The Galactic Positron Annihilation Radiation Bulge-to-Disk Ratio: The Problem and the Solution

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Summary

The Problem:

- INTEGRAL/SPI measured the 511 keV bulge/disk luminosity ratio to be ~2.
- The bulge/disk ratio of supernovae responsible for positron production as inferred from the stellar mass and light distribution is ~0.3
- **Nearly an order of magnitude discrepancy**

The Solution:

- Positrons must slow down to ≤10 keV in order to annihilate.
- Depending on the phase of the ISM, the distance traveled by the positrons may take them far from the supernovae that produced them.

Our Work:

1. **We show that careful consideration of all factors can eliminate the discrepancy**
2. **Our results also recreate the Positronium fraction observed by INTEGRAL/SPI**
3. **Our results predict broad line emission (~5.4 keV) dominating the 0.5<R<1.5 kpc region and narrow line (~1.3 keV) emission dominating the >0.5 kpc region.**
4. **Our results recreate the ratio of observed broad/narrow line emission in the bulge.**

The source of Galactic positrons has been long thought to be the decay of 56Ni, 44Ti, and 26Al from supernovae.

We studied positron production, propagation, and annihilation in the various regions and phases of the ISM.

We consider:

5 spatial regions: stellar bulge (<0.5 kpc), tilted disk (0.5--1.5 kpc), windy disk (1.5--3.5 kpc), main disk (3.5--8 kpc), and the halo (1.5--8 kpc), and

6 phases of the ISM: hot plasma, warm ionized, HII shells, warm HI, cold HI, and molecular H_2.

We assume:

56Ni, 44Ti, and **26Al** from supernovae as the source of positrons.

The radial distribution of supernovae follows stellar light and mass

The fraction in each ISM phase equals the filling factor, except for 26Al in SB galaxies

We calculate in each phase:

Positron slowing down time before annihilation

Positron 1-D diffusion mfp(?) or streaming speed along B field

Mean escape time from typical length of magnetic flux

Fraction of positrons annihilating before escaping

Relative fractions of positrons escaping into each neighboring phase

From the resulting matrix, we calculate:

Expected positron production, propagation, slowing down, and annihilation in each region.

We find that:

Positron propagation quite naturally explains the bulge/disk ratio of the 511 keV emission

It also explains the positronium fraction, and broad/narrow 511 keV flux ratio from the bulge.

Within the bulge we also predict:

The broad/narrow line ratio may vary x100 between the central molecular zone (<0.5 kpc) and the surrounding tilted disk (0.5--1.5 kpc).

Expected and Observed Galactic Positron Annihilation Radiation

	Expected	Observed	Reference
511 keV line flux			
(10^{-3} γ's/cm^2)			
Bulge (<0.5 kpc)	0.51±0.25	0.38±0.03	Weidenspointer et al. 2007
Bulge (0.5--1.5 kpc)	0.29±0.14	0.41±0.06	" "
Bulge (>1.5 kpc)	0.80±0.40	0.79±0.07	" "
Disk (1.5--8 kpc)	1.64±0.82	1.41±0.35	" "
Halo (>1.5 kpc)	1.27±0.63	0.86±0.59	" "
Annihilation Rate			
(10^{43} e^+/s)			
Bulge (<1.5 kpc)	0.97±0.48	1.0±0.25	Inferred from
Disk (1.5--8 kpc)	0.65±0.32	0.6±0.2	Weidenspointer et al. 2007
Halo (>1.5 kpc)	0.55±0.27	0.4±0.3	" "
Bulge/Disk Ratio	1.5±0.7	1.7±0.4	" "
Positronium Fraction			
Bulge (<1.5 kpc)	0.92±0.02	0.92±0.09	Weidenspointer et al. 2007
		0.94±0.06	Churazov et al. 2005
Disk (1.5--8 kpc)	0.91±0.02	---??---	
Halo (1.5--8 kpc)	0.65±0.07	---??---	
Broad/Narrow Line Ratio			
Bulge (<1.5 kpc)	0.56±0.28	0.49±0.17	Jean et al. 2006
		0.47±0.20	Churazov et al. 2005
Bulge (<0.5 kpc)	0.07±0.04	---??---	
Bulge (0.5--1.5 kpc)	4.9±2.5	---??---	
Disk (1.5--8 kpc)	0.05±0.02	---??---	