IGRINS Newsletter

Dear IGRINS Community,

It has been a year since the last IGRINS newsletter and we have a lot to report. Most critical to IGRINS science, we found that between April 2018 - May 2019 the resolving power in part of the K band was reduced from R=40,000 down to R=25,000. We have now corrected the K-band resolution change and re-optimized IGRINS' H-band focus.

IGRINS made the news at least twice in the last year with A Rare Icy Union on Neptunes Moon Triton and the Youngest Confirmed Exoplanet CI Tau b.

The third IGRINS visit to Lowell Observatory's Discovery Channel Telescope ended on May 1st, 2019. IGRINS is now back in the UT Austin lab while we prepare it to return to Gemini South for the 2020A semester. Proposals are due on September 30 or October 1, 2019, depending on the participant country. Full details are provided in the Gemini 2020A Call for Proposals and on our dedicated webpage https://sites.google.com/site/igrinsatgemini/.

We are also excited to report that Kimberly Sokal is now tackling real-world problems as a data scientist at Leidos after completing her Insight Data Science Fellowship. After 11 successful years of astronomy research in academia, she leaves our team with a rich archive of spectra and instrument documentation.

Finally, we take this opportunity to remind the IGRINS community that the full proprietary period is 24 months, and only 12 months at Gemini South. With new NSF funding (AST-1908892, PI: Gregory Mace) we are developing an online archive. We anticipate making IGRINS data available to non-PIs sometime in late 2020. Please don't hesitate contacting us if you have any questions!

With best wishes,

Dan Jaffe and the IGRINS Team

Contents

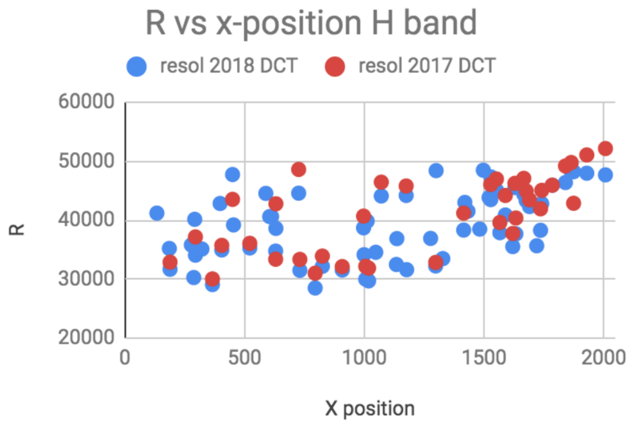
1 Updates

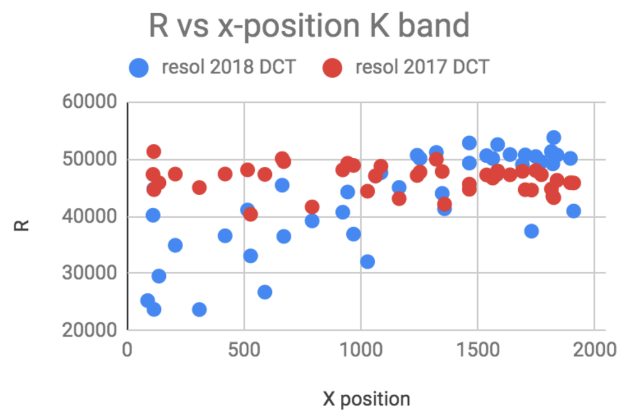
1.1 Current IGRINS Status

IGRINS has now completed the three, 6-month visits to the Discovery Channel Telescope that started in 2016. This is the end of that DCT agreement and we are now making preparations for IGRINS to return to Gemini South for the 2020A semester. We anticipate that IGRINS will be at Gemini South for at least the next two years. In the UT Austin lab we have exchanged the input optics and performed general instrument maintenance. As discussed in detail below, we also adjusted the H- and K-band detector mounts in order to achieve better focus across the echellograms. We have now transported IGRINS 18 times since it arrived in Austin from Korea in 2014. The next two years at Gemini South will be the longest duration between transport.

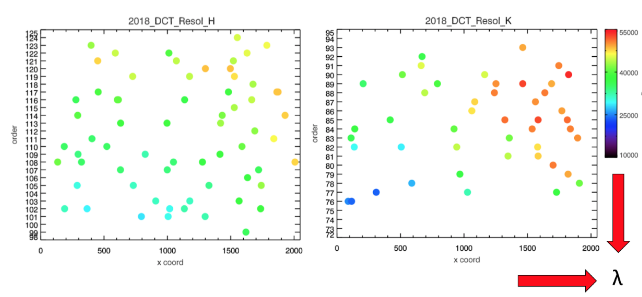
1.2 Resolution Variations

The measured line widths of OH sky lines across the K-band echellogram were changed in the commissioning data at Gemini South in April 2018. Prior to this (July 2014 - January 2018) the K-band spectral resolution was reliably >40,000. The line widths were changed for the entire visit to Gemini and the subsequent visit to the Discovery Channel Telescope. Changes in the H-band resolution were ±5% across the echellogram, with a mean resolution R>40,000. These variations to the H-band echellogram are noticed with each handling of IGRINS and are not considered to be an issue. The figure below shows measurements of OH line widths across IGRINS spectral orders (in pixel space). While only two epochs are shown (2017 and 2018, before and after the K-band resolution change) we have verified that these trends persist across many nights.

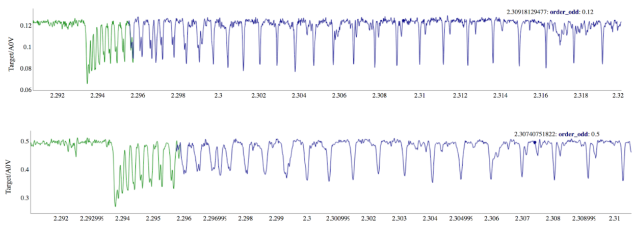




The 2D changes in spectral resolution are shown in the figure below. Just as in the plot above, OH line equivalent widths measured after April 2018 show significant variation in the K-band. Wavelengths on the IGRINS detector increase with increasing x-pixel and towards lower spectral orders. The largest change to the echellogram (reduction of the spectral resolution to R$\sim$20,000) occurs in the short-wavelength end of the long-wavelength K-band orders. This is where the CO bandheads are located ($\lambda > 2.3$ μm).



The 1D spectra of GJ 281 are shown below. The CO bandhead in two adjacent K-band orders depict the measured changes in the spectral resolution. The top spectrum is from 2017, before the resolution change, and the bottom is from early 2019. The long wavelength end of the 'green' order is unchanged while the short wavelength end of the 'blue' order shows the degraded spectral resolution.



The overall cause of the degraded resolution was a defocus of the K-band echellogram. In August 2019 we inspected IGRINS in the UT Austin lab. After finding loose fasteners on the K-band detector mount, we re-pinned it and then tightened everything. Cold testing on August 11th showed that the echellogram focus was corrected back to the design specifications. Additionally, we moved the H-band detector away from its camera by 200μm to achieve better focus. These adjustments should minimize future changes of IGRINS' spectral resolution.

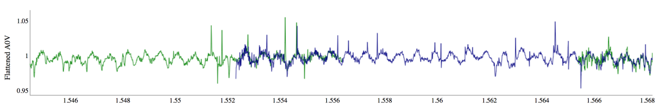
Since most significant changes to the spectral resolution have occurred along with handling and transport, future efforts to minimize these interactions should provide greater instrument stability. We will add new test procedures for IGRINS unpacking and will ship any needed spares and tools along with IGRINS to Gemini South.

What if you have IGRINS data impacted by this resolution change? The first thing to do is to quantify the resolution change in your own data. If it doesn't impact your science, then you don't need to do anything. Once the functional form of the change in resolution is known for your data, then it can be accounted for in your analysis. In the future we plan to provide all users with the information that they need to have a better understanding of the IGRINS spectral resolution on a nightly basis as part of the IGRINS Pipeline Package.

1.3 Fringing in IGRINS Spectra

Discussions during SPIE 2018 motivated the review of fringing in IGRINS spectra. Other instruments have experienced fringing effects, and it is generally traced back to the anti-reflection coatings on optics. When optics are developed and coated for large wavelength ranges, the number and thickness of the coating layers increases, which can cause fringing. The $\sim$1μm operating range of IGRINS is large, but not as large as the 1-5μm range of other variable-setting, near-IR spectrographs. The community is referred to this presentation by Peter Plavchan and Cale et al. 2019.

For IGRINS, we find that data from the 2.7m at McDonald Observatory does not show fringing. However, there is fringing with amplitudes $<4\%$ in the K band at the DCT, and in both the H and K bands in Gemini data. In the figure below, we show how the fringes repeat $\sim$28 times across the detector with a fixed frequency and amplitude. Because the fringing is in both the science data and the flat fields, it is removed by the standard flat-fielding process of the IGRINS Pipeline Package. However, residuals in the correction will persist for science that does not use the standard reduction process or for the brightest and faintest targets. Observers should consider this effect, check their spectra, and contact the IGRINS Team if questions arise.



1.4 Scientific Data from the McDonald Commissioning Runs

Any member of the astronomical community may examine the IGRINS commissioning data to help form their future proposals. The data format remains unchanged and this early data from IGRINS is still representative of what it can produce. Science verification data from the commissioning runs were processed using the current pipeline and available online http://kgmt.kasi.re.kr/igrins/pipeline/. Please be sure to read the Sample Data Policy, also available on the same website. More information on these data can be found in previous newsletters: HERE.

1.5 IGRINS PLP

In previous newsletters a few different versions of the data reduction pipeline were referenced. There is now a single version (2.2) that should be used for all data reduction https://github.com/igrins/plp/releases. With this release, Anaconda Python and conda environments can be used for easier installation https://github.com/igrins/plp/wiki/How-to-run-pipeline.

2 IGRINS @ Gemini

Proposals for 2020A at Gemini South are due on September 30 or October 1, 2019, depending on the participant country. IGRINS will be shipped to Gemini South in October of 2019. Once unpacked, we will validate the instrument health and prepare for installation on the telescope in January 2020. Full details are provided in the Gemini 2020A Call for Proposals and on our dedicated webpage https://sites.google.com/site/igrinsatgemini/. We anticipate IGRINS availability for the entire 2020A, 2020B, 2021A, and 2021B semesters. After this, IGRINS may visit the SOAR telescope or return to McDonald Observatory. There is also the option in the IGRINS agreement with AURA for up to four additional years at Gemini South.

A description of the modifications made to IGRINS for Gemini can be found in Mace et al. 2018. We are especially eager to highlight the IGRINS+Gemini science of Benjamin Kidder (UT Austin), Stephen Tegler (Northern Arizona University), Rafael Guerço (Observatorio Nacional, Rio de Janeiro), and Kenneth Hinkle (NOAO) in Section 4 of this newsletter.

3 IGRINS @ DCT

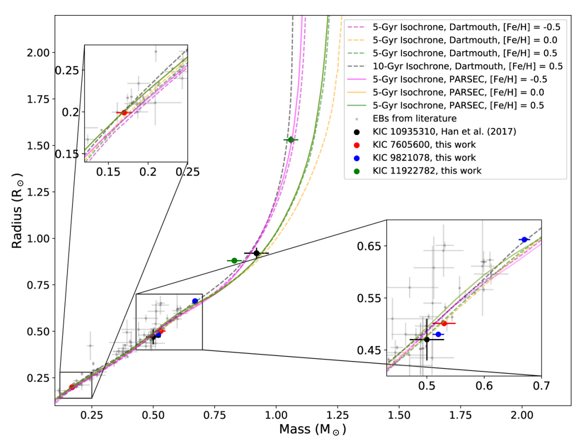
While IGRINS was at the DCT it was employed by at least one PI at each of the DCT partner institutions. In total, there were more than 20 IGRINS science PIs and there are ~16 PhD theses projects that include IGRINS data from the DCT. The total number of nights that IGRINS was scheduled at the DCT was ~350(excluding commissioning time), but many of these were partial nights.

At the writing of this Newsletter, there are 13 refereed IGRINS papers from the Discovery Channel Telescope with 137 citations. Some IGRINS+DCT science from Laura Flagg (Rice University), Eunkyu Han (Boston University), Brian Healy (Boston University), and Ricardo López-Valdivia (UT Austin) is summarized below.

4 Science Highlights

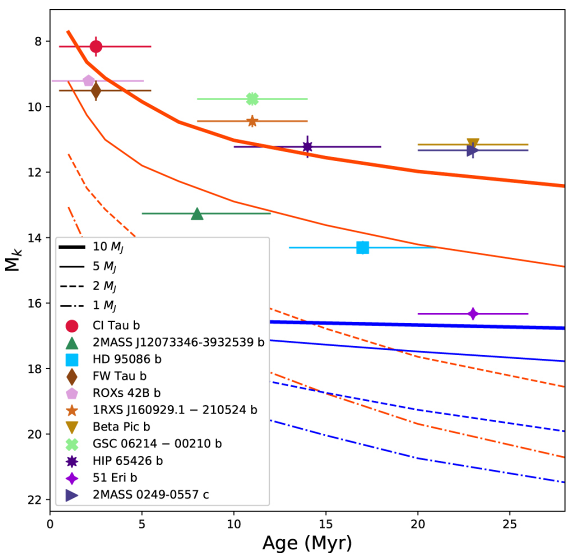
4.1 Magnetic Inflation and Stellar Mass. IV. Four Low-mass Kepler Eclipsing Binaries Consistent with Non-magnetic Stellar Evolutionary Models

Han et al. 2019 - Low-mass eclipsing binaries (EBs) show systematically larger radii than model predictions for their mass, metallicity, and age. Prominent explanations for the inflation involve enhanced magnetic fields generated by rapid rotation of the star that inhibit convection and/or suppress flux from the star via starspots. However, derived masses and radii for individual EB systems often disagree in the literature. In this paper, we continue to investigate low-mass EBs observed by NASAs Kepler spacecraft, deriving stellar masses and radii using high-quality space-based light curves and radial velocities from high-resolution infrared spectroscopy. We report masses and radii for three Kepler EBs, two of which agree with previously published masses and radii (KIC 11922782 and KIC 9821078). For the third EB (KIC 7605600), we report new masses and show the secondary component is likely fully convective ($M_2 = 0.17 \pm 0.01 M_\odot$ and R_2=0.199-0.002+0.001$R_\odot$). Combined with KIC 10935310 from Han et al., we find that the masses and radii for four low-mass Kepler EBs are consistent with modern stellar evolutionary models for M dwarf stars and do not require inhibited convection by magnetic fields to account for the stellar radii.



4.2 CO Detected in CI Tau b: Hot Start Implied by Planet Mass and M_K

Flagg et al. 2019 - We acquired high-resolution infrared spectra of CI Tau, the host star of one of the few young planet candidates amenable to direct spectroscopic detection. We confirm the planets existence with a direct detection of CO in the planets atmosphere. We also calculate a mass of 11.6 M_J based on the amplitude of its radial velocity variations. We estimate its flux contrast with its host star to get an absolute magnitude estimate for the planet of 8.17 in the K-band. This magnitude implies the planet formed via a hot start formation mechanism. This makes CI Tau b the youngest confirmed exoplanet as well as the first exoplanet around a T Tauri star with a directly determined, model-independent dynamical mass.



4.3 Magnetic Inflation and Stellar Mass. III. Revised Parameters for the Component Stars of NSVS 07394765

Healy et al. 2019 - We perform a new analysis of the M-dwarf−M-dwarf eclipsing binary system NSVS 07394765 in order to investigate the reported hyper-inflated radius of one of the component stars. Our analysis is based on archival photometry from the Wide Angle Search for Planets, new photometry from the 32 cm Command Module Observatory telescope in Arizona and the 70 cm telescope at Thacher Observatory in California, and new high-resolution infrared spectra obtained with the Immersion Grating Infrared Spectrograph on the Discovery Channel Telescope. The masses and radii we measure for each component star disagree with previously reported measurements. We show that both stars are early M-type main-sequence stars without evidence for youth or hyper-inflation (M_1=0.661-0.036+0.008 $M_\odot$, M_2=0.608-0.028+0.003 $M_\odot$, R_1=0.599-0.019+0.032 $R_\odot$, R_2=0.625-0.027+0.012 $R_\odot$), and we update the orbital period and eclipse ephemerides for the system. We suggest that the likely cause of the initial hyper-inflated result is the use of moderate-resolution spectroscopy for precise radial velocity measurements.

4.4 Effective Temperatures of Low-mass Stars from High-resolution H-band Spectroscopy

López-Valdivia et al. 2019 - High-resolution, near-infrared spectra will be the primary tool for finding and characterizing Earth-like planets around low-mass stars. Yet, the properties of exoplanets cannot be precisely determined without accurate and precise measurements of the host star. Spectra obtained with the Immersion Grating Infrared Spectrometer simultaneously provide diagnostics for most stellar parameters, but the first step in any analysis is the determination of the effective temperature. Here we report the calibration of high-resolution H-band spectra to accurately determine the effective temperature for stars between 4000 and 3000 K (∼K8−M5) using absorption line-depths of Fe I, OH, and Al I. The field star sample used here contains 254 K and M stars with temperatures derived using BT-Settl synthetic spectra. We use 106 stars with precise temperatures in the literature to calibrate our method, with typical errors of about 140 K, and systematic uncertainties less than ∼120 K. For the broadest applicability, we present T eff−line-depth-ratio relationships, which we test on 12 members of the TW Hydrae Association and at spectral resolving powers between ∼10,000 and 120,000. These ratios offer a simple but accurate measure of effective temperatures in cool stars that are distance and reddening independent.

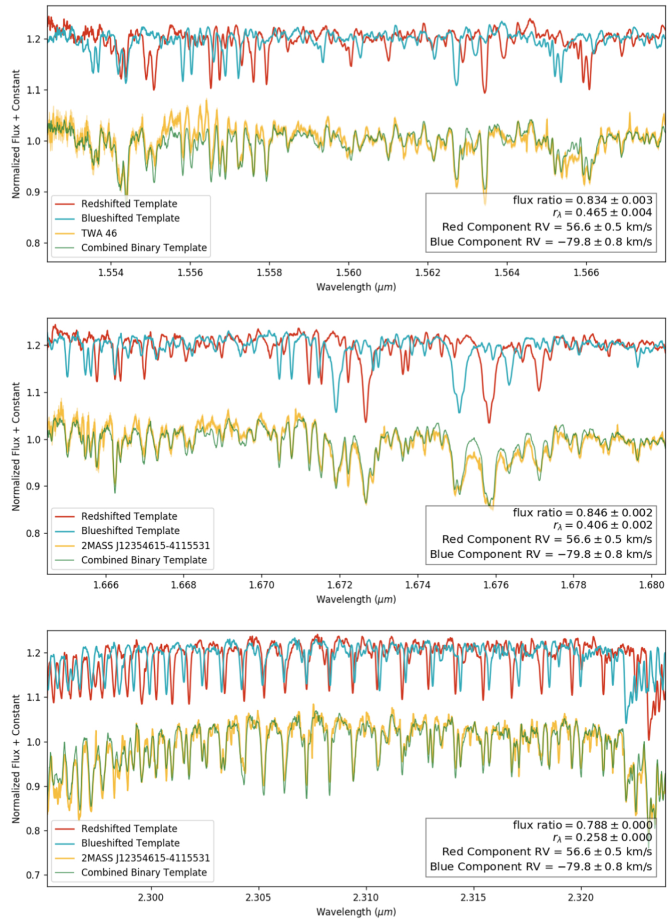
4.5 A New Two-molecule Combination Band as a Diagnostic of Carbon Monoxide Diluted in Nitrogen Ice on Triton

Tegler et al. 2019 - A combination band due to a mechanism whereby a photon excites two or more vibrational modes (e.g., a bend and a stretch) of an individual molecule is commonly seen in laboratory and astronomical spectroscopy. Here, we present evidence of a much less commonly seen combination band−one where a photon simultaneously excites two adjacent molecules in an ice. In particular, we present near-infrared spectra of laboratory CO/N2 ice samples where we identify a band at 4467.5 cm^{-1} (2.239 μm) that results from single photons exciting adjacent pairs of CO and N2 molecules. We also present a near-infrared spectrum of Neptunes largest satellite Triton taken with the Gemini-South 8.1 m telescope and the Immersion Grating Infrared Spectrograph that shows this 4467.5 cm^{-1} (2.239 μm) CO−N2 combination band. The existence of the band in a spectrum of Triton indicates that CO and N2 molecules are intimately mixed in the ice rather than existing as separate regions of pure CO and pure N2 deposits. Our finding is important because CO and N2 are the most volatile species on Triton and so dominate seasonal volatile transport across its surface. Our result will place constraints on the interaction between the surface and atmosphere of Triton.

4.6 Fluorine Abundances in the Globular Cluster M4

Guerço et al. 2019 - We present chemical abundances for the elements carbon, sodium, and fluorine in 15 red giants of the globular cluster M4, as well as six red giants of the globular cluster ω Centauri. The chemical abundances were calculated in LTE via spectral synthesis. The spectra analyzed are high-resolution spectra obtained in the near-infrared region around 2.3 μm with the Phoenix spectrograph on the 8.1 m Gemini South Telescope, the IGRINS spectrograph on the McDonald Observatory 2.7 m Telescope, and the CRIRES spectrograph on the ESO 8.2 m Very Large Telescope. The results indicate a significant reduction in the fluorine abundances when compared to previous values from the literature for M4 and ω Centauri, due to a downward revision in the excitation potentials of the HF (1−0) R9 line used in the analysis. The fluorine abundances obtained for the M4 red giants are found to be anti-correlated with those of Na, following the typical pattern of abundance variations seen in globular clusters between distinct stellar populations. In M4, as the Na abundance increases by +0.4 dex, the F abundance decreases by -0.2 dex. A comparison with abundance predictions from two sets of stellar evolution models finds that the models predict somewhat less F depletion (-0.1 dex) for the same increase of +0.4 dex in Na.

4.7 Radial Velocities of Low-mass Candidate TWA Members



Kidder et al. 2019 - Nearby young moving groups provide unique samples of similar age stars for testing the evolution of physical properties. Incomplete and/or incorrect group membership classifications reduce the usefulness of the group, which we assume to be coeval. With near-infrared spectra of two candidate members of the TW Hya Association, 2MASS J12354615−4115531 (TWA 46) and 2MASS J12371238−4021480 (TWA 47), we test their membership by adding radial velocity measurements to the literature. We find that 2MASS J12354615−4115531 is a close spectroscopic binary system with a center-of-mass radial velocity of −6.5 ± 3.9 km s^{-1}. This radial velocity and a Gaia parallax produces a TW Hydra association (TWA) membership probability of 41.9% using the Banyan Σ tool for 2MASS J12354615−4115531. The spectrum of 2MASS J12371238−4021480 shows that it appears to be a single star with a radial velocity consistent with the TW Hya Association and a membership probability of 99.5%. The reduced probability of TWA 46 as a true member of TWA highlights the importance of high-resolution, near-infrared spectra in validating low-mass moving group members.

4.8 Infrared Spectroscopy of Symbiotic Stars. XII. The Neutron Star SyXB System 4U 1700+24 = V934 Herculis

Hinkle et al. 2019 - The X-ray symbiotic (SyXB) V934 Her = 4U 1700+24 is an M giant-neutron star (NS) binary system. Employing optical and infrared radial velocities spanning 29 yr combined with the extensive velocities in the literature, we compute the spectroscopic orbit of the M giant in that system. We determine an orbital period of 4391 days, or 12.0 yr, the longest for any SyXB and far longer than the 404 day orbit commonly cited for this system in the literature. In addition to the 12.0 yr orbital period, we find a shorter period of 420 days, similar to the one previously found. Instead of orbital motion, we attribute this much shorter period to long secondary pulsation of the M3 III SRb variable. Our new orbit supports earlier work that concluded that the orbit is seen nearly pole-on, which is why X-ray pulsations associated with the NS have not been detected. We estimate an orbital inclination of 11.3 ± 0.4. Arguments are made that this low inclination supports a pulsation origin for the 420 day secondary period. We also measure the CNO and Fe peak abundances of the M giant and find it to be slightly metal-poor compared to the Sun, with no trace of the NS-forming supernova event. The basic properties of the M giant and NS are derived. We discuss the possible evolutionary paths that this system has taken to get to its current state.

5 Publication Policy

Observing PIs are expected to analyze and publish their data promptly. The current proprietary period is 24 months from the date the data are taken. Decisions about authors and author orders of publications are the responsibility of the proposal PI. The IGRINS team member(s) on the observing proposal(s) should be included as paper authors. Wherever possible, PI's should seek reasons to give first authorships to junior team members, in particular to students and postdocs. All authors should have intellectual ownership of the material and have contributed to the work. The IGRINS team is committed to ethics in publication and does not condone courtesy authorships. For this reason, please involve junior team members throughout the scientific process.

Acknowledgements: The standard acknowledgement for IGRINS is: "This work used the Immersion Grating Infrared Spectrometer (IGRINS) that was developed under a collaboration between the University of Texas at Austin and the Korea Astronomy and Space Science Institute (KASI) with the financial support of the US National Science Foundation under grants AST-1229522 and AST-1702267, of the University of Texas at Austin, and of the Korean GMT Project of KASI." The facility that IGRINS is used at should also be acknowledged. IGRINS' spectral resolution is R∼45,000.

Designated IGRINS instrument citations(s):

Park, C. et al., Design and early performance of IGRINS (Immersion Grating Infrared Spectrometer), Proc. SPIE 9147 (2014).

Jae-Joon Lee, Kevin Gullikson, & Kyle Kaplan. (2017, August 18). igrins/plp 2.2.0. Zenodo. http://doi.org/10.5281/zenodo.845059

Mace, G. et al., 300 nights of science with IGRINS at McDonald Observatory, Proc. SPIE 9980 (2016).

Mace, G. et al., IGRINS at the Discovery Channel Telescope and Gemini South. Proc. SPIE 107020Q (2018).

Refereeing: The IGRINS team has an internal refereeing process for observing and instrumentation papers. We strongly recommend that all papers to be submitted to a refereed journal, and using IGRINS data or technical information, go through the IGRINS internal refereeing process. Papers for non-refereed conference proceedings may also make use of this service. Revisions in response to these comments can be made at the discretion of the authors. First authors should inform Jae-Joon Lee (leejjoon@kasi.re.kr), Gregory Mace (gmace@utexas.edu), and/or Lisa Prato (lprato@lowell.edu) of submitted papers. At the time of acceptance, please provide us with the title, journal, volume, and full author list.