[OIII]/[CII]比と ALMA Cy2の初期結果

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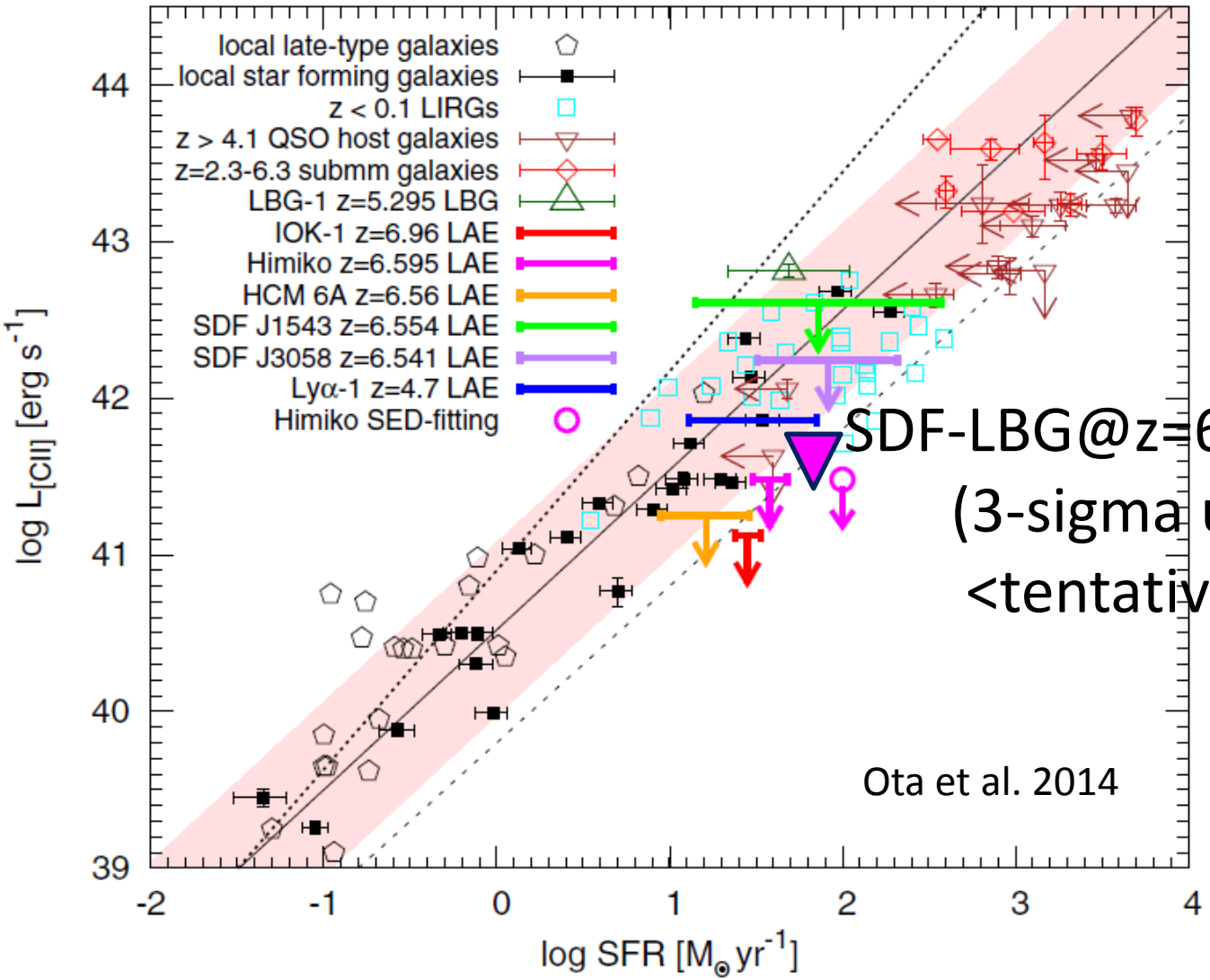
[CII]158 deficit in high-z galaxies?



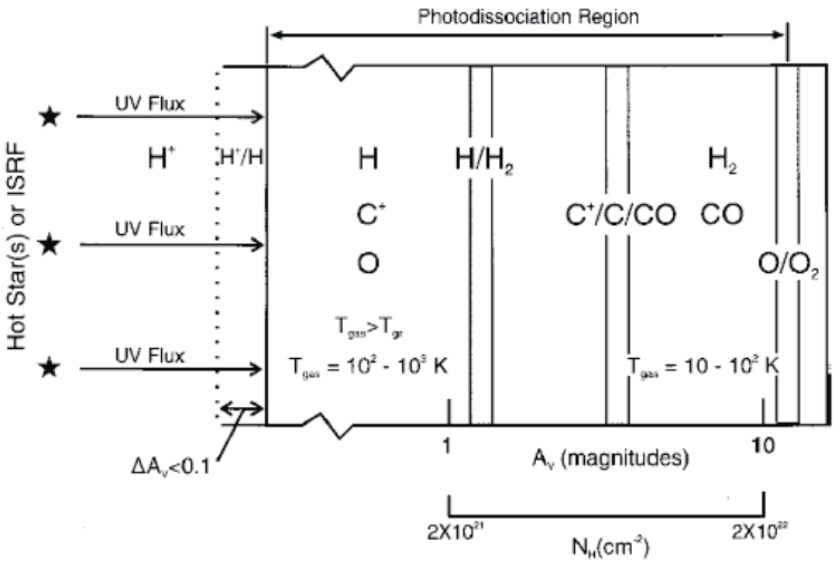
[CII]158 deficit in high-z galaxies?

- Low [CII]
  - Truncated PDR (matter-bounded, high-ionization)
  - Low C abundance

  → Check other PDR lines, HII region lines, and CIII/CIV lines

[OIII]88/[CII]158 diagnostics

- [OIII]88 traces HII gas
- [CII]158 traces HI gas
- Matter-bounded or photon-bounded?



Tielens & Hollenbach 2005

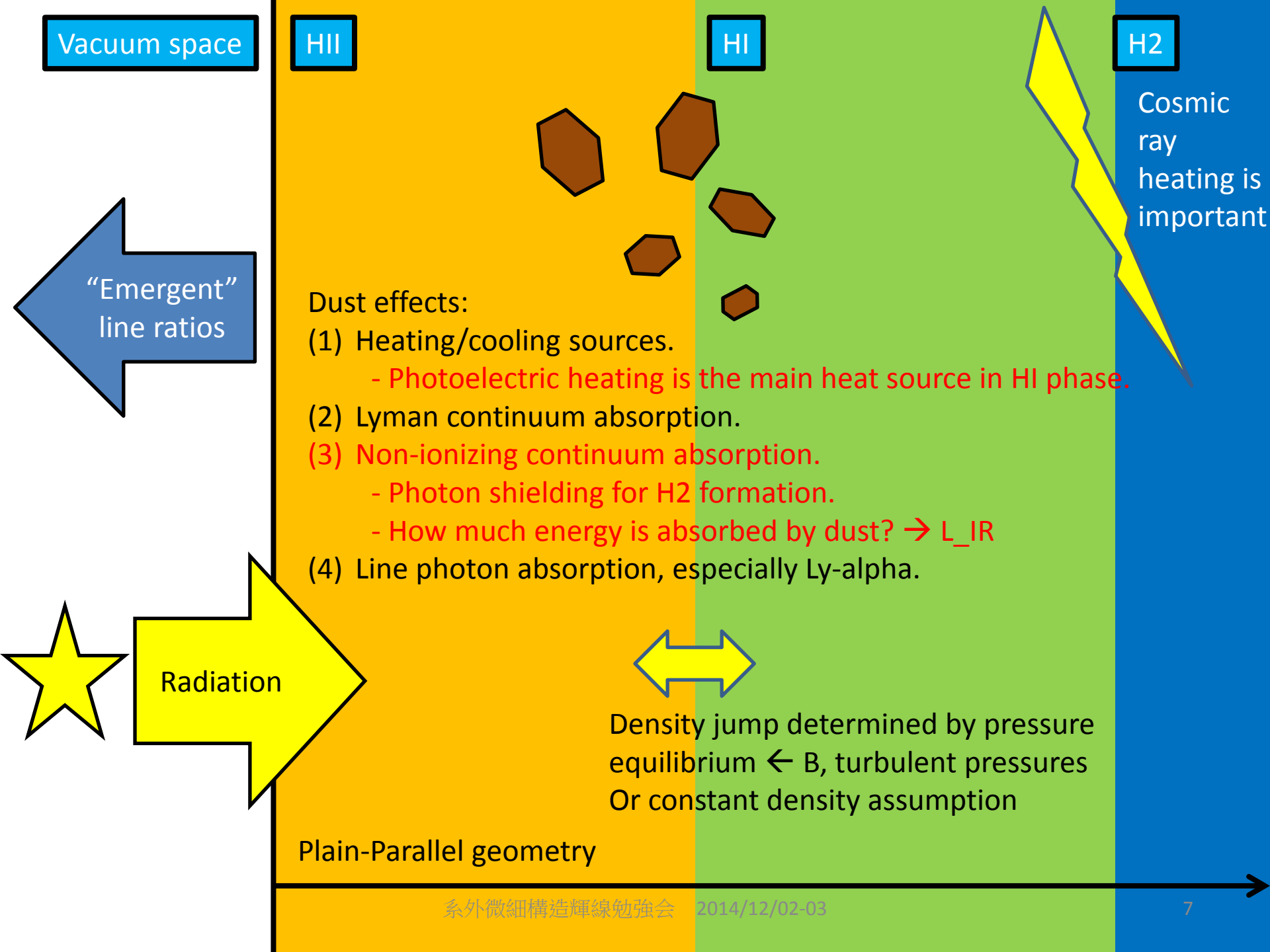
Cloudy HII/PDR calculation

c.f. Abel et al. 2005, Nagao et al. 2011/2012

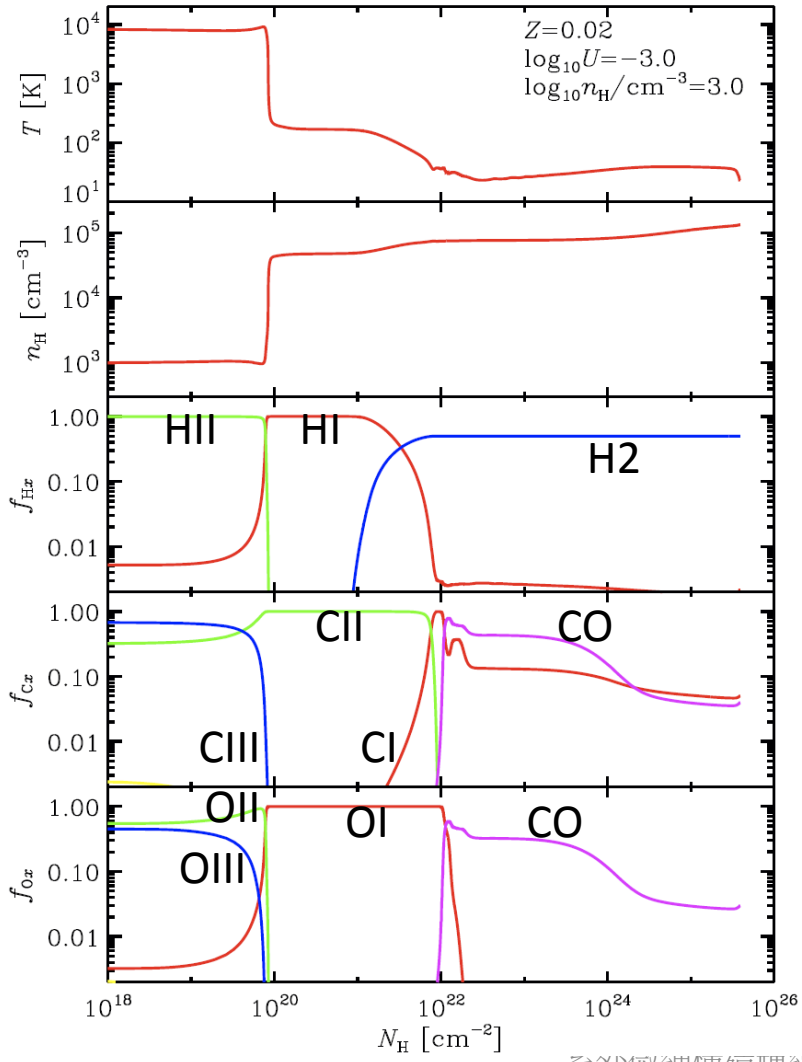
- Plain-parallel
- Constant pressure
- Orion chemical abundance (He & N modified)
- Orion grains and PAH
- B=10microG
- Turbulent pressure = magnetic pressure
  - v_tur = 3.3 km/s (B/10uG)(n/1e5 cm-3)^-1/2
- CMB @ z=7
- Haardt & Madau (2005) background @ z=7
- Cosmic ray background at MW ISM

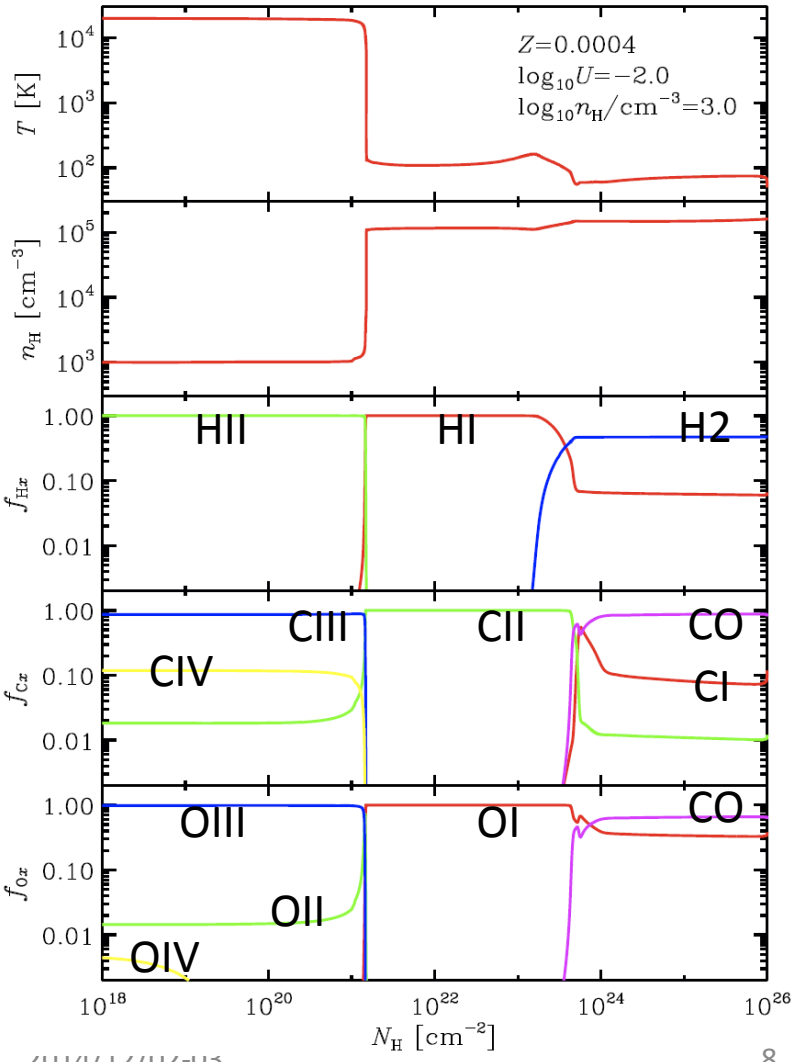
Cloudy HII/PDR calculation

- Stellar spectra taken from SB99
  - Padova track, Salpeter IMF 1—100 Msun, 10Myr?
  - Z=0.0004, 0.004, 0.008, 0.02
- Ionization parameter: U= ion photon flux/c/n_H
  - logU=-3.0, -2.0, -1.0
- Hydrogen density (at the top of slab)
  - logn_H=2.0, 3.0, 4.0


Vacuum space
HII
HI
H2
Cosmic ray heating is important
"Emergent" line ratios
Dust effects:
(1) Heating/cooling sources.
- Photoelectric heating is the main heat source in HI phase.
(2) Lyman continuum absorption.
(3) Non-ionizing continuum absorption.
- Photon shielding for H2 formation.
- How much energy is absorbed by dust? → L_IR
(4) Line photon absorption, especially Ly-alpha.
Radiation
Density jump determined by pressure equilibrium ← B, turbulent pressures
Or constant density assumption
Plain-Parallel geometry

Ionization structure



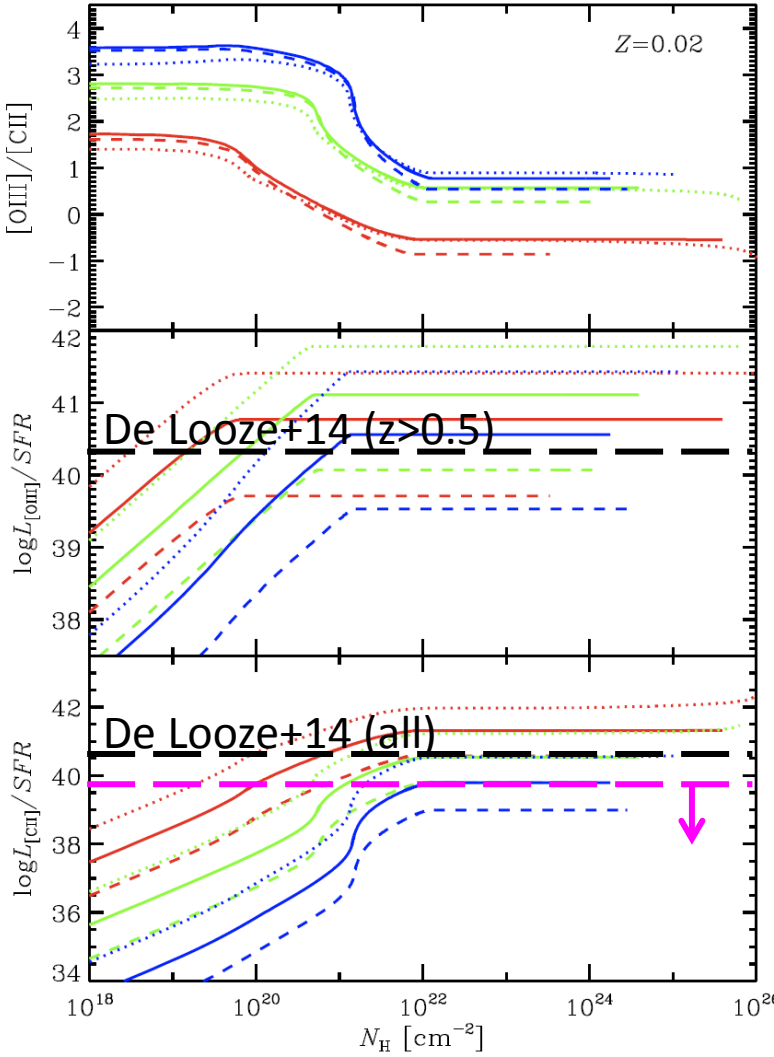


[OIII]88 & [CII]158 lines

Red: logU=-3.0, Green: logU=-2.0, Blue: logU=-1.0

Dotted: logn=2.0, Solid: logn=3.0, Dashed: logn=4.0

Scales may be wrong!



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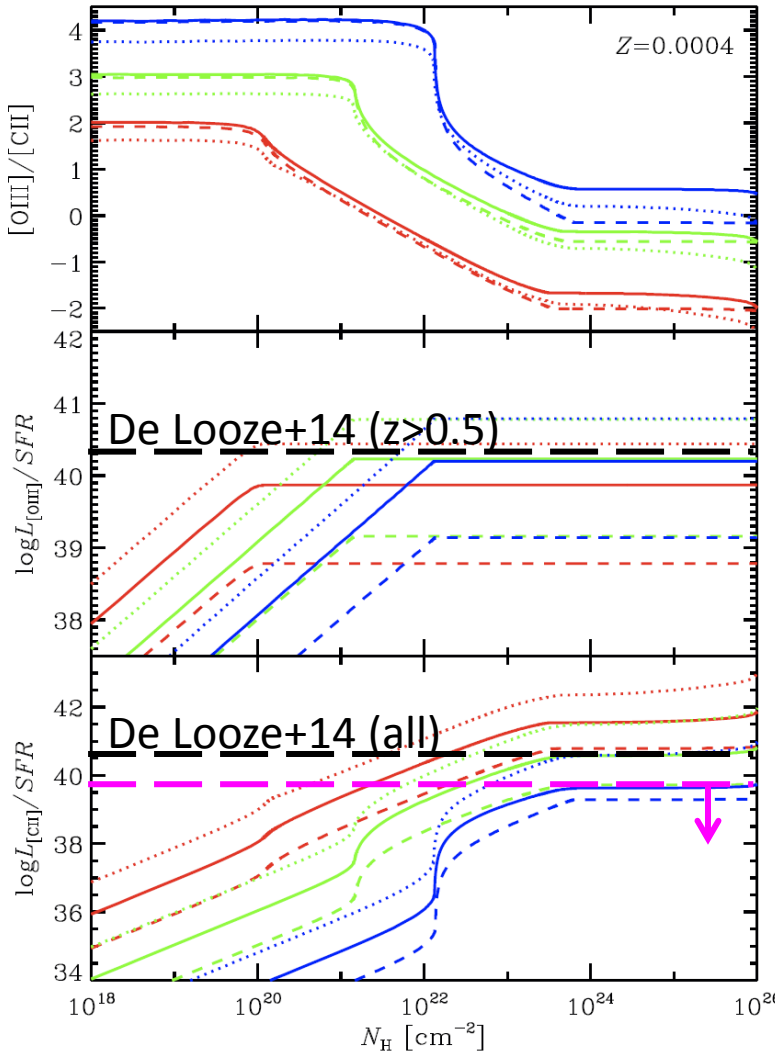
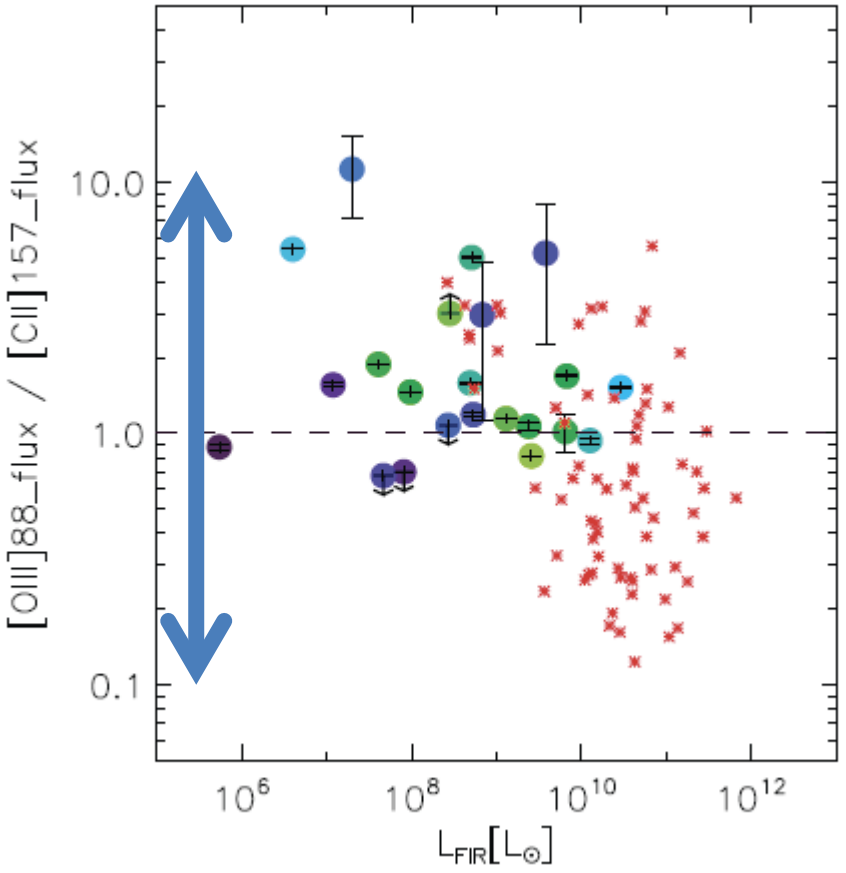


Nearby galaxies' [OIII]/[CII]

Nearby galaxies
[OIII]/[CII]~0.1—10

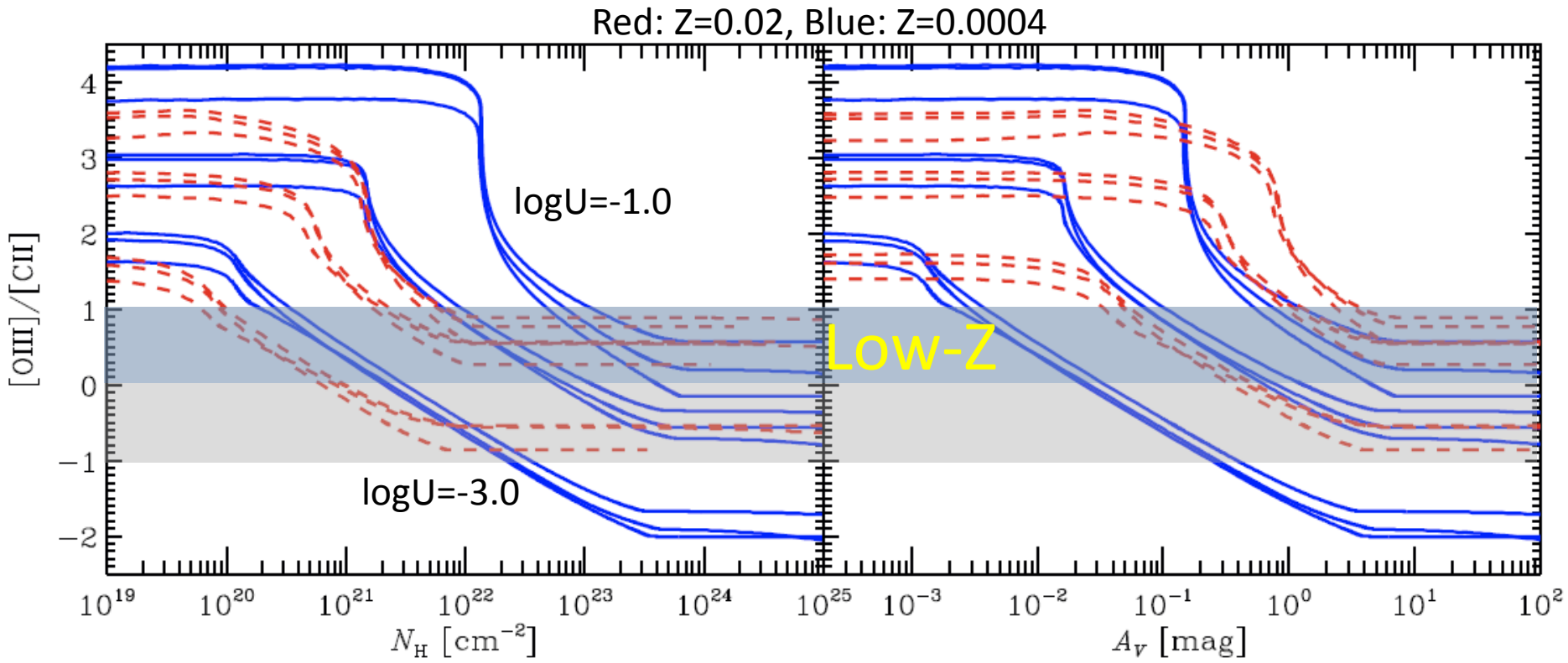
Low-Z galaxies
[OIII]/[CII]=1—10



Madden et al. (2012)

[OIII]88 & [CII]158 lines

- Z=0.02 fully PDR (logNH>23.5 or Av>10) can explain nearby galaxies's ratio.
  - NOTE: CMB and UVB at z=7
- Lower-Z galaxies may have higher U.
- High-z galaxies tend to have higher U (and lower-Z), suggesting higher [OIII]/[CII].



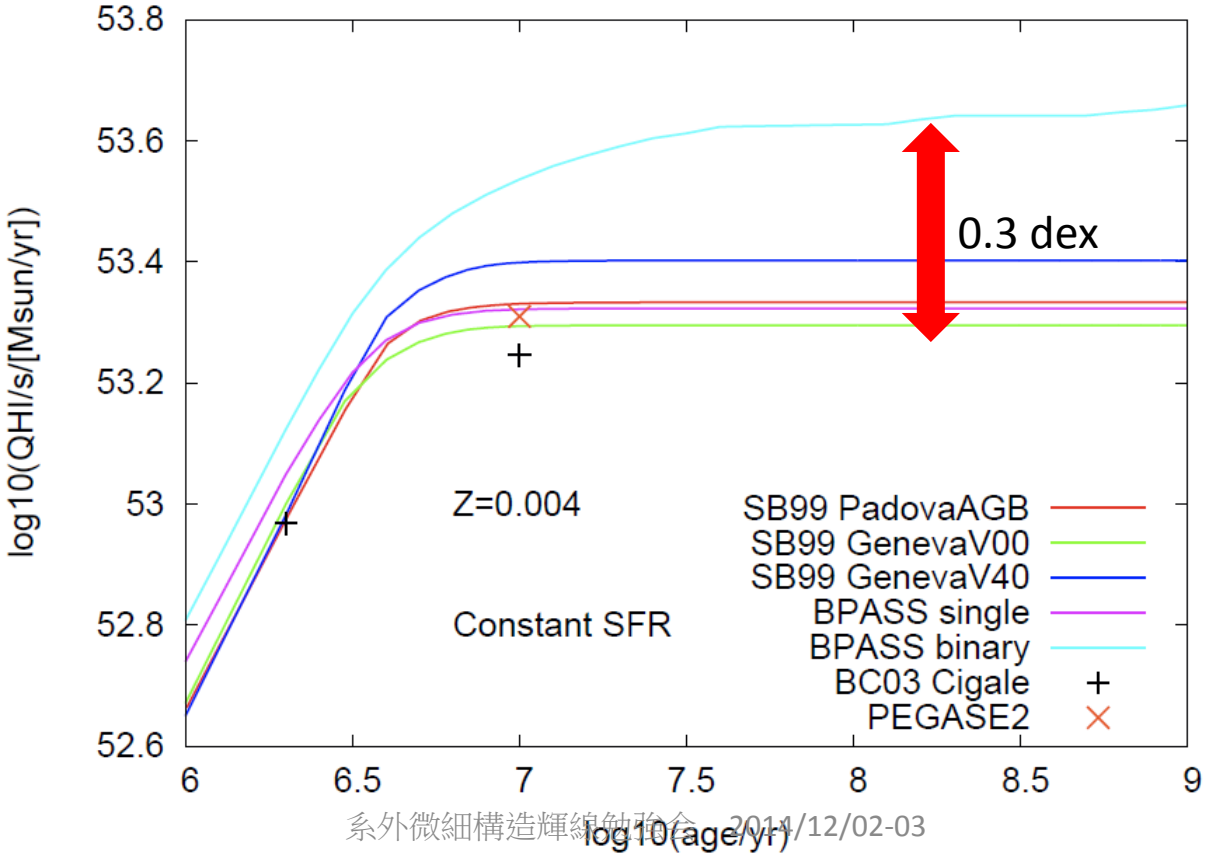
Summary

- Very high-z (z>6) galaxies are faint in [CII].
- To understand the [CII] deficit, a series of PDR calculations are performed (or performing).
  - A lot of parameters…
  - Need comparisons with observations
- [OIII]/[CII] ratios of nearby galaxies can be reproduced by fully PDR models.
- [OIII] observations of high-z [CII] deficit galaxies are required.
- For Cy3, galaxies detected in CIII]1909 are quite interesting.
  - Stark et al. 2014

おまけ：HII REGION LINES AMONG DIFFERENT POPULATION SYNTHESIS

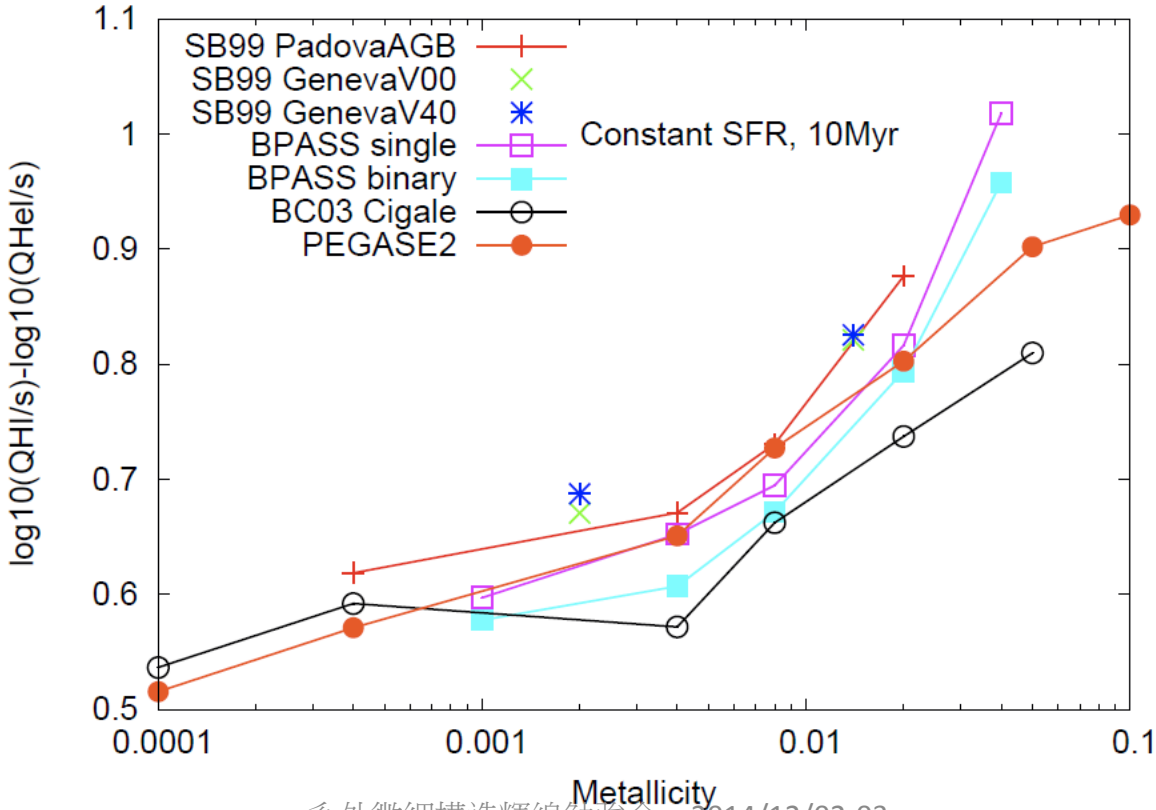
Absolute QHI?

- Stellar rotation and massive star binary enhance QHI by a factor of 2.



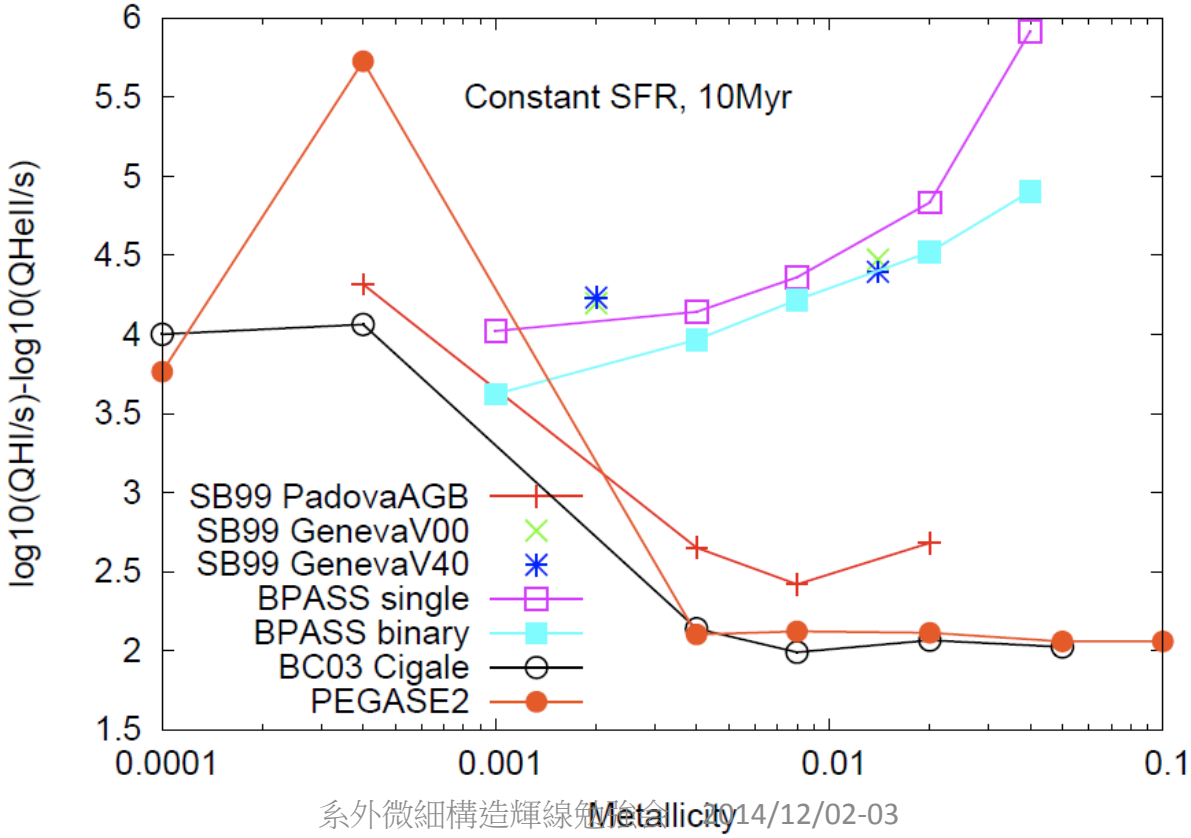
QHI/QHeI: Spectral shape of LyC 1

- Small difference among population synthesis models → Emission line ratios are robust?



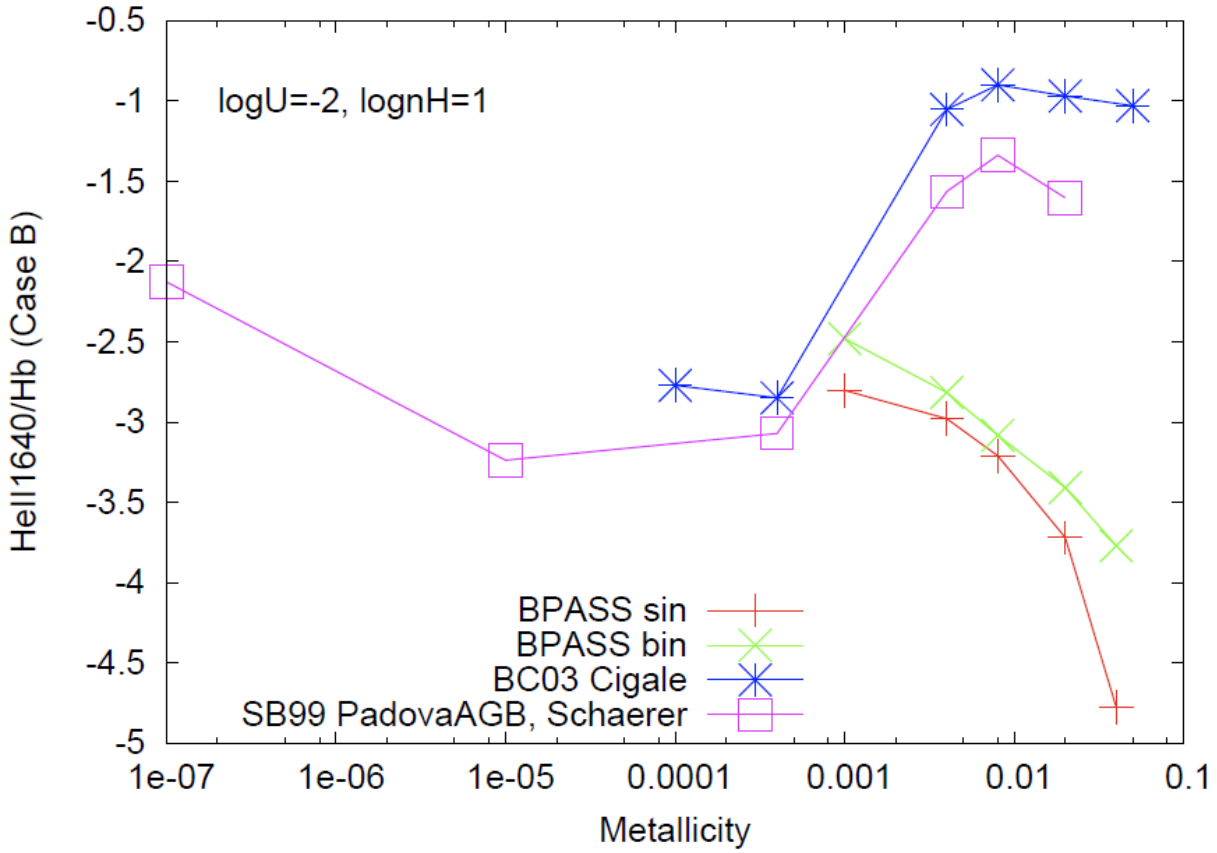
QHI/QHeII: Spectral shape of LyC 2

- Large difference between new and previous models → Large difference in HeII lines?



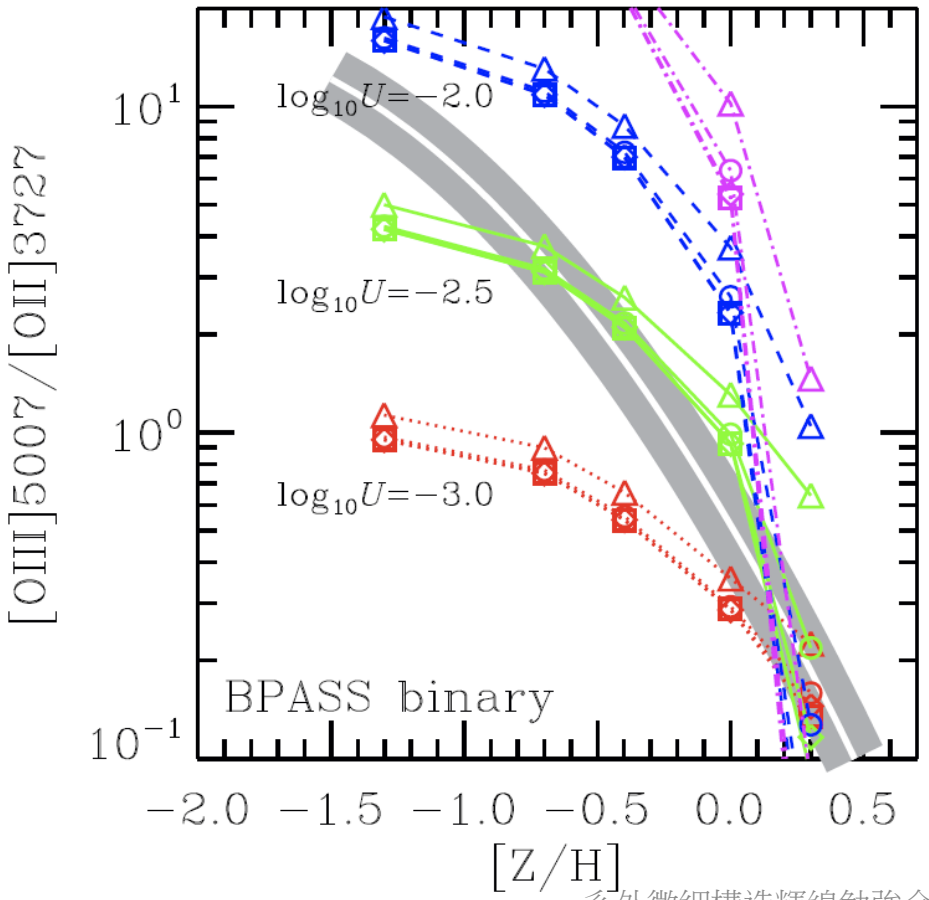
HeII 1640/Hb ratio

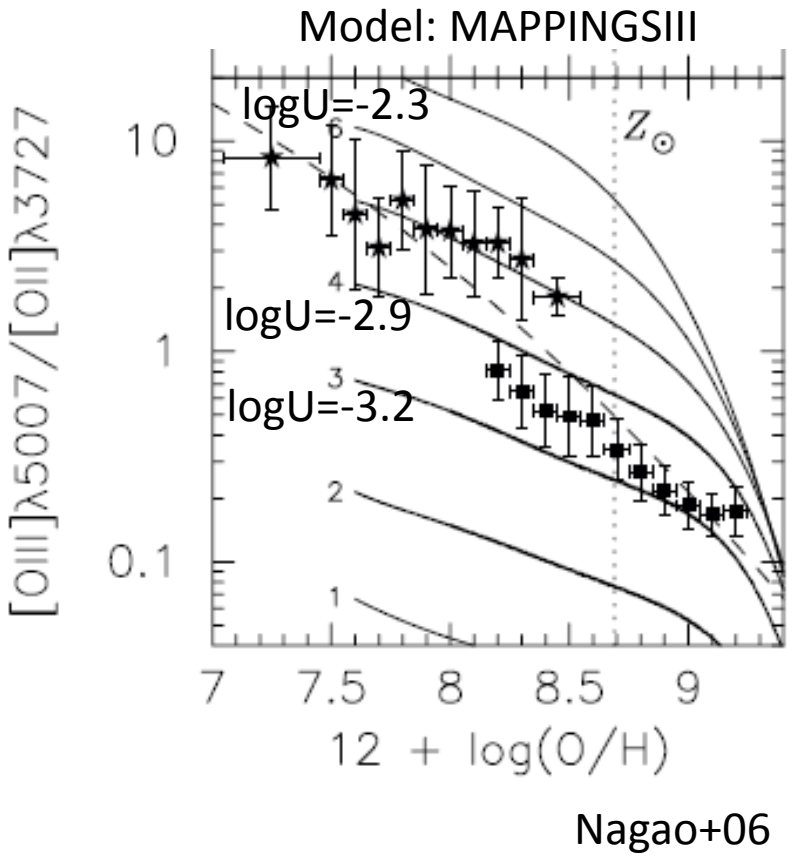
- Yes, large difference appears.



What nebular parameters?

- Z dependent logU?

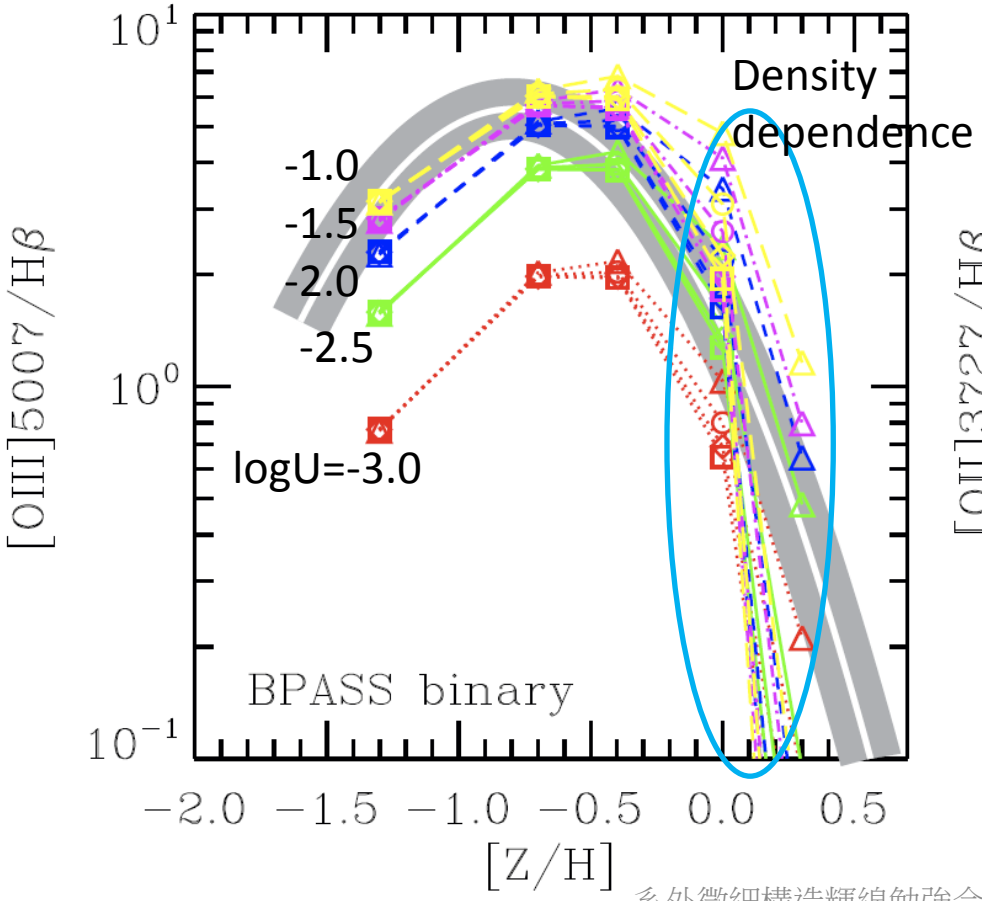


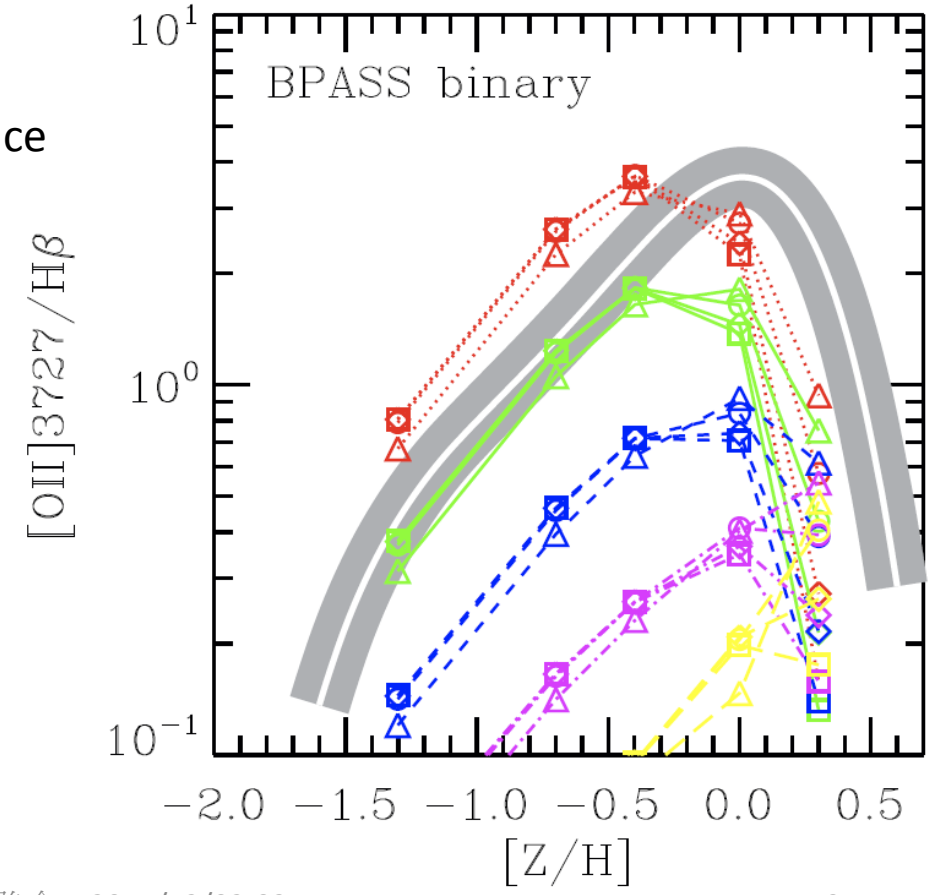


Nagao+06

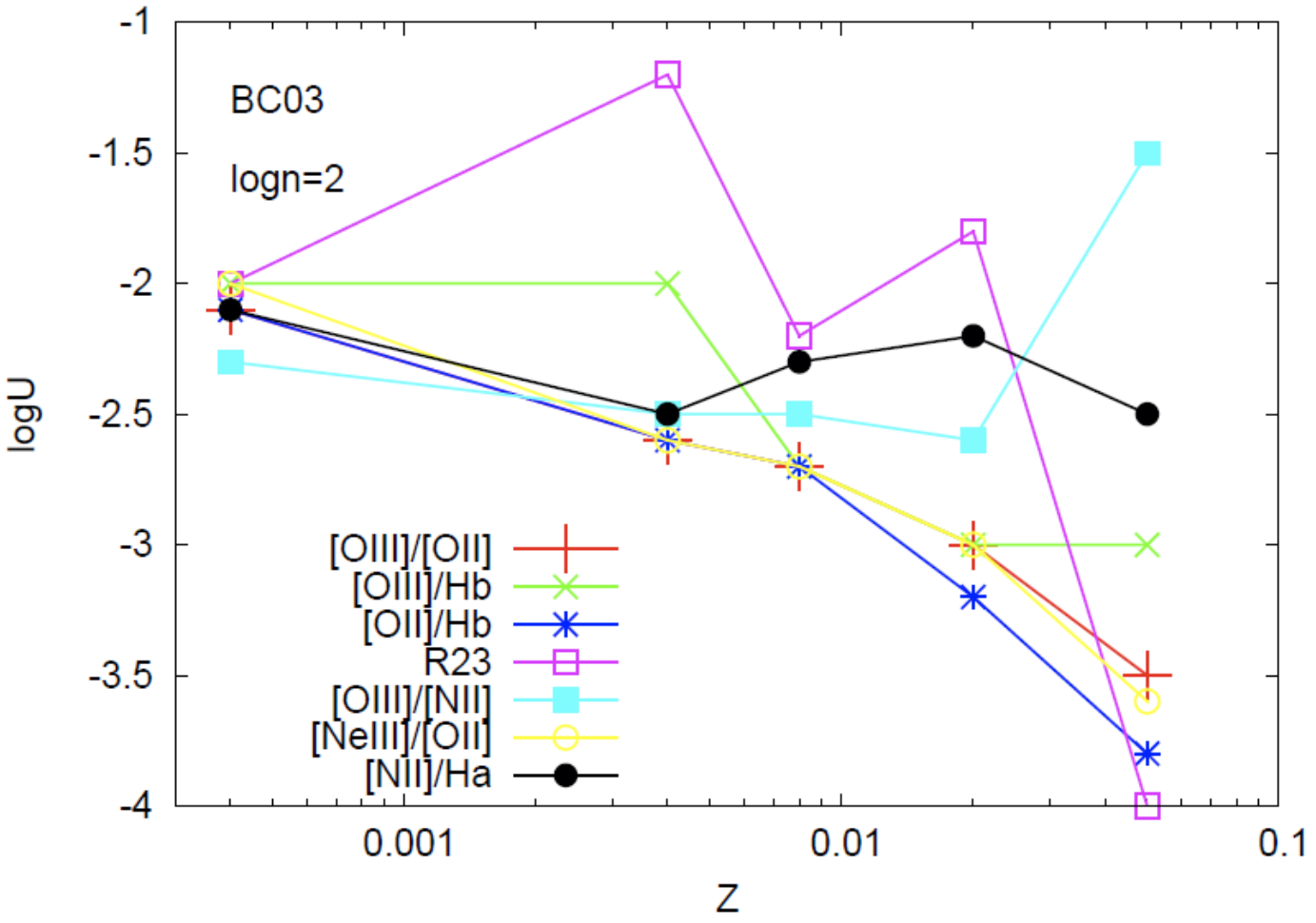
What nebular parameters?

- Z dependent logU?

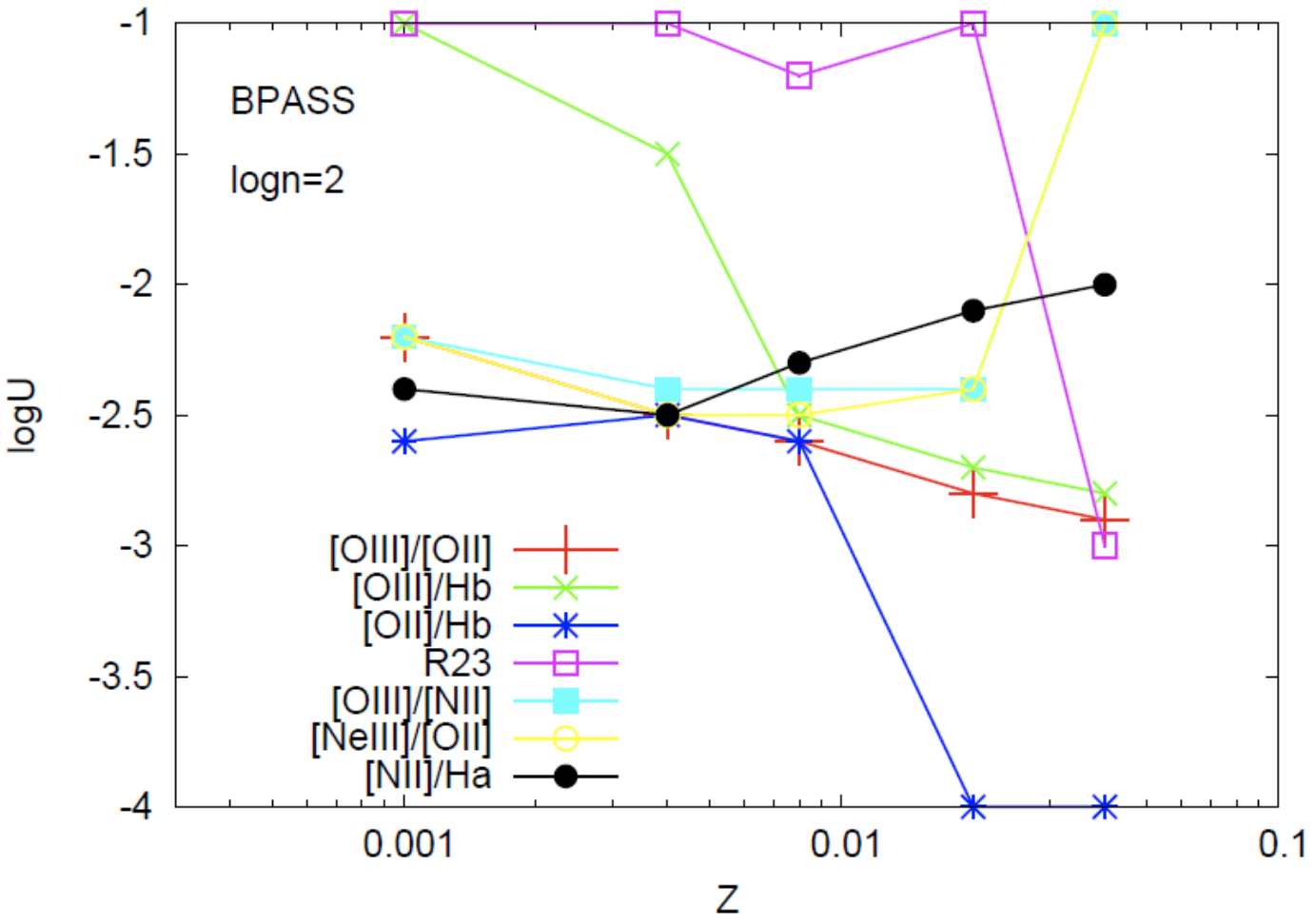




Z dependent logU?



Z dependent logU?



Summary for HII region lines

- Absolute QHIs are a problem.
  - Rotation and massive binary boost QHI by a factor of 2.
- Difference in LyC spectral shape among population synthesis models is relatively small, but be careful about highly excitation lines, e.g. HeII
- A fiducial nebular parameter set can be useful for users.
  - Metallicity dependent U (ionization parameter)?
    - Different Z-U relations obtained from different line ratios
  - A constant density, logn=2, seems OK?