SCExAO/MEC and CHARIS Discovery of a Low Mass, 6 au Separation Companion Using Stochastic Speckle Discrimination and High Contrast Spectroscopy[1]

S. Steiger[1], T. Currie[2,3,4], T. D. Brandt[1], O. Guyon[2,5,6,7], M. Kuzuhara[7,8], J. Chilcote[9], T. D. Groff[10], J. Lozi[2], A. B. Walter[11], N. Fruitwala[1], J. I. Bailey, III[1], N. Zobrist[1], N. Swimmer[1], I. Lipartito[1], J. P. Smith[1], C. Bockstiegel[12], S. R. Meeker[11], G. Coiffard[1], R. Dodkins[1], P. Szypryt[13,14], K. K. Davis[1], M. Daal[1], B. Bumble[11], S. Vievard[2], A. Sahoo[2], V. Deo[2], N. Jovanovic[15], F. Martinache[16], M. Tamura[7,8,17], N. J. Kasdin[18], and B. A. Mazin[1]

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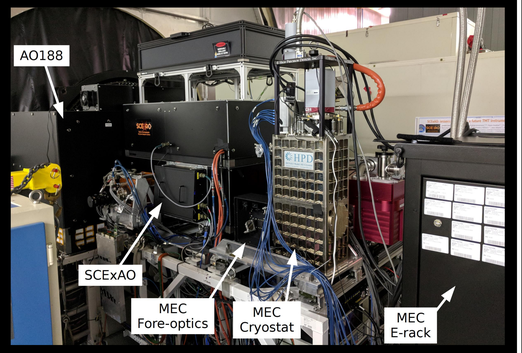
SCExAO/MEC and CHARIS

The MKID Exoplanet Camera (MEC) [2] is a Y-J band IFU located behind SCExAO (right). The key features of MEC, enabled by its Microwave Kinetic Inductance Detector array, include:



- Inherent energy resolution without the use of filters or gratings (R ~ 5)
- Microsecond timing resolution

The Coronagraphic High Angular Resolution Imaging Spectrograph (CHARIS) is an IFS for the Subaru telescope that covers JHK passbands with narrow (R ~ 70) or broadband (R ~ 18) coverage.

System Properties

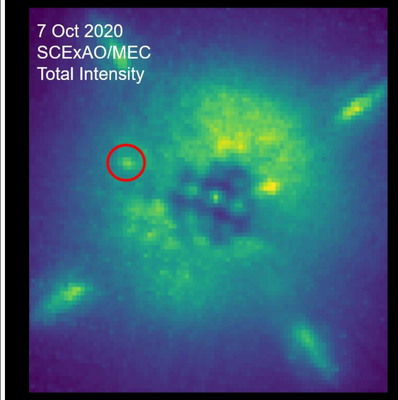
The primary is a nearby (~28 pc) type A1V star with an approximate age of 400-700Myr.

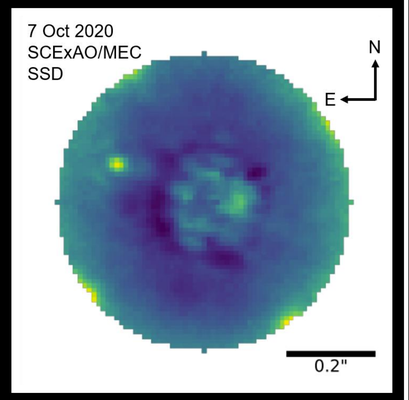
Astrometry derived from the Hipparcos-Gaia Catalogue of Accelerations (HGCA[3]) shows an ~11 σ significant acceleration which is why it was chosen as a target for direct imaging

References

1. Steiger et. al. 2021 (in prep)
2. Walter, A. B., Fruitwala, N., Steiger, S., et al. 2020, PASP, 132, 125005, doi: 10.1088/1538-3873/abc60f
3. Brandt, T. D. 2018, ApJS, 239, 31, doi: 10.3847/1538-4365/aaec06
4. Brandt. T.D. et. al. 2021 (submitted)

Stochastic Speckle Discrimination with MEC





Stochastic Speckle Discrimination (SSD) is a post processing technique that uses photon arrival time statistics to distinguish companions from a comparably bright speckle field (above). It is implemented in the following way:

1.) The total observation is broken up into a series of short (20ms) exposure images

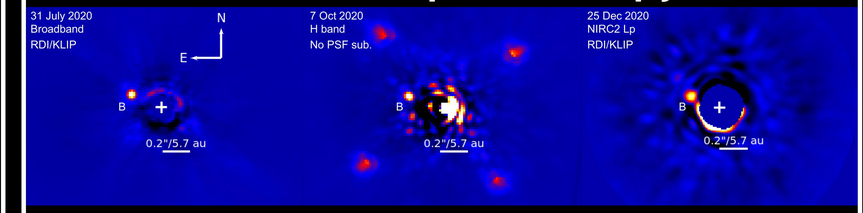
2.) A modified Rician (Equation 1) is fit for each pixel and Ic and Is are determined

3.) The ratio of Ic/Is is used as a diagnostic tool to distinguish between speckles and companions

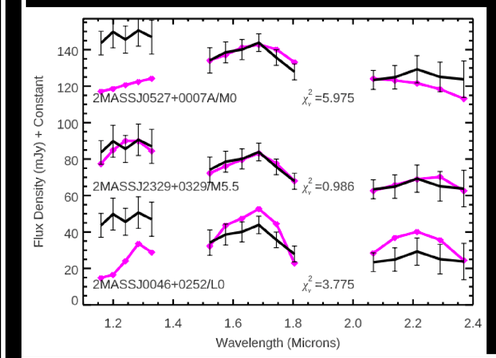
$$\rho_{MR}(I) = \frac{1}{I_S} exp\left(-\frac{I + I_C}{I_S}\right) I_0\left(\frac{2\sqrt{II_C}}{Is}\right) \quad (1)$$

SSD, using no PSF subtraction techniques and relying solely on photon arrival time statistics, achieves a comparable SNR to CHARIS data reduced with RDI

CHARIS Spectroscopy



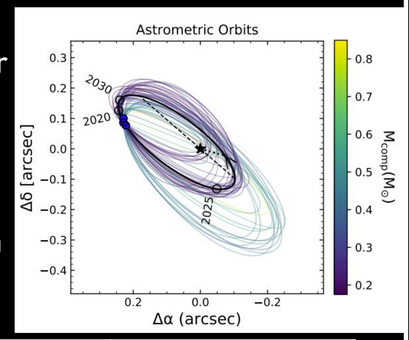
CHARIS (top left) and Keck/NIRC2 (top right) images of the companion using *Karhunen-Loe've Image Projection* (KLIP) for PSF subtraction.



The CHARIS spectrum was compared to spectra from the Montreal Spectral Library (left) . The best match spectrum corresponds to a M4-M5.5 object.

Orbit Fitting

The open-source code **orvara** [4] was used to fit the orbital parameters for this system using SCExAO/MEC and CHARIS relative astrometry, Keck NIRC2 astrometry, and HGCA absolute astrometry. The best fit dynamical mass is consistent with a companion mass of ~0.28 M_{sun}



Parameter	Fit Value	Prior
M_{pri} (M_{sun})	$2.09^{+0.16}_{-0.16}$	Gaussian, $2.1^{+0.15}_{-0.15}$
M_{sec} (M_{sun})	$0.280^{+0.18}_{-0.059}$	1/M
Semimajor axis a (au)	$6.55^{+3.0}_{-0.48}$	1/a
Eccentricity e	$0.54^{+0.28}_{-0.15}$	uniform
Inclination I (°)	$66.7^{+8.5}_{-14.0}$	sin(i)

1. Department of Physics, University of California, Santa Barbara, Santa Barbara, California, USA, 2. Subaru Telescope, National Astronomical Observatory of Japan, 650 North A'oh¯ok¯uPlace, Hilo, HI 96720, USA 3. NASA-Ames Research Center, Moffett Blvd., Moffett Field, CA, USA 4. Eureka Scientific, 2452 Delmer Street Suite 100, Oakland, CA, USA 5. Steward Observatory, The University of Arizona, Tucson, AZ 85721, USA 6. College of Optical Sciences, University of Arizona, Tucson, AZ 85721, USA 7. Astrobiology Center of NINS, 2-21-1, Osawa, Mitaka, Tokyo, 181-8588, Japan 8. National Astronomical Observatory of Japan, 2-21-2, Osawa, Mitaka, Tokyo 181-8588, Japan 9. Department of Physics, University of Notre Dame, South Bend, IN, USA 10. NASA-Goddard Space Flight Center, Greenbelt, MD, USA 11. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California 91125, USA 12. CERN - 1211 Geneva 23 – Switzerland 13. National Institute of Standards and Technology, Boulder, Colorado 80305, USA 14. Department of Physics, University of Colorado, Boulder, Colorado 80309, USA 15. Department of Astronomy, California Institute of Technology, 1200 E. California Blvd.,Pasadena, CA, 91125, USA 16. Universit´e C˜ote d'Azur, Observatoire de la C˜ote d'Azur, CNRS, Laboratoire Lagrange, France 17. Department of Astronomy, Graduate School of Science, The University of Tokyo, 7-3-1, Hongo, Bunkyo-ku, Tokyo, 113-0033, Japan 18. University of San Francisco, San Francisco, CA 94118