The Fermi Bubbles: 
An AGN Feedback Event in the Milky Way?

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Guo & Mathews, 2011b, arXiv:1103.0055
Guo, Mathews, Dobler, & Oh, 2011, to be submitted soon

Santa Cruz Galaxy Workshop, Santa Cruz, 08/12/2011
The Fermi Bubbles in the Milky Way

(NASA image)
What the Fermi Telescope observed is

All-sky Fermi-LAT 1.6 year maps in four energy bins

Su, Slatyer, and Finkbeiner, 2010
Fermi Bubbles: residual gamma ray emission

Su, Slatyer, and Finkbeiner, 2010
Observational Features of the Fermi Bubbles

- Symmetric about the Galactic plane, with one above and the other below the Galactic Center
- Roughly uniform gamma-ray surface brightness
- Sharp edges
- Hard and spatially-uniform spectrum $dN/dE \sim E^{-2}$ between $1 < E < 200$ GeV
Gamma-ray Emission Mechanisms

- **Relativistic cosmic-ray protons**
  \[ \text{CRp} + \text{thermal nucleus} \rightarrow \text{pions} \]
  neutral pion $\rightarrow 2\gamma$

- **Relativistic cosmic-ray electrons**
  Inverse-Compton upscattering of starlight or CMB photons
The Fermi Bubbles in Microwave?

Synchrotron emission of CR electrons?

Finkbeiner 2004; Su et al 2010
Possible Explanations

- Diffused CR electrons from the Galactic disk? -- ×

- Dark matter annihilations? --- seems unlikely

- Galactic or AGN winds from the Galactic Center? – Possible, but stellar/starburst winds are probably too slow: the required CR transport speed is around 10000 km/s.

- AGN jet activity --- our work
Motivation: AGN jets carry CRs and produce CR bubbles

- Radio bubbles due to synchrotron emission of CR electrons are seen in both ellipticals and Seyfert spirals.

M87 at 20 cm, VLA image

Cygnus A at 6 cm, Wilson et al 2006
Objective

- Identity physical mechanisms relevant for the Fermi bubbles
- Can the Fermi bubbles be produced by a recent AGN jet event?
- Constrain the properties of the AGN event

Methodology

- Hydrodynamic jet simulations with CR dynamics
- Simulations include hydrodynamics, CR transport, CR dynamics, Galactic potential well and a two-fluid jet originated from the GC
Results -- A successful run

Log (CR energy density)

Guo & Mathews 2011b
Compare with observations

Features reproduced: short age ~ 1 – 3 Myr, location, size, shape, sharp edges, spatially-uniform hard spectrum
Compare with observations

Inconsistencies: surface irregularities and limb darkening in surface brightness
What do these inconsistencies mean?

- They do not necessarily mean that our jet scenario for the Fermi bubbles is wrong

- They may be smoking-gun signatures of additional physics

- Surface irregularities induced by Kelvin-Helmholtz instabilities point toward the role of viscosity or magnetic tension

- Flat gamma ray intensity distribution suggests an edge-favored CR distribution
Simulations with Viscosity

Viscosity coefficient = 3 g/cm/s, much less than the Spitzer viscosity

Guo et al 2011, in prep
When viscosity is lower

Viscosity coefficient = 1 g/cm/s

Guo et al 2011, in prep
Flat Gamma Ray Surface Brightness

Projected CR distribution

Non-viscous run
Surface irregularities
Center-brightened

Viscous run
Smooth edges, but limb brightened
CR diffusion also plays a role
However, CR diffusion across the bubble edges must be suppressed significantly, probably due to the alignment of magnetic fields with bubble surface.

\[ D = 3 \times 10^{28} \text{ cm}^2/\text{s} \]

\[ D = 3 \times 10^{29} \text{ cm}^2/\text{s} \]

Guo & Mathews 2011b
What’s Next?

- Consolidate the result – other evidence for a recent powerful AGN event at the Galactic Center a few Myrs ago?

- Further constrain the jet properties

- Astronomical implications: Do AGN jet events happen regularly in the Galaxy? What triggers AGN jet events? What is the duty cycle? How does the jet activity affect the evolution of the Galactic bulge and the Galaxy (or more generally disk galaxies)? Can it explain the tight correlations between black holes and bulges and the low stellar fraction in disk galaxies? Have we seen Fermi bubbles in other disk galaxies?