The Galactic Habitable Zone

Jamie Tayar

Will Burns

Sarai Pegram

John Roebker

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Abstract

The purpose of this project was to determine the influence of the galactic bar on the galactic habitable zone. The galactic habitable zone is the area in the galaxy where terrestrial planets are likely to form. It was calculated in 2003 to be a ring around the galactic center starting at seven kiloparsecs from the galactic center and ending at nine kiloparsecs from the galactic center that will increase in size as the galaxy ages. At the time these calculations were done, however, our galaxy was not known to be a barred spiral.

Our group attempted to determine if the greater density of stars in the galactic bar would increase the radiation coming from the center of our galaxy and push the galactic habitable zone away from the center of the galaxy. We looked at the thermal, x-ray, gamma and ultraviolet radiation from the galactic bar based on the number of stars in the galactic bar and the frequency and flux of various classes of stars in our galaxy.

We determined that none of the various classes of radiation influenced the galactic habitable zone. Gamma rays were too infrequent, thermal and ultraviolet rays were too weak and x-rays could not penetrate an atmosphere. Though the gravity from the galactic bar may change the orbits of stars and thus the habitable zone, those calculations were beyond the scope of this project. Based on our calculations, the radiation from the galactic bar, and to our knowledge, the bar itself, does not influence the galactic habitable zone.

Introduction

The Galactic Habitable Zone (GHZ) is defined as the area in a galaxy where terrestrial planets are likely to form. This is usually determined using specific parameters such as the frequency of supernovas and the time necessary for planets and life to form. Another such parameters include the metallic content most likely to give rise to terrestrial planets based on the metallic composition of the star, specifically its iron to hydrogen ratio. Before the discovery of the galactic bar in the Milky Way galaxy the GHZ was determined to be the area between seven and nine kiloparsecs from the galactic center. (Lineweaver et al. 2003) The purpose of this project was to determine whether the galactic bar would influence this zone.

The galactic bar has been measured to be 8.8 kiloparsecs by 50 pc by 500 pc. The gravity from this bar disrupts the orbit of nearby stars, causing them to take nonelliptical orbits and even ejecting them from the galaxy. (Sundin) This would make the boarders of the galactic habitable zone less defined because it could cause more metallic stars could be found further from the galactic center than expected and that less metallic stars could be found closer to the galactic center. Sundin suggests that rather than determining the boarders of a habitable zone, the probability that life exists in an area based on the metallicity, frequency of supernovas, time to develop, and the likelihood that stars from other regions had been placed in that area by the gravity of the galactic bar should be determined. These calculations, however, are outside the scope of this project. The galactic bar is also a dense region of usually older stars and the location of frequent supernova explosions. (Dr. Moffit)

Our group set out to determine whether or not the newly discovered bar in the center of the Milky Way galaxy affected its habitable zone. In order to do this, we had to find the estimated number of stars in the galactic bar. The next step was to find the percentage of each type of star and their average luminosity, as that would determine how much radiation they would give off. Using that data, we used a luminosity function to determine the approximate luminosity of the bar. Then placed the variables into the inverse power law and find the temperature of the bar. Lastly, we had to obtain our results. We were also able to observe the NGC5566 galaxy and the NGC5426 galaxy, both barred spirals using the PROMPT telescopes located in La Silla, Chile.

Method

Our first step was to determine the number of stars in the galactic bar. We learned that there are roughly 30,000,000 stars that make up the galactic bar. Then we determined the percentage and luminosity of each star type, and based on our research we came up with the following conclusions:

Star Type	**Percentage**	**Luminosity (compared to the sun)**
M	63.3	.035
K	15.2	.4
G	10.1	1
F	5.1	6
A	3.8	60

B	2.5	$1x10^4$
O	.0001	$8x10^4$

Using the above data, we found the average luminosity of the galactic bar in the visible spectrum. To find the average we multiplied the luminosity of different star types by the numbers of stars in the galactic bar and their percentages in the galaxy. We then added these numbers together to get the average visible luminosity.

After this we worked to find the X-ray and Ultraviolet luminosities of the galactic bar. We used NASA star catalogues to find the fluxes of different star classes. By multiplying the average X-ray fluxes by the number of stars in the galactic bar and the percentages of star types in the galaxy, we discovered the average X-ray flux of the galactic bar on Earth. The flux was placed in a derivation of the Inverse Power Law to find the X-ray luminosity. Placing the luminosity back into the equation for a set distance we could also find the flux on a region of space different distances away. The same method was used for UV flux and luminosity. After the flux of the galactic bar was determined, we determined the amount of radiation that gets through our atmosphere and the amount of radiation needed to kill an organism. We then compared these values to determine if the radiation coming from the galactic bar was strong enough to prevent life from surviving on worlds about seven kiloparsecs from the galactic center.

Results

Our calculations showed that the electromagnetic radiation from the galactic bar was not strong enough to influence the galactic habitable zone.

Gamma radiation would kill all life within one kiloparsec; the galactic bar is too far away from the galactic habitable zone for gamma radiation to influence the galactic habitable zone.

Though the galactic bar emits $1.219287544 \times 10^{-4}$ erg cm^{-2} s^{-1} in x-ray frequency, according to the European Space Agency, x-ray radiation cannot pass through the earth's atmosphere. The wavelength of x-rays is too small for them to pass through.

Additionally, the calculations for Ultraviolet radiation showed that the galactic bar was too far away for its radiation to influence the galactic habitable zone. However, these calculations were made using an incomplete list of ultraviolet emissions from stars and may not be entirely accurate.

However, according to Sundin, the gravity of the bar will change the orbits of stars nearby. This will cause a spreading of many different types of stars in our galaxy. Therefore it is possible that the GHZ changes with the new orbits outside the galactic bar.

Conclusion

In conclusion, our research and calculations found that the GHZ is unchanged by radiation from the newly discovered bar. Further research should study the changing dynamics of stellar orbits due to the bar. These orbits might in some cases change the GHZ. From our calculations, although the GHZ was found to be unchanged, visible, x-ray, and ultraviolet luminosities were found for the bar. The ultraviolet luminosity should be further researched due to incomplete logs and data used in the calculations.

Works Cited

Browse Software Develop. "FAUST - Faust Far-UV Point Source Catalog." 8 Nov. 2004. NASA. 23 June 2006 <http://heasarc.gsfc.nasa.gov/W3Browse/all/faust.html>.

Binney, James, and Michael Merifield. Galactic Astronomy. Princeton, NJ: Princeton UP, 1998.

Brandt, John C. The Sun and Stars. New York: McGraw-Hill, 1966. 117.

Browse Software Developme. "XRAY - Master X-Ray Catalog." 21 May 2006. NASA. 23 June 2006 <http://heasarc.gsfc.nasa.gov/W3Browse/all/xray.html>.

Moffit, David. A Millennia of Supernovae. PARI, June 24, 2006.

Seeds, Michael A. Foundations of Astronomy. 4th ed. Belmont, CA: Wadsworth Company, 1997. 180-181.

Sundin, Maria. The Galactic Habitable Zone in Barred Galaxies. Goethenberg University. Goethenberg: The International Journal of Astrobiology, 2006.

Than, Ker. “The New Tourist’s Guide to the Milky Way.” Space.com <http://www.space.com>

Wikipedia: the Online Encylopedia. 23 June 2006 <www.wikipedia.com>.

Appendix

- Thermal Luminosity of the Galactic Bar
  - L_{GB}/L_{Sun} = (3x10^{7} x .633 x .035) + (3x10^{7} x .152 x .4) + (3x10^{7} x .101 x 1) + (3x10^{7} x .051 x 6) + (3x10^{7} x .038 x 60) + (3x10^{7} x .025 x 1x10^{4}) + (3x10^{7} x .0001 x 8x10^{4}) = 7.82309865x10^{9}
  - $L_{GB} = L_{GB}/L_{Sun} \times L_{Sun}$ = 7.82309865x10^{9} x 3.827x10^{26} W = 2.993899853x10^{36} W
- X-Ray Luminosity
  - F_X of Galactic Bar at Earth = (3x10^{7} x .633 x 2.71787x10^{-12} erg cm^{-2} s^{-1}) + (3x10^{7} x .152 x 3.86425x^{-12} erg cm^{-2} s^{-1}) + (3x10^{7} x .101 x 3.04905x10^{-12} erg cm^{-2} s^{-1}) + (3x10^{7} x .051 x 1.13479x10^{-12} erg cm^{-2} s^{-1}) + (3x10^{7} x .038 x 1.0814x10^{-12} erg cm^{-2} s^{-1}) + (3x10^{7} x .025 x 1.66825x10^{-12} erg cm^{-2} s^{-1}) + (3x10^{7} x .0001 x 2.96183x10^{-12} erg cm^{-2} s^{-1})= 8.2692165x10^{-5} erg cm^{-2} s^{-1}
  - $L_X = 4(3.14) \times R^2 \times F_X$ (Inverse Power Law)

- $L_X = 4(3.14)(2.9941488x10^{18}\ cm)^2\ (8.2692165x10^{-5}\ erg\ cm^{-2}\ s^{-1})=$ $9.311095143x10^{33}\ erg\ s^{-1}$
- F_X of Galactic Bar 7kpc away= $L_X/4(3.14)R^2 = 9.311095143x10^{33}\ erg\ s^{-1}$ / $4(3.14)(2.4657696x10^{18}\ cm)^2 = 1.219287544x10^{-4}\ erg\ cm^{-2}\ s^{-1}$

- UV Radiation (Incomplete Data)
  - Flux of Galactic Bar at Earth= $(3x10^{7}$ x .633 x 0) + $(3x10^{7}$ x .152 x $3.97800002x10^{-10}\ erg\ cm^{-2}\ s^{-1})$ + $(3x10^{7}$ x .101 x $1.98900001x10^{-10}\ erg\ cm^{-2}\ s^{-1})$ + $(3x10^{7}$ x .051 x $3.97800002x10^{-10}\ erg\ cm^{-2}\ s^{-1})$ + $(3x10^{7}$ x .038 x $1.591200006x10^{-9}\ erg\ cm^{-2}\ s^{-1})$ + $(3x10^{7}$ x .025 x $3.779100014x10^{-9}\ erg\ cm^{-2}\ s^{-1})$ + $(3x10^{7}$ x .0001 x $6.762600026x10^{-9}\ erg\ cm^{-2}\ s^{-1})$= .0076938498 $erg\ cm^{-2}\ s^{-1}$
  - $L_{UV} = F_{UV}\ (4)(3.14)R^2 = .0076938498\ erg\ cm^{-2}\ s^{-1}$ $(4)(3.14)(2.9941488x10^{18}\ cm)^2 = 8.663235143x10^{35}\ erg\ s^{-1}$
  - $F_{UV} = L_{UV}$ / $4(3.14)\ R^2$ (Inverse Power Law)

- F_{UV} at 7 kpc from Galactic Bar= $8.663235143 \times 10^{35}$ erg s^{-1} / $4(3.14)(2.4657696 \times 10^{18})^2$ = .011344503 erg cm^{-2} s^{-1}