



Spitzer Observations of HD 34078 and IC 405: Bow Shock and Mid IR Emission Variations



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Abstract

We present new infrared observations of the emission/reflection nebula IC 405 obtained with the *Spitzer Space Telescope*. Infrared images in the four IRAC bands and two MIPS bands (24 and 70 μm) are complemented by IRS spectroscopy (6 – 20 μm) of two nebular filaments. The IRAC (8.0 μm) and MIPS imaging shows evidence of a bow shock associated with the runaway O9.5V star, HD 34078. The ratio of emission at 24 to 70 μm is higher in the immediate vicinity of HD 34078 than in the outer filaments, providing evidence for elevated dust temperatures ($T_d > 90$ K) in the shock region. The nebular imaging reveals that the morphology is band dependent, with varying contributions from aromatic emission features, H_2 , and dust emission. Nebular spectroscopy is used to quantify these contributions, showing several aromatic emission bands between 6 and 14 μm , the $S(5)$, $S(3)$, $S(2)$, and $S(1)$ pure rotational emission lines of H_2 , and atomic fine structure lines. The low dispersion spectra provide constraints on the ionization state of the large molecules responsible for the aromatic infrared features. An average $T(\text{H}_2) \approx 400$ K is inferred, with evidence for additional non-uniform excitation by UV photons in the intense radiation field of HD 34078. The photoexcitation hypothesis is supported by direct measurement of the farUV H_2 fluorescence spectrum, obtained with *FUSE*

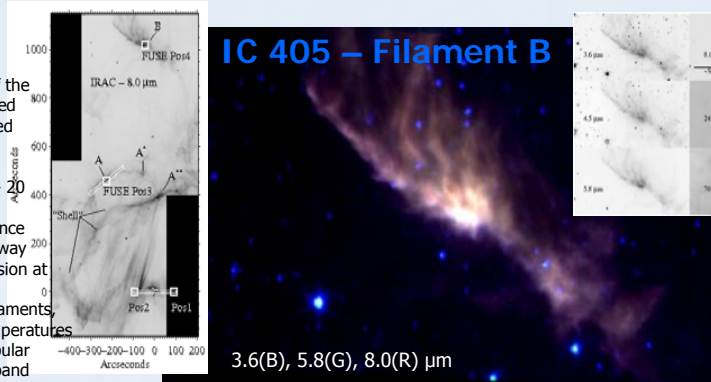


Fig2 – Upper Left- 8.0 μm IRAC image of IC 405, Above-3-color IRAC composite of Filament B, Upper Right-6-color mid/far-IR imaging of Filament B, Right-3-color mid/far-IR composite of Filament B

HD 34078 - Cometary Bow Shock

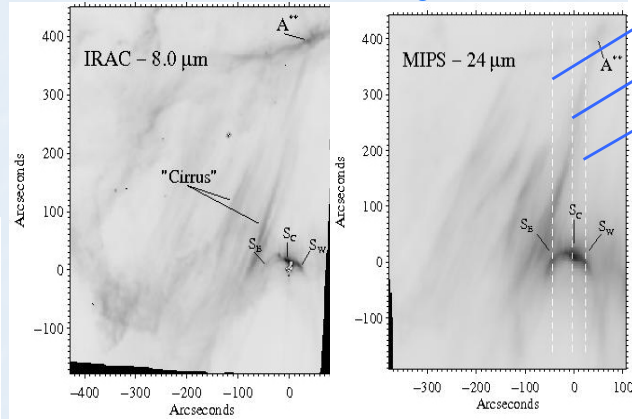


Fig3 – Bow shock, Left-IRAC and Right-MIPS

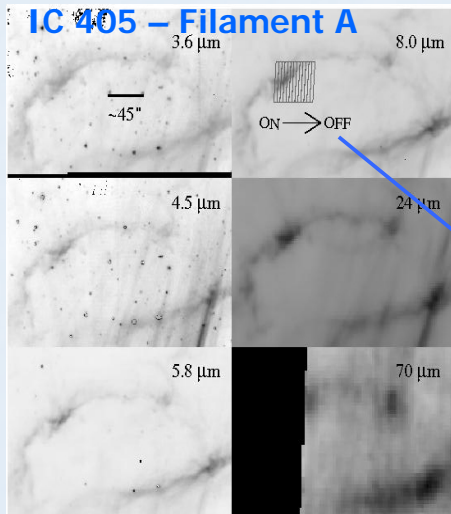


Fig1 – 6-color mid/far-IR (IRAC+MIPS) imaging of bright nebular Filament A.

IRS Line Strength Variations

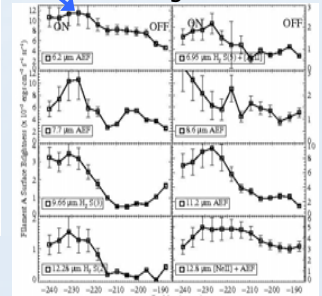


Fig4- Filament A IRS line strengths

IRS Spectra

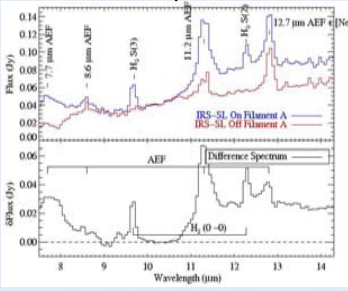
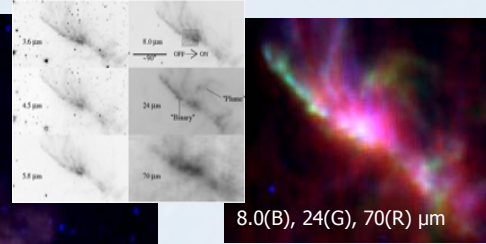


Fig5 – Filament A IRS spectra



Dust Temperature Profiles

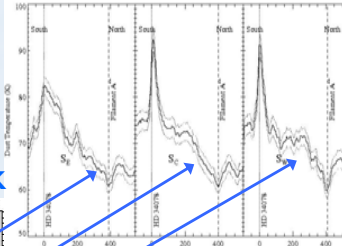


Fig6 – Dust temperature profiles across S_E , S_C , and S_W

Results- H_2 Temperature

Combining ratios of the H_2 rotational lines observed in the IRS data ($I(S(3))/I(S(2))$ and $I(S(2))/I(S(1))$) with energy levels and transition probabilities from the literature, we measure a $T(\text{H}_2) \approx 400$ K. There is evidence for additional excitation by UV photons, which is supported by *FUSE* observations (shown below).

FUSE Spectra

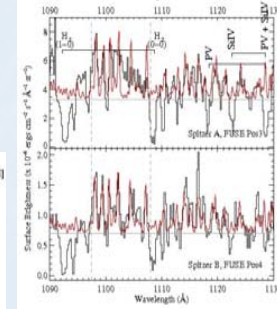


Fig7- Non-thermal (fluorescent) H_2 emission

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Results-Ionization Environment

Large carbonaceous molecules (PAHs) are thought to be the source of the strong 6 to 14 μm bands seen in many astronomical sources. The emission in a particular band depends upon the structure and charge state of the molecule. Cations produce enhanced 6 – 10 μm bands (C – C stretching modes), while neutrals dominate the 3.3 and 10 – 14 μm (C – H mode) emission. Ratios of these bands (6.2/11.2 μm for example) can be used to probe the ionization state of the PAHs in an intense radiation field environment ($G_0/n_0 \approx 10^4$ cm^2). Filament A shows evidence for enhanced PAH ionization with decreasing density as the IRS scan moves off the densest regions of the filament. Filament B, under the influence of a weaker radiation field, shows no correlation.

PAH Ionization

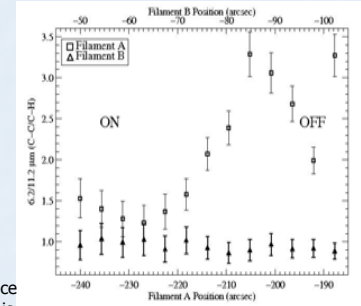


Fig8 – Band ratios show an increase in PAH ionization with decreasing density

Future Work - Diverse PDRs

M 27 - Low Density + Hard Radiation Field
IC 63 - Prototypical H_2 Fluorescence Nebula
M42 – Orion Bar – Classical PDR in Star Forming Region
HUT Spectrum of IC 63: Fluorescent H_2

See Lupu et al. - Poster 156.03