IRC +10420 - a Warm Hypergiant

Upper Left, an HST image of IRC +10420 in the optical red showing light scattered by dust in the mass-loss wind of this star. Note the very complex structures seen in the visible, suggesting a very complicated mass-loss process. To the upper right are LMIRCam images from the LBT at L’ and M showing a much smoother distribution for the dust. To the right is a polarization vector map of the dust surrounding IRC +10420 at 2.2 μm taken with MMTPol. The polarization is clearly centrosymmetric, indicating simple scattering of light from the central star.

After removing the underlying, diluting intensity of the stellar PSF, the fractional polarization is found to range from 20-80% (above left). For simple, optically thin scattering from a symmetric dust geometry, one would expect the fractional polarization to remain the same, dependent only on the mean scattering angle. However, examination of the surface brightness of the scattered light indicates the scattering optical depth ranges from 0.05 (thin) to 0.40 (moderate) across the nebula (above right). The scattering optical depth anti-correlates with the fractional polarization, suggesting multiple scatters degrade the polarization in certain areas. The high fractional polarization, with a moderate effect due to multiple scattering, places the dust surrounding IRC +10420 in the plane of the sky, suggesting a skirt structure in the equator of a bipolar outflow seen pole-on.

VY CMa – a Cool Hypergiant

Like IRC +10420, HST images of VY CMa show very complex morphology, suggesting a very complicated mass-loss process. High resolution imaging from 2-5 μm with LMIRCam on the LBT, which penetrates deep into the mass-loss wind, shows an optically thick clump to the SW of the star that just starts to become visible at R in the HST images. As with IRC +10420, the dust distribution in the IR is much simpler than seen in the visual, suggesting a relatively simple mass-loss mechanism. However, the presence of the Clump as a distinct feature with no apparent counterpart on the other side of the star is suggestive of an ejection event from a localized region of the star and is consistent with VY CMa’s history of asymmetric high-mass-loss events. The minimum mass of this clump is 5 Jupiter masses.

Imaging polarimetry of VY CMa at 1.33 μm reveals this clump as well as the NW arc. Imaging polarimetry at 3.1 μm also reveals the SW clump, but not the NW arc. Although moderate, the polarization of the clump at 1.33 and 3.1 μm require the dust grains to have a low albedo in order to suppress the second scatter, given that the clump is very optically thick. This suggests the albedo is lower at 1.33 μm (P≈40%) than at 3.1 μm (P≈24%).

Radial velocity measurements of line emission scattered off of the SW clump in the optical red suggested the dust was mostly in the plane of the sky with respect to the central star. This is confirmed with our imaging polarimetry. A scattering angle much different from 90° combined with the high optical depth would produce a polarization significantly lower than we observe.

Summary

By combining high spatial resolution and polarimetry at infrared wavelengths, we can penetrate deep inside the mass-loss winds of evolved stars and study the geometry of the mass-loss history. Compared to the visual, we find relatively simpler geometry for the dust distribution. Although stars like IRC +10420 are often considered to be the offspring of red supergiants like VY CMa, the cooler hypergiant is found to generate very massive, single mass-loss events not seen in the warmer hypergiant.