Unifying Theory and Observation to Measure Star Formation Rates

Jessica Maldonado, Physics
Mentor: Dr. Matthew S. Povich
Kellogg Honors College Capstone Project

Motivation

- ✧ Present new, straightforward visualization of the stellar parameters of a star-forming region.
  - Reduces uncertainty of plotting a single point
  - Combats adverse effects from opaque dust at the visible and near-infrared wavelengths
- ✧ Constrain the duration of star formation in the youngest, most massive star-forming regions by fitting theoretical models of stellar physical parameters to observational data.

Sample Selection and SED Fitting

- ✧ Sample consists of intermediate mass, pre-main sequence stars that emit X-rays and lack disks
- ✧ Wavelengths used: infrared bands J (1.2μm), H (1.6μm), K_S (2.2μm) (2MASS) 3.6 μm, 4.5 μm, 5.8 μm, 8.0 μm (*Spitzer Space Telescope*), X-ray Sources 0.5-8 keV (*Chandra X-ray Observatory*)
- ✧ Sample regions include M17 SWex, infrared dark cloud of M17 (Povich et al. 2016) and Trumpler 14 and Trumpler 15, clusters in the Great Carina Nebula (Povich et al. 2011). These regions represent a progression of the duration of star formation.
- ✧ M17 SWex: youngest stellar population that can be analyzed using the probabilistic HR Diagrams (pHRDs) with deep JHK_s data from UKIRT (Povich et al. 2016)
- ✧ 200,000 spectral energy distribution (SED) models with the following parameters:

Parameter	Description	Unit	Minimum	Maximum
t_*	Evolutionary Age	yr	10^4	10^{10}
M	Mass	$M_\odot$	0.1	60
L_{bol}	Bolometric Luminosity	$L_\odot$	$8.2x10^{-4}$	$5.4x10^5$
T_{eff}	Effective Temperature	K	2600	$4.8x10^4$
R_{eff}	Effective Radius	$R_\odot$	0.11	67
log10g	Surface Gravity	m s^{-2}	1.9	5.3

- ✧ Interpreted each star using the range of stellar parameters of models that fit the observed SEDs, using a well-fit cutoff of $X^2 \leq 2$.

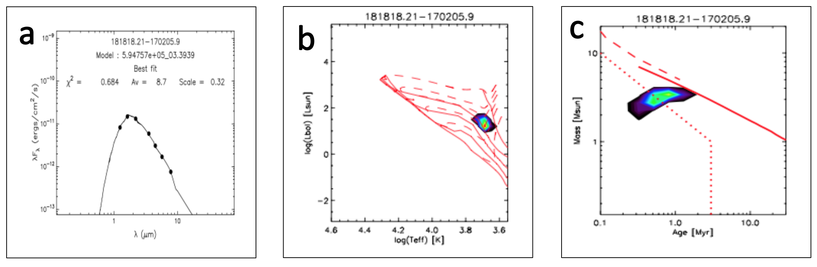


Figure 1. a) Best fit SED of M17 SWex source fit with 2019 models, b) Same M17 SWex source plotted as pHRD, c) Same M17 SWex source plotted as probabilistic mass-age diagram (pMAD)

References

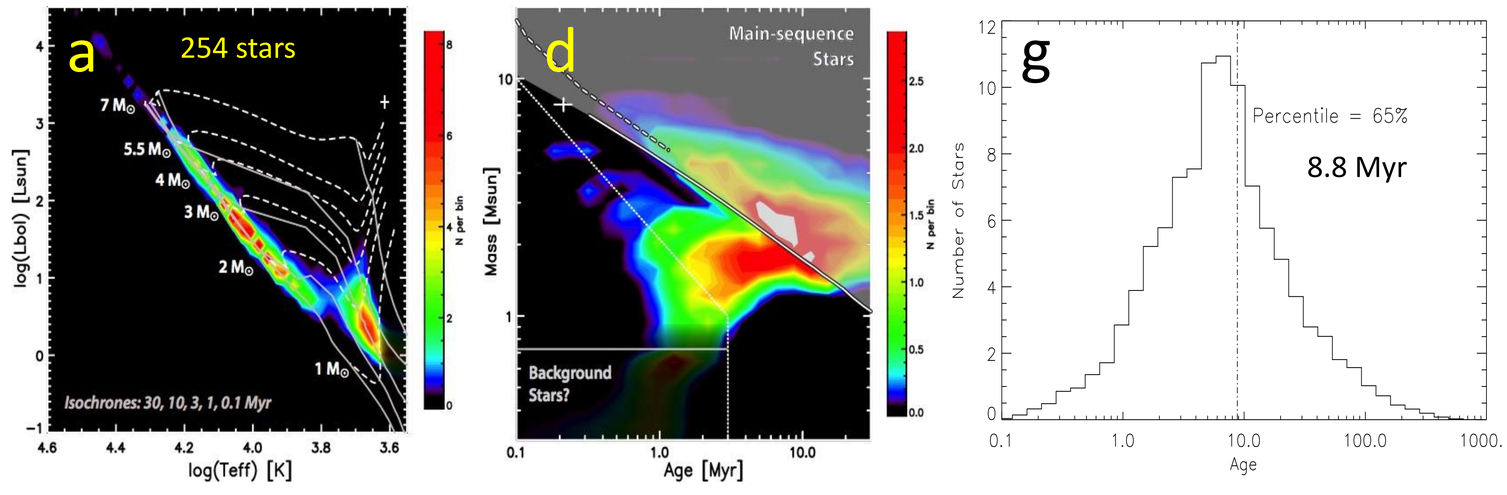
Ascenso, J., Alves, J., Vincente, S., et al. 2007, A&A 476, 199–215
Bernasconi, P. A. & Maeder, A. 1996, A&A, 307, 829
Carraro, G. 2002, MNRAS, 331, 785-794
Povich, M., Smith, N., Majewski, S., et al. 2011, ApJS, 194, 14
Povich, M., Townsley, L., Robitaille, T., et al. 2016, ApJ, in press (arXiv:1604.06497)
Robitaille, T. P., Whitney, B. A., Indebetouw, R., & Wood, K. 2007, ApJS, 169, 328
Siess, L., Dufour, E., & Forestini, M. 2000, A&A, 358, 593

Acknowledgements

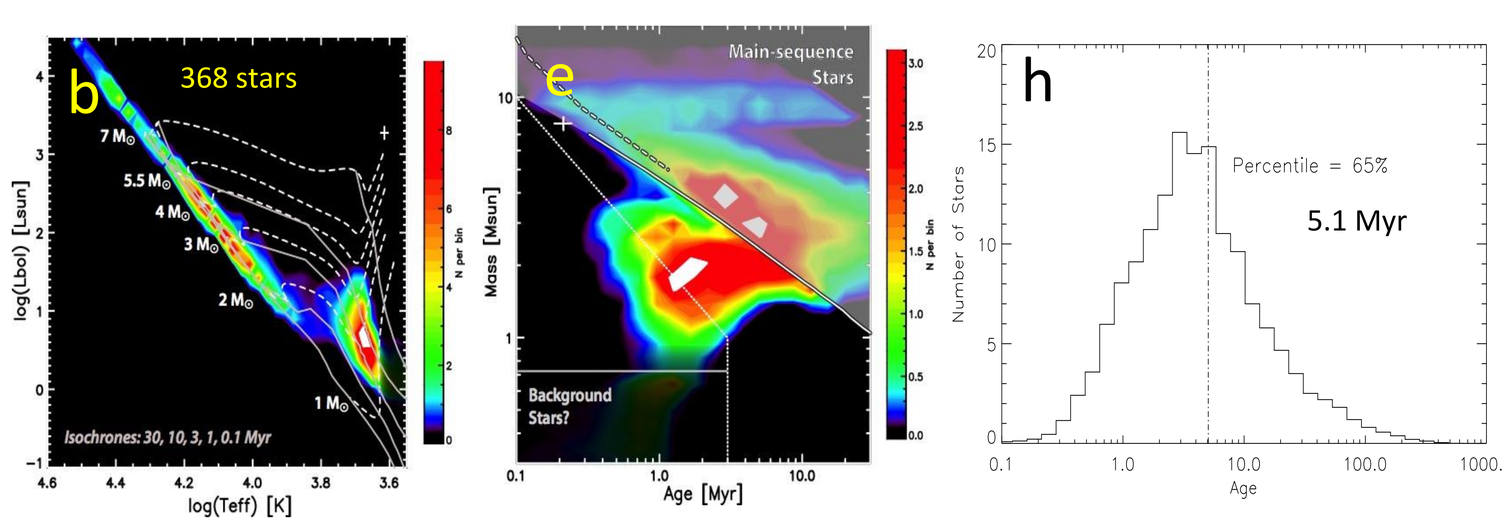
This material is supported by the National Science Foundation under Award Nos. CAREER-1454333 (PI M.S. Povich) and DUE-1356133, an S-STEM Grant for the Cal-Bridge CSU-UC PhD Bridge Program. JM is supported by an NSF S-STEM scholarship.
Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Probabilistic HR Diagram | **Probabilistic Mass-Age Diagram** | **Stellar Age Histogram**

Trumpler 15



Trumpler 14



M17 SWex

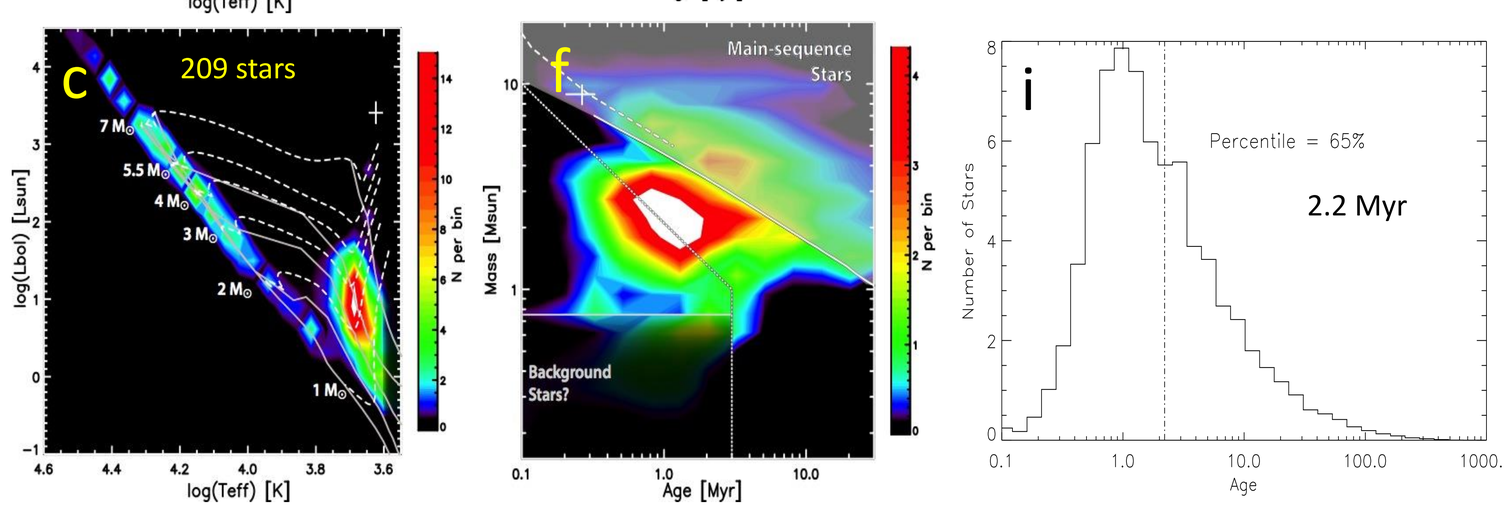


Figure 2. pHRDs and pMADs each display a sum of individual 2D histograms for each star. In all pHRDs (a,b,c), Siess et al. (2000) pre-main sequence tracks for indicated masses and curves that represent same age (0.1, 1, 3, 10, 30 Myr isochrones) are plotted as dashed and solid curves, respectively. In all pMADs (d,e,f), the zero-age main sequence, or the place where stars start burning hydrogen, is plotted as solid and dashed curves according to Siess et al. (2000) and Bernasconi & Maeder (1996), respectively. The dotted lines represent mass-dependent disk lifetimes. The stellar age histograms (g,h,i) are one dimensional distributions of the age parameter. The dash-dotted lines represents the 65th percentile.

Analysis

- ✧ Analyzed the distribution of masses, assumed the *age* distribution of intermediate-mass stars are representative of *all* stars, including the much more abundant low-mass stars
- ✧ Implemented a limiting mass cutoff to identify only the intermediate-mass range based on the Salpeter stellar initial mass function:
  - M17 SWex and Trumpler 14 cutoff at 2.6 $M_\odot$
  - Trumpler 15 cutoff at 2.3 $M_\odot$
- ✧ Plotted only stars above the cutoff masses to in the one-dimensional Stellar Age Histograms (Fig. 2ghi)
- ✧ Defined the duration of star formation as the 65th percentile in age of the diskless stars in the region. These regions also contain stars with disks but they are even younger than stars without disks.

Results & Future Work

- ✧ Sample of first stars formed in M17 SWex and places upperbound on the duration of star formation at 2.2 Myr
- ✧ Compared ages from pMAD of the Trumpler regions to work done by others in the field
  - Trumpler 15 duration of star formation 8.8 Myr, compared to Carro (2002) Trumpler 15 age 2-6Myr
  - Trumpler 14 duration of star formation 5.1 Myr, compared to Ascenso et al. (2007) Trumpler 14 age 0-5Myr
- ✧ Will apply technique to data sets from MYStIX project on other Galactic massive star-forming regions.