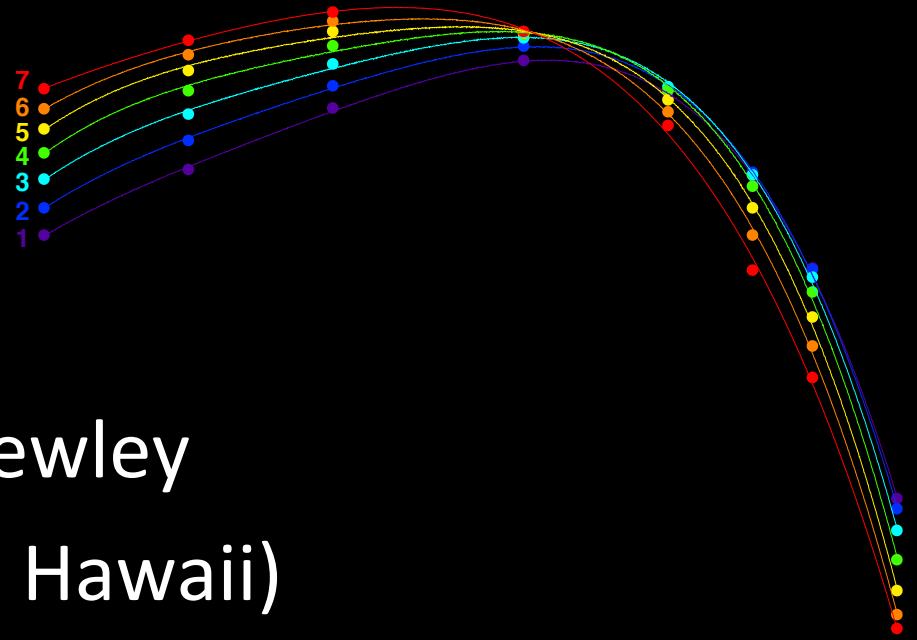
Strong Line Diagnostics



Lisa Kewley

(ANU, U. Hawaii)

Strong Line Diagnostics Summary

- Development
- Comparisons
- Problems
- Future Directions

Definitions

Metallicity = gas phase oxygen abundance

$$= \log\left(\frac{O}{H}\right) + 12$$

Ionization Parameter

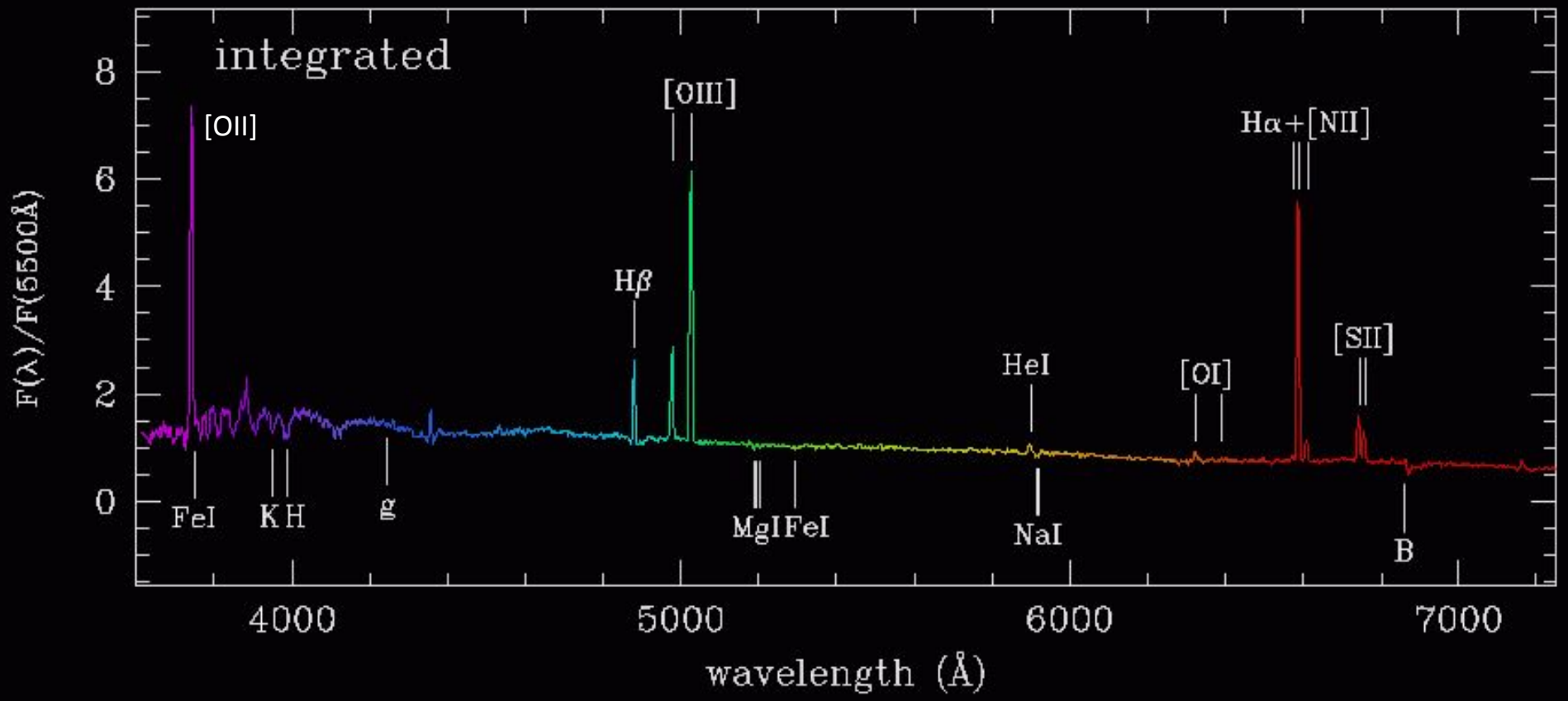
$$q = \frac{S_H}{n_H} \quad (cm/s)$$

H ionizing photons/Area/s

hydrogen density

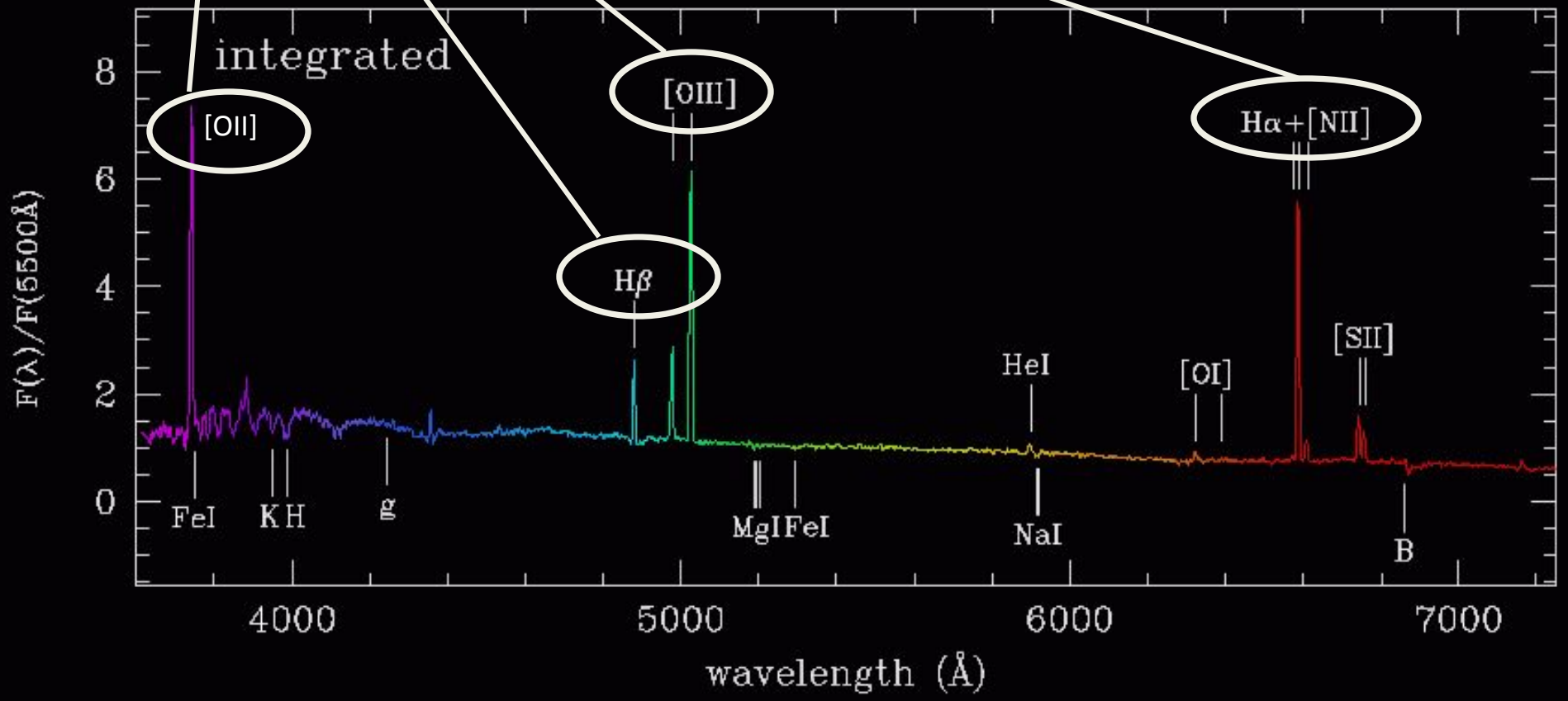
How do we measure strong-line metallicities?

Metallicity Units: log(O/H)+12
solar = 8.69 (see Asplund 2009 Annual Review)



How do we measure strong-line metallicities?

- Metallicity sensitive emission lines



Development of Diagnostics

1. Empirical: fits to Te metallicities from large HII region samples

2. Theoretical: Photoionization Models

e.g. Mappings (Sutherland & Dopita 1993, ...)

http://www.ifa.hawaii.edu/~kewley/Mappings

Cloudy (Ferland 2003)

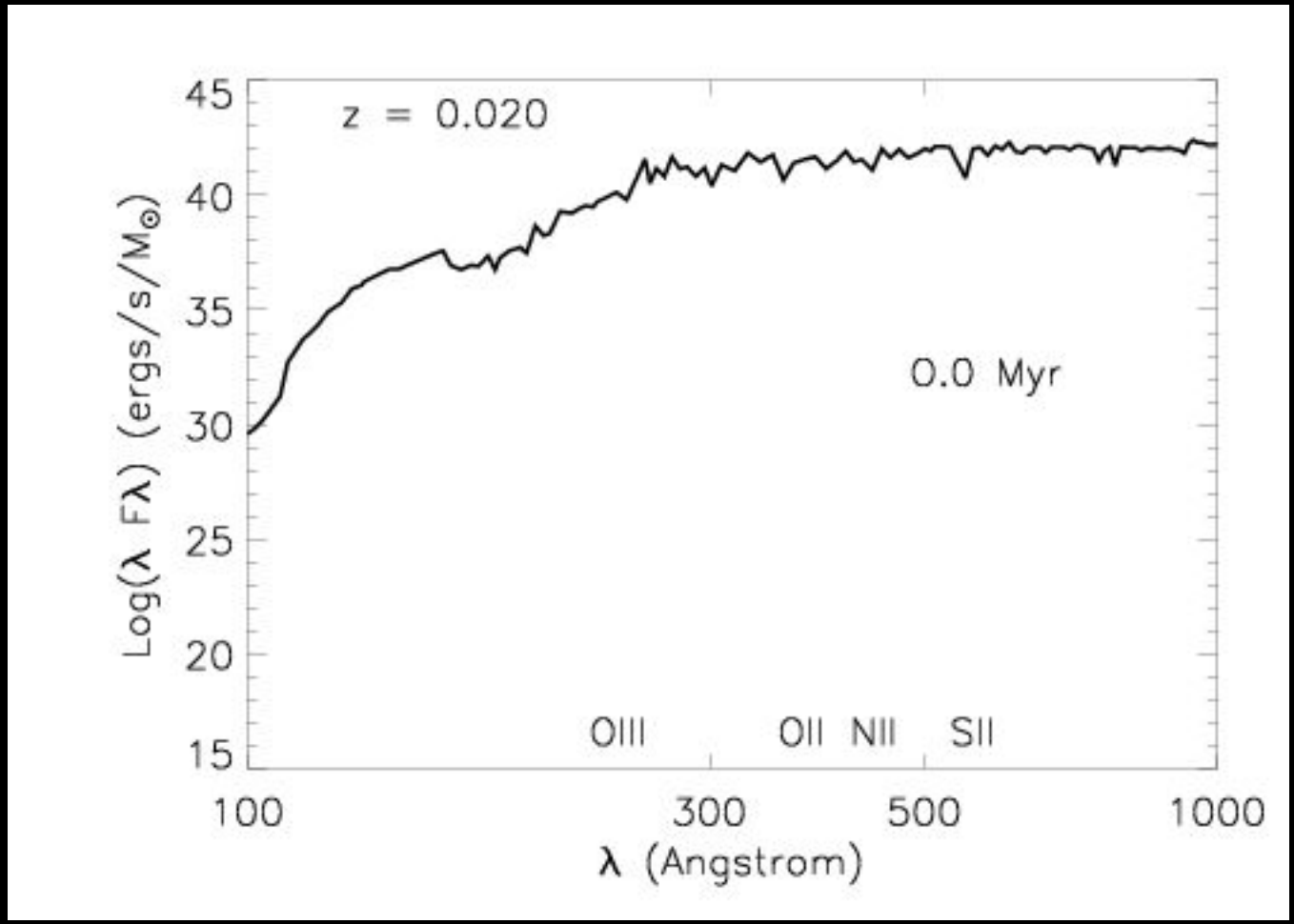
http://www.nublado.org

Stellar Population Synthesis

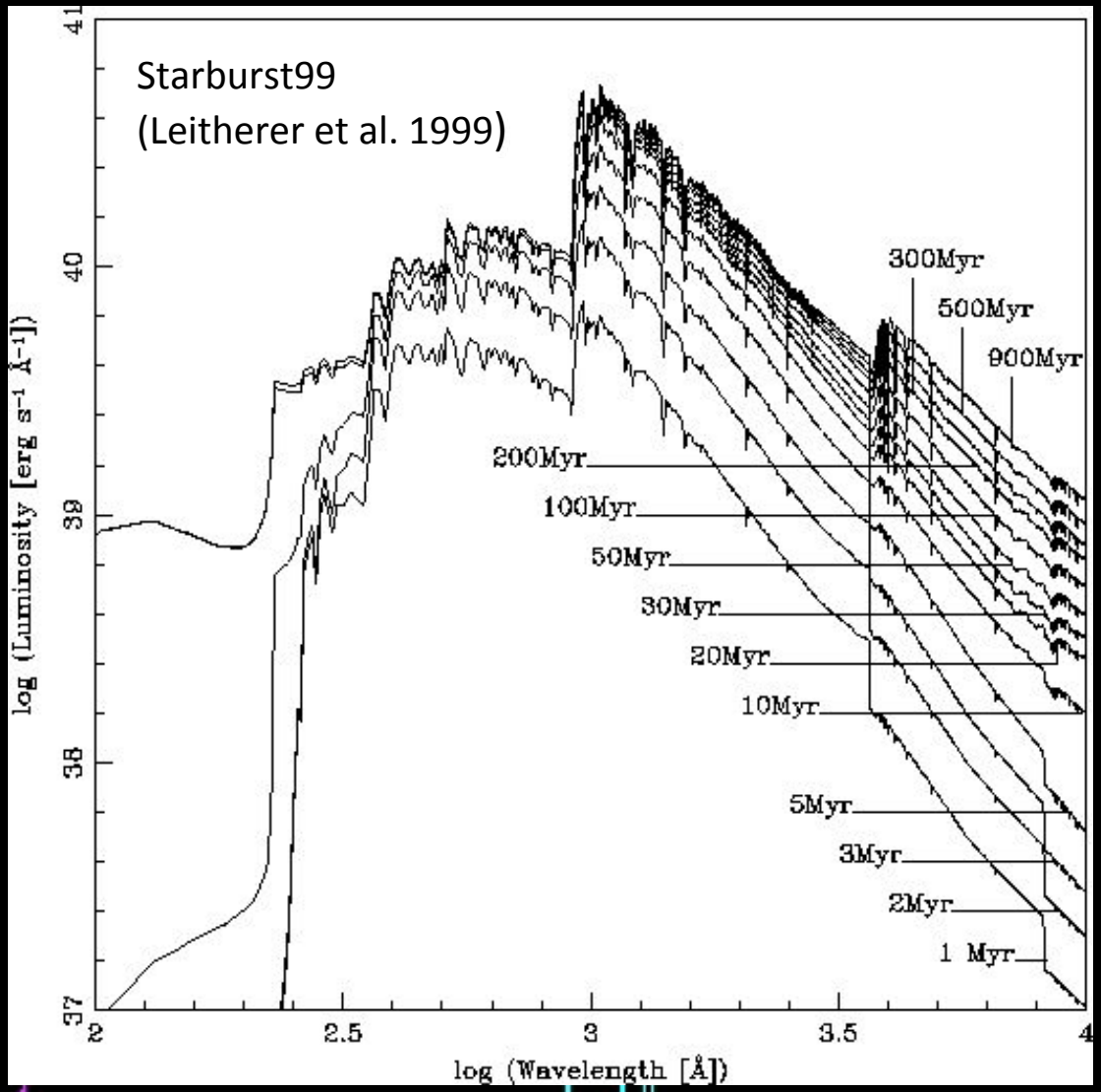
Model Ionizing radiation Field

Starburst99

Levesque, Kewley & Larson (2010)



Stellar Population Synthesis



Ionizing radiation Field

Varies with age

Photoionization Models

- Mappings (Sutherland & Dopita 1993, Groves et al. 2003,2004)
- Cloudy (Ferland 2003)

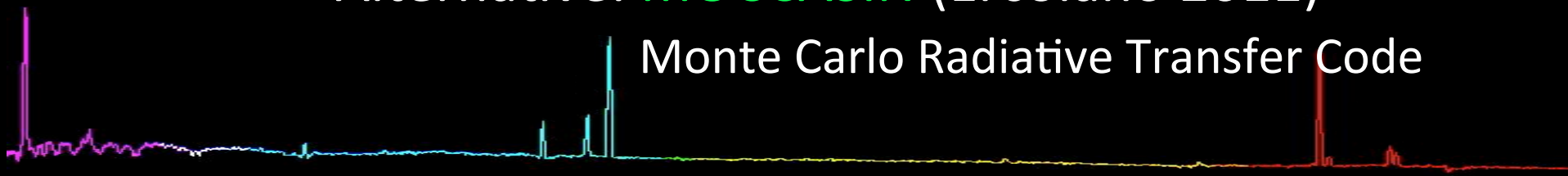
Geometry: Spherical or Plane Parallel

Dust Physics: absorption, grain charging, heating and re-emission, photoelectric heating

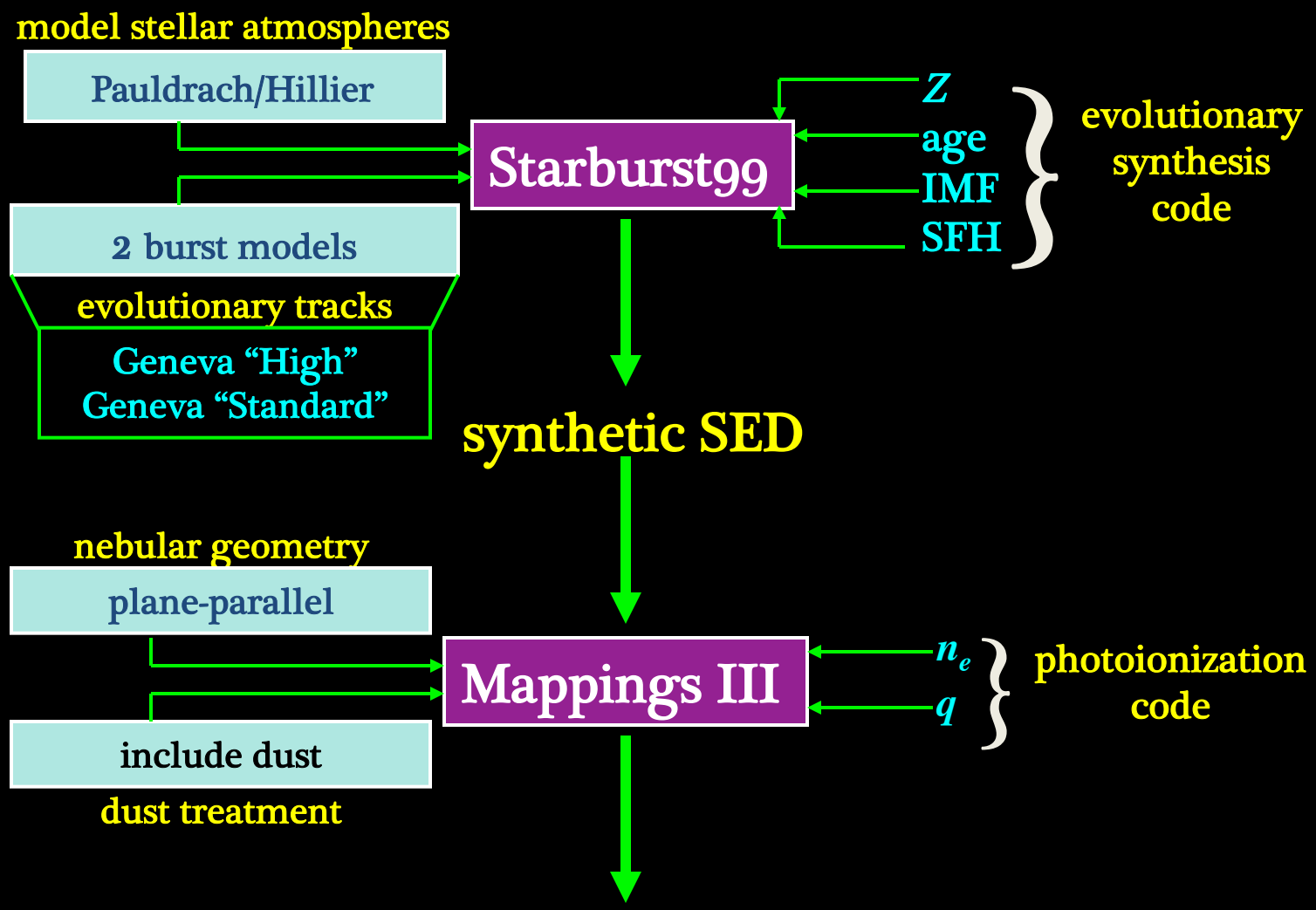
Wavelength range: typically 1A - 30,000μm

Alternative: MOCCASIN (Ercolano 2011)

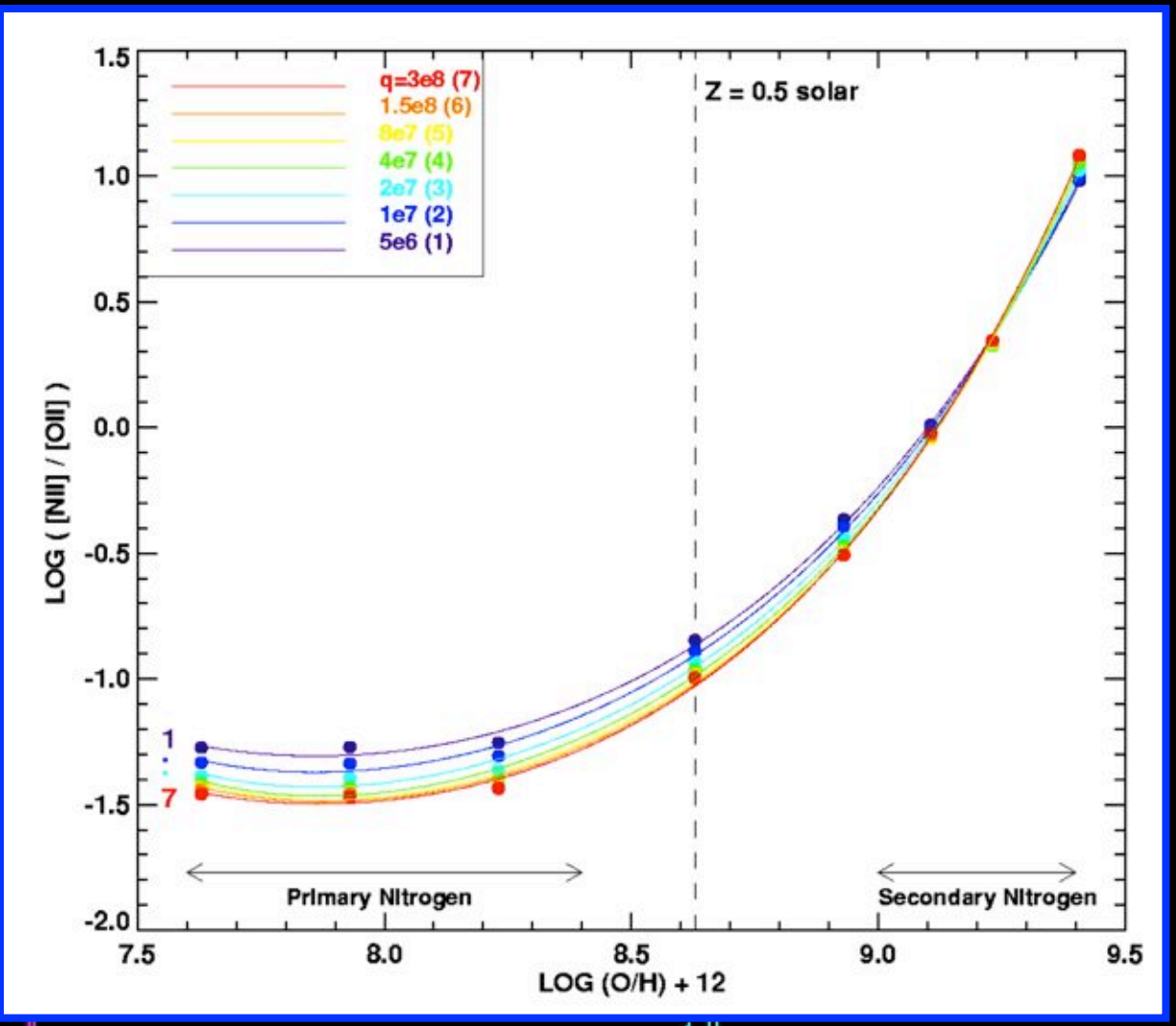
Monte Carlo Radiative Transfer Code



Stellar Population + Photoionization Models



The [NII]/[OII] Diagnostic



Advantages:

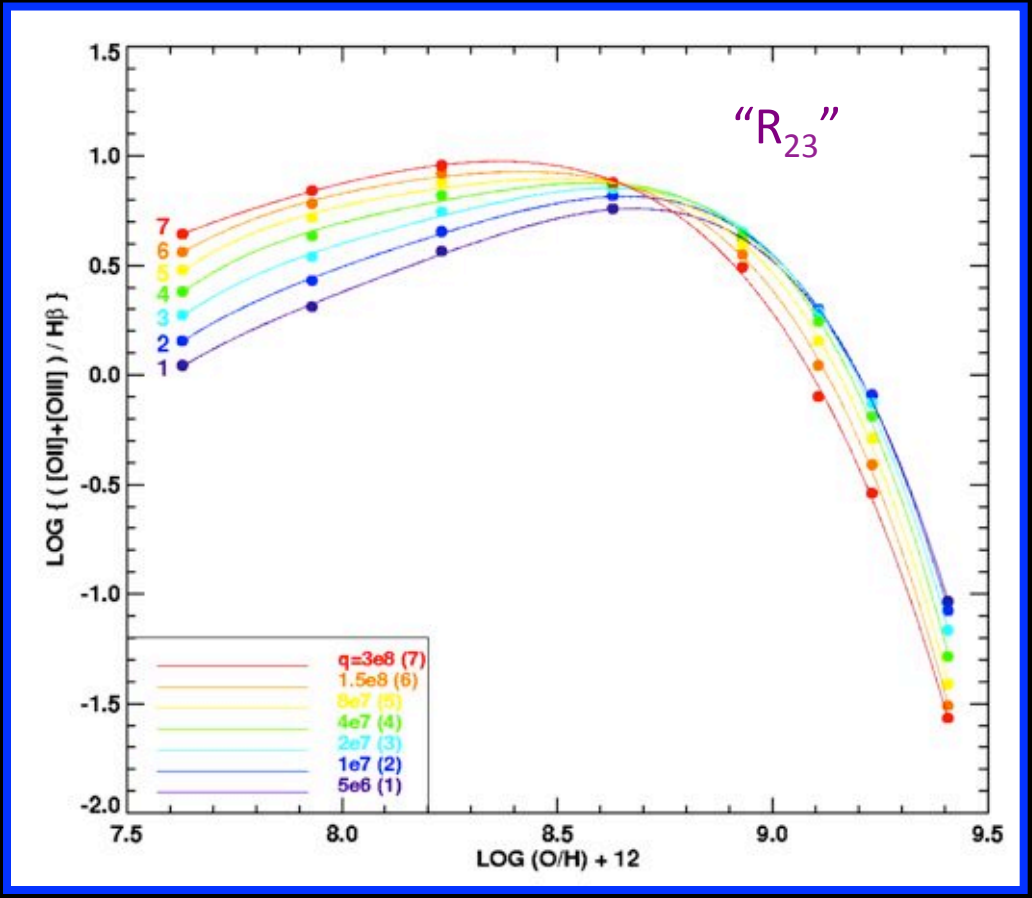
- Strong Function of O/H
- Insensitive to ionization parameter

Disadvantages:

- Sensitive to primary/ secondary N prescription
- Requires accurate extinction correction
- Does not work for log([NII]/[OII] < -1.2

Kewley & Dopita (2002, ApJS, 142, 35)

The R23 Diagnostic



Advantages:

- Strong Function of O/H
- Only uses blue lines (useful at high redshift)

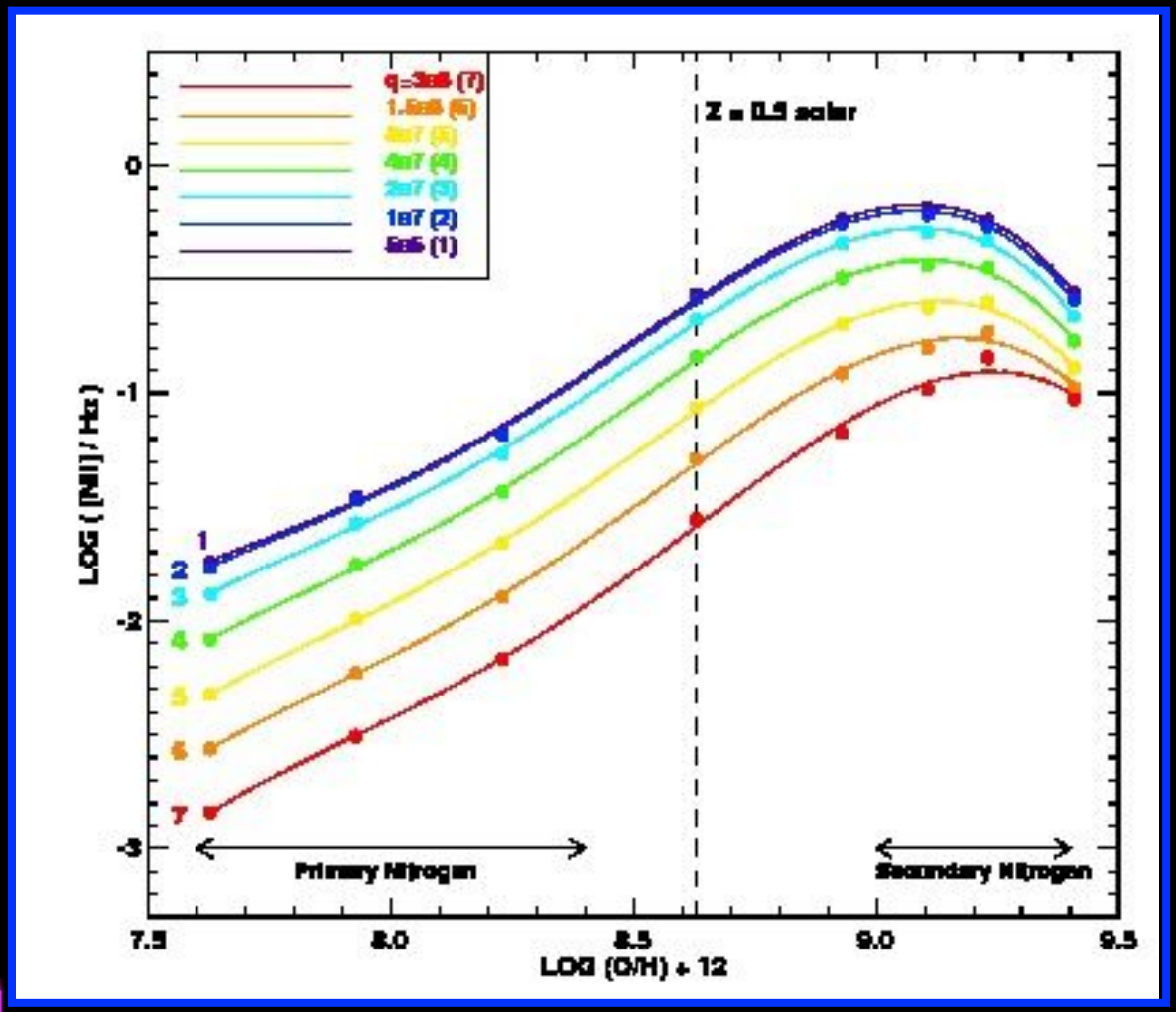
Disadvantages:

- Double valued – requires initial guess
- Sensitive to ionization parameter

Kewley & Dopita (2002, ApJS, 142, 35)

Also: Pagel (1979), McCall et al. (1985), ..., Skillman et al. (1989), McGaugh (1991),..., Zaritsky et al. (1994), Charlot (2001), ...

The [NII]/Hα Diagnostic



Advantages:

- Only uses red lines (useful at high redshift)
- Does not require extinction correction
- Does not require flux calibration

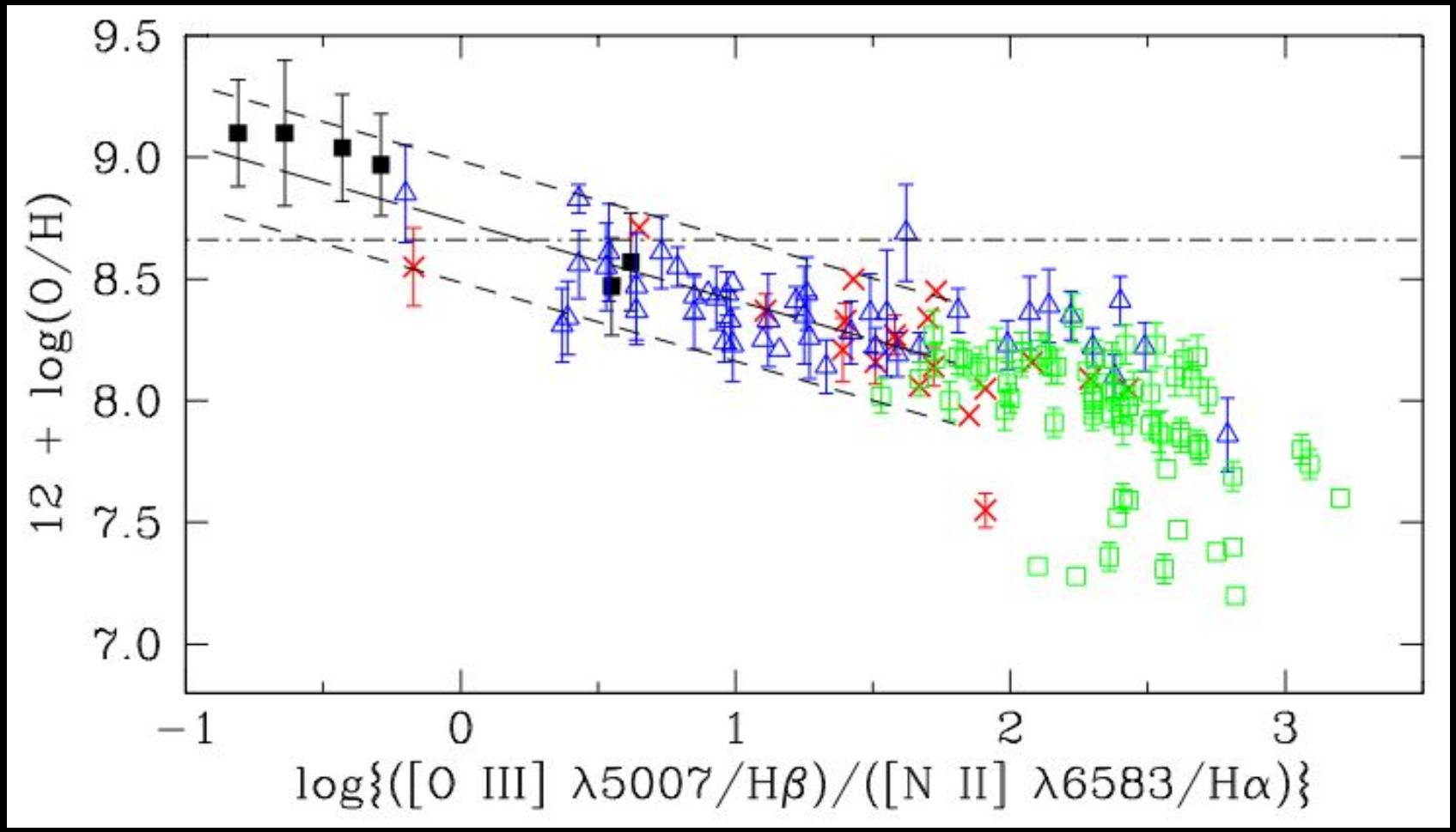
Disadvantages:

- Sensitive to ionization parameter
- Primary/secondary N dependence
- Double valued at high metallicities

Kewley & Dopita (2002, ApJS, 142, 35)

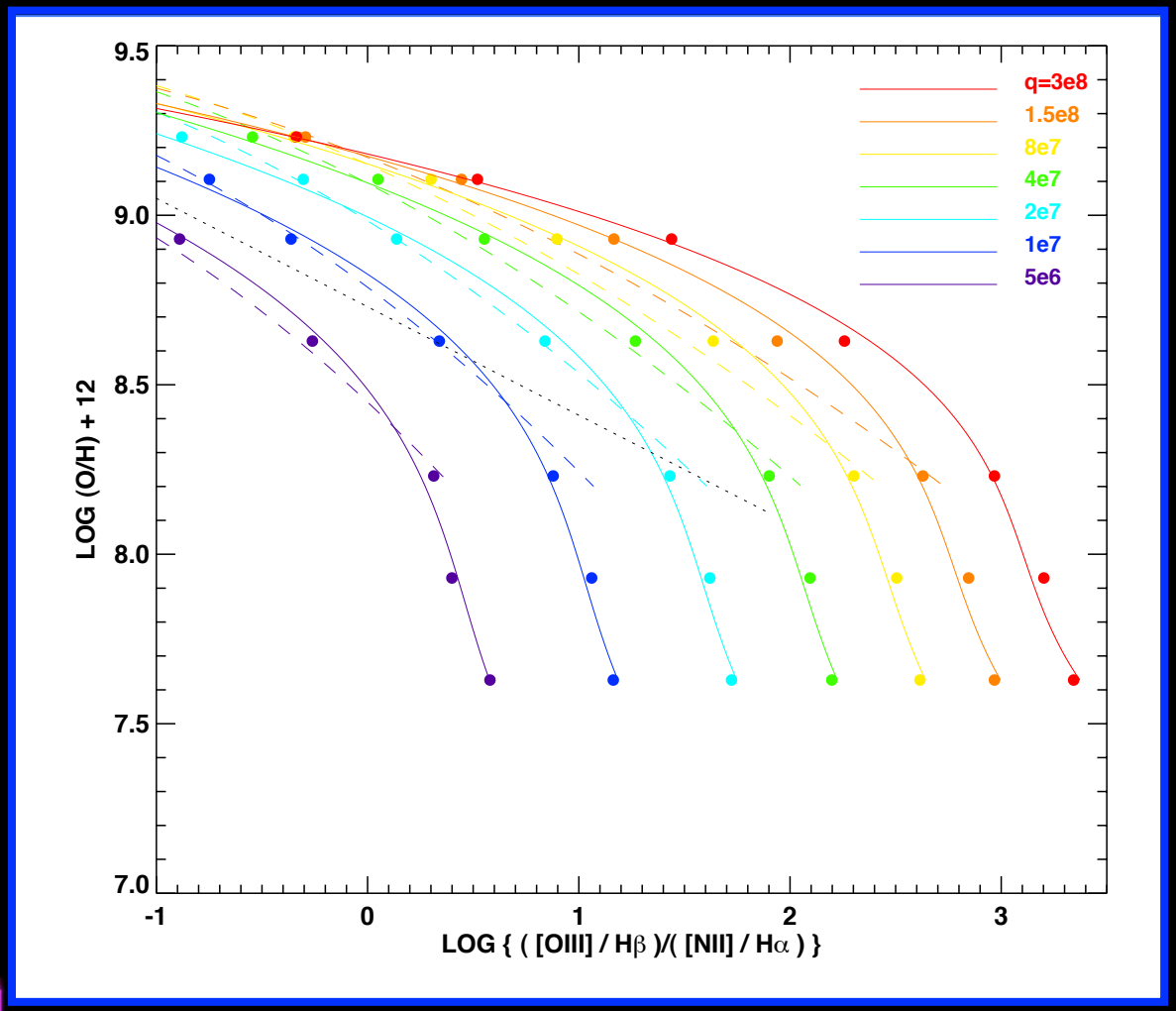
Also: Denicolo, Terlevich & Terlevich (2002), Pettini & Pagel (2004), Perez-Montero & Contini (2009)

The O3N2 Diagnostic - Empirical



Pettini & Pagel (2004)

The O3N2 Diagnostic - Theoretical



Advantages:

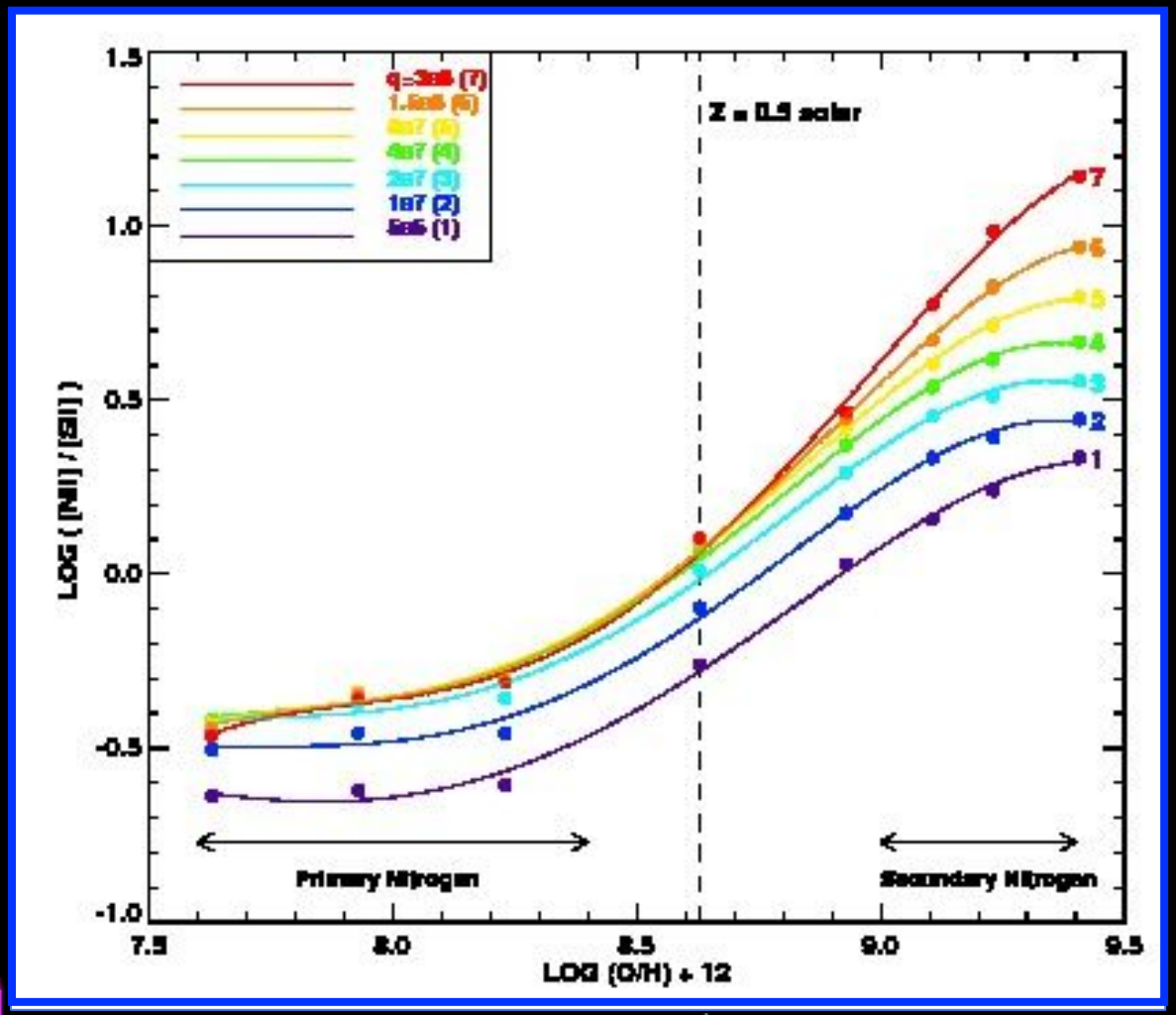
- Does not require extinction correction
- Does not require flux calibration

Disadvantages:

- Very sensitive to ionization parameter

Also: Pettini & Pagel (2004)

The [NII]/[SII] Diagnostic



Advantages:

- Does not require extinction correction
- Does not require flux calibration

Disadvantages:

- Very sensitive to ionization parameter

Also: Pettini & Pagel (2004)

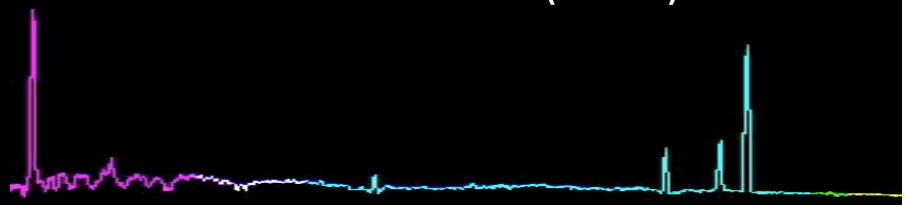
Kewley & Dopita (2002, ApJS, 142, 35)

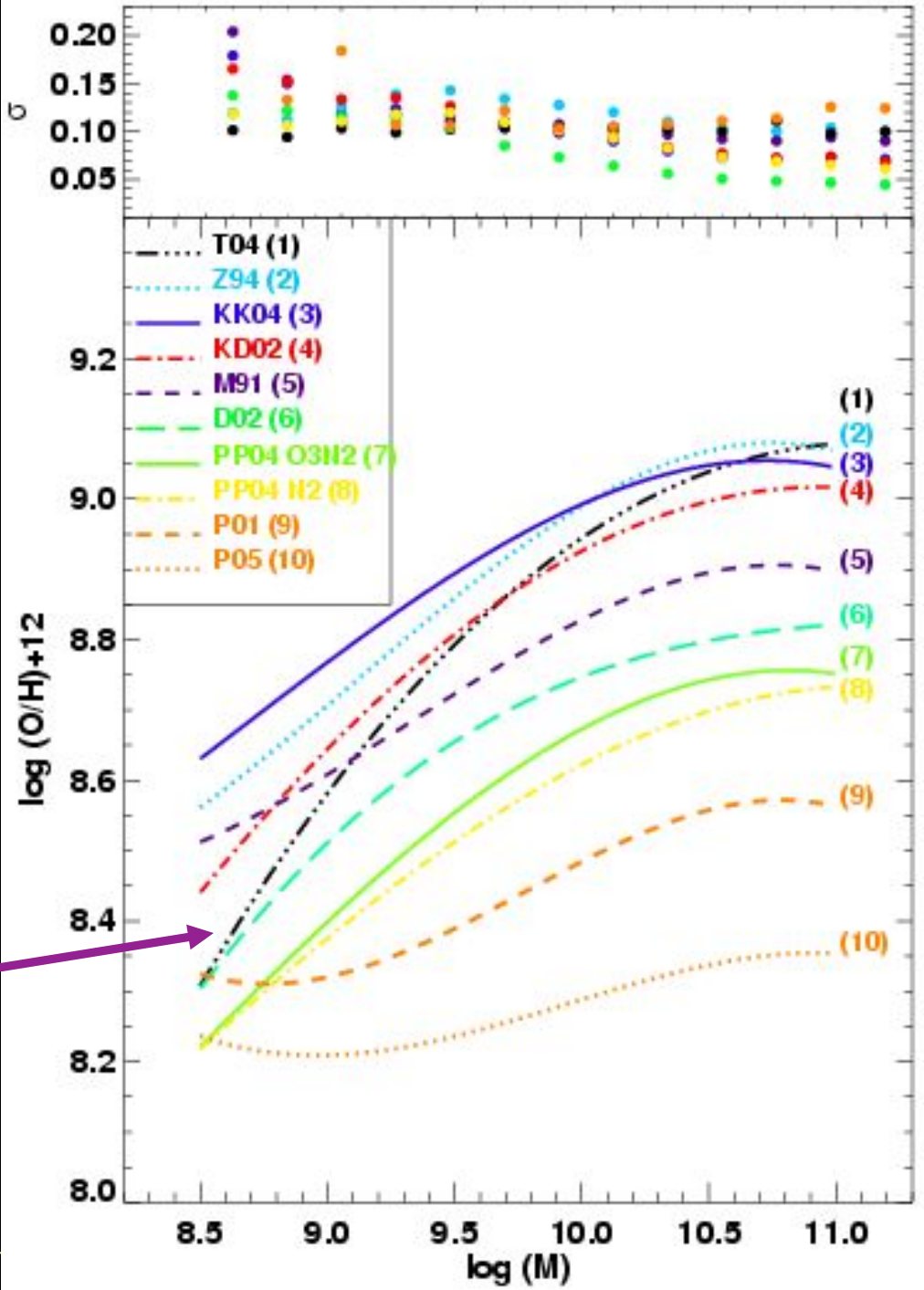
Strong Line Metallicity Discrepancies

Kewley & Ellison (2008)

SDSS mass-metallicity relation

Tremonti et al. (2004)





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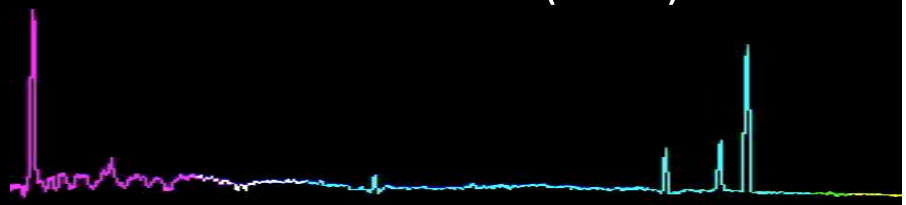

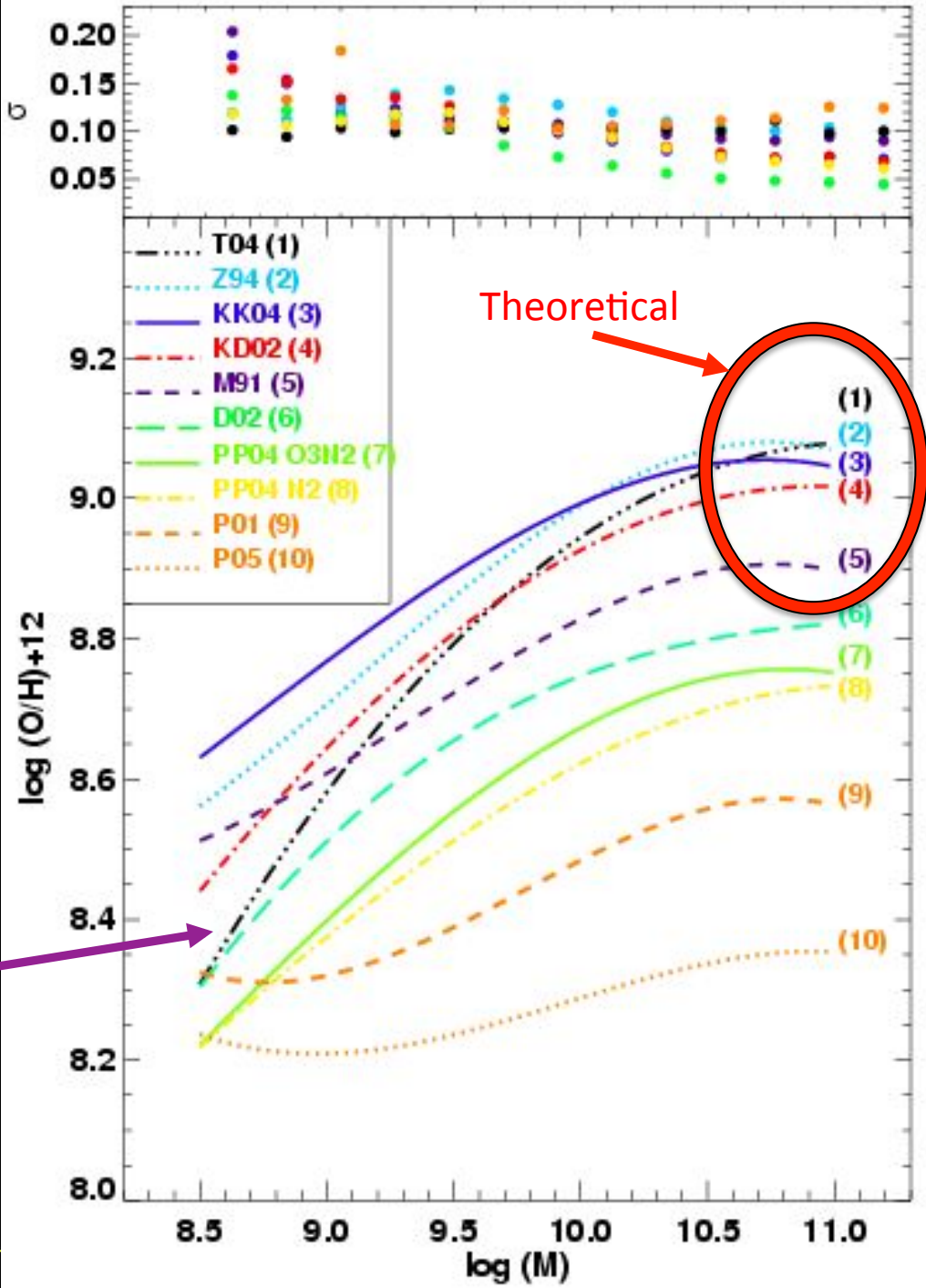

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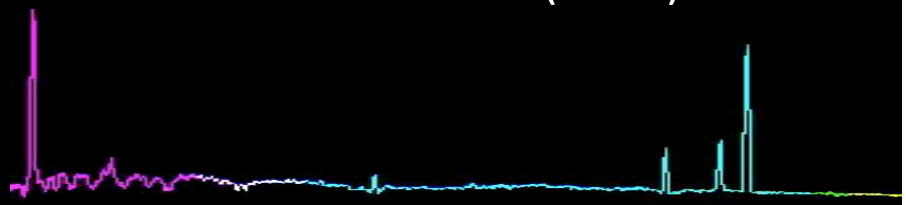

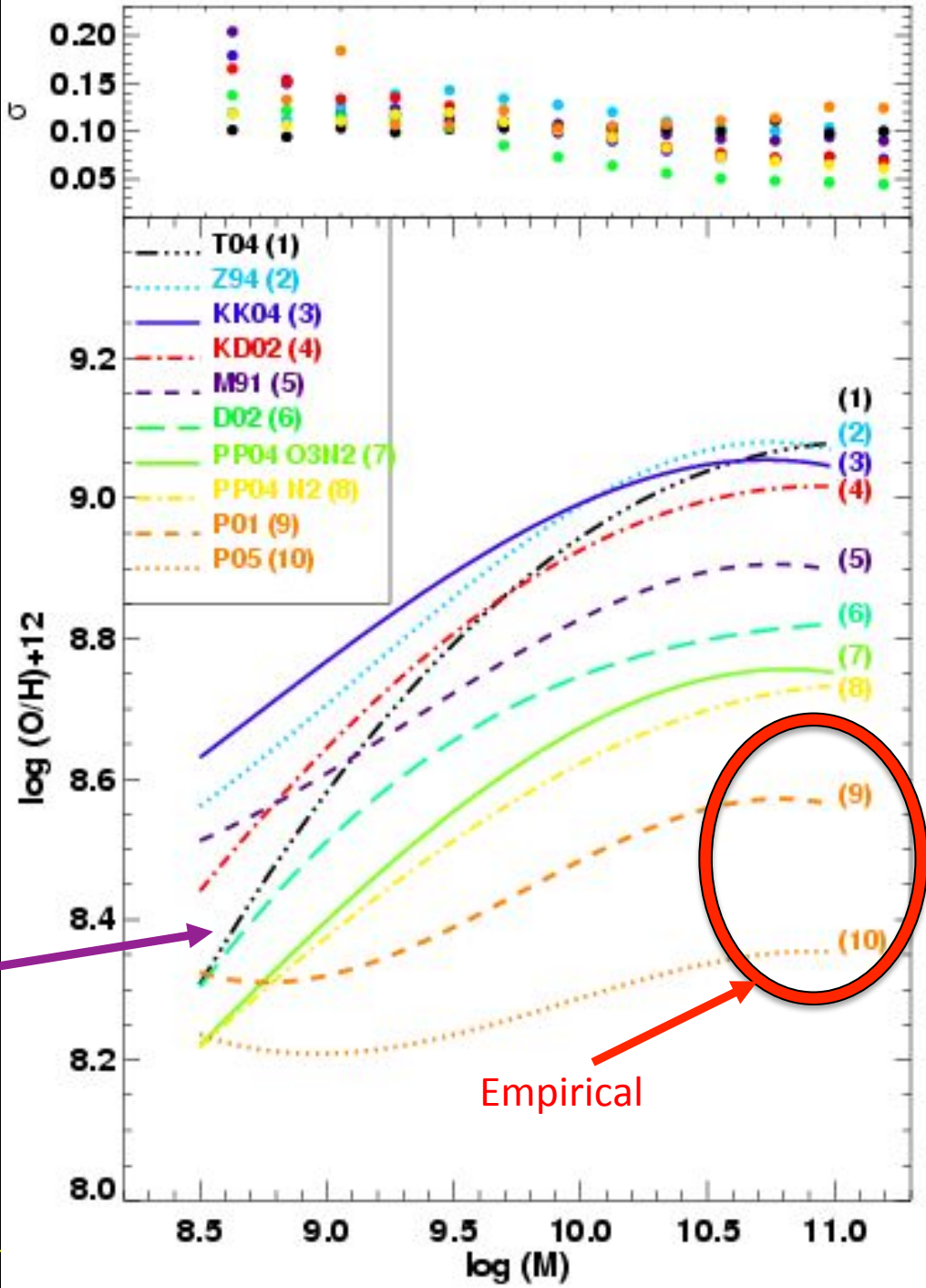

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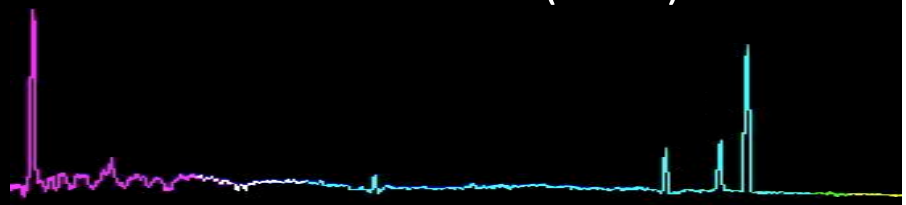
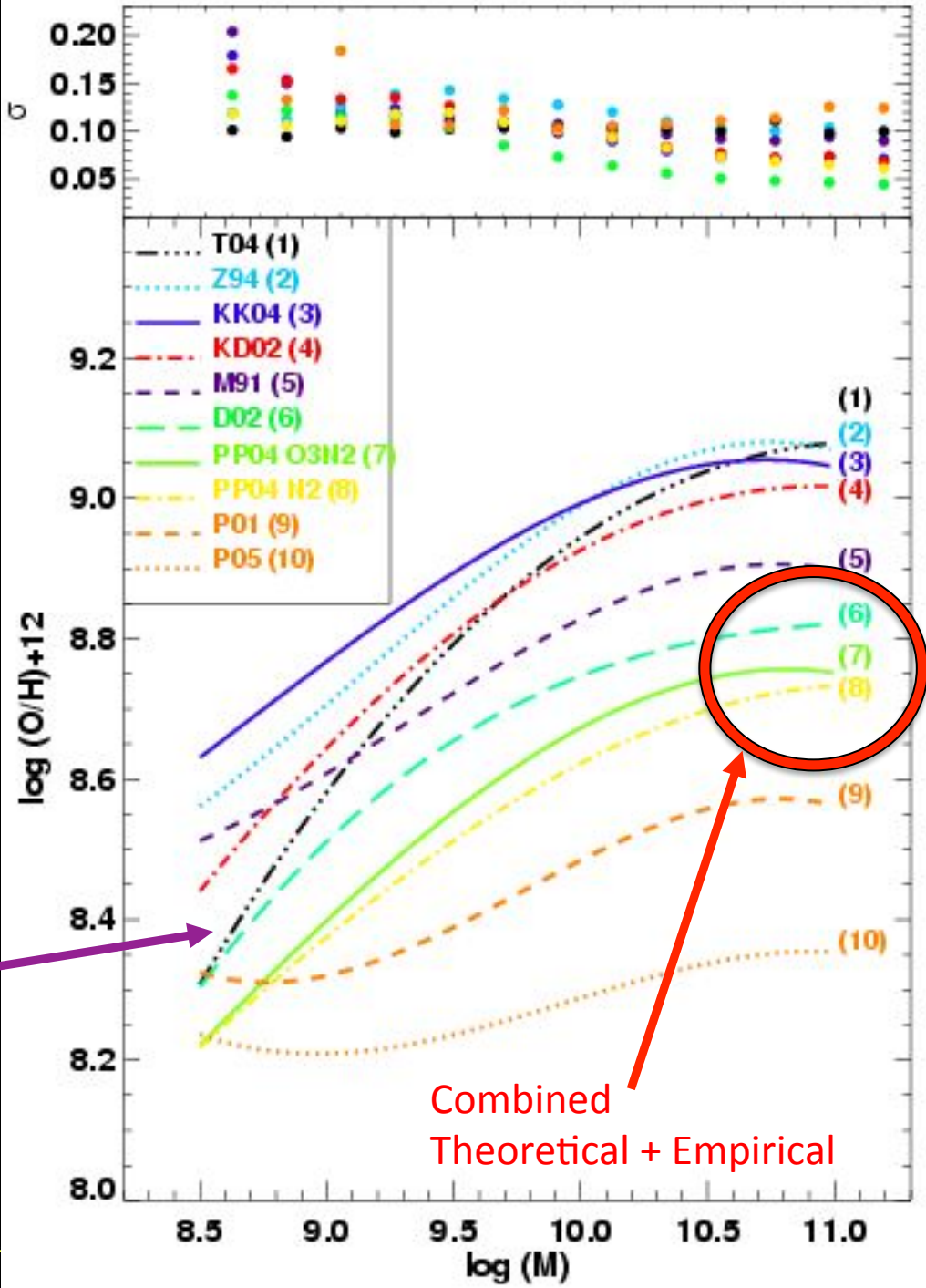


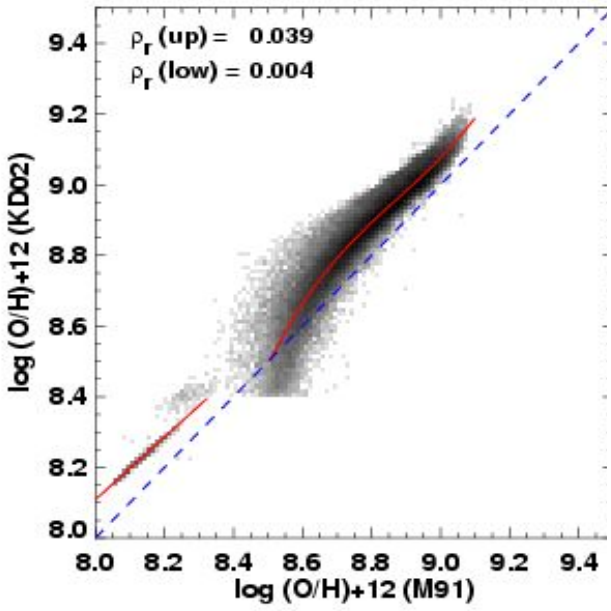


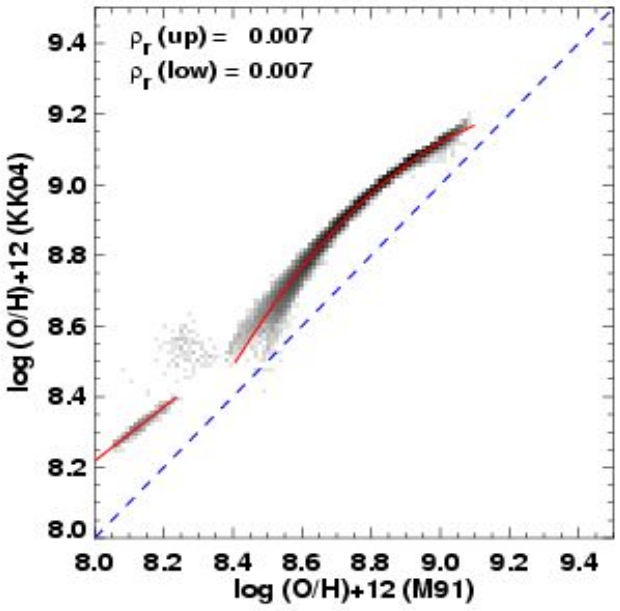
Metallicity Diagnostic Discrepancies

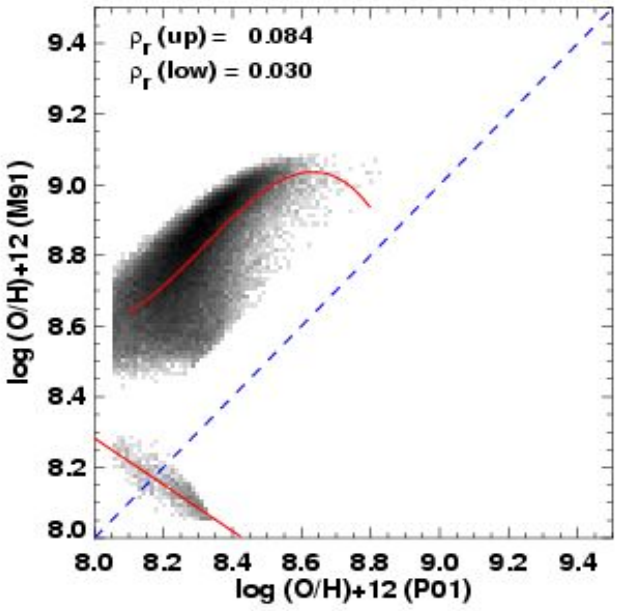
Simple fits to the offsets between different methods

=> Allows relative metallicities to be determined

⇒ But does not address the cause of the discrepancies

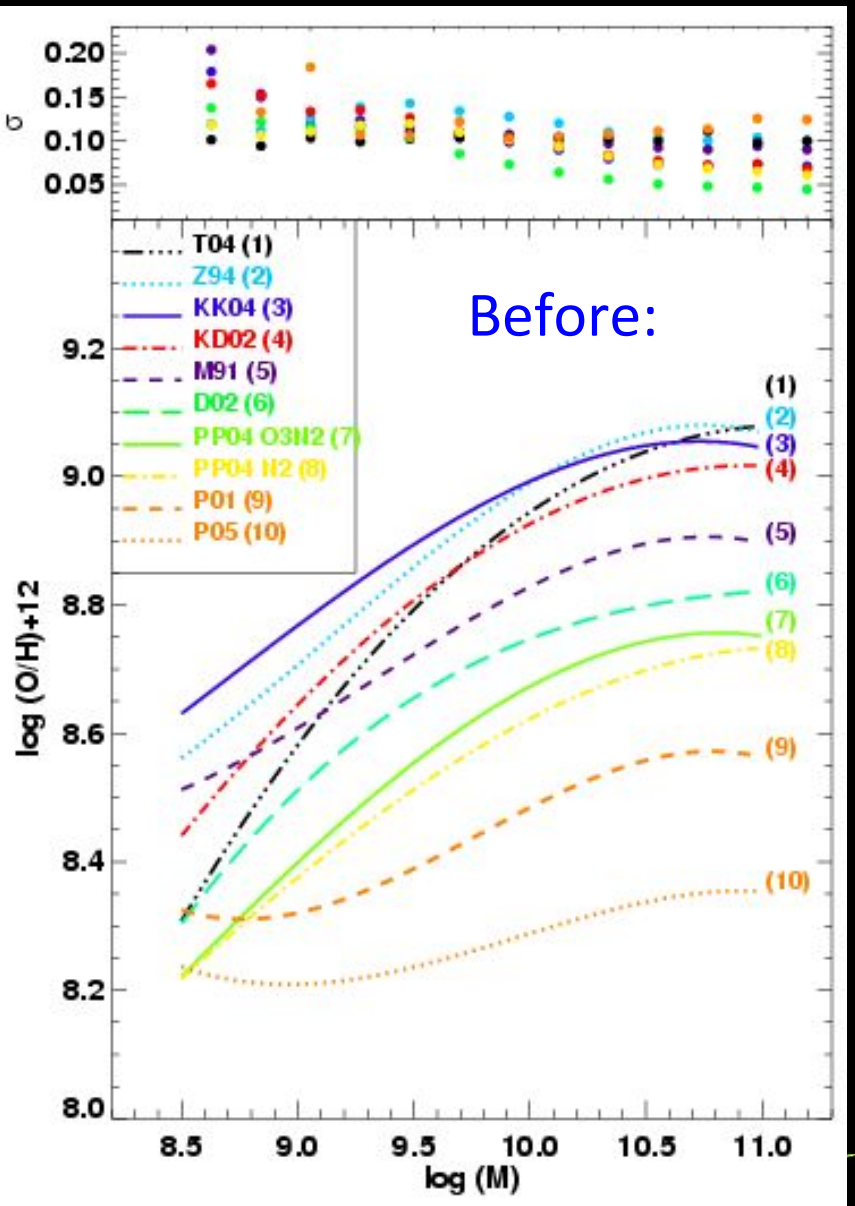


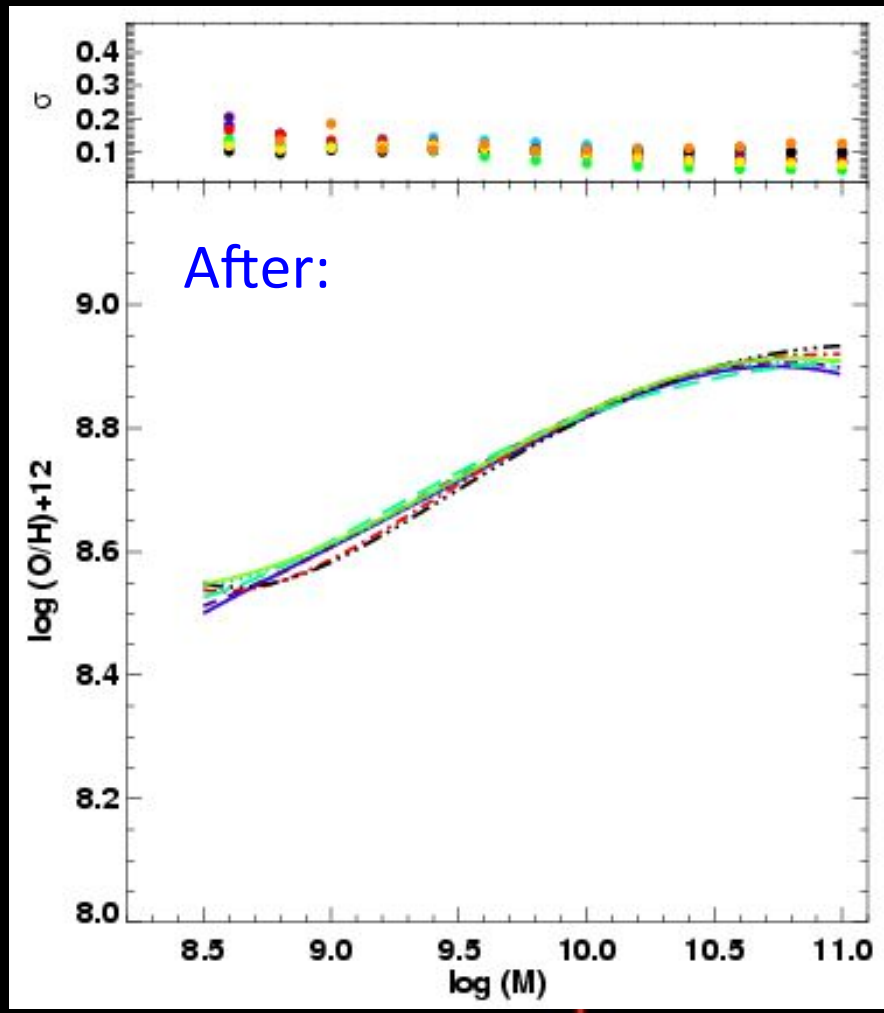




Kewley & Ellison (2008)

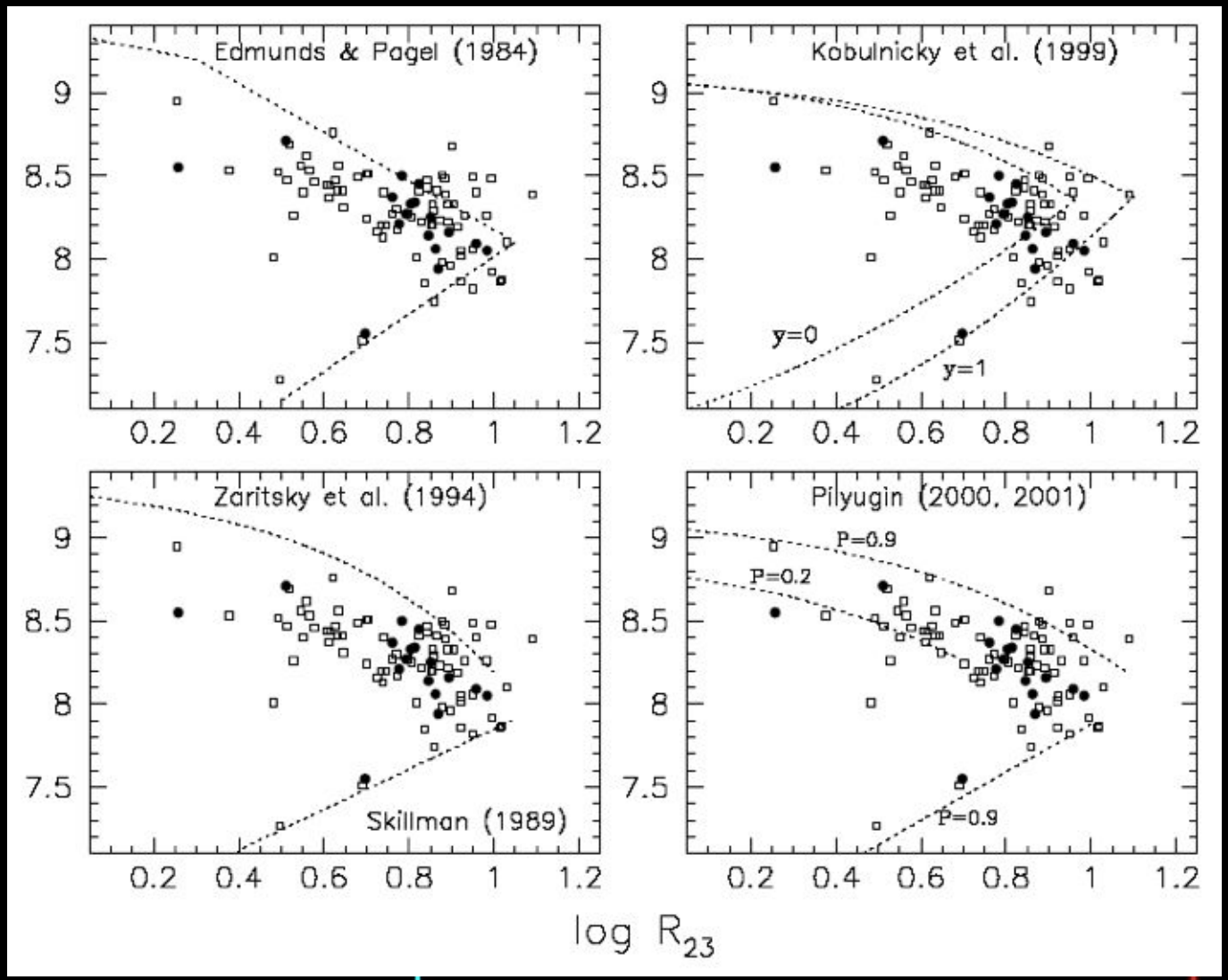
Metallicity Diagnostic Discrepancies





Kewley & Ellison (2008)

Strong lines vs Auroral Lines



Garnett, Kennicutt, Bresolin (2004)

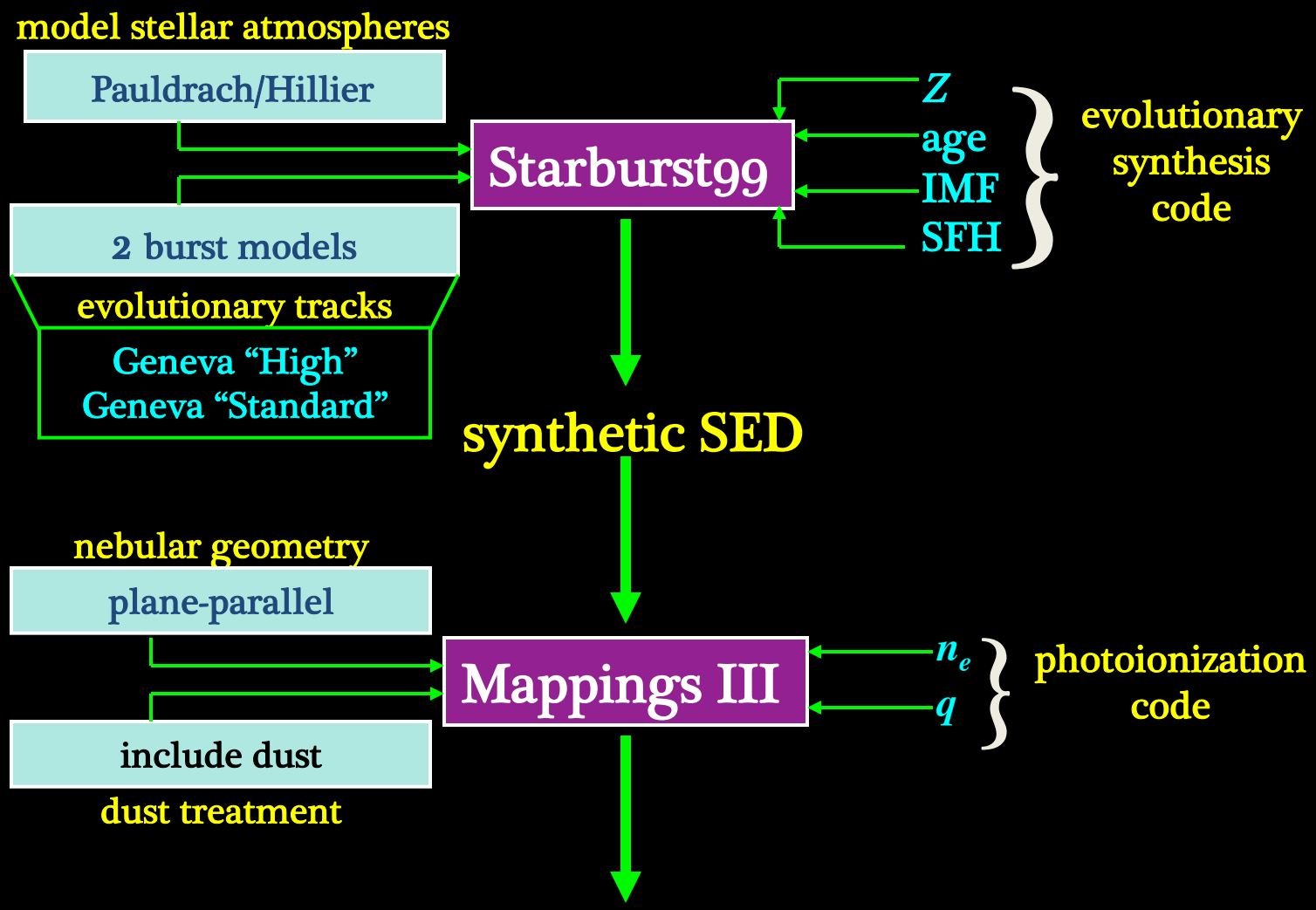
Solutions?

- Tailored photoionization modeling of individual simple HII regions (J. Zahid's PhD thesis)

- Investigation of photoionization model physics (e.g. D. Nicholls' PhD thesis)

- Broad investigations into temperature gradients and variations and their effect on the T_e method.
  (e.g., Lopez-Sanchez et al. 2012, arXiv:1203.5021
  Pena-Guerrero, Peimbert & Peimbert 2012, ...)

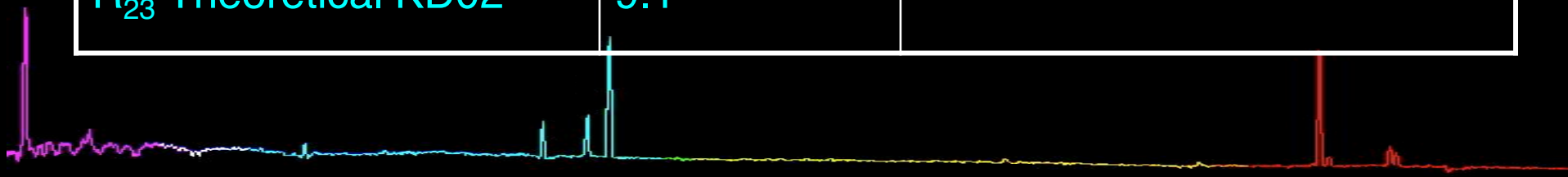
Stellar Population + Photoionization Models



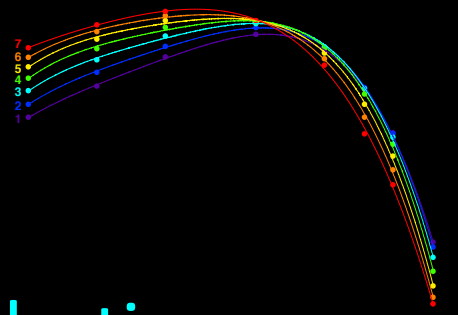
Tailored vs Generalized models

Case study: CCM 10 in M51

Method	log(O/H)+12	Reference
Te method	8.8 ★	Garnett et al. (2004)
Cloudy v. 74	9.1	Garnett et al. (2004)
Cloudy v.90.04	8.8 ★	Garnett et al. (2004)
R_{23} Theoretical M91	9.0	
[NII]/[OII] Theoretical KD02	9.1	
[NII]/Hα Theoretical KK04	8.8 ★	
R_{23} Theoretical KD02	9.1	



Future Directions



- New Optical Diagnostics – Kappa Distribution (see David Nicholls' talk)
- New UV Diagnostics – UV is significantly affected by Kappa
- Tailored HII region models to IFS data of nearby single star HII regions

Tailored vs Generalized models

Parameter	Tailored	Generalized
Ionizing Radiation Field	Mihalas (1972)	Starburst99
Turbulence	30 km/s	none
Filling Factor	0.02	1
Dust	No grain heating or charging	Grain heating and charging included
Oxygen Atomic Data?	different data sets v.74 to v.20.04 (opacity project data)	opacity project plus data circa 1990

and many more...