THE ORIGIN OF GAMMA-RAY EMISSION FROM CIRCINUS GALAXY

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INTRODUCTION

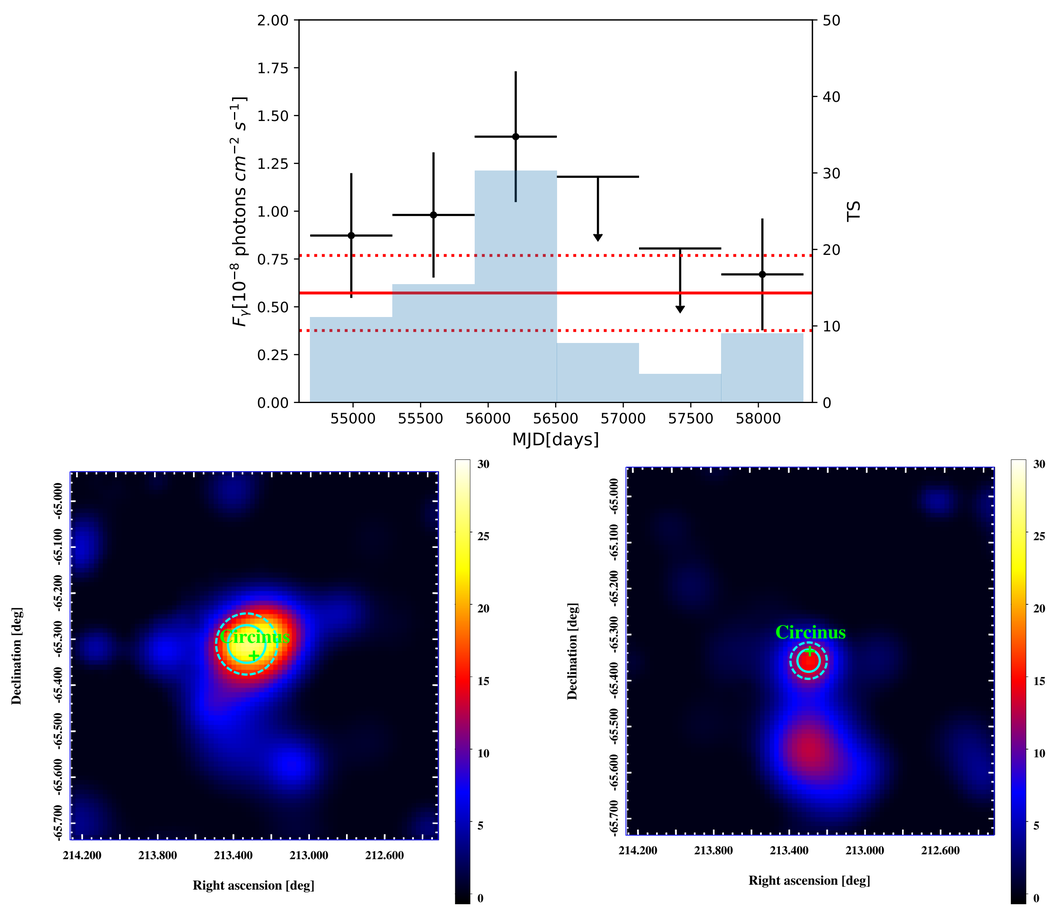
Circinus is a nearby (4.2 ± 0.7 Mpc) spiral galaxy. It is a composite starburst/AGN system. In addition, the large edge-brightened radio lobes, likely caused by jet-driven outflow, are detected. The gamma-ray emission was detected using 4-year *Fermi*-LAT Pass 7 data. In fact, it is the only "normal" gamma-ray Seyfert galaxy (i.e. not radio loud narrow line Seyfert Is) listed in the fourth *Fermi*-LAT AGN catalog. In comparison to other star-forming galaxies, Circinus seems to well deviate from the RC-γ and IR-γ luminosities correlations. Moreover, the emission from radio lobes likely fails to give an acceptable description of the broadband spectral energy distribution (SED).

DATA REDUCTION AND RESULTS

We analyzed *Fermi*-LAT Pass 8 data in the region of Circinus galaxy recorded from August 4, 2008 to August 4, 2018. The events with energies from 100 MeV to 500 GeV were chosen. The model also takes into account all nearby sources included in 4FGL, two new detected sources and the diffuse Galactic and extragalactic gamma-ray backgrounds. Circinus is associated with the point source 4FGL J1413.1-6519. The gamma-ray luminosity of $L_{0.1-100\ \mathrm{GeV}} = (1.17 \pm 0.44) \times 10^{40}$ erg s^{-1} was obtained. Our flux is lower than the value given in 4FGL and previous work.

We performed the variability analysis. The light curve is shown in Figure 1. We calculated the variability index and had $\mathrm{TS_{var}} = 12.8$ corresponding to a significance level of 2.24σ, which is very marginal. Nevertheless, we notice that the sum of TS values of the first five years is almost three times of that of the last five years. Therefore, the data of different energy ranges were divided into two equal parts by time. We found that the TS values of the first five years are about two times of that for the last five years, and the photon flux drops by a factor of $\sim 1.5-2$, suggesting a possible variability on timescales of years, which is evident in the bottom of Figure 1. **For more details, see reference [1].**

FIGURE 1

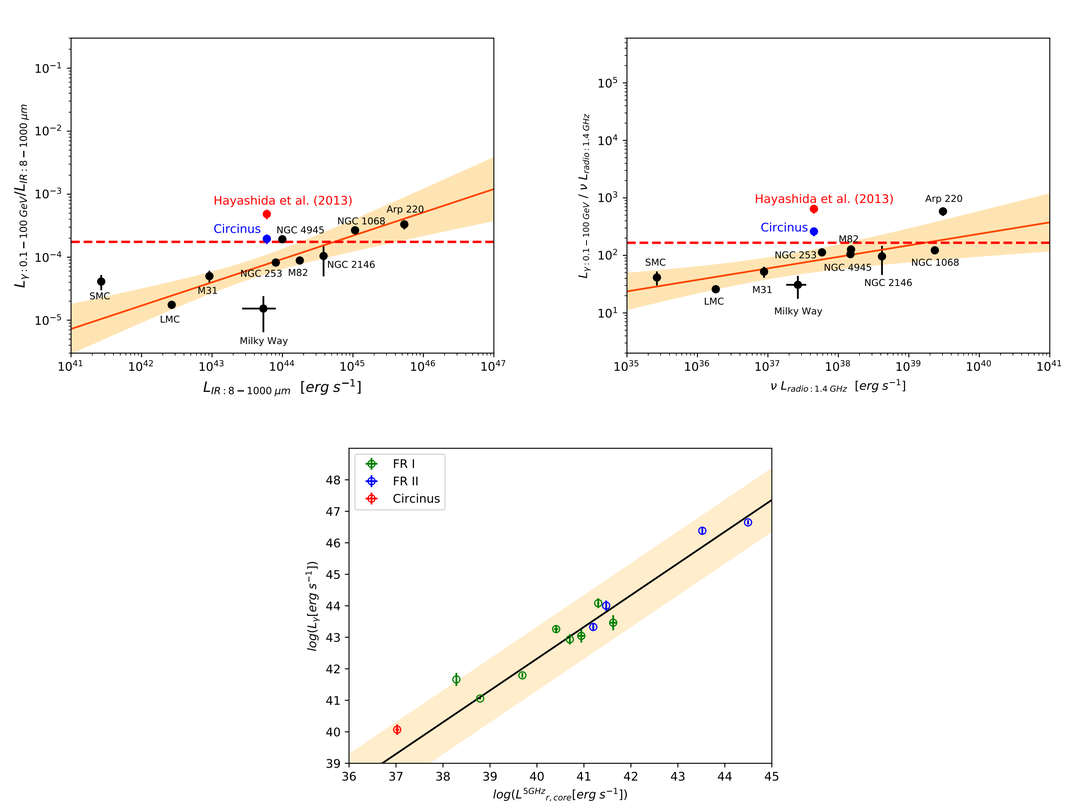


Top: The light curve of Circinus galaxy. *Bottom left:* $0.8^\circ \times 0.8^\circ$ TS map for the first five years above 10 GeV. *Bottom right:* TS map for the last the five years.

DISCUSSION

It it widely accepted that the gamma rays from star-forming galaxy is associated with the star formation process. The star formation rate (SFR) can be well traced by the total IR (8-1000 μm) (L_{IR}) and 1.4 GHz radio continuum ($L_{1.4\mathrm{GHz}}$) luminosities. For a proton calorimeter, the CR protons would interact with ambient gas before escaping from the galaxy. With the L_{IR} of 0.6×10^{44} erg s^{-1}, the corresponding L_γ is estimated to be 1.05×10^{40} erg s^{-1}, which is consistent with the observation value of $(1.17 \pm 0.44) \times 10^{40}$ erg s^{-1}. In addition, there are empirical relations for star-forming galaxies between L_γ and the L_{IR} / $L_{1.4\mathrm{GHz}}$. Circinus was above the scaling relations in previous work. Since the gamma-ray luminosity we calculated is lower, the discrepancy is decreased (see Figure 2). As shown in the figure, Circinus is basically in compliance with these relations, which is different from previous work. Meanwhile, the fact that Circinus locates near the line of proton calorimetric limit provides additional evidence as to be a possible proton calorimeter.

FIGURE 2



Left: The ratio between L_γ and L_{IR}. The red dashed line indicates the proton calorimetric limit. The red dot describes the ratio of Circinus computed this work. *Right:* The ratio between L_γ and $L_{1.4\mathrm{GHz}}$.

The mild gamma-ray variability on timescales from months to years has been detected in MAGNs (e.g., 3C 111). Considering the possible gamma-ray variability, we look up the position of Circinus in the $L_{\mathrm{radio-core}}$ - L_γ plot compared with known gamma-ray MAGNs. It is very interesting that Circinus is in compliance with the correlation of the MAGNs. If the contribution of the core-jet is indeed significant, Circinus could be a valuable target, shedding light on formation and energy dissipation of AGN jet in extreme environments.

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