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Color composite Image of the Chandra Sgr A* Field

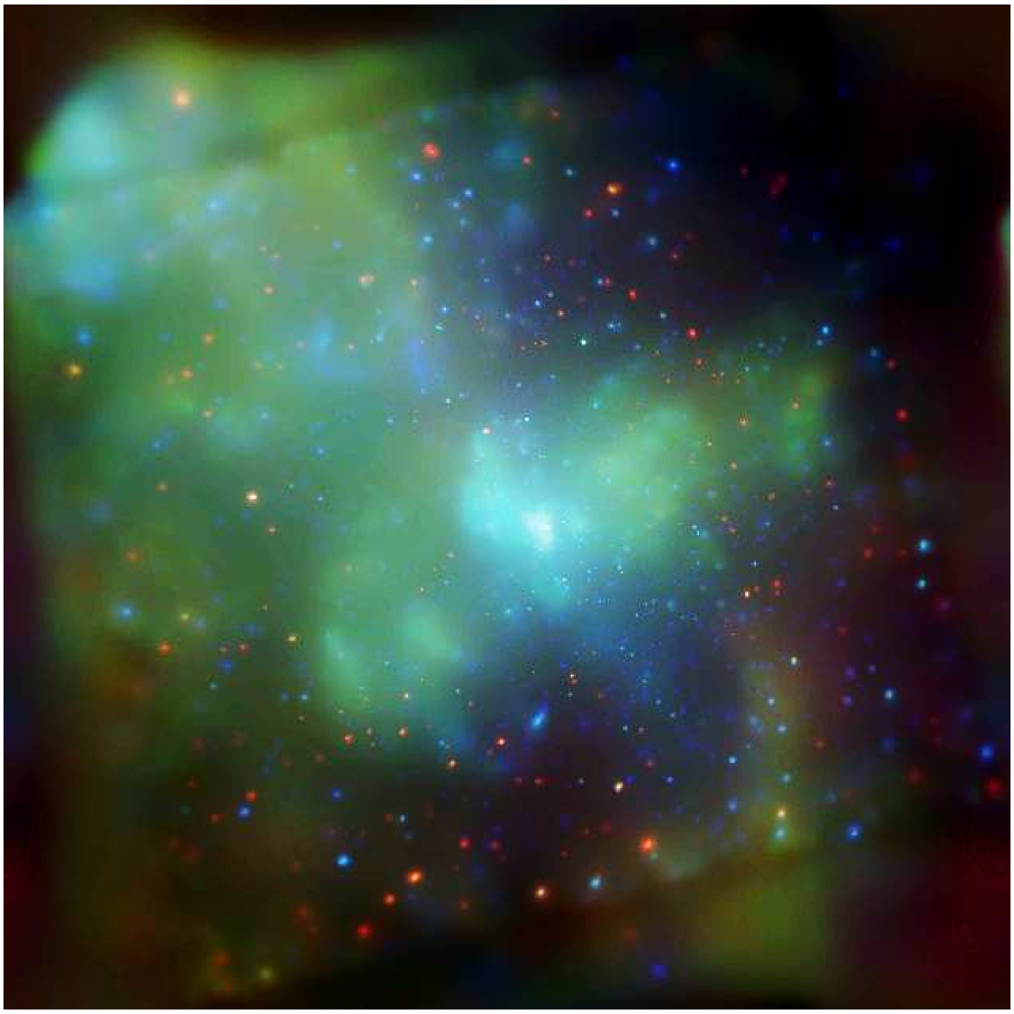

Figure 2 Three-color, smoothed image of the Sgr A* field. The red band is made from photons between 0.5–2.0 keV, the green from 2.0–4.0 keV, and the blue from 4.0–8.0 keV. The red sources lie in the foregound, and were not included in the analysis in this paper. Otherwise, the bulk of the diffuse emission is observed from the Galactic center between 2–8 keV. The point sources located near the Galactic center are most prominent in the 4–8 keV band.

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In the News

Angela Cotera

GCNEWS is back!

After an extended absence, we are pleased to bring you Volume 16 of GCNEWS. Since Vol. 15, there have been numerous changes here at GCNEWS, with more to come. First, as many of you already know, Heino Falcke has stepped down as one of the editors, and I shall be following him within the year. We are very grateful to him for helping get GCNEWs off the ground, as well as for the technical support and scripting which have made our work much easier. Lorant Sjouwerman has assumed the technical editor position, and has successfully moved the webpages to NRAO. GCNEWS can now be found at **http://www.aoc.nrao.edu/~gcnews/**. As you have probably noticed, Lorant has also resumed the very useful "Newsflash" service, and has been getting out the abstracts sent to us in the past year.

Because the GCNEWS Bonn email address was unattended for a while, and because people move, emails from some of our subscribers have bounced; these names have been removed from the list. Please inform your colleagues that GCNEWS is back, and that they will need to re-subscribe if they haven't gotten the latest issue. If you have moved but are still receiving GCNEWs, you are likely receiving a forward so please check that your address is current (see the **Subscribers** link on our home page). If you will be moving, please send updates by email or use the subscriber form.

With Heino's and my departures, the structure of GCNEWS is evolving; the first change is the establishment of a rotating "Editorial Board." This will give more of you the chance to both influence the direction of , e.g., future meetings as well as serving the community. We anticipate that this new approach will insure that GCNEWS will be uninterrupted in the future, and will continue to grow. Sera Markoff has agreed to remain on board for at least a year or two to bridge the gap, and we are pleased to welcome two new board members, Joe Lazio and Cornelia Lang. Joe has already been active in support of the GC community, by investigating the possibility of creating a more formal society under the auspices of the IAU. We are currently looking for a new member to represent the significant Japanese involvement in this field, so please contact us if you are interested.

We hope that GCNEWS will continue to serve as a link for the community, to encourage the planning of regular meetings, and to provide support as needed to the conference planners. Actually, with the amount of incredibly exciting GC research now in progress, I suggest it is not too soon to be thinking about the next workshop.

GC02 Conference Proceedings

The GC02 Conference Proceedings is finally in press. The proceedings will be sent to all of those who attended the conference. If you have changed addresses since the conference, please contact either Angela Cotera (cotera@asu.edu) or Tom Geballe (geballe@gemini.edu) with your new address, so we can insure you receive your copy. You will also be receiving a CD with the conference discussions sessions separately.

In the meantime, some of the proceedings are available online, and all of them should be shortly. You can access the articles from the publishers website, **http://www3.interscience.wiley.com/cgi-bin/jissue/104552537**. Finally, a much belated thanks to Tom Geballe, for an excellent conference, Andy Adamson for flawless transitions between the talk presentations, Gemini for providing superb staff support, and all of the participants for an excellent workshop. When and where shall we meet next?!

In this volume

As the first volume after a long hiatus, we have abstracts for a host of papers published in the last year. We know, however, that there have been many more articles published during this time. We encourage you to continue to submit your abstracts (even if published in the last year), to help keep the GC community informed of the latest research.

The featured article for this volume comes courtesy of Michael Muno. He provides us with a glimpse of the exciting science resulting from Chandra observations of the central parsecs of the Galaxy (our favorite place). We would also like to point out the abstract on results from XMM/Newton, which is also in this issue. Certainly one of the most striking aspects of the GC02 workshop was the extra dimension that X-ray observations are adding to our view of the GC.

We also have several abstracts about flares from Sgr A*, including recent results from the IR (and be sure to watch for a complementary article appearing in *Nature* this month).

Can Unresolved Point Sources Produce the Diffuse X-ray Emission from the Galactic Center?

Michael Muno (Hubble Fellow, University of California, Los Angeles)

Abstract. We compare the spectra of faint point sources and diffuse emission from a long Chandra observation of the Galactic center in order to place an upper limit on the fraction of the diffuse X-ray emission that could plausibly be produced by unresolved point sources. The diffuse X-rays can be described as emission from two collisional- equilibrium plasma components with $kT \approx 0.8$ keV and $kT \approx 8$ keV. The diffuse emission varies significantly both in intensity and spectrum on spatial scales of a few arcminutes. Therefore, unresolved point sources produce less than 40% of the total diffuse emission, and less than 45% of the putative $kT \approx 8$ keV emission. The surface density of unresolved point sources (inferred by extrapolating the number- flux distribution of observed sources) is remarkably consistent with the number of CVs expected in the field. The remaining hard, diffuse X-ray emission probably originates from a thermal or quasi-thermal plasma, or from interactions between cosmic ray electrons and background ions.

1 Introduction

The diffuse X-ray emission observed from the Galactic center is an inward extension of emission observed throughout the Galactic plane. However, despite two decades of study, the origin of the emission is still uncertain. The major problem in understanding this diffuse Galactic background is the presence of emission lines from He-like and H-like Fe, which are rarely associated with any of the processes that are known to heat the interstellar medium (e.g., Kaneda et al., 1997). Therefore, it has been proposed that this hard diffuse emission is produced by unresolved point sources. Unfortunately, unlike the cosmic X-ray background, the Galactic background has yet to be resolved unambiguously into discrete components.

Several observational clues suggest that the emission is truly diffuse. For instance, the deepest *Chandra* observations of the Galactic plane find that point sources brighter than 3×10^{-15} erg cm^{-2} s^{-1} contribute only 10% to the total diffuse Galactic ridge emission (Ebisawa et al., 2001). Likewise, *ASCA* observations of the Galactic plane reveal degree-scale variations in the intensity of the diffuse emission, which could only be produced by random variations in the numbers of point sources if they have intensities of $\approx 2 \times 10^{-13}$ erg cm^{-2} s^{-1} (Yamauchi et al., 1996). This apparently leaves no flux range over which point sources could account for all of the properties of the diffuse emission.

Nonetheless, the debate is not over. The variations in the intensity of the diffuse emission could be produced by any of several classes of extended X-ray features that have been discovered recently, including hot supernova remnants without radio counterparts (Bamba et al., 2003), magnetic filaments (Sakano et al., 2003; Lu, Wang, & Lang, 2003), and X-ray reflection nebulae (Sunyaev, Markevitch, & Pavlinsky, 1993; Murakami et al., 2000; Yusef-Zadeh, Law, & Wardle, 2002). We may also have identified the actual point sources that comprise the apparently diffuse emission. *Chandra* observations of the Galactic center reveal that the faint stellar X-ray sources have spectra that are remarkably similar to that of the hard component of the diffuse emission (Wang et al., 2002). Moreover, the $\log(N) - \log(S)$ distribution of resolved point sources within 20 pc of Sgr A* is so steep that the flux from unresolved point sources could explain all of the diffuse emission if the distribution extends down to only $\sim 10^{-16}$ erg cm^{-2} s^{-1} (Muno et al., 2003a). Therefore, it still seems plausible that point sources produce the hard background emission observed throughout the Galactic ridge.

The perfect opportunity to examine this question in more detail was recently presented to us in the form of a 626 ks *Chandra* exposure of the $17' \times 17'$ field around Sgr A*. Therefore, in this article, we compare the spectra of the point sources and diffuse emission in that field in order to place an upper limit on the fraction of the diffuse emission that is likely to be produced by unresolved point sources.

2 Observations

Twelve separate pointings toward the inner 20 pc of the Galaxy have been carried out in order to monitor Sgr A*

(see Table 2 in Muno et al. 2003) using the Advanced CCD Imaging Spectrometer imaging array (ACIS-I) aboard the *Chandra X-ray Observatory* (Weisskopf et al., 2002).The ACIS-I is a set of four 1024-by-1024 pixel CCDs, covering a field of view of 17′ by 17′. When placed on-axis at the focal plane of the grazing-incidence X-ray mirrors, the imaging resolution is determined primarily by the pixel size of the CCDs, 0.″492. The CCDs also measure the energies of incident photons, with a resolution of 50–300 eV (depending on photon energy and distance from the read-out node) within a calibrated energy band of 0.5–8 keV.

The raw event lists from each observation were processed and combined as described in Muno et al. (2003a). The resulting raw image is displayed in Figure 1, while a smoothed three-color image is presented in Figure 2. We identified 2353 point sources in this image using a wavelet-decomposition algorithm (`wavdetect`), and extracted spectra for groups of sources based on their intensity and spectrum. Next, we isolated the diffuse emission, using the mask illustrated by the circles in Figure 1 to remove the point sources. Figures 3 and 4 display the resulting images in the 2–4 keV and 4–8 keV bands, respectively. The spectra of the diffuse emission were extracted from the regions indicated in these figures. Representative spectra of the diffuse emission and point sources are displayed in Figure 5.

We modeled the spectra of the point sources and the diffuse emission using a standard least-χ^2 fitting package (`XSPEC`). We assumed the diffuse emission was produced by two thermal plasma components (the model `vapec`) and a Gaussian line to account for low-ionization Fe K-α emission at 6.4 keV. We allowed the abundances of Si, S, Ar, Ca, and Fe in the plasma model to vary independently, although we applied the same values to each component. We assumed that each plasma was absorbed by a different column of gas, which was modeled as (1) a uniform absorber that applied to the entire image plus (2) a partial-covering absorber that applied to a fraction f of the image. We will report the detailed results of the modeling in up-coming publications, so we only summarize them below.

2.1 Diffuse Emission

For the diffuse emission, we found that the lines of Si, S, Ar, and Ca constrain the low-temperature plasma to have $kT_1 \approx 0.8$ keV, while the continuum and Fe emission constrained the hotter component to have $kT_2 \approx 8$ keV. The fluxes from each continuum component in each region are listed in Table 1.

The hard component of the diffuse emission is most important to the current study, because its spectrum closely resembles that of the point sources in Figure 5. The surface brightness of the hard component varies by a factor of two across the image, from 1.5×10^{-13} erg cm^{-2} s^{-1} arcmin^{-2} in the darkest region to 2.6×10^{-13} erg cm^{-2} s^{-1} arcmin^{-2} in the Northeast (Figure 4). The inferred temperature of the plasma varies between 6–9 keV, because there are significant variations in the equivalent widths and flux ratios of the He-like and H-like iron lines.

The properties of the soft component represent a bit of a tangent. Its surface brightness is highest by far in the Northeast region, where the hard emission is also most intense (see Figure 3). This suggests that production mechanisms for the two plasma components are related.

2.2 Point Sources

As is clear from Figure 5, the point sources on average have a much harder spectrum than does the diffuse emission. Under the two-kT model used above, we find that the soft component of the plasma model is heavily absorbed in the point sources, so that it contributes only 3% of the total observed 2–8 keV flux. The hot plasma component, with a temperature of 9 keV, contributes the remainder of the flux. It is this hot component that produces the He-like and H-like iron lines that appear so similar to those in the diffuse emission (compare Wang et al., 2002).

In order to establish a fiducial spectrum for the unresolved point sources, we examined the spectra of the resolved sources as a function of their intensity. We selected only those sources which were not detected below 1.5 keV, as these are most likely to lie near the Galactic center. We found that the averaged spectra varied very little. The only significant trends were that as the point sources considered became fainter (1) the He-like Fe emission at 6.7 and 6.9 keV increased in intensity, while (2) the low-ionization Fe emission at 6.4 keV decreased in intensity. Therefore, for our fiducial point-source spectrum we used the faintest sources, those with fewer than 80 net counts.

We also note that, in contrast to the diffuse emission, the flux from resolved point sources in nearly constant at any given offset from Sgr A*. The fluxes from resolved point sources in each region are listed in Table 1.

3 Results

We determined an upper limit to the amount of flux that unresolved point sources can contribute to the diffuse emission by adding a spectral component representing the faintest resolved point sources to our model for the diffuse

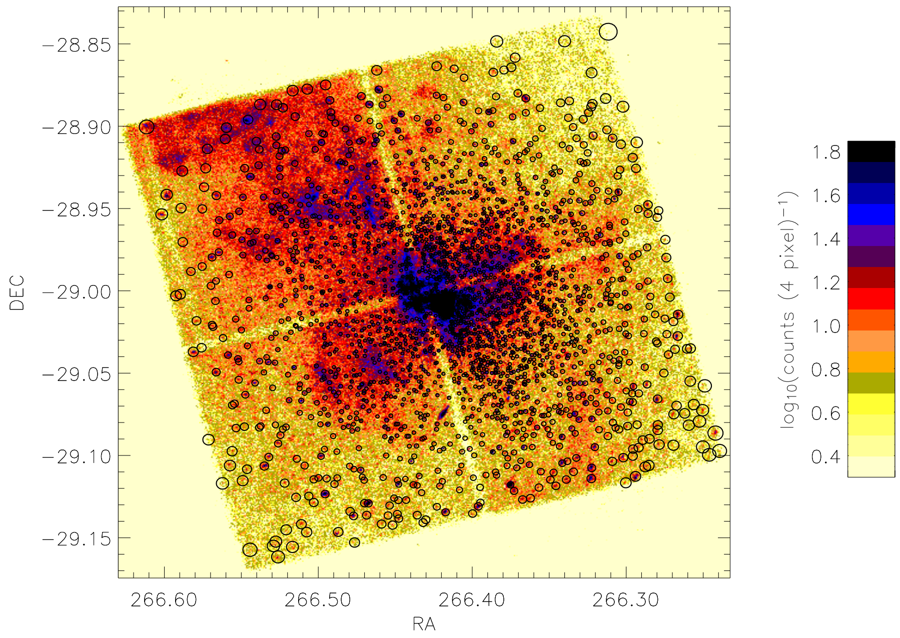

Figure 1 This 'Raw Counts Image of the Chandra Sgr A* Field' has been binned to have 2″ pixels. The circles that were used to exclude the 2353 point sources detected by Muno et al. (2003a) have been overlaid on the image. The Sgr A complex is saturated in the center of the image. Also evident are bipolar lobes centered on Sgr A* and oriented perpendicular to the Galactic plane, hard filamentary features to the northeast and south of the Sgr A complex, and bright, diffuse emission throughout the image (see Baganoff et al., 2003; Park et al., 2003).

emission. The unresolved point sources were assumed to have a fixed spectral shape identical to that of the resolved sources with fewer than 80 net counts. The normalization of the point-source component was then stepped over a range of values, while the temperatures, elemental abundances, and normalizations of the model for the diffuse emission were allowed to vary to minimize χ^2 for each normalization. We then found the largest value of the point-source normalization for which we obtained a χ^2 that was acceptable at the 90% confidence level, and used this normalization to compute an upper limit to the flux from unresolved point sources.

The surface brightness of the diffuse emission that can be accounted for by unresolved point sources is listed by region in Table 1, and is displayed graphically in Figure 6. Unresolved point sources may produce $(0.7-1.5)\times10^{-13}$ erg cm^{-2} s^{-1} arcmin^{-2} in the regions $7'$ from the Galactic center, which is 35–80% of the total observed diffuse flux. We also list in Table 1 the flux from the soft and hard components that remains when an unresolved point source contribution is included. The reduction in the inferred diffuse flux is most dramatic in the hard band. Nevertheless, including a point source contribution in the Northeast, Northwest, and East does not removed the need for an 8 keV plasma component.

The significant differences between the upper limits to the unresolved point source contribution in each region occur because the fluxes and ratios of the fluxes in the He-like and H-like Fe lines are spatially variable (Figure 6), and they match the spectra of the point sources better in some regions than in others. Since the surface brightness from resolved point sources is relatively constant from field-to-field in the dark regions (Table 1), it seems unlikely that the surface brightness of unresolved point sources at the Galactic center actually varies from field-to-field by a factor of two. It is equally unlikely that the average spectra from hundreds of point sources varies on arcminute scales. Therefore, the most reasonable upper limit to the unresolved flux from point sources is the lowest inferred value: 7×10^{-14} erg cm^{-2} s^{-1} arcmin^{-2} in the Northwest dark region.

We can use this value and the $\log(N)-\log(S)$ distribution from Equation 5 in Muno et al. (2003a) to compute an upper limit to the surface density of unresolved point sources near the Galactic center. We find that the total point-source flux in the Northwest region of Figure 2 could be produced by the integrated flux from sources brighter than $S_{\rm min}=4\times10^{-16}$ erg cm^{-2} s^{-1}. This is only a factor of ten lower than the completeness limit of Muno et al.

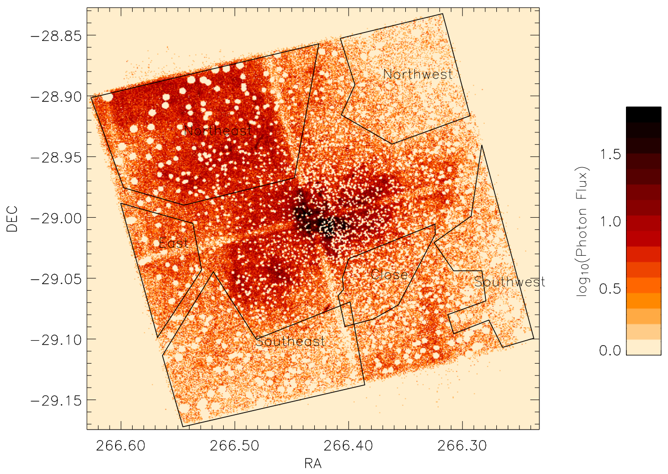

Figure 3 Image of the Sgr A* field in the 2–4 keV band, overlaid with the polygonal regions from which the spectra of the diffuse emission were extracted. The soft emission is most prominent at the bipolar lobes centered on Sgr A*, in the northeast, and in a ridge of emission in the Southwest.

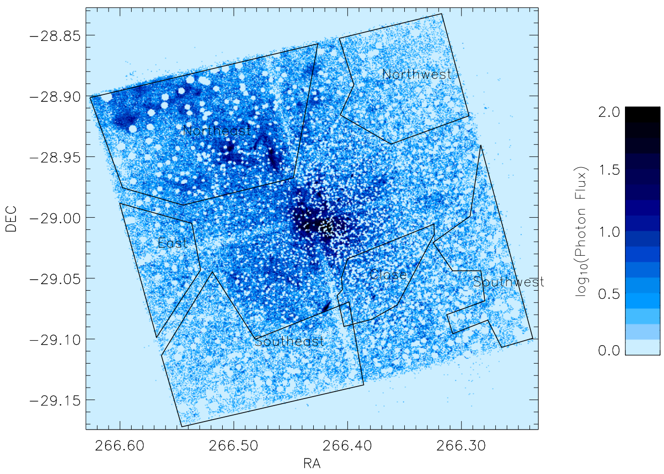

Figure 4 Image of the Sgr A* field in the 4–8 keV band, overlaid with the polygonal regions from which the spectra of the diffuse emission were extracted. The hard emission is more uniformly distributed in the soft, but is somewhat stronger in the northeast, particularly at several compact sites of neutral Fe emission (Park et al., 2003).

(2003a), and it corresponds to a luminosity of 3×10^{30} erg s^{-1} at 8 kpc. Moreover, this flux limit implies that there are 95 sources arcmin^{-2} at an offset from Sgr A* of $\theta = 8'$, which is 40 times higher than the number of sources resolved there by Muno et al. (2003a). Since the surface density of point sources increases as θ^{-1} toward Sgr A*, there could be as many as 750 sources arcmin^{-2} within $1'$ of Sgr A*.

4 Discussion

We have shown that unresolved point sources brighter than 3×10^{30} erg s^{-1} can account for nearly half of the hard component of the diffuse emission. Producing this amount of flux in the $17' \times 17'$ region around Sgr A* in Figure 2 would require over 44,000 point sources. The most likely candidates for such a large population of hot ($kT \sim 8$ keV) X-ray sources are cataclysmic variables (CVs; see Eracleous, Halpern, & Patterson, 1991; Mukai & Shiokawa, 1993; Ezuka & Ishida, 1999). Approximately 60% of CVs in the *ROSAT* sample of Verbunt et al. (1997) have luminosities higher than 3×10^{30} erg s^{-1}, so we would infer that unresolved $\sim 7 \times 10^4$ CVs are present near the Galactic center. This would imply a spatial density of 0.1 pc^{-3} in a volume of $40 \times 40 \times 300$ pc, which is 3000 times higher than the local space density of CVs (Schwope et al., 2002). Such a density of CVs is not unreasonable, since the stellar density within the inner 20 pc of the Galaxy is $\sim$ 6000 times higher than the local value (Launhardt, et al., 2002).

On the other hand, unresolved point sources can not produce all of the hard diffuse emission from the Galactic center, and so its origin is therefore still an open question. The 0.8 keV plasma is probably produced by supernova, which are the largest heating source for the ISM. Indeed, $\sim$ 1 keV plasma is commonly inferred to be present in supernova remnants, and the energy required to heat the plasma is only fraction of the kinetic energy known to be released by supernova. In contrast, supernova rarely produce plasma with $kT \gtrsim 3$ keV (Kaneda et al., 1997). Therefore, the hard diffuse emission has been variously modeled as originating from plasma heated and confined by magnetic filaments (Tanuma et al., 1999), quasi-thermal plasma continuously accelerated by shocks in the 0.8 keV plasma (Dogiel et al., 2002; Masai et al., 2002), and emission from cosmic-ray electrons (Valinia et al., 2000). These mechanisms are not entirely satisfying yet, because they all require significant assumptions about processes for which we have few other observational constraints (see the discussion in, e.g., Dogiel et al., 2002).

Further progress in understanding the origin of the diffuse X-ray emission from the Galactic plane awaits observations with much higher energy resolution. The major predictions of the quasi-thermal plasma and cosmic-ray

Table 1. Flux from the Plasma Components and Point Sources

	Southeast	Southwest	Northwest	East	Close	Northeast
$F_{\rm tot}$	1.80	1.84	1.72	2.27	3.02	4.49
$F_{\rm resolved}$	0.2	0.3	0.2	0.2	1.0	0.4
No Unresolved Point Sources						
F_1	0.26	0.17	0.20	0.62	0.36	1.83
F_2	1.47	1.64	1.53	1.63	2.48	2.64
With Unresolved Point Sources						
F_1	0.49	0.02	0.23	0.52	0.54	1.68
F_2	0.04	0.37	0.81	0.91	0.06	1.93
$F_{\rm unresolved}$	1.27	1.46	0.68	0.84	2.42	0.87

Note. — All fluxes are those observed between 2–8 keV, in units of 10^{-13} erg cm^{-2} s^{-1} arcmin^{-2}.

models are that the line strengths and ratios in the diffuse emission should differ significantly from their collisional-equilibrium values (Valinia et al., 2000; Masai et al., 2002). Unfortunately, the current *Chandra* observations appear unable to distinguish these from variations in the elemental abundances. ASTRO-E 2 will have a factor of 10 better energy resolution than ACIS-I on *Chandra*, which will enable us to resolve the He-like $n = 2 - 1$ triplet from Fe, and to detect radiative recombination continua from Si, S, Ar, and Fe. Therefore, the prospects for understanding the source of the hard diffuse X-ray emission within the next decade are excellent.

Acknowledgments

First, I would like to thank Fred Baganoff for bringing me onto this project right after I finished my Ph.D. I am also grateful to all of my collaborators on these Galactic center observations, for their advice on scientific issues, help with software, and insistence that I remain honest. Those collaborators are: Fred Baganoff, Mark Bautz, Niel Brandt, Pat Broos, Eric Feigelson, Gordon Garmire, Christian Howard, Mark Morris, Sangwook Park, George Ricker, and Leisa Townsley. This work was supported in part by NASA grants NAS 8-39073 and NAS 8-00128, and by a Hubble Fellowship grant from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Incorportated, under NASA contract NAS5-26555.

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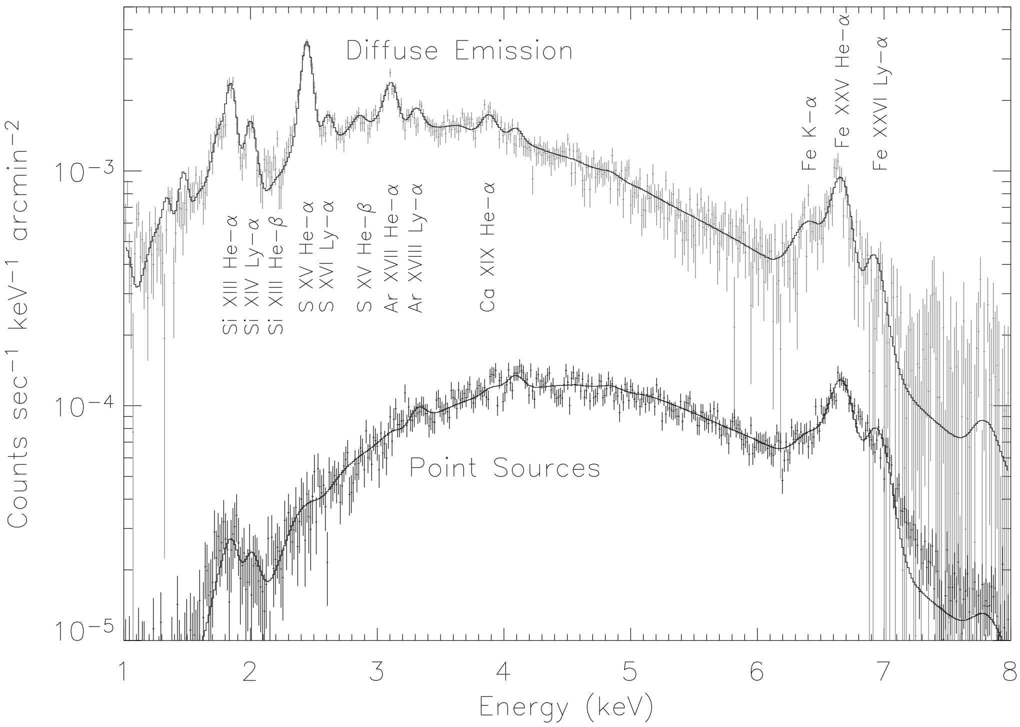

Figure 5 A comparison between the spectra of the point sources and diffuse emission from the Southeast region near the Galactic center. The relative normalizations of the two spectra accurately reflect their relative fluxes — the flux from point sources is about 10% of that from the diffuse emission. The average spectrum of the point sources is considerably harder than that of the diffuse emission. The identifications of the prominent emission lines are also indicated.

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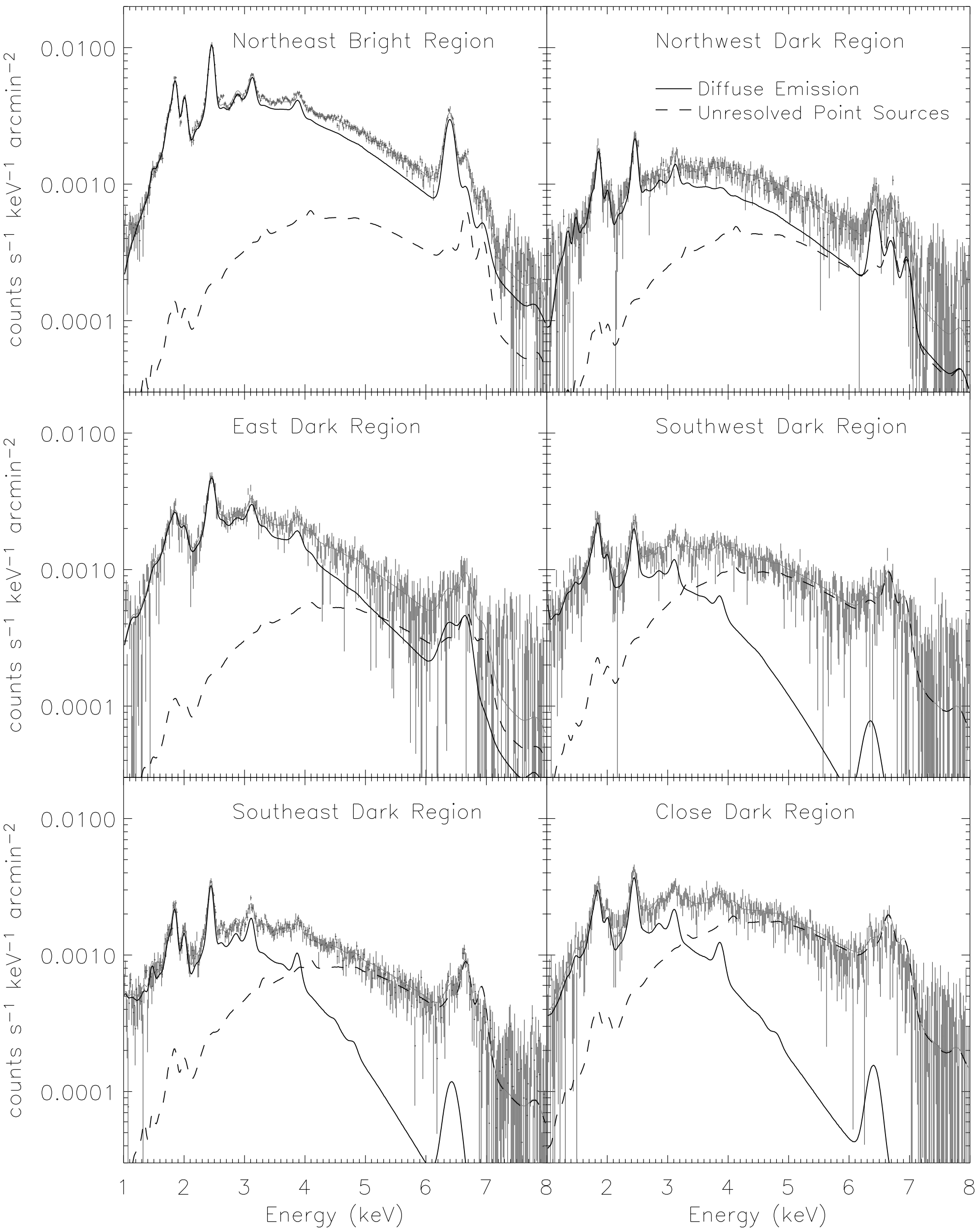

Figure 6 This figure illustrates the maximum amount that unresolved point sources could plausibly contribute to the diffuse emission. The background-subtracted spectrum of the diffuse emission is shown with the grey crosses. The upper limit to the contribution of unresolved point sources is based upon the spectrum of resolved sources with fewer than 80 net counts, and is shown with the dashed line. The remaining emission inferred to be truly diffuse is shown with the solid black line. The point sources are much harder than the total diffuse emission, but can not be responsible for all of the inferred hard component of the diffuse emission.

Abstracts

A New X-Ray Flare from the Galactic Nucleus Detected with the XMM-Newton Photon Imaging Cameras

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Sgr A*, the compact radio source, believed to be the counterpart of the massive black hole at the galactic nucleus, was observed to undergo rapid and intense flaring activity in X-rays with Chandra in October 2000. We report here the detection with XMM-Newton EPIC cameras of the early phase of a similar X-ray flare from this source, which occurred on September 4, 2001. The source 2-10 keV luminosity increased by a factor ≈ 20 to reach a level of 4 10^{34} erg s^{-1} in a time interval of about 900 s, just before the end of the observation. The data indicate that the source spectrum was hard during the flare. This XMM-Newton observation confirms the results obtained by Chandra and suggests that, in Sgr A*, rapid and intense X-ray flaring is not a rare event. This can constrain the emission mechanism models proposed for this source, and also implies that the crucial multiwavelength observation programs planned to explore the behaviour of the radio/submm and hard X-ray/gamma-ray emissions during the X-ray flares, have a good chance of success.

Ref.: ApJ Lett, Jul 2002, submitted
Email: goldwurm@discovery.saclay.cea.fr
Eprint: astro-ph/0207620

Limits on the Short Term Variability of Sagittarius A* in the Near-Infrared

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The recent detection of a 3-hr X-ray flare by the Chandra Observatory has raised the possibility of enhanced emission over a broad range of wavelengths from Sgr A*, the suspected 2.6 x 10^6 solar mass black hole at the Galactic Center, during a flaring event. We have, therefore, reconstructed 3-hr data sets from 2μm speckle and adaptive optics images (θ_{core} = 50 - 100 mas) obtained with the W. M. Keck 10-m telescopes between 1995 and 2001. In 25 separate observations, no evidence of any significant excess emission associated with Sgr A* was detected. The lowest of our detection limits gives an observed limit for the quiescent state of Sgr A* of 0.09$\pm$0.005 mJy, or, equivalently, a dereddened value of 2.0$\pm$0.1 mJy, which is a factor of 2 lower than the best previously published quiescent value. Under the assumption that there are random 3-hr flares producing both enhanced X-ray and near-infrared emission, our highest limit constrains the variable state of Sgr A* to $\leq$0.8 mJy (observed) or 19 mJy (dereddened). These results suggest that the model favored by Markoff et al. (2001), in which the flare is produced through local heating of relativistic particles surrounding Sgr A* (e.g., a sudden magnetic reconnection event), is unlikely, because it predicts peak 2μm emission of $\sim$300 mJy, well above our detection limit.

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Orbital Inspiral into a Massive Black Hole in a Galactic Center

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A massive black hole (MBH) in a galactic center drives a flow of stars into nearly radial orbits to replace those it destroyed. Stars whose orbits cross the event horizon r_s or the tidal disruption radius r_t are promptly destroyed in an orbital period P. Stars with orbital periapse r_p slightly larger than the sink

radius q=max(r_s,r_t) may slowly spiral in due to dissipative interactions with the MBH, e.g. gravitational wave emission, tidal heating or accretion disk drag, with observable consequences and implications for the MBH growth rate. Unlike prompt destruction, the inspiral time is typically >>P. This time is limited by the same scattering process that initially deflected the star into its eccentric orbit, since it can deflect it again to a wider orbit where dissipation is inefficient. The ratio between slow and prompt event rates is therefore much smaller than that implied by the ratio of cross-sections, r_p/q, and so only prompt disruption contributes significantly to the mass of the MBH. Conversely, most stars that scatter off the MBH survive the extreme tidal interaction ("tidal scattering"). We derive general expressions for the inspiral event rate and the mean number of inspiraling stars, and show that the survival probability of tidally scattered stars is 1, and that the number of tidally heated stars ("squeezars") and gravity wave emitting stars in the Galactic Center is 0.1-1.

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Squeezars: Tidally powered stars orbiting a massive black hole

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We propose that there exists a class of transient sources, "squeezars", which are stars caught in highly eccentric orbits around a massive (m< 10^8 $M_\odot$) black hole (MBH), whose atypically high luminosity (up to a significant fraction of their Eddington luminosity) is powered by tidal interactions with the MBH. Their existence follows from the presence of a mass sink, the MBH, in the galactic center, which drives a flow of stars into nearly radial orbits to replace those it has destroyed. We consider two limits for the stellar response to tidal heating: surface heating with radiative cooling ("hot squeezars") and bulk heating with adiabatic expansion ("cold squeezars"), and calculate the evolution of the squeezar orbit, size, luminosity and effective temperature. The squeezar formation rate is only ~0.05 that of tidal disruption flares, but squeezar lifetimes are many orders of magnitude longer, and so future observations of squeezars in nearby galaxies can probe the tidal process that feeds MBHs and the effects of extreme tides on stars. The mean number of squeezars orbiting the Galactic MBH is estimated at 0.1-1.

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AST/RO Observations of CO $J = 7 \to 6$ and $J = 4 \to 3$ Emission toward the Galactic Center Region

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We present position-velocity strip maps of the Galactic Center region in the CO $J = 7 \to 6$ and $J = 4 \to 3$ transitions observed with the Antarctic Submillimeter Telescope and Remote Observatory (AST/RO) located at Amundsen-Scott South Pole Station. Emission from the two rotational transitions of ^{12}CO was mapped at $b = 0°$ for $3.5° > \ell > -1.5°$, on a $1'$ grid with a FWHM beamsize of $58''$ at 806 GHz and $105''$ at 461 GHz. The (CO $J = 4 \to 3$)/(CO $J = 1 \to 0$) line ratio map is almost featureless across the entire Galactic Center region. A Large Velocity Gradient (LVG) analysis shows that aside from the two special regions Sgr A and Sgr B, the photon-dominated regions within a few hundred parsecs of the Galactic Center are remarkably uniform in mean density and kinetic temperature at $n = 2500$ to $4000\,\mathrm{cm}^{-3}$ and T = 30 to 45 K. The (CO $J = 7 \to 6$)/(CO $J = 4 \to 3$) line temperature ratios near Sgr B are a factor of two higher than those observed in the nuclear region of the starburst galaxy M82 (Mao et al. 2000), while the CO($J = 7 \to 6$)/CO($J = 4 \to 3$) line temperature ratios around Sgr A are similar to M82. The line ratio on large scales from the Galactic Center region is an order of magnitude less than that from M82.

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Absorption Line Survey of H_3^+ toward the Galactic Center Sources I. GCS 3-2 and GC IRS3

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We present high-resolution (R = 20000) spectroscopy of H_3^+ absorption toward the luminous Galactic center sources GCS 3-2 and GC IRS 3. With the efficient wavelength coverage afforded by Subaru IRCS, six absorption lines of H_3^+ have been detected in each source from 3.5 to 4.0 μm, three of which are new. In particular the 3.543 μm absorption line of the $R(3,\,3)^l$ transition arising from the metastable $(J,\,K) = (3,\,3)$ state has been tentatively detected for the first time in the interstellar medium, where previous observations of H_3^+ had been limited to absorption lines from the lowest levels: $(J,\,K) = (1,\,0)$ of ortho-H_3^+ and $(1,\,1)$ of para-H_3^+. The H_3^+ absorption toward the Galactic center takes place in dense and diffuse clouds along the line of sight as well as the molecular complex close to the Galactic nucleus. At least four kinematic components are found in the H_3^+ absorption lines. We suggest identifications of the velocity components with those of H I, CO, and H_2CO previously reported from radio and infrared observations. H_3^+ components with velocities that match those of weak and sharp CO and H_2CO lines are attributed to diffuse clouds. Our observation has revealed a striking difference between the absorption profiles of H_3^+ and CO, demonstrating that the spectroscopy of H_3^+ provides information complementary to that obtained from CO spectroscopy. The tentative detection of the $R(3,\,3)^l$ line and the non-detection of spectral lines from other $J > 1$ levels provide observational evidence for the metastability of the (3, 3) level, which is theoretically expected. This suggests that other metastable $J = K$ levels with higher J may also be populated.

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Massive Stars in the Arches Cluster

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We present and use new spectra and narrow-band images, along with previously published broad-band images, of stars in the Arches cluster to extract photometry, astrometry, equivalent width, and velocity information. The data are interpreted with a wind/atmosphere code to determine stellar temperatures, luminosities, mass-loss rates, and abundances. We have doubled the number of known emission-line stars, and we have also made the first spectroscopic identification of the main sequence for any population in the Galactic Center. We conclude that the most massive stars are bona-fide Wolf-Rayet (WR) stars and are some of the most massive stars known, having $M_{init} \sim 100\ M_\odot$, and prodigious winds, $\dot{M} > 10^{-5}\ M_\odot\ yr^{-1}$, that are enriched with helium and nitrogen; with these identifications, the Arches cluster contains about 5% of all known WR stars in the Galaxy. We find an upper limit to the velocity dispersion of 22 km s^{-1}, implying an upper limit to the cluster mass of $7(10^4)\ M_\odot$ within a radius of 0.23 pc; we also estimate the bulk heliocentric velocity of the cluster to be $v_{cluster,\odot} \approx +95$ km s^{-1}. Taken together, these results suggest that the Arches cluster was formed in a short, but massive, burst of star formation about 2.5±0.5 Myr ago, from a molecular cloud which is no longer present. The cluster hap-

pens to be approaching and ionizing the surface of a background molecular cloud, thus producing the Thermal Arched Filaments. We estimate that the cluster produces $4(10^{51})$ ionizing photons s^{-1}, more than enough to account for the observed thermal radio flux from the nearby cloud, $3(10^{49})$ ionizing photons s^{-1}. Commensurately, it produces $10^{7.8}$ $L_\odot$ in total luminosity, providing the heating source for the nearby molecular cloud, $L_{cloud} \approx 10^7$ $L_\odot$. These interactions between a cluster of hot stars and a wayward molecular cloud are similar to those seen in the "Quintuplet/Sickle" region. The small spread of formation times for the known young clusters in the Galactic Center, and the relative lack of intermediate-age stars (τ_{age}=$10^{7.0}$ to $10^{7.3}$ yrs), suggest that the Galactic Center has recently been host to a burst of star formation. Finally, we have made new identifications of near-infrared sources that are counterparts to recently identified x-ray and radio sources.

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Variability of Sagittarius A* - Flares at 1 Millimeter

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We report the results from recent observations of Sgr A* at short-/sub-millimeter wavelengths made with the partially finished Sub-Millimeter Array (SMA) on Mauna Kea. A total of 25 epochs of observations were carried out over the past 15 months in 2001 March to 2002 May. Noticeable variations in flux density at 1.3 mm were observed showing three "flares". The SMA observations suggest that Sgr A* highly increases towards submillimeter wavelengths during a flare suggesting the presence of a break wavelength in spectral index around 3 mm. A cross-correlation of the SMA data at 1 mm with the VLA data at 1 cm show a global delay of $t_{delay} > 3d$, suggesting that sub-millimeter wavelengths tend to peak first. Only marginal day-to-day variations in flux density (2-3σ) have been detected at 1.3 mm. No significant flares on a short time scale ($\sim$ 1 hr) have been observed at 1.3 mm. We also failed to detect significant periodic signals at a level of 5% (3σ) from Sgr A* in a periodic searching window ranging from 10 min to 2.5 hr. The flares observed at the wavelengths between short-centimeter and sub-millimeter might be a result of collective mass ejections associated with X-ray flares that originate from the inner region of the accretion disk near the supermassive black hole.

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The Molecular Component of the Galactic Center Arched Filament H II Complex: OVRO Observations of the CS(J=2−1) Line

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The Owens Valley Radio Observatory (OVRO) millimeter array was used to make observations of the CS(2-1) line (at 97.981 GHz) arising from the G0.07+0.04 region of the "−30 km s^{-1}" molecular cloud near the Galactic center with a spatial resolution of ∼8". The ionized edges of this cloud forms the Arched Filament HII regions which are ionized by the adjacent hes stellar cluster. The OVRO data were combined with single-dish data obtained at the 30-m IRAM telescope by Serabyn & Güsten (1987). A comparison of this CS(2-1) data and the H92α recombination line data of Lang, Goss & Morris (2001) reveals that the ionized and molecular gas are physically related, but that their velocities in this region differ by up to 35 km s^{-1}. This difference in velocity can be understood if the gas that gave rise to the G0.07+0.04 HII region has been fully ionized. An overall comparison of the molecular and ionized gas across the entire −30 km s^{-1} cloud based on the single dish CS(2-1) data and the H92α line data illustrates that such differences in velocity between the ionized and molecular gas are common and that the geometrical arrangement of these components is complicated. Much of the ionized gas resides on the near side (to the observer) of the molecular cloud; however, in several regions, some molecular material must lie in front of the HII region. The Arches stellar cluster therefore appears to be located in the midst of the molecular clouds such that some of the near-side cloud surfaces along our line of sight have not been exposed to the ionizing radiation.

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X-ray Thread G0.13-0.11: A Pulsar Wind Nebula?

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We have examined *Chandra* observations of the recently discovered X-ray thread G0.13-0.11 in the Galactic center Radio Arc region. Part of the *Chandra* data was studied by Yusef-Zadeh, Law, & Wardle (2002), who reported the detection of 6.4-keV line emission in this region. We find, however, that this line emission is *not* associated with G0.13-0.11. The X-ray spectrum of G0.13-0.11 is well characterized by a simple power law with an energy slope of $1.8^{+0.7}_{-0.4}$ (90% confidence uncertainties). Similarly, the X-ray spectrum of the point-like source embedded in G0.13-0.11 has a power law energy slope of $0.9^{+0.9}_{-0.7}$. The 2 – 10 keV band luminosities of these two components are $\sim 3.2 \times 10^{33}$ $ergs\ s^{-1}$ (G0.13-0.11) and $\sim 7.5 \times 10^{32}$ $ergs\ s^{-1}$ (point source) at the Galactic center distance of 8 kpc. The morphological, spectral, and luminosity properties strongly indicate that G0.13-0.11 represents the leading-edge of a pulsar wind nebula, produced by a pulsar (point source) moving in a strong magnetic field environment. The main body of this pulsar wind nebula is likely traced by a bow-shaped radio feature, which is apparently bordered by G0.13-0.11 and is possibly associated with the prominent nonthermal radio filaments of the Radio Arc. We speculate that young pulsars may be responsible for various unique nonthermal filamentary radio and X-ray features observed in the Galactic center region.

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A new Monte Carlo code for star cluster simulations: II. Central black hole and stellar collisions

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We have recently written a new code to simulate the long term evolution of spherical clusters of stars. It is based on the pioneering Monte Carlo scheme proposed by Hénon in the 70's. Unlike other implementations of this numerical method which were successfully used to investigate the dynamics of globular clusters, our code has been devised in the specific goal to treat dense galactic nuclei. In a previous paper, we described the basic version of our code which includes 2-body relaxation as the only physical process. In the present work, we go on and include further physical ingredients that are mostly pertinent to galactic nuclei, namely the presence of a central (growing) black hole (BH) and collisions between (main sequence) stars. Stars that venture too close to the BH are destroyed by the tidal field. We took particular care of this process because of its importance, both as a channel to feed the BH and a way to produce accretion flares from otherwise quiescent galactic nuclei. Collisions between stars have often been proposed as another mechanism to drive stellar matter into the central BH. Furthermore, non disruptive collisions may create peculiar stellar populations which are of great observational interest in the case of the central cluster of our Galaxy. To get the best handle on the role of this process in galactic nuclei, we include it with unpreceded realism through the use of a set of more than 10 000 collision simulations carried out with a SPH (Smoothed Particle Hydrodynamics) code. Stellar evolution has also been introduced in a simple way, similar to what has been done in previous dynamical simulations of galactic nuclei. To ensure that this physics is correctly simulated, we realized a variety of tests whose results are reported here. This unique code, featuring most important physical processes, allows million particle simulations, spanning a Hubble time, in a few CPU days on standard personal computers and provides a wealth of data only rivalized by N-body simulations.

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Gravitational waves from stars orbiting the Sagittarius A* black hole

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One of the main astrophysical processes leading to strong emission of gravitational waves to be detected by the future space-borne interferometer *LISA* is the capture of a compact star by a black hole with a mass of a few million solar masses in the center of a galaxy. In previous studies, main sequence stars were thought not to contribute because they suffer from early tidal disruption. Here we show that, according to our simulations of the stellar dynamics of the Sgr A* cluster, there must be one to a few low-mass main sequence stars sufficiently bound to the central Galactic black hole to be conspicuous sources in *LISA* observations. The probability that a white dwarf may be detectable is lower than 0.5 and, in spite of mass segregation, detection of a captured neutron star or stellar black hole in the center of the Milky Way is highly unlikely.

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Extinction close to the Galactic centre

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We extract J and K_s magnitudes from the 2MASS Point Source Catalog for approximately 6×10^6 stars with $8 \leq K_s \leq 13$ in order to build an A_K extinction map within 10° of the Galactic centre. The extinction was determined by fitting the upper giant branch of (K_s, J-K_s) colour-magnitude diagrams to a dereddened upper giant branch mean locus built from previously studied Bulge fields. The extinction values vary from A_K=0.05 in the edges of the map up to A_K=3.2 close to the Galactic centre. The 2MASS extinction map was compared to that recently derived from DENIS data. Both maps agree very well up to A_K=1.0. Above this limit, the comparison is affected by increased internal errors in both extinction determination methods. The 2MASS extinction values were also compared to those obtained from dust emission in the far infrared using DIRBE/IRAS. Several systematic effects likely to bias this comparison were addressed, including the presence of dust on the background of the bulk of 2MASS stars used in the extinction determination. For the region with $3° < |b| < 5°$, where the dust contribution on the far side of the Galaxy is $\approx$ 5 %, the two extinction determinations correlate well, but the dust emission A_K values are systematically higher than those from 2MASS. A calibration correction factor of 76% for the DIRBE/IRAS dust emission extinction is needed to eliminate this systematic effect. Similar comparisons were also carried out for the $1° < |b| < 3°$ and $|b| < 0.5°$ strips, revealing an increasing complexity in the relation between the two extinction values. Discrepancies are explained in terms of the calibration factor, increasing background dust contribution, temperature effects influencing the dust emission extinction and limitations in the 2MASS extinction determination in very high extinction regions ($|b| < 0.5°$). An asymmetry relative to the Galactic plane is observed in the dust maps, roughly in the sense that A_K values are 60% smaller in the south than in the north for $1° < |b| < 5°$. This asymmetry is due to the presence of foreground dust clouds mostly in the northern region of the Bulge.

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Really Cool Stars and the Star Formation History at the Galactic Center

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We present $\lambda/\Delta\lambda = 550$ to 1200 near infrared H and K spectra for a magnitude limited sample of 79 asymptotic giant branch and cool supergiant stars in the central ≈ 5 pc (diameter) of the Galaxy. We use a set of similar spectra obtained for solar neighborhood stars with known Teff and Mbol that is in the same range as the Galactic center (GC) sample to derive Teff and Mbol for the GC sample. We then construct the Hertzsprung–Russell (HRD) diagram for the GC sample. Using an automated maximum likelihood routine, we derive a coarse star formation history of the GC. We find (1) roughly 75% of the stars formed in the central few pc are older than 5 Gyr; (2) the star formation rate (SFR) is variable over time, with a roughly 4 times higher star formation rate in the last 100 Myr compared to the average SFR; (3) our model can only match dynamical limits on the total mass of stars formed by limiting the IMF to masses above 0.7 $M_\odot$. This could be a signature of mass segregation or of the bias toward massive star formation from the unique star formation conditions in the GC; (4) blue supergiants account for 12 % of the total sample observed, and the ratio of red to blue supergiants is roughly 1.5; (5) models with isochrones with [Fe/H] = 0.0 over all ages fit the stars in our HRD better than models with lower [Fe/H] in the oldest age bins, consistent with the finding of Ramirez et al. (2000) that stars with ages between 10 Myr and 1 Gyr have solar [Fe/H].

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Interferometric Detection of Linear Polarization from Sagittarius A* at 230 GHz

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We measured the linear polarization of Sagittarius A* to be $7.2 \pm 0.6\%$ at 230 GHz using the BIMA array with a resolution of 3.6×0.9 arcsec. This confirms the previously reported detection with the JCMT 14-m antenna. Our high resolution observations demonstrate that the polarization does not arise from dust but from a synchrotron source associated with Sgr A*. We see no change in the polarization position angle and only a small change in the polarization fraction in four observations distributed over 60 days. We find a position angle 139 ± 4 degrees that differs substantially from what was found in earlier JCMT observations at the same frequency. Polarized dust emission cannot account for this discrepancy leaving variability and observational error as the only explanations. The BIMA observations alone place an upper limit on the magnitude of the rotation measure of 2×10^6 rad m^{-2}. These new observations when combined with the JCMT observations at 150, 375 and 400 GHz suggest $RM = -4.3 \pm 0.1 \times 10^5$ rad m^{-2}. This RM may be caused by an external Faraday screen. Barring a special geometry or a high number of field reversals, this RM rules out accretion rates greater than $\sim 10^{-7} M_\odot$ yr^{-1}. This measurement is inconsistent with high accretion rates necessary in standard advection dominated accretion flow and Bondi-Hoyle models for Sgr A*. It argues for low accretion rates as a major factor in the overall faintness of Sgr A*.

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The Origin of the Galactic Center Nonthermal Radio Filaments: Young Stellar Clusters

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The unusual class of magnetized nonthermal radio filaments (NTF), threads and streaks with their unique physical characteristics are found only within the inner couple of degrees of the Galactic center. Also, a number of young, mass-losing and rare stellar clusters are recognized to lie in the Galactic center region. The latter characteristic of the Galactic center region is used to explain the origin of the nonthermal radio filaments. We consider a mechanism in which the collective winds of massive WR

and OB stars within a dense stellar environment produce shock waves that can accelerate particles to relativistic energies. This mechanism is an extension of a model originally proposed by Rosner and Bodo (1996), who suggested that energetic nonthermal particles are produced in a terminal shock of mass-losing stars. The large-scale distribution of the magnetic field in the context of this model is argued to have neither poloidal geometry nor pervasive throughout the Galactic center region.

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High Precision Stellar Radial Velocities in the Galactic Center

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We present radial velocities for 85 cool stars projected onto the central parsec of the Galaxy. The majority of these velocities have relative errors of $\sim$1 km s^{-1}, or a factor of $\sim$30-100 smaller than those previously obtained with proper motion or other radial velocity measurements for a similar stellar sample. The error in a typical individual stellar velocity, including all sources of uncertainty, is 1.7 km s^{-1}. Two similar data sets were obtained one month apart, and the total error in the relative velocities is 0.80 km s^{-1} in the case where an object is common to both data sets. The data are used to characterize the velocity distribution of the old population in the Galctic Center. We find that the stars have a Gaussian velocity distribution with a mean heliocentric velocity of -10.1 ± 11.0 km s^{-1} (blueshifted) and a standard deviation of 100.9 ± 7.7 km s^{-1}; the mean velocity of the sample is consistent with no bulk line-of-sight motion with respect to the Local Standard of Rest. At the 1 sigma level, the data are consistent with a symmetric velocity distribution about any arbitrary axis in the plane of the sky. We find evidence for a flattening in the distribution of late-type stars within a radius of $\sim$0.4 pc , and infer a volume density distribution of r$^{-1/4}$ in this region. Finally, we establish a first epoch of radial velocity measurements which can be compared to subsequent epochs to measure small accelerations (1 km s^{-1} yr^{-1}), corresponding to the magnitude expected over a timespan of several years for stars nearest to Sgr A*.

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Nonthermal Electrons in Radiatively Inefficient Accretion Flow Models of Sagittarius A*

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We investigate radiatively inefficient accretion flow models for Sgr A*, the supermassive black hole in our Galactic Center, in light of new observational constraints. Confirmation of linear polarization in the submm emission argues for accretion rates much less than the canonical Bondi rate. We consider models with low accretion rates and calculate the spectra produced by a hybrid electron population, consisting of both thermal and nonthermal particles. The thermal electrons produce the submm emission and can account for its linear polarization properties. As noted in previous work, the observed low-frequency radio spectrum can be explained if a small fraction ($\approx$ 1.5%) of the electron thermal energy resides in a soft power-law tail. In the innermost region of the accretion flow, turbulence and/or magnetic reconnection events may occasionally accelerate a fraction of the electrons into a harder power-law tail. We show that the synchrotron emission from these electrons, or the Compton up-scattering of synchrotron photons by the same electrons, may account for the X-ray flares observed by *Chandra*.

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The Eye of the Tornado—an isolated, high mass young stellar object near the Galactic centre

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We present infrared (AAT, UKIRT) and radio (VLA, SEST) observations of the Eye of the Tornado, a compact source apparently near the head of the Tornado Nebula. The near-infrared Brγ and He I lines are broad (FWHM 40 and 30 km s^{-1}, respectively) and have a line centre at $V_{LSR} \sim -205$km s^{-1}. This corresponds to a feature at the same velocity in the ^{12}CO J=1–0 line profile. The kinematic velocity derived from Galactic rotation places the Eye at the distance of the Galactic Centre (i.e. 8.5 kpc) and separated (probably foreground) from the Tornado Nebula. Four knots of emission are seen in the Brγ line and at 6 and 20 cm. Together with the flat radio spectral index, we confirm that the Eye contains ionized gas, but that this is embedded within a dense molecular core. The spectral energy distribution can be modelled as a two-component blackbody + greybody, peaking at far–IR wavelengths. The knots are UC HII regions, and the core contains a luminous ($\sim 2 \times 10^4\, L_\odot$), embedded, massive young stellar source. We also propose a geometrical model for the Eye to account for both its spectral energy distribution and its morphology.

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The line–of–sight distribution of the gas in the inner 60 pc of the Galaxy

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2MASS K_S band data of the inner 60 pc of the Galaxy are used to reconstruct the line-of-sight distances of the giant molecular clouds located in this region. Using the 2MASS H band image of the same region, two different populations of point sources are identified according to their flux ratio in the two bands. The population of blue point sources forms a homogeneous foreground that has to be subtracted before analyzing the K_S band image. The reconstruction is made using two basic assumptions: (i) an axis-symmetric stellar distribution in the region of interest and (ii) optically thick clouds with an area filling factor of $\sim$1 that block all light of stars located behind them. Due to the reconstruction method, the relative distance between the different cloud complexes is a robust result, whereas it is not excluded that the absolute distance with respect to Sgr A* of structures located more than 10 pc in front of Sgr A* are understimated by up to a factor of 2. It is shown that all structures observed in the 1.2 mm continuum and in the CS(2-1) line are present in absorption. We place the 50 km s^{-1} cloud complex close to, but in front of, Sgr A*. The 20 km s^{-1} cloud complex is located in front of the 50 km s^{-1} cloud complex and has a large LOS distance gradient along the direction of the galactic longitude. The bulk of the Circumnuclear Disk is not seen in absorption. This leads to an upper limit of the cloud sizes within the Circumnuclear Disk of $\sim$0.06 pc.

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Variable Infrared Emission from the Supermassive Black Hole at the Center of the Milky Way

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We report the detection of a variable point source, imaged at L'(3.8 microns) with the W. M. Keck II 10-meter telescope's adaptive optics system, that is coincident to within 12 mas of the Galaxy's central supermassive black hole and the unique radio source Sgr A*. While in 2002 this source (SgrA*-IR) was confused with the stellar source S0-2, in 2003 these two sources are separated by 87 mas allowing the new source's properties to be determined directly. On four separate nights, its observed L' magnitude ranges from 12.2 to 13.8, which corresponds to a flux density of 0.7 - 3 mJy, observed, and 4 - 17 mJy, dereddened; no other source in this region shows such large variations in flux density - a factor of 4 over a week and a factor of 2 over 40 min. In addition, it has a K-L' color greater than 2.1, which is at least 1 mag redder than any other source detected at L' in its vicinity. Between 2002 and 2003, the new source has no significant proper motion with an upper limit of 300 km/s, which is a factor of ¿20 smaller than that of the stellar sources measured within 10 mas of the dynamical center. Based on this source's coincidence with the Galaxy's dynamical center, its lack of motion, its variability, and its red color, we conclude that it is associated with the central supermassive black hole. The short timescale for the 3.8 micron flux density variations implies that the emission arises in the accretion flow on physical size scales smaller than 5 AU, or 80 R_s for a 4×10^6 M$_\odot$ black hole. We suggest that the 3.8 micron emission mechanism is synchrotron emission from the same population of electrons that gives rise to the X-ray flares, which implies that processes that can give rise to a high-energy power-law tail in the electron energy distribution are much more common than previously thought.

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An Extended Star Formation History for the Galactic Center from Hubble Space Telescope/NICMOS Observations

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We present Hubble Space Telescope (HST) Near-Infrared Camera and Multiobject Spectrometer (NICMOS) observations as evidence that continuous star formation has created much of the central stellar cusp of the Galaxy. The data are the deepest ever obtained for a Galactic Center (GC) population, being >50% complete for $M_{F205w} < 19.3$, or initial stellar masses $\gtrsim 2$ $M_\odot$. We use Geneva and Padova stellar evolution models to produce synthetic luminosity functions for burst and continuous star formation scenarios, finding that the observations are fit best by continuous star formation at a rate that is consistent with the recent star formation activity that produced the three massive young clusters in the central 50 pc . Further, it is not possible to fit the observations with ancient burst models, such as would be appropriate for an old population like that in Baade's Window or NGC6528.

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