Galactic Indigestion

“Giant Gamma-ray Bubbles from Fermi-LAT: Active Galactic Nucleus Activity or Bipolar Galactic Wind?”
Structure

- Fermi bubbles in a nutshell
- Three interesting questions dealt with in this paper:
  - 1) “How do you really know when you are seeing a signal?”
  - 2) “How can such large bubbles be explained physically?”
  - 3) “What questions might the Fermi bubble help to answer?”
- Summary of thoughts about the paper itself
- Conclusion
Fermi bubbles in a nutshell

- New data: higher resolution, sensitivity using Fermi-LAT
- Data reduction: model subtraction to prove the bubble structure
- Spectral fitting: flat spectrum, flat intensity, sharp edges
- Origin of the bubbles/CRs: where did they come from?
- Implications: what does the existence of the bubbles suggest?
Brought to you by...

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Timeline

2004 - “WMAP haze”
Haze of microwave emission found around the centre of the Galaxy (Finkbeiner et al, 2004)

2009 - “Fermi haze”
Matching haze of Fermi emission somewhat asserted to be dark matter annihilation (Dobler et al, 2010)

2010 - “Fermi bubbles”
Haze of microwave emission found around the centre of the Galaxy (Su et al, 2010)
“How do you really know when you are seeing a signal?”
Note: 1.6 year Fermi-LAT maps, vs. first release of 1 year data
Model subtraction

1: Fermi diffuse Galactic model (Fig. 2)

2: Dust-map/disk template model (Fig. 3)

3: Low-energy Fermi subtraction (Fig. 6)

Models show very faint signals from the raw data - with bubbles in all results

These different methods were to prove that the bubbles are real, not artifacts of a chosen data reduction technique
Spectral properties of the bubbles

- Similar to model subtraction
- Splitting into components to compare their spectra (Fig. 15)
- Same: if related, different: if not
- Challenging to create same intensity - not a shell? (Fig. 10)
- Explaining uniform intensity - magnetic reconnection?
“How can such large bubbles be explained physically?”
The Galactic centre

- We know the GC is a highly active region, with much star formation and interactions
- Sagittarius A*
- Massive black hole (MBH)
- High velocity stars (HVSs)
- Other suspects
Origin of the bubbles

- Age: $10^7 / (v/10^3 \text{ km s}^{-1})$ yr, where $v < 10^3 \text{ km s}^{-1} \Rightarrow 10$ Myr
- Past GC activity: X-ray nebulae, diffuse X-rays, OB stellar disk
- MBH accretion - not jet-shaped?
- Nuclear starburst - more SNRs?
- “Some large episode of energy ejection in the GC...”
Origin of the CRs

- Key difficulty: generating CRs of the same energy/intensity up to 10 kpc off the plane (Fig. 28)

- Are they generated:
  1) In the GC?
  2) Inside the bubbles?
  3) In the rim of the bubbles?

- Dark matter annihilation?
“What questions might the Fermi bubbles help to answer?”
Gamma-ray background

- Origin of gamma ray background? (blue background in the image)
- The extragalactic gamma-ray BG is thought to originate from outflow
- Local evidence for such outflows?
- This could lead to energetic CRs that escape galaxies to be detected as the cosmic gamma-ray background
Hypervelocity stars

- Ejection of high velocity stars - with speeds of 60-100 km/s faster than allowed by Galactic rotation
- These are thought to originate from the MBH in the GC, in relation to accretion events and interaction
- May be ejected periodically
- Are the Fermi bubbles linked to their ejection?
Future of the bubbles

- Will there be fragmentation of the Fermi bubbles as they age?
- Timescale of fragmentation and re-ejection of matter
- If so, this ejection could reach the Galactic halo
- Blowout (ala supershell)?
- Feedback mechanism
Missing baryons/HVCs

- Suggestion of hot gas feedback into the Galactic halo
- Missing baryons
- Contributing to the origin of HVCs?
- It is possible that we might find tracers of past bubbles in HVCs
- May provide a timescale for bubble formation, if HVCs are linked
Metallicity

- Ejection of gas into IGM - if it is channeled in the Galactic wind
- Metal-rich vs. metal-poor outflow
- Metals in the IGM thought to be an indicator of metal-rich outflow
- May also help explain the value of metallicity detected in the IGM
Comments on the paper

-Thorough - it is clear that a lot of thought about possible origins of the bubbles went into it, with various scenarios presented.

-Indecisive - it is not very clear which of the various scenarios the authors believe is the most likely (but they don’t know yet).

-Figures - it is good that there are a lot, but it seems that more thought could have gone into condensing the results, or in culling uninteresting plots for the sake of clarity (Fig. 5, 22).

-Context - they put their work in context of different fields, which adds a lot to the overall impact of the paper.
Conclusions

- Bubble structures present up to 50° off the plane
- Coincident with WMAP haze and soft ROSAT X-rays
- Origin as a large episode of energy injection associated with GC
- Dark matter annihilation: possibly an efficient means of CR injection at high latitudes, but not all evidence supports this
- Future data from eROSITA/Planck will better resolve structures
- Need clear physical understanding of bubbles