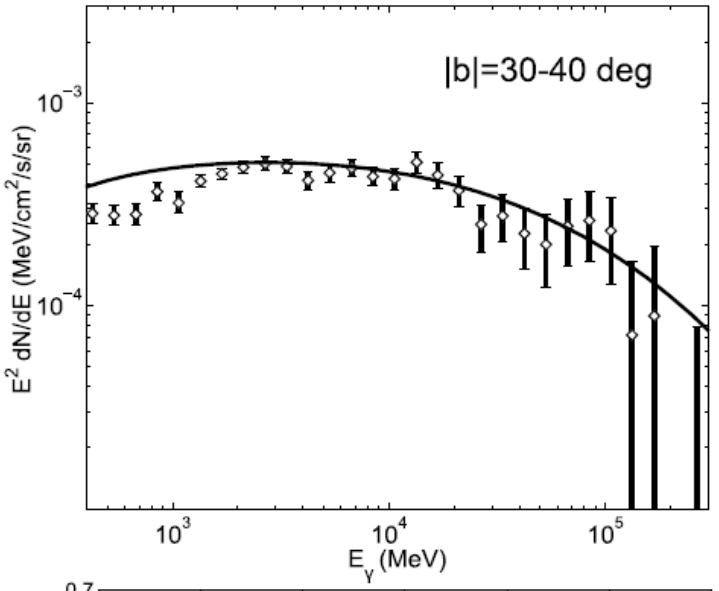
- Bloemen et al. 1993; Breitschwerdt et al. 2002:

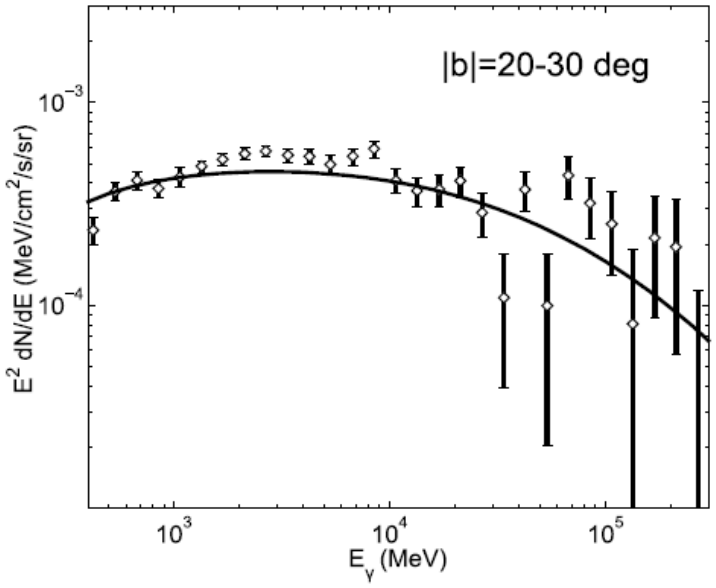
$$u(z) = 3vz, \qquad v = 10^{-15}s^{-1}$$

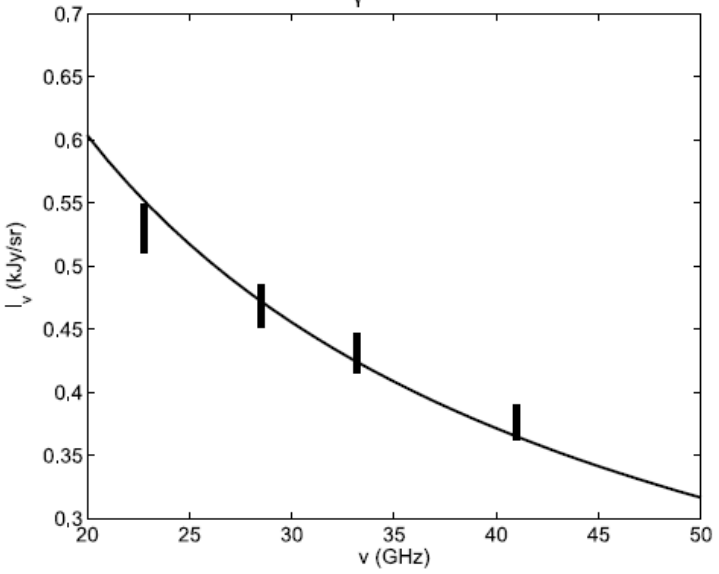


Leptonic model require outflow!





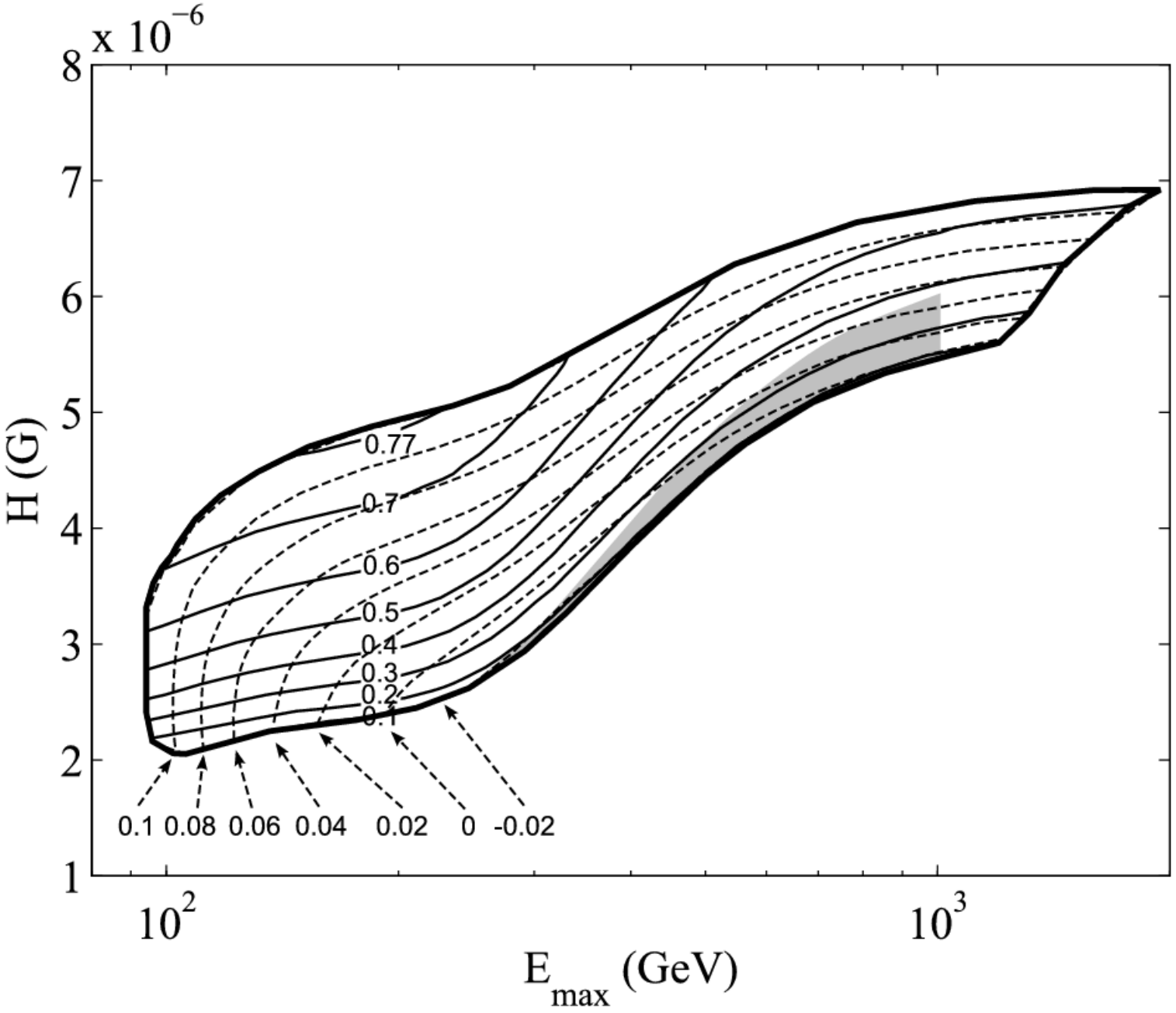




Hadronic models

- Losses-influenced spectrum of electrons is too steep!
- Adiabatic losses should dominate over synchro-compton – no way
- Additional primary leptonic component is required (where it comes from? Outflow?)

Range of parameters



Conclusion

- **Both hadronic and leptonic models require outflow from the inner few kpc of the Galaxy**
  - Should be taken into account in CR models
- **Magnetic field strength is restricted by**
  - 2.5 – 6 μG in leptonic models
  - 2 – 7 μG in hadronic models
  - Jones et al. (2012), Carretti et al. (2013): 6 - 15 μG
- **More and better data are required to set better restrictions**