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

Evan Haze Núñez[1,2], Joel Leja[2], Charlie Conroy[2]

[1]California State Polytechnic University, Pomona, [2]Harvard-Smithsonian Center for Astrophysics

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: $\mathbf{L_{H\alpha} \propto Q_H}$

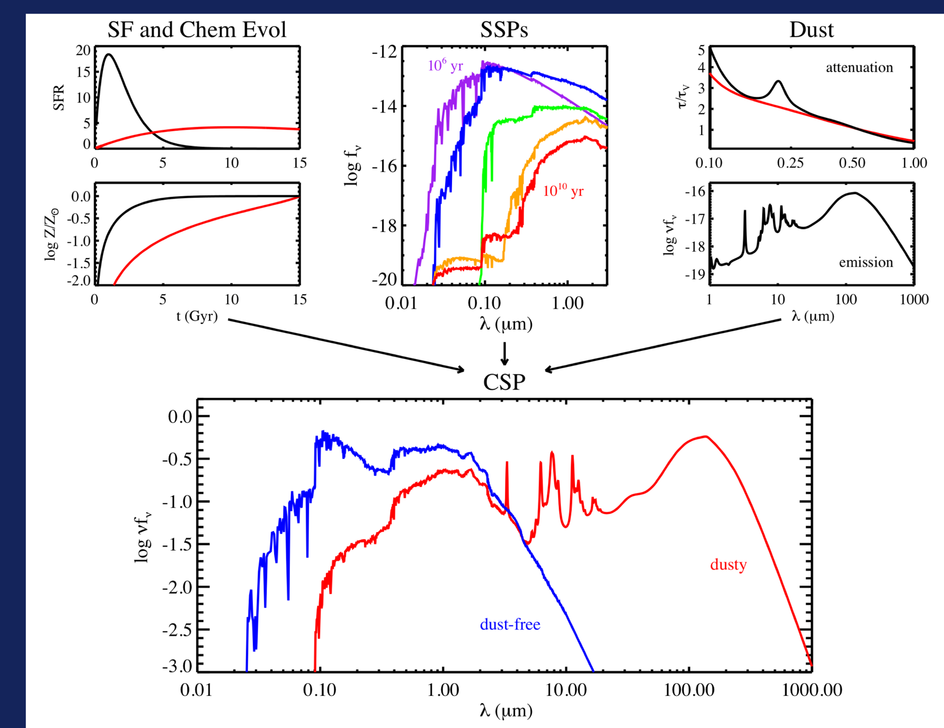
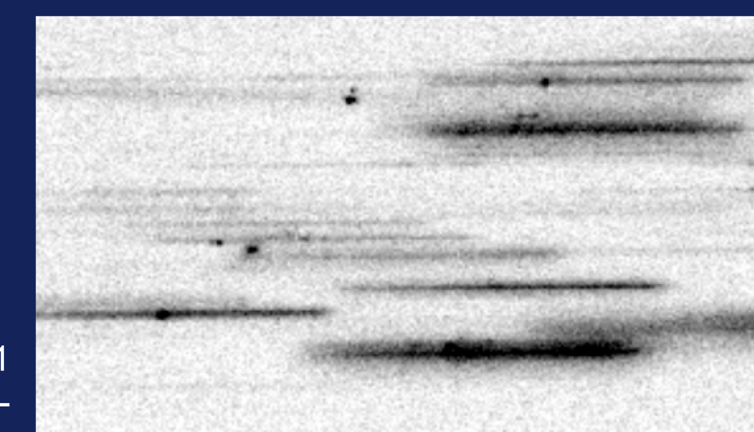


Figure 1. Components of a Composite Stellar Population (Conroy et al. 2013)

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



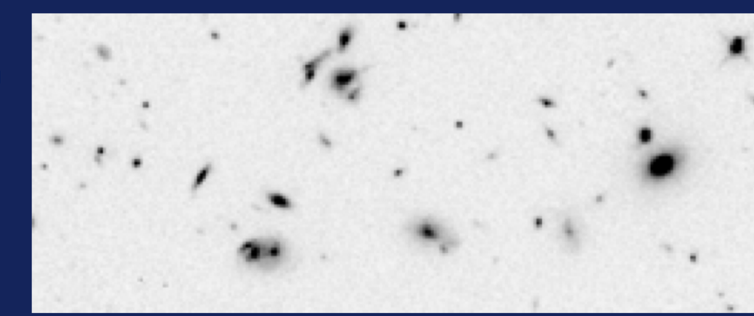
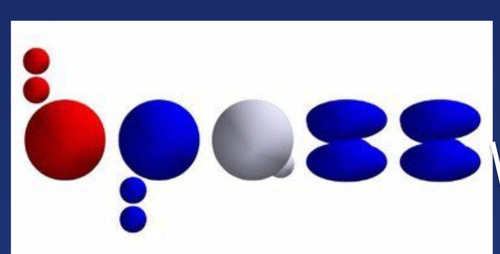


Figure 2: *HST* WFC3 G141 grism spectra of a GOODS-South pointing (above, Brammer et al. 2012)

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



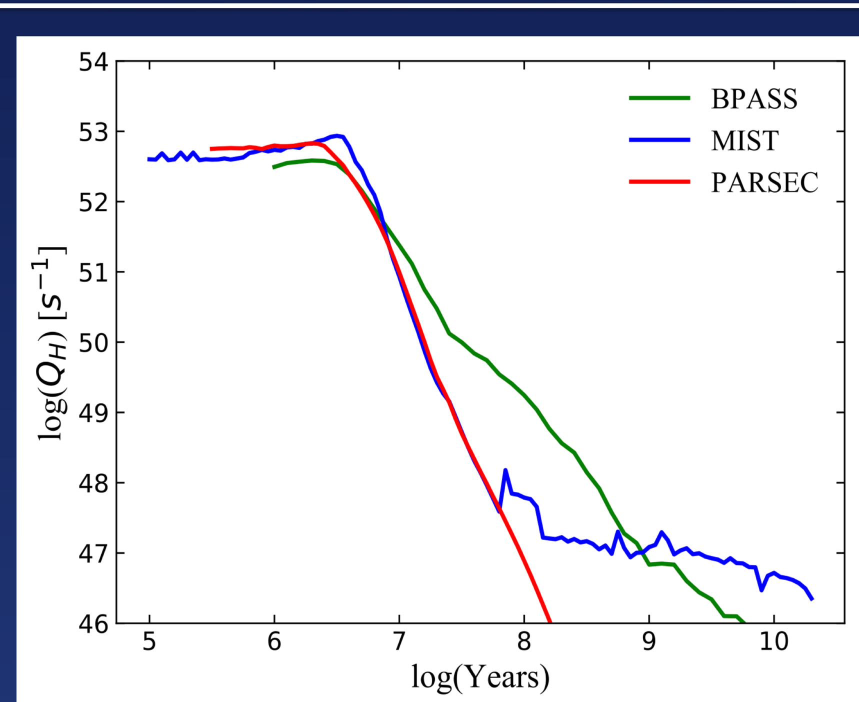


Figure 4. Q_H over time for each isochrone

MIST

PARSEC

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

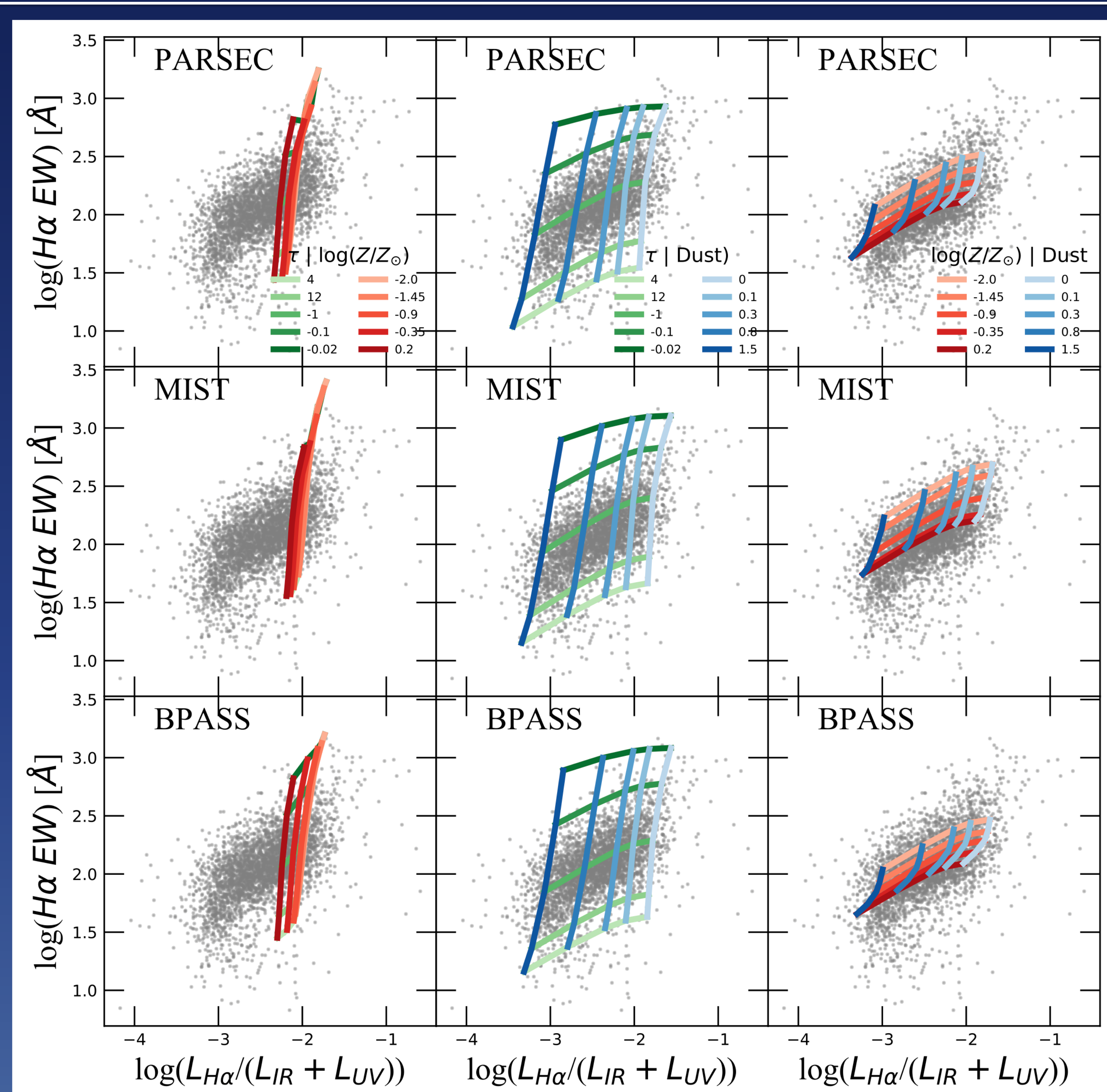


Figure 5. FSPS grid space showing BPASS, MIST and PARSEC Isochrones overlayed onto 3D-HST data

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

Acknowledgements

The Astronomy Smithsonian Astrophysical Research Experience of Undergraduates (SAO REU) program is funded in part by the National Science Foundation REU and Department of Defense ASSURE programs under NSF Grant no. AST1659473, and by the Smithsonian Institution. E.H.N. is supported by the National Science Foundation under Award No. DUE-1356133, an S-STEM Grant for the Cal-Bridge CSU-UC PhD Bridge Program. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

References

Brammer et al. 2012, *ApJS*, 200, 13

Bressan et al. 2012, *MNRAS*, 427, 127

Conroy et al. 2009, *ApJ*, *699*, 486

Conroy et al. 2013, *ARAA*, 51, 393

Choi et al. 2016, *ApJ*, 823, 102

Eldridge et al. 2017, *PASA*, 34, e058

Get this poster as a PDF!

Cal-Bridge

A California State University–University of California PhD Bridge Program