ESO

European Organisation
for Astronomical
Research in the
Southern Hemisphere

Emission nebulae at high redshift

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Conference in honour of Bob Fosbury, 25 May 2011

Objective

use high-*z* nebula to trace early chemical evolution - from primordial stars onwards

what features do we expect to observe in the objects hosting very low-metallicity (hot) stars

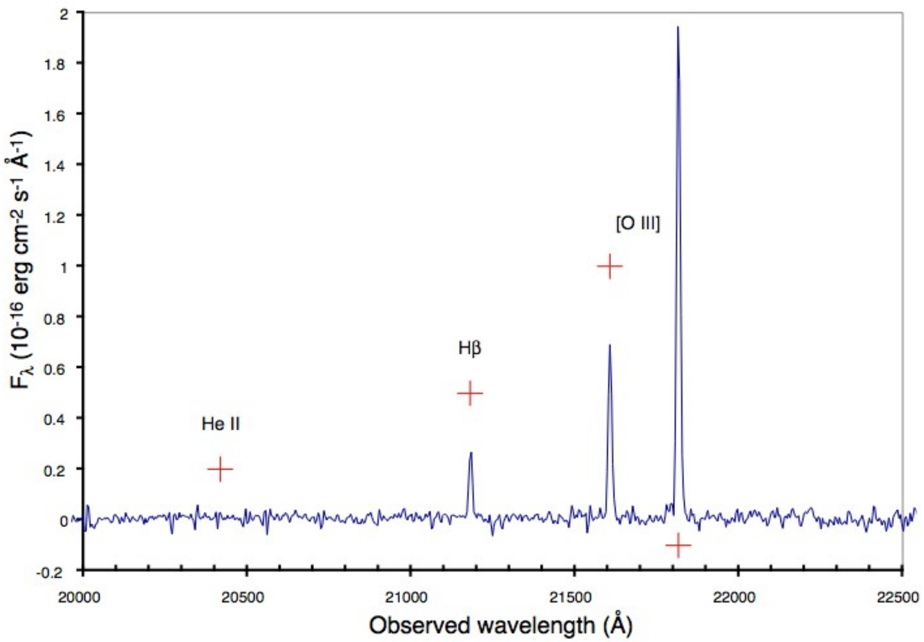
Part I: UV metal emission lines

The Lynx Arc

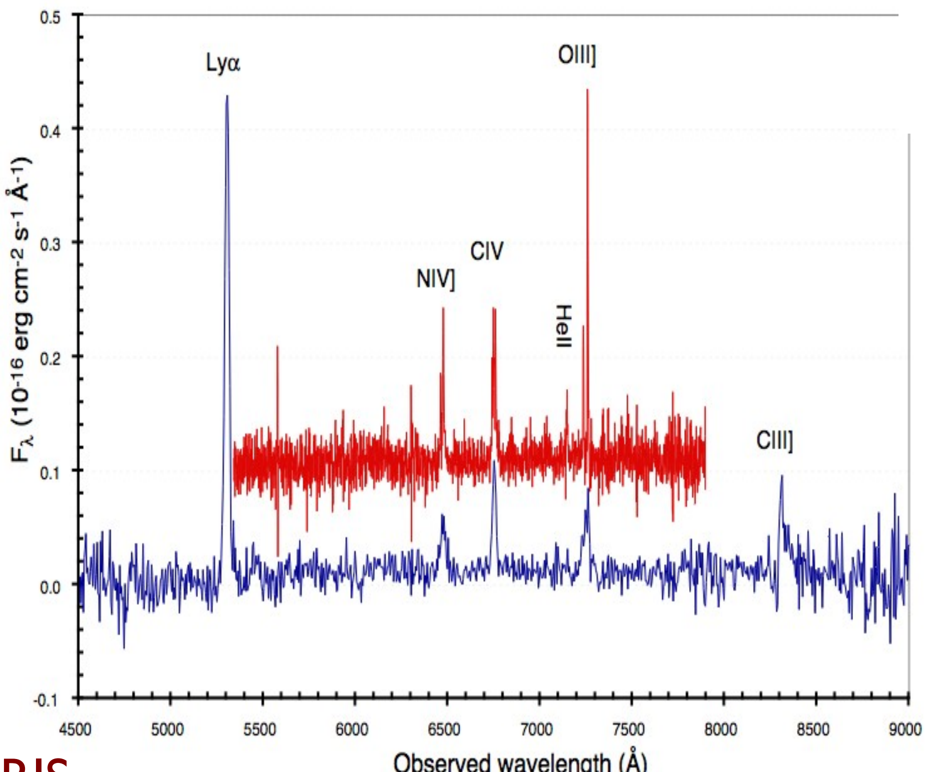
other sources

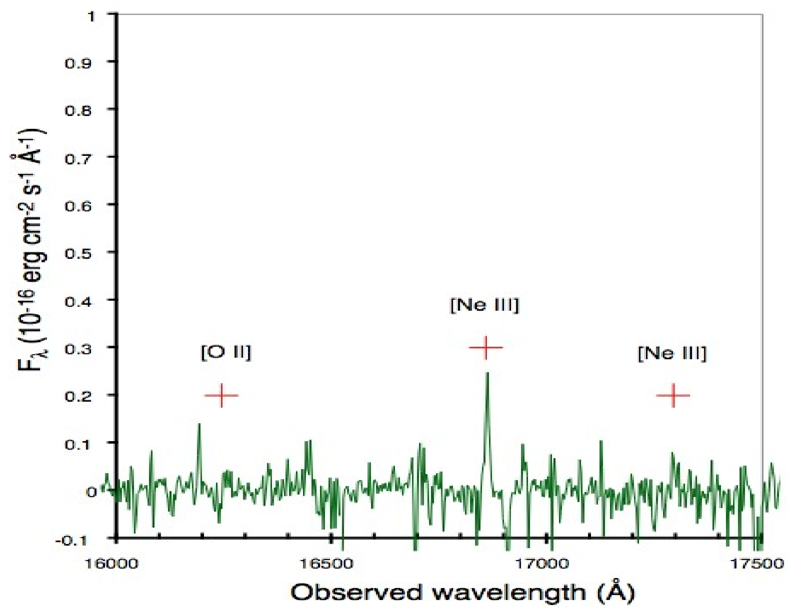
The Lynx arc, z=3.357

- Fosbury et al. 2003 ApJ, 596, 797
- Binette et al. 2003, A&A, 405, 975
- Villar – Martin et al. 2004, MNRAS, 355, 1132



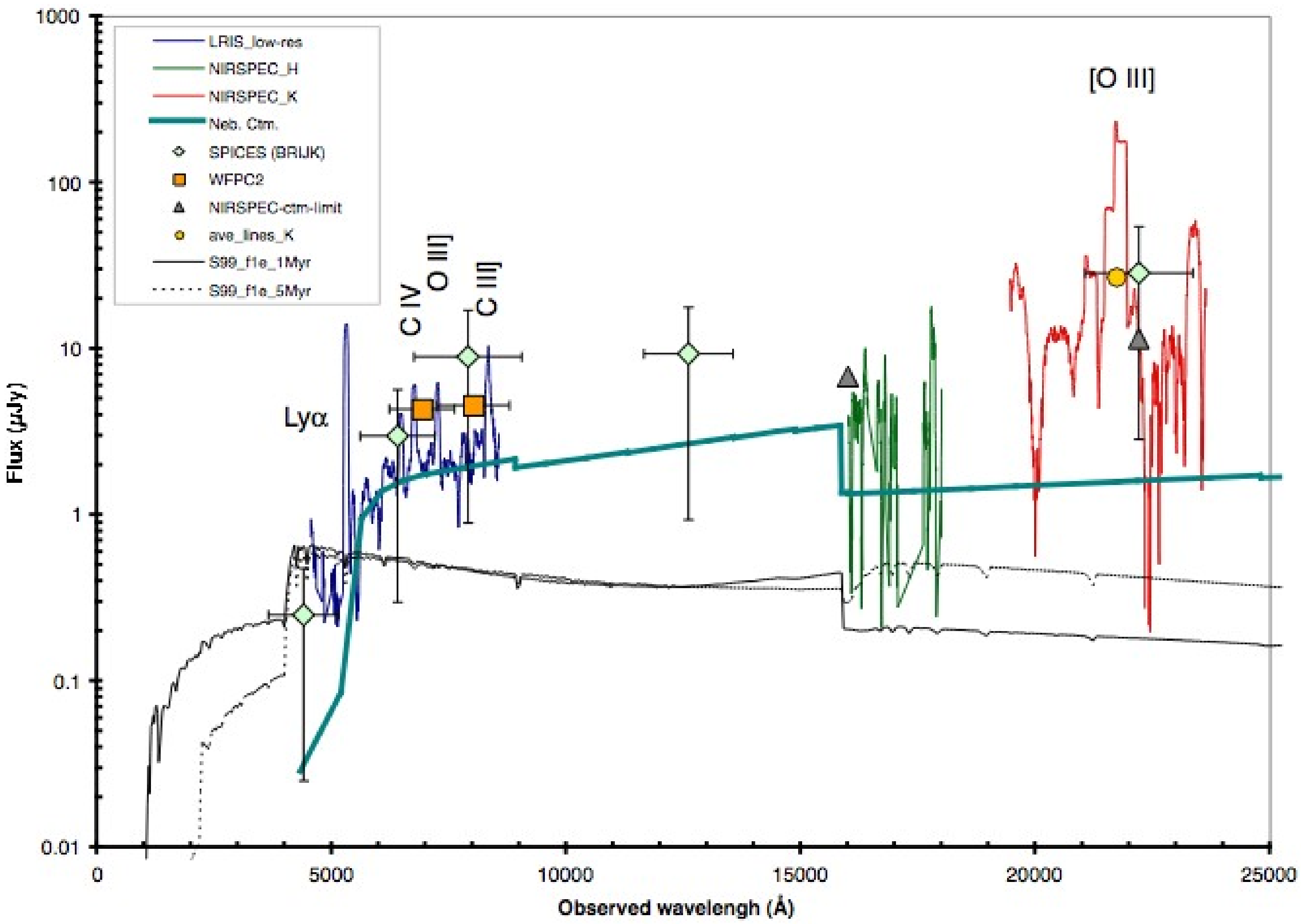
Keck NIRSPEC



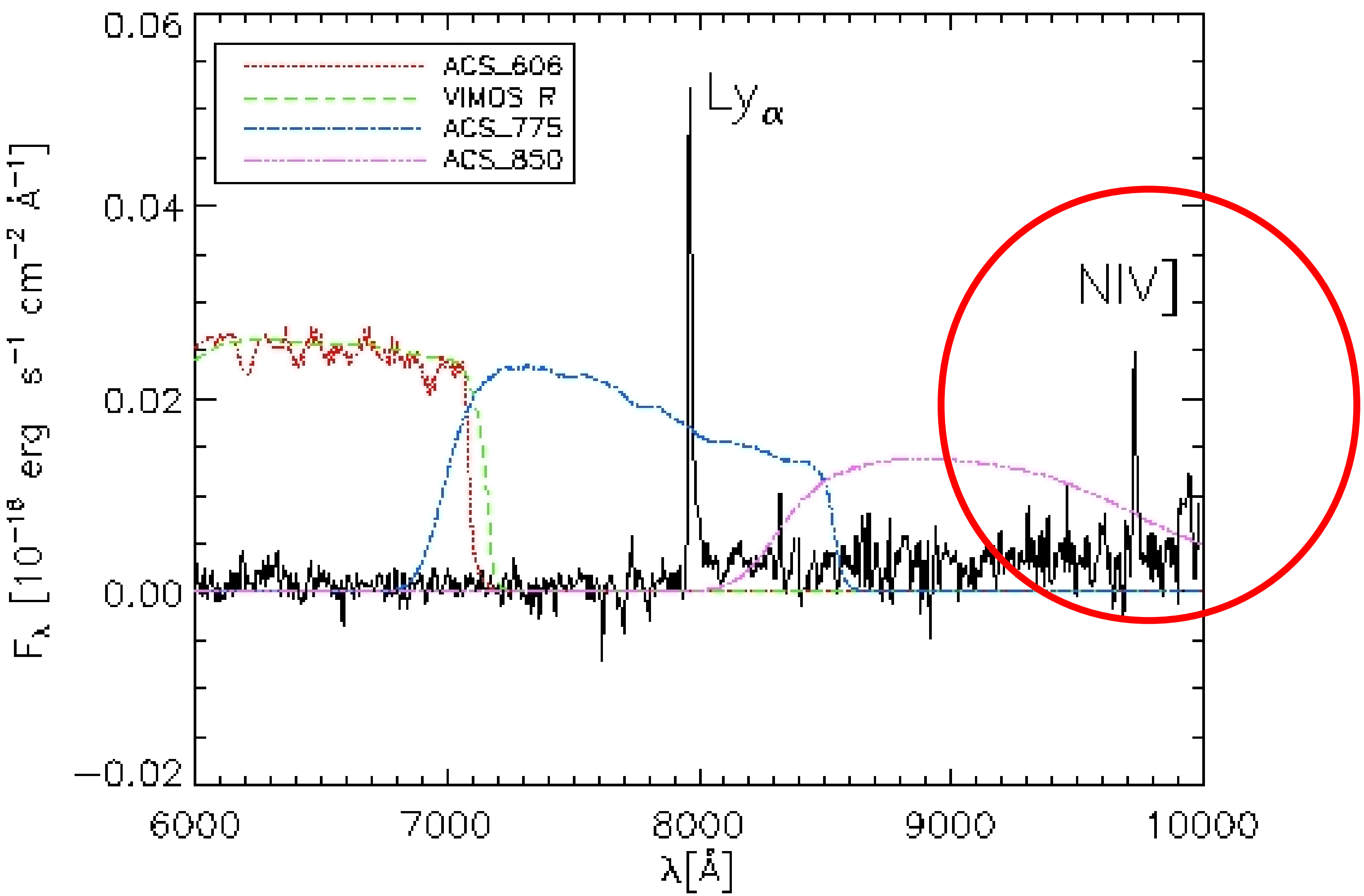


LRIS

Photometry: Lynx arc

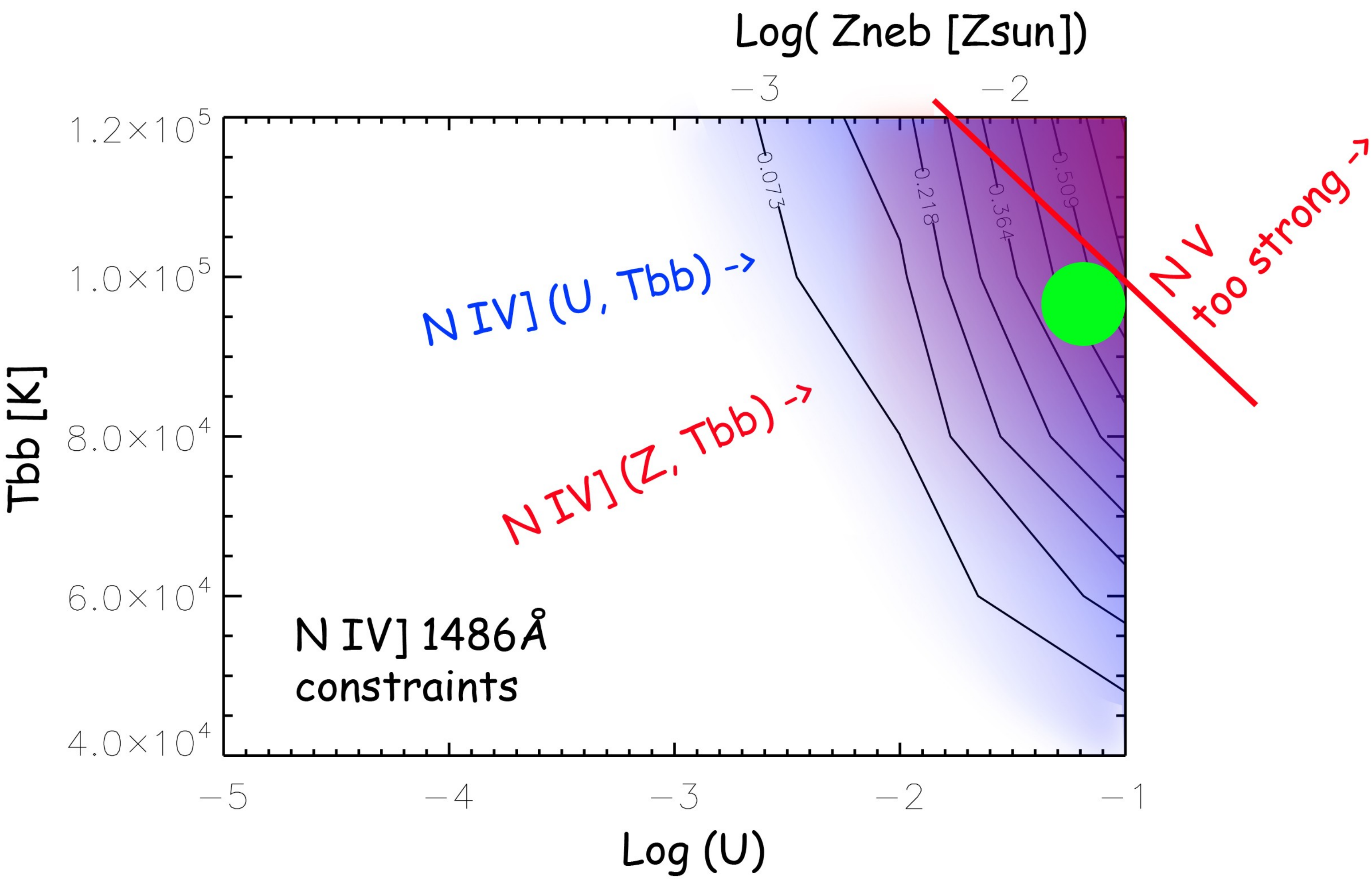


The case of
GDS J033218.92-275302.7 @ z=5.563



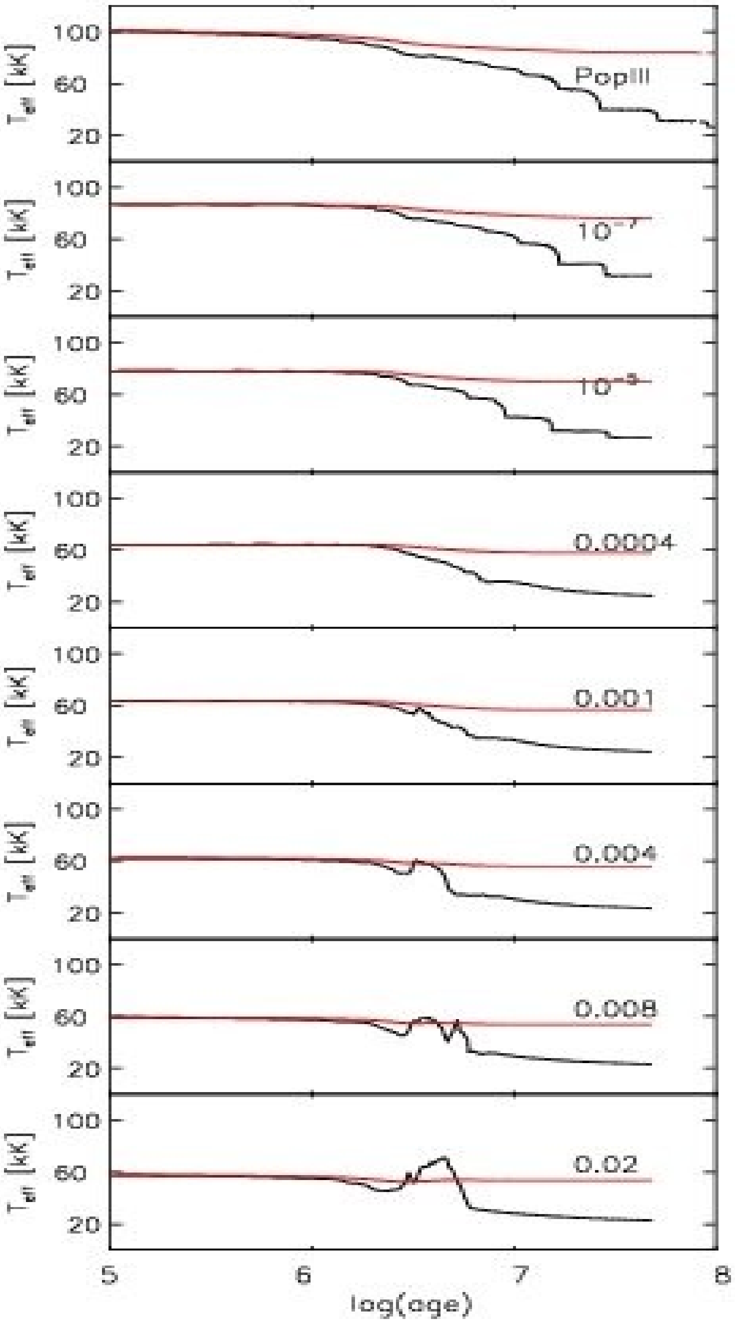
FORS2 spectrum – R ~ 660, L(NIV]1483+87) ~ 10^{43} erg/s

Modelling – how to produce N IV] line



Temperature vs metallicity

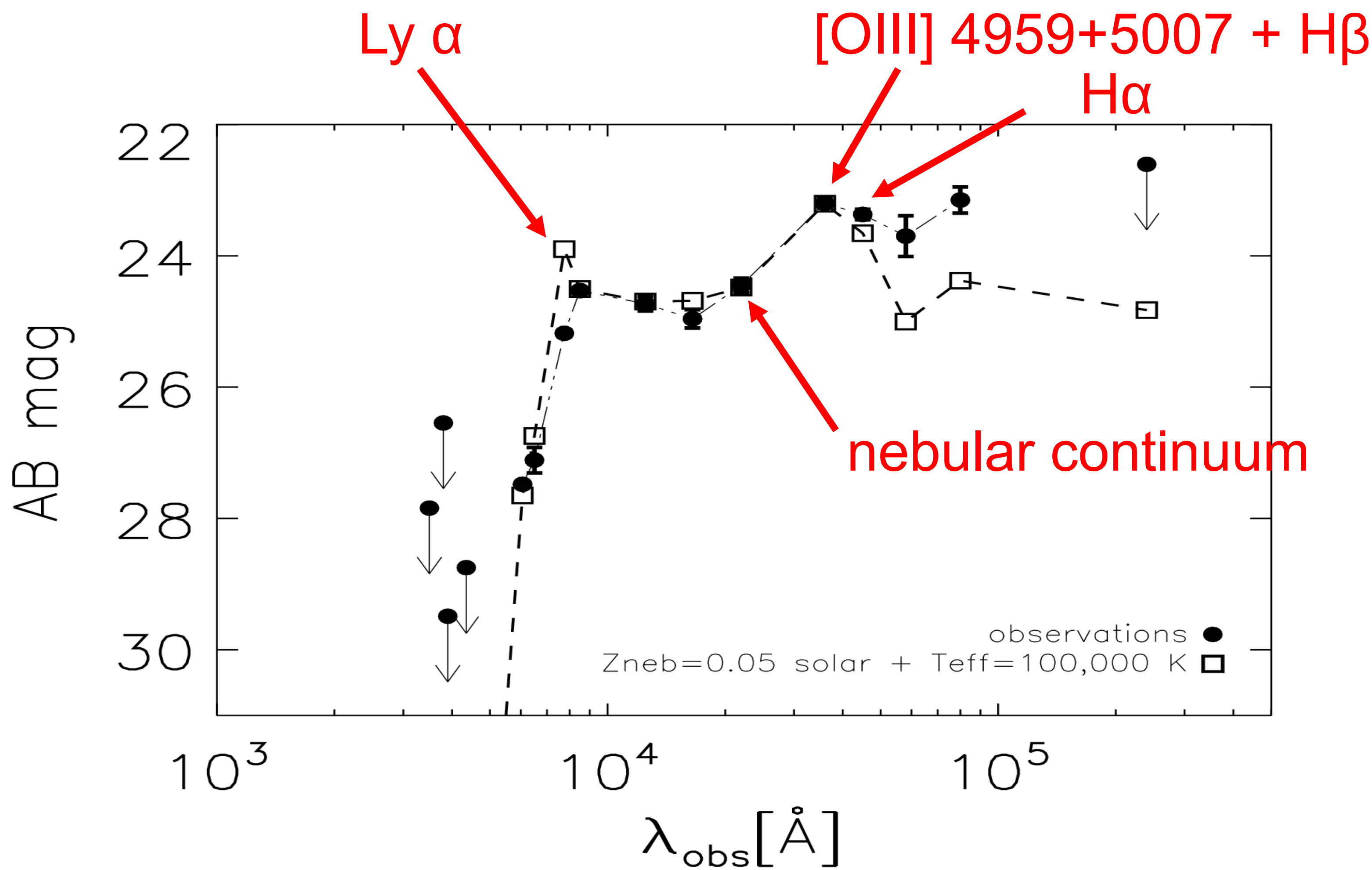
Teff [K]



Pop III

solar

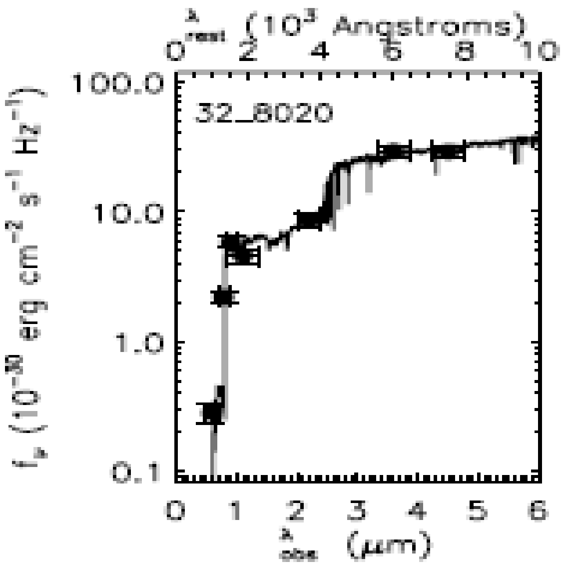
Photometry: GDS J033218.92-275302.7



Data: GOODS

GDS J033218.92-275302.7 – modelling

standard SED fitting



- old stellar population – age$_*$ = 0.9 Gyr
- no reddening
- $M_* = \sim 10^{11}\ M_\odot$

Stark 2007, Wiklind 2008

nebular emission modelling

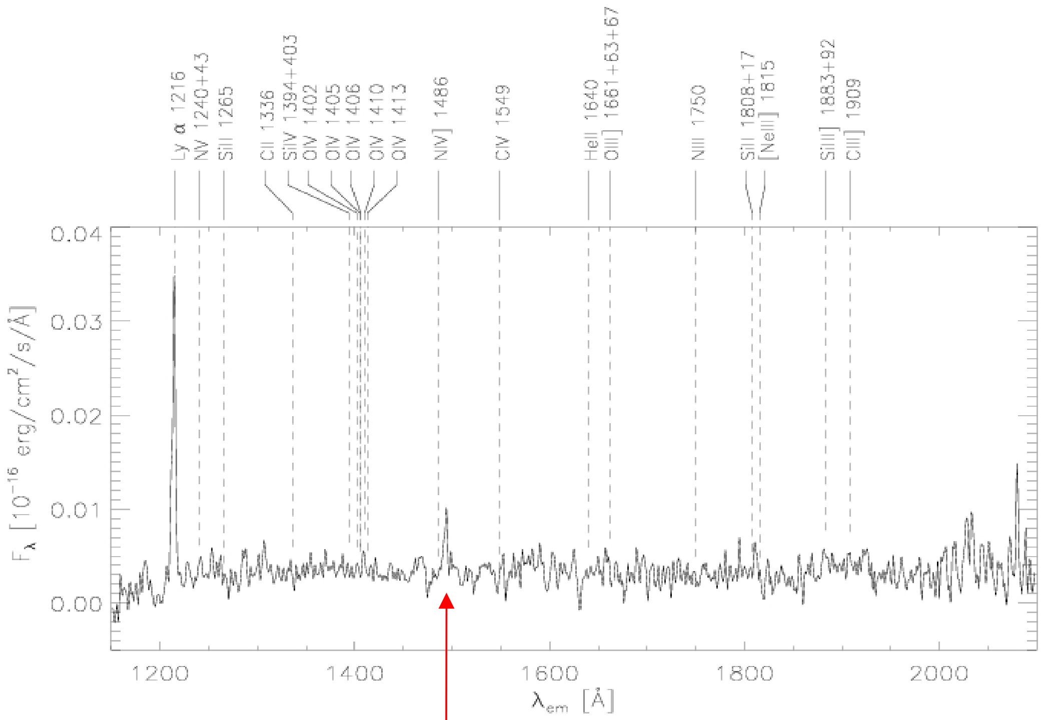
(assumes: spherical geometry, no assumptions on the IMF, constant density)

- Teff = ~100,000 K (Z_* ~ primordial)
- log(U) = -1
- Zneb = ~ 5 % $Z_\odot$
- Q(H) = ~ 3 x 10^{55} s^{-1}
- no dust in the nebula
- nebular emission dominates the SED – it explains the flat continuum and accounts for the observed Ks-IRAC1 bump ([OIII] lines mimic the Balmer break of old stellar population !!!)
- M ~ 3 x 10^8 $M_\odot$

Raiter A., Fosbury R.A.E., Taimoorinia H. A&A, 2010

Also: Zackrisson et al. 2008, Schaerer & De Barros 2009

More sources



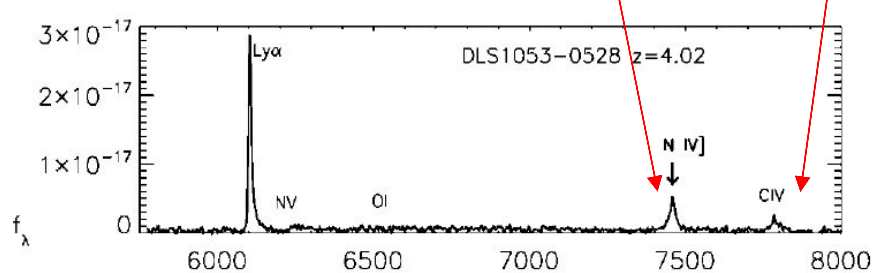
z=3.652 (J033217.22-274754.4) from the GOODS-S

N IV] 1486 Å

z=4.02 from Glickman et al. 2007

N IV] 1486 Å

C IV 1549 Å



Part II
H and He emission:
Lyα, 2γ continuum, He II 1640 Å

In collaboration with Daniel Schaerer (Geneva Observatory)

Raiter A., Schaerer D., Fosbury R.A.E. A&A, 2010

- **Search for PopIII sources at high redshifts:**
- **Strong Lyα**
- **He II 1640 line emission**

- **At low density L(2γ) = 0.5(Lyα)**

H

$$L(Ly\alpha) \sim Q(H) * f_{coll}$$

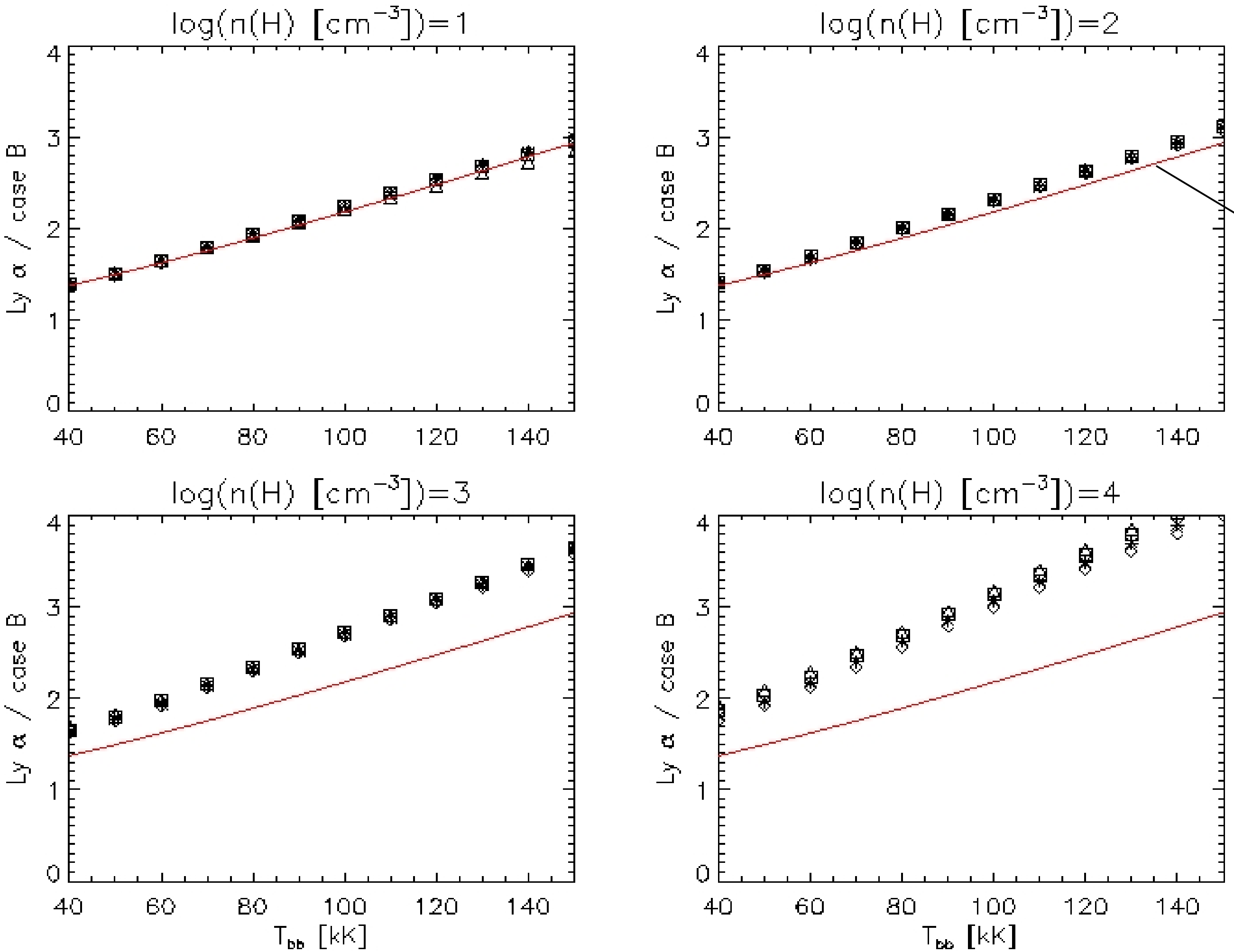
Case B

He

$$L(HeII\ 1640\ \text{Å}) \sim Q(He^{+})$$

L(Lyα) CLOUDY / case B

Stellar population + nebular physics



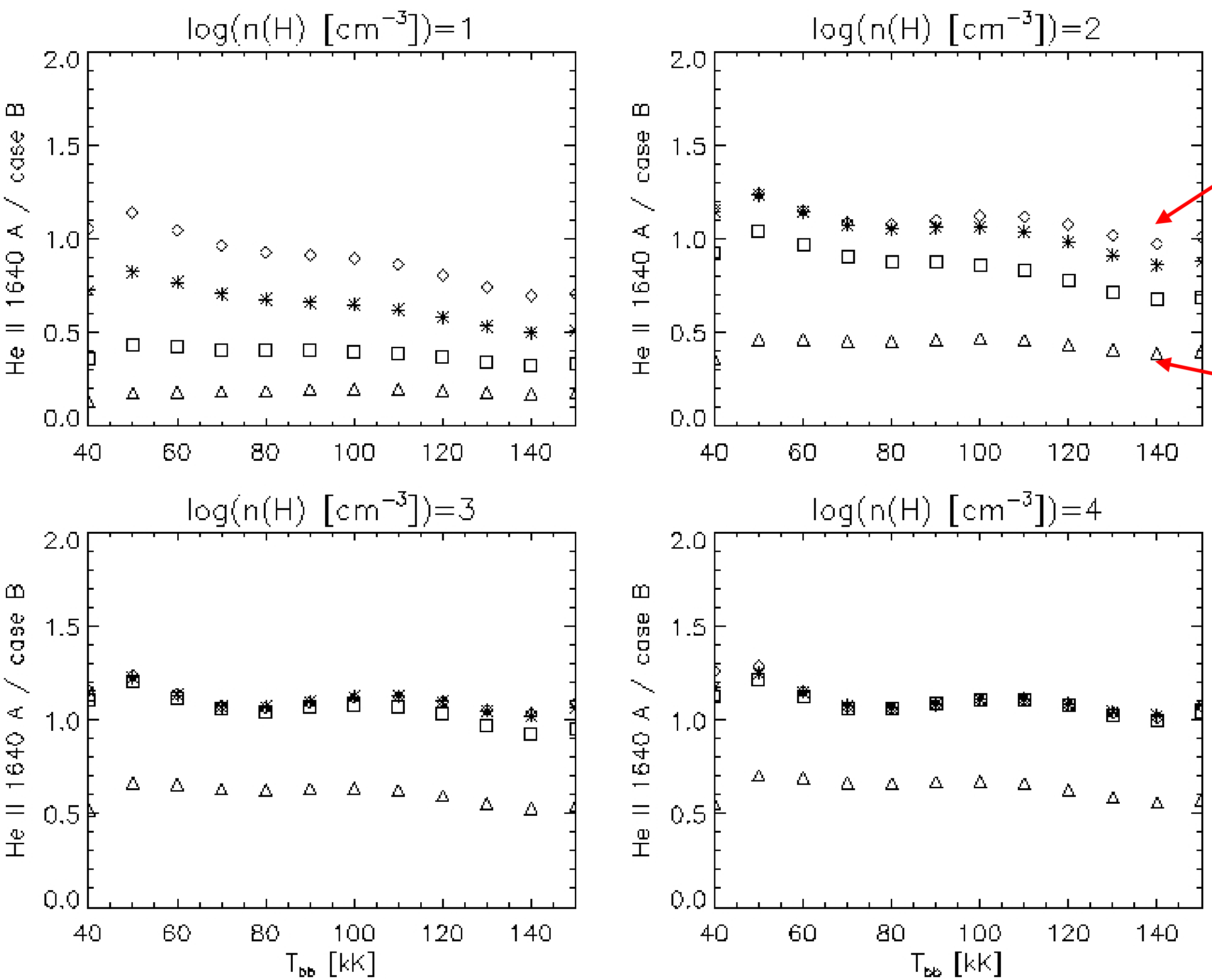
<E> / 13.6 eV

ionizing photons carry energies > 13.6 eV

$$L(Ly\alpha) \sim Q(H) * f_{coll} * \langle E \rangle / 13.6$$

L(He II 1640 Å) CLOUDY / case B

Stellar population + nebular physics

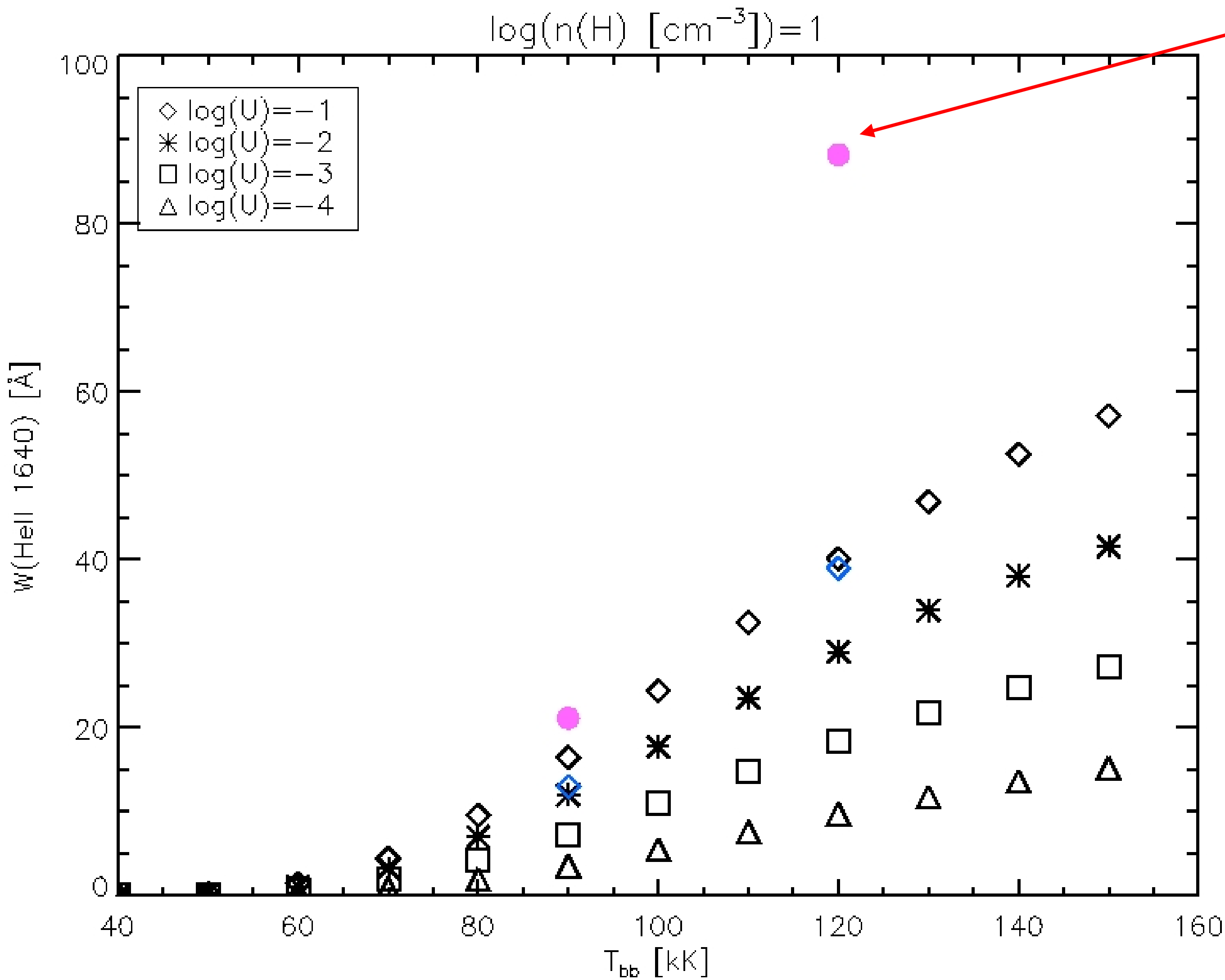


High U (0.1)

Low U (0.0001)

Stasinska-Tylenda effect

He II 1640 Å equivalent width (CLOUDY)



Case B prediction

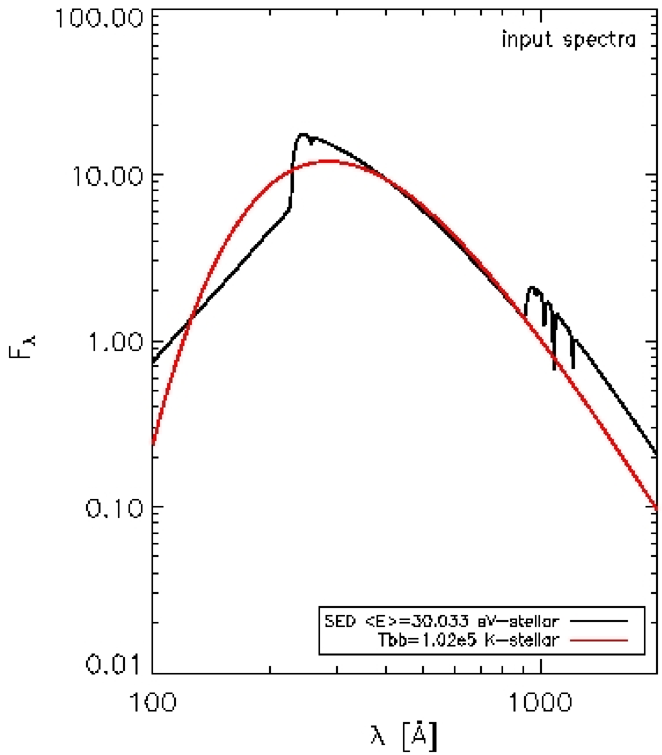
Importance of 2γ continuum:

- **enhanced like Lyα**
- **can be dominant at 1216-1600 Å**
- **decreases EW of UV emission lines**

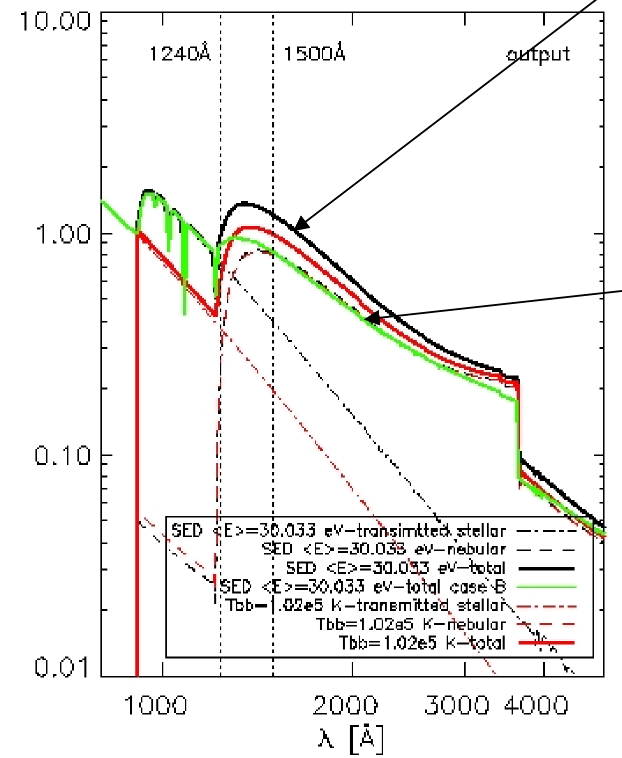
2γ continuum

Enhanced (~ x 2)
2γ emission

Case B



hot ionizing source



resulting nebular emission

Search criteria

- Lyα emission
- Other emission line(s) to diagnose the ionization mechanism
- Rule out AGN (power law)
- Indicate high T_{eff}

Diagnostics

- Lyα – He II dual emitters
- Hot stellar photoionization T_{eff} ~ 100kK
- Evidence for low nebular metallicity (but non-zero)
- NIV] 1483 + 86 Å – high T_{eff} in the absence of N III] and N V
- Ionization by hot stars can result in a nebular spectrum (continuum approximately flat in fν and lines) that dominates the rest-frame UV-optical-NIR photometry

Conclusions

- **Lyα : can be enhanced (especially for hot ionizing stars) – can help to explain high EWs found in some surveys**

- **2γ continuum: enhanced in the same way, changes EWs of UV emission lines**

- **He II 1640 Å can be weaker than expected from synthesis models (maybe we need to observe deeper to detect it at high-*z*)**

- **Case B approximation might not be good in case of the nebular emission coming from the gas at high-*z***

- **It is worth looking for other emission lines at high-*z* (to distinguish the ionization mechanism and determine the effective temperature of the source)**

Future prospects

- Observations:
- emission line spectroscopy at high redshift, access to the rest-frame intercombination lines of C, N, O and Si
- PDR studies: [C II] line + other MIR cooling lines
- Theory:
- explain the enrichment process and create some general scenario (stellar winds, SNe)