# FINAL MOMENTS: PRE-SUPERNOVA EMISSION AND FLASH SPECTROSCOPY AS SINGULAR PROBES OF LATE-STAGE RED SUPERGIANT EVOLUTION

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### WHAT DO MASSIVE STARS DO BEFORE THEY DIE?



Kochanek+ 2017

### WHAT DO MASSIVE STARS DO BEFORE THEY DIE?

Direct detection of type II progenitors indicates red supergiant quiescence



(Davies+ 2022)

### WHAT DO RED SUPERGIANTS DO IN THE YEAR(S) BEFORE THEY DIE?



Tight constraints on precursor acvitivty in very nearby events: SNe 2023ixf & 2024ggi



Shresha+ 2024

### WHAT DO RED SUPERGIANTS DO IN THE YEAR(S) BEFORE THEY DIE?

Ultra-rapid ("flash") spectroscopy of type II supernovae indicates enhanced red supergiant mass loss



Shresha+ 2024







HI



Conclusions

**EXAMPLE CASE:**  $\dot{M} = 10^{-2} \text{ M}_{\odot} \text{yr}^{-1}, r \approx 10^{15} \text{ cm}$ 







#### **Pre-SN Emission**

Flash Spectroscopy

#### Conclusions

# **RADIATIVE TRANSFER MODELS**



### **CMFGEN CSM Density Profiles**



#### **Mass-loss Continuum?**

Conclusions

# **RADIATIVE TRANSFER MODELS**

### Linking observables to progenitor mass-loss and CSM structure



Dessart & WJG 2023; WJG+ 2023, 2024a,b



### **A PHYSICAL PICTURE OF A RED SUPERGIANT BEFORE COLLAPSE**

- 1. Densest CSM: Extended SBO + rising ionization ( $r < 10^{14}$  cm)
- 2. Pretty Dense CSM: Rising ionization + IIn-like signature ( $r < 7 \times 10^{14}$  cm)
- **3.** Extended Wind: Sustained CSM-interaction + SN II profiles ( $r > 10^{15}$  cm)



# **FUTURE: PRE-SUPERNOVA EMISSION**

### ★ Physically motivated precursor models

 $\star$  Larger datasets from survey telescopes



WJG+ 2022a

Flash Spectroscopy

# **FUTURE: FLASH SPECTROSCOPY**

- ★ Higher resolution grids of radiative transfer models with CMFGEN
- ★ Volume-limited samples of CSM-interacting SNe II
- ★ Very nearby (<7 Mpc) SNe e.g., 2023ixf, 2024ggi
- ★ "Flash" UV spectroscopy (*HST*, *UVEX*)





Dessert & WJG 2023

**Pre-SN Emission** 

Flash Spectroscopy

Conclusions

# **QUESTIONS?**

















#### Motivation

#### **Pre-SN Emission**

#### **Future Work**

Conclusions







 $t_{\rm IIn} = 5.5 \pm 1 \text{ days}$  $\dot{M} \approx 10^{-3} - 10^{-2} \text{ M}_{\odot} \text{yr}^{-1}$ 

