Utilizing *CFHT/MegaCam* images for Identifying X-ray Sources in Globular clusters

Ting-Ni Lu, Albert Kong
Institute of Astronomy, National Tsing Hua University, Taiwan
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Why Studying X-ray Sources in GCs?

- Studying the population and properties of the X-ray sources in globular clusters (GCs) in order to investigate their formation mechanisms.

- To help constrain the dynamical evolution scenarios/models of the X-ray sources and/or GCs.

- Each type of X-ray sources exhibits distinct properties in multi-wavelength observations

- Perform high resolution *Chandra* and *HST* observations to identify the nature of the X-ray sources in globular clusters.

Why *CFHT/MegaCam?*

- Extremely crowding environments in the **core of globular clusters** may cause **false matches** when multi-wavelength observations performed and compared.
- Relative astrometry would greatly improve the positional precision when dealing with counterparts.
- A **wide-field** reference image is needed in relative astrometry of dense environments like globular clusters.

Why *CFHT/MegaCam*? -- Wide Field Image

- Advantages and necessity for **wide field images** of globular clusters as reference frames?
  - register stars **outside** the core of globular clusters (using isolated stars in the much less dense region).
  - largely reduce the chance of false matches between different observations.

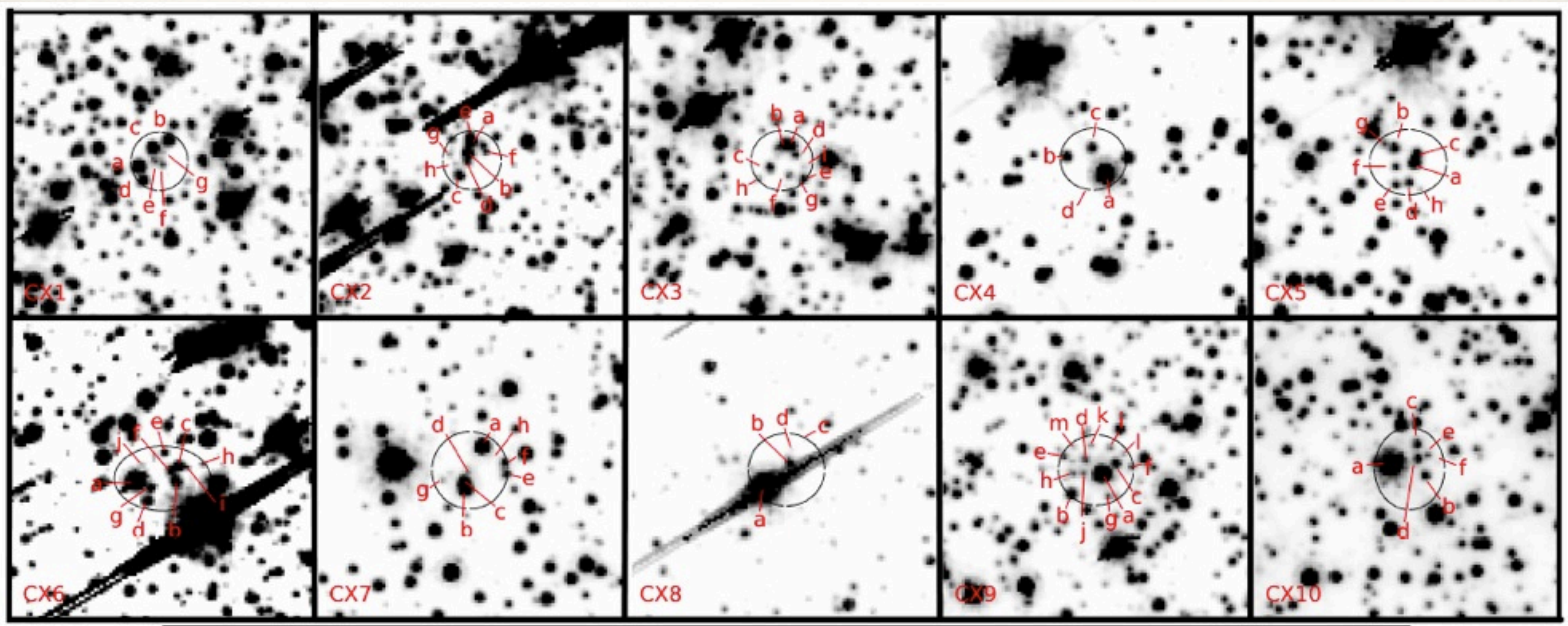
- Relative astrometry
  - put the high resolution X-ray and optical images on the reference image frame and coordinate system individually.
  - use ***CFHT/MegaCam* images** as reference frames and register stars in our works.

Relative Astrometry & Wide Field Image

- Position error circle
  - the quadratic sum of
    1) the position uncertainty of the X-ray sources (given by the *Chandra* source detection tool).
    2) the uncertainty of the astrometry in the *MegaCam* and *HST* image alignment.
    3) the uncertainty of the *Chandra* X-ray image boresight correction (*Chandra* to *MagaCam* astrometry).

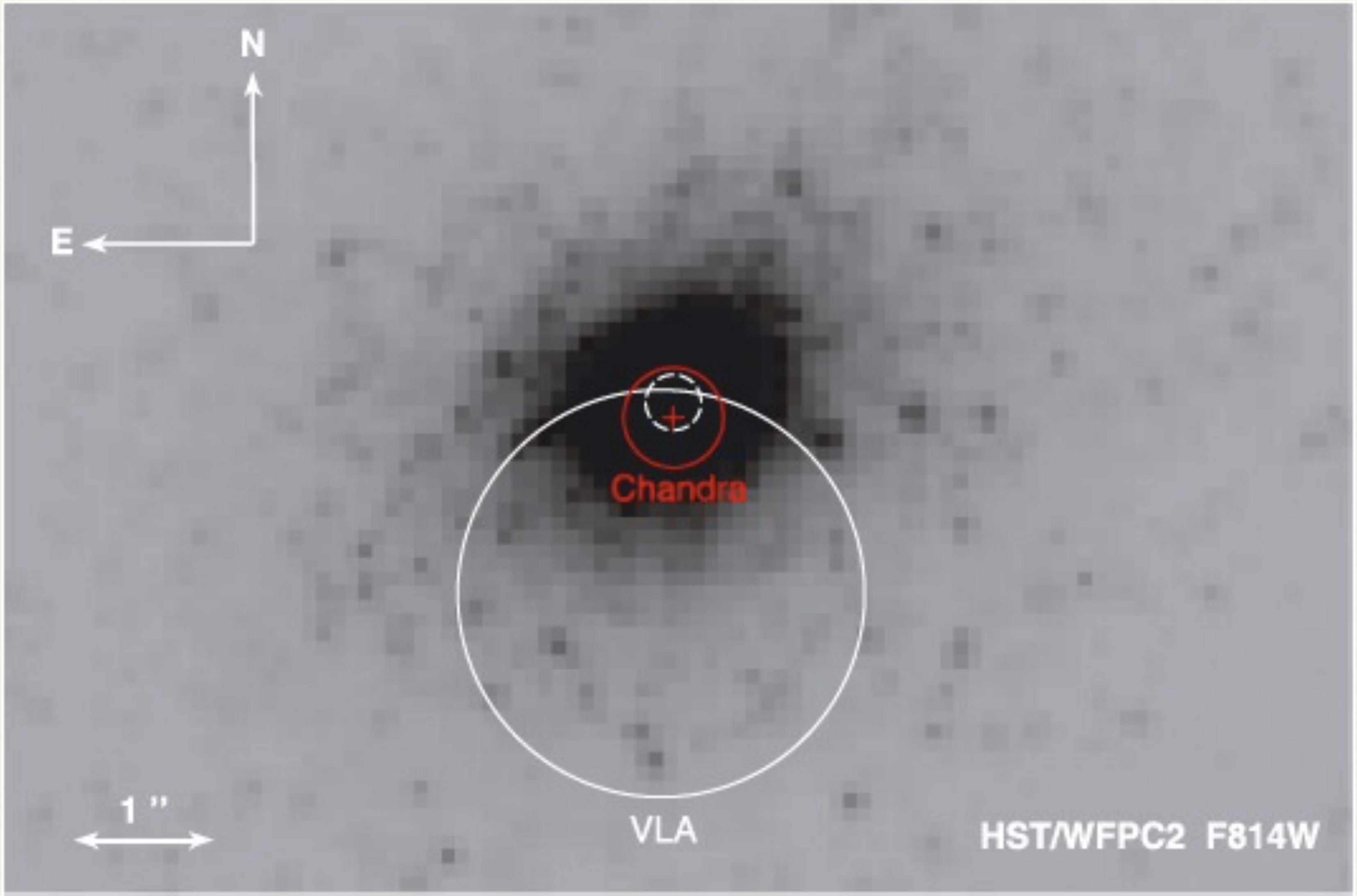
  - 1σ position error varies from **0.3″** to **0.7″** for all the X-ray sources in M92 and **0.15″** for G1.

Counterparts of M92



- The 5″×5″ finding charts for the X-ray sources inside the *HST ACS* field of view. The background optical image is the drizzled R-band (F625W) *HST* image. The 95% error circles of X-ray sources have been laid on the charts. The optical counterpart candidates are marked with letters. In all the images, north is up and east is left.

Counterpart of G1



Kong et al. 2010

- *HST WFPC2* F814W images of G1. The red circle is the 95% error circle (0.36″ in radius) of the *Chandra* source and its centre is marked by a plus sign. The white dashed circle at the centre is the core radius (0.2″; Ma et al. 2007; Barmby et al. 2007) of G1, while the white circle is the 95% error circle (1.47″ in radius) of the *VLA* source.

Identification Results

- **M92**
  - 4~13 optical counterparts for each X-ray source.
  - use CMDs to distinguish X-ray sources.
  - 5 CV candidates and 1 CV/AB candidates identified among the 10 X-ray sources within the half-mass radius of M92.

- **G1**
  - the X-ray source is within the core radius (0.19″) of G1 and very close (~0.11″) to the cluster centre.
  - the X-ray emission could be due to either accretion on to a central intermediate-mass black hole (IMBH) or an ordinary low-mass X-ray binary (LMXB).
  - an additional **EVLA** observation in 2011 is approved to reveal the nature of this object.

CFHT/Chandra/HST Observations

- Besides **M92**, we collect *CFHT* / *Chandra* / *HST* observations for low core-density globular clusters:
  NGC6362, **NGC6535**, **Terzan 3.**

- Our publication using the astrometry technique:
  Kong et al. 2006, ApJ, 647, 1065 (**NGC288**)
  Lu et al. 2009, ApJ, 705, 175 (**M12**)
  Lan et al. 2010, ApJ, 712, 380 (**E3**, **NGC6144**)
  Kong et al. 2010, MNRAS, 407, L84 (**G1**)

Thank you!