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2.2 μm Keck Images of the Galaxy's Central Stellar Cluster at 0.″05 Resolution

B. L. Klein, A. M. Ghez, M. Morris, E. E. Becklin

UCLA Department of Physics and Astronomy,
8371 M.S. Bldg., Los Angeles, CA 90095

Abstract. We present preliminary results from a high angular resolution study of the inner 5″×5″ of the central Galactic stellar cluster. This program was carried out at the W. M. Keck telescope using the facility near-infrared camera with a K[2.2μm]-band filter. A few thousand short exposure frames, combined using a shift-and-add algorithm, contribute to the final image which has the diffraction-limited resolution of 0.″05. Even prior to deconvolution, sources as faint as $\sim 15^{th}$ Kmag are detected at the 5σ level and new isolated point sources are identified.

1. Introduction

Since the discovery of the near-infrared (NIR) emission from the Galactic Center (Becklin & Neugebauer 1968), the central stellar cluster has been the focus of many NIR studies. Recently, tremendous advances have been made in the angular resolution of NIR images of this region via methods which compensate for atmospheric distortions (Eckart et al. 1995, 1993; also Close et al. 1995, DePoy & Sharp 1991, Simons & Becklin 1996). Nonetheless, studies of the Sagittarius A* (IR) complex - the apparent concentration of infrared sources within ∼0.″5 of SgrA* - remain confusion limited. The W.M. Keck telescope, which has a position-angle-dependent maximum baseline of 9.0-11.0 meters (Nelson 1989), offers a unique opportunity to probe the detailed structure of our Galaxy's central stellar cluster.

At Mauna Kea, the mean atmospheric seeing conditions constrain traditional images to angular resolutions of θ_{seeing} ∼0.″5 at 2.2 μm. Although this image size is excellent by conventional standards, it is still a factor of 10 worse than the diffraction limit of Keck, which at $\lambda = 2.2$ μm is $\theta_{diff} \sim \frac{\lambda}{D} \sim 0.''05$ (= 420 AU at 8.5 kpc). We exploit this high resolving power by employing high-resolution imaging techniques to recover the diffraction limit in post processing. The viability of diffraction limited imaging with the fully-phased Keck telescope has been demonstrated by Ghez (1996) and Matthews et al. (1996).

2. Observations

Our K-band observations incorporated three key elements for obtaining data suitable for the reconstruction of diffraction limited images.

- *Short Exposures:* 120 ms integrations were used in these observations. Under good seeing conditions at Keck this has proven to be sufficiently short to freeze the atmospheric distortions and preserve high-resolution information (see Figure 1).
- *Fine pixel scale:* A scale of 20 milliarcseconds per pixel is available with the facility camera, NIRC (256×256 InSb array). This is accomplished with the recently installed "image converter" (Matthews et al. 1996) that magnifies the field of view from the standard $38'' \times 38''$ to $5'' \times 5''$ which is Nyquist sampled at 2.2 μm.
- *Telemetry:* We collected ~10,000 frames centered near the position of SgrA*. From this data, 2,741 of the best seeing quality frames were selected to be incorporated in the final image presented here (Figure 3).

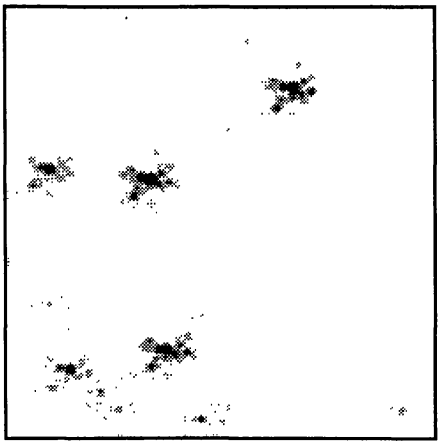

Figure 1: A single 120 ms short exposure (a specklegram) of the inner 3.5 arcseconds of the central stellar cluster. High resolution information is clearly contained in this image. It is worth noting that the speckle patterns for different sources are nearly identical across the field.

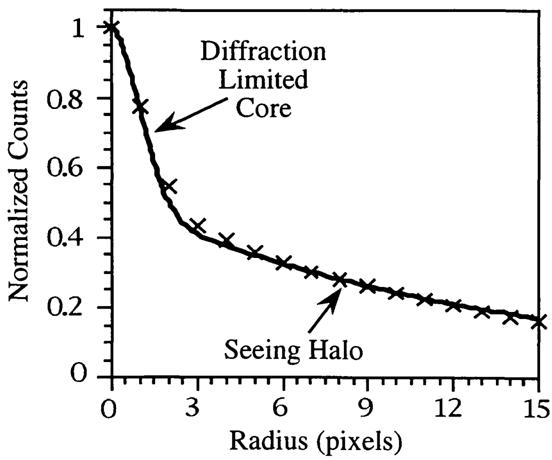

Figure 2: A model fit through measured data of the shift-and-add point spread function (PSF) radial profile. The diffraction limited core is built up from the brightest speckle in each contributed frame while the 'seeing halo' results from the fainter surrounding speckles. The core contains ~10 percent of the flux and has the expected FWHM of $\theta = 0.''05$.

3. Shift-And-Add

One method for obtaining diffraction limited images from a series of short exposures (specklegrams) is "shift-and-add" (e.g., Christou 1991). In a short exposure such as the one shown in Figure 1, the image breaks up into a number of speckles, each of which can be thought of as a noisy diffraction limited image of the source. Shift-and-add builds up signal while preserving high resolution information by registering all the frames on the brightest speckle for each exposure. In this scheme the surrounding fainter speckles are treated as noise. The resulting image of a point source has a diffraction limited core on top of a "seeing halo" (see Figure 2).

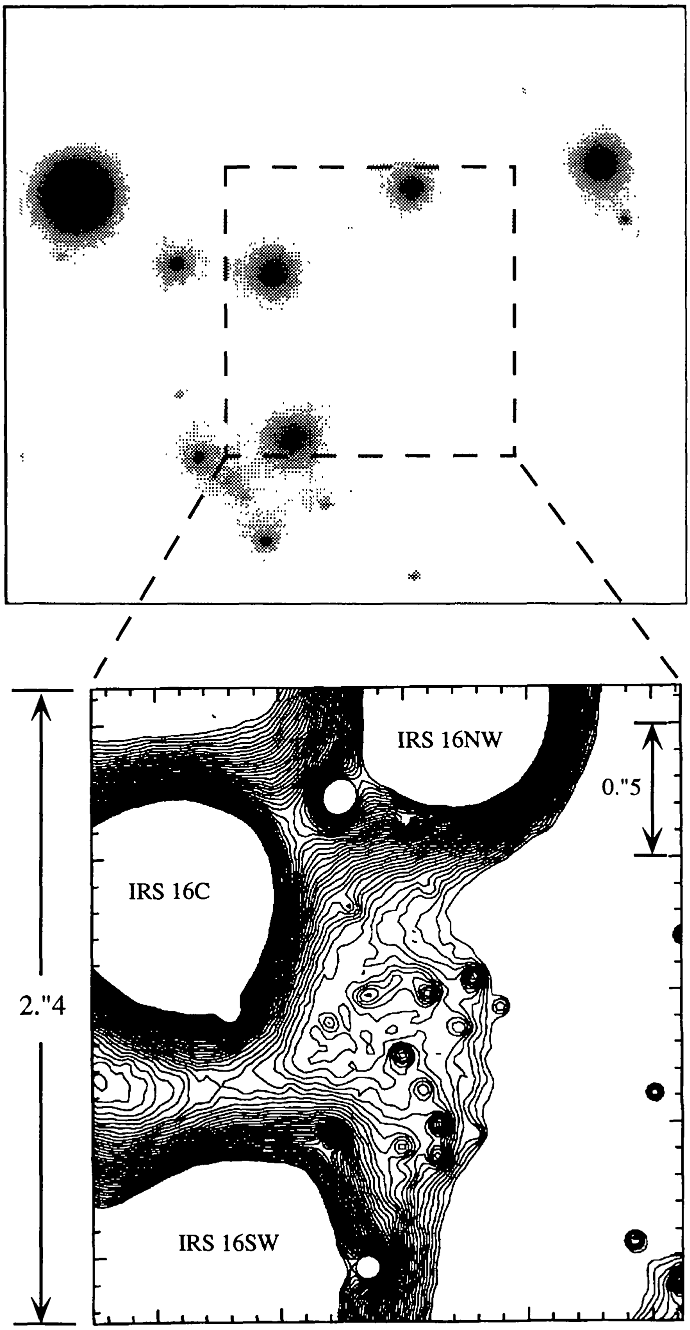

Figure 3: A shift-and-add image of the central 5″×5″ comprised of 2,741 seeing selected frames taken in June, 1995. The contours do not correspond directly to flux density levels since these images are not deconvolved. Nonetheless, comparisons with previously published maps at lower resolution indicate that sources as faint as 15th Kmag are easily identified. At the resolution of 0.″05 (=420 AU at 8.5 Kpc), new isolated point sources are detected.

4. Results

The results of shift-and-add are shown in Figure 3. The (linear) intensity display on top is scaled to show the PSF cores of the brighter members of IRS 16. The contour plot of the central $2.''4 \times 2.''4$ region is scaled to display the structure of the SgrA*(IR) complex. Sources as faint as K ~15 mag are detected at the 5σ level in these "raw" (i.e. not deconvolved) images. The images shown in Figure 3 are in general agreement with the earlier results of Eckart et al. (1995 and this volume: resolution $0.''15$). Much of the extended emission seen in the previous maps is now resolved into point sources.

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References

Becklin, E. E. & Neugebauer, G. 1968, ApJ, 151, 145

Christou, J. C. 1991, PASP, 103, 1040

Close, L. M., McCarthy, D. W., & Melia, F. 1995 ApJ, 439, 682

DePoy, D. L. & Sharp, N. A. 1991, AJ, 101, 1324

Eckart, A. et al. 1996, this proceedings

Eckart, A., Genzel, R., Hofmann, R., Sams, B. J. & Tacconi-Garman, L. E. 1995, ApJ, 445, L23

Eckart, A., Genzel, R., Hofmann, R., Sams, B. J. & Tacconi-Garman, L. E. 1993, ApJ, 407, L77

Ghez, A. M. 1996 in NATO Advanced Summer Institute, "Evolutionary Processes in Binary Stars", in press

Matthews, K., Ghez, A., Weinberger, A., & Neugebauer, G. 1996, PASP, in press

Nelson, J. 1989, AmSci, 77, 170

Simons, D. & Becklin, E. E. 1996, AJ, in press