# Mid-Infrared Observations of Extended Light in the Spiral Galaxy NGC 5907

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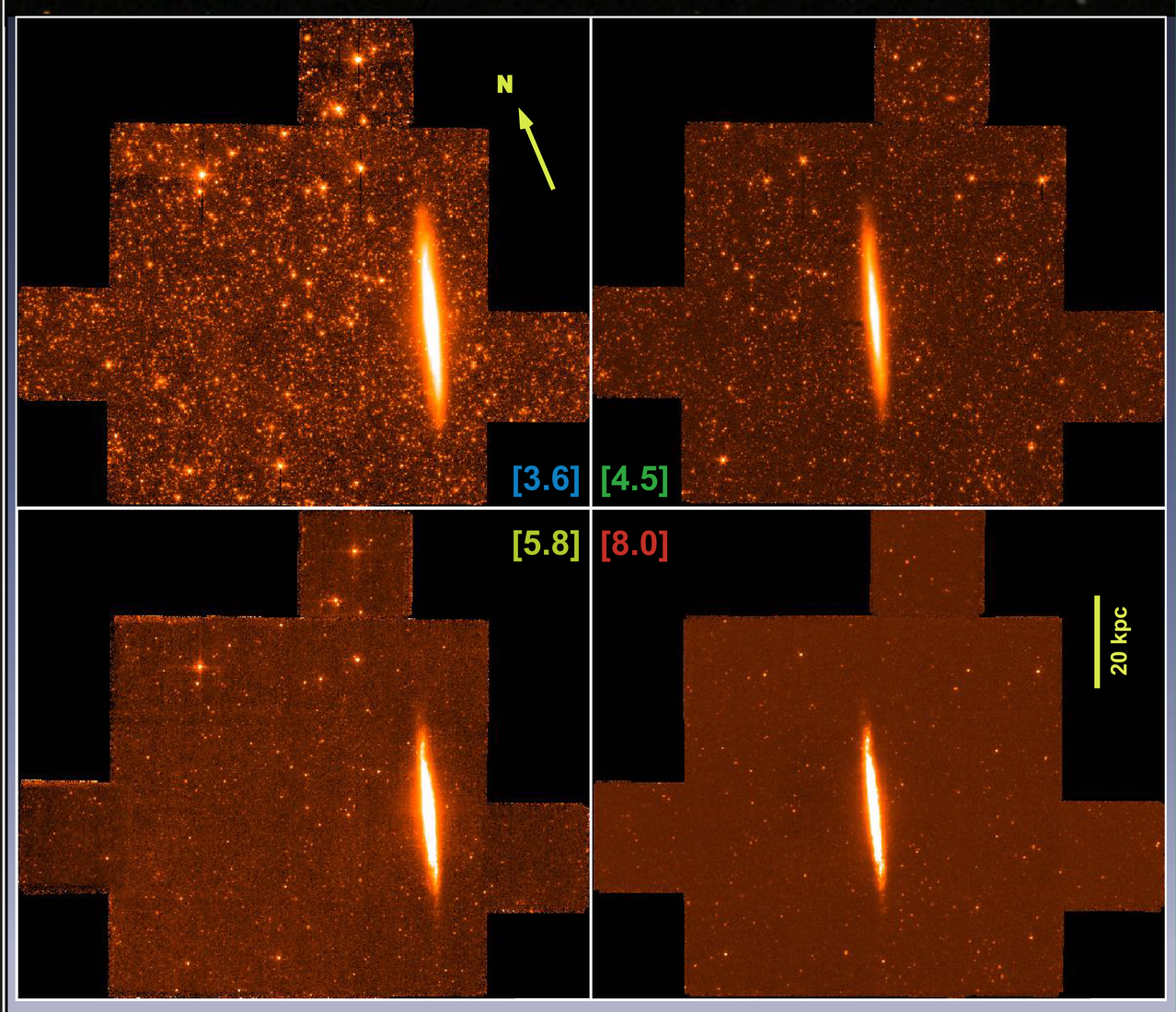
We have carried out a program to search for very faint, extended emission in NGC 5907 using the InfraRed Array Camera (IRAC) aboard the Spitzer Space Telescope. This nearby, relatively bright edge-on spiral galaxy has been the subject of many such studies, but this is the first time it has been imaged in the mid-infrared from space with such high sensitivity and angular resolution, and low backgrounds. Our data place strong limits on the faint, extended halo emission implied by the rotation curve -- and imply the presence of a thick disk: a component composed of vast numbers of unresolved faintly luminous objects. These may comprise some kind of brown dwarf population, as suggested by analogy with the findings of the MACHO collaboration for the Milky Way halo. In this particular galaxy, the halo is believed to have a mass of 0.8-1.4 x $10^{11}$ solar masses.

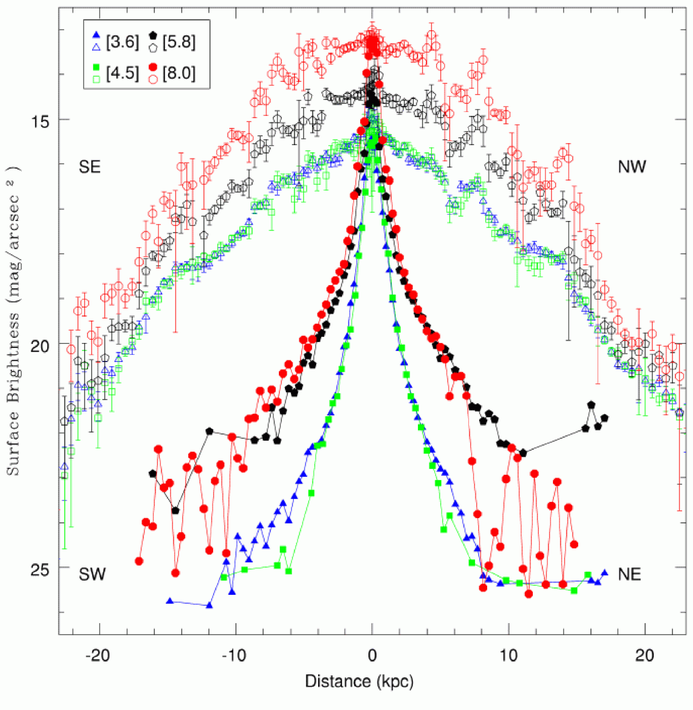
NGC 5907 is the first galaxy in our sample of edge-on spirals to have been imaged in the mid-infrared with IRAC (another, NGC 891, has also been observed recently, and those data are being analyzed) to search directly for extended halo emission -- if the halo has a significant component of brown dwarfs or perhaps some other red population, IRAC is the ideal instrument to detect them and to characterize their mass distribution.

Image from 3rd data release, SDSS




The images above are mosaics constructed from the rastered images acquired by IRAC at four wavebands: 3.6, 4.5, 5.8, and 8.0 microns. The observations were carried out at the end of December 2003 in two campaigns separated by 24 hours. To control for instrumental artifacts, observations of the galaxy were interleaved with identical exposures on three control fields, giving these mosaics their jagged appearance. Result: at sensitivity levels that reach into the confusion limit at 3.6 and 4.5 microns, the mosaics are free of residual image contamination and spurious background variations that might mimic a red halo, except for a scattered light feature in the 4.5 micron image that was masked for our analysis. The 5.8 and 8.0 micron images are similarly free of artifacts.

## MAJOR, MINOR AXIS SURFACE BRIGHTNESS PROFILES




Left: surface brightness profiles measured in all four IRAC bands along the galaxy disk (SE-NW tracks; open symbols) and perpendicular to the galaxy midplane along the minor axis (SW-NE tracks; solid symbols). Foreground stars and background galaxies were masked. Superficially, the disk appears thicker at longer wavelengths, but not as red in [5.8]-[8.0] as the disk, which exhibits strong PAH emission. Away from the disk, these observations extend down below 25 mag/arcsec$^2$ at 3.6 and 4.5 microns. All magnitudes are on the Vega system.

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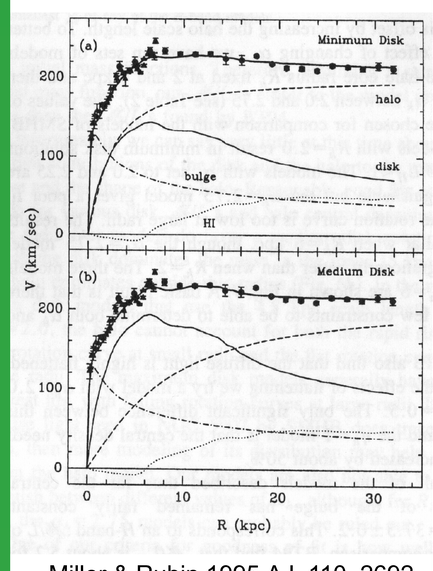
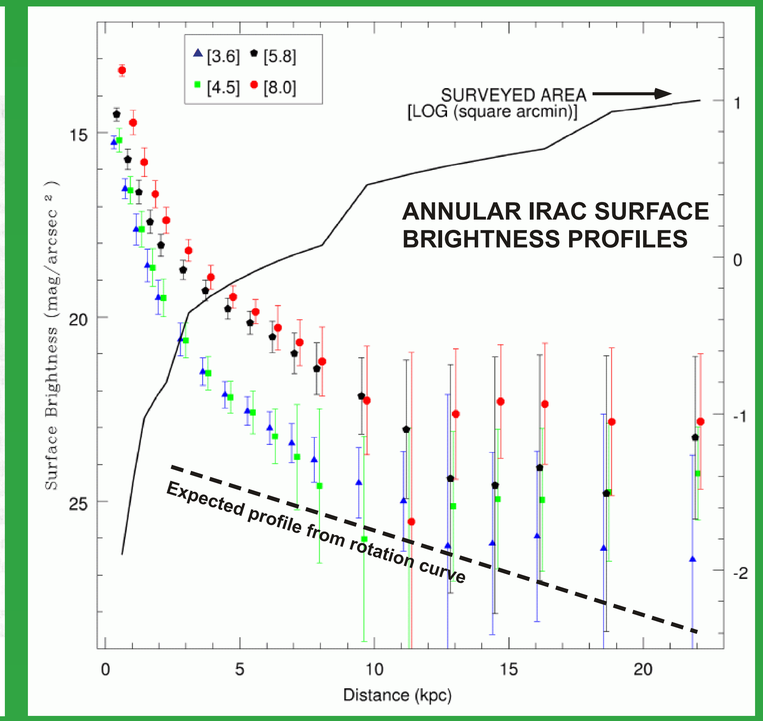
HI + H-alpha rotation curve, and two mass models

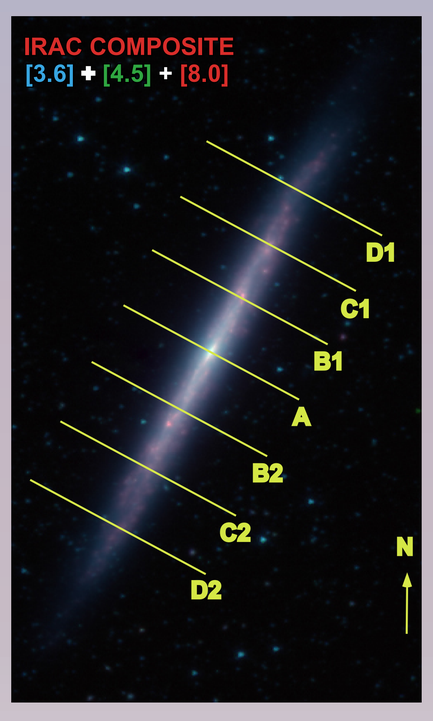


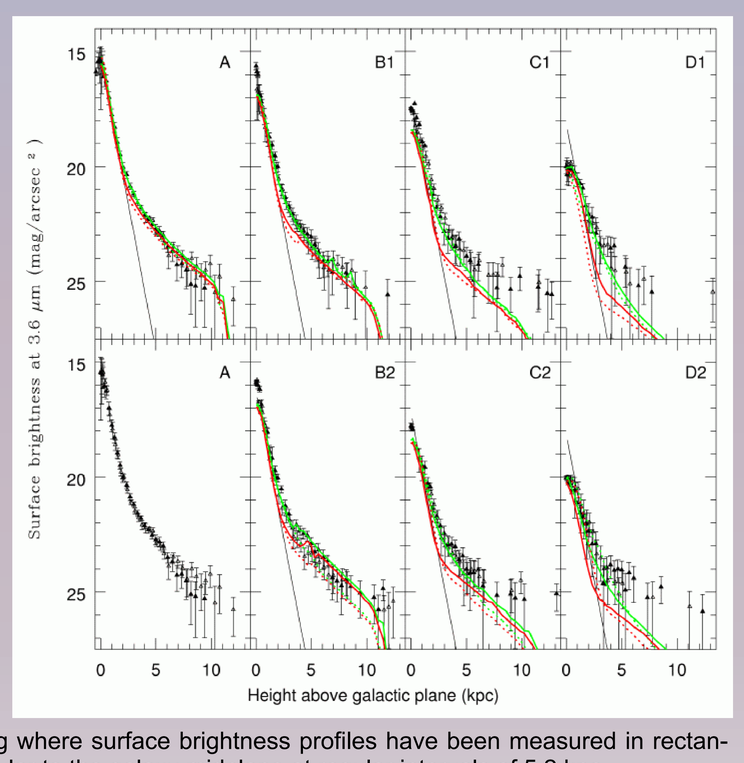

Miller & Rubin 1995 AJ, 110, 2692




Left: The flat rotation curve requires a large contribution from a dark halo beyond 10-30 kpc. Two cases are illustrated, a minimum and a medium disk. The total dark halo mass is estimated as roughly $10^{11}$ solar masses (Casertano 1983, MNRAS 203, 735, and van der Kruit & Searle 1982, A&A, 95, 105).
Right: measured mid-infrared surface brightnesses (solid icons, referenced to the left vertical axis) within annuli at increasing radii from the galaxy center. All emission within 45 degrees of the galaxy midplane was masked, as were all pixels containing more than roughly 6 electrons from photons originating in foreground stars and background galaxies. The solid black line, referenced to the right vertical axis, indicates the log of the area in square arcminutes over which the surface brightness measurements were carried out, not counting masked pixels. Beyond 10 kpc, there is no perceptible slope in the surface brightness data, despite a factor of 10 change in the surveyed area. The expected slope is indicated by the dashed line.
Conclusion: down to surface brightness levels of ~26 mag/arcsec$^2$, at 3.6 microns (and somewhat brighter limits for the longer wavelengths), there is no indication of detectable halo emission beyond 10 kpc from the midplane (i.e., beyond 2.5 arcmin; we assume a distance of 14 Mpc based on H-band Tully-Fisher following Zepf et al 2000, AJ, 119, 1701). But the profiles have more to say! See below.

## A VERY RED, THICK STELLAR DISK




Left: a composite IRAC image indicating where surface brightness profiles have been measured in rectangular bins along seven tracks perpendicular to the galaxy midplane at regular intervals of 5.2 kpc.
Right: measured 3.6 micron surface brightnesses, and models that include a GALFIT best-fit thick disk+bulge+thin disk (green) and the same without the thick disk (red). The data have been folded about the midplane. Solid icons are for measurements to the NE, open icons are for tracks to the SW. The thin black line is the best H-band thin disk fit from Morrison et al 1994, AJ, 108, 1191 but shifted by 4 mag/arcsec$^2$ -- not a fit to the IRAC data! We therefore infer a similar thin disk morphology as do Morrison et al, but also detect what appears to be a thick disk at 2-5 kpc having a scale height of roughly 2 kpc based on the fits. The results at 4.5 microns are very similar; we are resolving the last minor issues for the fitting at 5.8 and 8.0 microns, which require careful handling of the IRAC PSF. When compared to earlier, near-infrared observations, it appears the profiles are consistent with a very red stellar thick disk.