Numerical Simulations of Fermi Bubbles

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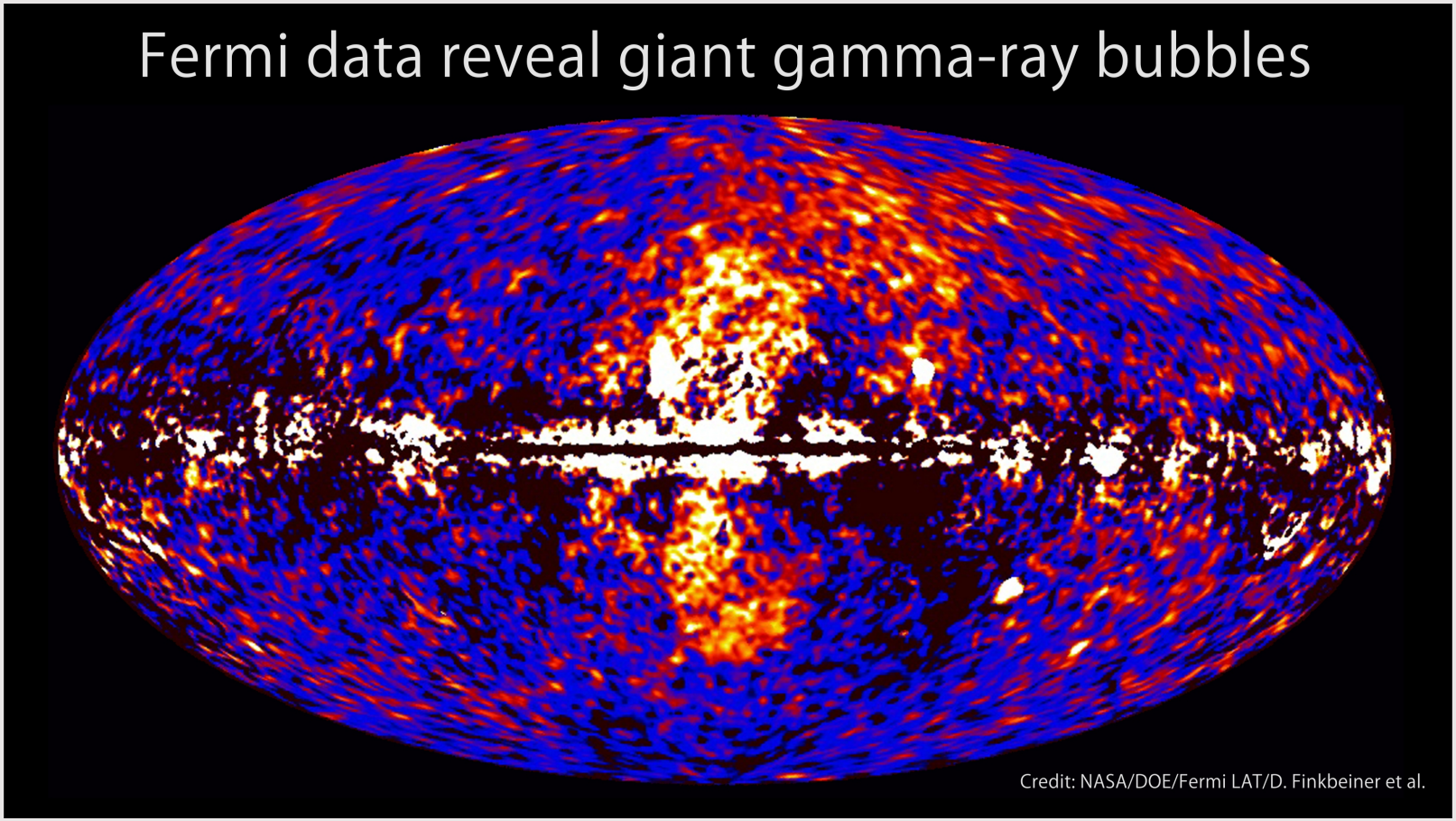
Overview

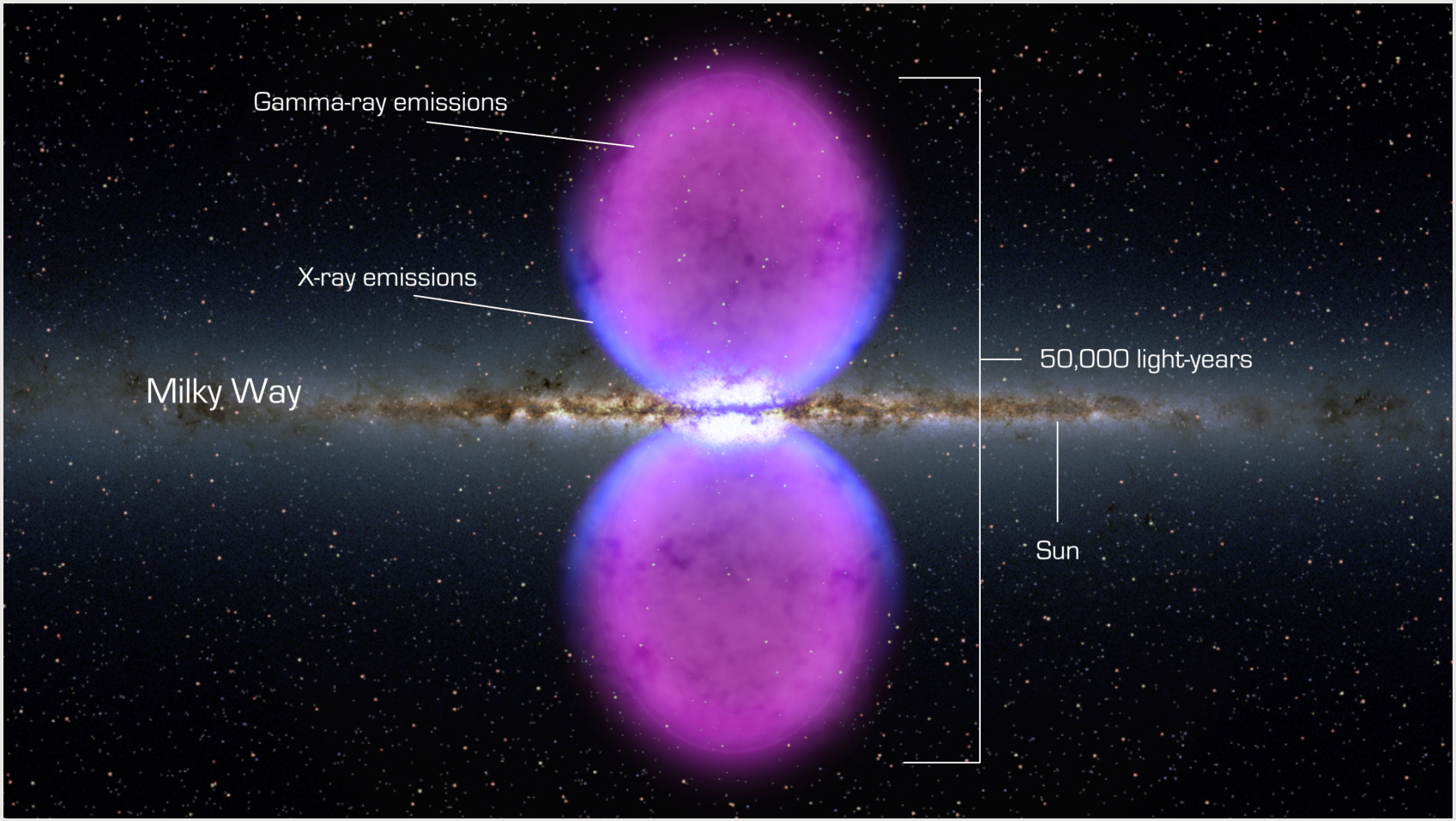
What Are Fermi Bubbles?

Fermi Satellite Image



What Are Fermi Bubbles?

What We Know



Courtesy: NASA's Goddard Space Flight Center

Fundamental Postulates

- The Milky Way hosted an active galactic nucleus (AGN)
- Fermi bubbles were created from an AGN event

Our Model

Euler Gas Dynamical Equations

Conservation of Mass

$$\partial_t \rho + \nabla \cdot (\rho \mathbf{u}) = 0$$

Conservation of Momentum

$$\rho\left(\partial_t \mathbf{u} + \mathbf{u} \cdot \nabla \mathbf{u}\right) + \nabla P = 0$$

Conservation of Energy

$$\partial_t E + \nabla \cdot \Big(\mathbf{u}(E + P)\Big) = -n^2 \Lambda(T)$$

Our Model

The Algorithm

- Gas is assumed to be dilute and monatomic ($\gamma = 5/3$)
- We utilize a WENO (weighted essentially non-oscillatory) numerical scheme
- The cooling, $-n^2\Lambda$, models H_2 and the 10 most abundant elements

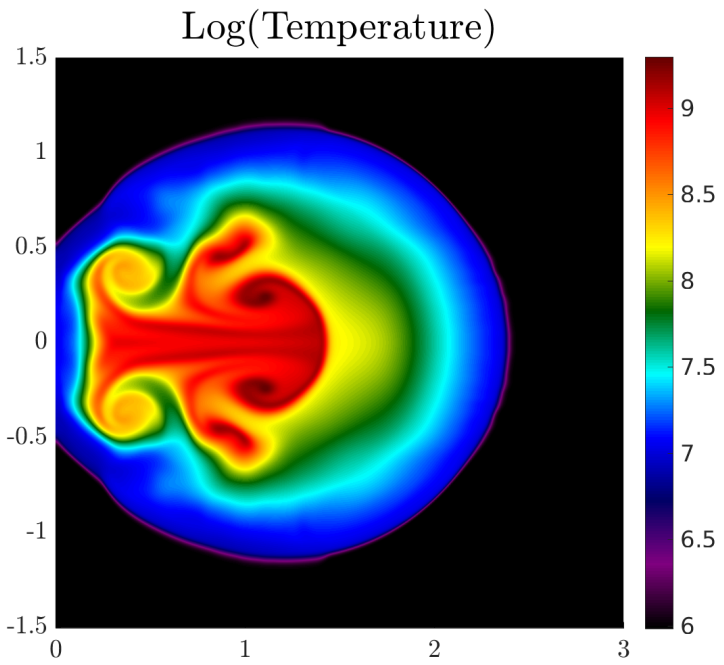
Our Model

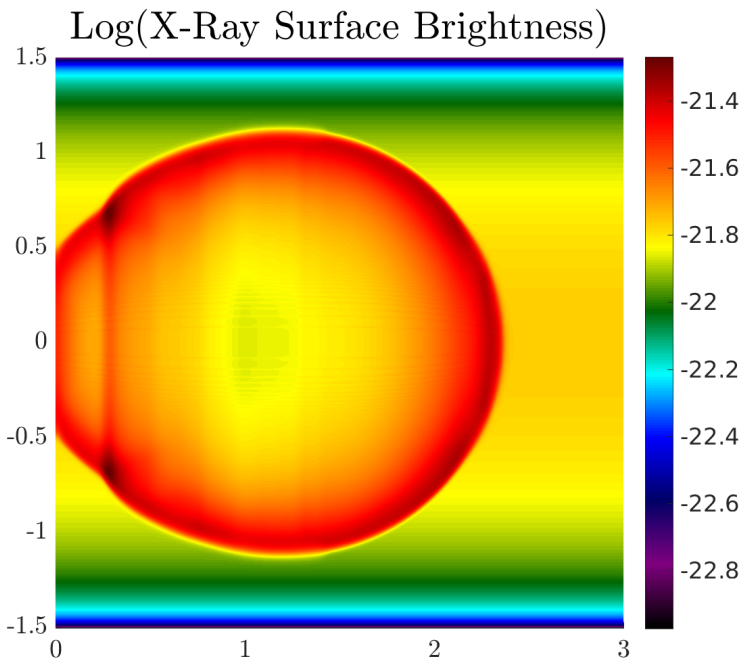
Physical Parameters

Ambient	Bubble
$T_a = 10^6$ K $\rho_a = 1$ H/cm^3	$T_b = 10^8$ K $\rho_b = 3 \cdot 10^{-5}$ H/cm^3 $v_b = 3 \cdot 10^4$ m/s $\tau_b = 2.3$ Myr

Results

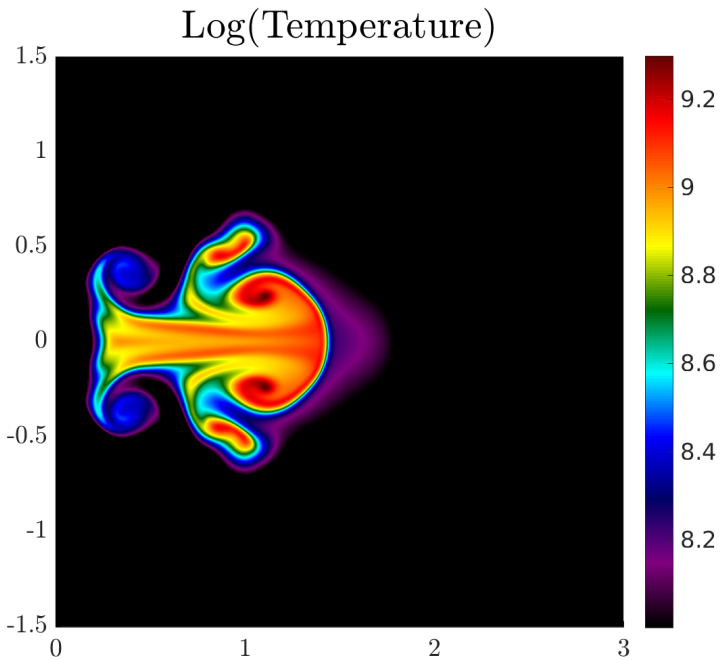
X-Ray Surface Brightness

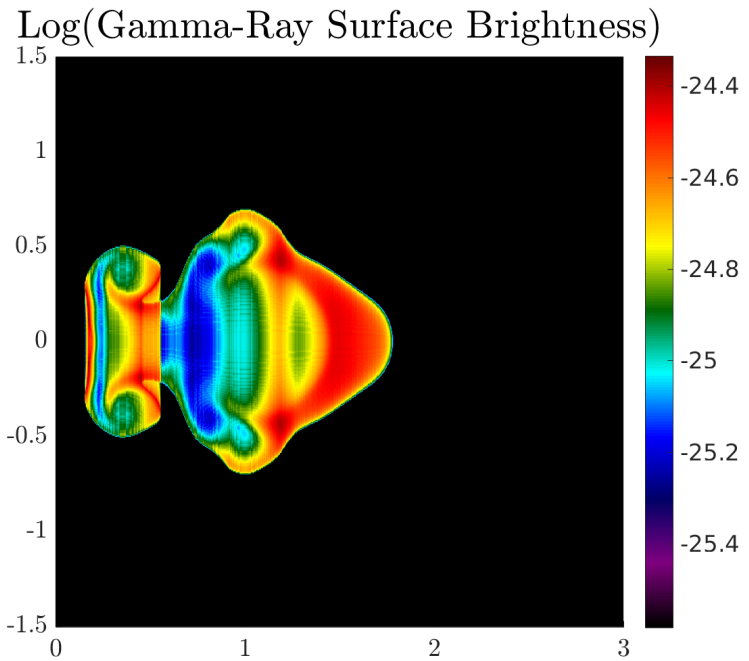




Results

Gamma-Ray Surface Brightness





Conclusions

Conclusions and Further Work

Success	Further Work
• Correct bubble topology • Ambient and bubble temperatures • Bulk cooling distribution	• Obtain proper x-ray surface brightness • Obtain proper gamma-ray surface brightness

Thank You

- Dr. Carl Gardner
- NASA Space Grant Program
- School of Mathematical and Statistical Sciences