Globular Clusters and Low-Mass X-Ray Binaries in M87

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   - Motivation
   - Globular Clusters
   - Low-Mass X-Ray Binaries
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2. Data Analysis
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   - Chandra Data

3. Results and Conclusions
   - Discussion
   - Results
Motivation

- In Milky Way globular clusters form LMXBs efficiently
  - Small sample!
  - Look at M87
- M87 richest globular cluster system in local universe
  - Increased GC sample of $\sim 14000$
  - Study properties of GCs hosting LMXBs
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Globular Clusters

- Spherical collection of stars orbiting a galaxy
  - Small and dense
  - Dust and gas free
  - Diameter independent of mass
- Old systems, mainly population II stars
- Luminosity Function used as standard candle
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Low-Mass X-Ray Binaries

- Binary Systems
  - Neutron star or blackhole primary
  - Late-type secondary $M \lesssim 2.0 M_{\odot}$
- Mass overflow (Roche lobe filling)
  - $L \sim 10^{35} - 10^{39}$ erg/s
  - Older than $10^9$ yr
- Possible formation
  - Direct formation
  - Tidal capture
  - Binary exchange processes
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Optical and X-Ray data

ACS Wide Field Camera
202” × 202” FoV
2×560s + 90s F850LP (≃ z band)
2×375s F475W (≃ g band)

ACIS Imaging mode
8’ × 8’ FoV (S3)
105 ks exposure time
Obtaining optical data
Obtaining optical data

- Obtain data from [http://archive.stsci.edu/hst](http://archive.stsci.edu/hst)

- Program ID: GO-9401

- Program PI: Patrick Côté
Processing optical data

- **Software**: PyRAF
- **Necessity of drizzling with multidrizzle (calibration files)**
  - corrects for built-in geometric distortion (off-axis location of instrument)
  - restores information lost due to undersampling
  - combines dithered images
  - filters cosmic rays
Processing optical data

- Software: SExtractor
- Source extracting in both bands
  - DETECT_MINAREA 5
  - DETECT_THRESH 3
  - PHOT_APERTURES 4 8 10 16
  - SATUR_LEVEL 65000
  - MAGZEROPOINT 26.068 (F475W, AB)
  - MAGZEROPOINT 24.862 (F850LP, AB)
  - PIXEL_SCALE 0.049
  - SEEING_FWHM 0.098
  - BACK_SIZE 32
Processing optical data

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- **Source extracting in both bands**
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Processing optical data

- 2608 sources (F475W)
- 2372 sources (F850LP)
- 1911 sources (cross-matched) with TOPCAT
Processing optical data

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Filtering optical data

- Aladin filter applied to cross-matched catalog
  - $0.5 \leq g-z \leq 1.9$
  - $m_z > 19$
  - $m_g > 19$
  - $0 < \text{elongation} < 2$
Filtering optical data

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GCs and LMXBs in M87
Analyzing optical data

- Calculate distance
  - \( m_z - M_z = 5 \log d - 5 + A_z \)
  - \( E(B - V) = 0.022 \) (taken from NED database)
  - \( A_z = 1.485 \times E(B - V) \) (from Jordán et al., 2004)
  - \( m_{\text{peak}} \approx 22.8 \) (for the z band)
  - \( (M_{\text{peak}}/L_{\text{peak}})_z \approx 1.5 \times (M_\odot/L_\odot) \) (from PÉGASE models)
  - \( M_{\text{peak}} - M_\odot = 2.5 \log(L_\odot/L_{\text{peak}}) \)

Where \( m, M, A_z \) are apparent and absolute magnitudes and extinction, resp.
Analyzing optical data

- Calculate distance

16.1 Mpc
Analyzing optical data

- Two distinct populations
  - \( g - z < 1.2 \)
  - \( g - z > 1.2 \)

Two different mean metallicities
Analyzing optical data

- Comparison between inner and outer part of the population
  - Define two regions
  - No significant shift of the peaks
  - BUT: More metal-rich in inner part
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Analyzing optical data

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## Obtaining X-ray data

### HST Data

- **Target Name:** M87
- **Name Resolver:** SIMBAD/NED
- **RA/Long:** 12 30 49.42
- **Dec/Lat:** -12 23 28.04
- **Radius:** 10
- **Equinox:** 2000
- **Proposal Number:** 2707
- **PI Name:**
- **Observer Name:**
- **Exposure Time (ks):**
- **Status:** Partially Observed
- **Science Category:** Solar System, Stars and WD, WD Binaries and CV, BH and NS Binaries, SN, SNR and Isolated NS
- **Instrument:** ACIS-I, ACIS-S, HRC-I, HRC-S
- **Grating:** None, LETG, HETG
- **Type:** TOO, CAL, GO, GTO, DDT
- **Observing Cycle:** A00, A01, A02, A03, A04

### Chandra Data

- **Target Name:** M87
- **Name Resolver:** SIMBAD/NED
- **RA/Long:** 12 30 49.42
- **Dec/Lat:** -12 23 28.04
- **Radius:** 10
- **Equinox:** 2000
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For online support please contact the CXC Helpdesk.

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GCs and LMXBs in M87
Obtaining X-ray data

- **Obtain data from**
  - [http://cda.harvard.edu/chaser/dispatchOcat.do](http://cda.harvard.edu/chaser/dispatchOcat.do)
- **Obs ID**: 2707
- **Program PI**: Patrick Côté
Processing X-ray data

- One event per photon
- Photon energy, position & time of arrival stored
  → Possibility of obtaining spectra and images
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Processing X-ray data

- 6 ACIS chips
- Using Software CIAO to:
  - Cut to S3
  - Restrict the image to HST FoV
  - Construct the background light curve (S1)
  - No background flares
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Processing X-ray data

- `celldetect` source extraction algorithm (alt. `wavdetect`)
- Manual removal of problematic regions
Processing X-ray data

- *celldetect* source extraction algorithm (alt. *wavdetect*)
- Manual removal of problematic regions
Analyzing X-ray data

- LF shape compatible with LMXB population, peak artificial
- Higher luminosities suggest possible BH presence
Cross-matching optical & X-rays

- RGB image (ds9)
  - Red: F850LP ($\sim$ Sloan z)
  - Green: F475W ($\sim$ Sloan g)
  - Blue: X-ray

- Cross-matching the catalogues
  - Green: Optical catalogue
  - White: X-ray catalogue
  - Red: Cross-matched
Cross-matching optical & X-rays

- RGB image (ds9)
  - Red: F850LP ($\approx$ Sloan z)
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- Cross-matching the catalogues
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  - Red: Cross-matched
Cross-matching optical & X-rays

- Cross-match performed with TOPCAT
- Using RA & DEC for matching (0.1” threshold)
  - 1769 optical sources
  - 179 X-ray sources
  - 57 cross-matches
Properties of optical counterparts

- Redder in color
- Brighter in g & z mag
- \( \sim 2 \) times more frequent in the red peak
Properties of optical counterparts

- Different behaviour of two populations
  - GCs containing LMXBs are brighter
- Higher density favours LMXB formation
THANK YOU!