GCNEWS

The Newsletter of Galactic Center Research

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The H.E.S.S. View of the Galactic Center

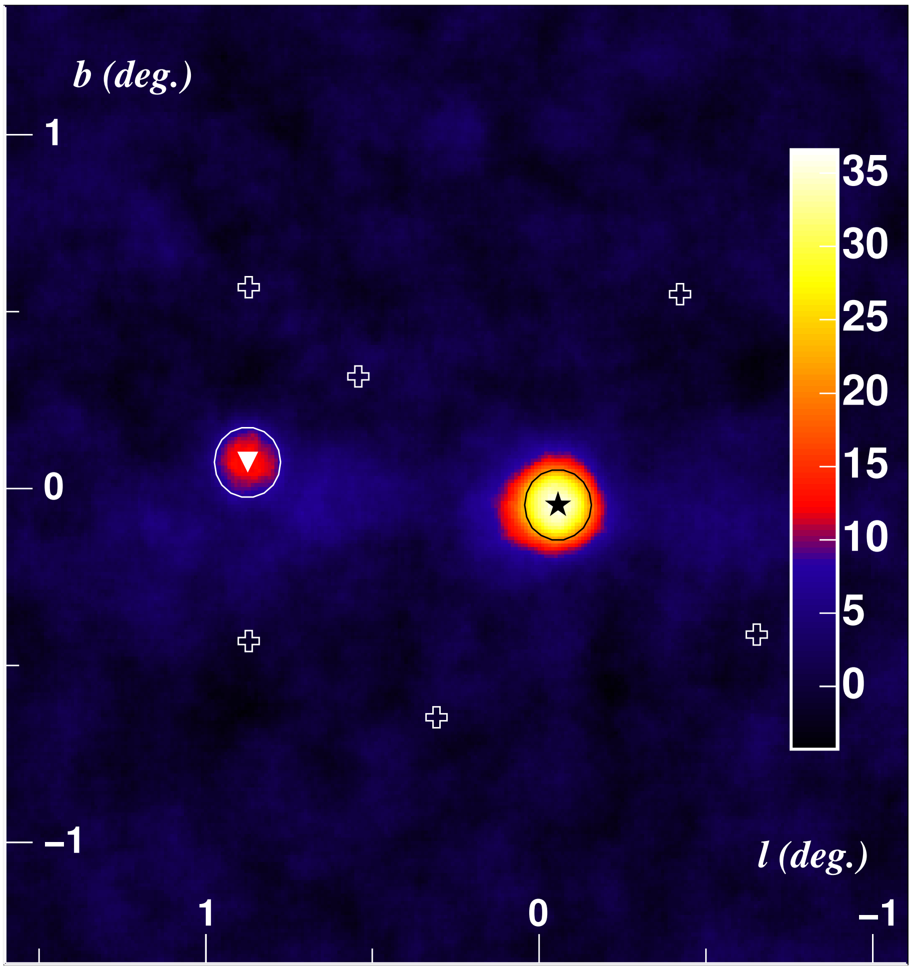

Figure 1 From Hinton & Aharonian's invited article. Statistical significance of the Galactic Centre region derived from the 2004 dataset of H.E.S.S.. White crosses show the tracking positions used. G 0.9+0.1 is shown as a triangle and Sgr A* as a star. The two circles show the integration radius used in the calculation of significance. Galactic coordinates are used.

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In the News

Sera Markoff & Rainer Schödel

It seems like 2005 is turning into the "Year of the Galactic Center" as well as being the Einstein Year, since there have already been two GC-related meetings so far and there will be at least two more before the New Year! Clearly the advent of several new high-energy instruments has stimulated interest in the GC region from the Cosmic Ray and Particle Physics community as well as the extended Astronomy/Astrophysics community. This shift is reflected in the focus of these meetings, which are either looking to these higher energies, or at more specific problems within the central regions.

In this volume we have a short summary and links to the presentations for the recent GC Meeting at the KITP in Santa Barbara, as well as links to the talks from the "High Energy Phenomena in the Galactic Center" meeting which was held June 15-17 in Paris (see below). We also have some initial information about two GC-related workshops that will occur in the Fall.

It is our pleasure to host the last article in our series highlighting the recent results from high-energy observatories. Starting with *INTEGRAL* in Vol. 19 and moving on to *Whipple/VERITAS* in Vol. 20, we finish with an article by Jim Hinton and Felix Aharonian about *H.E.S.S.*. Beyond the actual measurements, which were also covered in the last volume, the authors discuss in more detail some of the theoretical models which may be tested with the new observations.

And of course, we have the latest abstracts.

KITP GC Meeting Summary – *Rainer Schödel*

On April 14-16, 2005 the GC community plus some new friends came together at the Kavli Institute for Theoretical Physics (KITP) in Santa Barbara. Andrea Ghez, Sera Markoff, and Eliot Quataert were the organizers of the three-day workshop "The Paradoxes of Massive Black Holes: A Case Study in the Milky Way". The conference was focused mainly on two topics: understanding the emission of Sgr A* across all wavelengths, and, understanding the presence of young stars in the vicinity of Sgr A*.

Here, we provide a brief summary of the main topics and debates of the conference. The complete program as well as slides and audio files of all the talks can be found online at the KITP web site: http://online.itp.ucsb.edu/online/galactic_c05/

Besides the bright so-called He-stars in the central parsec that were identified as massive young stars more than a decade ago, the fainter stars in the immediate environment of Sgr A*—the overwhelming majority of the so-called S-stars—have now also been identified as young stars. With the help of integral-field-spectroscopy and adaptive optics they have been classified as B-type main sequence stars. The presence of these stars in immediate proximity to the supermassive black hole is not yet understood. Currently, there are largely two approaches for explaining the paradox of the young stars: the infall and dissolution of a massive cluster, or star formation in a formerly present accretion disk. In case of the first scenario, a question of considerable interest and debate in the conference was the question whether infalling clusters may contain intermediate mass black holes. Recent observations of the circumnuclear disk with millimeter interferometry indicate that gas densities in the the CND may be high enough to protect the clouds from tidal disruption as well as to support star formation in the CND or in a cloud core infalling from the CND into the central parsec. Clusters forming in the CND would have to migrate only a short distance into the central parsec. Hence, requirements on their densities and total masses could be less extreme than in the case of an infalling cluster that formed at distances 5-10 pc from Sgr A*. However even with higher densities, the strong tidal forces and most likely low star formation efficiency make it unclear as to whether a feature with the properties of the CND could form a single cluster with enough mass to account for the young stars in the central parsec.

Variable emission from Sgr A* can now be observed routinely at radio to submm-wavelengths, in the near-infrared, and in the X-ray regime. The first campaigns have recently been successful in simultaneously measuring the emission from Sgr A* in the different wavelength regimes. There appears to be a close correlation between emission at NIR/X-ray wavelengths. It has become clear that the extreme under-luminosity of Sgr A* is, on the one hand, due to a very low mass accretion rate. On the other hand, low mass accretion is not sufficient to explain the observations: The accretion flow in Sgr A* must be of the ADAF/RIAF type (Advection Dominated Accretion Flow/Radiatively Inefficient Accretion Flow), i.e. the gravitational energy released in the infalling plasma is advected beyond the event horizon. Also, from a comparison between the mass within the Bondi capture radius and the measured limits on the actually accreted mass there must be a considerable outflow of matter from the black hole. Here, one of the main debates is the existence of a jet and in as much it contributes to/dominates the emission and mass outflow from Sgr A*. While the direct observability of a jet with millimeter interferometry may still lie some years in the future, other methods, such as measuring position shifts of Sgr A* with frequency, may be able to provide some constraints in the near future.

As for the flaring of Sgr A*, i.e. the outbursts that are observed with a frequency of up to several times per day at X-ray/NIR wavelengths, there is general agreement that only small modifications in the properties of the radiating electron population are needed for their explanation. Synchrotron emission and synchrotron self-Compton emission then can produce the observed emission and rapid variability. It is still not clear what exactly causes the flares, e.g. magnetic reconnection as in solar flares, and whether flares may represent tentative phase transitions toward a different accretion/emission state of Sgr A*, in which it moves closer to the characteristics observed in brighter accreting black holes.

Paris GC Meeting Notes

The "High Energy Phenomena in the Galactic Center" Workshop, held last month in Paris, June 15-17, naturally placed a greater emphasis on the newest X-ray and γ-ray observations in this region. There was also a special session on dark matter in the GC, as well as several talks exploring possible sites of high-energy cosmic ray acceleration. The conference website can be found at: http://cdfinfo.in2p3.fr/APC_CS/Animation/HEP_GC/Conference/

The talks are not yet online, but Andrea Goldwurm from the SOC will be posting them under the scientific program link.

Upcoming GC Meetings

We only have preliminary information for the two GC-related workshops occurring later this year, but they are both smaller-scaled meetings which are not open for general registration. We will hopefully have summaries in future volumes.

On September 1, there will be a one day "mini-symposium" on the GC as part of a *GLAST* collaboration meeting at Stanford/SLAC. The website is not yet up, but will be posted on the main website: http://www-glast.slac.stanford.edu/. The meeting is being organized by the *GLAST* Science Working Group, including Chuck Dermer, Steve Ritz and Peter Michelson.

There will also be a series of two one-week Galactic Center meetings at the International Space Science Institute (ISSI, Bern, Switzerland), with preliminary plans for the first to be held in November-December 2005 and the second in May-June 2006. The first meeting will focus on the inner few pc, and the second will extend to 300 pc. These are not open meetings, but rather will bring together about a dozen experts for a week of focused discussion. The meetings were successfully proposed to the ISSI by Felix Aharonian, Anne Decourchelle and Bob Warwick. More information will be posted at http://www.issi.unibe.ch/.

In April 2006 there will be a larger-scale GC meeting in Bad Honnef, which will be open to the community and fall along the lines of previous meetings in Tucson and Hawaii. Please see the announcement at the end of the Newsletter!

The H.E.S.S. View of the Galactic Centre

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1 Introduction

The central 100 pc of our Galaxy is an extraordinary region that harbours many remarkable objects - potential sites of effective particle acceleration and copious γ-ray production. The wide field of view of the High Energy Stereoscopic System (H.E.S.S.) of imaging atmospheric Cherenkov telescopes, (5°), allows us to observe all of these candidate sources with a single pointing of the instrument.

Perhaps the most exciting of these candidates is the mysterious source Sgr A* at the kinematic centre of our galaxy. This source has now been identified as a supermassive (2.6×10^6 M$_\odot$) black hole (see e.g. (1)). Variable (non-thermal) X-ray and infrared emission from this source confirm its very compact nature. Several mechanisms for production of high energy γ-ray emission close to the event horizon of massive black holes have been suggested. These include interactions of ultra-high energy protons with the magnetic and radiation fields, as well as with the gas of the accretion flow, and curvature and inverse Compton radiation of multi-TeV electrons.

Very close to Sgr A* lies the unusually compact and powerfully supernova remnant (SNR) Sgr A East. As the prime candidate for the acceleration of cosmic rays, SNRs have long been of interest to γ-ray astronomers. The very dense medium in and around this remnant provides an enhanced target density for the production of γ-rays produced in interactions of particles accelerated in the supernova shell. This region also contains several other SNRs and pulsar wind nebulae such as G 0.9+0.1 and the so-called Mouse. Diffuse TeV emission is also expected from interactions of cosmic rays with dense molecular clouds within the central 100 pc region.

Yet another tantalizing possibility is the detection of dark matter annihilation in the central cusp in the dark matter density profile of our galaxy.

VHE γ-ray observations of this region by the H.E.S.S., CANGAROO and Whipple collaborations were published in 2004. Below we overview the HESS observations and compare our results with the results reported by the CANGAROO and Whipple groups.

2 Very high energy γ-ray observations

The H.E.S.S. array, in the Khomas Highlands of Namibia, is the first 3rd generation instrument (2) to be completed and reaches a sensitivity one order of magnitude below the 2nd generation instruments. For comparison the TeV energy flux at the level of 0.1 Crab from a point-like source can be probed by HESS in less than 30 minutes of observation time, while the detection of the same flux by the previous generation detectors required tens of hours of observations.

H.E.S.S. consists of four 13 m diameter telescopes operating in a stereoscopic coincidence mode (3). The greatly increased mirror area of the system results in a reduced energy threshold of ≈100 GeV and the stereoscopic measurement of showers results in improved energy and angular resolution. The wide field of view of the instrument ≈5° also provides an advantage in observations of extended objects or complex regions.

The first VHE observations of the GC region were conducted by the Whipple collaboration between 1995 and 2003. These observations occurred at large zenith angles, due to the Northern Hemisphere location of the instrument, resulting in an energy threshold of 2.8 TeV, and resulted in a marginal detection with a significance of 3.7 σ from 26 hours of data (4). The position of the γ-ray excess is consistent with the position of Sgr A* within the 15$'$ 95% C.L. error circle. The flux of this GC source has recently been revised downwards by ∼40% to $\approx 5 \times 10^{-13}$ cm^{-2}s^{-1} (above 2.8 TeV) (5).

Observations with the CANGAROO-II instrument in 2001 and 2002 led to the detection of sub-TeV γ-rays with an origin within 6$'$ of Sgr A* from 67 hours of (on-source) data (6). The reported spectrum is very steep,

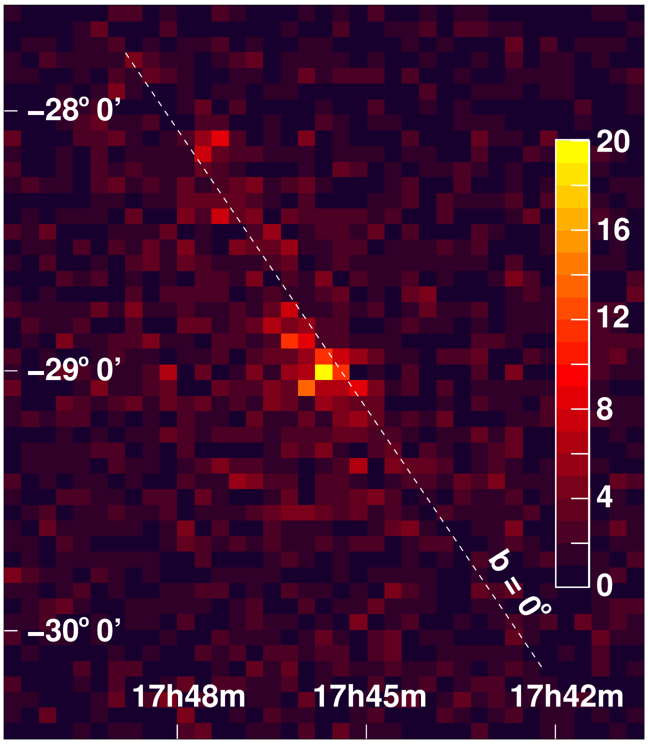

Figure 2 A γ-ray count map of the galactic centre region derived from the H.E.S.S. 2003 data. Sgr A* lies at the centre of the map. Coordinates are RA/Declination.

$F(E) \propto E^{-4.6\pm0.5}$ and incompatible with the Whipple observation. However, a recent reanalysis of these data yielded a much larger error on the photon index: $-4.6^{+1.2}_{-5.0}$ (7).

The first H.E.S.S. data on the GC region were taken during the construction phase of the instrument. This 2003 (17 hour) dataset revealed a clear VHE γ-ray signal from the Galactic Centre (Fig. 2) (8). Using the improved sensitivity and angular resolution of H.E.S.S. this γ-ray signal could be localised to within $1'$ and is still compatible with the position of Sgr A*. Although the localisation of the γ-ray emission with H.E.S.S. is almost a factor 10 better than previous measurements, an unambiguous identification of the source is still not possible given the complex nature of the GC region. We therefore refer to this source as HESS J1745−290. The energy spectrum of the source is consistent with a power law with photon index $\Gamma = 2.21 \pm 0.09$ and a flux normalisation at 1 TeV of $F_0 = (2.50 \pm 0.21) \times 10^{-12}\mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{TeV}^{-1}$. Figure 3 shows a comparison of the energy spectrum of the GC sources as measured by H.E.S.S. and Whipple. The large systematic error on the CANGAROO-II result makes a visual representation of these data difficult, they are therefore omitted from this figure. However, we note that even with the increased systematic error, the CANGAROO-II and H.E.S.S. photon indices differ at the $\approx 2\sigma$ level.

A 50 hour observation with the full 4-telescope array in 2004 greatly increased the statistical significance of the signal from HESS J1745−290. (up to 36 σ). A preliminary spectral analysis yields a result consistent with the 2003 data but with extended energy coverage. The error on the position of the γ-ray excess is now dominated by systematic errors of approximately $20''$ in each coordinate. Therefore, whilst the position of the γ-ray signal seen by H.E.S.S. is consistent with the position of Sgr A* an origin of the emission in the supernova remnant Sgr A East cannot be excluded at 95% confidence. It is anticipated that the systematic error on the position of HESS J1745−290 can be reduced to $\sim 10''$ during 2005. A significance map from H.E.S.S. 2004 data is shown in the lower panel of Fig. 1 (see cover). As well as the strong signal from HESS J1745−290 a second source is clearly visible $\sim$1° away from Sgr A. This new source has been identified as the SNR G 0.9+0.1 (9).

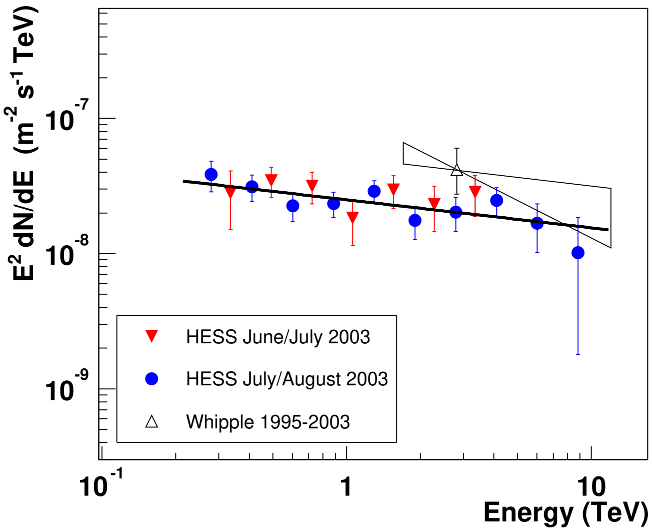

Figure 3 The γ-ray spectrum of the galactic centre as measured by the CANGAROO-II, Whipple and H.E.S.S. instruments. The Whipple data shown is the amended version taken from (5)

2.1 The Supernova Remnant G 0.9+0.1

The supernova remnant G 0.9+0.1 is a composite object, consisting of a bright compact core ($\sim 2^\circ$ across) surrounded by an $8'$ diameter shell (10). X-ray observations of the nebula (11)(12) showed that the core region is very likely a pulsar wind nebula (PWN). These X-ray observations imply the existence of a population of very energetic electrons (> 10 TeV) in the core of the remnant. VHE γ-ray emission from this object was detected serendipitously by H.E.S.S. during observations of the GC in 2004. The observed energy spectrum is consistent with a power law with photon index $\Gamma = 2.40 \pm 0.11_{stat} \pm 0.20_{sys}$ and a flux above 200 GeV of $(5.7 \pm 0.7_{stat} \pm 1.2_{sys}) \times 10^{-12}$ cm^{-2}s^{-1}. As can be seen from Figure 4, the detected γ-ray source is consistent with the point-spread function of the instrument, allowing us to derive upper limits on the size of the emission region, assuming a Gaussian-like ($\sigma_{\rm source} < 1.3'$) or a shell-like ($r_{\rm source} < 2.2'$) morphology. VHE emission from the SNR shell therefore appears to be excluded and an origin in the plerionic core of the nebula seems likely. A plausible interpretation of the emission is Inverse Compton radiation off the energetic electrons in the PWN on the enhanced radiation fields of the GC region.

Although G 0.9+0.1 is one of the weakest sources ever detected at TeV energies, the detection presented here is statistically highly significant ($13\,\sigma$), demonstrating the sensitivity of the H.E.S.S. instrument.

3 On the origin of TeV emission

The origin of TeV radiation detected by H.E.S.S. from the direction of the Galactic Centre is not yet established. The 3-arcminute upper limit on the source size implies that several objects, in particular the young SNR Sgr A East (14), the Dark Matter Halo (15), the compact radio source Sgr A* (with several γ-ray production scenarios with both direct and indirect links to the central massive black hole (16; 17)) can be considered as potential candidates for TeV emission within the central 10 pc region.

In addition to γ-rays emitted in compact regions in the vicinity of the massive black hole, one should expect also a diffuse (extended) component of radiation associated with interactions of the runaway protons with the surrounding dense interstellar gas(18). The relative contribution of this component to the total TeV flux, as well as the spectral and angular characteristics of π^0-decay γ-rays significantly depend on the rate of injection of accelerated protons into the interstellar medium, as well as on the regime of (energy-dependent) diffusion of protons in the dense central region. For certain combinations of principal model parameters the diffuse γ-rays from pp interactions can satisfactorily explain both the absolute flux and energy spectrum of TeV radiation reported by H.E.S.S.. This is demonstrated in Fig.5

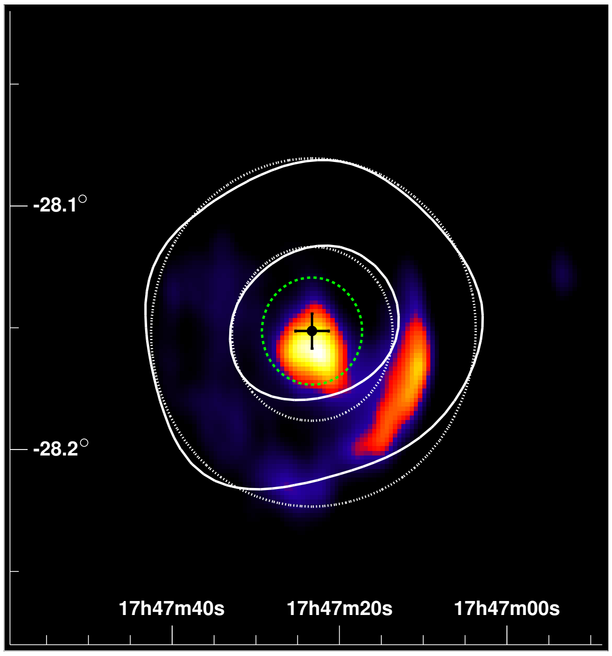

Figure 4 90 cm radio flux map of G 0.9+0.1 from LaRosa et al. ((13)), overlayed with contours (at 40% and 80% peak brightness) of the smoothed count map of γ-ray candidates (solid lines). The point-spread function of the instrument is shown with dotted lines. The best fit position of the VHE γ-ray is shown at the centre. The innermost circle (dashed) illustrates the 95% confidence limit on the rms size of the emission region.

The flux of this radiation component depends not only on the density of the ambient gas and the injection rate of protons, but also on the speed of their propagation in the interstellar medium. The TeV radiation detected by H.E.S.S. is localised within an angular diameter of several arcminutes. This implies that, for the distance to the Galactic Centre $d \simeq 8$ kpc, the linear size of the γ-ray production region can be as large as 10 pc. The density of the diffuse interstellar gas in this region is very high, $n \simeq 10^3\ \mathrm{cm}^{-3}$. The lifetime of protons in this dense environment against nuclear p-p interactions is $t_{\mathrm{pp}} \approx 5 \times 10^4$ yr. Thus, in the case of absolute confinement of protons, the γ-ray luminosity after $\sim 10^5$ years of continuous injection of protons achieves its maximum ("saturated") level, $L_\gamma = \eta \dot{W}_{\mathrm{p}}$, with an efficiency $\eta \simeq 1/3$ (the fraction of energy released in neutral π-mesons). However, the confinement time in the 10 pc region is rather limited; even in the Bohm diffusion regime the escape time of protons from this region is $t_{\mathrm{esc}} \sim R^2/r_g c \simeq 3 \times 10^5 (E/100\ \mathrm{TeV})^{-1} (\mathrm{B}/100\ \mu\mathrm{G})$ yr. Thus for any realistic diffusion coefficient $D(E)$, TeV protons leave the region before they loose their energy in p-p interactions. This not only reduces the γ-ray production efficiency but also, in the case of energy-dependent diffusion, modifies the energy distribution of the protons occupying the 10 pc region.

The impact of the energy-dependent diffusion on the resulting radiation spectra is demonstrated in Fig.5. It is assumed that over a period of 10^5 years protons are injected (quasi)continuously into the interstellar medium of density $n = 10^3\ \mathrm{cm}^{-3}$. The initial spectrum of protons is assumed to be a power-law with an exponential cutoff, $Q(E) = Q_0 E^{-\alpha} \exp(-E/E_0)$. The cutoff energy is fixed at $E_0 = 10^{15}$ eV, which is an obvious condition for effective production of γ-rays to at least 10 TeV. The choice of the power-law index depends on the assumed diffusion coefficient, if one intends to explain the energy spectrum of γ-rays detected by H.E.S.S., $J(E) = (2.5 \pm 0.21) \times 10^{-12} E^{-\Gamma}$ photons/(cm^2 s TeV) with $\Gamma = 2.21 \pm 0.09$.

The diffusion coefficient is assumed to have the following form: $D(E) = 10^{28} (E/1\ \mathrm{GeV})^{\beta} \kappa\ \mathrm{cm}^2/\mathrm{s}$. The values of $\kappa \sim 1$ and $\beta \sim 0.5$ correspond to the CR diffusion in the galactic disk. Of course, in the central region of the Galaxy one may expect significant deviation from the character of particle diffusion in "ordinary" parts of the galactic disk. In the case of effective confinement of protons, e.g. with $\kappa = 10^{-4}$ and $\beta = 0.5$, the escape time of multi-TeV protons is comparable with the characteristic time of p-p interactions. This prevents strong modification of the initial proton spectrum. Therefore, the injection spectrum of protons with power-law index $\alpha = 2.2$ fits quite well the observed TeV spectrum (curve 2 of Fig.5). Because of the effective confinement, the required injection rate of protons is rather

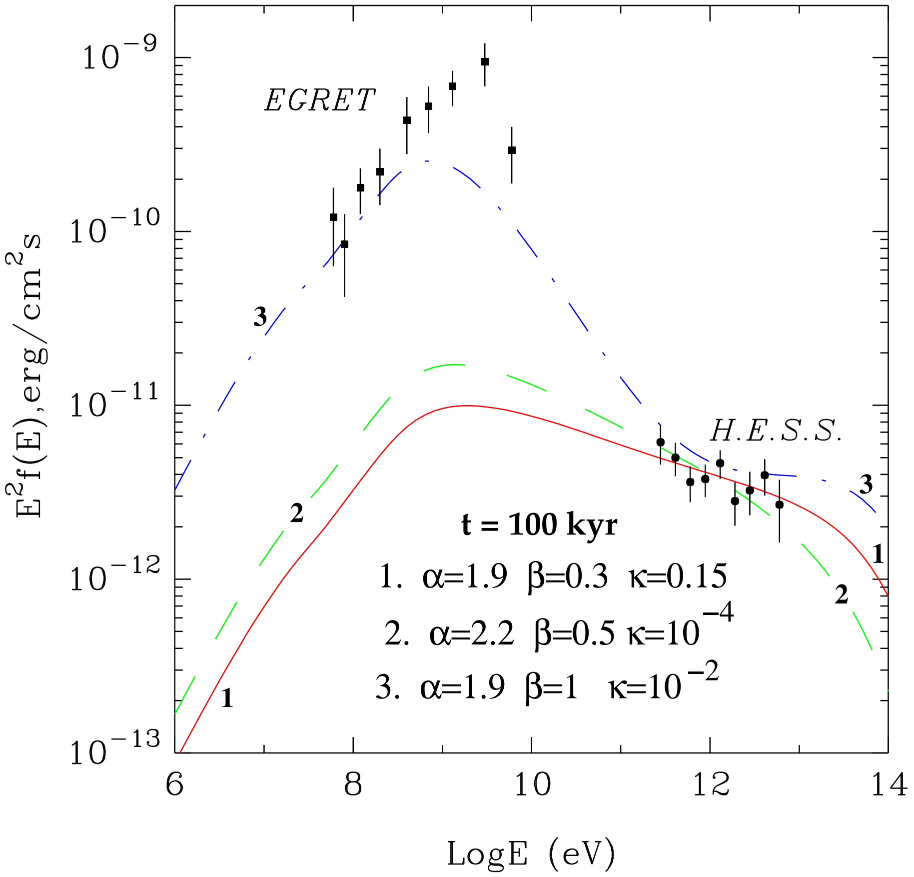

Figure 5 Energy spectra of γ-rays from pp interactions in the central 10 pc region of the Galactic Centre calculated under different assumptions concerning the proton injection spectrum and diffusion coefficients (described in the text).

modest, $\dot{W}_{\rm p} = 7 \times 10^{36}$ erg/s.

In the case of faster diffusion, the spectral index of injection is determined as $\alpha \simeq \Gamma - \beta$. For example, for $\kappa = 0.15$ and $\beta = 0.3$ (a diffusion regime which corresponds to Kolmogorov type turbulence), the γ-ray observations are well explained assuming the following parameters $\alpha = 1.9$ and $\dot{W}_{\rm p} = 7.5 \times 10^{37}$ erg/s (curve 1 in Fig.5).

Finally, one should note that the injection spectrum remains unchanged with very fast escape. For example, for $\kappa = 10^{-2}$ and $\beta = 1$ (an energy-dependence close to the one expected in Bohm diffusion, but with much larger diffusion coefficient), the particles propagate in the diffusion regime up to energies of several TeV. At higher energies they escape the source almost rectilinearly on timescales $R/c \sim 30$ years. This implies that while at low energies the protons inside the 10 pc region suffer significant spectral deformation, $\alpha' \to \alpha + \beta$, at very high energies the shape of the initial spectrum is essentially recovered. Such an interesting modulation of the proton spectrum is reflected in the resulting γ-ray spectrum (curve 3 in Fig.5). In this case the requirement for the injection power of protons is higher than in the previous cases, $\dot{W}_{\rm p} = 10^{39}$ erg/s.

Although the diffuse component can be extended to distances 100 pc and beyond, because of the enhanced product of the CR and gas densities in the central 10 pc region one should expect a bright γ-ray core within several arcminutes around Sgr A*. Moreover in the case of fast diffusion (curve 3), the flux of TeV protons decreases with distance as $1/r^2$. This would result in sharp increase of relativistic protons towards the GC, and consequently to a point-like source of TeV γ-rays centered on the particle accelerator. Thus if the acceleration of protons takes place in the central black hole, this could naturally explain the existence in the H.E.S.S. data of a point-like TeV component without any indication of variability on timescales ≥ 1 hour.

4 Summary

H.E.S.S. has provided the best view so far of the Galactic Centre region in γ-rays. Whilst the origin of the γ-ray emission close to Sgr A* remains a mystery, rapid progress is being made experimentally. The accurate localisation of this central source is a key issue. H.E.S.S. data taken over the next few years promise to reduce the localisation error to the $10''$ level required to distinguish between Sgr A East and A*, the primary suspects for the particle accelerator.

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Abstracts

Galactic Centre stellar winds and Sgr A* accretion

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We present a detailed discussion of our new 3D numerical models for the accretion of stellar winds on to Sgr A*. In our most sophisticated models, we put stellar wind sources on realistic orbits around Sgr A*, we include recently discovered 'slow' winds ($v_w \sim 300$ km s^{-1}), and we account for optically thin radiative cooling. We test our approach by first modelling only one phase 'fast' stellar winds ($v_w \sim 1000$ km s^{-1}). For stellar wind sources fixed in space, the accretion rate is of the order of $\dot{M} \simeq 10^{-5} M_\odot$ yr^{-1}, fluctuates by $\lesssim 10\%$, and is in a good agreement with previous models. In contrast, $\dot{M}$ decreases by an order of magnitude for wind sources following circular orbits, and fluctuates by $\sim 50\%$. Then we allow a fraction of stars to produce slow winds. Much of these winds cool radiatively after being shocked, forming cold clumps and filaments immersed into the X-ray emitting gas. We investigate two orbital configurations for the stars in this scenario, an isotropic distribution and two rotating discs with perpendicular orientation. The morphology of cold gas is quite sensitive to the orbital distribution of the stars. In both cases, however, most of the accreted gas is hot, producing a quasi steady 'floor' in the accretion rate, of the order of $\sim 3 \times 10^{-6} M_\odot$ yr^{-1}, consistent with the values deduced from *Chandra* observations. The cold gas accretes in intermittent, short but powerful accretion episodes which may give rise to large amplitude variability in the luminosity of Sgr A* on time scales of tens to hundreds of years. The circularisation radii for the flows are about 10^3 and 10^4 Schwarzschild radii, for the one and two-phase wind simulations, respectively, never forming the quasi-spherical accretion flows suggested in some previous work. Our work suggests that, averaged over time scales of hundreds to thousands of years, the radiative and mechanical luminosity of Sgr A* may be orders of magnitude higher than it is in its current state. Further improvements of the wind accretion modelling of Sgr A* will rely on improved observational constraints for the wind velocities, mass loss rates and stellar orbits.

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Eprint: astro-ph/0505382
http://www.mpa-garching.mpg.de/~jcuadra/Winds/

Evidence for a Weak Galactic Center Magnetic Field from Diffuse Low Frequency Nonthermal Radio Emission

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New low frequency 74 and 330 MHz observations of the Galactic center (GC) region reveal the presence of a large-scale ($6^\circ \times 2^\circ$) diffuse source of nonthermal synchrotron emission. A minimum energy analysis of this emission yields a total energy of $\sim (\phi^{4/7} f^{3/7}) \times 10^{52}$ ergs and a magnetic field strength of $\sim 6(\phi/f)^{2/7}$ μG, (where ϕ is the proton to electron energy ratio and f is the filling factor of the synchrotron emitting gas). The equipartition particle energy density is $1.2(\phi/f)^{2/7}$ erg/cm^3, a value consistent with cosmic ray data. However, the derived magnetic field is several orders of magnitude below the 1 mG field commonly invoked for the GC. The shorter electron radiation lifetimes in such a strong field requires that energy be resupplied to the source at an implausibly high rate. Furthermore, a strong

magnetic field implies an abnormally low GC cosmic ray energy density. We conclude that the mean magnetic field in the GC region must be weak, of order 10 μG (at least on size scales $\gtrsim 125''$).

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A Black Hole in the Galactic Center Complex IRS 13E?

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The IRS 13E complex is an unusual concentration of massive, early-type stars at a projected distance of ~0.13 pc from the Milky Way's central supermassive black hole Sagittarius A* (Sgr A*). Because of their similar proper motion and their common nature as massive, young stars it has recently been suggested that IRS 13E may be the remnant of a massive stellar cluster containing an intermediate-mass black hole (IMBH) that binds its members gravitationally in the tidal field of Sgr A*. Here, we present an analysis of the proper motions in the IRS 13E environment that combines the currently best available data with a time line of 10 years (based on observations at the Very Large Telescope (VLT) of the European Southern Observatory (ESO) on Paranal in Chile). We find that an IMBH in IRS 13E must have a minimum mass of $\sim 10^4$ $M_\odot$ in order to bind the source complex gravitationally. This high mass limit in combination with the absence so far of compelling evidence for a non-thermal radio and X-ray source in IRS 13E make it appear unlikely that an IMBH exists in IRS 13E that is sufficiently massive to bind the system gravitationally.

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Theoretical Isochrones with Extinction in the K-Band

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We calculate theoretical isochrones, in a consistent way, for five filters in the atmospheric window between 1.9 μm and 2.5 μm, K, K', K_s, F205W, and F222M, using the Padova stellar evolutionary models by Girardi et al. Even when displayed in the same Vega magnitude system, the near-infrared colors of the same isochrone can differ by up to 0.18 mag at its bright end, depending on the filter. We present magnitude transformations between K-band filters as a function of color from H & K band filters. Isochrones with extinction at K of up to 6 mag are also presented. We find that care is needed when comparing extinction values that are estimated using different filter sets in the K-band, in particular when comparing those between atmospheric and space filter sets: extinction values for space filters can be in error by up to 0.3 mag. To reduce this error, we introduce an "effective extinction slope" for each filter set and isochrone model, which describes the extinction behaviour of isochrones in the color-magnitude diagram more correctly than the actual extinction law. Our calculation also suggests that the extinction law implied by the observations of Rieke, Rieke, & Paul for wavelengths between H and K bands is better described by a power-law function with an exponent of 1.61, instead of 1.55, which is commonly used with an assumption that the transmission functions of H and K filters are Dirac delta functions.

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IRS 16SW - A New Comoving Group of Young Stars in the Central Parsec of the Milky Way

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One of the most perplexing problems associated with the supermassive black hole at the center of our Galaxy is the origin of the young stars in its close vicinity. Using proper motion measurements and stellar number density counts based on 9 years of diffraction-limited K(2.2 μm)-band speckle imaging at the W. M. Keck 10-meter telescopes, we have identified a new comoving group of stars, which we call the IRS 16SW comoving group, located 1.″9 (0.08 pc, in projection) from the central black hole. Four of the five members of this comoving group have been spectroscopically identified as massive young stars, specifically He I emission-line stars and OBN stars. This is the second young comoving group within the central parsec of the Milky Way to be recognized and is the closest, by a factor of 2, in projection to the central black hole. These comoving groups may be the surviving cores of massive infalling star clusters that are undergoing disruption in the strong tidal field of the central supermassive black hole.

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INTEGRAL/IBIS search for e^-e^+ annihilation radiation from the Galactic Center Region

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Electron-positron annihilation radiation from the Galactic Center region has been detected since the seventies, but its astrophysical origin is still a topic of a scientific debate. We have analyzed data of the gamma-ray imager IBIS/ISGRI onboard of ESA's INTEGRAL platform in the e^-e^+ line. During the first year of the missions Galactic Center Deep Exposure no evidence for point sources at 511 keV has been found in the ISGRI data; the 2σ upper limit for resolved single point sources is estimated to be 1.6×10^{-4} $ph\ cm^{-2}\ s^{-1}$.

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http://arxiv.org/abs/astro-ph/0501123

Stellar Orbits Around the Galactic Center Black Hole

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We present new diffraction-limited images of the Galactic Center, obtained with the W. M. Keck I 10-meter telescope. Within 0.″4 of the Galaxy's central dark mass, 17 proper motion stars, with K magnitudes ranging from 14.0 to 16.8, are identified and 10 of these are new detections (6 were also independently discovered by Schödel et al. 2003). In this sample, three newly identified (S0-16, S0-19, and S0-20) and four previously known (S0-1, S0-2, S0-4, and S0-5) sources have measured proper motions that reveal orbital solutions. Orbits are derived *simultaneously* so that they jointly constrain the central dark object's properties: its mass, its position, and, for the first time using orbits, its motion on the plane of the sky. This analysis pinpoints the Galaxy's central dark mass to within 1.3 mas (10 AU) and limits its proper motion to 1.5 ± 0.5 mas yr^{-1} (or equivalently 60 ± 20 km s^{-1}) with respect to the central stellar cluster. This localization of the central dark mass is consistent with our derivation of the position of the radio source Sgr A* in the infrared reference frame (± 10 mas), but with an uncertainty that is a factor 8 times smaller, which greatly facilitates searches for near-infrared counterparts to the central black hole. Consequently, one previous claim for such a counterpart can now be ascribed to a close stellar passage in 1996. Furthermore, we can place a conservative upper limit of 15.5 mag on any steady-state counter-part emission. The estimated central dark mass from orbital motions is $3.7(\pm 0.2) \times 10^6 (\frac{R_o}{8kpc})^3 M_\odot$; this is a more direct measure of mass than those obtained from velocity dispersion measurements, which are as much as a factor of two smaller. The Galactic Center's distance, which adds an additional 19% uncertainty in the estimated mass, is now the limiting source of uncertainty in the absolute mass. For stars in this sample, the closest approach is achieved by S0-16, which came within a mere 45 AU (= 0.0002 pc = 600 R_s) at a velocity of 12,000 km s^{-1}. This increases the inferred dark mass density by four orders of magnitude compared to earlier analyses based on velocity and acceleration vectors, making the Milky Way the strongest existing case for a supermassive black hole at the center of a normal type galaxy. Well determined orbital parameters for these seven Sgr A* cluster stars provide new constraints on how these apparently massive, young (<10 Myr) stars formed in a region that seems to be hostile to star formation. Unlike the more distant He-I emission line stars - another population of young stars in the Galactic Center - that appear to have co-planar orbits, the Sgr A* cluster stars have orbital properties (eccentricities, angular momentum vectors, and apoapse directions) that are consistent with an isotropic distribution. Therefore many of the mechanisms proposed for the formation of the He-I stars, such as formation from a pre-existing disk, are unlikely solutions for the Sgr A* cluster stars. Unfortunately, alternative theories for producing young stars, or old stars that look young, in close proximity to a central supermassive black hole, are all also somewhat problematic. Understanding the apparent youth of stars in the Sgr A* cluster, as well as the more distant He I emission line stars, has now become one of the major outstanding issues in the study of the Galactic Center.

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Contribution to diffuse gamma-rays in the Galactic center region from unresolved millisecond pulsars

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The diffuse gamma-rays in the Galactic center region have been studied. We propose that there exists a population of millisecond pulsars (MSPs) in the Galactic Center, which will emit GeV gamma-rays through the synchrotron-curvature radiation as predicted by outer gap models. These GeV gamma-rays from unresolved millisecond pulsars probably contribute to the diffuse gamma-ray spectrum detected by EGRET which displays a break at a few GeV. We have used the Monte Carlo method to obtain the simulated samples of millisecond pulsars in the Galactic center region covered by EGRET ($\sim 1.5°$) according to the different period and magnetic field distributions from the observed millisecond pulsars in the Galactic field and globular clusters, and superposed their synchrotron-curvature spectra to derive the total GeV flux. Our simulated results suggest that there probably exist about 6000 unresolved millisecond pulsars in the region of the angular resolution for EGRET, whose emissions could contribute significantly to the observed diffuse gamma-rays in the Galactic center.

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Intra-day Variability of Sagittarius A* at 3 Millimeters

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We report observations and analysis of flux monitoring of Sagittarius A* at 3-mm wavelength using the OVRO millimeter interferometer over a period of eight days (2002 May 23–30). Frequent phase and flux referencing (every 5 minutes) with the nearby calibrator source J1744−312 was employed to control for instrumental and atmospheric effects. Time variations are sought by computing and subtracting, from each visibility in the database, an average visibility obtained from all the data acquired in our monitoring program having similar uv-spacings. This removes the confusing effects of baseline-dependent, correlated flux interference caused by the static, thermal emission from the extended source Sgr A West. Few-day variations up to $\sim 20\%$ and intra-day variability of $\sim 20\%$ and in some cases up to $\sim 40\%$ on few-hour time scales emerge from the differenced data on SgrA*. Power spectra of the residuals indicate the presence of hourly variations on all but two of the eight days. Monte Carlo simulation of red-noise light curves indicates that the hourly variations are well described by a red-noise power spectrum with $P(f) \propto f^{-1}$. Of particular interest is a ~ 2.5 hour variation seen prominently on two consecutive days. An average power spectrum from all eight days of data reveals noteworthy power on this time scale. There is some indication that

few-hour variations are more pronounced on days when the average daily flux is highest. We briefly discuss the possibility that these few-hour variations are due to the dynamical modulation of accreting gas around the central supermassive black hole, as well as the implications for the structure of the SgrA* photosphere at 3 mm. Finally, these data have enabled us to produce a high sensitivity 3-mm map of the extended thermal emission surrounding SgrA*.

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An upper limit to the masses of stars

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There is no accepted upper mass limit for stars. Such a basic quantity escapes both theory, because of incomplete understanding of star formation, and observation, because of incompleteness in surveying the Galaxy. The Arches cluster is ideal for such a test, being massive enough to expect stars at least as massive as 400 solar masses, and young enough for its most massive members to still be visible. It is old enough to be free of its natal molecular cloud, and close enough, and at a well-established distance, for us to discern its individual stars. Here I report an absence of stars with initial masses greater than 130 M in the Arches cluster, where the typical mass function predicts 18. I conclude that this indicates a firm limit of 150 M for stars as the probability that the observations are consistent with no limit is 10-8.

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At the Heart of the Milky Way

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The center of our galaxy, the Milky Way, contains unique magnetic structures that remain incompletely understood. In their Perspective, Lazio and LaRosa review advances toward characterizing and understanding these structures. Recent observations at radio and submillimeter wavelengths have revealed that the magnetic filaments are more widespread than previously thought, and also exhibit a geometric complexity not accounted for in current models of the magnetic environment at the galactic center. Observations at even higher resolution and sensitivity will be required to understand fully the origin, properties, and role of the magnetic field at the galactic center.

Ref.: Science (2005), Vol. 307 (4 February 2005), p.686–687
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Announcements

GC 06! Bad Honnef, Germany

The next full-scale Galactic Center Workshop will be held on April 18-22, 2006 in the Physics Center in Bad Honnef, Germany. Similar to the GC 2002 Workshop held in Kona, the intention is to bring together astronomers from the entire GC community to discuss the recent findings and problems related to the center of the Milky Way. In order to place the GC into a broader context, we will for the first time widen the focus of a GC conference somewhat to include exemplary nearby low-luminosity galactic nuclei.

The conference will take place right after Easter (talks will be from Tuesday to Saturday). A rudimentary web site with the most essential information can be found at:

http://www.ph1.uni-koeln.de/workgroups/obs_astronomy/galactic_center/new/gcconf.html

A list of the preliminary members of the LOC and SOC can be found here:

http://www.ph1.uni-koeln.de/workgroups/obs_astronomy/galactic_center/new/gc06/committees.html

Bad Honnef is a beautiful small town, located a few kilometers south of Bonn on the opposite bank of the Rhine. The Physikzentrum in Bad Honnef is an old "castle-style" house owned by the German Physical Society. It features, among other things, a brand new lecture room and a "cosy" hunting-lodge-style bar in the basement for nightly discussions.

There will be a hard upper limit of 120 to the number of participants, so early registration will be essential. Please expect registration to begin in November/December 2005. Start of registration as well as further new information concerning GC06 will be announced in GCNEWS, so please stay tuned!

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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