Mid-Infrared Studies with High Angular Resolution at Gemini South

Dan Li\(^1\), Charles M. Telesco\(^1\), Frank Varosi\(^1\) and Margaret M. Moerchen\(^1,2\)

\(^1\)Department of Astronomy, University of Florida, 211 Bryant Space Science Center, Gainesville, FL-32611, USA
\(^2\)European Southern Observatory, Alonso de Cordova 3107, Casilla 19001, Vitacura, Santiago 19, Chile

ABSTRACT

We analyzed about 1900 images obtained with T-RecS to characterize a key aspect of the mid-IR performance of the 8-meter telescope at Gemini South, namely, the appearance and stability of its delivered mid-infrared image profiles. All images are flux standards, and recorded with one or more of the following filters: S12.8.74\,\mu m, N-10.36\,\mu m, S5-11.66\,\mu m and Qa-18.3\,\mu m. We measure the full-width at half-maximum (FWHM), ellipticity, position angle (PA) and Strehl-ratio (SR) by fitting three PSF models (Lorentzian, Gaussian, and Moffat) to each image profile, and find that the long time-scale image quality is quite stable. The knowledge acquired from this work can help the prospective observer take the full advantage of the mid-IR capability of Gemini-S. To illustrate that we use a previous observation, in which a dust disk with a characteristic radius of only 3\,AU (comparable in size to our solar system’s asteroid belt) was detected within the debris disk around Zeta Lep, as an example of how we can use this mid-IR high-angular-resolution capability at Gemini-S to study the inner disk structure around stars.

![Fig. 1. Strehl-ratio vs. J.D. Vertical dashed lines represent the beginning of each calendar year. There seems to be no long a time-scale drift, but short time-scale fluctuations are obvious. For N images, the dispersion became smaller at the beginning of 2006, and has been relatively stable since. For Qa images, SR dispersion was smallest in 2006, and getting larger in the following two years; the average value (not shown in the plot) was also dropped slightly in 2007 and 2008, which might indicate a small downgrade in image quality.](image1)

![Fig. 2. SR distributions. Dotted lines are the cumulative distributions. N-band images obtained before 2006 are not included. Generally there is a trend that as wavelength increases SR also increases, which is consistent with our knowledge regarding the image quality of a non-AO system.](image2)

![Fig. 3. Ellipticity distributions. Ellipticity is another indicator of image quality, and is especially useful in the case where the 2-D PSF shape is the major concern, for example, in the observation of a circumstellar disk with a non-zero inclination.](image3)

![Fig. 4. The distributions of wing intensities. The low-intensity wings are of particular importance for the study of a circumstellar disk. To estimate the wing intensity, we first subtract the fitted Gaussian core from the original PSF, after which the mean value (solid line), or the peak value (dotted lines), among all pixels within an annular aperture is measured (and normalized to the PSF peak) to characterize the wing intensity. As shown above, the wing intensity is less than 5% of the PSF peak for most sources in our database.](image4)

![Fig. 5. We examined the correlation between image quality and many other parameters such as the observational date and time, ambient temperature and humidity, detector temperature, and airmass. We found a weak dependence of the IQ of Qa images on the ambient humidity. This suggests that the IQ in Qa band is more sensitive to high humidity than are the other filters, which is not surprising since there are indeed many strong water absorption lines within the Qa band.](image5)

![Fig. 6. The averaged Gaussian and Moffat PSF profiles. They are useful references when no high-quality PSF reference star is available during an observation.](image6)

![Fig. 7. An example of how we can use the mid-IR high-angular-resolution capability at Gemini-S to study the structure of the inner part of a circumstellar disk. ζ Lep is a 230 Myr-old star with a disk resolved by T-RecS. This figure shows the azimuthally averaged intensity profiles at 18.3\,μm of ζ Lep (diamonds) and a reference PSF star (dots). The FWHM difference between the two profiles is indicated by the two vertical lines. The intrinsic half-width of the deconvolved disk is only 3\,AU, which is comparable to the size of the Solar System’s asteroid belt. This discovery is important because the source may be the archetype for a whole new class of source: the asteroid-belt analogs. It also places our Solar System into the broader context of possible planetary-system configurations. The emitting region of ζ Lep is just barely resolved, and thus reliable information about the mid-IR PSF is crucial for an accurate assessment of the disk size. In this sense, our work will benefit prospective observers by providing them with a comprehensive information about the mid-IR image PSF delivered by Gemini-S.](image7)

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