Are Wolf-Rayet stars progenitors of type Ib/c supernova?

Joanne Bibby & Paul Crowther

University of Sheffield, UK

Core-collapse supernovae

Massive stars end their lives as core-collapse supernova

What is a Type Ib/c supernova?

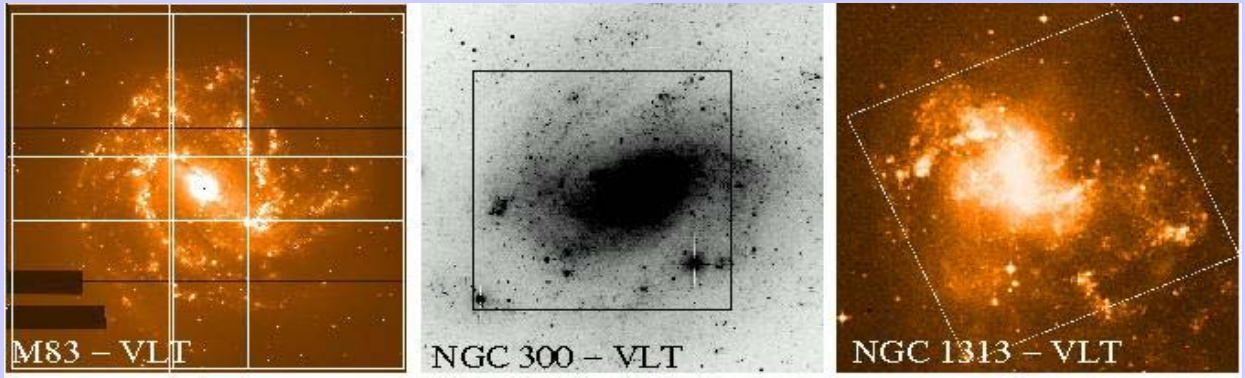
- Type Ib → no hydrogen, no silicon
- Type Ic → no hydrogen, silicon or helium

What are the possible progenitors?

- Single O-type star (M_{int}>25$M_\odot$) → 8+$M_\odot$ He core (Wolf-Rayet star)

- Close binary B-type stars (M_{int} = 12 + 9$M_\odot$) → 2$M_\odot$ He core + 18 $M_\odot$ B-type companion (conservative mass transfer)

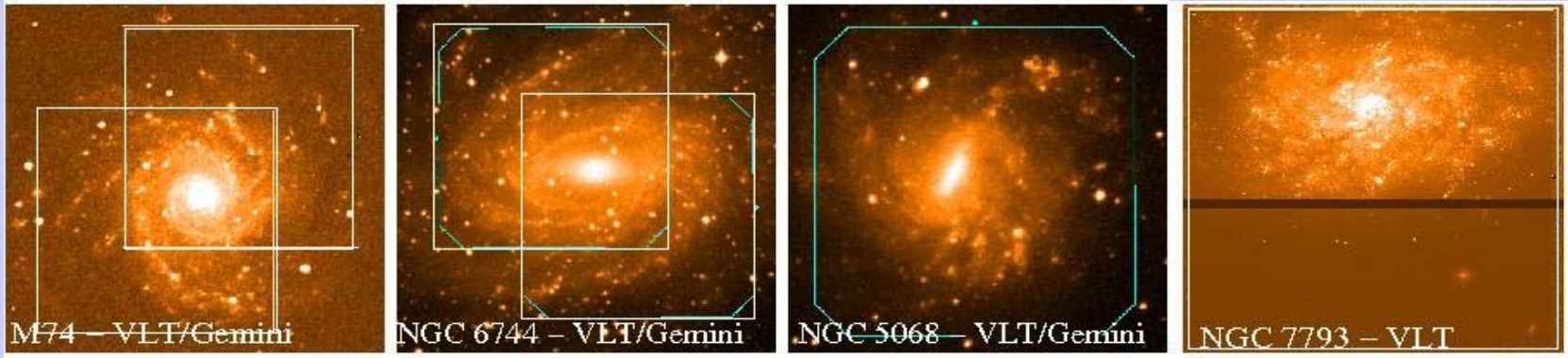
Galaxy Survey

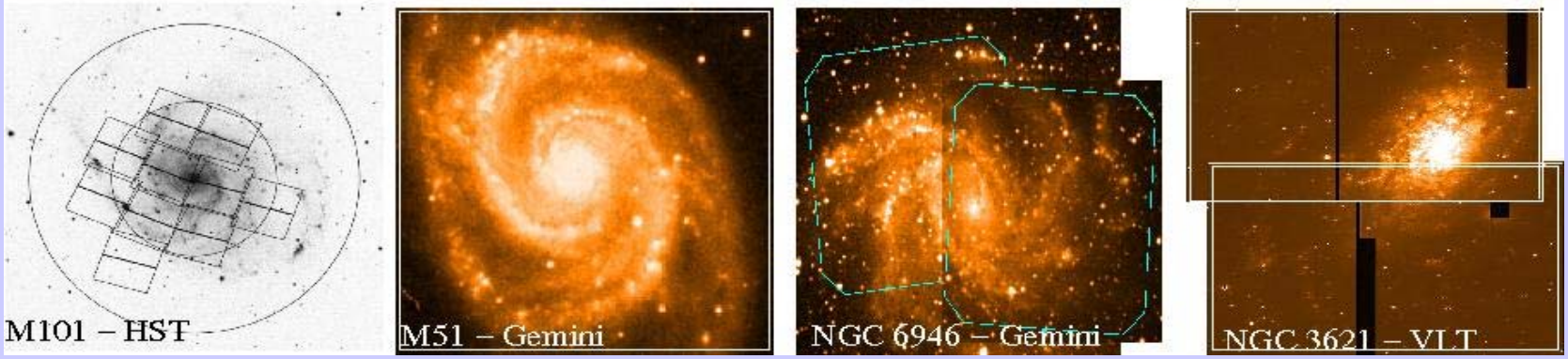


D = 2-10 Mpc

SFR = 3-7 $M_{\odot} yr^{-1}$

Metallicity from LMC to super-solar

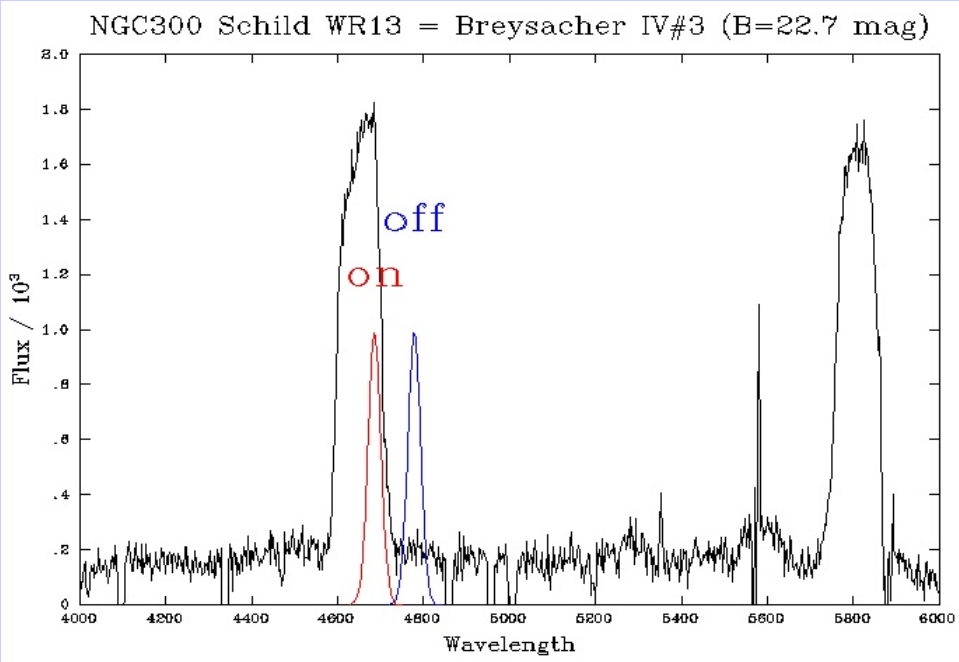




How do we find WR stars?

If Wolf-Rayet stars are progenitors of type Ib/c SNe, how do we identify them before core-collapse?

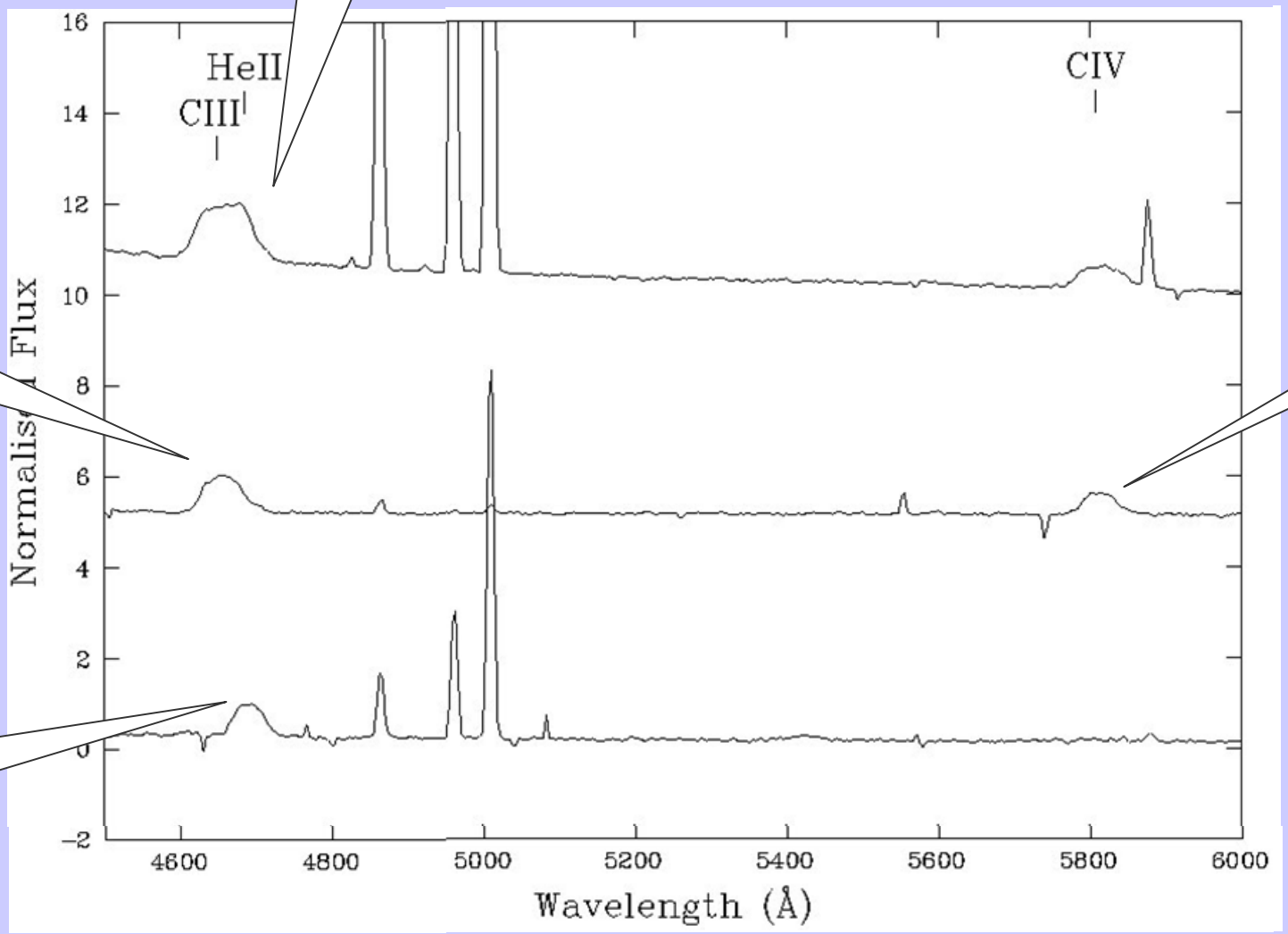
WR stars have very strong, broad emission which we can identify from narrow band imaging



Schild et al. (2003)

Spectral properties of WR stars

NGC 7793 with VLT/FORS



Narrow Band Imaging

NGC 7793

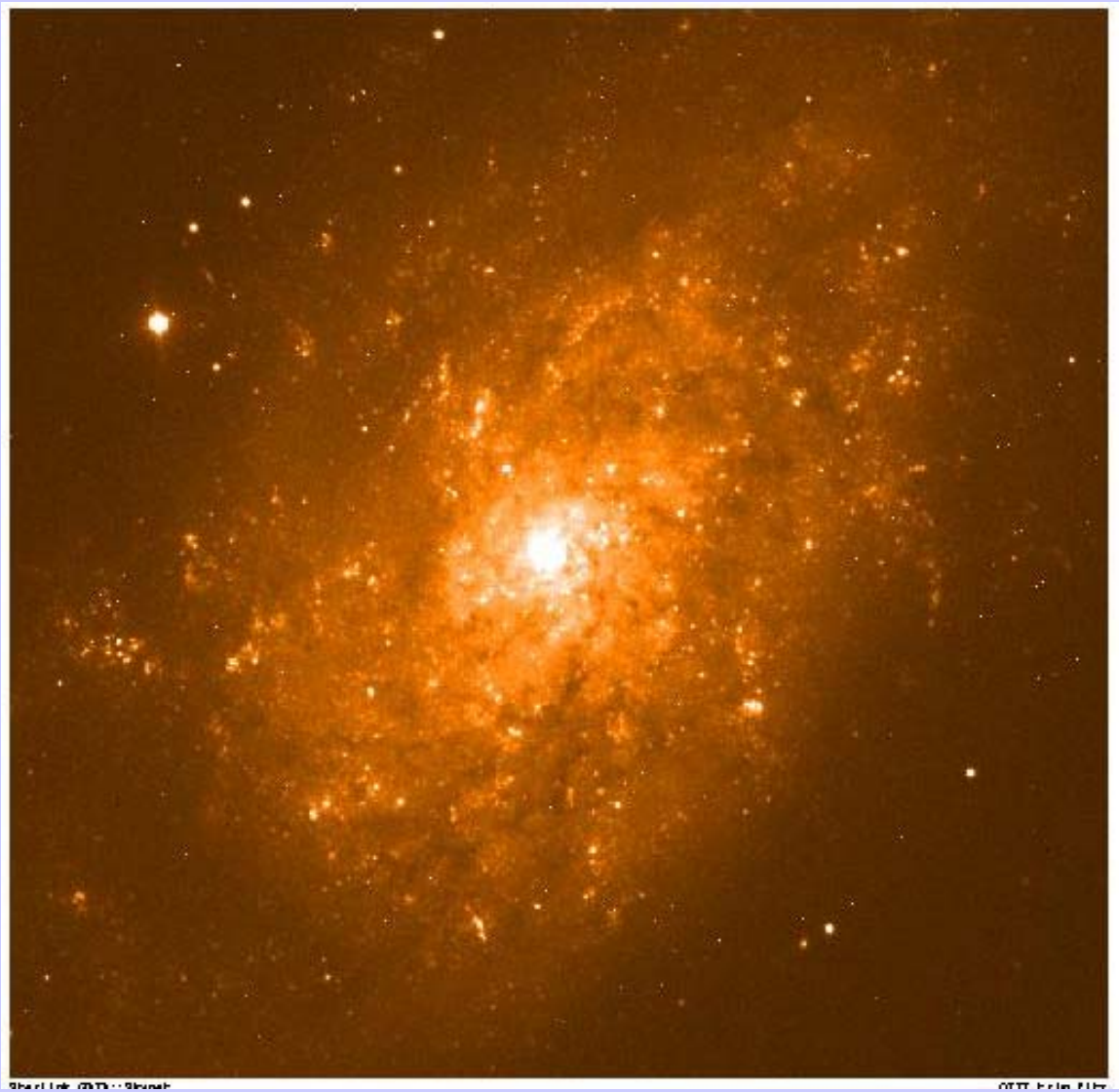
VLT/FORS

OIII continuum

λc = 5100Å

Archival Data

(PI: Royer)



D = 3.9Mpc
(Karachentsev et al. 2003)
6.5' x 6.5'
7.8 x 7.8 kpc

Narrow Band Imaging

NGC 7793

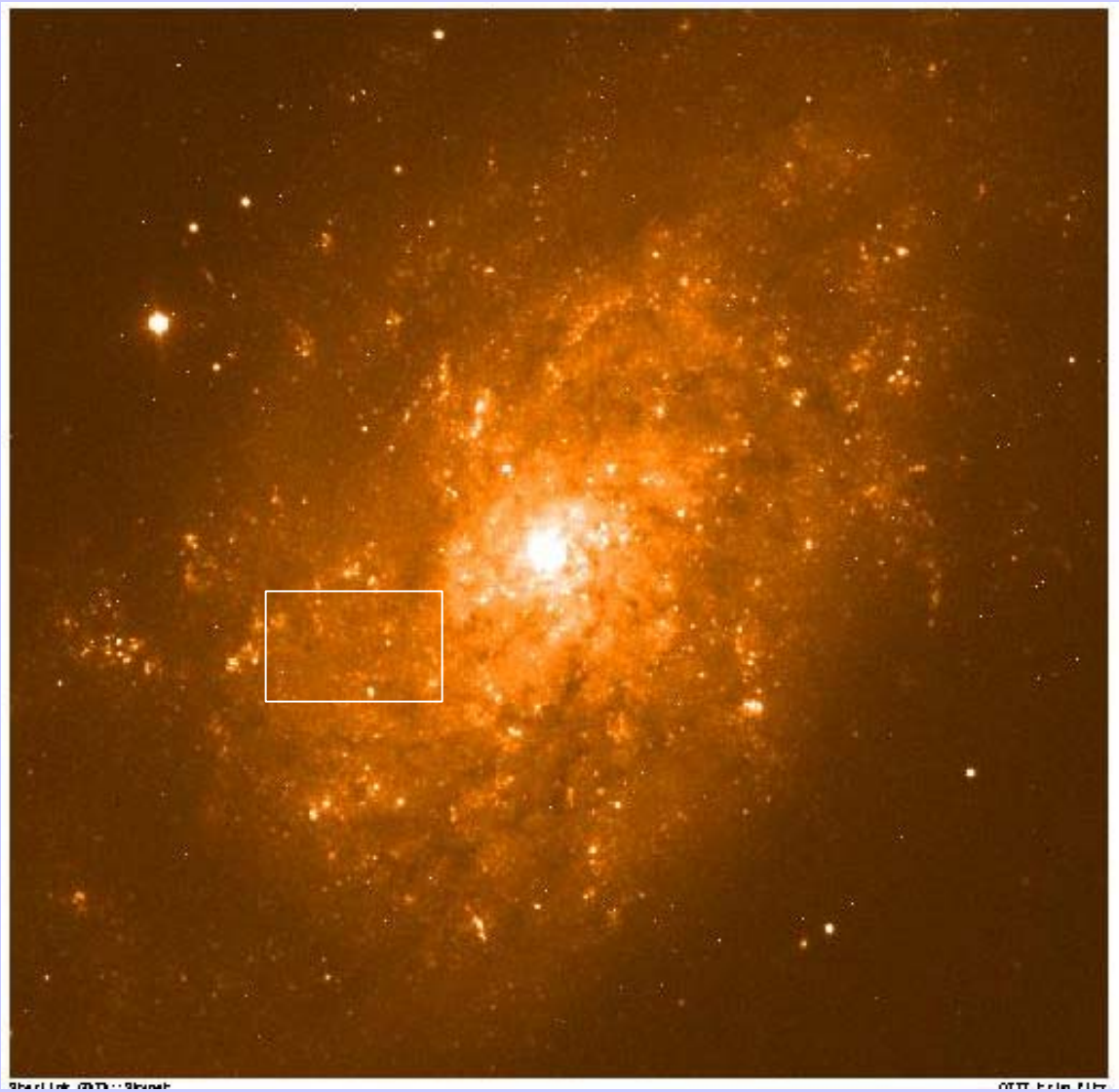
VLT/FORS

OIII continuum

λc = 5100Å

Archival Data

(PI: Royer)



D = 3.9Mpc
(Karachentsev et al. 2003)
6.5' x 6.5'
7.8 x 7.8 kpc

Narrow-Band Imaging

NGC 7793

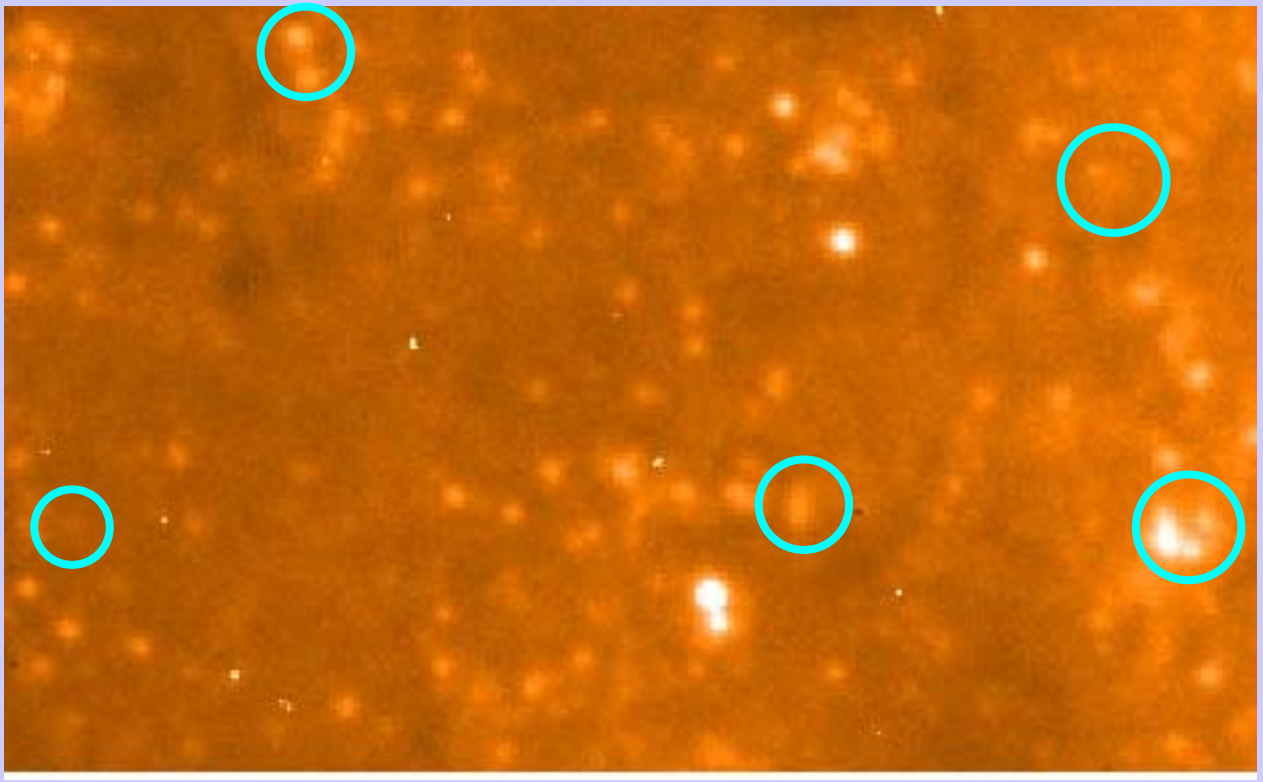
VLT/FORS

OIII continuum

λc = 5100Å

Archival Data

(PI: Royer)



1.5 x 0.5 kpc

Narrow-Band Imaging

NGC 7793

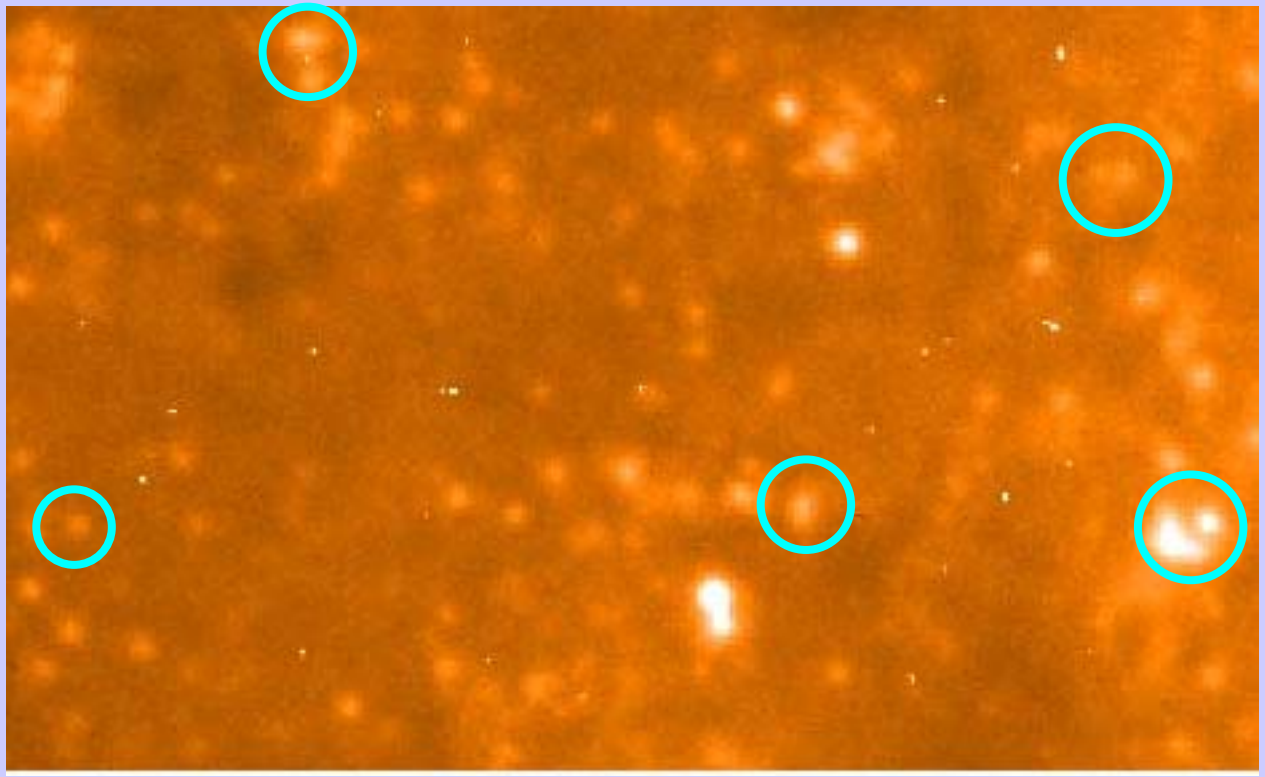
VLT/FORS

HeII

λc = 4686Å

Archival Data

(PI: Royer)



1.5 x 0.5 kpc

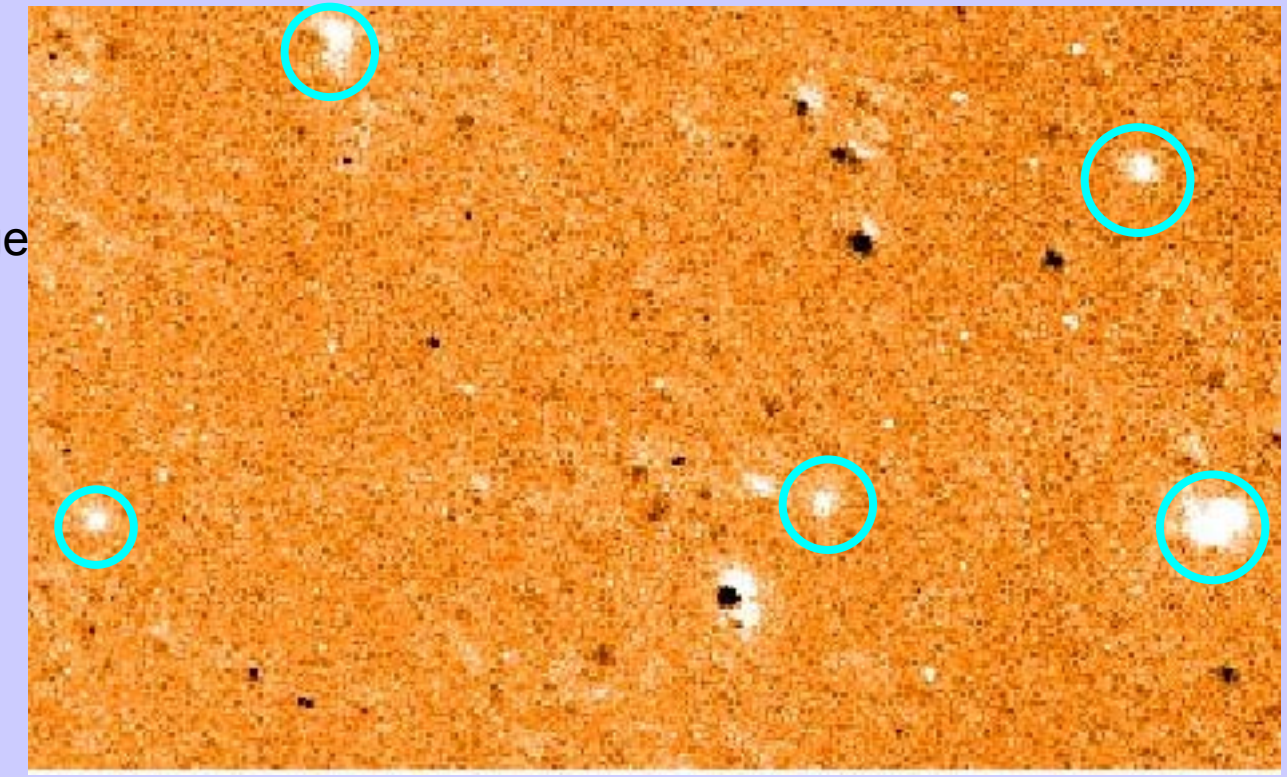
Narrow-Band Imaging

NGC 7793

VLT/FORS

HeII – OIII cont.

Continuum subtracted image



1.5 x 0.5 kpc

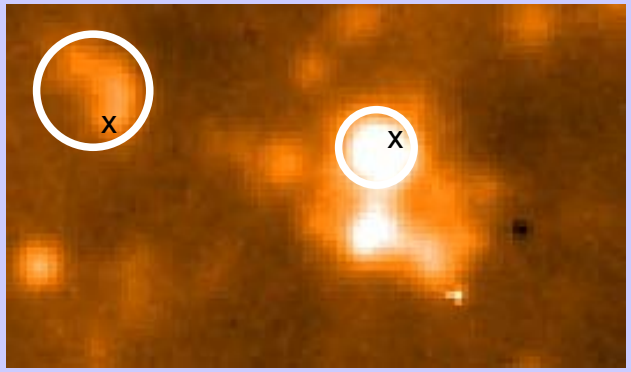
Spatial Resolution

Spatial resolution of 8m telescopes (Gemini & VLT) is more problematic → use supplemental HST archival data

For NGC 7793:

Ground-based under 0.8" seeing resolves ~25pc

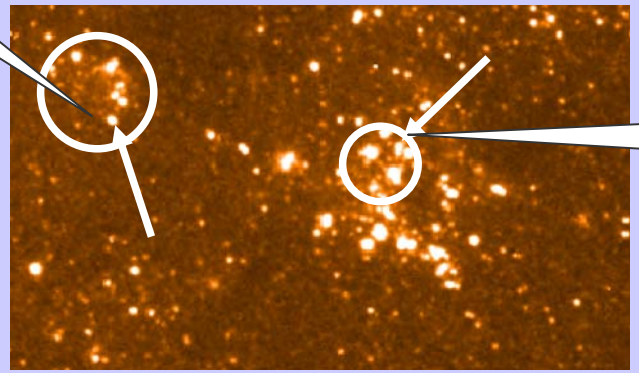
HST resolves ~2pc



VLT/FORS - HeII

WC + WN

Mv = -7.3



ACS/WFC - F435W

WNE x 2

Mv = -8.3

N

E

460 x 160 pc

23" x 10 "

Follow-up Spectroscopy

- To determine the subtype of the Wolf-Rayet star(s)
  - WN – Nitrogen rich → Type Ib SNe
  - WC – Carbon rich → Type Ic SNe
  - WO – Oxygen rich

- Multi-object spectroscopy can observe 19-35 objects per mask

- Use line flux of the HeII(4686) or CIV(5808) emission to estimate the number of WN and WC stars respectively

- Line flux is a function of metallicity (weaker at low Z)!

Preliminary results

NGC 7793:

- ~80 candidates were identified from the HeII continuum subtracted image
- We obtained spectra of 40 of these
  - 31 (78%) had WR features present
  - 75% of WR stars are in HII regions
  - One of our emission sources was a Quasar at z~2

Core-collapse supernova rates

$$SFR(M_{\odot}yr^{-1}) = 49\,\upsilon_{ccSN}(yr^{-1})$$

(Conti, Crowther & Leitherer, 2008)

- For our 11 galaxies $\sum_{SFR}$ ~$50M_{\odot}yr^{-1}$ → assume 50% detection rate → 30% of ccSN are type Ib/c (Smartt et al. 2009) → upper limit of $\upsilon_{SN(Ib/c)}$ ~ 1 every 7 years.

- From observations, 26 SNe have been detected in our 11 galaxies over the past 100 years (Thöne et al. 2009) → 20% of all SNe are type Ib/c → lower limit for $\upsilon_{SN(Ib/c)}$ ~ 1 every 20 years

Within the next 7-20 years, we expect to detect at least one type Ib/c supernova, resulting in the unambiguous identification of the progenitor.

Summary

- Narrow-band imaging can identify Wolf-Rayet stars
- Spectroscopy can determine the subtype of WR stars
- Galaxies surveyed so far have been successful
- We aim to survey 11 galaxies
- Taking into account rates of type Ib/c SNe we expect to identify a progenitor within the next 20 years