Resolving the Mass-loss from Wolf-Rayet Binaries Enshrouded by Dusty Spirals

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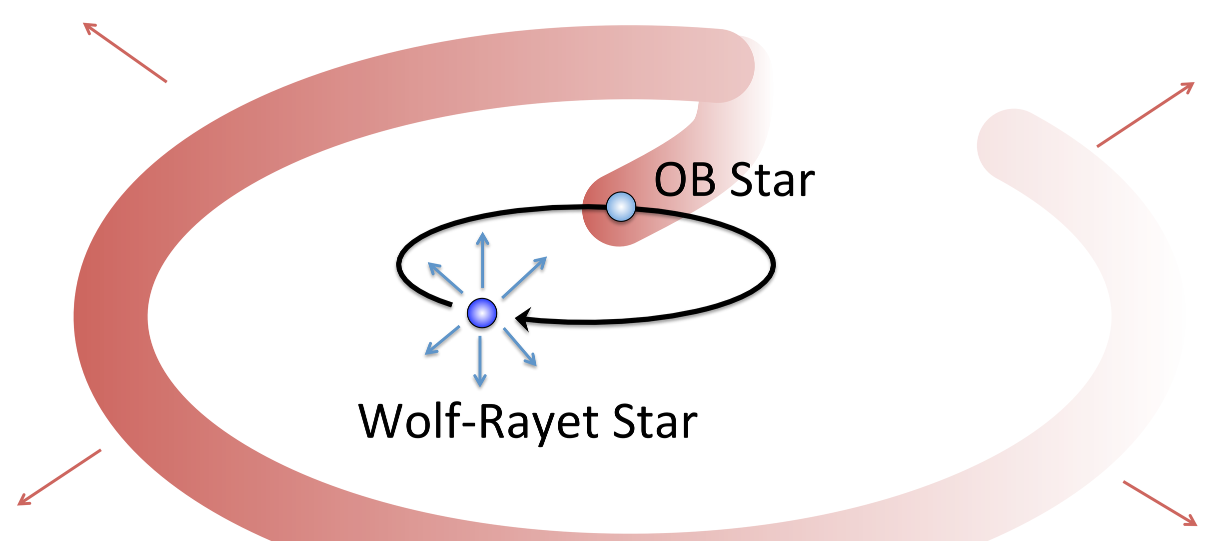
Dusty Pinwheels in the Galactic Center



Graphic inspired by Fig. 2 of Tuthill et al. (1999) [1]

★ **Dust condenses in the dense regions of OB companion's wake and swept out along binary orbital plane**

★ **Dust may also condense in the WR winds if the outflow is sufficiently dense (e.g. clumping; [2])**

How do massive stars evolve in the final moments of their lives?

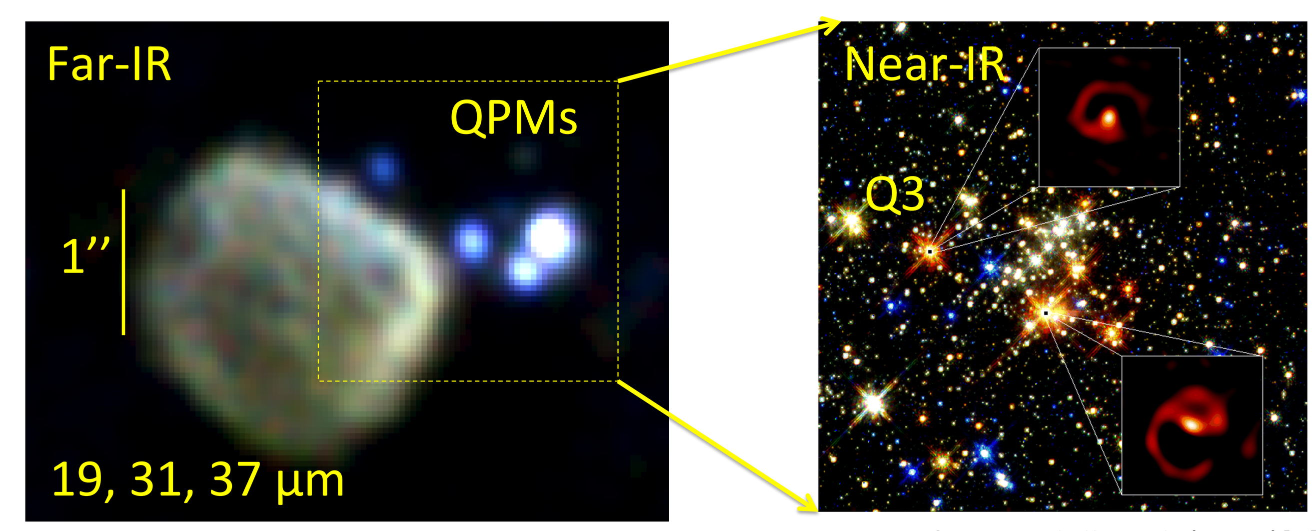
- Massive stars have a profound influence on the ISM, particularly after leaving the main-sequence where they undergo intense phases of mass-loss (e.g. [3])
- A large majority of massive stars is believed to have closely orbiting binary companions, which can lead to mass exchange or mergers and strongly influence their evolution and mass-loss [4]
- Due to their relatively short lifetimes, neither their evolutionary track nor the full extent of binary influence is well understood

The Quintuplet Proper Members (QPMs)

- The QPMs the five dust-enshrouded, featureless sources in the Quintuplet cluster at the Galactic center [5]
- Previous high spatial-resolution near-IR imaging of the QPMs revealed rotating spiral plumes characteristic of colliding-wind Wolf-Rayet+OB star binaries [6]
- Images of the QPMs at 19, 25, 31, and 37 µm [7] were obtained using FORCAST with the 2.5-m telescope aboard the Stratospheric Observatory for Infrared Astronomy (SOFIA)

Key Findings

- Mid to far-IR photometry suggests the presence of cooler (T_D < 300 K), extended dust components
- QPMs are unresolved at mid and far-IR wavelengths. It is difficult to determine if the cooler component is an extension of the spiral or a detached shell
- We present two dust emission models with different morphologies that match the observed near to far-IR fluxes from Q3. Models indicate different dominant mass-loss modes: colliding winds (spiral) or single star winds (shell)
- Simulated TMT/IRIS images of the QPMs show that the TMT will be able to resolve this degeneracy and determine the dominant mass-loss mode

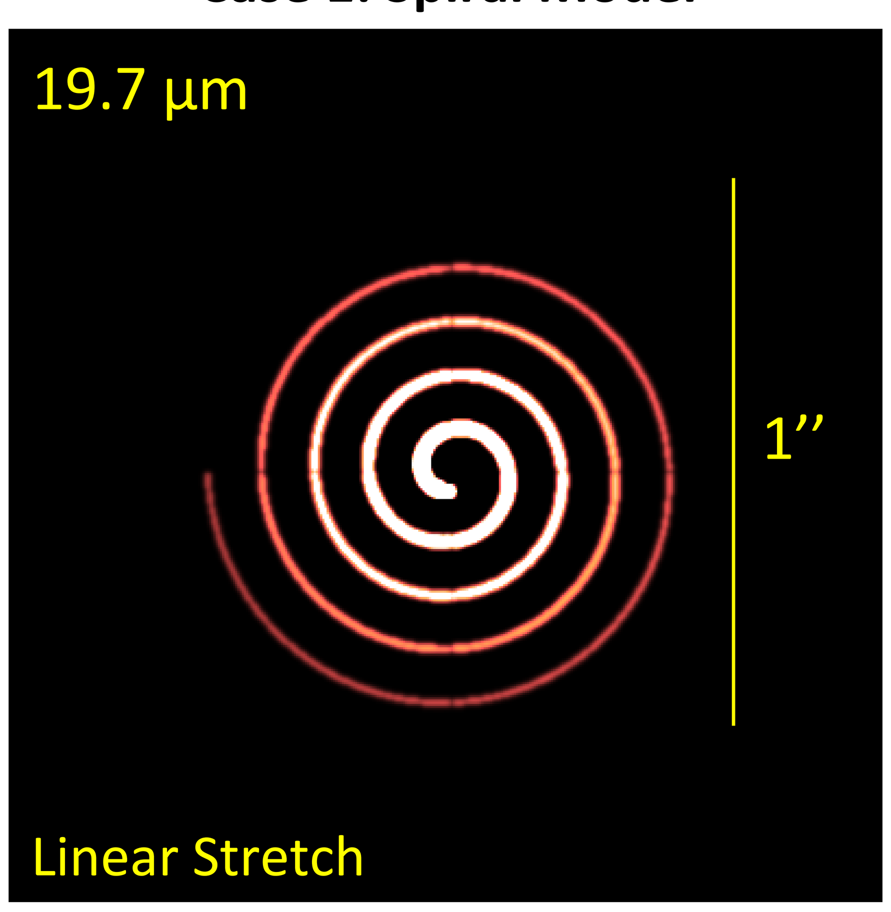


QPMs and the Pistol nebula [7]

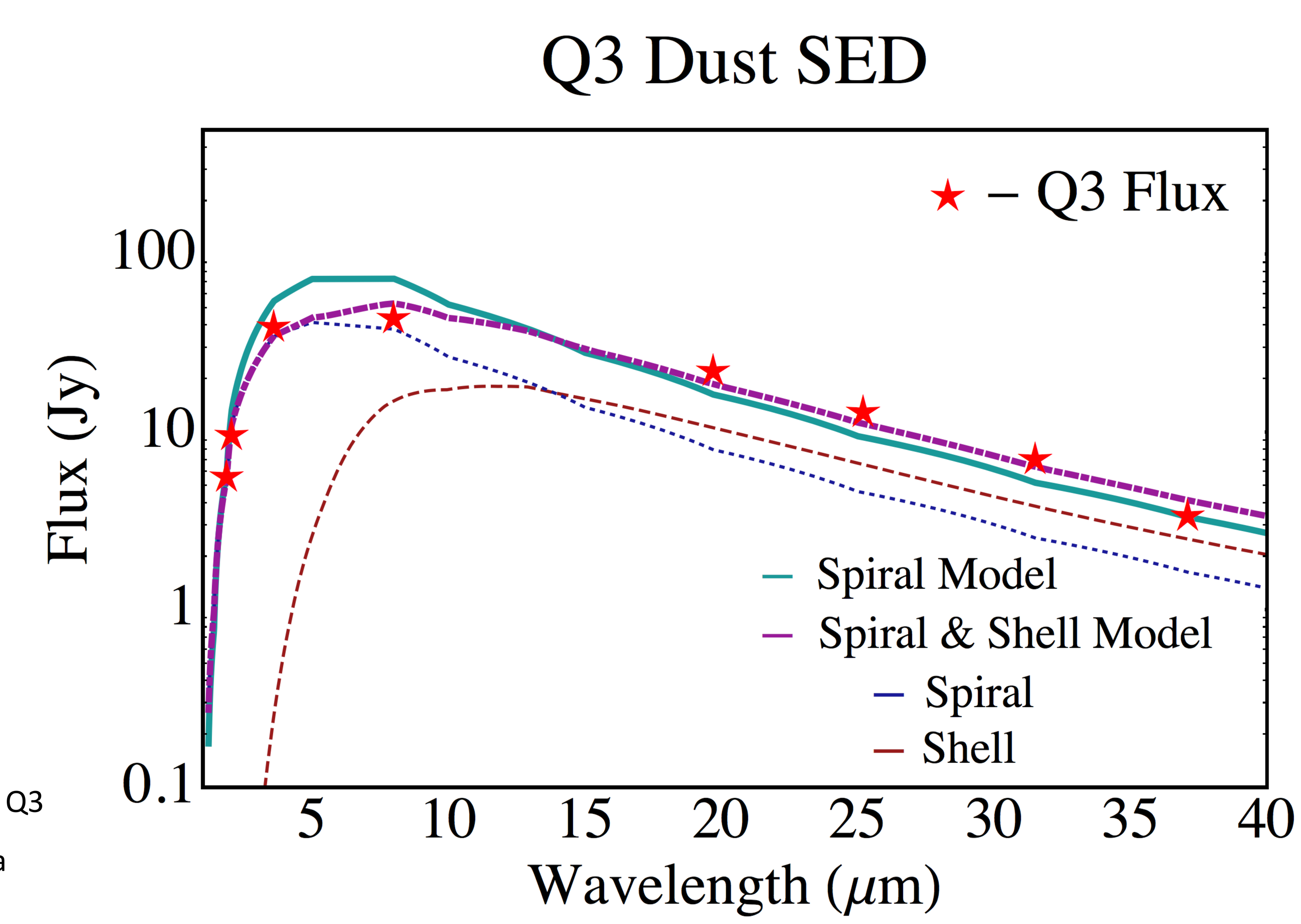
Fig. S1 from Tuthill et al. (2006)[6]

Constraining Morphology and Mass Loss

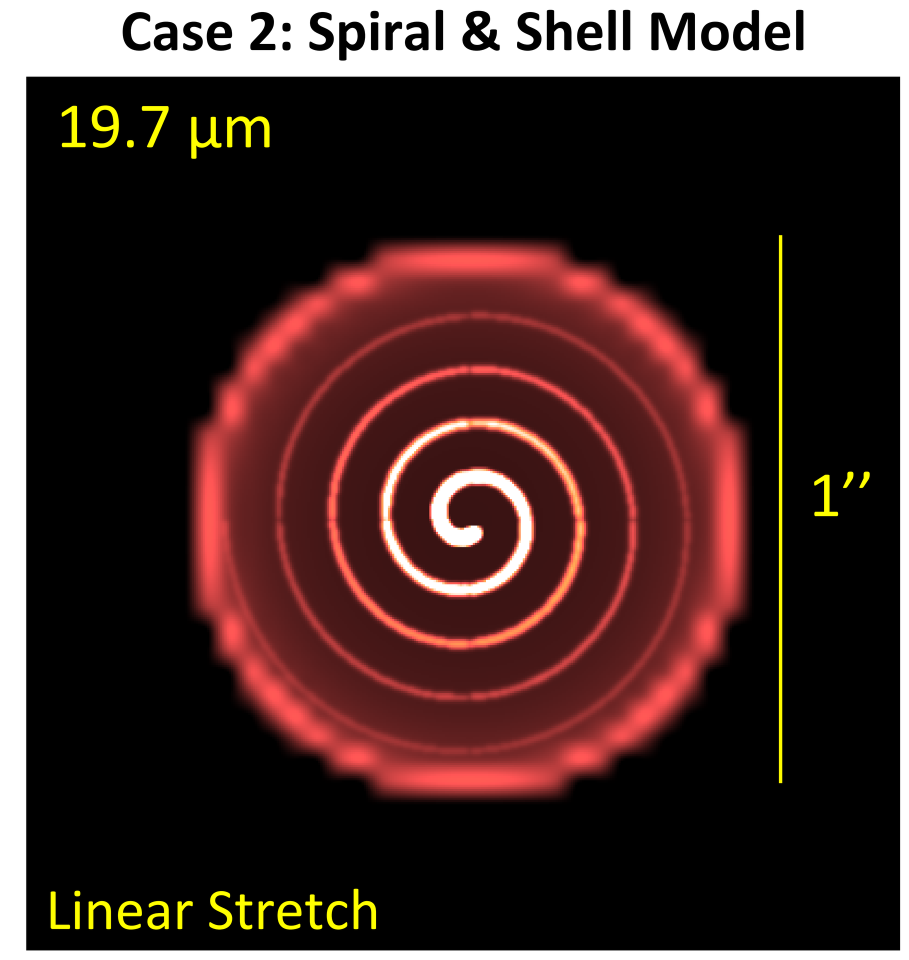
Case 1: Spiral Model



- Spiral morphology can reproduce near to far-IR flux from Q3
- Model assumes an inner dust temperature of 840 K and a total dust mass of 3.4×10^{-5} $M_\odot$

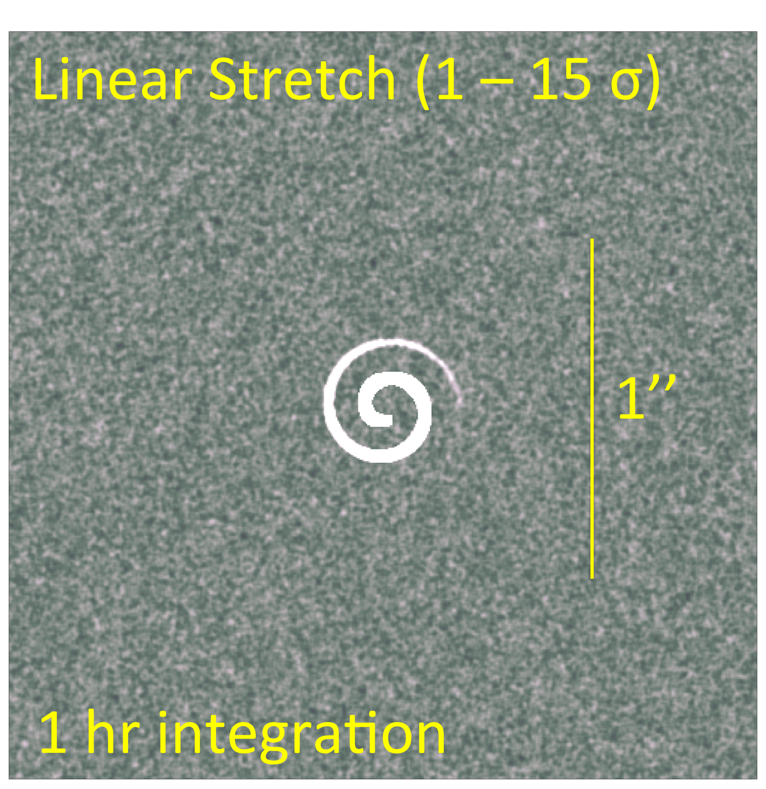


Case 2: Spiral & Shell Model

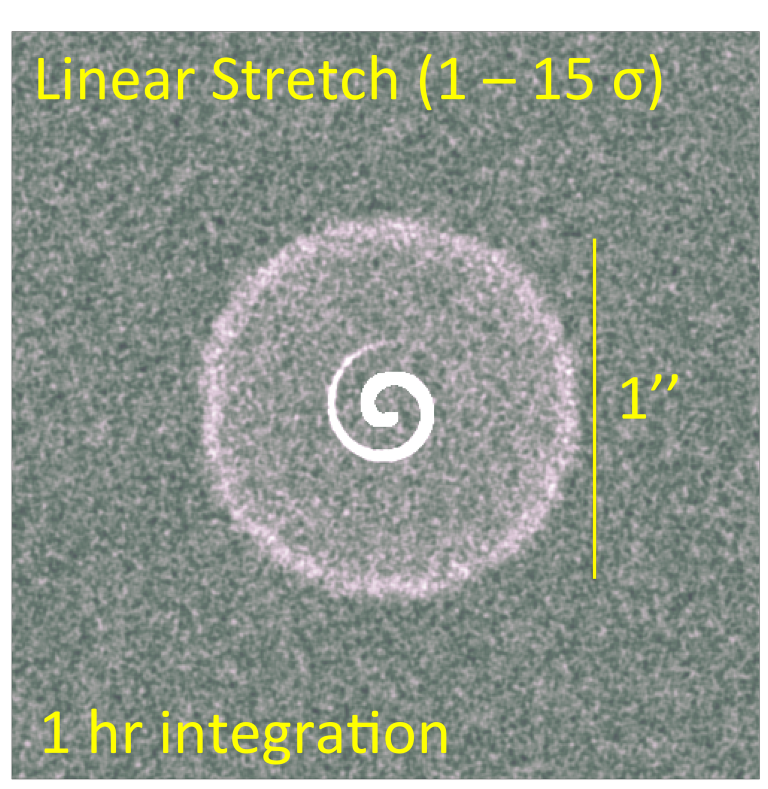


- Flux can also be reproduced by a 2-component model: a hotter spiral and detached outer shell
- Model assumes an inner dust temperature of 940 K and a total dust mass of 6.1×10^{-5} $M_\odot$ (4.5×10^{-5} $M_\odot$ in shell)

Simulated TMT/IRIS Imaging



Case 1



Case 2

Simulated K Band Image of Q3

- Based on sensitivity estimates of a 100-σ detection for a K = 27 mag (AB) source and 5 hrs of total integration time [8]
- Estimated 5-σ sensitivity per pixel (4 mas/pix) is 2 nJy for 1 hr total integration time
- Images convolved to 10 mas Gaussian PSF
- TMT observations will help constrain morphologies and determine the dominant form of mass loss from dusty WR binaries

Summary of Q3 Dust Model Properties

	T_D (K)	M_D ($M_\odot$)	n_0 (cm^{-3})	L_{IR} ($L_\odot$)	r_0 (AU)
Case 1 Spiral	<840	3.4×10^{-5}	1.1×10^7	1.3×10^5	260
Case 2 Spiral	<940	1.7×10^{-5}	1.0×10^7	7.8×10^4	190
Case 2 Shell	300	4.5×10^{-5}	1.0×10^4	1.2×10^4	3800

T_D is the dust temperature, M_D is the total dust mass, n_0 is the HII density at the inner radius, r_0, and L_{IR} is the integrated IR luminosity. Dust is assumed to be composed of amorphous carbon.

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