Binary Populations of Open Clusters NGC 7789 and NGC 2506

Katelyn Milliman
Preliminary Exam June 1, 2011
Advisor: Bob Mathieu
Identifying Binary Stars

Visual -
Astrometric

Photometric -
Eclipsing

Spectroscopic -
Radial Velocity

Daniel Verschatse - Observatorio Antilhue -
Identifying Binaries: Radial Velocity
Binary Solution: Triple System

Inner Binary
Period = 3.56 days
Eccentricity = 0.1
Mass Ratio = 0.862

Tertiary
Seen in 14 out of 17 spectra
Period > 1200 days
Binaries in NGC 188

Mathieu & Geller 2009

Main Sequence

Blue Stragglers
Formation Mechanisms of Blue Stagglers

(1) Triple system with inner binary mergers (Perets & Fabrycky 2009)
(2) Direct stellar collisions during dynamical encounters of binary systems (Geller et al. 2010)
(3) Binary mass transfer
Hierarchical triple system where the inner binary mergers through a combination of tidal and Kozai effects. Results in:

- Blue Straggler
- Main sequence companion
- Long orbital period
(1) Triple System Merger: Kozai Mechanism

Inner Binary:
M = 1 Solar Mass
a = 2AU
Low eccentricity

Outer Tertiary:
M = 0.5 Solar Mass
a = 50AU
e = 0
i = 48°

Perets & Fabrycky 2009
(2) Collision During Dynamical Encounters

Results in:
Blue Straggler
Main sequence companion

Plays a role, even if not direct cause of straggler formation (Leigh & Sills 2011)
Dynamical Encounters and Binaries

\[ \sigma_{1+1} \sim \frac{8\pi G m R}{v_{re}}^2, \quad (A1) \]

\[ \sigma_{1+2} \sim \frac{3\pi G m a_b}{v_{re}}^2, \quad (A2) \]

\[ \sigma_{2+2} \sim \frac{8\pi G m a_b}{v_{re}}^2, \quad (A3) \]

\[ \sigma_{1+3} \sim \frac{4\pi G m a_t}{v_{re}}^2, \quad (A4) \]

\[ \sigma_{2+3} \sim \frac{5\pi G m (a_b + a_t)}{v_{re}}^2, \quad (A5) \]

\[ \sigma_{3+3} \sim \frac{12\pi G m a_t}{v_{re}}^2. \quad (A6) \]

\[ \tau_{1+1} = 1.1 \times 10^{10} (1 - f_b - f_t)^{-2} \left( \frac{1pc}{r_c} \right)^3 \left( \frac{10^3 pc^{-3}}{n_0} \right)^2 \]
\[ \left( \frac{v_{rms}}{5km/s} \right) \left( \frac{0.5M_\odot}{<m>} \right) \left( \frac{0.5R_\odot}{<R>} \right) \text{ years,} \quad (A9) \]

\[ \tau_{2+2} = 1.3 \times 10^7 f_b^{-2} \left( \frac{1pc}{r_c} \right)^3 \left( \frac{10^3 pc^{-3}}{n_0} \right)^2 \]
\[ \left( \frac{v_{rms}}{5km/s} \right) \left( \frac{0.5M_\odot}{<m>} \right) \left( \frac{1AU}{a_b} \right) \text{ years.} \quad (A8) \]

\[ \tau_{3+3} = 8.3 \times 10^6 f_t^{-2} \left( \frac{1pc}{r_c} \right)^3 \left( \frac{10^3 pc^{-3}}{n_0} \right)^2 \]
\[ \left( \frac{v_{rms}}{5km/s} \right) \left( \frac{0.5M_\odot}{<m>} \right) \left( \frac{1AU}{a_t} \right) \text{ years.} \quad (A13) \]
(3) Mass Transfer

From Giant Star to MS companion
Most likely a MS stripping an AGB companion
(Chen & Han 2008)

Results in:
  Blue Straggler
  White dwarf companion
**NGC 7789**

- Age 1.8 Gyr
- [Fe/H] = -0.1
- 27 Blue Straggler Candidates

**NGC 2506**

- Age 2.1 Gyr
- [Fe/H] = -0.4
- 10 Blue Straggler Candidates

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Gim et al. 1998b

Mikolaitis et al. 2011
NGC 7789  NGC 2506

- 6008 spectra of 1595 stars
  - 274 velocity variable stars
  - 455 single or non-member stars

- 2942 spectra of 927 stars
  - 122 velocity variable stars
  - 330 single or non-member stars
NGC 7789: Completed Orbital Solutions
NGC 7789: Completed Orbital Solutions
NGC 7789: Period- Eccentricity

![Graph showing the relationship between period and eccentricity for NGC 7789. The graph includes points for main sequence, giant, and unknown objects, indicating variations in eccentricity with respect to the log of period.](image-url)
NGC 7789: Period- Eccentricity

Star 17028

Period: 3.554 days
Eccentricity: 0.113
Mass Ratio: 0.714
Mₐsin³ᵢ= 1.913Mₛ
Mₜsin³ᵢ= 1.365Mₛ
Possibly Eclipsing
NGC 7789: Period- Eccentricity

**Star 9020**
- Period: 5.5 days
- Eccentricity: 0.139
- Mass Ratio: 0.939
- $M_a \sin^3 i = 1.252 \, M_\odot$
- $M_b \sin^3 i = 1.176 \, M_\odot$
Future Work

- Co-mentoring an REU student this summer with Nick Hill
  - Focusing on Star 9020 and Star 17028

- Photometry and light curve information with WIYN 0.9 m

- Completing more orbital solutions for NGC 7789
  - Hydra run in July

- Increasing effort on NGC 2506
Tidal Circularization

\[ t_{\text{circ}} = \frac{t_{\text{diss}}}{21 \lambda_{\text{circ}} q(1 + q) \left( \frac{a}{R} \right)^8} \]

Zahn 1989

Geller et al. 2010