Star Formation through Time
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Modeling high-metallicity extragalactic HII regions: a test for hot-star models

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- Introduction: IMF in metal rich RHIIs
- UV light: Constraints on IMF.
- Nebular lines.
- WR features in metal rich RHIIs.
- Implications for hot-star models.

IMF in metal rich HII regions

❖ *Which stars form in starbursts?* The amount of mass transformed into stars and the mass range of the newly formed stars determine the period of time over which a galaxy can support a starburst phase, and therefore the effect of starbursts on the evolution of galaxies. Thus, it is crucial to know if starbursts have an extreme IMF.

- Rieke et al (1980): A top heavy IMF (with a deficit of stars below 3-8 Msol). To explain M/L ratio estimated from K-band photometry and a dynamical mass measurement.
- The analysis of the nebular optical (Bresolin et al 1999) and NIR lines (Goldader et al 1997; Coziol el at 2001) of high metallicity RHIIs: **Stars more massive than 30 Msol don't form.**
- UV continuum: suggests the formation of massive stars (Leitherer 1996)
- Detection of WR-star features (Schaerer et al 2000; Bresolin & Kennicutt 2002; Pindao et al 2002): suggests the formation of massive stars.

IMF in metal rich HII regions

González Delgado, Leitherer, Stasinska & Heckman (2002) (astro-ph/0209067):

- High-spatial resolution UV and Optical spectroscopy (HST+STIS) of the metal rich nuclear starburst in NGC 3049.
- UV resonance wind lines and the optical nebular lines: constrain the IMF

Pindao, Schaerer, González Delgado & Stasinska (2002) (astro-ph/0208226):

- FORS1/VLT optical spectra of 85 disk HII regions in nearby spiral galaxies.
- Detection of WR-star features: constrain the IMF

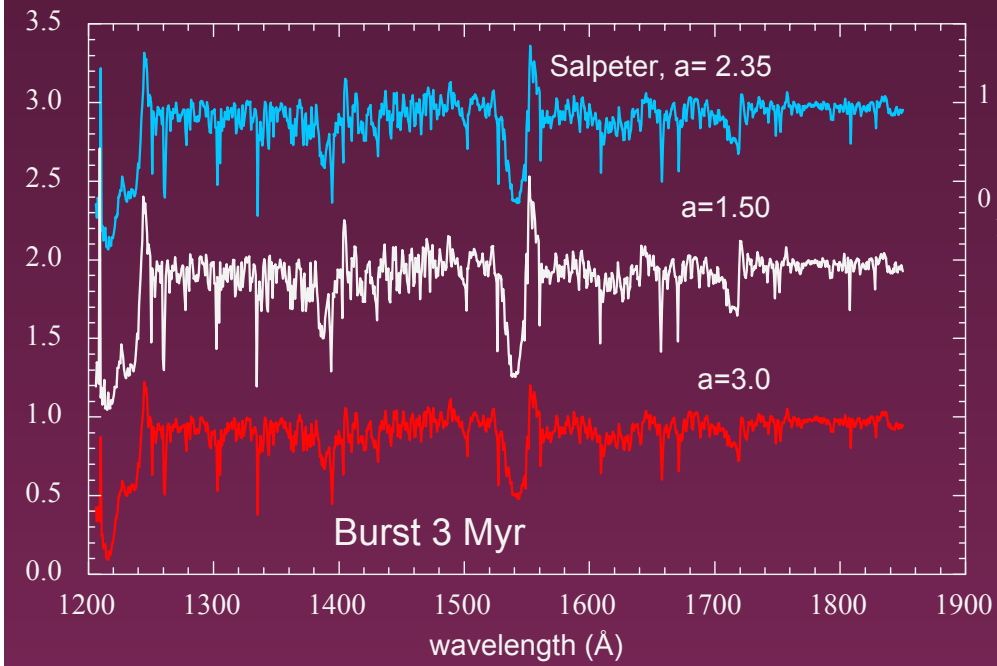
Goals:

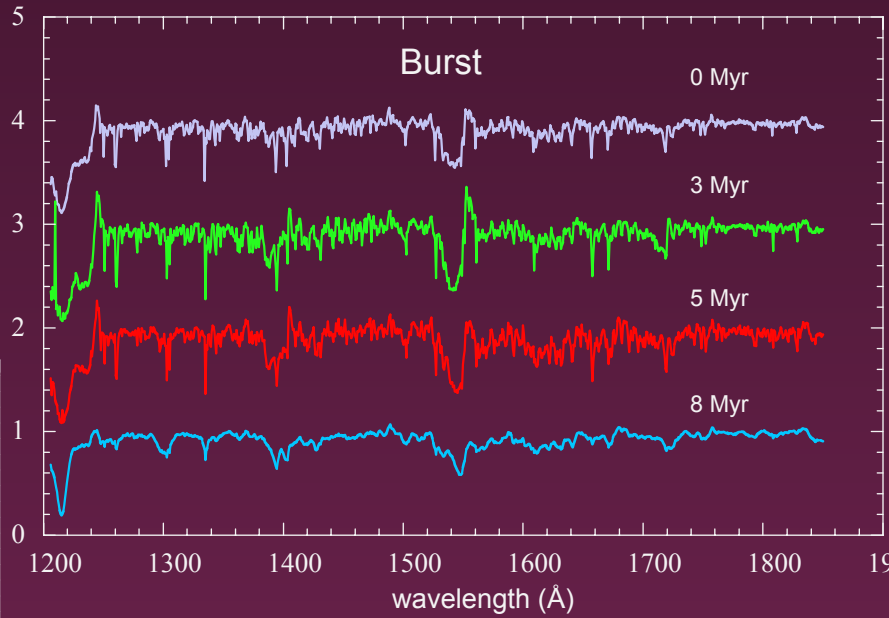
- To seek evidence for or against the depletion of massive stars in metal-rich HII regions.
- To perform a consistency test of the lastest generation of hot-stars models at high metallicity.

UV light-IMF

UV wind lines (Robert et al 1993):

- **IMF (slope and Mup)**
- **Age**





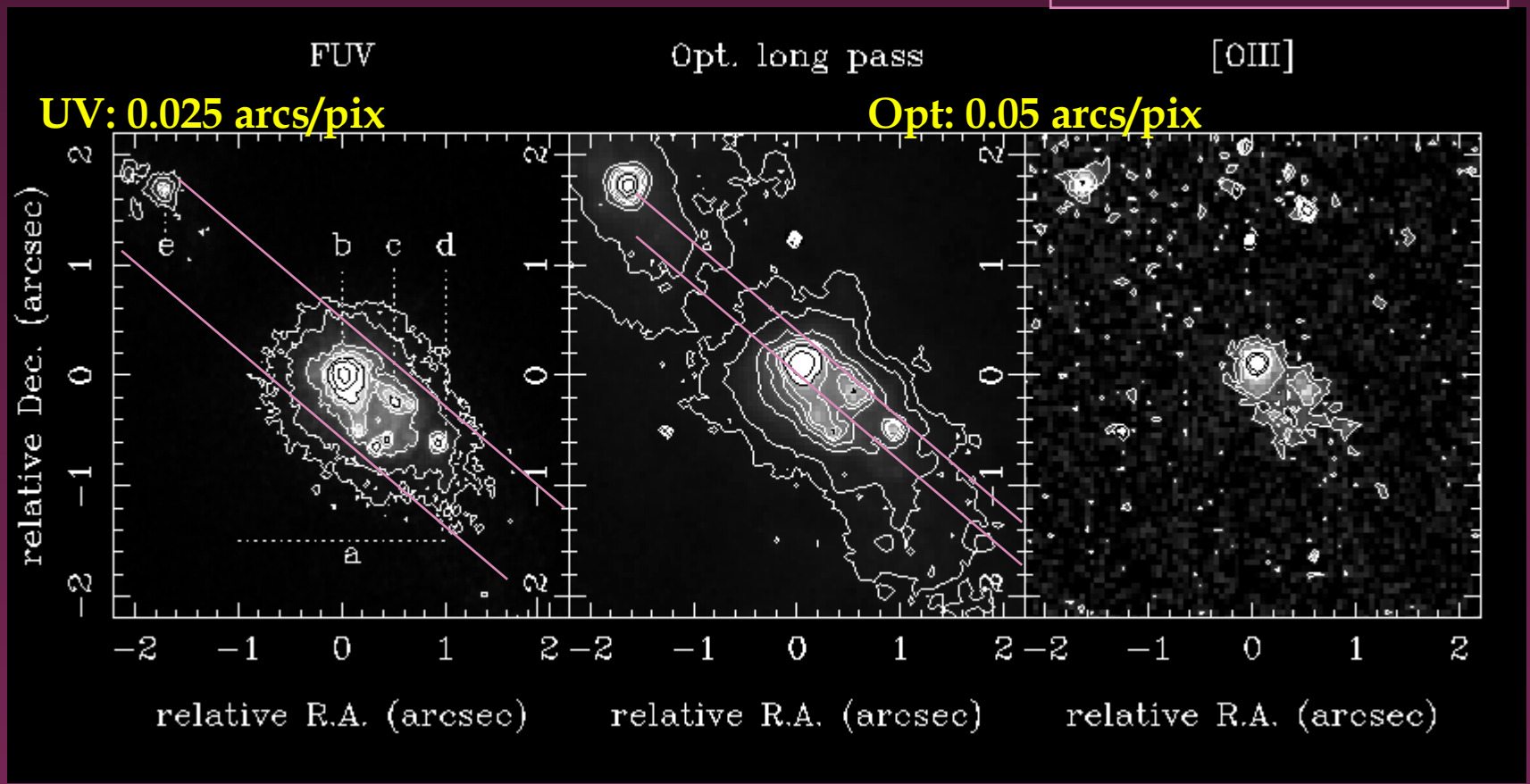
Nuclear Starburst:

- Virgo cluster
- Metal-rich: 12+log(O/H)=9.0

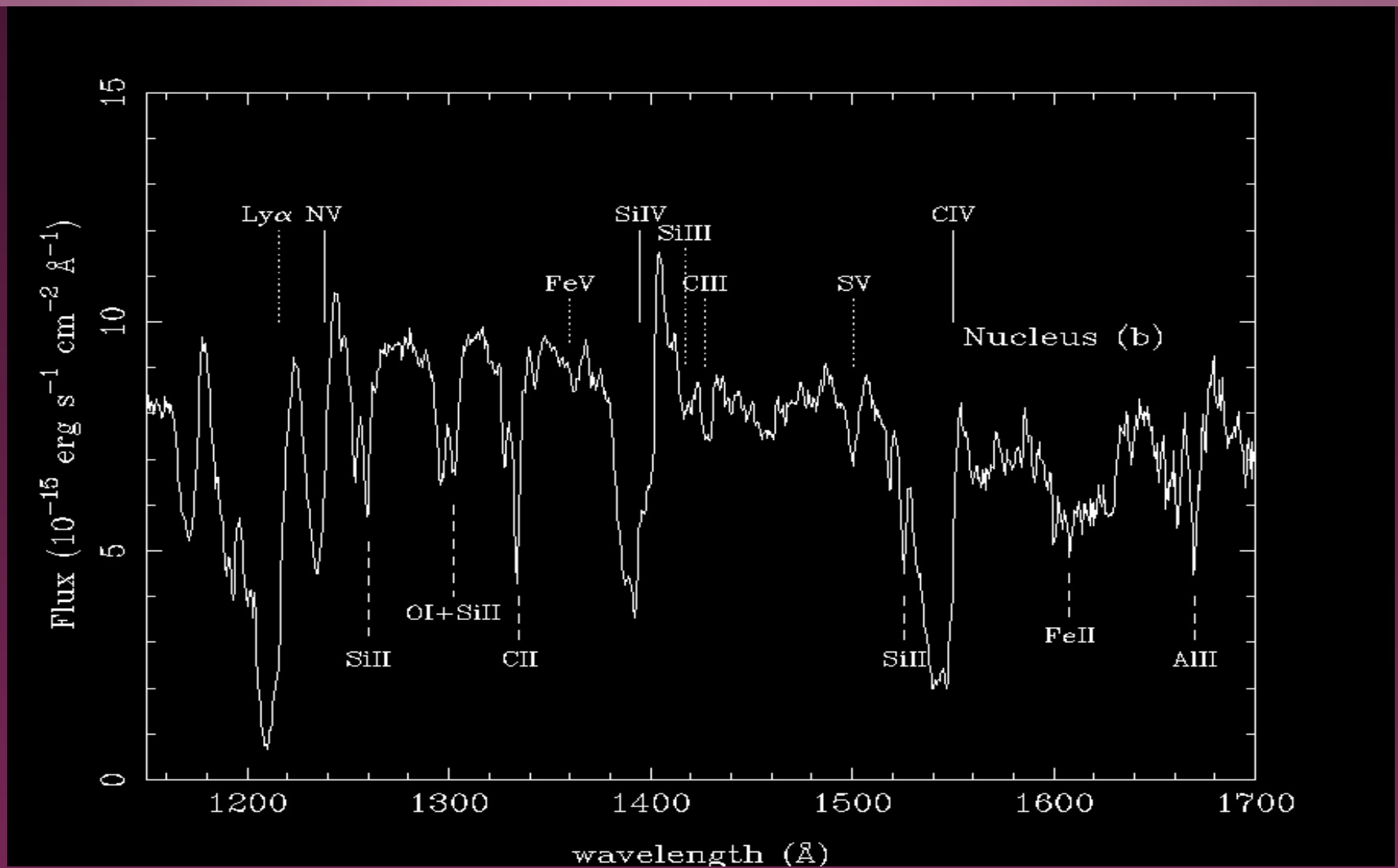
NGC 3049

HST+STIS

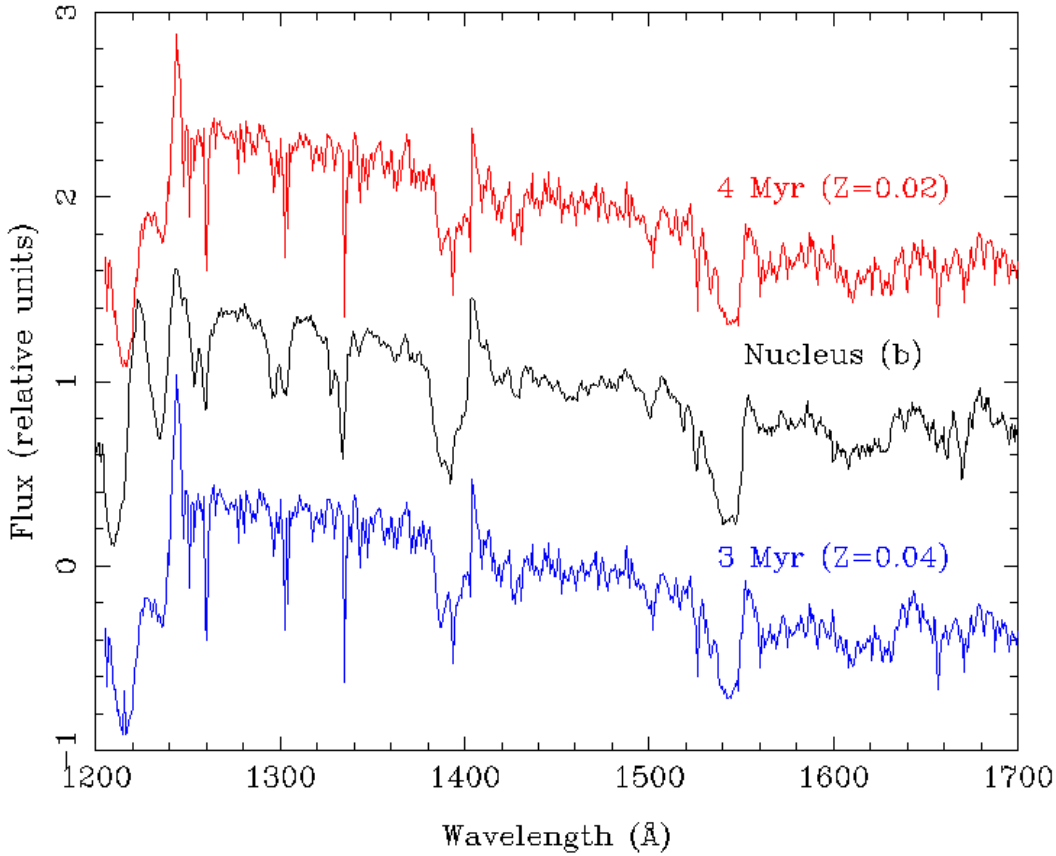
- 1 arcsec= 78 pc
- Slit P.A= -138º



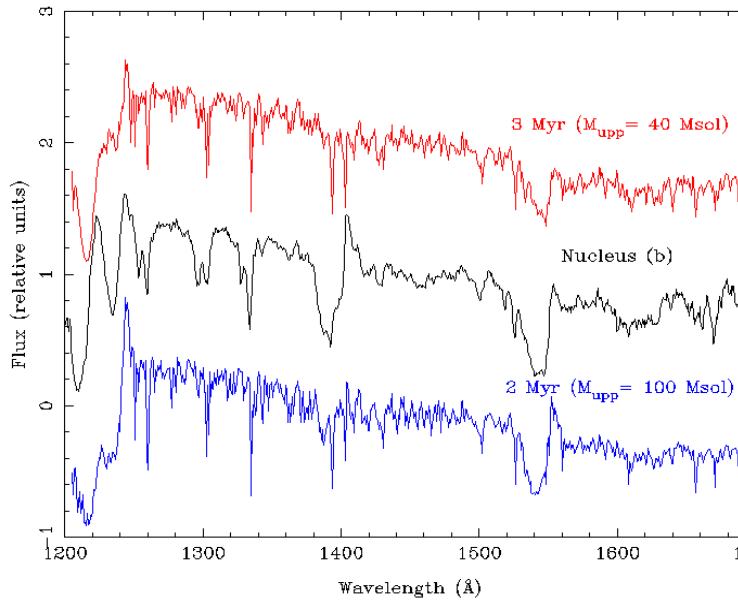
NGC 3049: nuclear spectrum (0.5x0.5 arcsec)



NGC 3049: UV light

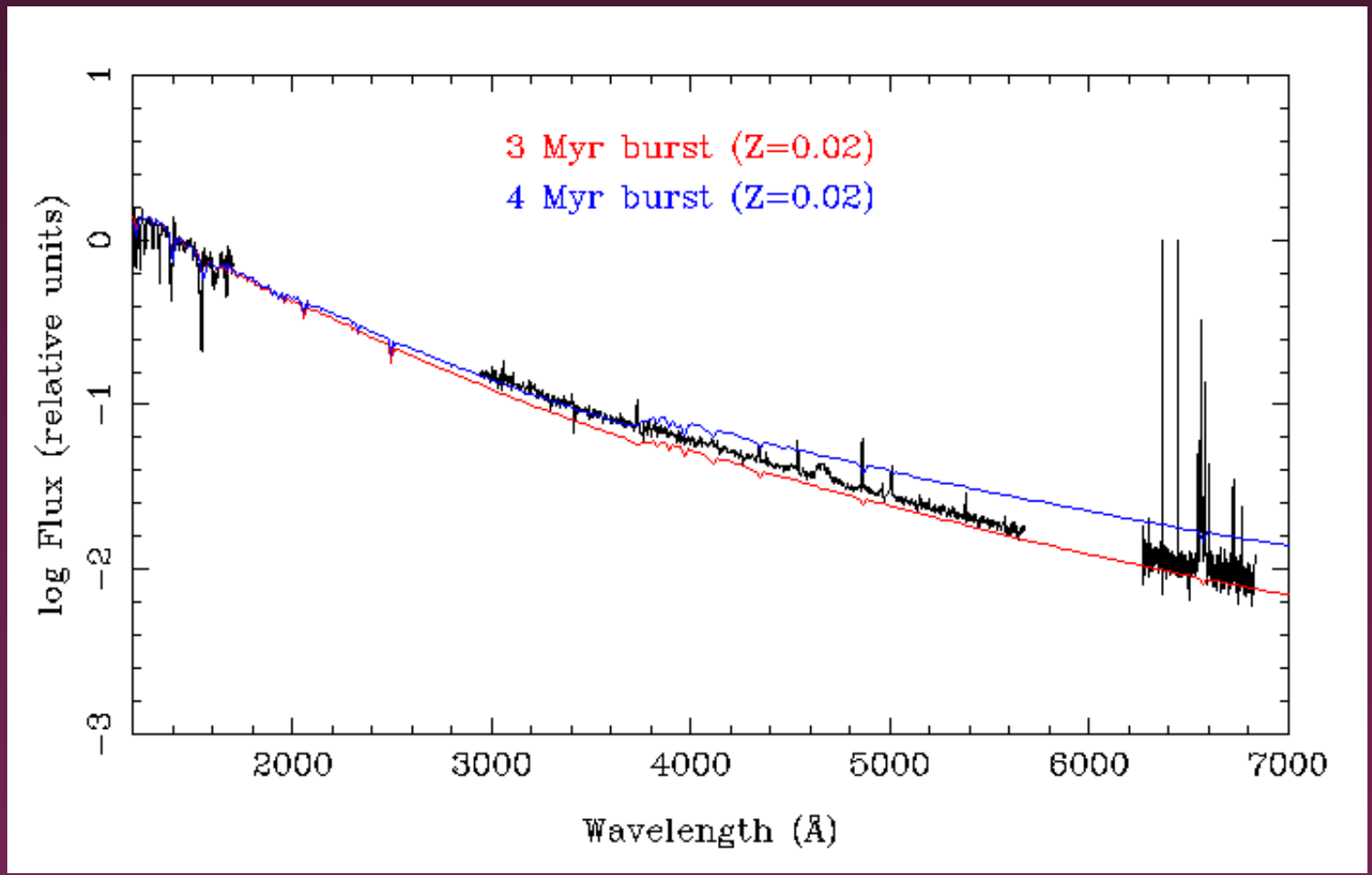


- 3-4 Myr IB
- Z=0.02 or 0.04
- Salpeter IMF (Mup>60 Msol)
- Mass= 10^6 Msol



- IMF Salpeter
- 3-4 Myr IB
- E(B-V)=0.2

NGC 3049: UV-Optical light



The nebular lines

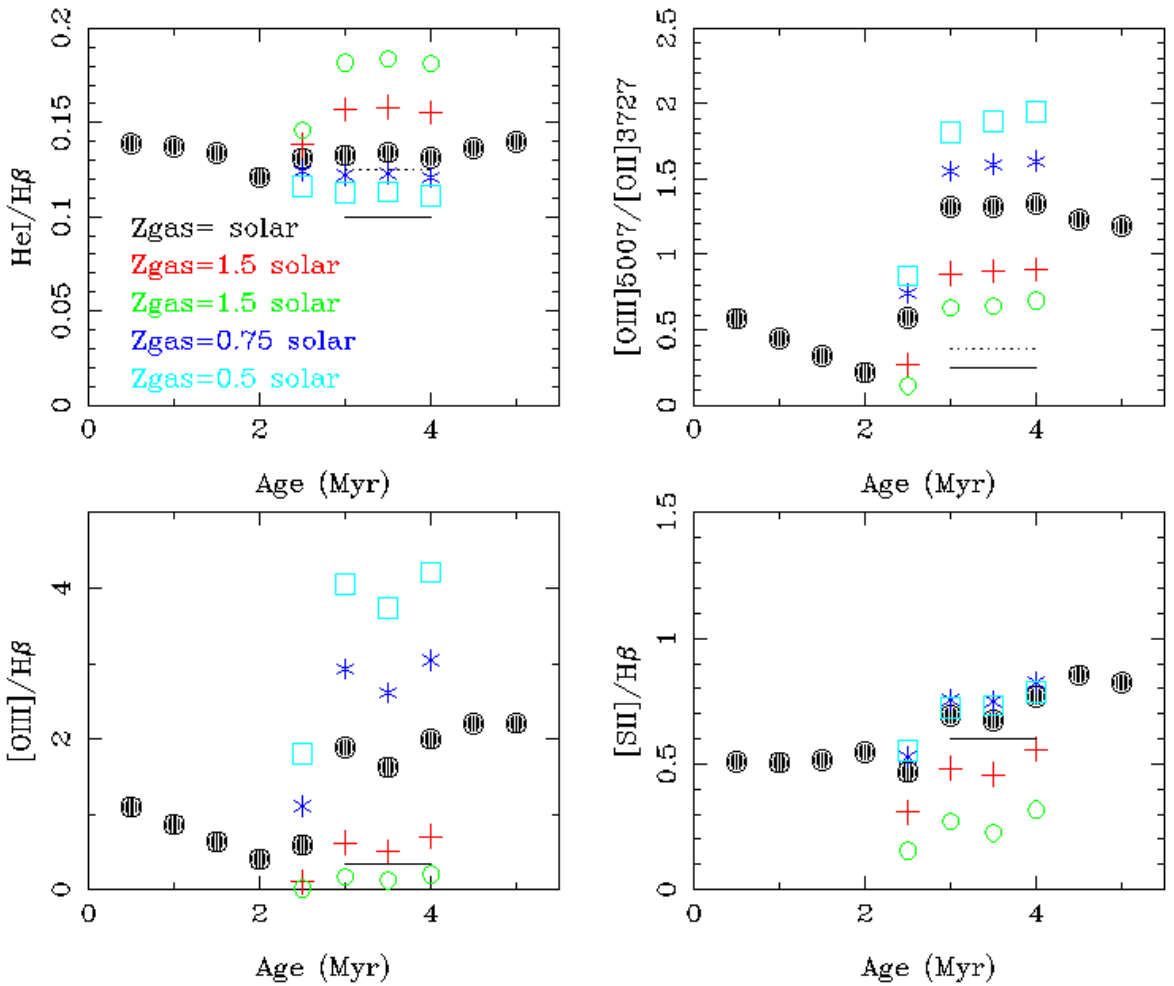
- The modelling of HII regions is a degenerate problem:
  - Radiation field from the ionizing stellar cluster.
  - Chemical abundance of the ionized gas.
  - Electron density structure and geometry of the region.
- It is possible to constrain the stellar content, age and IMF of the cluster using
    - photoionization + evolutionary synthesis codes
- Observables:
  - Collisionally excited: [OIII]/Hβ , [OI]/Hβ , η=([OIII]/[OII])/([SIII]/[SII]) , IR fine structure lines ([NeIII]/[NeII] , [ArIII]/[ArII] , [SIV]/[SIII])
  - Recombination lines: HeI 5876/Hβ depend on Q(He)/Q(H)
  - Ew(Hβ) depends on Q(H)

Modelling the nebular lines: NGC 3049

Starburst99+CLOUDY:

- IMF Salpeter
- Mup=100 Msol
- 0-5 Myr IB
- Z=0.02 (stars)
- Atmospheres: Lejeune+Schmutz (unblanketed WR)

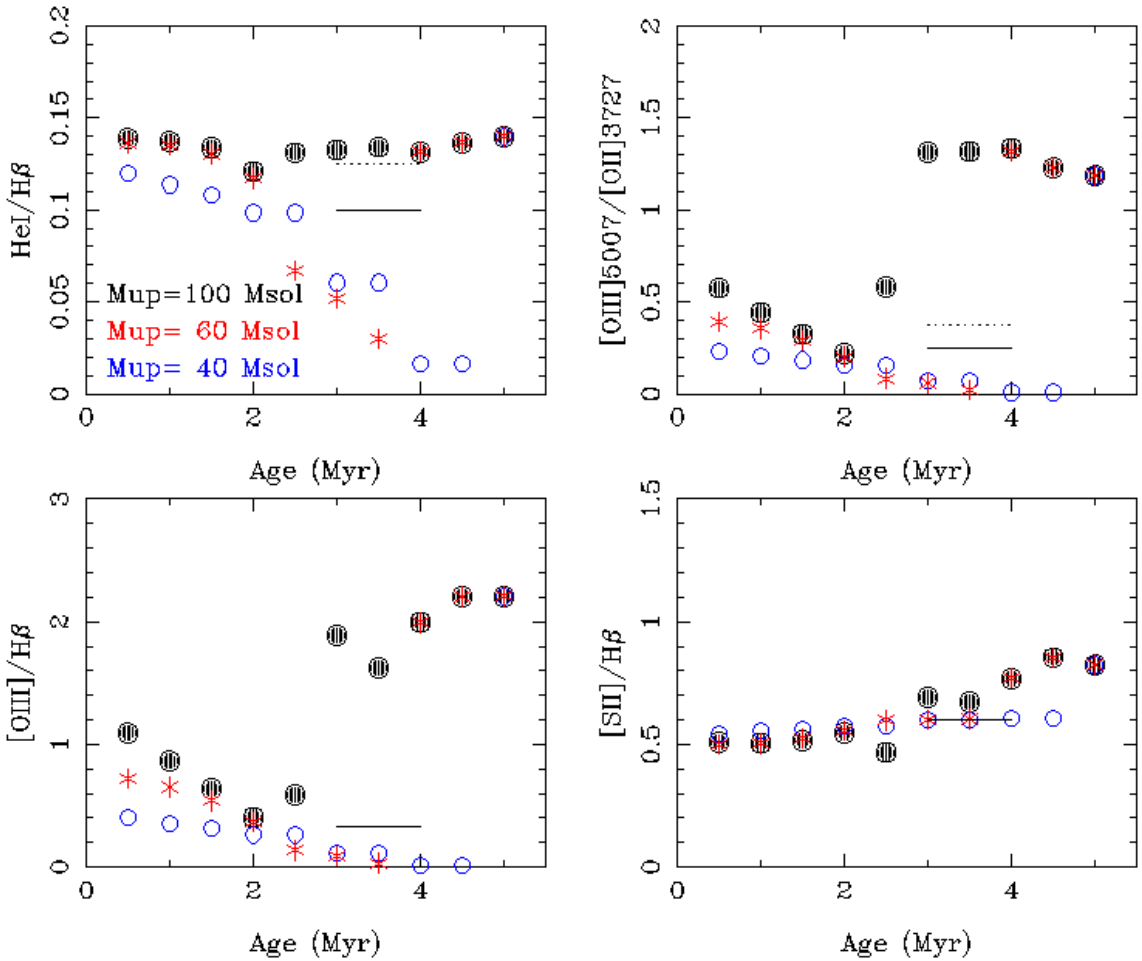
- Photoionization models are not able to explain the em.line ratios



Modelling the nebular lines: NGC 3049

- IMF Salpeter
- Zgas=solar
- 0-5 Myr IB
- Z=0.02 (stars)
- Atmospheres: Lejeune+Schmutz

- The em.line ratios suggest that massive stars are not formed in the starburst.

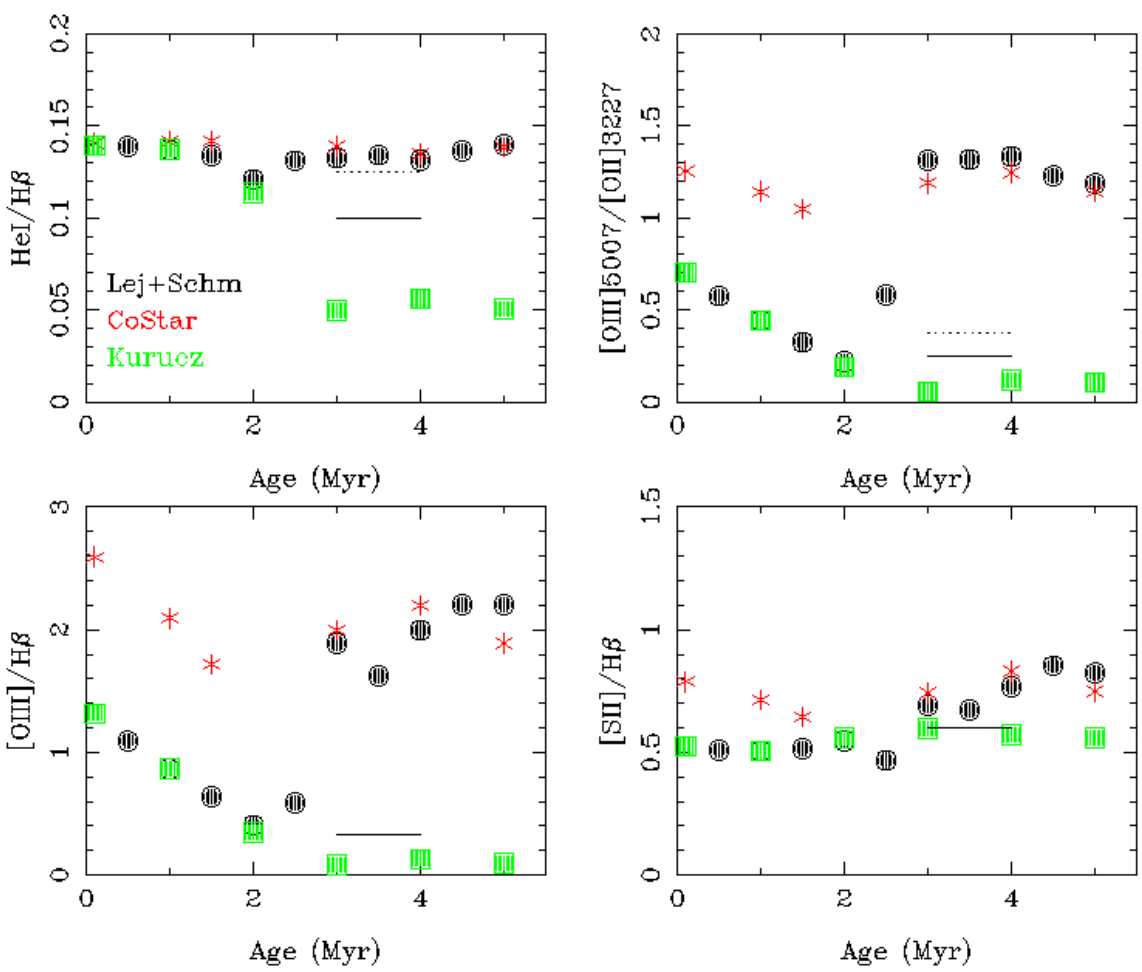


Modelling the nebular lines: NGC 3049

Atmospheres:

- **Lejeune+Schmutz**
- **CoStar (Schaerer)**
- **Kurucz**

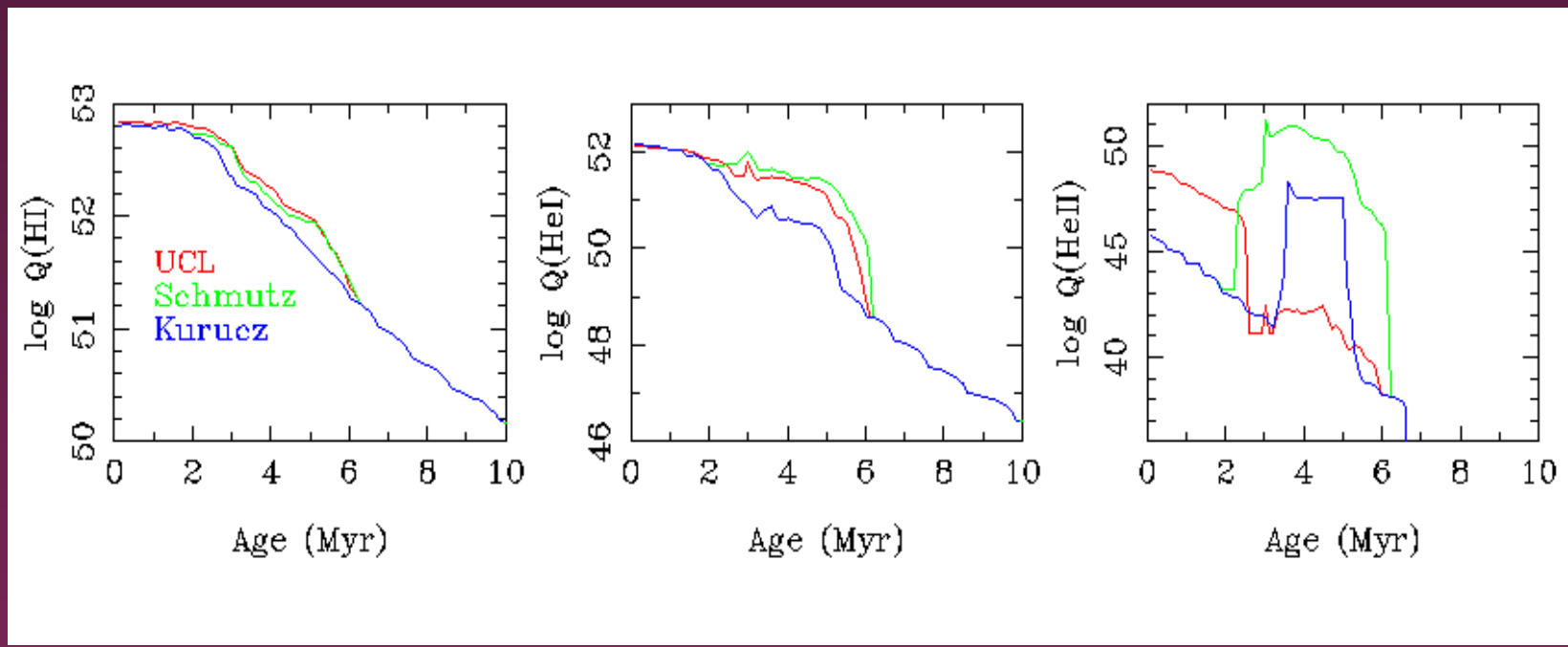
- **These stellar atmospheres models are not adequate to model high-metallicity HII regions with many massive stars.**



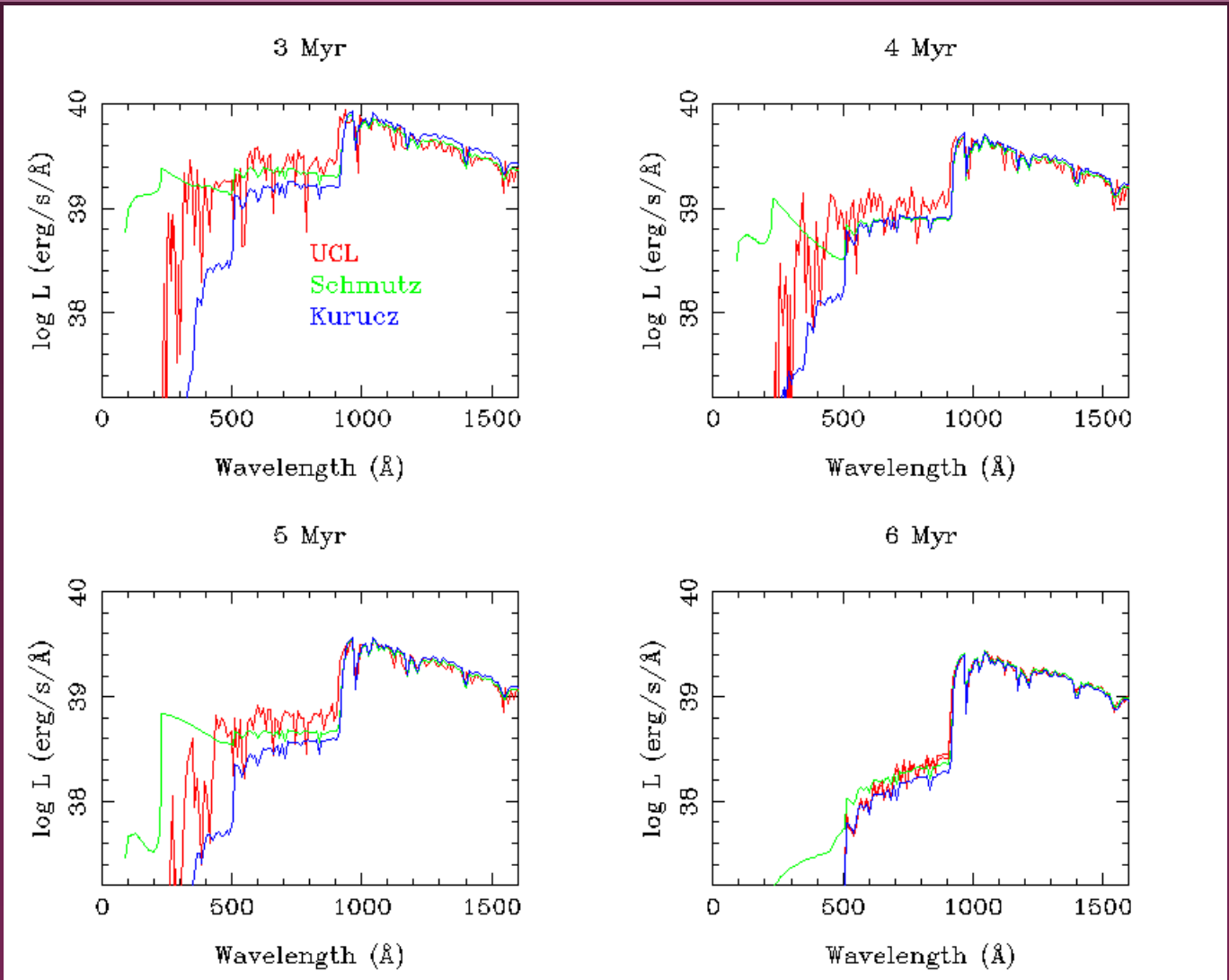
UCL stellar atmospheres

Smith, Norris & Crowther (2002):

- **O and WR atmospheres with line-blanketing (Pauldrach +Hillier)**
- **Implemented in SB99: the coupling between WR temperature of the evolutionary tracks and the new atmospheres**



UCL stellar atmospheres: Implemented in SB99
A softening of the far-UV radiation field



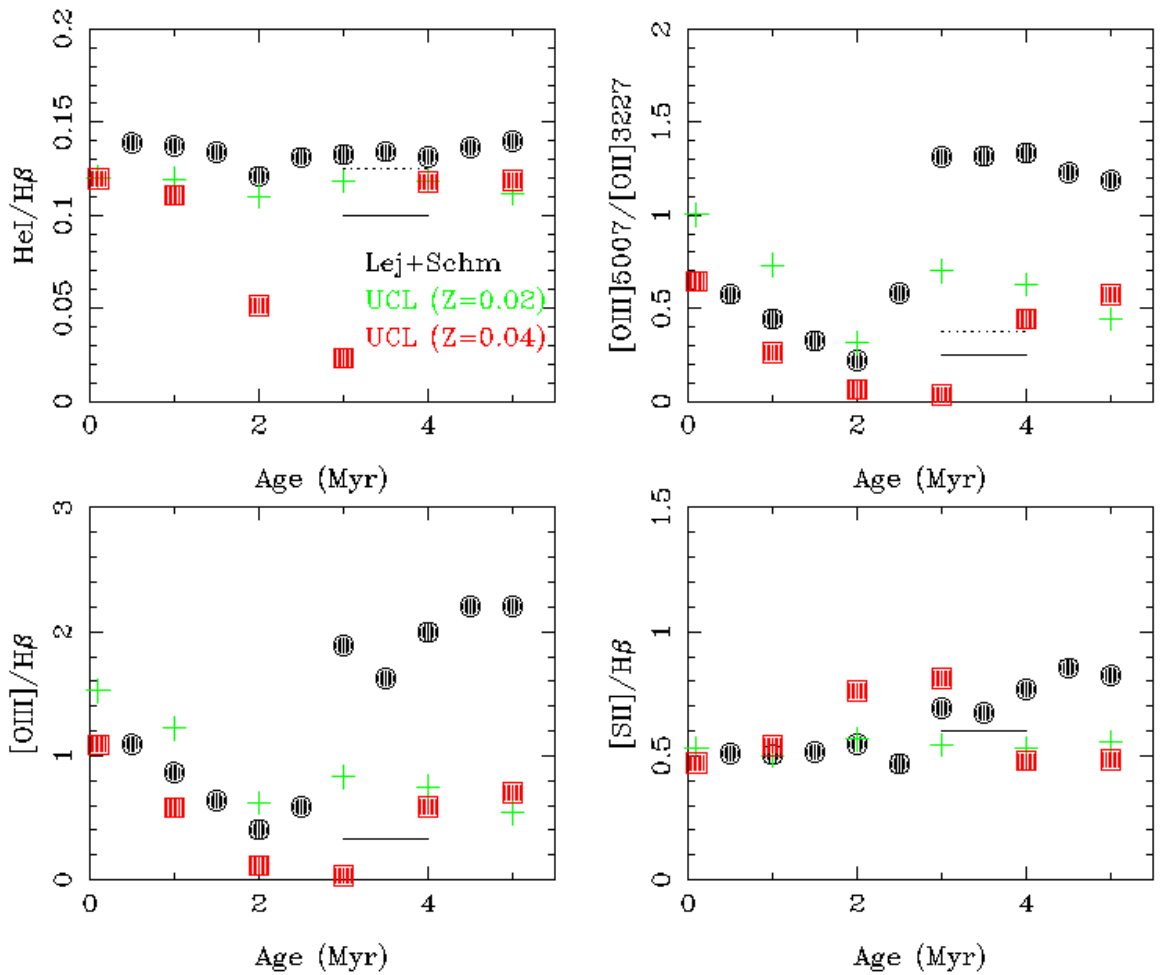
Modelling the nebular lines: NGC 3049:

The models are compatible with the formation of many massive stars (IMF Salpeter and Mup=100 Msol)

Atmospheres:

- **Lejeune+Schmutz**
- **UCL**

- **This comparison with NGC 3049 suports the view that the softening of the FUV radiation field at high metallicity is not only a consequence of the inclusion the line-blanketing effect but also of the coupling between the WR temperature of the evolutionary tracks and the atmospheres.**

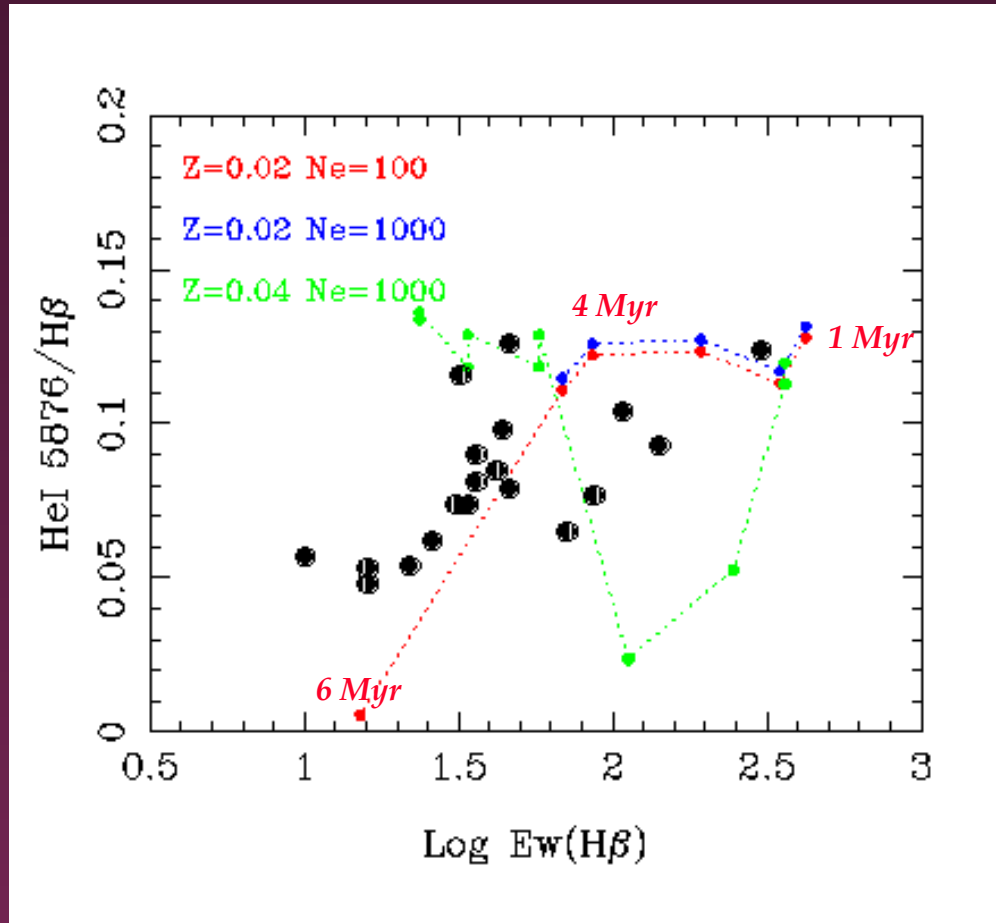


Modelling the HeI/Hβ and EW(Hβ):

Data: Bresolin & Kennicutt (2002)

- HII regions in M83, NGC 3351 and NGC 6384

- Regions with low HeI 5876/Hβ (<0.1) and high EW(Hβ) (>100 A): high-metallicity (Z> Zsol)

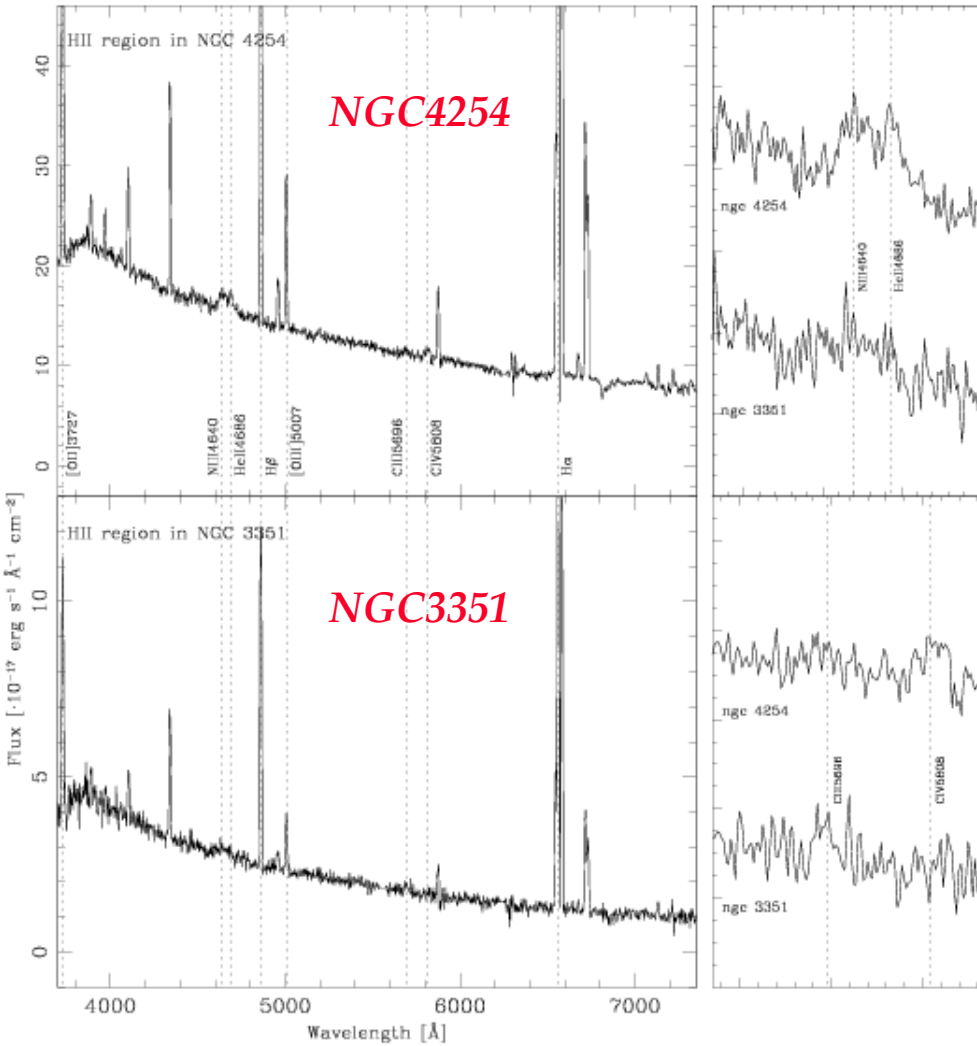


Wolf-Rayet features in high-metallicity HII regions:

Pindao, Schaerer, González Delgado & Stasinska (2002) (astro-ph/0208226)

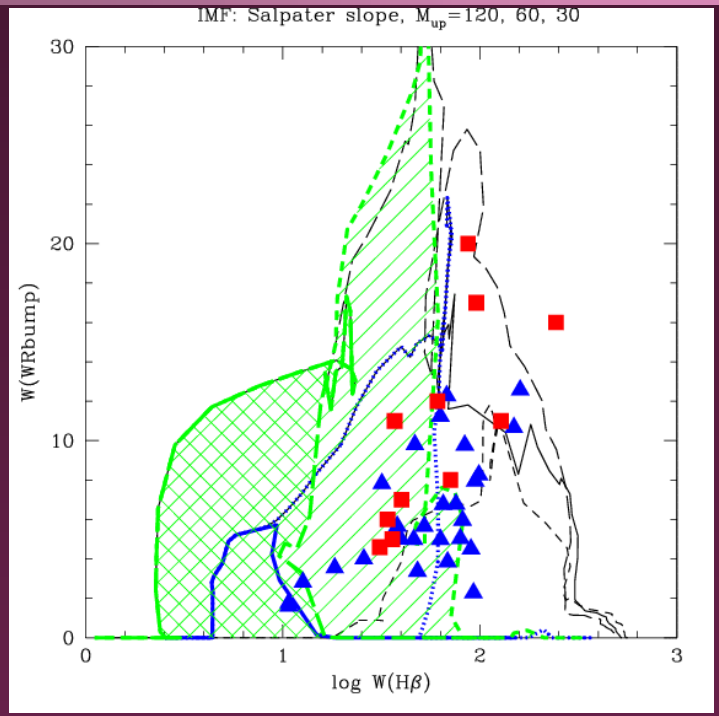
- High-metallicity HII regions: NGC 3351, NGC 3521, NGC 4254, NGC 4303, NGC 4321
- FORS1/VLT optical spectra: 85 disk HII regions

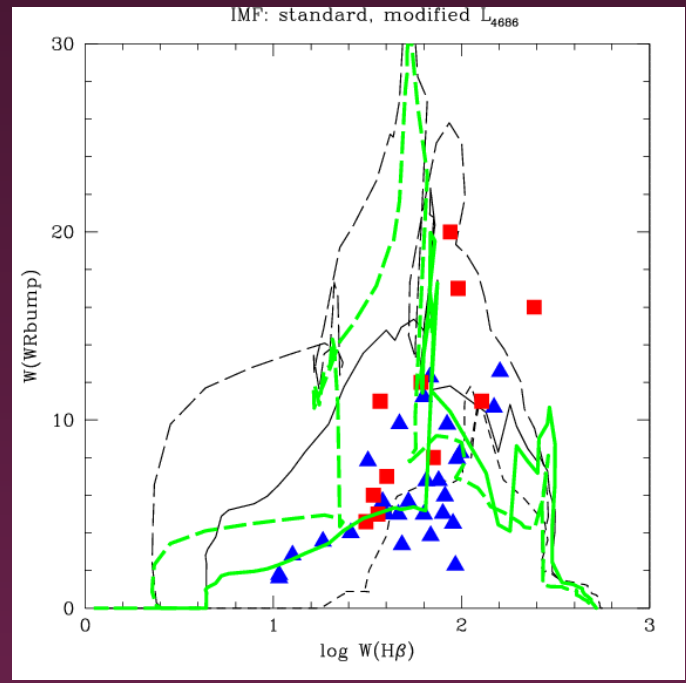
- WR stars are detected in 27 RHIIs
- 14 over 27 RHIIs have WC stars
- 15 RHIIs may also have WR, and 6 of these have WC stars.



Wolf-Rayet features in high-metallicity HII regions:

Pindao, Schaerer, González Delgado & Stasinska (2002) (astro-ph/0208226)





- Double-dashed area: Mup=30 Msol
- Dashed area: Mup= 60 Msol
- Green: Z=0.04 (two solar)
- Black: Z=0.02 (solar)
- IMF: Mup>= 60 Msol

Modified L_{4686} calibration (green lines):

- WNL with log (L/Lsol) > 6 :
  - $L_{4686} = 3.1 \times 10^{36}$ erg/s
- WNL with log (L/Lsol) < 6 :
  - $L_{4686} = 5.6 \times 10^{35}$ erg/s

Conclusions

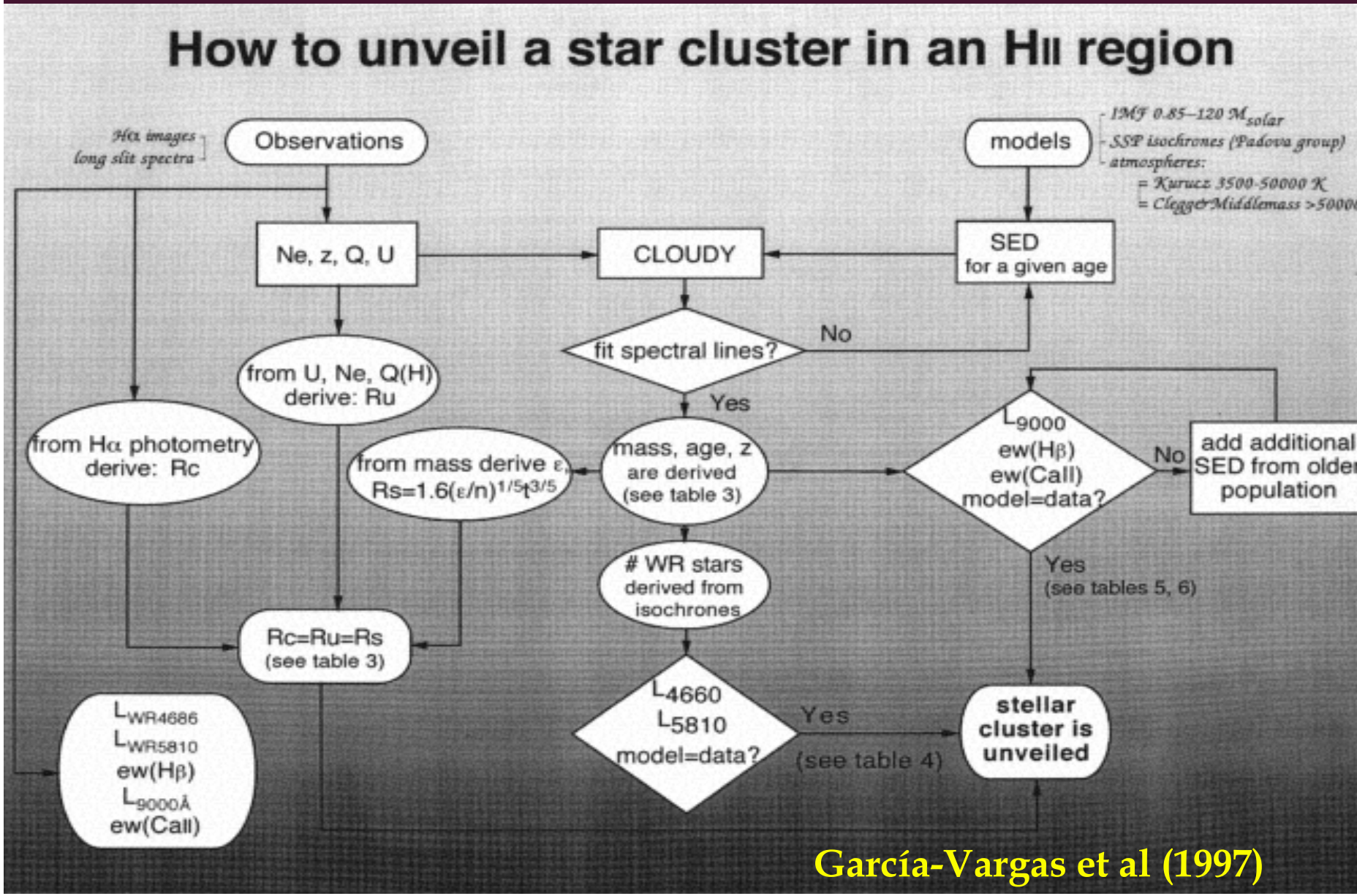
- *Strong evidence against a depletion of massive stars in high-metallicity HII regions: Models with Mup > 60 Msol and ages between 3-5 Myr are consistent with the detection of WR features and the strength of the UV wind lines.*

- *The nebular lines are badly reproduced by 3-5 Myr instantaneous bursts with Mup > 60 Msol, when unblanketed WR and/or Kurucz stellar atmospheres are used.*

- *The new UCL blanketed WR and O atmospheres and adjusted WR temperatures predict a softer far-UV radiation field, providing a better match to the emission line ratios in high-metallicity HII regions.*

- *Results of the modelling depend on:*
  - *Stellar atmosphere models*
  - *Ingredients on the calibration of WR properties*

Modelling the nebular lines



García-Vargas et al (1997)

Liner/Transition Objects: high-metallicity nuclei

(see poster Stellar population of Liners/Transition Objects)

UCL atmospheres do not reproduce emission line ratios of Liner/Transition Objects (dashed boxes)

