Cosmic Constraints on the Initial Mass Function

John Moustakas
UC San Diego
(Extended) AGN and Galaxy Evolution Survey (AGES) Team

Michael Brown (Monash)
Nelson Caldwell (CfA)
Richard Cool (Carnegie/Princeton)
Arjun Dey (NOAO)
Daniel Eisenstein (Arizona)
Anthony Gonzalez (Florida)
Paul Green (CfA)

Buell Jannuzi (NOAO)
Chris Kochanek (P.I., Ohio)
Casey Papovich (Texas A&M)
George Rieke (Arizona)
Wiphu Rujopakarn (Arizona)
Dennis Zaritsky (Arizona)
Basic idea

- **SFR (star formation rate):** number of >5 $M_{\odot}$ stars

- **Stellar mass:** number of ~1 $M_{\odot}$ stars

- Integral of the cosmic star formation history should track the stellar mass density evolution

Hopkins+04; Hopkins & Beacom 06; Wilkins+08a,b
Important to minimize random & systematic errors in the SFR and stellar mass measurements.

Basic idea

Hopkins+04; Hopkins & Beacom 06; Wilkins+08a,b
The Plan

1. New measurements of the SFR density at $0<z<1.3$ based on observations of the 24-micron luminosity function

2. Compare the integrated star formation history with the stellar mass density at $z=0$

3. Ongoing work measuring the coevolution of star formation and stellar mass buildup in galaxies

4. PRIMUS - a new galaxy redshift survey to $z\sim 1$
AGES I\textsubscript{Vega} < 20
MIPS f\textsubscript{24} > 0.27 mJy

AGN and Galaxy Evolution Survey (AGES)

- **MMT/Hectospec optical spectroscopy** – 3700–9200 Å, ~6 Å FWHM; ~11000 galaxies with I\textsubscript{Vega} < 20 at 0 < z < 0.8 (Kochanek+10; Cool+10)
- **X-ray** 0.5–7 keV – XBootes (Kenter+05; Murray+05)
- **FUV,NUV** – GALEX AIS/MIS (Martin+05)
- **BwRIz** – NOAO Deep Wide Field Survey (NDWFS); zBootes (Jannuzi+10; Cool+07)
- **JHKs** – NEWFIRM (Gonzalez+10)
- **3.6–8 micron** – Spitzer/IRAC Deep Wide-Field Survey (SDWFS; Ashby+09)
- **24 micron** – Spitzer/MIPS deep survey (Papovich+04)
- **20 cm** – VLA/FIRST (de Vries+02)
AGES 24-micron Luminosity Functions

- Local (z=0) luminosity function well-fit by a double power-law
- Observed evolution for star-forming galaxies consistent with pure luminosity evolution
- AGN have been excluded using X-ray and IRAC color-color criteria
- Convert L(24)→SFR using Rieke+09 recipes

Defining the IMF

- Consider generalized IMF with a fixed low-mass slope and a variable high-mass slope $\Gamma$ (cf Baldry & Glazebrook+03)

- “Cosmic” IMF may be different from the stellar IMF or even the IGIMF (e.g., Weidner & Kroupa+05)

- Key assumption: $\Gamma \neq \Gamma(t)$

\[ \xi_{\log m} \propto \begin{cases} m^{-0.5} & 0.1 < m/M_{\odot} < 0.5 \\ m^{-\Gamma} & 0.5 < m/M_{\odot} < 120 \end{cases} \]
Cosmic star formation history at $0 < z < 1.1$ well-determined; larger uncertainties at $z=1-5$.

- Consider a range of possible star formation histories.
Stellar Mass Function & Density at $z=0$

- Local (SDSS) stellar mass function is a modified Schechter function.
- Stellar mass density at $z=0$ is well-determined, modulo uncertainties in the IMF.

- $M^* \sim 6 \times 10^{10}\, M_{\odot}$
- $\alpha_1 \sim -0.5$
- $\alpha_2 \sim -1.5$
- $\rho^* \sim 5 \times 10^8\, M_{\odot}\, Mpc^{-3}$

Cole+01; Bell+03; Baldry+08; Panter+07; Gallazzi+08; Blanton & Moustakas 09
Cosmic Constraints on $\Gamma$

Intersection of local stellar mass density and the integral of the cosmic star formation history yields $\Gamma \sim 1.15 \pm 0.15$

Salpeter IMF overproduces the mass density at $z=0$
Cosmic Constraints on $\Gamma$

![Graph showing constraints on $\Gamma$ with different values of $\Gamma$.](image-url)
PRIsm MUlti-Object Survey (PRIMUS)

- A new paradigm for faint galaxy redshift surveys: low-dispersion prism spectroscopy
- $>10^5$ galaxy redshifts over $\sim 10$ deg$^2$ across multiple multiwavelength deep fields
- $dz/(1+z)<0.03$ with $\sim 5\%$ catastrophic outliers

http://cmb.as.arizona.edu/~eisenste/primus

Coil+10; Cool+10; Wong+10; Zhu+10; Moustakas+10b, all in prep.
Summary

1. We can place meaningful constraints on the IMF by studying the integrated ensemble properties of galaxies.
2. We use AGES to measure the 24-micron luminosity function at $0<z<0.65$, and constrain the SFR density evolution to $z=1.2$.
3. We find a best-fit “cosmic” IMF with high-mass slope $\Gamma = 1.15 \pm 0.15$.
4. Work in progress to study the coevolution of stellar mass and star formation to $z=1$.
5. Stay tuned for first results from PRIMUS!