

NGC 6791: SIM Plans for Binaries, Colors, Parallaxes

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- Find SIM Targets: RHB stars for parallax, RHB-MSTO binaries for stellar masses
- Use color-color plots, spectral calculations to establish reddening, metallicity, binarity
- Derive binary frequency, mass distribution
- So constrain single and binary evolution

NGC 6791: Old and Metal-rich

- A template for old red-and-dead galaxies
- Age 8 +/- 0.5 Gyr; distance 3.5 - 5 kpc; massive
- Reddening significant: $E(B-V)$ from 0.10 to 0.22
- $[Fe/H] = +0.4$, 3x solar; $[Na/Fe]$ high
- No planets, despite high metallicity
- Yet ~50% of main-sequence stars are binaries
- Other binary populations: blue stragglers, very hot horizontal branch (EHB) stars
- This unpredictable blue population mimics youth

Two types of SIM targets

- **RHB single** stars for parallax cluster distance
 - At 4 kpc, cluster parallax $\sim 250\mu\text{as}$
 - Reddening-independent; constrains CMD fits to age
 - Further constraints from stellar parameters (below)
- **RHB or SGB binaries** for stellar masses
 - MS companion likely; too faint to confuse SIM orbit
 - Yet MSTO companion detectable in blue spectra at phases of large velocity separation
 - RHB + MS pairs: $>1\text{AU}$ semi-major axis, $\sim 250\mu\text{as}$
 - Double-lined spectroscopic + visual binary \Rightarrow stellar masses

Identifying SIM targets

- Distinguish binaries initially via radial velocities
 - Lick echelle survey 1997 - now: RV's to +/-0.2 km/s
 - 88 red stars, $V < 14.7$ (RHB), 42 twice or more
 - Cluster RV = -46.4 ± 0.2 km/s, $\sigma = 1.3 \pm 0.1$ km/s
 - Three variables with five+ velocities: RGB, SGB, X
 - Three RHB's constant after five or more velocities
- Must further constrain with photometry as well
 - Interpreting masses via CMD requires no interaction
 - Non-interacting RHB pairs have >1 AU separation, >1 yr period, high eccentricity: \Rightarrow Small RV variation
 - This implies some 'single' RHB stars may be double

Binaries in Color-Color Plots

- Stars of solar metallicity are **always bluer in the blue** at any given red color than stars with three times solar $[Fe/H]$, but disparate binaries are **bluer in the blue and redder in the red**
- Extensive photometry, notably u^*griz & near-IR
- Take reddening and metallicity nearly constant
- Identify members from proper motions
- Plot members only, establish single-star relationship from lower envelope
- Plot non-members, establish metallicity dependence by comparing lower envelope

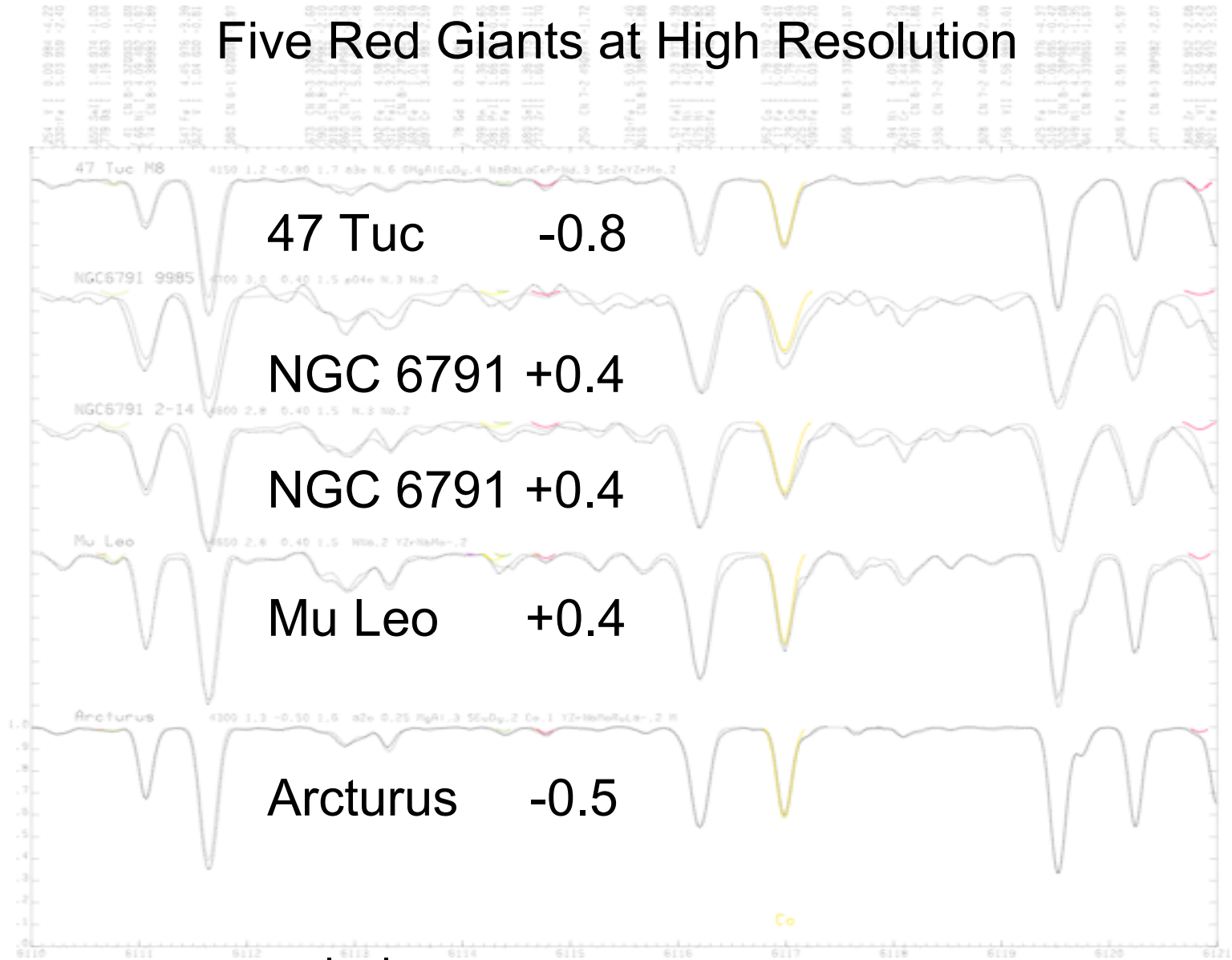
Stellar Parameters from Spectral Flux Calculations

- Goal: derive effective temperature, metallicity, reddening, binarity from color-color diagrams
- Procedure: calculate full spectral flux at high resolution for RGB and MSTO stars of various metallicities. Co-add to produce binaries. Convolve with filter functions to produce colors.
- Calibration: compare line-by-line spectra with high-resolution observations of standard stars
- So far, good agreement in red, but CN and CH poorly matched in blue, and missing atomic lines compromise near-UV at high metallicity

Plots of theoretical vs. observed stellar spectra for sub- and super-solar giants

- Plots show the **observed** spectrum of a star as a **heavy** line, and the normalized relevant *theoretical* spectrum as a *light* line, with its star ID and *atmospheric model parameters*.
- Wavelength in Ångstroms is given along the bottom. Ticks on the left represent 10% of the full normalized flux. Zero flux is at the bottom.
- At the top are line identifications. Note CN!

Five Red Giants at High Resolution



6110A

| |
CN Fe

6121A

Present limitations of our theoretical spectra

- Limited to stars in old systems, ≥ 1 Gyr, by the range of stellar standards for calibration
- 2600Å - 3000Å in dwarfs and 3500Å - 4100Å in giants not yet fit at solar [Fe/H]
- Calculations are restricted to 2200Å - 9000Å
 - Castelli models stop at 3500K
 - Line-list improvements stop at 9000Å
 - No TiO as yet, so no proper M giant contribution
- Are fits unique? No goodness-of-fit metrics

NGC 6791 Binary Characteristics

- Combine theoretical spectra of MS + MS and RGB + MS stars, calculate colors from the composite theoretical spectra
- Compare against colors of members to identify binaries and approximate companions
- Combine with estimates of MS + MS binaries of similar type, from CMD, to get complete binary fraction and mass distribution
- Check ramifications for blue stragglers, EHB