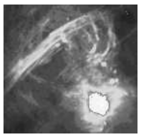
GCNEWS



The Newsletter of Galactic Center Research

Edited by Angela Cotera & Heino Falcke

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GC 98 Program and Abstract Booklet

"The Central Parsecs" — Galactic Center Workhop

Tucson Sep. 7-11, 1998

The conference "The Central Parsecs" was jointly organized by the Galactic Center Newsletter, the Sonderforschungsbereich 328 (Heidelberg), the Physics Department and the Steward Observatory of the University of Arizona, and the Max-Planck-Institut für Radioastronomie (Bonn). This special issue of GCNEWS contains all abstracts submitted for this workshop.

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GC98 Workshop Schedule

(Page numbers of abstracts are given in square brackets)

Sunday, September 6th

17:00-20:00	Registration (Lobby Mezzanine)
19:00-21:00	Reception (Poolside)

Monday, September 7th

Session I: What is the Central Matter Distribution?

Session moderator: Eric Becklin (Seminar Room)

08:55-09:00	Introduction and Workshop Welcome (Angela Cotera)		
09:00-09:30	The Dark Mass in the Center of the Milky Way	*(Reinhard Genzel)**	*[-]*
09:30-09:50	New Proper Motion Data	*(Andreas Eckart)**	*[6]*
09:50-10:10	High Proper Motion Stars in the Vicinity of Sgr A*	*(Andrea Ghez)**	*[6]*
10:10-10:30	Constraints on the mass of SgrA* from its proper motion	*(Mark Reid)**	*[7]*
10:30-11:00	Coffee Break (Canyon Suite II)		
11:00-11:30	NICMOS observations of the central Parsec	*(Marcia Rieke)**	*[7]*
11:30-11:50	NICMOS Observations of the Central Parsec: Deep Imaging at 1.6 microns, Short-Term Variability, and Ionized Emission	*(Susan Stolovy)**	*[7]*
11:50-12:30	Discussion		
12:30	Lunch (Sundance Cafe)		

Session II: Can VLBI constrain the size and structure of Sgr A*?

Session moderator: Anton Zensus (Seminar Room)

14:30-14:50	Corruption of the Visibility of Sgr A* by Intervening Plasma	*(Don Backer)**	*[7]*
14:50-15:10	7mm evidence for intrinsic source size and structure of Sgr A*	*(K.Y. Lo/J.H. Zhao)**	*[8]*
15:10-15:30	7 mm VLBI Imaging of Sgr A*	*(Geoff Bower)**	*[8]*
15:30-15:50	Millimeter Observations of Sgr A*	*(Thomas Krichbaum)**	*[8]*
15:50-16:20	Coffee Break (Canyon Suite II)		
16:20-16:40	86GHz VLBI observations of Sgr A*	*(Shep Doeleman)**	*[8]*
16:40-17:00	Flare of Sgr A* at 100 Ghz	*(Masato Tsuboi)**	*[9]*
17:00-18:00	Discussion		
20:00	Volleyball (Sportsfield, Volleyball Courts)		

Tuesday, September 8th

Session III: How to reconcile Models and Observations of Sgr A*?

Session moderator: Reinhard Genzel (Seminar Room)

09:00-09:30	Introduction	*(Fulvio Melia)**	*[9]*
09:30-09:50	Explaining the spectrum of Sgr A* using a two temperature plasma	*(Rohan Mahadevan)**	*[9]*
09:50-10:10	The Influence of an Advection-dominated Accretion Flow on the Appearance of Sgr A*	*(T. Beckert)**	*[9]*
10:10-10:40	Coffee Break (Canyon Suite II)		
10:40-11:00	The jet model for Sgr A* and the nature of the submm-bump	*(Heino Falcke)**	*[10]*
11:00-11:20	Sgr A* - The radio spectrum	*(Wolfgang Duschl)**	*[-]*
11:20-12:20	Discussion		
12:20	Lunch (Sundance Cafe)		

Session IV: Morphology and Gas Dynamics within Sgr A West: How are the various components of Sgr A West related?

Session moderator: Peter Mezger (Seminar Room)

14:20-14:50	The Various Components of the Sgr A Complex and their Interrelationship	*(Farhad Yusef-Zadeh)**	*[10]*
14:50-15:10	3D Simulations of the Gas Dynamics in the Central Region	*(Robert Coker)**	*[10]*
15:10-15:30	Proper Motions and Structure of the Radio Components around Sgr A*	*(Jun-Hui Zhao)**	*[10]*
15:30-15:50	Sgr A* in the Mid-Infrared Reference Frame: The Relationship Between the Radio and Infrared Sources in the Central Parsec	*(Dan Gezari)**	*[11]*
15:50-16:20	Coffee Break (Canyon Suite II)		
16:20-16:40	Mid-infrared observations of Sgr A West from Keck	*(Angela Cotera)**	*[11]*
16:40-17:00	Theoretical studies of the Circumnuclear Disk	*(Robert Sanders)**	*[11]*
17:00-18:00	Discussion		

Wednesday, September 9th

08:00-12:00	Arizona Sonoran Desert Museum
12:00	Lunch (on your own)

Session V: How, when, where and why are stars formed in the GC?

Session moderator: Kris Sellgren (Seminar Room)

13:30-13:50	Stellar Content of the Galactic Center	*(Bob Blum)**	*[11]*
13:50-14:10	Stellar Content of the central 30pc	*(Peter G. Mezger)**	*[12]*
14:10-14:30	The star formation/AGN connection in the GC and Other Galaxies	*(George Rieke)**	*[12]*
14:30-15:00	Discussion		
15:00-15:30	Coffee Break (Canyon Suite II)		
15:30-15:50	Properties of stars in the galactic center	*(Thomas Ott)**	*[12]*
15:50-16:10	The Arches Cluster	*(Gene Serabyn)**	*[12]*
16:10-16:30	NICMOS observations of the Quintuplet Cluster	*(Don Figer)**	*[13]*
16:30-16:50	Theoretical modelling of stars	*(Paco Najarro)**	*[13]*

16:50-17:30	Discussion		
18:30	No host Cocktail Hour (The Last Territory)		
19:30	Workshop Banquet (The Last Territory)		

Thursday, September 10th

Session VI: What is the metallicity as determined by old and new stars?

Session moderator: Wolfgang Duschl (Seminar Room)

09:00-09:20	Stellar abundances at the GC	*(Solange Ramirez)**	*[13]*
09:20-09:40	OH/IR stars as signposts for ancient starburst activity in the Galactic center	*(Lorant Sjouwerman)**	*[13]*
09:40-10:00	Discussion		
10:00-10:30	Coffee Break (Canyon Suite II)		

Session VII: How do the various components of the inner 100 parsecs interact with each other?

Session moderator: Miller Goss (Seminar Room)

10:30-10:50	Wide-field Imaging of the Galactic Center	*(Namir Kassim)**	*[13]*
10:50-11:10	Sgr East and it's interactions with the surrounding gas	*(Robert Zylka)**	*[14]*
11:10-11:30	Recombination lines from the SgrA complex near 20 cm	*(K.R. Anantharamaiah)**	*[14]*
11:30-12:00	Discussion		
12:00	Lunch (Sundance Cafe)		
14:00-14:20	OH 1720 MHz Masers at the GC	*(Mark Wardle)**	*[14]*
14:20-14:40	Free Electrons and Radio-Wave Scattering in the GC	*(T. Joseph Lazio)**	*[15]*
14:40-15:30	Discussion		
15:30-16:00	Coffee Break (Canyon Suite II)		

Session VIII: What is the strength of the magnetic field in the GC and what are its large and small scale effects?

Session moderator: Yoshiaki Sofue (Seminar Room)

16:00-16:20	Magnetic Fields in the Sagittarius A region	*(Doug Roberts)**	*[15]*
16:20-16:40	Far-infrared/Submillimeter Polarimetric Observations of the Galactic Center	*(Giles Novak)**	*[15]*
16:40-17:00	The Galactic Center Radio Threads: A Multifrequency, Polarimetric Study	*(Cornelia Lang)**	*[15]*
17:00-17:30	Discussion		
19:30	Tour of the Mirror Lab (meet in the Seminar Room)		

Friday, September 11th

Session IX: How "standard" are the central regions of our Galaxy? What would the GC look like from 1 Mpc?

Session moderator: Heino Falcke (Seminar Room)

09:00-09:20	The GC in comparison to AGN	*(Ski Antonucci)**	*[16]*
09:20-09:40	The MIR Spectrum in the GC: a Starburst Nucleus	*(Janet Simpson)**	*[16]*
09:40-10:00	Discussion		
10:00-10:20	Coffee Break (Canyon Suite II)		

Session X: What can we learn from High-energy emission in the GC?

Session Moderator: Fulvio Melia (Seminar Room)

10:20-10:40	Cosmic rays in the GC	*(Peter Biermann)**	*[16]*
10:40-11:00	γ-rays from the GC: A Point-like or Diffuse Source?	*(Sera Markoff)**	*[17]*
11:00-11:20	The Galactic Center EGRET Source and the Broad-band Spectrum of Sgr A East	*(Marco Fatuzzo)**	*[17]*
11:20-11:40	Cold Matter measurements in the GC with the X-ray satellite ASCA	*(Masaaki Sakano)**	*[17]*
11:40-12:00	Coffee Break (Canyon Suite II)		
12:00-12:30	Discussion		
12:30-13:00	Closing Thoughts and Workshop Summary	*(Charles Townes)**	*[-]*
14:00	Leave for the Grand Canyon (optional)		

All Week

POSTER SESSION

(only first Author is listed here, poster size is 4x4 ft.)

Accretion Disk Instabilities in the Vicinity of Black Holes	*(W. Auer)**	*[17]*
Gas Streamer Feeding the Circumnuclear Disk	*(Alison Coil)**	*[18]*
EDAF models for Sgr A*	*(Alina-Catalina Donea)**	*[18]*
SHARC 350 micron Mapping of the Galactic Center from the Caltech Submillimeter Observatory	*(C. Darren Dowell)^x*	*[18]*
Acceleration processes towards a quasi-monoenergetic electron distribution	*(Zeno Jauch)**	*[18]*
A Wide Field Image of the Galactic Center Region at 330 MHz	*(Ted LaRosa)^x*	*[19]*
ASCA Observations of the Sgr A region	*(Y. Maeda)**	*[19]*
Is the Sgr B2 cloud an X-ray Reflection Nebula?	*(Hiroshi Murakami)^x*	*[19]*
Life Time of the Radio Arc Filaments determined by mm-Wave Observations with the 100-m Telescope	*(Y. Sofue)**	*[19]*
Spatially Resolved Dust Shells in the Central Parcec	*(Angelle Tanner)**	*[20]*
The Minispiral revisited	*(Bernd Vollmer)**	*[20]*
Physical Properties of OH/IR Stars Close to the Galactic Center	*(Anders Winnberg)**	*[20]*

GC98 Abstracts

Abstracts are listed in chronological order

New Proper Motion Data

A. Eckart, R. Genzel

MPE

Recent high spatial resolution, near-infrared imaging and spectroscopy have made it possible in the last few years to measure stellar velocities down to separations of less than five light days from the compact radio source SgrA* at the dynamic center of the Milky Way. These measurements make a compelling case for the presence of a compact, central dark mass of $2.6{\times}10^6$ solar masses. Simple physical considerations show that this dark mass cannot consist of a stable cluster of stars, stellar remnants, substellar condensations or a degenerate gas of elementary particles. Energy equipartition requires that at least 10^5 solar masses must be associated with SgrA* itself and is enclosed within less than 8 light minutes - equivalent to 15 Schwarzschild radii of a million solar mass black hole.

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High Proper Motion Stars in the Vicinity of Sgr A*

Ghez, A.M., Morris, M., and Becklin, E. E.

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Over a three year period, we have conducted a diffraction-limited imaging study at 2.2 μm of the inner $6'' \times 6''$ of the Galaxy's central stellar cluster using the W. M. Keck 10-m telescope. The K band images obtained have the highest angular resolution obtained at near-infrared wavelengths from ground or space (θ_{res} = $0\rlap{.}''05$ = 0.002 pc) and reveal a large population of faint stars. We use an unbiased approach for identifying and selecting stars to be included in this proper motion study, which results in a sample of 90 stars with brightness ranging from K = 9 to 17 mag and two-dimensional velocities as large as 1,400 ± 100 km/sec. Compared to earlier work (Eckart et al. 1997; Genzel et al. 1997), the source confusion is reduced by a factor of 9, the number of stars with proper motion measurement in the central 25 $arcsec^2$ of our galaxy is doubled, and the accuracy of the velocity measurements in the central 1 $arcsec^2$ is increased by a factor of 4.

The peaks of both the stellar surface density and the velocity dispersion are consistent with the position of the unusual radio source and black hole candidate, Sgr A*, suggesting that Sgr A* is coincident (± $0\rlap{.}''1$) with the dynamical center of the Galaxy. As a function of distance from Sgr A*, the velocity dispersion displays a falloff well fit by Keplerian motion ($\sigma_v \sim r^{-0.5\pm0.1}$) about a central dark mass of $2.6(\pm0.2) \times 10^6 M_\odot$ confined to a volume of at most $10^{-6} pc^3$, consistent with earlier results. Although uncertainties in the measurements mathematically allow for the matter to be distributed over this volume as a cluster, none of these clusters are physically tenable. Thus, independent of the presence of Sgr A*, the large inferred central density of at least $10^{12} M_\odot/pc^3$, which exceeds the volume-averaged mass densities found at the center of any other galaxy, leads us to the conclusion that our Galaxy harbors a massive central black hole.

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Constraints on the Mass of SgrA* from its Proper Motion

Reid, M. J.[1]; Readhead, A. C. S. & Vermeulen, R. C.[2]; Treuhaft, R. N.[3]

[1] Harvard–Smithsonian Center for Astrophysics; [2] Caltech; [3] JPL;

We observed SgrA* and two extragalactic radio sources with the VLBA over a period of two years. Relative positions of the sources were measured with an accuracy approaching 0.0001 arcsec. The apparent proper motion of SgrA* was determined to be 0.0060 +/- 0.0004 arcsec per year, almost entirely in the plane of the Galaxy. The effects of the orbit of the Sun around the galactic center can account for our observations, and any residual proper motion of SgrA*, with respect to extragalactic sources, is less than about 20 km/sec. Our results and those of Backer and Sramek, from observations with the VLA, appear consistent, making the observational constraints robust.

The large observed speeds of stars in the inner region of the dense central cluster surrounding SgrA*, coupled with the very slow speed of SgrA*, yields a lower limit to the mass of SgrA*. If SgrA* is a massive object, dominating the central gravitational potential, then equipartition of kinetic energy cannot be used to place a limit on the mass of SgrA* from stellar motions in the central cluster. Instead, direct gravitational interactions dominate, and simple arguments based on conservation of angular momentum (as well as N-body simulations) yield a lower limit on the mass of SgrA* of order 1,000 solar masses. While the low luminosity of SgrA* might possibly have come from, for example, a contact binary containing of order 10 solar masses and radiating near its Eddington limit, the proper motions rule out a "stellar" origin for SgrA*. Current observations are consistent with SgrA* containing all of the nearly 2.6 million solar masses, inferred from the stellar motions, in the form of massive black hole and radiating at less than 0.1 percent of the Eddington limit.

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NICMOS Observations of the Galactic Center

Marcia Rieke[1]; Almudena Alonso-Herrero; Eric Becklin; Donald McCarthy; George Rieke; Nick Scoville; Susan Stolovy

[1]Steward Observatory, Tucson

The NICMOS team devised a comprehensive program of observations of the Galactic Center. The suite of observations include those aimed at measuring proper motions, at determining the spectral type at the tip of the main sequence from the last episode of star formation, at searching for variability near SgrA*, and at looking at the distribution of ionized gas. Data in hand gives a detailed look at the colors and extinctions for faint star near SgrA*. A search for the tip of the main sequence will discussed where NICMOS has demonstrated adequate sensitivity and photometric precision to identify likely 08-B1 stars at the Galactic Center.

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NICMOS Observations of the Central Parsec: Deep Imaging at 1.6 microns, Short-Term Variability, and Ionized Emission

Stolovy, S. R.[1];; McCarthy, D. W. [1];; Melia, F.[1];; Yusef-Zadeh, F. [2];; Rieke, G.[1],; Rieke, M.[1]

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A suite of diffraction-limited observations of the central parsec taken with Camera 1 (11$''$ FOV) of NICMOS is presented. The search for Sgr A* at 1.6 microns is discussed, as well as an exploration of possible short-term variability that could be expected from an inhomegeneity in the accretion flow. High-resolution NICMOS Pa alpha and [FeII] images illustrating the complex morphology of the ionized gas in the region are also presented.

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Corruption of the Visibility of Sgr A* by Intervening Plasma

Backer, D. C.

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Diffraction resulting from small scale "turbulence" in the intervening plasma acts as a filter on the visibility function of Sgr A*. This filter is strongly frequency dependent owing to the index of refraction law of cold plasma. Observations of nearby OH masers are similarly filtered. The asymmetry of the resultant apparent images of Sgr A* and the OH masers has been interpreted in terms of asymmetric "turbulence" resulting from magnetic pressure dominating plasma and turbulent pressures. The steady march of VLBI observations from cm to mm wavelengths has been directed toward evading the effects of diffraction. The possible mm/submm "bump" in the spectrum can mean that when good resolution is obtained at these wavelengths, we will be looking at a different source than that which produces the cm spectrum. Resolution of the cm spectrum will take a flyby in some future millenium! The 17-y VLA proper motion study of Backer & Sramek includes observations at both 6 cm and at 3.4 cm wavelengths. The precision is significantly smaller than the diameter of the diffractive image. Comparison of the two VLA results as well as Reid's VLBA result at 7 mm places stringent limits on refractive effects in the intervening plasma.

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Intrinsic Size of Sgr A*: 72 Schwarzschild Radii

K. Y. Lo[1], Z.-Q. Shen[1,2], Jun-Hui Zhao[3,4] P. T. P. Ho[3]

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By means of near-simultaneous multi-wavelength VLBA measurements, we determine for the first time the intrinsic size of Sgr A* to be 72 $R_{sc}(\star)$ by $< 20R_{sc}(\star)$, with the major axis oriented essentially north-south, where $R_{sc}(\star) \equiv\ 7.5 \times 10^{11}$ cm is the Schwarzschild radius for a $2.5 \times 10^6 M_\odot$ black hole. Contrary to previous expectation that the intrinsic structure of Sgr A* is observable only at $\lambda \leq 1$ mm, we can discern the intrinsic source size at λ 7 mm because (1) the scattering size along the minor axis is half that along the major axis, and (2) the near simultaneous multi-wavelength mapping of Sgr A* makes it possible to extrapolate precisely the minor axis scattering angle at λ 7 mm. The intrinsic size and shape place direct constraints on the various emission models for Sgr A*. In particular, the advection dominated accretion flow model may have to incorporate a radio jet in order to account for the structure of Sgr A*.

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7 mm VLBA Observations of Sgr A*

Bower, G.C.[1]; Backer, D.C[2]

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We present 7 mm lambda VLBA observations of the compact nonthermal radio source in the Galactic Center, Sgr A*. These observations confirm the hypothesis that the image of Sgr A* is a resolved elliptical Gaussian caused by the scattering of an intervening thermal with the predicted scattering size of 0.67 +/- 0.03. We find an axial ratio of 0.73 +/- 0.10 and a position angle of 77.0 +/- 7.4 degrees. These results are fully consistent with VLBI observations at longer wavelengths and at 3 mm lambda . We find no evidence for any additional compact structure to a limit of 35 mJy. The underlying radio source must be smaller than 4.1 AU for a galactocentric distance of 8.5 kpc. This result is consistent with the conclusion that the radio emission from Sgr A* results from synchrotron or cyclo-synchrotron radiation of gas in the vicinity of a black hole with a mass near$10^6 M_\odot$.
We also present recent results from the BIMA array and the VLA on the polarization of Sgr A* at 4.8 and 86 GHz. At 4.8 GHz, we find an upper limit to the linear polarization of 0.1%. At 86 GHz, we find $p = 1 \pm 1$ %. We discuss interstellar propagation effects and the predictions of different models.

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Millimeter VLBI Observations of Sgr A*

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We present recent results from 86 and 215 GHz VLBI observations of the compact radio source at the Galactic Center. At 86 GHz we find a size consistent or only marginal larger than the expected scattering size at this frequency. A zero closure phase indicates a point-like or symmetrical structrue. At 215 GHz we have detected for the first time Sgr A* with VLBI. This detection (on the baseline Pico Veleta - Plateau de Bure) yields a tentative size estimate, which depends on the assumption of the total (zero-spacing) flux and the antenna calibration. We find evidence that the size could be larger than the scattering size at 215 GHz (20 micro-arcseconds). If confirmed by follow up observations, the intrinisc structure of Sgr A* could be studied with a spatial resolution of only a few 10 Schwarzschild radii.

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86GHz VLBI observations of SgrA*

S. Doeleman[1]; G. Bower[2]; D. Backer[3]; M. Wright[3], A. Rogers[1]

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[3]UC Berkeley

We present recent 3mm-VLBI results on the Galactic Center using an array of four antennas. We find the closure phase measured around a triplet of antennas to be near zero. This places some constraints on the asymmetric structure of SgrA* along the position angles measured by our interferometer. We also discuss the problems and importance of calibration in VLBI measurements.

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Flare of SgrA* at 100 GHz

Tsuboi, M.[1]; Miyazaki, A.[1];Tsutsumi, T.[2]

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We have performed 3 sets of one-month flux density monitoring of the compact synchrotron source, Sgr A* at 100 GHz using the Nobeyama Millimeter Array (NMA) in 1996-1998. The NMA observations allow us to spatially separate Sgr A* from the surrounding thermal component. All the observations were made with the same array configuration. We detected a flare of Sgr A* in March of 1998, although there is no such significant variability during other observing months. The flux density of Sgr A* at 100 GHz flared by 200% in a week and decreased to the mean flux density within two weeks. No remakable change is seen in NRAO monitoring data at 2 and 8 GHz during the flare. The rapid flux density variability at mm wavelengths was observed previously but is still controversial. The entire time profile of a flare is clearly displayed in our data. Some implications of the results are discussed.

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Modelling Sgr A*

Melia, F.[1]

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Our understanding of the nature of Sgr A* has evolved rather rapidly since the early 90's, in part due to the growing interest among theorists and a growing body of observational constraints. We will briefly review what now appears to be widely accepted, and highlight the areas where the observational uncertainties allow for a variance of assumptions that may lead to different interpretations.

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Explaining the spectrum of Sgr A* using a two temperature plasma

Rohan Mahadevan

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Recently Narayan et al. (1998) have used an advection dominated accretion flow (ADAF) model to explain the low luminosity and spectrum from Sgr A*. This model explains the millimeter to hard X-ray spectrum quite well, but has had difficulty in agreeing with the low energy radio observations. An essential element of the model is that the thermal electrons must co-exist with hot (nearly virial) protons throughout the flow. Until now, this two temperature nature has been little more than theoretical speculation. We show that an emission process associated with the protons naturally resolves the observed discrepancy and low radio energies. In particular, the hot protons produce charged pions which subsequently decay into electrons and positrons. These high energy particles interact with the local magnetic fields to produce synchrotron radiation which naturally reproduces the observed spectral break at $\sim$ 86 GHz as well as the low energy radio spectrum. No fine tuning of the model is allowed. This provides observational support for both a two temperature plasma, and a power–law energy distribution of protons. Further, it gives increasing support to the idea that Sgr A* most probably accretes via an ADAF.

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Sgr A* as a test case for Advection-Dominated Accretion and consequences for other low-luminosity AGN

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We present local models of advection-dominated accretion flows (ADAF) into supermassive black holes. The thermal balance for ions and electrons is solved as a function of radius while using an approximation to the radial structure of the flow. Energy is exchanged between ions and electrons only by Coulomb collisions, and viscous heating is assumed to heat ions and electrons according to the mass ratio. We include thermal conductivity as a local cooling process for electrons and ions separately. The resulting synchrotron spectrum of thermal electrons is applied to Sgr A*. We investigate the luminosity of ADAF's as a function of the mass accretion rate and show that the transition from advection-dominated flows to thin standard accretion disks can explain the distinction between low-luminosity AGN on the one hand and Quasars and Seyfert 1 nuclei on the other.

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The jet model for Sgr A* and the nature of the submm-bump

Falcke, H.

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I briefly review observations of the radio spectrum of Sgr A*, its variability, and the evidence for a submm-bump. The latter, if real, indicates an extremely compact size of Sgr A* which in principle would allow to directly image the suspected supermassive black hole with future mm-VLBI experiments. For this, however, we need to understand the nature of this source which is currently hotly debated. I show that a jet model can reproduce well all the observed radio properties of Sgr A*, i.e. the spectrum and the size (limits) as a function of frequency. The model is very simple and has extremely few free parameters but nevertheless can be used to fit other jet sources like NGC 4258, M81*, or even GRS 1915+105 without twisting the parameters. However, while in these other sources the (derived) jet power always seems to be comparable to the associated accretion disk luminosity, the NIR upper limits of Sgr A* severly constrain the structure of any associated accretion disk—if one ignores the possibility of intrinsic obscuration. The jet model indicates that the accretion rate near the black hole has to be at least $\sim 10^{-7} M_{\odot}/\mathrm{yr}$ while the NIR fluxes allow only much lower accretion rates if a standard α-disk is assumed. Therefore the jet model supports a non-standard accretion disk in Sgr A*, which could either be described by an ADAF or an EDAF model (an Ejection Dominated Accretion Flow, where most of the locally produced energy is channeled into an outflowing wind.)

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The Various Components of the Sgr A Complex and their Interrelationship

Yusef-Zadeh, F.

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After a brief overview of the physical characteristics of Sgr A West, Sgr A East and their respective associated molecular clouds the CND and the 50 km/s clouds, we present a number of new observations based on the VLA, HST and AAT. Preliminary results based on the synthesis of molecular hydrogen, OH (1720 MHz), thermal and nonthermal radio continuum data as well as proper motion of ionized gas in Sgr A West , suggest a strong evidence of shocks in these clouds and a picture which is consistent with the the 50 km/s cloud /Sgr A East interacting with the CND /Sgr A West and that a cloud of atomic gas is falling in toward the Galactic center.

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3D Simulations of the Gas Dynamics in the Central Region

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It is thought that many characteristics of the central parsec of our Galaxy, from Sgr A* to the "mini-cavity", are associated with the accretion of ambient gas by a central concentration of mass. Using a 3D hydrodynamical code, we have been simulating this accretion process, in order to realistically model the gaseous flows in the center of our Galaxy. In the most recent simulations, we have taken into account the multi-point-like distribution of stellar wind sources, as well as the magnetic heating and radiative cooling of these stellar winds. As expected, we find that the structure of the flow is significantly different from that due to a uniform medium. We also investigate the possibility that Sgr A* is due to a distributed mass concentration instead of the canonical point mass of a black hole. We discuss the physical state of the accreting gas and how our results suggest that Sgr A* is unlikely to be associated with a "dark cluster".

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Proper Motions and Structure of the Radio Components near Sgr A*

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Proper motions and radio structure of the HII component near Sgr A* have been determined based on high resolution (0.1") observations at 13 and 7 mm in the past 7 years (1991-1998). Large proper motions up to 30 mas/yr (or 1200 km/s) have been observed for a number of prominent features. The large proper motion measured from the compact HII components can be explained by motions of a clumpy HII gas accelerated by either strong winds and outflows or explosive events at the Galactic center. Large pattern speeds due to wave or shock motions in the circumnuclear medium at the Galactic center can also be responsible for part of the observed proper motions. In addition, the HII components near Sgr A* (within the central 2.5" or 0.1 pc) show filamentary structures suggesting that the HII components are tidally disrupted by tides due to the concentration of mass at the Galactic center. High precision measurements of the proper motions for these HII components can be used to track the motions of the accreting gas in close proximity to the super massive black hole apparently associated with Sgr A*.

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SGR A* IN THE MID-INFRARED REFERENCE FRAME: THE RELATIONSHIP BETWEEN THE RADIO AND INFRARED SOURCES IN THE CENTRAL PARSEC

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There is growing support for the idea that a massive black hole may be located at the Galactic Center, and that the non-thermal radio continuum emission of Sgr A* results from infall of material into an accretion disc around it. Comparison of the infrared and radio source distributions can shed light on three important questions which are relevant to this issue: 1) Can the radio source Sgr A* be identified with any other source observed at any other wavelength? 2) Is there any evidence that Sgr A* directly interacts with other observed matter in the central parsec? 3) Is the relationship between the infrared and radio source distributions consistent with the idea that a massive black hole is present at the position of Sgr A*? We have independently determined the position of Sgr A* with respect to the mid-infrared sources in the central parsec by a direct correlation of our 12.4 (m image and the 2-cm continuum VLA data of Yusef-Zadeh (1996, private communication), without a priori knowledge of any other position determinations (e.g. Menten et al. 1997). The registration was achieved by an iterative process, correlating structure in the extended emission as well as the compact peaks, and relaxing all preconceptions about which sources must coincide (recognizing the possibility that some of the objects may actually be compact clusters of sources, or the radio and infred components arise from completely independent objects). The results are compared to other astrometry, and the discrepancies are investigated as possible clues to real morphological differences which could bear upon the fundamental questions posed above.

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Mid-Infrared Observations of Sgr A West from Keck

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Images of Sgr A West at 8.7 μm, 12.5 μm, 20.8 μm and 24.5 μm were taken on 13 and 15 March 1998, and 15 June 1998 at the Keck 10m telescope with the mid-infrared camera MIRLIN. MIRLIN uses a 128 X 128 Si:As BIB (hi-flux) detector with a scale at Keck of 0.138 $''$/pixel. The images are diffraction limited at 24.5 μm and near diffraction limited at 8.7 μm with the seeing FWHM$\sim$0.15$''$ at 8.7μm. The images will be presented and a limit on the flux at the position of Sgr A* will be calculated at all wavelengths. In addition, the images will be used to investigate the color temperature and dust density distribution within the field.

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Theoretical Studies of the Circumnuclear Disk

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I argue that the circumnuclear disk (CND) and the ionized gas filaments can be understood in terms of the tidal capture and disruption of gas clouds on low angular momentum orbits in a potential containing a point mass. The general pattern of such capture is the tidal stretching of the cloud into a long filament which repeatedly collides with itself before settling into a relatively long-lived asymmetric elliptical torus precessing counter to the direction of rotation. During the collisions, compression in strong shocks is likely to lead to star formation even in the near tidal field of a black hole. This process may have general reldevance to accretion onto massive black holes in normal and active galactic nuclei.

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The Stellar Content of the Galactic Center

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We present H and K band spectra for a nearly complete sample of K-band bright stars in the central few parsecs of the Milky Way. The sample is defined as those stars in the Galactic Center (GC) K-band luminosity function which are brighter than the brightest stars in the Baade's Window K-band luminosity function. The new spectra of the K-band bright stars uniformly show CO 2.3 micron absorption, the signature of luminous, cool stars. Perhaps not surprisingly, it is the luminous cool stars which dominate the bright end of GC K-band luminosity function. We compare the atomic and molecular line strengths of the GC stars to those for nearby and bulge populations. We also use the GC K-band bright star properties as derived from their spectra and broad band magnitudes to discuss implications for recent and past star formation.

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Stellar Content of the central 30pc

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In an ongoing project of mapping the central region of our galaxy at three wavelengths in the Near Infrared, we obtained a K band ($\lambda 2.2\,\mu$m) mosaic of an area of $\Delta\alpha \times \Delta\delta \sim 650'' \times 710''$ ($R_{equiv} \sim 15.8$pc for $R_0 = 8.5$kpc) centered approximately on Sgr A*. These observations were performed at the European Southern Observatory, La Silla, Chile, using the IRAC2B camera with the ESO-MPG 2.2m telescope yielding a detection limit of $S'_{\rm K} \sim 100\,\mu$Jy and a completeness limit of $S'_{\rm K} \sim 2000\,\mu$Jy.
An estimate of K band luminosities of different stars reddened by an absorption corresponding to a visual extinction of $A_{\rm V} \sim 31$ mag shows that within these limits only MS stars earlier than spectral type B5, giants and supergiants will be observed as individual stars; they account for less than 10% of the stellar mass but for more than one half of the K band luminosity of the mosaic. MS stars later than B5 are not resolved and appear as an extended continuum in the mosaic. Special care was therefore taken to apply an observing technique which allows to recover the extended background emission. The resolved sources were separated from the unresolved background continuum by fitting Lorentzian distributions to the sources. The integrated characteristics, the radial dependence and the core radius of both the unresolved and resolved stars within the mosaic were determined. We also determine the K band luminosity functions (KLF's) of the $\sim 6 \times 10^4$ resolved and fitted stars for both the mosaic and two subregions within the mosaic (Sgr A East and M-0.13-0.08) and discuss their relevance for an analysis of the stellar populations in Nuclear Bulge, Galactic Bulge and Disk. A model KLF based on the Salpeter IMF and an estimated total stellar mass of $M_* \sim 1.2 \times 10^8 M_\odot$ for the central 31.6 pc fits the observed K band continuum well and joins smoothly with the observed KLF for the more luminous stars.

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The star formation/AGN connection in the GC and Other Galaxies

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It is now amply demonstrated that the Galactic Center is not presently the site of an AGN, yet it appears to have many of the ingredients we believe make up an active nucleus. Do these ingredients indicate that the GC had a significant level of activity in the past, and/or that it may show activity in the future? From the details we see in the GC, what can we learn about the conditions in other galactic nuclei that may lead to flaring of AGNs? How common are the conditions we see in the GC, as deduced from a careful evaluation of the nuclei in Local Group galaxies? In particular, does the bright blue nucleus in M33 indicate an ultra-compact population of young stars, with a resemblance in some way to the compact cluster of massive, young stars around Sgr A*?

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Properties of stars in the galactic center

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We present the results of a time-series analysis of high resolution photometry covering 6 consecutive years. Some long-period variables already discovered by other authors are approved and are probably Miras or luminous blue variables. We also report on short period variables in the range of 3-10 days which give a clue to the actual masses and radii of the stars in the innermost parsec of our galaxy. In addition, we report on the results of a search for embedded objects in the galactic center, giving a hint on where these objects have formed and how old they are.

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The Arches Cluste

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The mass distribution of newborn stars (the stellar initial mass function or IMF) is key to the evolution of galaxies, as it determines whether a galaxy's interstellar medium is funneled predominantly into dim, long-lived, low-mass stars, as is the case in normal galactic disks, or into bright, short-lived, massive stars, as is perhaps the case in "starburst" nuclei. Our own galactic nucleus is not a full-fledged starburst, but its star-formation rate per volume is nevertheless well above that of the galactic disk (by a factor of $\sim 10^3$). Even so , the Milky Way's nuclear IMF remains uncertain, because high obscuration and the large background population of bright, elderly giant stars have impeded the detection of normal hydrogen-burning (or "main-sequence") stars. Our high-resolution infrared observations of a compact stellar cluster in the nucleus now reveal the presence of numerous young, massive main sequence stars, several of which may number among the galaxy's most massive. Dwarfing all other known young Galactic clusters, the "Arches" cluster may in fact be a weaker analog of the "super star-clusters" found in starburst nuclei.

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HST/NICMOS Imaging of the Quintuplet and Arches Clusters

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We discuss HST/NICMOS observations of two extraordinary massive clusters of young stars near the Galactic Center. The observations reveal the presence of a main sequence, in addition to previously identified emission-line stars, i.e., Wolf-Rayet stars. These clusters are the most massive in the Galaxy and can be viewed as the nearest templates for the super-star clusters in other galaxies.

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Theoretical modelling of hot stars

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Recent progress in model atmospheres for hot stars will be presented. A new generation of NLTE wind blanketed models, together with high S/N spectra of the hot star population in the central parsec which are being obtained will yield metal abundance determinations (Fe, Si, Mg, Na, etc). These results will provide major constraints not only on the theory of evolution of massive stars but also to solve the puzzle of the central parsecs of the Galaxy.

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Stellar abundances at the Galactic Center

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We are measuring chemical abundances of cool, luminous, Galactic Center (GC) stars. Stellar abundances are determined from high-resolution (R=40,000) $K-$band spectra obtained on the IRTF using CSHELL. Other researchers have observed increasing metallicities in HII regions with decreasing radius in the Milky Way. Chemical abundances in the disks of spiral galaxies are also observed to reach their highest values at the center. This suggests that the GC should have a high metallicity. Nevertheless, our results for [Fe/H] in five stars in the GC are consistent with solar iron abundances.

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OH/IR stars as signposts for ancient starburst activity in the Galactic center

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A recent sensitive survey has doubled the number of OH/IR stars known in the Galactic center (GC). The distribution of expansion velocities of the circumstellar shells of these stars shows an unexpectedly narrow peak at the high end tail.
From this, we conclude that this sample of stars has a higher metallicity than any other sample known, and that a large fraction of stars has formed in an epoch of enhanced star formation at least one Giga-year ago. Thus one can distinguish three different groups of stars in the direction of the GC: an old bulge-like population, a group of relatively young stars formed from continously infalling gas, and a shrinking population of low-mass stars that formed in an isolated era - probably a starburst.
This is a striking conclusion that can only be drawn from OH/IR stars, because they form the only tracable population older than a few hundred million years in the GC.

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Wide-field Imaging of the Galactic Center

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Long wavelength observations of the Galactic center, with their intrinsically large field of view and and high surface brightness sensitivity, offer unique insights into this complex region. We have reprocessed the early 90 cm VLA observations of the Galactic center with 3D software to compensate for the non-coplanar effects, and the resulting image contains a number of new features which had not been recognized before. We are also engaged in a program to observe the Galactic center with the new 74 MHz VLA system, and the status of those observations will be reviewed.

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Sgr A East and its interaction with surrounding gas

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We report on results of a recent on-the-fly mapping observations of the molecular gas within a projected distance $\sim 15'$ from Sgr A*. The gas volume density and column density tracing transitions of CS(2-1), CS(3-2) and ^{13}CO(2-1) were recorded in parallel. The kinematics of the gas and, in particular, the impact of the explosion that created the synchrotron source Sgr A East on the gas distribution will be discussed. The relative location of the features observed in this region will be determined by comparing the mm- and near Infrared data.

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Radio Recombination Lines near $\lambda = 20$ cm from the Sgr A Complex

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We have observed the H168α recombination line (ν = 1374.6 MHz) from the Sgri A complex using the C and D configurations of the VLA. The angular resolution is 50" $\times$ 20", the velocity resoltution is $\sim$21 km s^{-1} and the velocity coverage is $\pm$650 km s^{-1}. Relatively strong recombination line emssion is detected from the SgrA-East and the SgrA-West region of the SgrA complex. The line emission is spread over a velocity range of $\pm$ 200 km s^{-1}. Weaker emission is also observed from the halo region surrounding the SgrA-West and SgrA-East components. In this paper we present the results and a discussion of the kinematics of the ionzied gas and the possible association of thermal gas with the halo surrounding the SgrA region.

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OH 1720 MHz masers at the Galactic Centre

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OH(1720 MHz) masers unaccompanied by 1665/7 MHz line masers have recently been proposed as indicators of the interaction of supernova remnants (SNRs) and molecular clouds. We present a model for the masing region in which water produced in a C-type shock wave driven into the molecular cloud is dissociated as a result of the X-ray flux from the SNR. We discuss the interaction of Sgr A East, a SNR candidate, with the 50 km/s cloud at the Galactic Centre and present near-infrared observations of H_2 emission towards the regions where OH(1720 MHz) maser emission is concentrated. The magnetic field strength obtained from earlier Zeeman measurements is consistent with rough pressure equilibrium between the postshock gas and the X-ray gas filling Sgr A East detected by ASCA. Further, the intensity of the v=1–0 S(1) line of H_2 is consistent with the shock strength expected to be driven into the molecular gas by this pressure.

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Radio-Wave Scattering and Free Electrons in the Galactic Center

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The scattering diameters of Sgr A* and several nearby OH masers ($\approx 1''$ at 1 GHz) indicate that a region of enhanced scattering is along the line of sight to the Galactic center (GC). We first demonstrate that the enhanced scattering region is likely to be associated with the GC; a likelihood analysis indicates that the GC-scattering region separation is $\Delta_{\rm GC} = 150$ pc. The extent of the region in Galactic longitude is $\psi_\ell = 0.^\circ5$–1°. At the distance of the GC, $D_{\rm GC}$, the equivalent linear size of the scattering region, $\psi_\ell\,D_{\rm GC}$, is comparable to $\Delta_{\rm GC}$. The close correspondence between $\Delta_{\rm GC}$ and $\psi_\ell\,D_{\rm GC}$ suggests that the scattering region encloses the Galactic center.
The strength of scattering is not uniform across the region, however, and order of magnitude changes in the strength of scattering are seen over scales of a few arcminutes (10–20 pc at the distance of the GC). A scattering region that is clumpy on scales of 10–20 pc, with an angular extent of $0.^\circ5$–1°, leads us to favor an "interface" model, in which the scattering arises on the ionized surfaces of molecular clouds exposed to the X-ray emitting, 10^7 K gas; in this model the scattering medium is hot ($T_e \sim 10^6$ K) and dense ($n_{\rm e} \sim 10$ cm^{-3}).
We also illustrate the impact of the scattering region on the search for pulsars in the Galactic center. We stress the uniqueness of the GC scattering region, probably resulting from the high-pressure environment in the GC.

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Magnetic Fields in the Sagittarius A region

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Early models of the magnetic field structure of the Galactic Center suggested very strong field strengths. In the past decade or so, there have been many projects to investigate the morphology and strength of the magnetic fields in the inner parsec of the Galactic Center. Magnetic field observations include primarily near and far-infrared polarization and Zeeman measurements. The infrared polarization measurements along with a model for the polarization mechanism provide the magnetic field morphology in the plane of the sky. The only direct quantitative measurement of the magnetic field strength in the Galactic Center is obtained from observing the Zeeman effect in radio frequency spectral lines. Centimeter-wavelength Zeeman observations of Sgr A have been carried out in several gas components: neutral hydrogen (HI), hydroxyl (OH), and hydrogen recombination lines (H92α). Line-of-sight fields have been measured at the level of a few milligauss. These fields are much stronger than those in the ambient interstellar medium (whose average is a few microgauss) and are similar to fields in the cores of dense molecular clouds. This talk will discuss new observations of the Zeeman effect in OH(1720MHz) line observed in a maser in the Circumnuclear disk (CND) and the correlation with the HI Z

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Far-infrared/Submillimeter Polarimetric Observations of the Galactic Center

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Measurements of the linear polarization of far-infrared and submillimeter thermal emission from interstellar dust grains provide information on the configuration of the magnetic field lines that thread molecular clouds. During the last ten years, far-infrared and/or submillimeter polarization has been measured for six distinct regions within the Galactic Center. We compare recent results, including the first detection of submillimeter polarization from clouds in Sgr A, with earlier work, including far-infrared polarimetry of Sgr B2, the 3-pc circumnuclear disk, and the arched filaments. We suggest that the data indicate: (1) a globally azimuthal field beyond a Galactocentric radius of 50 pc, and (2) a more complicated geometry inside 50 pc radius, where we see magnetic fields (in cool regions) that appear to be nearly orthogonal to the Galactic plane. We also show that the expansion of Sgr A(East) has left a clear imprint upon the magnetic field. Finally, we discuss the implications for the magnetic accretion disk model that has been applied to the 3-pc circumnuclear disk.

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The Galactic Center Radio Threads: A Multifrequency, Polarimetric Study

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Multifrequency, polarimetric observations have been made with the VLA of two of the peculiar non-thermal filaments (NTFs), a class of objects unique to the Galactic Center whose origin is not well understood. The Northern and Southern Threads (G0.08+0.15 and G359.96+0.09) are associated with both the ionized and molecular components in and around SgrA and the Radio Arc. This association may offer clues as to the particle accleration mechanism responsible for their generation. The current observations provide high enough resolution to resolve the width of these NTFs for the first time. The Threads are very narrow:$<$ 0.1 pc in some places but extend for up to 30 pc in length. There is significant detail detected in the NTFs, reminiscent of the other Galactic Center NTFs. In addition, polarization measures confirm that the Threads are non-thermal, with fractional polarizations $>$ 50% in some instances. The Faraday corrected polarization vectors reveal that the intrinsic magnetic field orientation is predominately aligned along the long axis of the NTFs, as expected. The results and analysis of the Galactic Center Radio Threads observations will be presented.

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The GC in comparison to AGN

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There is strong evidence that most or all AGN are surrounded by geometrically thick dusty tori, and the connection with the Circum- Nuclear Disk was made almost immediately after this discovery. We now have X-ray columns from sight lines to many such AGN, and mm interferometers are just attaining the resolution and sensitivity to map the tori. The high densities and temperatures make them very strong HCN emitters. Through the flux and angular size magnification of gravitational lensing, similar tori are being detected and mapped in luminous AGN at high redshift. Finally, the GC "broad emission line region," and a class of "micro Seyfert" BLRs, are noted to differ qualitatively from Seyferts and quasars, as revealed by their lack of variability.

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The Mid-Infrared Spectrum of the Galactic Center, a Starburst Nucleus

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At a distance of 1 Mpc, the Galactic Center (GC) would appear 125 times smaller; thus an estimate of its appearance at 1 Mpc in a typical mid-IR field-of-view (FOV) would require averaging over a region of at least $\sim 4'$ or larger in size. Using the MSX Michelson interferometer, we have taken spectra of many positions in the central $25'$ of the GC with a $6' \times 9'$ FOV. The spectral coverage was 380 to 1700 cm^{-1} (6 to 26 μm) and the resolution was ~ 21 cm^{-1}. The spectra exhibit strong UIR/PAH features at 6.2, 7.7, 8.6, and 11.3 μm, in addition to the ionic lines of [Ne II] at 12.8 μm, [S III] 18.7 μm, and [Ar II] 6.98 μm. (This contrasts with the $14'' \times 20''$ FOV ISO spectrum, Lutz et al. 1996, A&A, 315, L269, of the GC near Sgr A* in which the PAH features were not detected.) There are deep silicate absorption features at 10 and 18 μm and a cold continuum increasing at the longest wavelengths. Additional weak features are present in the spectra. We discuss the variation of the relative strengths of the features as a function of location in the GC and the variation in the extinction at 10 μm. We compare the GC spectra with the MSX spectrum of the Orion Nebula (ApJ, 508, in press), smoothed to the same resolution and multiplied by the estimated GC extinction. The spectra have similar PAH features, but the Orion Nebula also has strong lines of [Ne III] 15.5 μm, [S IV] 10.5 μm, and [Ar III] 8.99 μm and its 25 μm continuum is stronger (colder). Thus, the GC exhibits the mid-IR spectrum of a low excitation H II region and a nearby molecular cloud with a surface photodissociation region (PDR). This is in excellent agreement with the canonical model of a starburst nucleus (such as M82 or NGC 253) in which the hot stars and molecular clouds are randomly distributed. The outer surfaces of the clouds are photodissociated and ionized by the photons from the stars located outside the clouds. The PAH molecules are transiently heated by the stellar photons. Since the exciting stars are located well outside the clouds, the radiation field is dilute compared to a newly-formed blister H II region like Orion; this dilute radiation field causes the relatively low excitation of the ionic lines.

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Cosmic Rays in the Galactic Center Region

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There is some evidence, that high energy cosmic rays from the Galactic Center have been detected, near 10^{18} eV. If this detection is real, it is most readily interpreted as energetic neutrons, as a result of p-p or p-γ interactions of high energy cosmic ray particles in the Galactic Center region. I review briefly the possible sources for such energies, and demonstrate that massive stars with their winds and their ensuing supernova explosions are natural candidates to have produced the cosmic ray particles up to $\sim 3\,10^{18}$ eV in the Galactic Center region - as elsewhere in the Galaxy. With interactions near the source sites we also obtain a ready interpretation for the EGRET γ-spectrum of the inner Galaxy. Many tasks remain, such as calculating the emission spectrum from the powerful shocks that run through the winds of evolved massive stars, including γ-line emission, and to take into account the powerful heating and ionization that must occur near the source sites of supernovae. For sufficiently high hadronic interaction columns, as seems plausible in the Galactic Center region, an entire cascade of interactions and emissions ensues. These effects are just for the normal stars we believe to understand well.

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Gamma-rays from the Galactic Center: A Point-Like or Diffuse Source?

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Recently, EGRET onboard NASA telescope Compton GRO detected gamma-rays from the Galactic Center (GC). The data can be fit by a power-law of spectral index roughly 1.7, but the nature of the source of these photons is still a matter of debate. While some groups favor the massive black hole candidate Sgr A*, others postulate a diffuse source. The lack of variability in the flux seems to suggest the latter, but recent hydrodynamical simulations of the accretion process indicate that the fluctuations may be below the detection level of the current observations. Until instruments with the capability to resolve the details of this region in the extreme high-energy evolve, we are left to determine the source by identifying the most likely candidates and attempting to model their spectra based on what we know of their physical environments. In this talk I will present the results of our model for Sgr A*. Having completed a detailed treatment of photon production by hadronic collisions and other processes, we can now begin to draw firm conclusions about whether or not the broadband spectrum from this process in an accreting black hole environment is consistent with the data.

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The Galactic Center EGRET Source and the Broad-band Spectrum of Sgr A East

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Continuum low-frequency radio observations of the Galactic Center reveal the presence of a prominent elliptical shell structure known as Sgr A East. Although morphologically similar to supernova remnants (SNRs), its inferred energetics and size appear to be extreme and have generated some uncertainty regarding this interpretation. Regardless, recent observations of this region at 1720 MHz (the transition frequency of OH maser emission) have revealed the presence of several maser spots, suggesting the presence of shocks produced at the interface with a molecular cloud. Therefore, it should not be surprising to see nonthermal emission from the Sgr A East shell. Radio continuum observations of Sgr A East suggest a synchrotron source with a relativistic electron distribution, though its spectral index (3) is unlike that thought to be produced directly in shock acceleration and appears to be different from the spectral indeces inferred for other SNRs. Sgr A East's possible kinship with SNRs is further suggested by the central (¡ 1 degree) continuum gamma-ray source observed by EGRET on board the CGRO. In this talk, I will demonstrate in a self-consistent manner how the radio through TeV spectrum of Sgr A East (including this gamma-ray source) may be accounted for with a single physical process, and how it can be placed in context with the other EGRET SNRs when one takes into account the differences between the ambient medium surrounding Sgr A East and that of the other remnants.

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Cold matter in the Galactic Center region measured with the X-ray satellite ASCA

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We report the cold matter distribution in the Galactic Center region. We measured the column density of X-ray binaries in the region using the X-ray satellite ASCA, and derive the total mass and distribution of the cold matter in this region. The column densities are given by a smooth function of the angular distance from the Galactic Plane. Assuming a disk-like mass distribution with 500 pc radius, we estimate the total mass to be $\sim 6 \times 10^7 M_\odot$. Together with other wavelength results, we discuss the physical conditions of the cold matter in the Galactic Center region.

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Accretion Disk Instabilities in the Vicinity of Black Holes

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Accretion disks around massive black holes will themselves become massive. The α-viscosity can no longer be valid in the case where accretion disk mass is comparable to the mass of the accretor, as shown by Duschl *et al.* (1998). Using a modified viscosity prescription, one that takes into consideration the massive disk, leads to noticeably different disk structure. We present preliminary results of black holes with masses ranging from 10^6 $M_\odot$ to 10^{10} $M_\odot$ and mass accretion rates ranging from 10^{-9} $M_\odot$/a to 10^1 $M_\odot$/a.

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Gas Streamer Feeding the Circumnuclear Disk

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We present VLA maps of $NH_3(1,1)$ and $NH_3(2,2)$ emission in the inner 10 pc of the Galaxy, covering Sgr A*, the circumnuclear disk (CND) and the 20 and 50 km/s clouds. In the central 3 parsecs surrounding Sgr A* we map a portion of the CND, which is connected to a long, narrow 2 pc×10 pc streamer of clumpy molecular gas located towards the south. This southern streamer appears to be carrying gas from the nearby 20 km sec^{-1} cloud to the CND. We find a velocity gradient along the streamer, with progressively higher velocities as the gas approaches Sgr A*. The gas is the northern tip of the streamer is heated and the line width increases dramatically, which may be a kinematic signature of accretion onto the CND. We also report on preliminary results of the interaction between the 50 km/s cloud and Sgr A East.

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Accretion disk with jet, ADAF, or EDAF models for Sgr A*?

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We investigate various models of accretion disks for Sgr A*, the most puzzling region of our Galaxy. The generic image we have taken into account consists of a black hole, an accretion disk and a jet. There are various accretion models to explain the low NIR flux of Sgr A* : a standard accretion disk with a jet, an ADAF, or an EDAF model. We find that all of these models are conceptually similar. The accretion model which allows the formation of the jet at the innermost edge of the disk requires a subkeplerian gas motion and a very large base of the jet. The large base of the jet may be unrealistic for Sgr A*, since the jet model and the observations suggest that the jet is collimated and anchored in the disk in a very narrow region of the disk close to the black hole. Nevertheless a large fraction of the energy is taken up by the jet while the remaining energy, which is not converted into radiation, goes directly to the black hole through an advection dominated flow or can escape through an EDAF flow outwards.

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SHARC 350 μm Mapping of the Galactic Center from the Caltech Submillimeter Observatory

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Using the 20-pixel camera SHARC, we have mapped the dust emission from a 60′ by 12′ region in the Galactic center – by far the largest 350 μm coverage to date. A comparable region has been obsererved at 800 μm by Lis & Carlstrom (1994); the SHARC map has better spatial resolution and sensitivity to extended emission, however. Dust emission within a few arcminutes of the Sgr D core is detected for the first time, showing an anticorrelation with the diffuse radio continuum emission. 350 μm sources are associated with both H_2O masers in Sgr D, but only 1-2 out of 5 OH masers (Mehringer et al. 1998). Faint emission at the same Galactic longitude as the Dust Ridge (Lis & Carlstrom 1994) but at opposite latitude is visible, as well as a compact source at the base of a thermal radio filament at negative Galactic latitude. The 350 μm/800 μm ratio for the Galactic center is discussed.

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Acceleration processes towards a quasi-monoenergetic electron distribution

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We present the results of an investigation of acceleration processes in galactic centers and show that a quasi-monoenergetic electron distribution (pile-up) forms in quite a natural way under the combined action of diffusive shock wave acceleration, stochastic acceleration on turbulent MHD waves and radiation losses. We follow the temporal evolution of both the electron and the photon distribution. This requires the numerical solution of two kinetic equations, i.e., a fully coupled set of non-linear partial integro-differential equations. We apply the results to the non-thermal radio emission from the Galactic Center source Sgr A*, which we interpret as being optically thin synchrotron radiation from these quasi-monoenergetic electrons.

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A Wide Field Image of the Galactic Center Region at 330 MHz

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We present a wide field ($\approx$ 4 X 4 degrees), 330 MHz, VLA image of the galactic center region. All significant sources found on the image have been identified and labeled. The 330 MHz source properties are presented in an extensive table. Where appropriate the source spectral index between 1616 and 330 MHz is determined. In particular the spectral index variation with length along some of the isolated nonthermal filaments has been determined. Implications for the physics of the nonthermal filaments will be discussed.

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ASCA Observations of the Sgr A region

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We present the *ASCA* results of the first high quality X-ray images and spectra near Sgr A in the wide X-ray band of 0.7 - 10 keV. (1) We found a new X-ray source AX J1745.6−2901 about $1'.3$ south-west from the nuclear supermassive black hole candidate Sgr A*. We discovered a type-I X-ray burst and eclipses from AX J1745.6−2901, hence established AX J1745.6−2901 to be an eclipsing low-mass X-ray binary. Excess soft X-rays during the eclipse were detected, which is well explained by the scattering process of interstellar dust-grains. (2)The X-rays in the brightest region near Sgr A* would come from a hot gas filling the interstellar space with the thermal energy of about 2×10^{50} erg. We also detected no significant time variability from Sgr A*.

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Is the Sgr B2 cloud an X-ray Reflection Nebula ?

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We present the results of the *ASCA* imaging spectroscopy of the giant molecular cloud Sgr B2. The X-ray spectrum is found to be very peculiar; it exhibits a strong emission line at 6.4 keV, large absorption at low energy below 4 keV and pronounced edge-structure at 7.1 keV. The X-ray image is found to be extended with the peak position offset to the Galactic center direction by about 1–2 arcminute from the core of the molecular cloud. This morphology, as well as the X-ray spectrum, is well reproduced by a model that a strong X-ray source located at the Galactic center side is irradiating the molecular cloud Sgr B2, and only the reflected and the fluorescent X-rays are in our line of sight. Thus Sgr B2 is a new type of X-ray object, which may be called as an "X-ray reflection nebula". Possible implications of the Galactic center activity related to this unique source are presented.

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Life Time of the Radio Arc Filaments determined by mm-Wave Observations with the 100-m Telescope

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High-resolution continuum mapping of the Radio Arc has been made at 43 GHz using the Effelsberg 100-m telescope in order to investigate spatial variation of the spectrum. The straight nonthermal filaments, clearly seen at 32 GHz and lower frequencies, are very weak at 43 GHz. The spectral index of the brightest filaments, which is flat at lower frequencies, turns to be as steep as $\alpha \sim -1$ between 32 and 43 GHz, indicating a spectral turnover between these frequencies. Assuming that the magnetic field strength is $\sim$ 1 mG, we estimate the life time of cosmic-ray electrons to be several thousand years, showing that the filaments are short-lived structures. The present result would give a constraint on the location and epoch as well as the initial energy distribution of injected cosmic-ray electrons. On the other hand, "Sickle" is clearly visible at 43 GHz and has a flat spectrum, which confirms its thermal characteristics. "Pistol" appears to show a peculiarly inverted spectrum, suggesting a two-component spectrum.

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Spatially Resolved Dust Shells in the Central Parcec

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Recent diffraction-limited K-band [2.2 μm] imaging observations with the Keck 10-m telescope have unambiguously resolved, for the first time at this wavelength, the unusual cool stellar stellar sources IRS 21, 1W, and 10W. We have estimated the intrinsic sizes of these objects to

be $\sim$ 1000 AU, placing them among the largest stellar objects known. These measurements, along with modeling of their SEDs, lead us to conclude that these sources are self-luminous, composed of a central heating source and a surrounding dust shell. We will present both the images and detailed modeling of these sources.

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The Minispiral in the Galactic Centre

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We used [NeII] line emission data (12.8μm), in order to investigate the detailed kinematic structure of the inner 3×4 pc of the Galaxy. The quality of [NeII] as a tracer of ionized gas is examined by comparing it to radio data. A three dimensional representation of the data cube allowed an exact distinction of the different features, which are reviewed in detail. A model of rotating gas in different plains is fitted to the data. Thus a classification of the different features could be made. It was found that most of them are situated together with the CND in the main plain. Finally we reconstructed the real three dimensional space with the help of the model.

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Physical Properties of OH/IR Stars Close to the Galactic Center

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Physical properties deduced from OH flux density and circumstellar envelope expansion velocity are studied in a statistical sense for a sample of about 140 OH/IR stars close to the Galactic Center (GC). The sample is confined to an area on the sky of about 1.5 square degrees roughly centered on the GC and the 3σ sensitivity of the survey is about 60 mJy (Lindqvist et al., 1992). The distribution of the expansion velocities shows an asymmetric shape with a much steeper gradient on the high v_{exp} side than on the low v_{exp} side. It has a median value of about 18 km s^{-1} whereas OH/IR stars elsewhere in the Galaxy show significantly lower average expansion velocities. OH/IR stars from all parts of the Galaxy show a strong anti-correlation between expansion velocity and Galactic latitude. Thus expansion velocity is correlated with age and therefore with mass of the central star. However, close to the GC the effect of higher metallicity probably plays an important rôle in determining the expansion velocity. The flux density distributions for GC OH/IR stars with expansion velocities smaller than (Group I) and larger than 18 km s^{-1} (Group II) are significantly different. Group I contains stars with higher flux densities than Group II does. Although Group I has a more extended volume density distribution than Group II this fact alone probably cannot explain the difference in their flux densities and a real difference in their OH luminosity functions has to be invoked. The dependence of mass loss rate on OH flux density and v_{exp} is discussed. An upper limit of the mass loss rate for the GC OH/IR stars is about $5 \times 10^{-5} M_\odot yr^{-1}$ using the formula by Baud & Habing (1983).

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