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Abstract. Positron annihilation radiation from the Galaxy has been observed by the OSSE, SMM and TGRS instruments. Improved spectral modeling of OSSE observations has allowed studies of the distribution of both positron annihilation radiation components, the narrow line emission at 511 keV and the positronium continuum emission. The results derived for each individual annihilation component are then compared with each other. These comparisons reveal approximate agreement between the distribution of these two emissions. In certain regions of the sky (notably in the vicinity of the previously reported positive latitude enhancement), the distribution of the emissions differ. We discuss these differences and the methods currently being employed to understand whether the differences are physical or a systematic error in the present analysis.

I INTRODUCTION

Nine years of observations made with the Oriented Scintillation Spectrometer Experiment (OSSE) on-board NASA's COMPTON observatory (1991-2000) [1], eight years of observations made with the Gamma-Ray Spectrometer on-board the Solar Maximum Mission (SMM) (1980-1989) [2], and two years of observations made with the Transient Gamma-Ray Spectrometer (TGRS) on-board the WIND mission (1995-1997) [3] have been utilized to study the galactic distribution of positron annihilation radiation. The OSSE instrument featured a 3.8° x 11.4° FWHM FoV, a $\sim$3 x 10^{-5} photons cm^{-2} s^{-1} line sensitivity (10^6 s on-source time), and a 45 keV energy resolution at 511 keV. These detector attributes have permitted the first detailed studies of the distribution of annihilation radiation in the inner radian of the Galaxy. The annihilation of positrons with electrons gives rise to two spectral features, a line emission at 511 keV and a positronium continuum emission (which increases in intensity with energy roughly as a power law up to 511 keV and falls abruptly to zero above 511 keV) [4]. The TGRS instrument, which featured a germanium detectors with excellent energy resolution, has demonstrated that the integrated flux from the inner radian is best described as a narrow 511 keV line (FWHM $\leq$ 1.8 keV) and a positronium continuum to 511 keV line ratio of $\sim$ 3.6 (which corresponds to a positronium fraction of f_{Ps}=0.94) [3].

Purcell et al. (1997) (hereafter PURC97) [6] reported results from OSSE/SMM/TGRS studies of the 511 keV line component of annihilation radiation. They found the 511 keV emission to be comprised of three components; 1) an intense bulge emission, 2) a fainter disk emission, and 3) an enhancement of emission at positive latitudes (hereafter called a PLE). The PLE was also reported by Cheng et al. (1997) [7], and has been interpreted to be an "annihilation fountain" by Dermer & Skibo [8]. PURC97 characterized the emission via mapping, employing the SVD matrix inversion algorithm, and via model fitting, testing the combination of a spheroidal Gaussian bulge, a disk that is flat in longitude to $\pm 40°$ and Gaussian in latitude (FWHM = 9°), and a spheroidal PLE. The two characterizations differ in the thickness of the Gaussian disk (SVD being narrower) and the extension of the PLE. The enhancement of the PLE differed between the two characterizations, varying from 1.5 x 10^{-4} photons cm^{-2} s^{-1} for the SVD map to 9 x 10^{-4} photons cm^{-2} s^{-1} for the broad 2D Gaussian PLE (FWHM = 16.4°). A parallel study of both line and continuum annihilation radiation along the galactic plane by Kinzer et al. (1996,2001) [9,10] reported that positronium continuum emission is similarly distributed as 511 keV line emission. The Kinzer studies did not investigate the PLE.

We report here updates from our continuing analysis which extends the study of PURC97 (see also Milne et al. (1998,1999) [11,12]). The primary differences between current studies and PURC97 are; 1) the inclusion of more observations, both archival and data collected after PURC97, and 2) reporting maps of the positronium continuum emission in addition to the 511 keV line. To extract the positronium continuum component from the underlying galactic continuum emission, we widened the spectral modeling to include thermal bremsstrahlung and exponentially-truncated power-law models. We also removed high-energy diffuse continuum emission following a prescription from Kinzer et al. (1999), distributing the emission spectrally according to an α = -1.65 power-law and spatially according to a 90° x 5° 2D Gaussian [13]. Two maps of the 511 keV line emission and two maps of the positronium continuum emission are shown in Figure 1.

II DISCUSSION

Although not identical, the two 511 keV maps share certain fundamental features. Both exhibit an intense bulge emission and a fainter planar emission. The regions that appear anomalous in the RL map (relative to symmetrical bulge and disk emissions) are also anomalous in the SVD map. The positronium continuum maps are also dominated by an intense bulge and a fainter disk component. Pairings of bulge and disk components suggest the same families of solutions. Both suggest

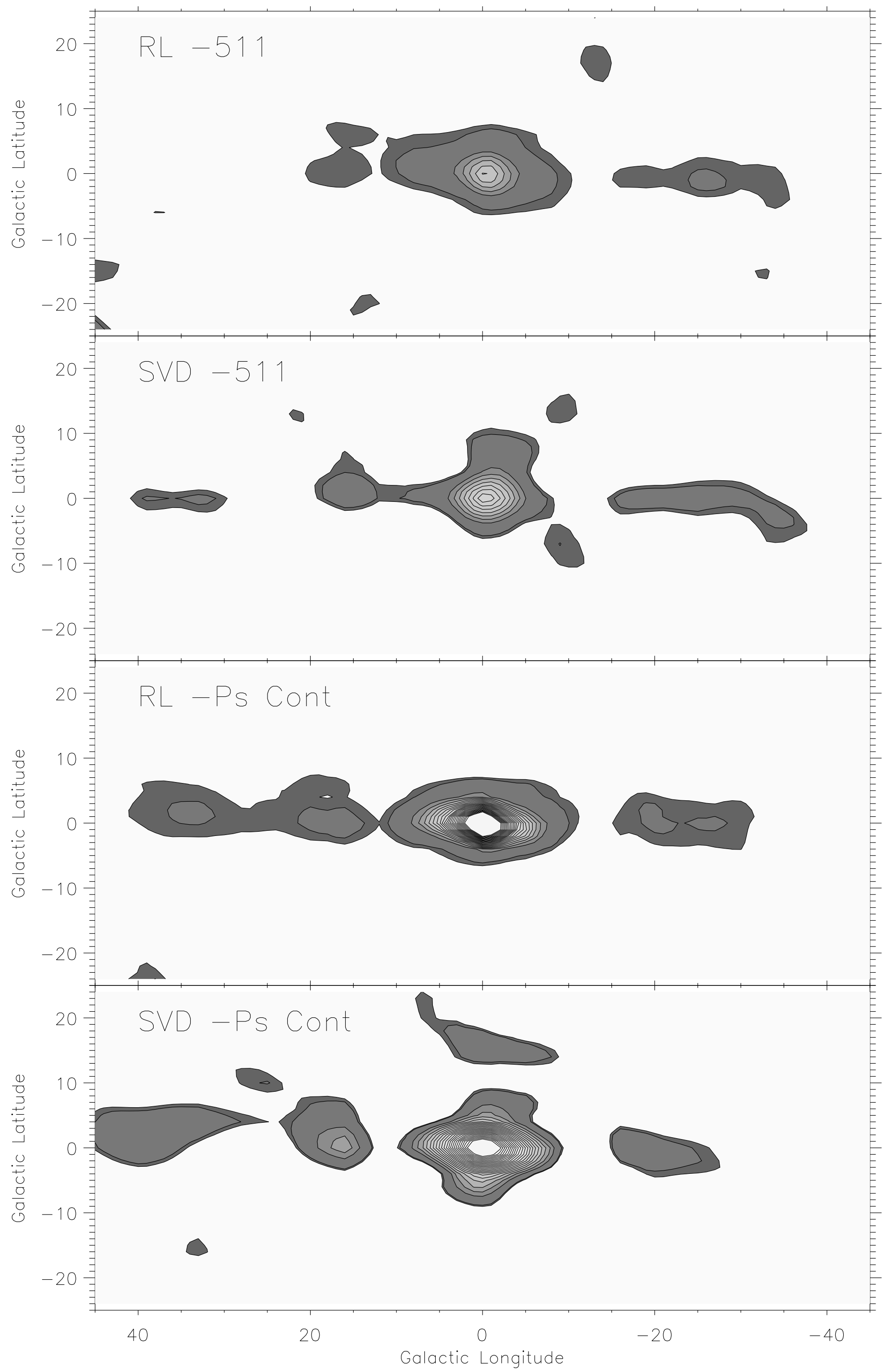

FIGURE 1. Four characterizations of positron annihilation radiation. The upper two panels are Richardson-Lucy and SVD maps of 511 keV line emission. The lower two panels are Richardson-Lucy and SVD maps of positronium continuum emission.

that the bulge-to-disk ratio can vary from 0.2 -3 depending upon whether the bulge component features a halo (which leads to a large B/D). The most noticeable difference between the four maps is how the PLE is characterized.

Both mapping algorithms suggest enhancement of 511 keV line emission from the region reported in PURC97, although at lower flux levels ($\leq$ 1.0 x 10^{-4} photons cm^{-2} s^{-1}). The broad 2D Gaussian PLE described in PURC97 is *not* an acceptable solution; the quality of fit is much worse than solutions without a PLE. By contrast, there is no suggestion of a PLE at the location reported in PURC97 (l, b = -2°, 7°) in either of the positronium continuum maps. Shown in Figure 2 are 1° wide cuts cuts through the four maps, taken at 70° relative to the negative-longitude galactic plane. It is apparent that the four curves are consistent with the same distribution towards negative latitudes, but differ at positive latitudes. The lower panel of Figure 2 shows the positive latitude cut after subtraction of the mirror negative latitude cut. The enhancement at 511 keV has a corresponding *deficit* for positronium continuum for both mapping algorithms.

An enhancement of 511 keV emission that is due to an additional source of positrons (relative to the Galaxy-wide bulge and disk components) would be expected to feature an enhancement of both annihilation components. For the lowest f_{Ps} value of zero, we would expect the positronium continuum emission to be symmetric and the 511 keV line emission to be enhanced. A positronium continuum *deficit* at positive latitudes would not be expected. If, alternatively, the PLE is a region with no excess of positrons but is where the local f_{Ps} varies from the integrated f_{Ps}=0.94 (suggested both by OSSE analysis [10], and by wide FoV germanium detectors [3]), then the 511 keV line emission could be enhanced and the positronium continuum emission could be deficient. However, variations of the f_{Ps} it do not conserve photon flux. The 1:1 enhancement-to-deficit ratio suggested in Figure 2b would not be expected. A third possibility is that the enhancement is instead due to the influence of gamma-ray sources that corrupt the spectral fitting. Two possible mechanisms for this biasing could be from observations made while a source is exhibiting a hard X-ray flare, and/or if the source exhibits a previously undetected hard tail. The fact that both the line and positronium continuum components peak at 511 keV combined with the 45 keV FWHM energy resolution of the OSSE instrument mean that as many as 30% of the counts at that energy are due to positronium continuum photons. It is unclear whether flaring gamma-ray sources can bias the the spectral fitting to a large enough extent to entirely account for the apparent asymmetry in the annihilation radiation.

A few compact sources which produce this type of biasing have been identified. At the present time, it has not been established which of the three explanations is correct. The CGRO/BATSE instrument made observations of these sources which were nearly simultaneous with the OSSE observations [14]. It is an objective of the current analysis effort to determine whether joint analysis of OSSE & BATSE observations of these sources will permit the unambiguous extraction of annihilation radiation from this complex environment. Fortunately, although other regions of the inner galactic radian may be similarly biased, the majority of the region is not

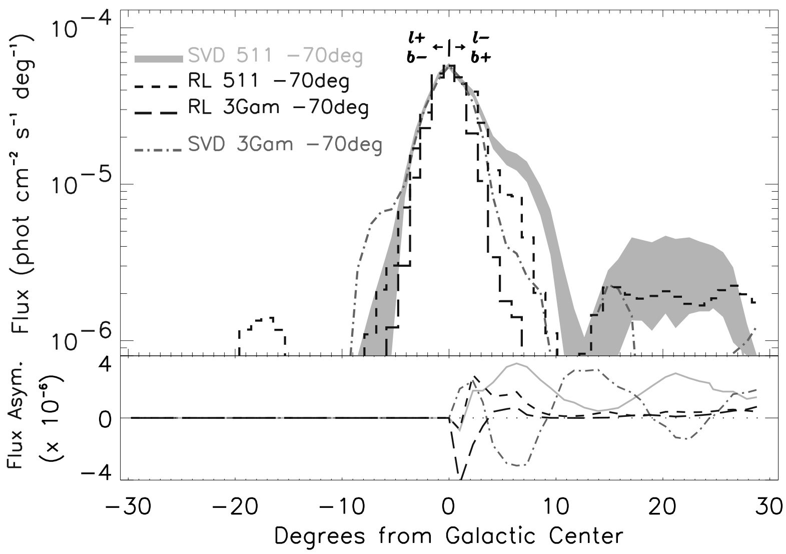

FIGURE 2. Cuts through the positive latitude enhancement taken at 70° relative to the negative-longitude galactic plane displayed on a logarithmic scale. Shown in the upper panel is a 1° wide cut through the RL and SVD maps of line and continuum annihilation radiation. The SVD -511 maps shows 1σ error bars. The lower panel shows the positive latitude portion of the cuts with the mirror negative latitude portion subtracted off.

expected to have been affected. The wealth of information available both from the complete OSSE data-set as well as from the expanding data-set of monitoring of compact sources with the BATSE instrument may permit definitive statements as to the galactic distribution of positron annihilation radiation, particularly of the existence of a PLE.

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