Title: Probing the Warm Ionized Medium (WIM) on arcsecond scales
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The column density to an FRB, the dispersion measure (DM), is the most important extrinsic parameter of an FRB. The measured DM is the sum of DM within the Milky Way, in the IGM/CGM and within the host galaxy. The Warm Ionized Medium (WIM) is the primary source of DM in the Milky Way. The medium is pervasive (fill factor of 0.25, in the disk; unity in the upper and extended halo). The FRB signals also undergo scattering due to very fine structure within the WIM. Pulsars with parallax provide fundamental underpinnings to our model of the WIM. Optical observations of recombination line (primarily H-alpha) and "nebular" (forbidden) lines (primarily [NII] and [OII]; other lines such as [NI], [OII], [OIII] have not been exploited) have provided us insight into the physical properties: the WIM temperature varies between 6000 K and 10^4 K; the ionization fraction of hydrogen is 90% while the ionization fraction of helium may be as low as 0.2. The Wisconsin H-alpha Mapper (WHAM), a dual-etalon Fabry-Perot imager, is the workhorse for optical emission line studies. The angular beam of WHAM is large, about a degree in diameter.

Recall that the signal-to-noise ratio (SNR) for surface brightness measurements is proportional to the square root of the product of the collecting area, A, the beam solid angle, **Ω***,* the integration time, t, and high spectral resolution, R. WHAM achieves high sensitivity by having a large beam (**Ω**=1 deg^2) and high spectral resolution (R=15,0000) and modest collecting area (60-cm siderostat). Thus, if one wants to study the structure of the WIM, on say, arcsecond scales, then one needs to increase the collecting area by large factor and increase the integration time. Alternatively, one could observe in the mid-IR where the lines are readily excited, as opposed to the optical lines which suffer are excited by a smaller population of energetic electrons. That is the approach that we took.

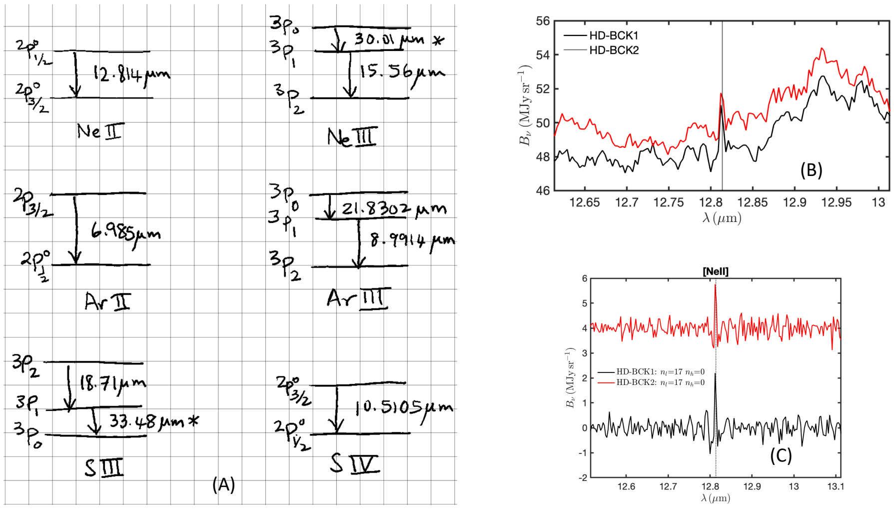

Figure 1. (A) Grotrian diagram of mid-IR fine structure lines accessible to MIRI-MRS. (B) Detection of [NeII] 12.8μm line. The two spectra are from the background field to HD166433 but taken on different days. (C) The same as in (B) but after Fourier filtering.

James Webb Space Telescope has a large collecting area, 25.4 m^2. It is equipped with two integral field unit (IFU) spectrographs. Of interest to us is the MIRI-Medium Resolution Spectrometer (MRS) which has a field-of-view of 5"x5" and operates in the 5 to 30 **μ**m. As can be seen from Figure 1A, this wavelength range includes a number of mid-IR fine structurelines. The spectral resolution is about 2000.

We downloaded Level 3 data of a calibration dataset (HD 163466; on source and background field which was observed twice). Our analysis treated the entire IFU field as a "light bucket". In that spirit,we took the median of each image slice of the 3-D IFU data cube. [NeII]12.8 micron is readily detected both in the background field (see Figure 1B) and also in the sky spectrum of HD163466 (albeit at a lower SNR owing to scattering from the bright calibration star). IFU spectrographs, whilst powerful, are infamous for the complexity in data reduction. STScI is refining the pipeline reduction for MIRI-MRS. It is clear from Figure 1B that the sky spectrum suffers from "lumpy" baselines and "fringing" (pixel-to-pixel variation). Fortunately, the expected emission from the WIM is an unresolved line. Given this expectation we applied a low-pass filter (to flatten the baseline) and a high-pass filter (to get rid of fringing). As can be seen from Figure 1C the resulting sky spectrum shows a robust detection of [NeII] emission. The inferred EM in this direction is less than 16 cm^{-3} pc, squarely in the range expected from the WIM.

We followed up with searches for other lines. From a photon-noise persepctive many other lines should be detectable. However, the present level of IFU pipeline data reduction is far from this ideal limit. We detect [SIII] and perhaps a trace of [SIV]. The expected SNR for [ArII] and [ArIII] is nominally about 10, the detection of which would require a data reduction pipeline operating at the photon noise level limit.These initial findings suggest that the diffuse EUV ionizing field incicent on the WIM is "soft" and supports the low helium ionization fraction, <0.2, inferred from radio recombination lines.

Any hour-long observation with MIRI-MRS, regardless of the intent of the proposing astronomer, will lead to detection of emission from WIM. Separately, I draw attention of the reader to the development of powerful high resolution IFU spectrographs such as MUSE on VLT and the Keck Cosmic Imager (KCI) on Keck. Take for instance, the red-arm of KCI, "Keck Cosmic Recombination Imager' (KCRM). With a photon-to-photoelectron througput of better than 0.2, a spectral resolution of better than 15,000, and $\mathbf{\Omega}$=160 arcsec^2, the instrument, in the light bucket mode, is well suited to detecting nebular lines from the WIM. As with JWST any moderately deep observation of KCI will result in detection of optical lines from the WIM. In short, we are on the verge of a new cottage industry with both JWST and Keck that will provide steady data for the study of the WIM on arcsecond scales.

This report is drawn from a paper titled "Mid-infrared fine structure lines from the Galactic warm ionized medium" by S. R. Kulkarni, C. Beichman and M. E. Ressler which will shortly be submitted to PASP.

The author. I am a professor of astronomy at Caltech but spending this Fall semester at Cornell University. My interests have evolved and also changed over time. My thesis was centered on the atomic phase of the Galactic ISM (primarily HI) and radio astronomy instrumentation. Towards end of my thesis, under the guidance of Don Backer, I discovered the first millisecond pulsar. I left the field of interstellar medium studies as soon as I obtained my PhD switching to millisecond pulsars, globular cluster pulsars and soft gamma-ray repeaters. Working with Dale Frail I showed that soft gamma-ray bursters were Galactic in origin, arising from massive stars and with some having a plerionic nebula. After this phase I switched to high dynamic range imaging at optical wavelengths and infra-red interferometry. Our group discovered the first brown dwarf (Gliese 229B). I then switched to gamma-ray bursts (GRBs) and our group showed that GRBs are of extra-galactic origin. Dale Frail and I discovered radio afterglow from GRBs. I then switched to an ambitious study of the dynamic night sky, successively developing and commissioning Palomar Transient Factory, intermediate Palomar Transient Factory and Zwicky Transient Facility (ZTF; 2017-present). My student Chris Bochenek (graduated in 2021) developed STARE2 (taking advantage of the considerable engineering development for the DSA-10 and DSA-110 projects) which detected a mega Jansky burst from a Galactic magnetar (2020). After stepping down as Director of the Caltech Optical Observatory (COO) I elected to return to the field of Galactic ISM studies. I am currently focused on the Warm Ionized Medium (WIM) and, over the next few years, hope to successively work up to the Warm Neutral Medium (WNM) and the Cold Neutral Medium (CNM).