



FTI



MAKE THE WORLD MORE INFORMED,
PRODUCTIVE AND SECURE

THE ALL-SKY VISIBLE AND INFRARED ASTRONOMICAL CATALOG ENCOMPASS 3.0

Dr. Jennifer Simmerer, Dr.
Thomas Murdock, Dr. Leah
Roach, Ryan Hartzell, and
Dr. Brian Muccioli

Sept. 21, 2020

cal con
www.calcon.sdl.usu.edu

- Project goals and catalog use cases
- Catalog construction basics
- Overview of source data
- Validation: strategy, challenges, and results
- Data products

Not included here:

- Astronomical extended (resolved non-stellar) sources
- Data cleaning and processing: visible and IR catalogs
- Spectral fitting procedure: strategy and challenges

➤ Goals

- Create an inventory of known astronomical objects outside the solar system with accurate positions
- For all those objects, derive blackbody function parameters
- From those parameters, calculate an arbitrary in-band irradiance between 0.4 μm and 25 μm to an accuracy of at least 0.5 mag

➤ The result is FTI's revised and updated stellar catalog, Encompass 3.0

- Visible wavelengths: 1 billion point sources, 1.5 million resolved sources
- Infrared wavelengths: 750 million point sources, 3 million resolved sources

➤ Use Cases

- Stellar navigation (where are you pointing?)
- Mission/survey planning (what is in the sky when?)
- Sensor simulation and design (what will your sensor see?)
- Data analysis support and algorithm design (are you capturing the information you want from your sensor?)
- Sensor calibration (how radiometrically stable is your sensor?)

How do you do that?

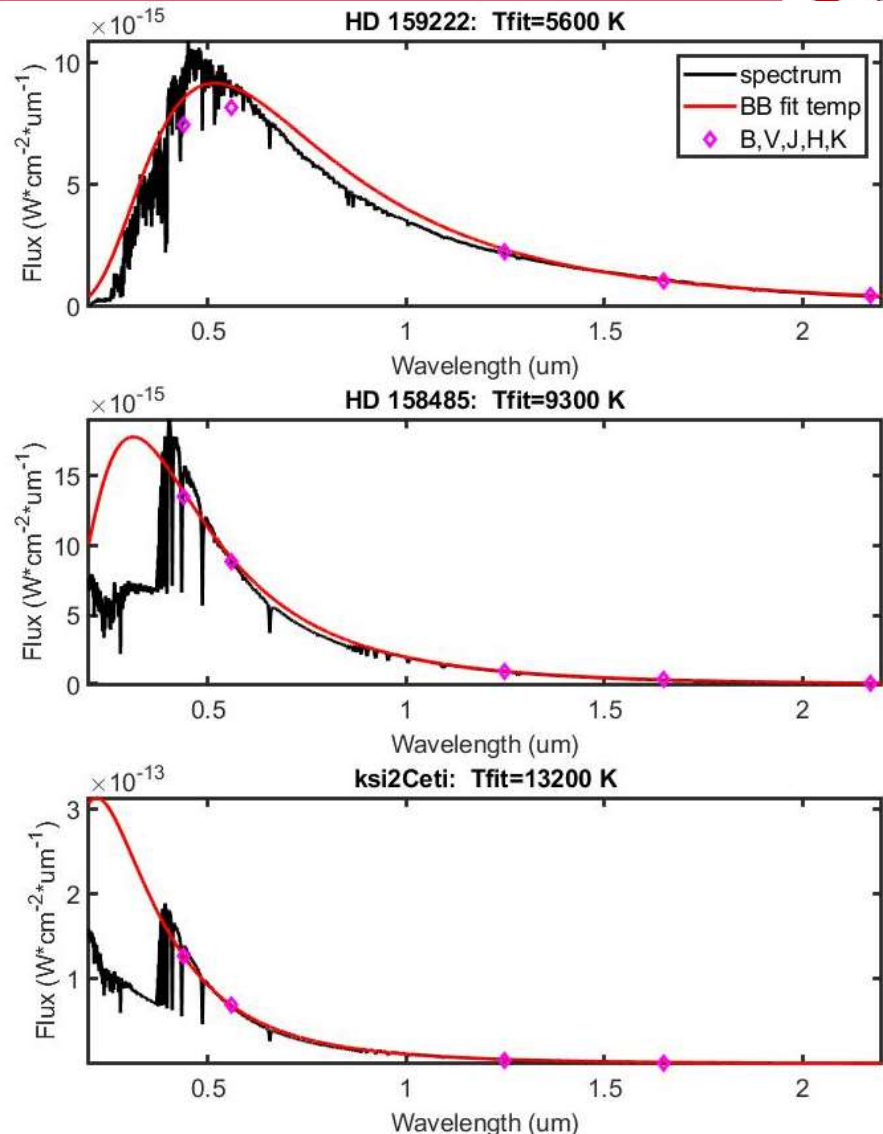
- Most astronomical objects radiate like blackbodies:

$$B(\lambda, T) = A \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda kT}} - 1}$$

- Spectral irradiance B at wavelength λ is function of object temperature T and a scale factor A
- Public all-sky star surveys report measurements of B integrated over a known λ passband
 - Fit survey data to derive A, T

Note on magnitudes as a unit:

$$\text{mag}_1 - \text{mag}_2 = 2.5 \times \log \frac{B_2}{B_1}$$

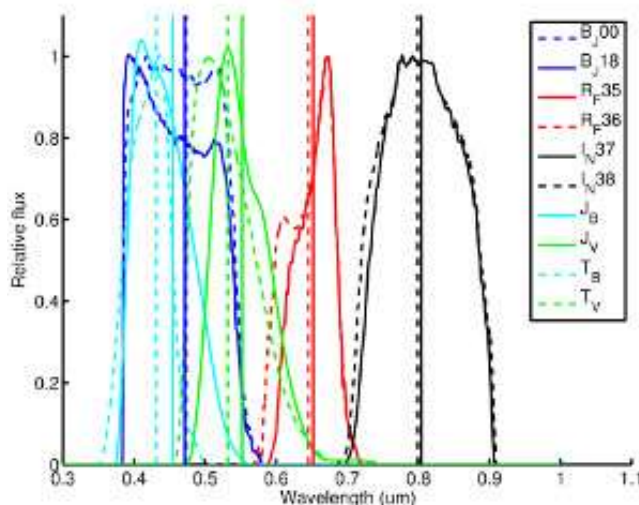


Spectra from CALSPEC database, fits from Encompass 3.0
Real stars are not pure blackbodies, but they're close!

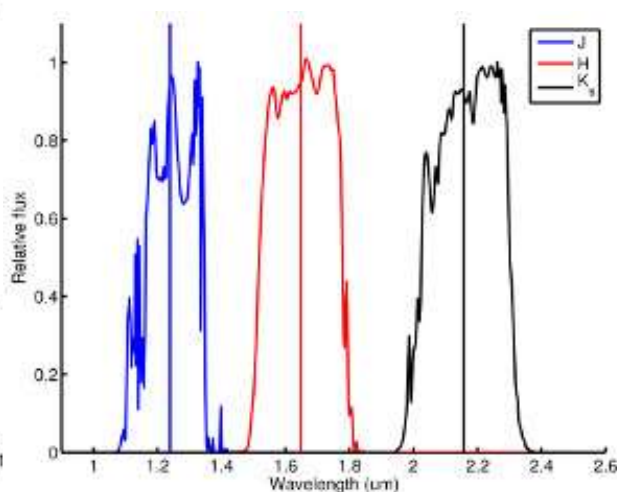
Overview of Source Data



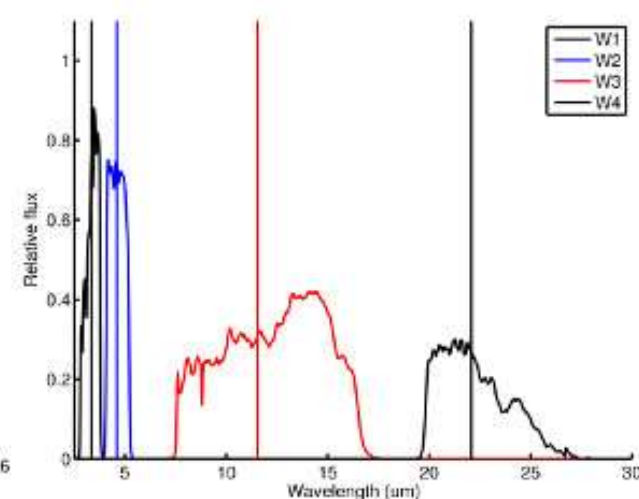
GSC 2.3 survey bands



2MASS survey bands



WISE survey bands



Source VIS: HST Guide Star Catalog 2.3

Catalog	# Objects	Measured Bands	Astrometric Accuracy (arcsec)
HST GSC 2.3 (ground)	945,592,683	B _J , R _F , I _N	0.13-0.37 (SDSS)
GSC 2.3 includes			
SKY2000	175,632	B, V	N/A
Tycho-2	2,523,552	B _T , V _T	0.007-0.06
2MASS	470,922,875	JHK _s	0.06-0.18
Complete to ~20 mag			

Source IR: AllWISE

Catalog	# Objects	Measured Bands	Astrometric Accuracy (arcsec)
AllWISE (space)	747,634,026	W1, W2, W3, W4	0.08-0.4 (UCAC4)
AllWISE includes			
WISE	563,921,584	W1, W2, W3, W4	0.15-0.4
NEOWISE		W1, W2	N/A
2MASS	470,992,970	J, H, K _s	0.06-0.18
Complete to ~17 mag			

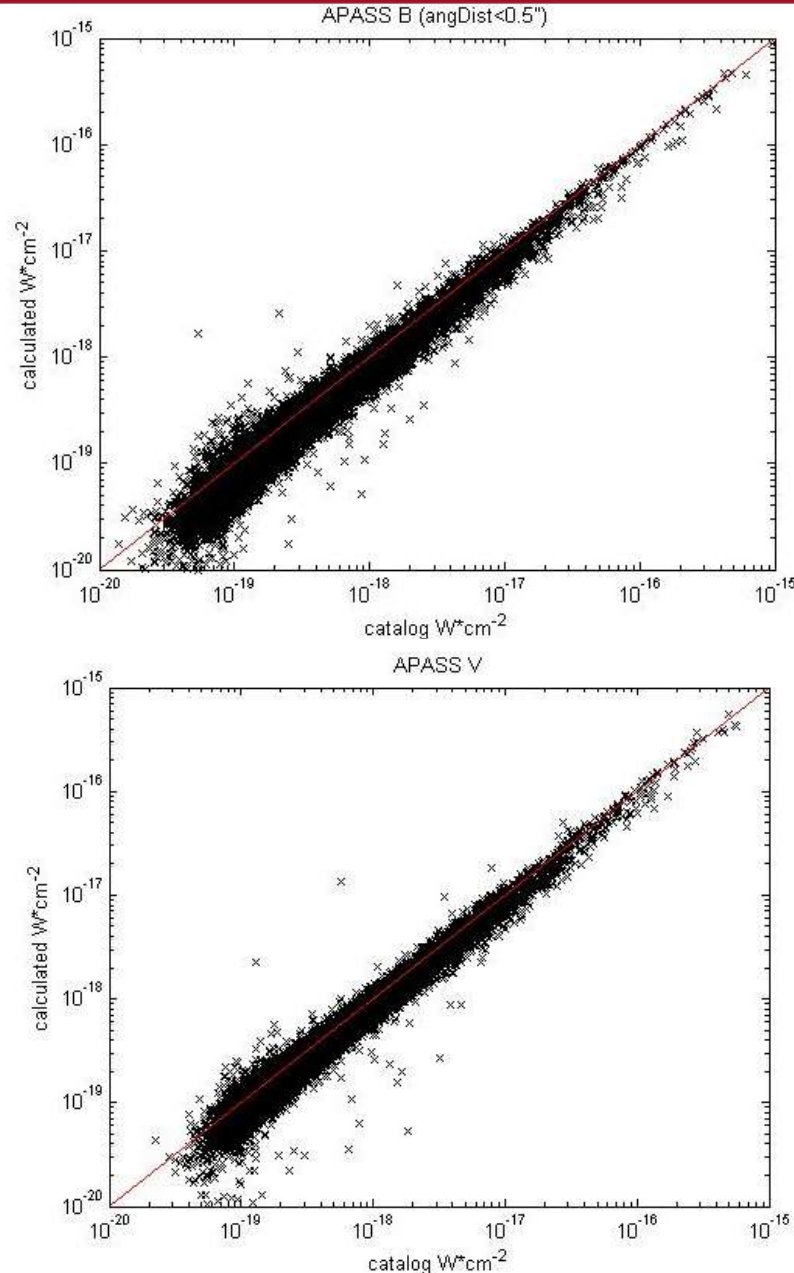
Validation: VIS Point Sources



How well can we reproduce an arbitrary observed irradiance from the Encompass *A*, *T* database?

~20,000 stars from the AAVSO Photometric All-Sky Survey (APASS)

- Ground-based survey in Johnson B and V, plus Sloan u' , g' , r' , i' , z_s and Z
- No significant offset, good agreement over 4 orders of magnitude in irradiance!

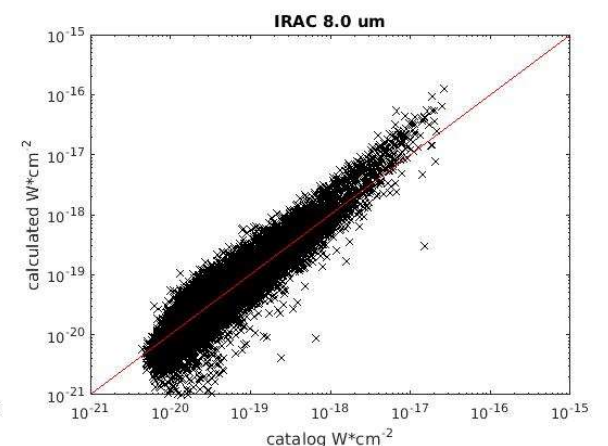
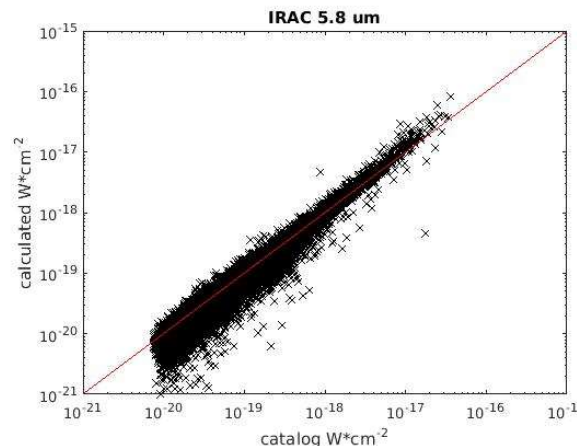
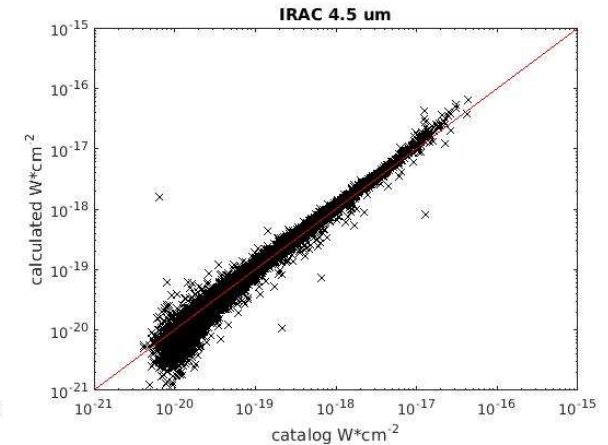
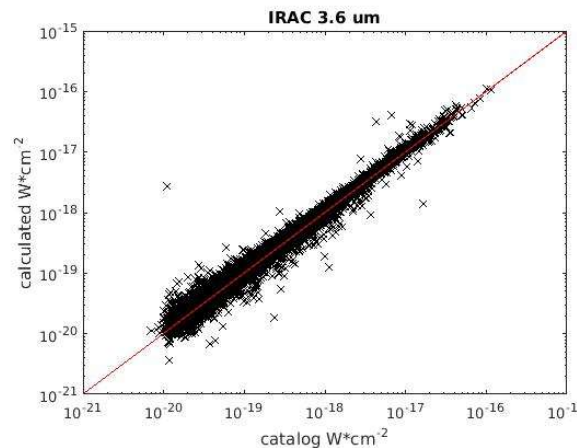


Validation: IR Point Sources



~20,000 stars from the
Galactic Legacy Infrared
Midplane Survey
Extraordinaire
(GLIMPSE)

- Survey of central Galactic Plane with the Infrared Array Camera (IRAC) aboard the Spitzer Space Telescope (SST).
- Four IRAC bands from 3.6 μm to 8 μm
- No significant offset, good agreement over 4 orders of magnitude in irradiance!



Validation Summary



Band Name	Band Center (um)	Band Width (um)	Survey	% of objects within 0.25 mag	% of objects within 0.5 mag
B	0.43	0.084	APASS	52%	92%
V	0.54	0.087	APASS	72%	98%
IRAC 3.6	3.55	0.750	GLIMPSE (Spitzer)	90%	98%
IRAC 4.5	4.49	1.015	GLIMPSE (Spitzer)	84%	98%
IRAC 5.8	5.73	1.425	GLIMPSE (Spitzer)	71%	93%
IRAC 8.0	7.87	2.905	GLIMPSE (Spitzer)	65%	86%

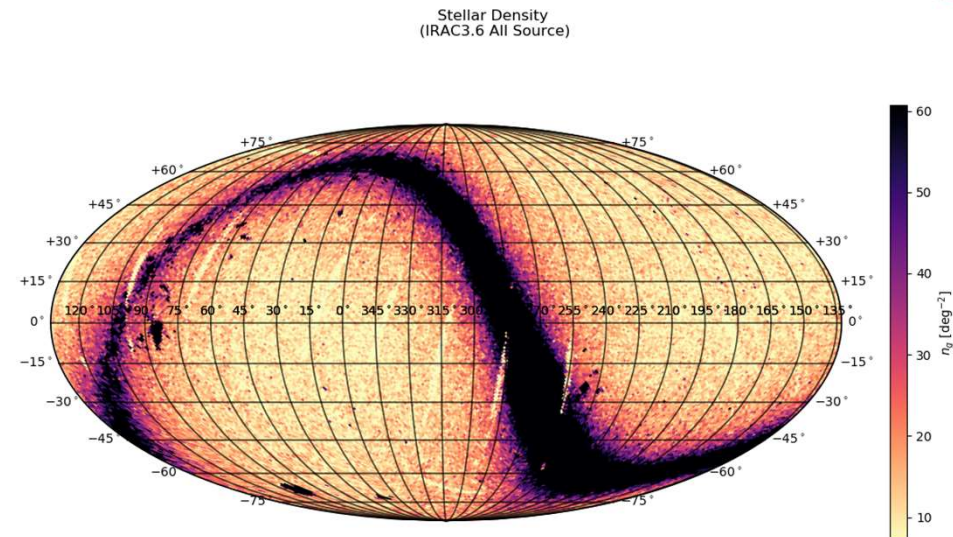
➤ Encompass 3.0 can predict independent survey results to 0.5 mag!

Brightness-limited complete catalog files for program bandpass

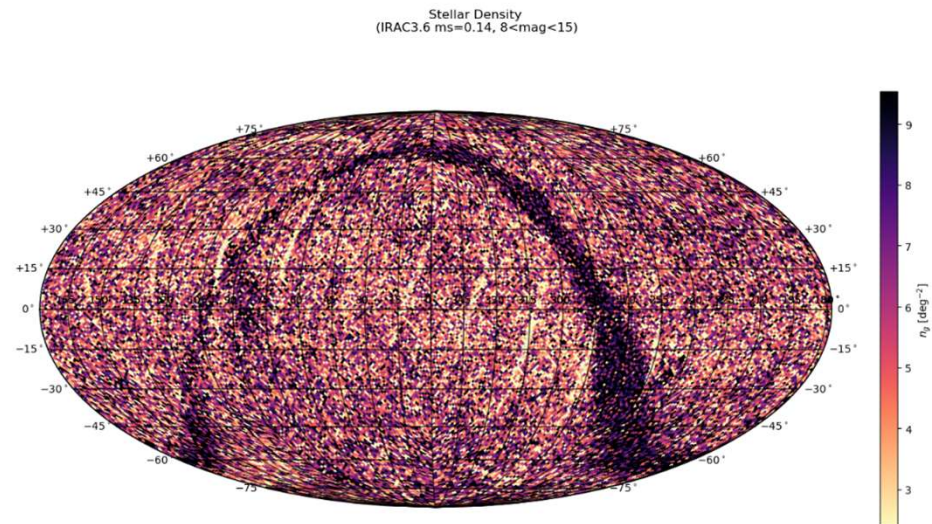
- Includes unique star ID, position, calculated in-band irradiance
 - RA/Dec cuts, mag limits

Reference catalog files for program bandpass

- Includes unique star ID, position, calculated in-band irradiance
 - Known variable stars removed
 - Density-limited
 - Gridded or minimum separation constraint
 - RA/Dec cuts, mag limits



All sources for derived IRAC 3.6 um band

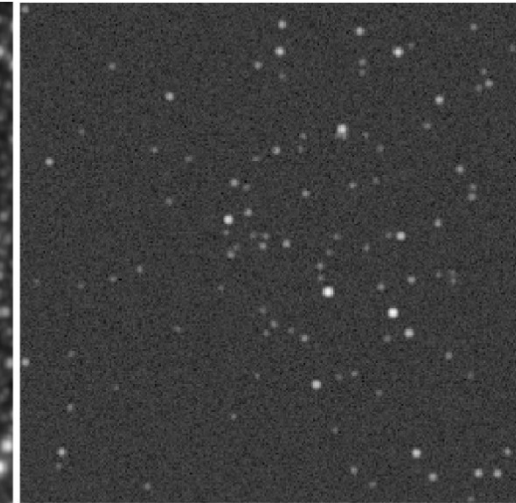


Derived source density with variable stars removed and magnitude, minimum separation, and source density limits

Simulated images: IR
(for qualitative
comparison only)



W1 band image from WISE

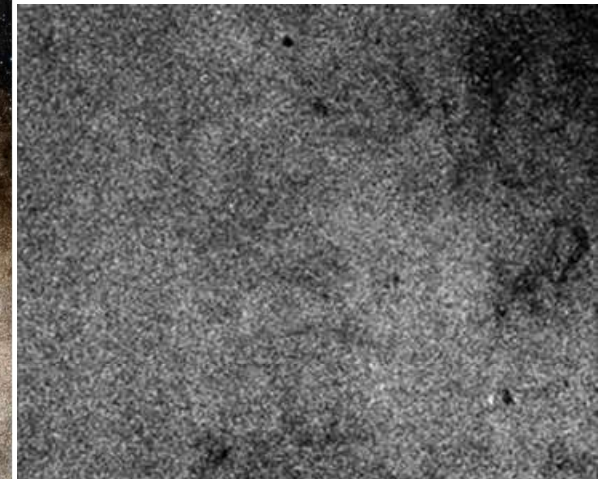


Simulated IRAC 3.6 band for
WISE-like sensor (15 mag limit)

Simulated images: VIS
(for qualitative
comparison only)



Full-color visible bands image from
DSS



Simulated wide visible band for DSS-like
sensor (18 mag limit)

Thank you!