GCNEWS

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Edited by Robin Herrnstein, Cornelia Lang, Joseph Lazio, Sera Markoff, Rainer Schödel & Loránt Sjouwerman

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Very-High-Energy Gamma-Ray Emission from the Galactic Center

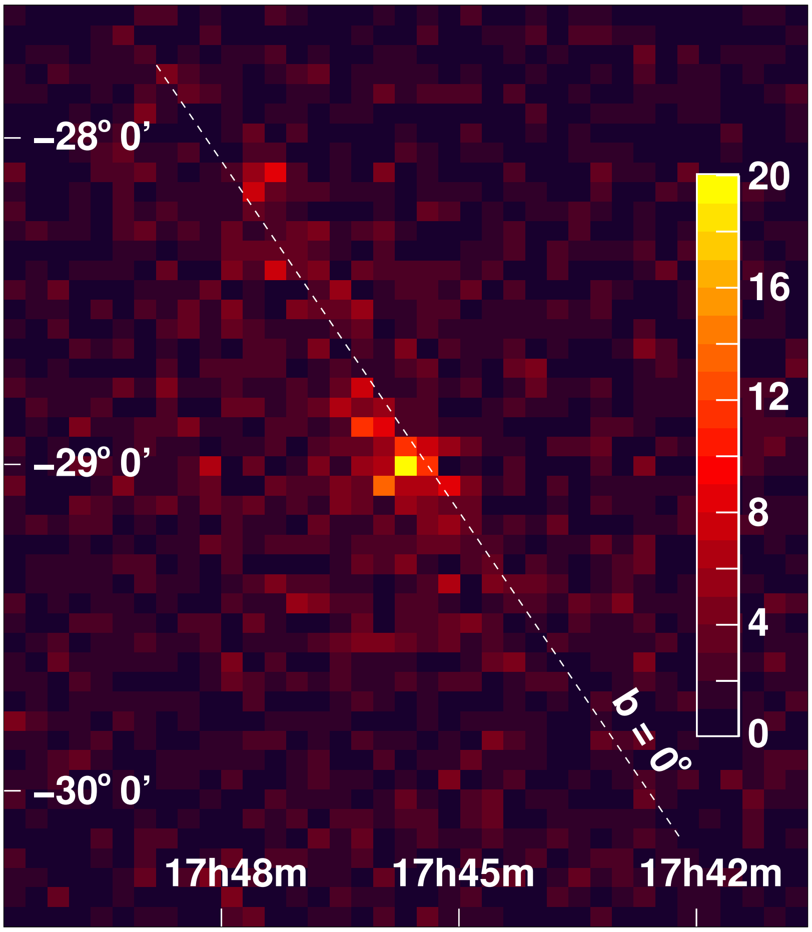

Figure 1 **b** from Buckley’s invited article: Image of excess events from the Galactic Center region made with HESS telescope array (Aharonian et al. 2004).

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In the News

Robin Herrnstein, Joseph Lazio, & Sera Markoff

Welcome to the first GCNEWS of 2005!

As always, please feel free to contact any of us with GC newsworthy items and/or future article ideas. We also remind our readers to *please submit their abstracts* to GCNEWS. As you know, GCNEWS promises rapid delivery of your results to fellow GC researchers. With dozens of *astro-ph* abstracts each day, it is easy for a listing to be overlooked. GCNEWS is a great way to ensure that your paper is noticed by people with an acknowledged interest in GC science. Instructions for abstract submission can be found at:
http://www.aoc.nrao.edu/~gcnews/home/submission.shtml

In this Volume

In this volume, we report on the winter meeting of the American Astronomical Society as well as highlight a number of upcoming GC-related conferences.

We are excited to have an invited review article by James Buckley, in which he updates us on very high energy γ-ray emission from the GC as observed by Whipple, HESS, and CANGAROO. He discusses the most likely sources for the observed emission and looks at prospects for the future including the VERITAS array.

Finally, we've received a number of GC abstracts this winter (but we could always use more!), and they are listed at the end of the issue.

January 2005 AAS Cameos

As usual, there was a strong GC presence at the winter AAS meeting in San Diego (January 9–13). In addition to various papers describing new instruments that may be valuable for future GC research, there were a host of papers summarizing results from current work. We describe briefly those papers with a GC component at the AAS meeting, with apologies to anybody whose work we might have missed. We give the AAS paper number in parentheses at the end of each summary.

Sgr A* attracted a fair amount of attention:

- Hornstein et al. conducted a coordinated monitoring campaign and found infrared but no X-ray variations. They also suggest that the infrared colors of Sgr A* are consistent with synchrotron emission. (24.04)
- Ghez et al. presented the first laser guide star adaptive optics imaging of the GC. Such observations offer considerable promise, and they have already found previously undetected extended emission around Sgr A*. (24.06)
- Dermer & Atoyan suggest that Sgr A* may be surrounded by a non-thermal nebula ("plerion") responsible, in part, for the TeV gamma-ray emission seen from the GC by the HESS telescope. (32.01)
- Nord et al. presented the lowest frequency detection to date of Sgr A* (at 330 MHz) along with a plethora of new nonthermal magnetic filaments. (32.03)
- Marrone et al. detected polarized emission from Sgr A* in observations with the Submillimeter Array at 340 GHz. Because of their use of an interferometer, they were able to reduce the potential contamination from dust emission, and they suggest that the Faraday rotation that they measure is too low to be explained by an ADAF onto Sgr A*. (32.04)
- Darren Dowell et al. also reported on submillimeter observations of Sgr A*, using SHARC II on the Caltech Submillimeter Observatory, and search for potential variability at these wavelengths. (32.05)

The stars in the GC, and particularly the central stellar cluster, had their share of observations and modelling:

- In an effort to explain how the young, hot stars in the central cluster were pulled into orbit around Sgr A*, Berukoff & Hansen conducted N-body simulations of the interaction between Sgr A* and a stellar cluster containing an intermediate-mass black hole. (24.02)
- Oh et al. used near-IR photometry and spectroscopy to identify the spectral class of stars and try to map out the mass distribution in the central regions. (24.03)
- Fickenscher et al. are using moderate resolution, near-IR spectroscopy to try to identify a more normal population of stars in the central cluster with the aim studying aspects such as the mass function and age of the cluster. (24.05)

- De Pree et al. observed what may someday be another massive cluster in the GC. By studying the H 52α recombination line, they identified a number of potential ultracompact and hypercompact H II regions in Sgr B2. Their results are consistent with an ionized outflow from high mass stars. (24.07)
- Muno et al. find a substantial overabundance of X-ray transients within the central parsecs, using Chandra, though the nature of these transients is not yet known. (32.06)
- Laycock et al. continued the Chandra Multiwavelength Project (ChaMPlane) with a series of near-IR observations designed to separate foreground X-ray sources from those in the GC. (32.08)
- Lu et al. reported the discovery a new cluster of stars within the central parsec, IRS 16SW. This is only the second cluster which is consistent with being gravitationally bound to Sgr A*. (85.06)

The various phases of the interstellar medium attracted attention from numerous groups:

- Moerchen et al. used near- to mid-IR observations to probe the dust heating in the central parsec, and compared their results to the nearby Galaxy M82. (24.01)
- LaRosa et al. argued that the amount of low radio frequency emission (at 74 and 330 MHz) from the GC is too low to be consistent with a milliGauss magnetic field strength, as is usually assumed. (32.07)
- Tothill, on behalf of the AST/RO team, reported on a survey of millimeter- and sub-millimeter–wavelength emission from the GC. (140.05)

Finally,

- Finkbeiner argued that the WMAP observations could not only yield information about the distant Universe, but also about the central regions of the Galaxy. He found an excess of emission toward the inner Galaxy/Galactic center that he attributes to WIMP annihilation. (82.01)
- Teegarden et al. used INTEGRAL observations to revisit the claim that the inner Galaxy/Galactic center may be a source of electron-position annihilation radiation. (84.07)

Upcoming GC Meetings

The Paradoxes of Massive Black Holes: 2005 April 14–16

This conference on the Galactic Center will be held at the Kavli Institute for Theoretical Physics, 2005 April 14–16. Its focus will be on the twin puzzles of (1) star formation and the young stellar population in the central parsec of the Galactic Center, and (2) the "luminous" source Sagittarius A* associated with the massive black hole in the Galactic Center. Recent observations have revealed many surprising results on massive stars in the central part of our Galaxy, especially in the vicinity of the supermassive black hole. How these stars form and survive so close to a massive black hole is a major unsolved mystery. Equally remarkable are the observational results on radiation from gas in the vicinity of the massive black hole, including rapid IR and X-ray flaring. The Galactic Center is also one of the most important testing grounds for theoretical models of gas dynamics in the vicinity of black holes. Our goal is to bring together scientists with expertise in the Galactic Center, star formation and stellar dynamics, and accretion disks and jets to discuss these results. We expect a very exciting conference, with adequate time for discussions and debate of the forefront issues in the field.

A list of confirmed speakers is available at the conference website http://www.kitp.ucsb.edu/activities/galactic_c05/?id=320. Because of the very limited time for speakers, there are regrettably no opportunities for contributed talks. There will however be several joint discussions and poster sessions where research may be presented. Poster presenters will be able to bring up relevant slides during discussion as well. We strongly encourage attendance from the Galactic Center community. Email Eliot Quataert (eliot@astron.berkeley.edu) if you are interested in giving a poster.

Please register for the conference now at the web address given above. If you have any questions, please contact Andrea Ghez (ghez@astro.UCLA.EDU), Sera Markoff (sera@space.mit.edu), or Eliot Quataert (eliot@astron.berkeley.edu).

We hope you can all join us in lovely Santa Barbara.

High Energy Phenomena in the Galactic Center: 2005 June

This conference is organized within the framework of the Institute of Astro-Particle physics and Cosmology workshop 2005 and is intended as an international meeting for in depth discussion of the recent results obtained from the high energy observations of the Galactic Center (GC) region, in particular the results from Chandra, XMM-Newton, INTEGRAL and HESS on the emission from the central few degrees ($\sim$ 500 pc) of the Galaxy.

Chandra and XMM-Newton have now drawn the maps of the X-ray emission of the region, with the discovery of a large population of point sources and several bright new transients, with the morphological and spectral (both line and continuum) characterization of the diffuse emission, with the detection of non-thermal shells and filaments and the study of both quiescent and flaring activity of Sgr A*, the GC super massive black hole (SMBH).

INTEGRAL has revealed the presence of emission at energies > 20 keV from the center of the Galaxy and HESS has discovered a TeV source also coincident with the position of Sgr A*. The INTEGRAL and HESS gamma-ray sources are still not unequivocally associated to one of the sources of region and the contribution from the SMBH or other objects in the Sgr A complex is presently a matter of study and discussions. Other sources like G0.9+0.1 have been detected with HESS in the region, while on a much larger scale INTEGRAL is defining the characteristics of the 511 keV line emission from the Galactic bulge.

To disantangle these contributions and understand physical processes taking place in the GC, it is also important to consider results from observations at lower energies, in particular at infrared and radio/sub-mm frequencies. Efforts to perform coordinated multiwavelength observations in particular of Sgr A* have been done in the last years. In 2005 June a number of new results from the 2004 (or even the early 2005) observation campaign will be available and it will be possible to present and discuss all these data and try to assess a number of open questions.

This conference will be dedicated to discussing recent advances on the observations and models of the massive BH, Sgr A*, on the characteristics and origin of the diffuse X-ray emission, the role of the non thermal sources of the region like Sgr A East to the high energy phenomena taking place in the Center of the Galaxy. But we would also like to discuss the implications that the TeV HESS and the 511 keV INTEGRAL observations have on models involving dark matter annihilation or generation of fluxes of neutrinos in the central regions.

The conference is part of the APC workshop. As such its program will favor discussion between astrophysicists, particle physicists and theoreticians and therefore a number of review talks on the main topics are proposed. The talks will be mainly invited reviews (30–40 min.) or solicited contributions (20–30 min.). We can possibly accomodate a few other proposed oral contributions from participants but the program will not be generally open to contributed papers.

The related APC workshop includes a set of lectures and courses for students, post-docs and researchers of the Parisian area.

For more information on either the workshop or the conference, please see http://apc-p7.org/HEP_GC/.

Very-High-Energy Gamma-Ray Emission from the Galactic Center

J. Buckley [1]

[1] *Department of Physics, Washington University, St. Louis, MO 63130, USA; buckley@wuphys.wustl.edu*

1 Introduction

Any optical, radio, or X-ray astronomer is well aware of the large number of astronomical objects that can lie within any typical few-arcminute patch on the sky, but for gamma-ray astronomy, where a point-spread function of 0.1 degree is typical, an association is often claimed if a source lies in the general neighborhood of a favorite candidate. As there are very few of the extreme variety of sources capable of producing TeV photons in the entire sky (perhaps 10 at last count) source confusion is usually not a problem; typically the most violent object in the neighborhood is the likely suspect. For AGNs, a clear identification has often been possible by association of the gamma-ray spectral or temporal properties of the source with measurements in the X-ray waveband. In one supernova remnant, SNR RXJ1713.7−3946, a clear association was made based on the resolved gamma-ray image of the source showing a shell morphology that matched the X-ray and radio observations (Aharonian et al., 2004b). However, there are other sources in the Galactic plane where an association has not been possible (to date there are 170 or so EGRET unidentified sources and one TeV unidentified source).

Currently, there are four different detections of GeV-TeV gamma-ray emission from the Galactic Center (GC) region, and many have naturally tried to attribute all of these to a single source (e.g., Sgr A*) or to a single emission mechanism. However, for the time being, all of these detections might better be considered as separate unidentified sources until definitive associations are made. More work is also required to mitigate against potential sources of systematic error in these measurements. Of course observations of the GC are particularly complicated since, in addition to the massive black hole Sgr A*, the GC region contains a dense cluster of stars and compact stellar remnants (including low-mass X-ray binaries and black hole candidates), molecular clouds, and a large structure that may be the remnant of a powerful supernova, Sgr A East (Fatuzzo & Melia, 2003).

To anticipate what might be learned from the very-high-energy (VHE) measurements, we can turn to lessons learned from observations of active galaxies and Galactic sources. It is quite possible that in every case that we have detected TeV emission, we have observed photons produced by a single mechanism: inverse-Compton scattering of low-energy photons by high-energy electrons. While a hadronic component (e.g., π^0-decay gamma-rays) might be possible for some of the Galactic sources, there is still no compelling evidence for anything besides a leptonic component. While the VHE production mechanisms may well lack diversity, for many of these sources observation of this new spectral component has provided important new physical constraints on the emission region. In general, the TeV observations have provided much more than an esoteric measurement of the tail of steeply declining power-law spectrum.

For the gamma-ray blazars Markarian 421, Markarian 501, and 1ES1959+650, for example, multiwavelength observations have revealed correlated X-ray and TeV variability and have produced important new information about the nonthermal emission mechanisms at play and about the physical parameters in the relativistic jet (Buckley et al., 1996; Catanese et al., 1997; Fossati et al., 2004). For both Mrk 421 and Mrk 501 it now appears that the VHE gamma-ray emission is cospatial with the source of the rapid X-ray flaring, and that the VHE gamma-ray component is produced by inverse-Compton scattering by the same population of electrons responsible for producing the X-ray synchrotron emission. Thus, the gamma-ray observations provide a separate constraint on the maximum electron energy that can be used to break degeneracies in the physical parameters inferred from the synchrotron component alone. Observations of correlated hour-scale flares indicated magnetic fields of a fraction of a Gauss, and very high Doppler factors ranging from 20–100 (e.g., Buckley (1999)). If electrons are accelerated in the vicinity of the GC, VHE gamma-ray observations of a new inverse-Compton component could yield similar constraints.

A number of astrophysical mechanisms could be responsible for the high-energy emission from the region around Sgr A* including: π^0 decay gamma-rays from shock accelerated protons (Fatuzzo & Melia, 2003), inverse-Compton scattering by very high-energy electrons accelerated in a super-plerionic wind termination shock (Atoyan & Dermer, 2004), high-energy IC emission from electrons accelerated in the accretion disk or by shocks in a (misaligned) jet of Sgr A*.

High-energy gamma-ray observations of the GC are also the subject of particular interest to physicists given the possibility of detecting the signature of annihilating dark matter in the inner halo of our galaxy (e.g., Bergström, Ullio, & Buckley (1998)). Sgr A*, at the dynamical center of our Galaxy, may well be surrounded by a cusp or spike in the dark matter halo distribution (e.g., Dubinski & Carlberg (1991); Navarro, Frenk, & White (1996); Gondolo & Silk (1999); Merritt (2003)). Annihilation of these hypothetical weakly interacting massive particles (typically, neutralinos) could also contribute to the luminosity in the vicinity of Sgr A* in the radio through gamma-ray waveband. Annihilation of dark matter would be enhanced by a factor proportional to the density squared, and might result in an observable gamma-ray line (from direct annihilation to gamma rays) as well as continuum emission (from secondary products of annihilation to quarks and fermions) (Silk & Bloemen, 1987; Bergstrom, 1989; Giudice & Griest, 1989; Jungman & Kamionkowski, 1995). The presence of the massive black hole and dense stellar cluster could further steepen the density profile of the dark matter halo, producing very high radio and gamma-ray fluxes that in some cases even exceed the current observational upper bounds (Gondolo & Silk, 1999; Merritt, 2004; Gnedin & Primack, 2004). The details of the halo model on scales < 100 pc and the formation history of the central black hole are critical to predicting the gamma-ray flux, but are, unfortunately, still poorly understood.

The very high-energy extent of the GC spectrum, if it really comes from dark matter annihilation, would point to a very massive neutralino, with rest mass above roughly 10 TeV, beyond the range of theoretical expectations for the likely mass range. While this mass does not yet violate unitarity or other fundamental cosmological constraints, it probably requires a degree of fine tuning in the model parameters that stretches credibility. On the other hand, it is good to keep in mind the wealth of data that point to nonbaryonic dark matter in our galaxy. Measurements of galactic rotation curves and the X-ray emitting gas in clusters point to a dark matter component whose gravitational influence exceeds that of visible matter by an order of magnitude. Self-consistent models of structure formation require cold dark matter, and typically predict a power-law halo density distribution with a central cusp. Primordial nucleosynthesis and recent CMBR measurements point to nonbaryonic dark matter. If we really believe in the existence of abundant nonbaryonic dark matter, it is not unreasonable to expect us one day to detect it.

2 Experimental Results

2.1 EGRET

The EGRET experiment on board the *Compton Gamma-Ray Observatory* detected a strong (unidentified) source of >100 MeV gamma-rays marginally consistent with the position of the GC (Hartman et al., 1999; Mayer-Hasselwander et al., 1998). More recently, Hooper & Dingus (2002) and Pohl (2004) re-analyzed the higher energy (GeV) gamma-ray data from this source and have found that the most likely position of the EGRET source may be offset from Sgr A*. All three of these results point to a hard spectrum that softens significantly or even cuts off above a few GeV. Both of the new analyses reach similar conclusions that the position of Sgr A* is excluded at the $\sim$95% confidence level. Systematic uncertainties in the gamma-ray background models, possible source confusion and limited angular resolution make the analysis of the source in the GC region difficult, however. Nonetheless, Dingus, Pohl, and others from the EGRET instrument team seem confident that at GeV energies such effects should be small, and the offset source position appears to be a solid experimental result. In any event, the GLAST experiment, with its improved angular resolution and sensitivity should make a significant contribution to understanding this region. In particular, the self-vetoing effect that dramatically limited the effective area of EGRET above $\sim$ 10 GeV will not be a problem for GLAST. This should enable GLAST to make use of the larger number of detected GeV photons to better pinpoint and resolve the Galactic Center and to determine the shape of the spectral cutoff.

2.2 Atmospheric Cherenkov Telescopes

Imaging Atmospheric Cherenkov Telescopes, like the Whipple, HESS, and CANGAROO ground-based gamma-ray observatories, detect high-energy photons by imaging the flashes of Cherenkov light emitted as gamma-rays interact in the Earth's atmosphere. Imaging Cherenkov telescopes consist of large reflectors (10–13 m diameter) that focus the faint UV/blue Cherenkov flashes onto photomultiplier-tube cameras. These cameras have fields of view of several degrees. Off-line software analysis characterizes each candidate shower image, and separates signal (gamma-ray-like) from background (cosmic-ray-like) events based on the shape and orientation of the Cherenkov images. The event reconstruction determines the point of origin and energy of each gamma-ray event. For the GC observations, both the CANGAROO and Whipple experiments employed a single telescope with a single photon angular resolution of between 0.1 and 0.2 degrees. The HESS observations utilized stereoscopic imaging with two and then four 13-m atmospheric Cherenkov telescopes (as the array came on line). The use of stereoscopic imaging results in a dramatic reduction in background, provides better energy resolution and angular resolution and allows the energy threshold to be substantially reduced (from perhaps 350 GeV for a single 10-m class telescope to 100 GeV for the full HESS array).

CANGAROO (located in Woomera, Australia) and HESS (located in Namibia) are both southern hemisphere instruments, making them well situated for observations of the GC. The GC transits at a very large zenith angle (61°) as seen from the Whipple Observatory (31.7° N latitude). This significantly alters the shower geometry and threshold energy, and requires a modified data analysis procedure. To properly account for the effects of large-zenith-angle (LZA) observations, the Whipple group developed a new set of gamma-ray selection criteria that scale with zenith angle and energy according to empirical scaling laws derived from detailed simulations of large-zenith-angle gamma-rays. The gamma-ray selection criteria were then optimized on contemporaneous observations of the Crab Nebula observed over the same range of zenith angles. The Crab Nebula was used for optimization and calibration because it is a bright, steady gamma-ray source with a known spectrum. This a-priori method was then applied to the GC data and to an independent set of LZA Crab data for normalization.

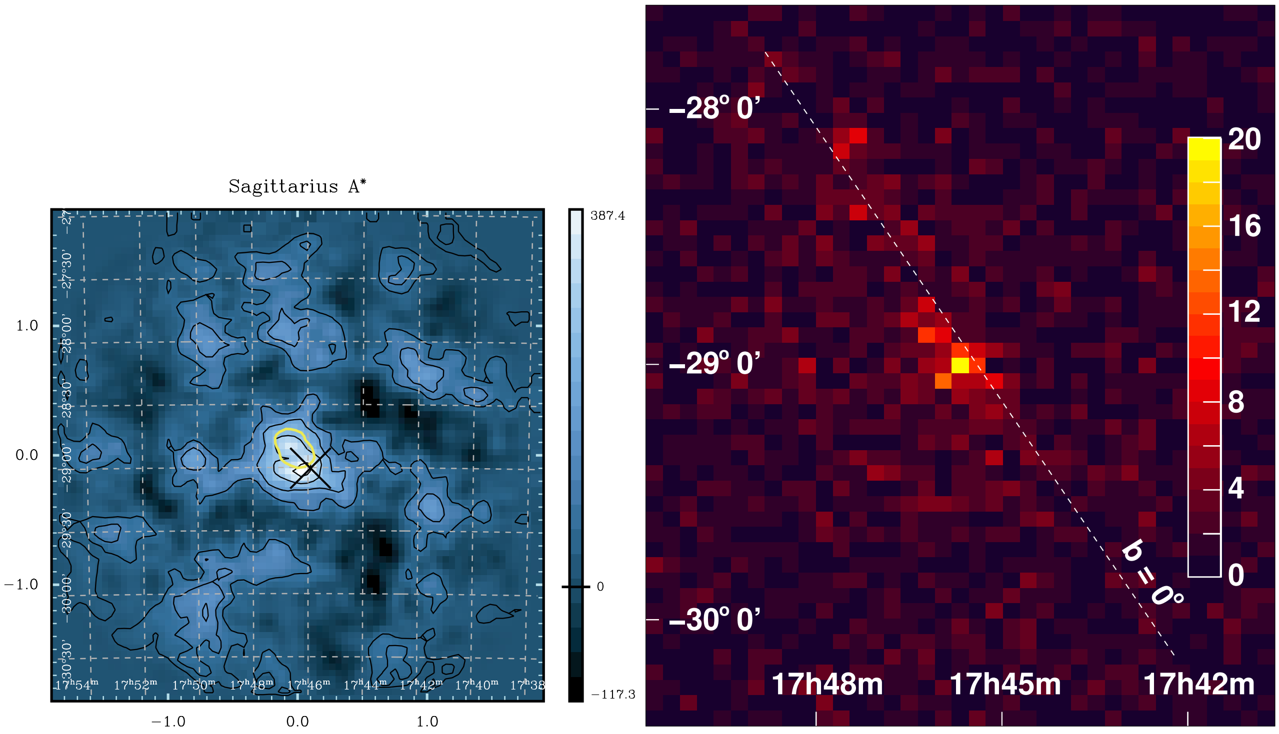

Figure 1 *Left:* Whipple image of TeV emission from the region around Sgr A* (Kosack et al., 2004b). The image is of excess counts (ON-source minus OFF-source) falling within a circular aperture at each grid point and is overlaid with significance contours (1 standard deviation per contour). Also shown as the light yellow contour is the 99% confidence region for the EGRET observations (Hooper & Dingus , 2002). *Right:* Image of excess events from the GC region with HESS telescope array (Aharonian et al., 2004a).

While the Whipple detection is weak (about a 4σ result), the Whipple data on the GC are unique in that they provided the first evidence for a TeV source, and cover a 10 year period from 1994 to 2004. The first hint of a TeV signal from the GC was a 2.5σ excess (interpreted as an upper limit) seen in Whipple data taken before 1997 (Buckley et. al., 1997). A positive signal from the source was seen in every subsequent epoch. In the results presented in the Kosack et al. (2004b) paper, all observations of Sgr A* from 1995 through 2003 were combined to obtain 26 hours of ON-source exposure (and 26 hours of matching OFF-source observations at an average zenith angle of 61°).

Figure 1 shows the resulting 2-D map of gamma-ray excess with overlaid significance contours. The position of Sgr A* is plotted as a cross in the image. This image shows a 4.2 standard deviation (σ) excess at the corrected center position. To check the robustness of this result, we re-ran the analysis ten times to account for variations due to the Gaussian padding procedure (see below). We found the average significance at the corrected center position is $(3.7 \pm 0.13)\ \sigma$, somewhat below the initial result. Subsequent to the original result, (Kosack et al., 2004c) included additional data from the 2005 season and performed a more detailed spectral analysis, and more careful calculation of the LZA Crab flux (used for normalization). This more careful analysis resulted in a lower flux (0.2 Crab rather than 0.4 Crab) and flat spectrum. This result will be described in detail in a subsequent VERITAS collaboration paper in preparation. Figure 2 shows the preliminary spectrum (Kosack et al., 2004c) along with the spectrum of the contemporaneous LZA Crab data and the HESS GC result.

The HESS group detected emission consistent with a point-like source of gamma-rays within $1'$ of Sgr A*. They found that the gamma-ray spectrum was a power-law with spectral index $-2.2 \pm 0.09 \pm 0.15$ and a flux of $1.82 \pm 0.22 \times 10^{-7}\mathrm{m}^{-2}\mathrm{s}^{-1}$. Figure 1 shows a two dimensional histogram of gamma-ray events detected with HESS around the position of the galactic center. To date the HESS group has not made a definitive statement about a possible extended component along the Galactic plane that may be present in this figure, but new results based on additional data taken with the four-telescope array should be forthcoming (perhaps by the time of the printing of this article.) The HESS result had a high significance ($> 9\sigma$) and, together with the Whipple detection, provides the first *confirmed* high-confidence detection of a TeV source in the GC.

About the same time the Whipple result was first announced (Kosack et al., 2004a) the CANGAROO group announced the detection of the GC at energies above 250 GeV with the CANGAROO-II IACT. This result is essentially identical to the earlier preliminary analysis presented by (Tsuchiya et al., 2003) in a poster presentation at the International Cosmic-Ray Conference. The CANGAROO group found the flux to be about 0.1 Crab at 1 TeV, with a very soft spectrum $\approx E^{-4.6\pm0.5}$. It is difficult to reconcile this result with the HESS and Whipple results unless this result corresponds to another nearby source, or there is some systematic error in the spectral reconstruction. Significant differences are seen in the HESS and CANGAROO observations of other sources as well. For the time being, it is probably simplest to attribute the CANGAROO detection to some other source.

One particular difficulty in observing the GC with a single atmospheric Cherenkov telescope comes from the considerable difference in sky-brightness between the ON-source region (centered on Sgr A*) and the OFF-source region (used for background subtraction). The diffuse brightness of the Galactic plane as well as light from discrete stars contributes Poisson noise to the Cherenkov images. This excess noise can promote (or demote) image pixels above the analysis threshold and result in a substantial systematic bias in the number of misidentified background cosmic-ray events in the ON and OFF-source regions. To compensate for this bias, the Whipple group uses a technique known as *software padding*. During a data run, artificial triggers are injected throughout the duration of the ON and OFF-source exposures. These artificially-triggered events, which contain no Cherenkov images, provide a measure of the Poisson fluctuations in the background light. In the subsequent off-line analysis, random Gaussian deviates are added to the corresponding image pixels in the ON and OFF source runs to guarantee that the same amount of noise is present in matching pixels in both runs. After this procedure, only pixels with signals well above the noise level are included in further image processing. This Gaussian *padding* combined with a high software trigger threshold largely removes systematic biases arising from brightness differences, but increases the energy threshold and decreases the sensitivity. Thus the method reduces systematic errors at a cost of reducing statistical significance; for this reason other groups have typically not employed this method. Neglecting to take this effect into account can have a dramatic effect. For example, when the Whipple group first observed G78.2+2.1 (a supernova remnant in the Cygnus region) we initially obtained an excess of 6σ. After the above procedure was applied, the excess vanished and the final result was within one standard deviation of the null hypothesis. Fortunately, telescope arrays such as HESS are largely immune to this bias, due to the improved background rejection and multiple images of a single shower with different parallactic displacements with respect to the background star-light distribution.

To determine the probability for steady emission, a χ^2 fit of a constant function was applied to the Whipple GC data and, for comparison, to a series of data taken of Mrk 421 (a source which is known to be highly variable) at a similar zenith angle range as Sgr A*. The total significance of this Mrk 421 data sample was 2.3σ. The Sgr A* data yielded a constant count rate of $0.22 \pm 0.05\ \gamma \cdot \mathrm{min}^{-1}$ with a reduced χ^2 of 1.13 (with 54 degrees of freedom), a remarkably good fit considering the changes in the Whipple instrument over the period of observations. The result for Mrk 421 yielded a constant count rate of $0.25 \pm 0.21\ \gamma \cdot \mathrm{min}^{-1}$ with a reduced χ^2 of 3.03 (with 6 degrees of freedom). In this case, there is only a 1.2% chance of obtaining a χ^2 value this large or larger if there is no variability. While this method is by no means statistically rigorous, together with the agreement of the Whipple and HESS

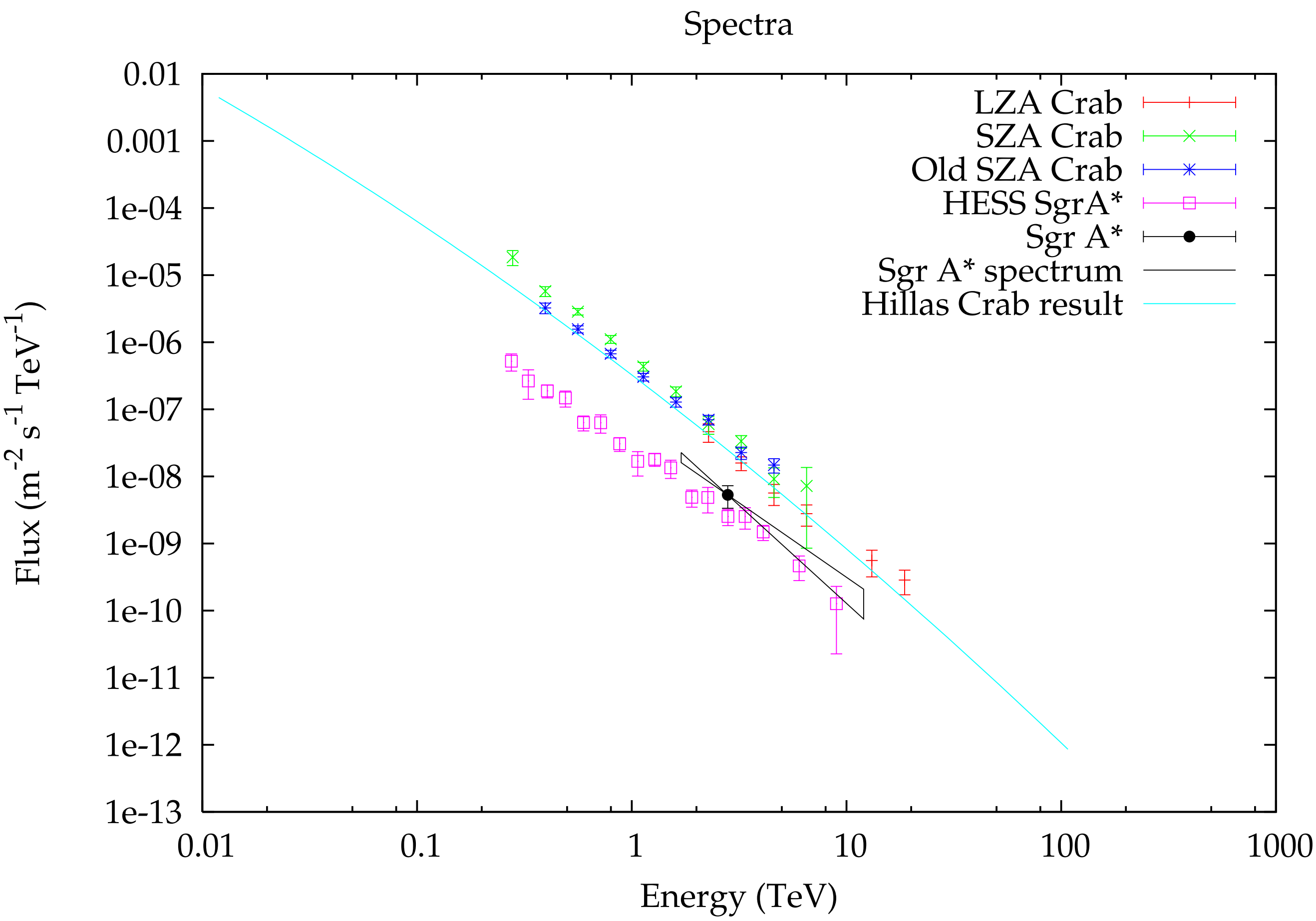

Figure 2 Plot comparing the GC spectrum measured with the HESS experiment (Aharonian et al., 2004a) and Whipple (bow-tie) (from (Kosack et al., 2004c)). Also shown for reference is the spectrum of the Crab Nebula, from both small-zenith angle and contemporaneous large-zenith angle data. The LZA Crab data were obtained at the same range of zenith angles as the GC and the spectrum analyzed by the same method as that used to derive the GC spectrum. The reconstructed Whipple Crab spectrum is in excellent agreement with the spectral fit determined by (Hillas et al., 1998) for the Crab nebula (shown as the solid curve).

results, this analysis provides some indication that the VHE GC source is not dramatically time variable.

3 Discussion

I've argued that the EGRET GeV source, CANGAROO detection, and Whipple/HESS source constitute three distinct, as yet, unidentified sources. The Whipple and HESS results now appear to be consistent, and indicate a relatively steady flat-spectrum source with emission extending up above 3 TeV. The HESS results indicate that this source is within $1'$ of Sgr A*. The high level of apparent brightness ≈ 0.2 Crab, at a distance of roughly four times that of the Crab Nebula, qualifies this as an unusually luminous Galactic source. Previous TeV observations of relatively nearby Galactic sources such as X-ray binaries and shell-type and plerionic supernovae have produced numerous upper-limits, or (at best) unconfirmed detections, making the detection of such an object at 8.5 kpc even more unlikely. If the Sgr A East supernova shock were the source of the EGRET gamma rays or the TeV detection, it would have been an unusually intense explosion (Khokhlov & Melia, 1996) and a density of 1000 cm^{-3} and magnetic field of $B \sim 0.18$ mG (well above the canonical values) would be required (Fatuzzo & Melia, 2003). While a typical Galactic source such as an SNR, pulsar, or stellar mass black hole is unlikely, an association with Sgr A* is still

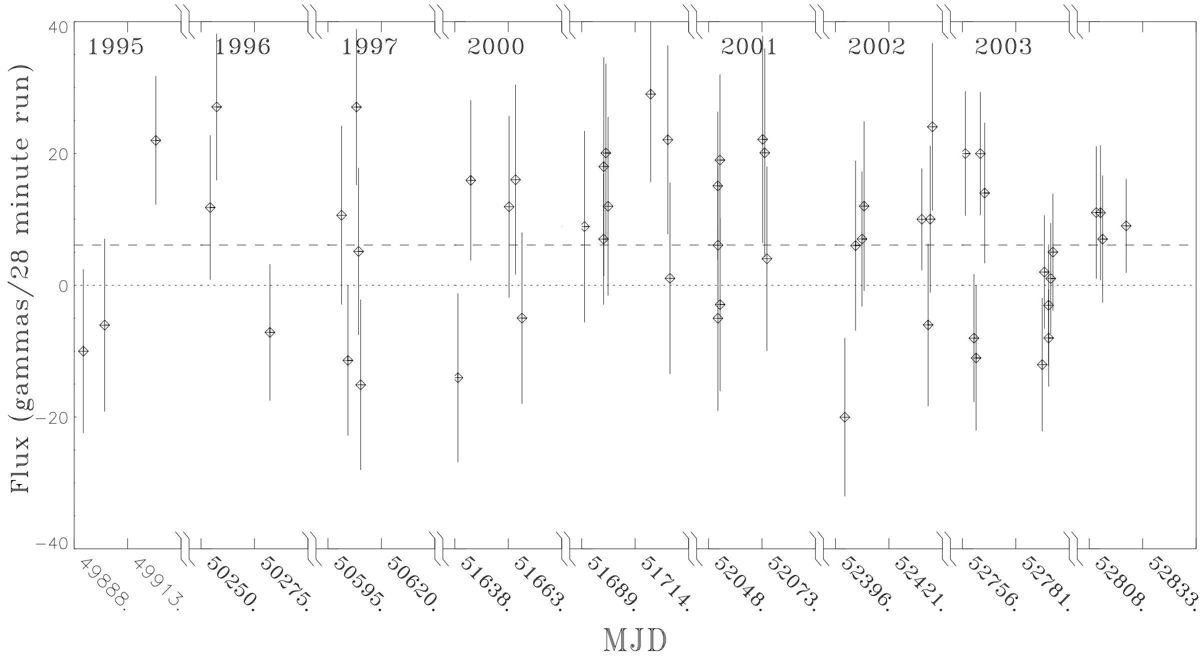

Figure 3 Flux of Sgr A* as a function of time (Kosack et al., 2004a). Each data point represents a single 28 minute run. Time gaps in the data have been removed where indicated. The dashed line is a least squares fit of a constant function to the data.

a viable possibility and the detection of correlated variability in future gamma-ray and X-ray observations could make the identification compelling. If we associate this emission with either the super-massive black hole Sgr A* or the associated black-hole plerion, for example, the observed emission could come from self-Compton scattering by electrons with energies up to at least 2.8 TeV or from pion-decay gamma-rays from primary protons of even higher energy (kinematics require their energy to be at least several times the maximum gamma-ray energy). The lack of significant variability and the consistency with the GC position allow more exotic possibilities such as the annihilation of very high mass (> 10 TeV) dark matter particles at the GC.

Looking forward to the future, new atmospheric telescope arrays such as HESS, CANGAROO, and VERITAS should make dramatic improvements in our understanding of the complex region in our GC. The HESS Cherenkov telescope array has demonstrated a sensitivity of $\approx 1\sigma \ \mathrm{min}^{-1/2}\sqrt{t_{\mathrm{min}}}$ for a 100 mCrab source at an energy of 100 GeV. When the VERITAS array is complete, we can expect a very similar sensitivity for northern hemisphere sources. While the GC is a southern source it will also be visible with the VERITAS telescope array, currently under construction at Kitt Peak National Observatory in Arizona. At larger zenith angles, the distance to *shower-max* (the point where the electromagnetic shower reaches its maximum development) increases and the Cherenkov light pool spreads over a larger area. This results in an increase in energy threshold by a factor of about 6, but it also results in an increase in the effective area by a factor of ≈4. Thus we might expect VERITAS to have an energy threshold of about 600 GeV for the GC, but to have a better sensitivity (per unit observing time) above this energy by a factor of $\sqrt{4}$ compared with small-zenith angle HESS observations. As can be seen in Figure 2, the statistical errors of the HESS array and Whipple telescope are comparable above a few TeV. However, the HESS spectral points should be considered of higher quality than the Whipple results, since the improved background rejection afforded by stereoscopic reconstruction means that these results are limited by photon-counting, while the Whipple results are still very much background dominated and therefore susceptible to systematic biases. Clearly stereo reconstruction beats large zenith-angle observations for high-energy sensitivity. But when the VERITAS array is completed in 2006, it might well provide better high-energy sensitivity per unit observing time than HESS, making it a valuable additional component of scheduled multiwavelength campaigns on the GC region.

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References

Aharonian, F. A., et al. 2004a, A&A, 425, L13
Aharonian, F. A., et al. 2004b, Nat., 432, 75
Atoyan, A., & Dermer, C. D. 2004, ApJ, 617, L123
Bergstrom, L. 1989, Particle Astrophysics: Forefront Experimental Issues, 255
Bergström, L., Ullio, P., & Buckley, J. H. 1998, Astroparticle Physics, 9, 137
Buckley, J. H., et al. 1996, ApJ, 472, L9
Buckley, J. H. et al. 1997, Proceedings of 25th ICRC (Durban) 3, 237.
Buckley, J. H. 1999, Astroparticle Physics, 11, 119
Catanese, M., et al. 1997, ApJ, 487, L143
Dubinski, J. & Carlberg, R. G. 1991, ApJ, 378, 496
Fatuzzo, M. &Melia, F. 2003, ApJ
Fossati, G., Buckley, J., Edelson, R. A., Horns, D., & Jordan, M. 2004, New Astronomy Review, 48, 419
Giudice, G. F. & Griest, K. 1989, Phys. Rev. D, 40, 2549
Gnedin, O. Y., & Primack, J. R. 2004, Physical Review Letters, 93, 061302
Gondolo, P. & Silk, J. 1999, Physical Review Letters, 83, 1719
Hartman, R. C. et al. 1999, ApJS, 123, 79
Hillas, A. M., et al. 1998, ApJ, 503, 744
Hooper, D. and B. Dingus, 2002, astro-ph/0212509.
Jungman, G. & Kamionkowski, M. 1995, Phys. Rev. D, 51, 3121
Khokhlov, A. & Melia, F. 1996, ApJ, 457, L61
Kosack, K. et al. 2004a, astro-ph/0403422
Kosack, K. et al. 2004b, ApJ, 608, L97
Kosack, K. et al., 2004c, AAS/High Energy Astrophysics, 8, 1509
Krennrich, F. etal. 1999, ApJ, 511, 149
Lessard, R. W., Buckley, J. H.,Connaughton, V., & Le Bohec, S. 2001, Astroparticle Physics, 15, 1
Liu, S. & Melia, F. 2002, ApJ, 566, L77
Mayer-Hasselwander, H. A. et al. 1998, A&A, 335, 161
Merritt, D. 2004, Physical Review Letters, 92, 201304
Merritt, D. 2003, astro-ph/0311594
Mohanty, G., et al. 1998, Astroparticle Physics, 9, 15
Navarro, J. F., Frenk, C. S., & White, S. D. M. 1996, ApJ, 462, 563
Pohl, M. 2004, astro-ph/0412603
Schödel, R. et al. 2002, Nat., 419, 694
Silk, J. & Bloemen, H. 1987, ApJ, 313, L47
Tanimori, T. etal. 1994, ApJ, 429, L61
Tsuchiya, K. et al. 2003. Proceedings 28th ICRC (Tsukuba).
Tsuchiya, K., et al. 2004, ApJ, 606, L115
Yuan, F., Markoff, S., & Falcke, H. 2002, A&A, 383, 854
Yuan, F., Quataert, E., & Narayan, R. 2003, astro-ph/0304125

Abstracts

A disk in the Galactic Center in the past?

Emmi Meyer-Hofmeister, Friedrich Meyer and Bifang Liu

Max-Planck-Institut für Astrophysik, Garching, Germany

We raise the question whether in the past a disk could have existed in our Galactic Center which has disappeared now. Our model for the interaction of a cool disk and a hot corona above (Liu et al. 2004) allows to estimate an upper limit for the mass that might have been present in a putative accretion disk after a last star forming event, but would now have evaporated by coronal action.

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Email: emm@MPA-Garching.MPG.DE
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A λ20cm Survey of the Galactic Center Region I: Detection of Numerous Linear Filaments

F. Yusef-Zadeh[1] J. Hewitt[1] W. Cotton[2]

(1) Department of Physics and Astronomy, Northwestern University, Evanston, Il. 60208 (zadeh@northwestern.edu, j-hewitt@northwestern.edu) (2) National Radio Astronomy Observatory, Charlottesville, VA 22903 (bcotton@nrao.edu)

This is a first in a series of papers presenting a sensitive λ20cm VLA continuum survey of the Galactic center region using new and archival data based on multi-configuration observations taken with relatively uniform *uv* coverage. The high dynamic range images cover the regions within $-2^\circ < l < 5^\circ$ and $-40' < b < 40'$ with a spatial resolution of $\approx 30''$ and $10''$. The wide field imaging technique is used to construct a low-resolution mosaic of 40 overlapping pointings. The mosaic image includes the Effelsburg observations filling the low spatial frequency *uv* data. We also present high resolution images of twenty three overlapping fields using DnC and CnB array configurations. These high-resolution images are sensitive to both compact and extended continuum features with a wide range of angular scales with rms noise of 0.2 mJy beam^{-1} in the outer parts of the Galactic center region. The survey has resulted in a catalog of 345 discrete sources as well as 140 images revealing structural details of HII regions, SNRs, pulsar wind nebulae and more than 80 linear filaments distributed toward the complex region of the Galactic center. These observations show the evidence for an order of magnitude increase in the number of faint linear filaments with typical lengths of few arcminutes. Many of the filaments show morphological characteristics similar to the Galactic center nonthermal radio filaments (NRFs). The linear filaments are not isolated but are generally clustered in star forming regions where prominent NRFs had been detected previously. The extensions of many of these linear filaments appear to terminate at either a compact source or a resolved shell-like thermal source. A relationship between the filaments, the compact and extended thermal sources as well as a lack of preferred orientation for many RFs should constrain models that are proposed to explain the origin of nonthermal radio filaments in the Galactic center.

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Email: zadeh@northwestern.edu
Eprint: astro-ph/0409292

TeV Emission from the Galactic Center Black-Hole Plerion

Armen Atoyan[1] and Charles D. Dermer[2]

(1) CRM, Université de Montréal, C.P. 6128, Montréal, Canada H3C 3J7; atoyan@crm.umontreal.ca (2) E O. Hulburt Center for Space Research, Code 7653, Naval Research Laboratory, Washington, DC 20375-5352; dermer@gamma.nrl.navy.mil

The HESS collaboration recently reported highly significant detection of TeV γ-rays coincident with Sgr A*. In the context of other Galactic Center (GC) observations, this points to the following scenario: In the extreme advection-dominated accretion flow (ADAF) regime of the GC black hole (BH), synchrotron radio/sub-mm emission of $\sim 100\,MeV$ electrons emanates from an inefficiently radiating turbu-

lent magnetized corona within 20 R_S (Schwarzschild radii) of the GCBH. These electrons are accelerated through second-order Fermi processes by MHD turbulence, as suggested by Liu et al. (2004). Closer to the innermost stable orbit of the ADAF, instabilities and shocks within the flow inject power-law electrons through first-order Fermi acceleration to make synchrotron X-ray flares observed with Chandra, XMM, and INTEGRAL. A subrelativistic MHD wind subtending a $\sim 1\,sr$ cone with power $\gtrsim 10^{37}\,erg\,s^{-1}$ is driven by the ADAF from the vicinity of the GCBH. As in pulsar powered plerions, electrons are accelerated at the wind termination shock, at $\gtrsim 10^{16.5}$ cm from the GCBH, and Compton-scatter the ADAF and the far infra-red (FIR) dust radiation to TeV energies. The synchrotron radiation of these electrons forms the quiescent X-ray source resolved by Chandra. The radio counterpart of this TeV/X-ray plerion, formed when the injected electrons cool on timescales of $\gtrsim 10^4\,yrs$, could explain the origin of nonthermal radio emission in the pc-scale bar of the radio nebula Sgr A West.

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Email: atoyan@CRM.UMontreal.CA
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Variable Linear Polarization from Sagittarius A*: Evidence for a Hot Turbulent Accretion Flow

Geoffrey C. Bower[1], *Heino Falcke*[2], *Melvyn C.H. Wright*[1], *Donald C. Backer*[1]

(1)Astronomy Department & Radio Astronomy Laboratory, Berkeley (2)Radio Observatory Westerbork, The Netherlands

We report the discovery of variability in the linear polarization from the Galactic Center black hole source, Sagittarius A*. New polarimetry obtained with the Berkeley-Illinois-Maryland Association array at a wavelength of 1.3 mm shows a position angle that differs by 28 ± 5 degrees from observations 6 months prior and then remains stable for 15 months. This difference may be due to a change in the source emission region on a scale of 10 Schwarzschild radii or due to a change of 3×10^5 rad m^{-2} in the rotation measure. We consider a change in the source physics unlikely, however, since we see no corresponding change in the total intensity or polarized intensity fraction. On the other hand, turbulence in the accretion region at a radius ~ 10 to $1000 R_s$ could readily account for the magnitude and time scale of the position angle change.

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Email: gbower@astron.Berkeley.EDU
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Sgr A* in context: daily flares as a probe of the fundamental X-ray emission process in accreting black holes

Sera Markoff

Massachusetts Institute of Technology, Center for Space Research, Rm. NE80-6035, Cambridge, MA 02139

Our central Galactic supermassive black hole, Sgr A*, exists mostly in a very stable, extremely low-luminosity ($\sim 10^{-9} L_{Edd}$), thermal quiescent state, which is interrupted roughly daily by a brief, nonthermal X-ray flare. Because they are not accompanied by significant changes in the radio wavelengths, the flares make Sgr A* unusual in the context of black holes accreting at slightly higher rates. Those sources display a radio/X-ray luminosity correlation whose normalization scales with central mass, and that holds over orders of magnitude in accretion power. There is significant scatter in this correlation, due in part to measurement uncertainties and intrinsic variability. By studying the correlation in sources bracketing Sgr A* in radio luminosity and whose physical parameters are well measured, we can derive a statistical measure of this local scatter. We find that Sgr A* in quiescence and the lower intensity flares fall well below the correlation in X-ray luminosity. The brightest flares are consistent within the scatter, which may indicate an upper bound on the X-ray luminosity. This trend is suggestive of a state transition at the extreme low end of accretion activity, only above which the radio/X-ray correlation is tracked. This scenario is easily testable because it must fulfill three unique observational predictions: 1) As long as Sgr A* remains at its current radio luminosity, no X-ray flare will be seen which statistically exceeds the prediction of the correlation, 2) no source already on the correlation will be seen to flare in the X-rays similar to Sgr A* (i.e., without corresponding increases in the radio luminosity), and 3) sources below a critical accretion rate or luminosity will show similar flares as Sgr A*, on timescales appropriate to their masses.

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Email: sera@space.mit.edu

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An Overabundance of Transient X-ray Binaries within 1 pc of the Galactic Center

M. P. Muno[1,2] *E. Pfahl*[3] *F. K. Baganoff*[4] *W. N. Brandt*[5] *A. Ghez*[1] *J. Lu*[1] *and M. R. Morris*[1]

(1) Department of Physics and Astronomy, University of California, Los Angeles, CA 90095; mmuno@astro.ucla.edu (2) Hubble Fellow (3) Chandra Fellow, Department of Astronomy, University of Virginia, Charlottesville, VA 22904 (4) Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology, Cambridge, MA 02139 (5) Department of Astronomy and Astrophysics, The Pennsylvania State University, University Park, PA 16802

During five years of Chandra observations, we have identified seven X-ray transients located within 23 pc of Sgr A*. These sources each vary in luminosity by more than a factor of 10, and have peak X-ray luminosities greater than 5×10^{33} ergs, which strongly suggests that they are accreting black holes or neutron stars. The peak luminosities of the transients are intermediate between those typically considered outburst and quiescence for X-ray binaries. Remarkably four of these transients lie within only 1 pc of Sgr A*. This implies that, compared to the numbers of similar systems located between 1 and 23 pc, transients are over-abundant by a factor of ≈ 20 per unit stellar mass within 1 pc of Sgr A*. It is likely that the excess transient X-ray sources are low-mass X-ray binaries that were produced, as in the cores of globular clusters, by three-body interactions between binary star systems and either black holes or neutron stars that have been concentrated in the central parsec through dynamical friction. Alternatively, they could be high-mass X-ray binaries that formed among the young stars that are present in the central parsec.

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Email: mmuno@astro.UCLA.EDU
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Weighing the cusp at the Galactic Centre

N. Mouawad [1] *and A. Eckart*[1] *and S. Pfalzner*[1] *and R. Schödel*[1] *and J. Moultaka*[1] *and R. Spurzem*[2]

(1) I. Physikalisches Institut, Universität zu Köln, Zülpicher Str.77, 50937 Köln, Germany (2) Astronomisches Recheninstitut, Mönchhofstr. 12-14, 69120 Heidelberg, Germany

As stars close to the galactic centre have short orbital periods it has been possible to trace large fractions of their orbits in the recent years. Previously the data of the orbit of the star S2 have been fitted with Keplerian orbits corresponding to a massive black hole (MBH) with a mass of M_{BH}=3-4$\times 10^6 M_\odot$ implying an insignificant cusp mass. However, it has also been shown that the central black hole resides in a $\sim$1" diameter stellar cluster of a priori unknown mass. In a spherical potential which is neither Keplerian nor harmonic, orbits will precess resulting in inclined rosetta shaped trajectories on the sky. In this case, the assumption of non-Keplerian orbits is a more physical approach. It is also the only approach through which cusp mass information can be obtained via stellar dynamics of the cusp members. This paper presents the first exemplary modelling efforts in this direction. Using positional and radial data of star S2, we find that there could exist an unobserved extended mass component of several $10^5 M_\odot$ forming a so-called 'cusp' centered on the black hole position. Considering only the fraction of the cusp mass $M_{S2_{apo}}$ within the apo-center of the S2 orbit we find as an upper limit that $M_{S2_{apo}}/(M_{BH} + M_{S2_{apo}}) \leq 0.05$. A large extended cusp mass, if present, is unlikely to be composed of sub-solar mass constituents, but could be explained rather well by a cluster of high M/L stellar remnants, which we find to form a stable configuration.

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A Distinct Structure Inside the Galactic Bar

Shogo Nishiyama[1], *Tetsuya Nagata*[2], *Daisuke Baba*[1], *Yasuaki Haba*[1], *Ryota Kadowaki*[1], *Daisuke Kato*[1], *Mikio Kurita*[1], *Chie Nagashima*[1], *Takahiro Nagayama*[2], *Yuka Murai*[2], *Yasushi Nakajima*[3], *Motohide Tamura*[3], *Hidehiko Nakaya*[4], *Koji Sugitani*[5], *Takahiro Naoi*[6], *Noriyuki Matsunaga*[7], *Toshihiko Tanabe*[7], *Nobuhiko Kusakabe*[8], *Shuji Sato*[1]

(1) Department of Astrophysics, Nagoya University, Nagoya, 464-8602, Japan (2) Department of Astronomy, Kyoto University, Kyoto, 606-8502, Japan (3) National Astronomical Observatory of Japan, Mitaka, 181-8588, Japan (4) Subaru Telescope, National

Astronomical Observatory of Japan, 650 North A'ohoku Place, Hilo, HI 96720, U.S.A. (5) Institute of Natural Science, Nagoya City University, Nagoya, 464-8602, Japan (6) Department of Earth and Planetary Sciences The University of Tokyo, Tokyo, 113-0033, Japan (7) Institute of Astronomy, School of Science, The University of Tokyo, Tokyo, 181-0015, Japan (8) Department of Astronomy and Earth Sciences, Tokyo Gakugei University, Tokyo, 184-8501, Japan

We present the result of a near-infrared (JHK_S) survey along the Galactic plane, $-10.5 \leq l \leq 10.5$ and $b = +1$ deg, with the IRSF 1.4m telescope and the SIRIUS camera. K_S vs. $H - K_S$ color-magnitude diagrams reveal a well-defined population of red clump (RC) stars whose apparent magnitude peak changes continuously along the Galactic plane, from $K_S = 13.4$ at $l = -10$ deg to $K_S = 12.2$ at $l = 10$ deg after dereddening. This variation can be explained by the bar-like structure found in previous studies, but we find an additional inner structure at $\mid l \mid \lesssim 4°$, where the longitude - apparent magnitude relation is distinct from the outer bar, and the apparent magnitude peak changes by only ≈ 0.1 mag over the central 8°. The exact nature of this inner structure is as yet uncertain.

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http://www.z.phys.nagoya-u.ac.jp/~shogo/papers/DistinctStructure.pdf

Stellar Bowshocks in the Northern Arm of the Galactic Center: More Members and Kinematics of the Massive Star Population

A. Tanner[1], A. M. Ghez[1], M. R. Morris[1], and J. C. Christou[2]

(1) UCLA Department of Physics and Astronomy, Los Angeles, CA 90095-1562 (2) Center for Adaptive Optics, Santa Cruz, CA

We present new 2.2 μm diffraction-limited images from the W. M. Keck 10 m and Gemini 8 m telescopes of the cool Galactic Center sources, IRS 1W, 5, 8, 10W, and 21 along with new proper motions for IRS 1W, 10W and 21. These observations were carried out to test the bowshock hypothesis presented by Tanner et al. as an alternative to a very recent (10^4 yr) epoch of star formation within the tidal stream of gas and dust known as the Northern Arm. Resolved asymmetric structure is detected in all the sources, with bowshock morphologies associated with IRS 1W, 5, 8 and 10W. For IRS 1W and 10W, there is an agreement between the position angle of the asymmetry and that of the inferred relative velocity vector of the near-infrared source with respect to the Northern Arm gas, strengthening the bowshock hypothesis. We therefore conclude that the observed morphology is indeed a bowshock generated by sources plowing through the Northern Arm. Furthermore, the large extent of the resolved structures (310-1340 AU), along with their luminosities ($\sim 10^{4-5}$ $L_\odot$), suggests that their central sources are Wolf-Rayet stars, comparable to the broad He emission-line stars, which have strong winds on the order of 1000 km s^{-1}. The bowshock geometry, along with the proper motion measurements, provide three-dimensional orbital solutions for this enigmatic class of objects. The orientations of the orbital planes of IRS 1W and 10W are consistent with that of the putative clockwise plane which has been proposed as a solution for the He I emission-line stars. While these observations eliminate the need to invoke star formation within the Northern Arm, they increase by 10% the total known population of massive, young stars with strong winds, whose origin remains unexplained in the context of the nearby supermassive black hole.

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Angelle.M.Tanner-120278@mailhub.jpl.nasa.gov

Accretion of cool stellar winds on Sgr A∗: another puzzle of the Galactic Centre?

J. Cuadra[1], S. Nayakshin[1], V. Springel[1], & T. Di Matteo[1,2]

(1) Max-Planck-Institut für Astrophysik, Garching, Germany (2) new address: Dept. of Physics, Carnegie Mellon University, Pittsburgh, PA 15213, USA

Sgr A∗ is currently being fed by winds from a cluster of gravitationally bound young mass-loosing stars. Using observational constraints on the orbits, mass loss rates and wind velocities of these stars, we numerically model the distribution of gas in the ~ 0.1–$10''$ region around Sgr A∗. We find that radiative cooling of recently discovered slow winds leads to the formation of many cool filaments and blobs, and to a thin and rather light accretion disc with a scale of about an arcsecond. The disc however does not extend all the way to our inner boundary. Instead, hot X-ray emitting gas dominates the inner

arcsecond. In our simulations, cool streams of gas frequently enter this region on low angular momentum orbits, and are then disrupted and heated up to the ambient hot gas temperature. The accreting gas around Sgr A$*$ is thus two-phase, with a hot component, observable at X-ray wavelengths, and a cool component, which may be responsible for the majority of time variability of Sgr A$*$ emission on hundred and thousand years time-scales.

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Email: jcuadra@ibm-2.MPA-Garching.MPG.DE
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http://www.mpa-garching.mpg.de/~jcuadra/Winds/

SINFONI in the Galactic Center: young stars and IR flares in the central light month

F.Eisenhauer[1], *R.Genzel*[1,2], *T.Alexander*[3,6], *R.Abuter*[1], *T.Paumard*[1], *T.Ott*[1], *A.Gilbert*[1], *S.Gillessen*[1], *M.Horrobin*[1], *S.Trippe*[1], *H.Bonnet*[4], *C.Dumas*[4], *N.Hubin*[4], *A.Kaufer*[4], *M.Kissler-Patig*[4], *G.Monnet*[4], *S.Ströbele*[4], *T.Szeifert*[4], *A.Eckart*[5], *R.Schödel*[5] & *S.Zucker*[3]

(1) Max-Planck-Institut für Extraterrestrische, Garching, Germany (2) Dept. of Physics, University of California, Berkeley, USA (3) Center for Astrophysics, Weizmann Institute of Science, Rehovot, Israel (4) European Southern Observatory, Garching, FRG (5) Physikalisches Institut der Universität Köln, FRG (6) Incumbent of the William Z. and Eda Bess Novic career development chair

We report 75 milli-arcsec resolution, near-IR imaging spectroscopy within the central 30 light days of the Galactic Center, taken with the new adaptive optics assisted, integral field spectrometer SINFONI on the ESO-VLT. To a limiting magnitude of K 16, 9 of 10 stars in the central 0.4″, and 13 of 17 stars out to 0.7″from the central black hole have spectral properties of B0-B9, main sequence stars. Based on the 2.1127μm HeI line width all brighter early type stars have normal rotation velocities, similar to solar neighborhood stars. We combine the new radial velocities with SHARP/NACO astrometry to derive improved 3d stellar orbits for six of these 'S'-stars in the central 0.5″. Their orientations in space appear random. Their orbital planes are not co-aligned with those of the two disks of massive young stars 1-10″from SgrA*. We can thus exclude the hypothesis that the S-stars as a group inhabit the inner regions of these disks. They also cannot have been located/formed in these disks and then migrated inwards within their planes. From the combination of their normal rotation and random orbital orientations we conclude that the S-stars were most likely brought into the central light month by strong individual scattering events. The updated estimate of distance to the Galactic center from the S2 orbit fit is $R_0 = 7.62 \pm 0.32$ kpc, resulting in a central mass value of $3.61 \pm 0.32 \times 10^6 M_\odot$. We happened to catch two smaller flaring events from SgrA* during our spectral observations. The 1.7-2.45μm spectral energy distributions of these flares are fit by a featureless, 'red' power law of spectral index $\alpha' = -4 \pm 1 (S_\nu \approx \nu^{\alpha'})$. The observed spectral slope is in good agreement with synchrotron models in which the infrared emission comes from accelerated non-thermal, high energy electrons in a radiative inefficient accretion flow in the central R 10 Rs region.

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Email: ott@mpe.mpg.de
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A powerful bursting radio source towards the Galactic Center

Scott D. Hyman[1], *T. Joseph W. Lazio*[2], *Namir E. Kassim*[2], *Paul S. Ray*[3], *Craig B. Markwardt*[4] & *Farhad Yusef-Zadeh*[5]

(1) Dept. of Physics and Engineering, Sweet Briar College, Sweet Briar, VA, 24595 (2) Naval Research Laboratory, Code 7213, Washington, DC, 20375-5320 (3) E. O. Hulburt Center for Space Research, Naval Research Laboratory, Washington, DC, 20375 (4) Laboratory for High Energy Astrophyics, NASA Goddard Space Flight Center, Greenbelt, Maryland, 20771 (5) Northwestern University, Dept. of Phyics and Astronomy, Evanston, IL, 60208

Transient astronomical sources are typically powered by compact objects and usually signify highly explosive or dynamic events. While radio astronomy has an impressive record of obtaining high time resolution observations, usually it is achieved in quite narrow fields-of-view. Consequently, the dynamic radio sky is poorly sampled, in contrast to the situation in the X- and γ-ray bands in which wide-field instruments routinely detect transient sources. Here we report a new transient source, GCRT J1745−3009, detected in 2002 during a moderately wide-field radio transient monitoring program of the Galactic center (GC) region at 0.33 GHz. The characteristics of its bursts are unlike those known for any other class of radio transient. If located in or near the GC, its brightness temperature ($\sim 10^{16}$ K) and the implied energy density within GCRT J1745−3009 vastly exceeds that observed in most other classes of radio astronomical sources, and is consistent with coherent emission processes rarely observed. We conclude that GCRT J1745−3009 is the first member of a new class of radio transient sources, the first of possibly many new classes to be identified through current and upcoming radio surveys.

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Email: shyman@sbc.edu
Eprint: astro-ph/0503052

Announcements

New Book: The Formation of Stars

Wiley-VCH announces the publication of The Formation of Stars, by Steven W. Stahler and Francesco Palla. This book is a comprehensive treatment of star formation, one of the most active fields of modern astronomy. The reader is guided through the subject in a logically compelling manner. Starting from a general description of stars and interstellar clouds, the authors delineate the earliest phases of stellar evolution. They discuss formation activity not only in the Milky Way, but also in other galaxies, both now and in the remote past. Theory and observation are thoroughly integrated, with the aid of numerous figures and images. In summary, this book is an invaluable resource, both as a text for physics and astronomy graduate students, and as a reference for professional scientists.

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MODEST-6

MOdelling DEnse STellar Systems 6 (MODEST-6) will be held at Northwestern University on August 29-31, 2005. In the tradition of previous MODEST meetings, this meeting will be a genuine workshop, with plenty of time for discussions and collaborations.
For more information go to http://www.astro.northwestern.edu/MODEST6/ .

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Sera Markoff
MIT Center for Space Research
sera@space.mit.edu

Loránt Sjouwerman
National Radio Astronomy Observatory
lsjouwer@aoc.nrao.edu

Joseph Lazio
Naval Research Laboratory
joseph.lazio@nrl.navy.mil

Cornelia Lang
University of Iowa
cornelia-lang@uiowa.edu

Rainer Schödel
Universität zu Köln
rainer@ph1.uni-koeln.de

Robin Herrnstein
Columbia University
herrnstein@astro.columbia.edu

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