HESS J1858+020: A GeV-TeV source possibly powered by cosmic rays from SNR G35.6-0.4

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The supernova remnant (SNR) G35.6−0.4 shows a non-thermal radio shell, however, no gamma-ray or X-ray counterparts have been found for it thus far. One TeV source, HESS J1858+020, was found near the SNR and this source is spatially associated with some clouds at 3.6 kpc. To attain a better understanding of the origin of HESS J1858+020, we further investigate the association between SNR cosmic rays (CRs) and the clouds through the Fermi-LAT analysis and hadronic modeling.

We carried out an analysis the Fermi-LAT data at SNR G35.6−0.4 and discovered two GeV sources using the >5 GeV data. A soft GeV source -SrcX1 is located at the northern edge of the SNR, a hard GeV source-SrcX2 is in spatial coincident with HESS J1858+020 and the molecular cloud complex at east-CloudX2. The spectral index of SrcX1 and SrcX2 are 3.09 ± 0.09 and 2.27 ± 0.14, respectively. The GeV spectrum of SrcX2 connects well with the TeV spectrum of HESS J1858+020. The entire GeV-TeV spectrum of SrcX2 is flat and it covers a wide energy range, from several GeV up to tens of TeV. We find that SNR G35.6−0.4 is possibly a middle-aged SNR, and this argument is supported by three pieces of indirect observational evidence. Firstly, we find that the lack of diffuse X-ray emission, especially for the keV band, is likely due to an intrinsic weak source rather than the heavy absorption. Secondly, if the SrcX2 is indeed powered by the SNR CRs, then the GeV emission found at CloudX2 indicates that CRs with energies down to $\sim$10 GeV have been released from the SNR. Thirdly, the radio index of SNR G35.6−0.4 is much harder than that of a young SNR. However, this evidence is not conclusive and we look forward to future observations of SNR G35.6−0.4. We built a hadronic model to explain the GeV-TeV emission of SrcX2 with SNR CRs. By adopting the acceleration theory of non-resonant streaming instability, our model can generate CRs with energies of $\gtrsim$100 TeV during the early SNR stage. The damping of magnetic waves by the neutrals was adopted for the late SNR stage and it leads to the release of CRs with energies down to $\sim$10 GeV. Our model requires a diffusion coefficient that is much lower than the Galactic value and, in particular, a hard index of diffusion coefficients is needed to suppress the diffusion of early-released TeV CRs.