Using Distant Galaxies to Constrain the Ionizing Photon Budget of Massive Stars

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Motivation

The ionizing photon production rate (Q_H) [s^{-1}] of massive stars is poorly constrained.

Ionizing photons: $\lambda < 912$ Å

Massive stars: $M > 8\ M_\odot$

Q_H determines:

- Nebular energy budget
- Used to measure the star formation rate galaxies
- When the universe was reionized

Flexible Stellar Population Synthesis

Flexible Stellar Population Synthesis (FSPS) Models (Conroy et al. 2009):

- Many properties affect observations, including Q_H
- FSPS allows you to set these properties, providing a bridge between models and observations

We use FSPS to create complex stellar populations by varying the star formation history, metallicity, and dust of a galaxy.

Observables allow us to isolate Q_H such as the following proportionality: $\mathbf{L_{H\alpha} \propto Q_H}$

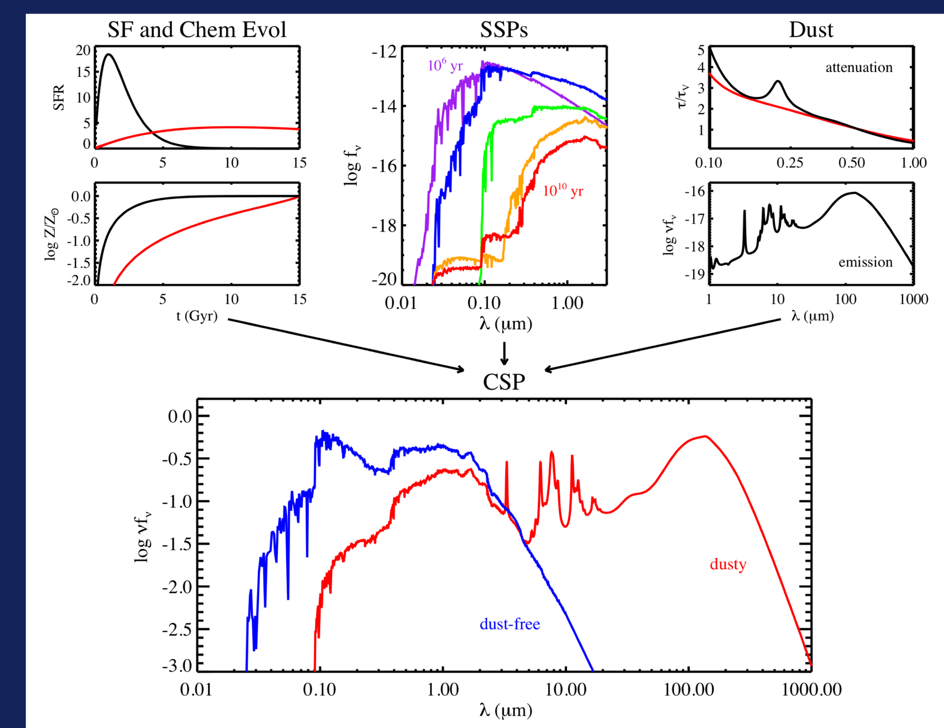

Figure 1. Components of a Composite Stellar Population (Conroy et al. 2013)

3D-HST Survey

- Require an Hα, IR and UV detection
- $0.7 < z < 1.5$, for Hα detection on G141
- Hα S/N > 5
- ~3,500 of 200,000 galaxies met criteria

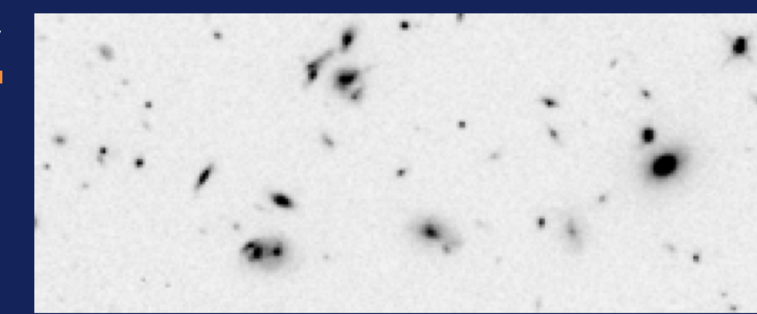

Figure 2: *HST* WFC3 G141 grism spectra of a GOODS-South pointing (above, Brammer et al. 2012)

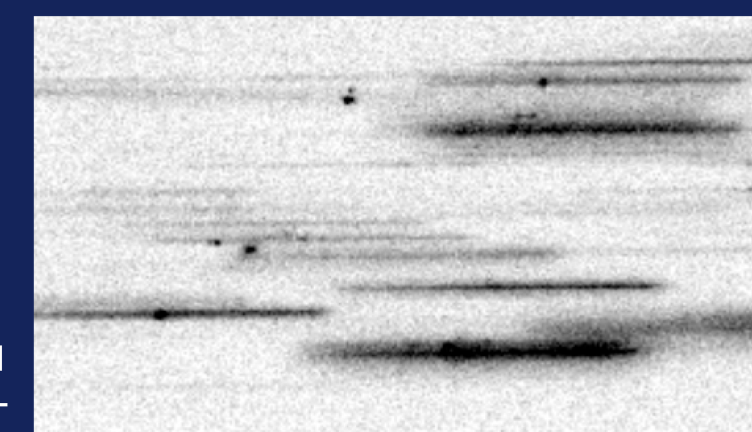

Figure 3. *HST* WFC3 F140W direct image of same GOODS-South pointing (below)

Isochrones

- Contain different massive star models whose integrated predictions of Q_H vary by a factor of two

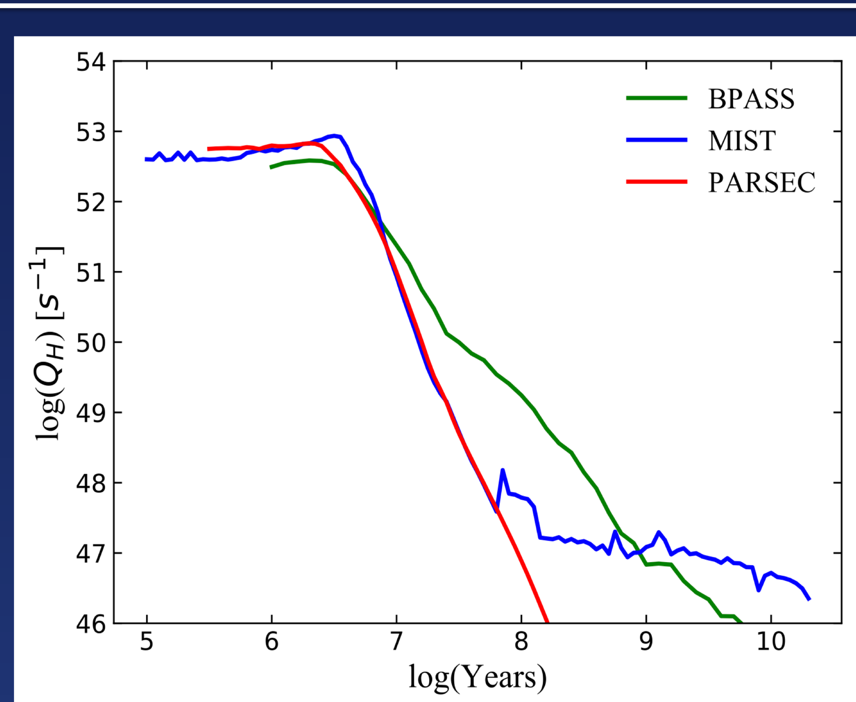

Figure 4. Q_H over time for each isochrone

Binary interactions (Eldridge et al. 2017)

Rapid stellar rotation (Choi et al. 2016)

Standard evolution (Bressan et al. 2012)

Isolating the Effects of Q_H

The goal of this grid space is to isolate the effects of Q_H. The axes are Hα Emission Line Luminosity ($L_{H\alpha}$) normalized in two ways:

- Stellar continuum → Hα Equivalent Width (Hα EW)
- Galaxy star formation rate → IR and UV Luminosity ($L_{IR} + L_{UV}$)

Grid Parameters

τ: Modulates star formation history where SFH = $Ae^{-t/\tau}$

Dust: Modulates the amount of dust in the galaxy

Log(Z/Z$_\odot$): Modulates metallicity in the galaxy

Data: 3D-HST Survey Galaxies

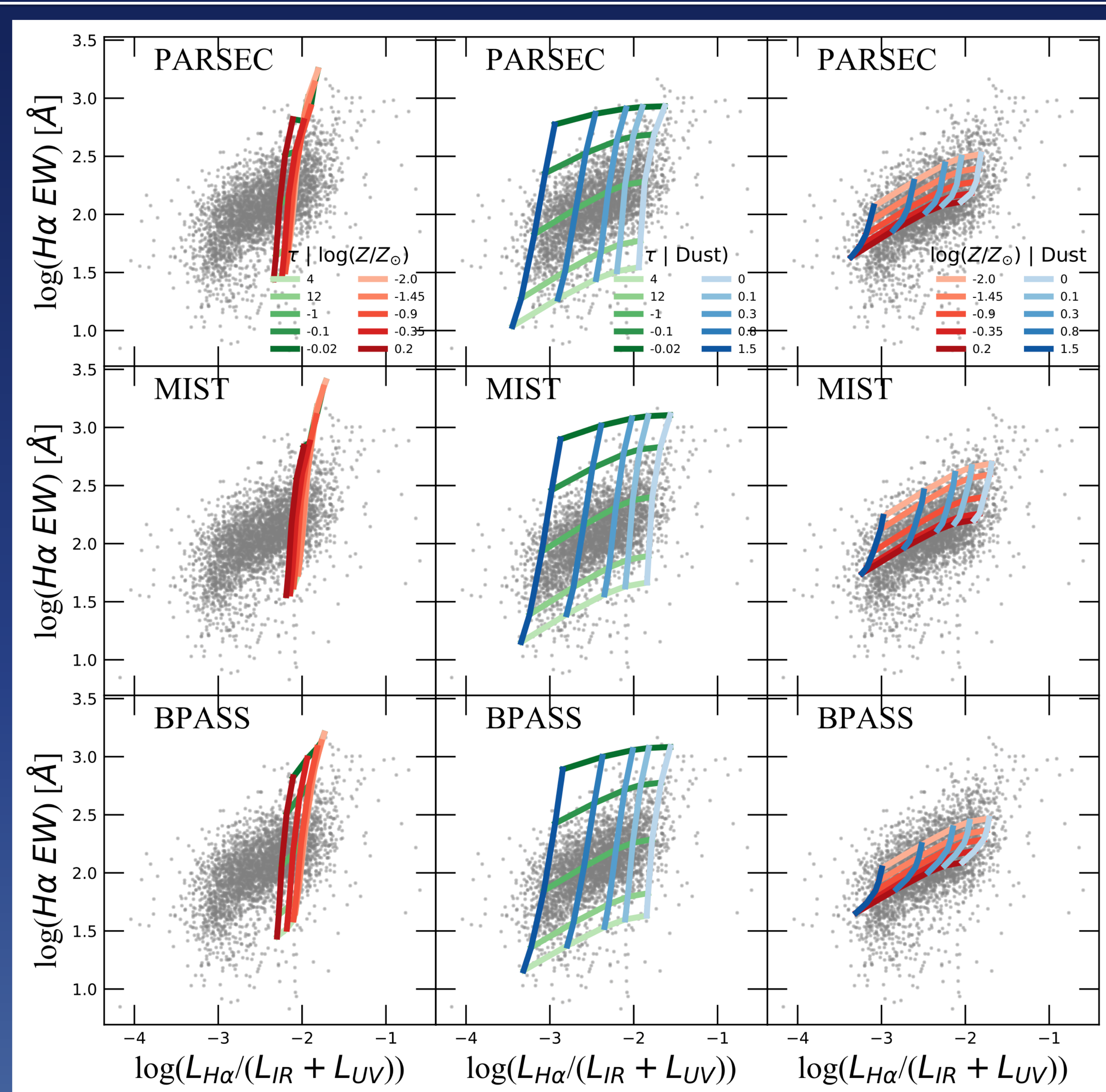

Figure 5. FSPS grid space showing BPASS, MIST and PARSEC Isochrones overlayed onto 3D-HST data

Conclusions

- Expected variation in SFH, dust and metallicity can explain most of the variation in the grid space
- The envelope of highly star forming galaxies can't be reproduced with 'normal' galaxy variation. May require more exotic explanation (as described in Future Work)

Future Work

- Investigate the effects of IMF change, bursty star formation, or altered massive stars models to explain highly star forming galaxies
- Estimate galaxies properties on object by object basis using constraints from photometry

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