HESS J1852−000: A Very High Energy Gamma-ray source near the Supernova Remnant Kes 78

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Abstract: Many new sources of very-high-energy (VHE) gamma rays have been discovered thanks to deeper observations in the on-going H.E.S.S. Galactic Plane Survey. Of these new sources, some can be at least tentatively associated with remnants of supernova explosions, which are well-known sites of high-energy particle acceleration. Here, we present a new unidentified gamma-ray source that may be partially associated with either with an interaction of the elongated shell-type SNR Kes 78 with a nearby molecular cloud, or with a previously undiscovered pulsar-wind nebula. Several emission scenarios are discussed along with a multi-wavelength search for counterparts.

Keywords: HESS, VHE, Gamma Ray, Supernova Remnant, unidentified

1 Introduction

The notion of where high-energy cosmic rays are accelerated within our galaxy is one of the fundamental questions in high-energy astrophysics. Very High Energy (VHE) Gamma-ray ($E > 100$ GeV) telescopes are particularly suited to looking for such acceleration sites because VHE gamma rays can only be produced via the same non-thermal processes that accelerate cosmic ray electrons and hadrons above TeV energies and they are not deflected along the light of sight by magnetic fields. The shocks formed by remnants of supernovae are likely acceleration sites for high-energy hadronic cosmic rays, and indeed both shell-type SNRs and pulsar wind nebulae are known VHE gamma-ray emitters. However, differentiating between hadronic (pion decay) and leptonic (inverse-Compton) gamma-ray production mechanisms has so far been difficult. In the case of young SNRs that are interacting with dense molecular cloud targets are currently though to be the best case for observing hadronic-only emission [7]. For this reason, such objects are currently being studied by gamma-ray telescopes. Here we present a new and currently unidentified VHE gamma-ray source, HESS J1852−000, that is close to the shell-type supernova remnant Kes 78 and we explore the possibility that all or part of it can be associated with either the remnant or a pulsar wind nebula.

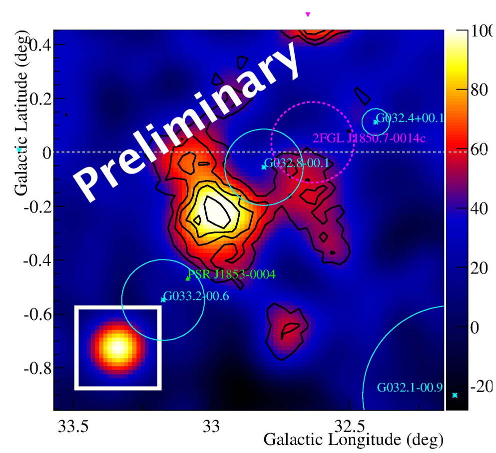

Figure 1: A VHE gamma-ray image (above 500 GeV) of the unidentified source HESS J1852−000. The colors indicate excess gamma rays and are smoothed with a Gaussian of 0.07°. Background is estimated using the ring technique [4]. Overlaid are 3,4,5,6,7 significance contours. The positions and approximate sizes of nearby cataloged objects are shown as points and circles (cyan: Supernova [1], green: pulsars with spin-down flux $\dot{E}/D^2 > 10^{33}\mathrm{ergs}^{-1}\mathrm{kpc}^{-2}$ [2]) , Magenta: sources in the Fermi 2FGL and INTEGRAL catalogs). The smoothing kernel convolved with the PSF is inlaid.

2 H.E.S.S. Observations and Analysis

HESS J1852−000 is an extended, galactic very-high-energy (VHE) gamma-ray source lying close to the Galactic plane, centered at approximately RA=$18^{\rm h}52^{\rm m}13^{\rm s}$, Dec=$-00°00'23''$ (J2000). It was detected after deeper observations in the region covered by the HESS Galactic Plane Survey, which currently spans $\pm3°$ in galactic longitude and about $\pm80°$ in latitude. HESS is an imaging atmospheric Cherenkov telescope array that is sensitive to gamma rays from a few hundred GeV to about 100 TeV (the energy threshold is predominantly dependent on the night sky backgroun level, the zenith angle of the pointing and the offset in the FOV). For details of the HESS instrument, see e.g. [3]

Since the source was not known *a priori*, the data set is comprised of survey-mode observations (centered on regular grid points withing the survey region) combined with fixed-target observations of several nearby objects. Because of this, the distribution of the radial offset of HESS J1852−000 and the pointing position for each exposure is quite broad and much of the data were taken with the source near the edge of the field of view. Such observations may introduce significant systematic error for energy reconstruction, but nevertheless are fairly robust for source detection. The source was detected in a blind search, with a statistical significance of over 8σ, well above the trials-factor corrected threshold for source detection in the HESS Survey.

The background-subtracted excess gamma-ray image shown in Figure 1 combines approximately 80 hours of observations (50 hours of offset-corrected exposure at the center of the image). The data were analyzed using a standard Hillas-parameter-based analysis, with gamma-ray candidate events were selected using *hard cuts* [3], which provide a better signal to noise at the expense of a higher energy threshold. The remaining cosmic ray background was modeled from the surrounding region using the *ring* technique [4], using an adaptive ring radius at each image position to maximize statistics while excluding nearby known sources. To reduce statistical fluctuations, the image was smoothed with a Gaussian kernel with $\sigma = 0.07°$, which is approximately the instrumental PSF for this data set. The morphology of the peak of the emission is not consistent with the PSF of the instrument, and can be reasonably modeled with a sum of two elongated Gaussians, suggesting the source is not point-like. Additionally there is a low-significance (4σ pre-trials) extension toward western galactic longitude that may be associated with the source, or may simply a statistical fluctuation.

A spectral analysis was also performed using the *reflected region* technique [4], using a circular on-source region that encloses the entire significant emission shown in the figure (with a radius of $0.45°$). The integral flux of the emission in the energy range $1-10$ TeV is $(3\pm1)\cdot10^{-12}\,{\rm erg\,cm^{-2}\,s^{-1}}$.

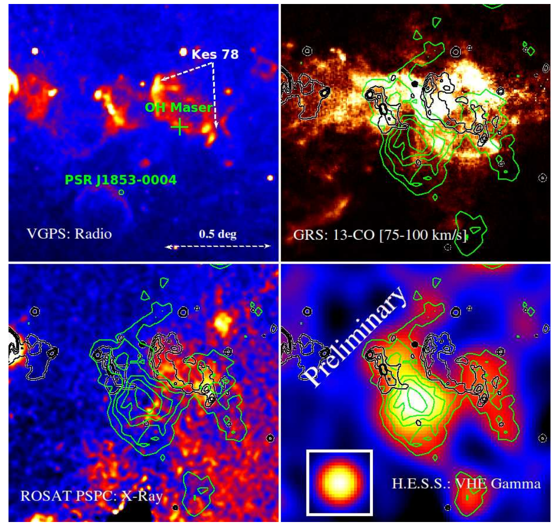

Figure 2: Multi-wavelength view of the region around HESS J1852−000. The radio shell of the SNR is shown in the upper-left panel, and is overlaid on the GRS ^{13}CO image (integrated over a velocity range that includes the OH maser and cloud), as well as on the smoothed ROSAT/ PSPC count map and the H.E.S.S. smoothed excess count map as in Figure 1, with 3 to 7 σ significance contours in green.

3 Multi-wavelength Counterpart Search

A catalog search was made around the position of the HESS source covering likely Galactic VHE gamma-ray emission candidates: high-spin-down-power pulsars, X-ray binaries, Wolf-Rayet stars, supernova remnants, pulsar wind nebulae, and Fermi-GST (1FGL and 2FGL) sources. While no obvious counterpart was found that matches the position and morphology of HESS J1852−000, the emission lies close to the rim of supernova remnant Kes 78, the high spindown-power pulsar PSR J1853−0004, and the Fermi point source 2FGL J1850.7-0014c.

Figure 2 shows a comparison of the HESS emission with existing Radio (VLA), X-ray (ROSAT), and ^{13}CO (GRS) data. For the latter, a velocity profile was made around the HESS source, and the resulting map was integrated over the largest peak in the distribution, which also corresponds to the velocity range of an OH maser associated with the SNR Kes 78 [5].

The extended morphology of the HESS source is difficult to characterize and given the statistics and large PSF, no statement can be made on whether it is a single source, or a collection of overlapping emission regions. In comparison with the multi-wavelength picture, the following points can qualitatively be made:

- The ROSAT data shows weak X-ray emission near one of the radio hot spots on the rim of Kes 78, which is positionally coincident with the weak 4-sigma extension of the HESS source toward Galactic West and lies partially within the error circle of 1FGL J1850.7-0014c.

- The peak of the HESS emission excluding the western extension is slightly offset from the rim of Kes 78.
- The peak of the HESS emission above 500 GeV is not coincident with the peak of the ^{13}CO emission in the velocity range near the OH maser line. This emission may not be at the same distance as the HESS source, however.

4 Possible Emission Scenarios

Though no clear counterpart to HESS J1852−000 has been found in searches of existing multi-wavelength data and catalogs, we can propose two possible scenarios based on experience with other extended VHE gamma-ray sources detected in the Galactic Plane. The first is that all or part of the VHE emission is connected to high-energy cosmic rays produced by supernova remnant Kes 78, and the second is that it is related to an undiscovered pulsar wind nebula associated with either the nearby pulsar PSR J1853−0004 or to some as-yet-undetected pulsar. As with all extended sources in the galactic plane, there is also the possibility of source confusion, and that more than one process is responsible for the observed emission.

4.1 Supernova-Molecular Cloud Interaction

The nearby object Kes 78 is a shell-type supernova with an unusually elongated morphology ($10' \times 20'$) [1], which may indicate that it is expanding into a non-uniform surrounding medium. The presence of an 1720 MHz OH maser on the rim of the remnant (at V=$90\,\mathrm{km\,s^{-1}}$) [5], is indication that the shock of Kes 78 is interacting with surrounding molecular material. The line-of-sight magnetic field at the maser position is measured to be 1.5 ± 0.3uG [5], similar to values measured for W44, W28, and Sgr A East. Assuming the remnant is at the same distance as the maser, it is surrounded by a ring of molecular cloud material, as can be seen traced by ^{13}CO emission in Figure 2.

High-energy cosmic rays escaping supernova remnants are predicted to produce VHE emission in the case where they are interacting with giant molecular clouds (e.g. [6], [7]). This scenario has been used to explain the emission in other VHE sources, for example W28/HESS J1801−233 [8], W51/HESS J1923+141 [9], CTB 37A/HESS J1714−385 [10]. However, though there is significant VHE emission near the OH maser in Kes 78, the emission extends well beyond the region of the molecular material, therefore this scenario may only explain part of the observed emission; or it may be that the SNR is not at the assumed distance, or that ^{13}CO is not a good tracer of the target material.

The presence of GeV gamma-ray emission (the Fermi source 2FGL J1850.7-0014c) near the rim of Kes 78 may simply be coincidental - the source is associated in the 2FGL catalog instead with the SNR G32.4+00.1, which is well outside the VHE emission region.

4.2 Gamma-ray Pulsar Wind Nebula

A growing number of previously-unidentified extended, galactic, VHE sources have been revealed to be pulsar wind nebulae (PWNe) that had not yet been detected at longer wavelengths (e.g. [12]). VHE PWNe are typically found around pulsars with a spindown-flux of $\dot{E}/D^2 > 10^{34}\,\mathrm{erg\,s^{-1}\,Mpc^{-1}}$ [11]. A common characteristic of these sources is that the peak of the VHE emission is not centered on the pulsar position, but offset by up to 0.5. If the nearby energetic pulsar PSR J1853−0004 ($\dot{E} = 2.1 \times 10^{35}\,\mathrm{erg\,s^{-1}}$, $D = 6.58\,\mathrm{kpc}$) powers a VHE nebula, it would require a fairly high ($\simeq 20\%$) efficiency for converting spin-down-power to gamma-ray luminosity compared with other VHE PWNe to explain the observed emission. Additionally, the nebula would also have an unusually large offset from the pulsar position (of nearly $0.5°$, $\simeq 60$ pc).

4.3 Comments

Deeper VHE observations of HESS J1852−000 (ongoing) will provide the increased statistics needed to do a better morphological and spectral study of the object, and will likely help us to constrain the nature of this new gamma-ray source and on the processes that accelerate high-energy cosmic rays in our galaxy.

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