Globular Cluster X-ray Binaries

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I. *Chandra* Globular Cluster Gallery

II. Classifying the Low L_X Sources

III. MSPs: the L_X – E Relation

IV. Neutron Star Radii

X-ray Binaries in the Chandra and XMM-Newton Era Workshop
November 14 & 15, 2002

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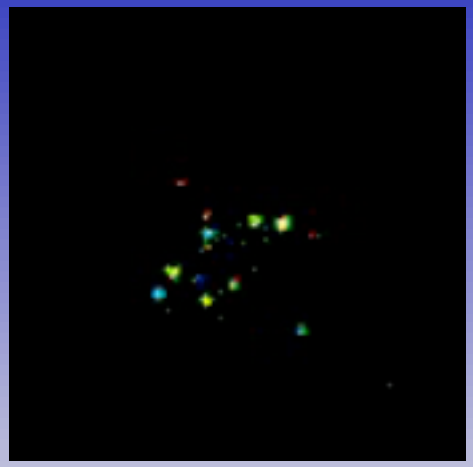
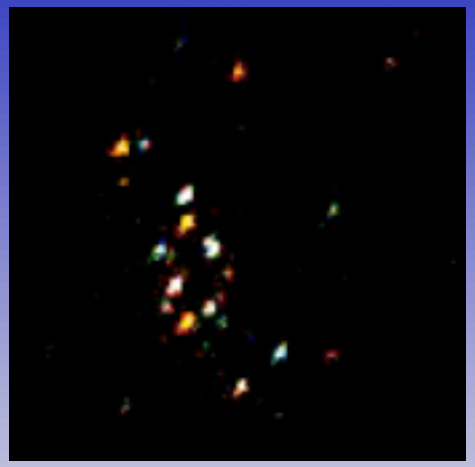
"True color" images: 0.5 – 1.2 keV (red)
1.2 – 2 keV (green)
2 – 6 keV (blue)

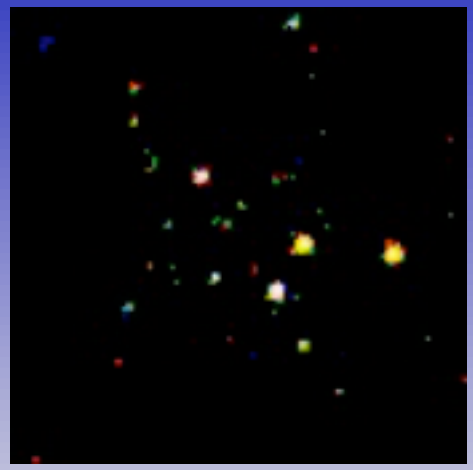
1' x 1' centered on cluster core



NGC 6440
d = 8.4 kpc
E(B-V) = 1.07
cf = 175



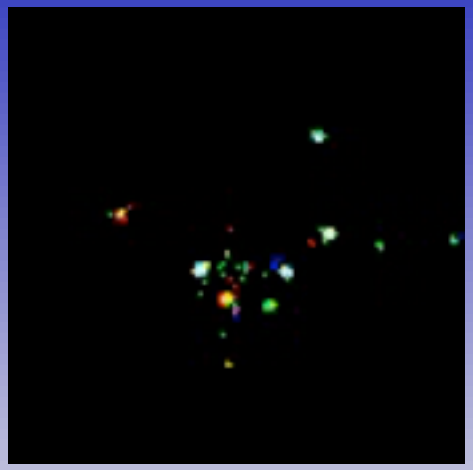
NGC 6266
d = 6.9 kpc
E(B-V) = 0.47
cf = 135



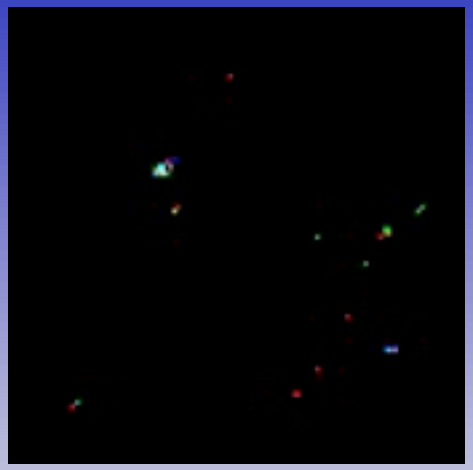
47 Tuc
d = 4.5 kpc
E(B-V) = 0.04
cf = 100

$$cf \quad \square_0^2 r_c^3$$

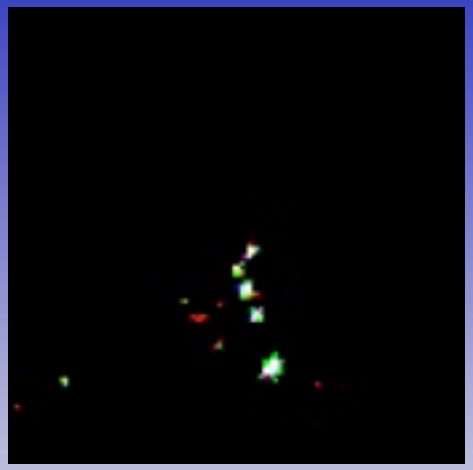
0.5 - 1.2 keV (red)
1.2 - 2 keV (green)
2 - 6 keV (blue)



NGC 6093
d = 10 kpc
E(B-V) = 0.18
cf = 42



NGC 5904
d = 7.5 kpc
E(B-V) = 0.03
cf = 8

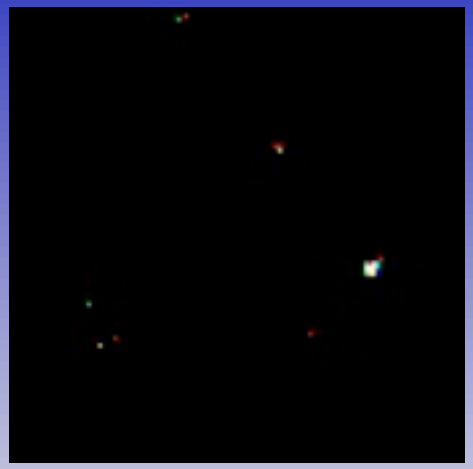


NGC 6752
d = 4.1 kpc
E(B-V) = 0.04
cf = 8

$$cf \quad \square_0^2 r_c^3$$

0.5 - 1.2 keV (red)
1.2 - 2 keV (green)
2 - 6 keV (blue)

NGC 6397
d = 2.3 kpc
E(B-V) = 0.18
cf = 1



NGC 6121
d = 2.2 kpc
E(B-V) = 0.36
cf = 1

$$cf \quad \Box_0^2 r_c^3$$

0.5 - 1.2 keV (red)
1.2 - 2 keV (green)
2 - 6 keV (blue)

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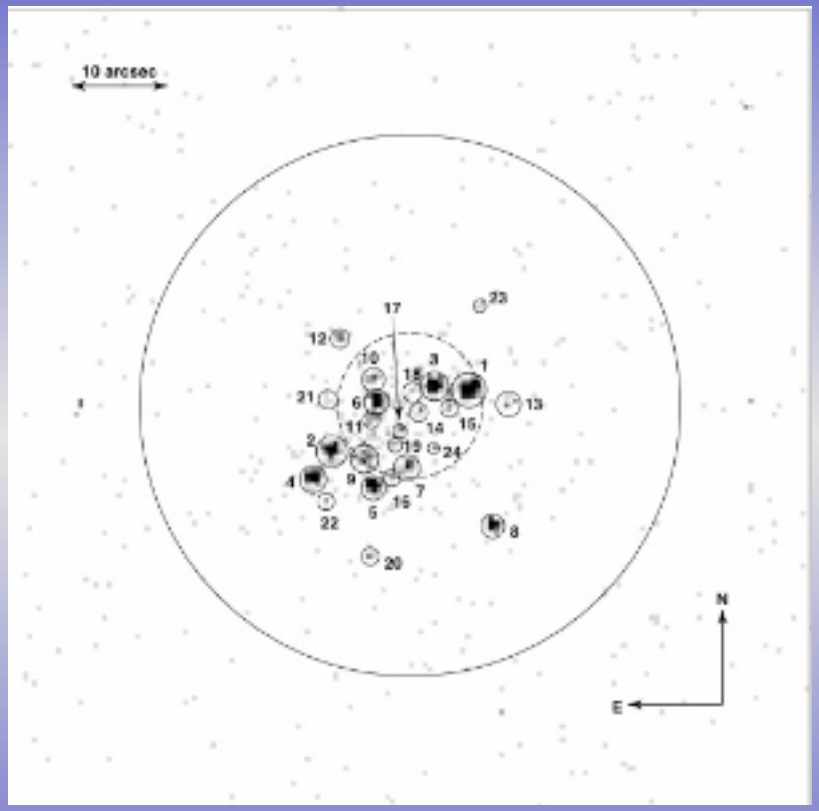
Expect a variety of unusual systems:
- Low mass X-ray binaries
- Cataclysmic Variables
- Millisecond Pulsars
- RS CVn / BY Dra
- Blue Stragglers

With as few as ~5 counts for some X-ray sources, we need an optical and/or radio counterpart to classify the nature of the source.

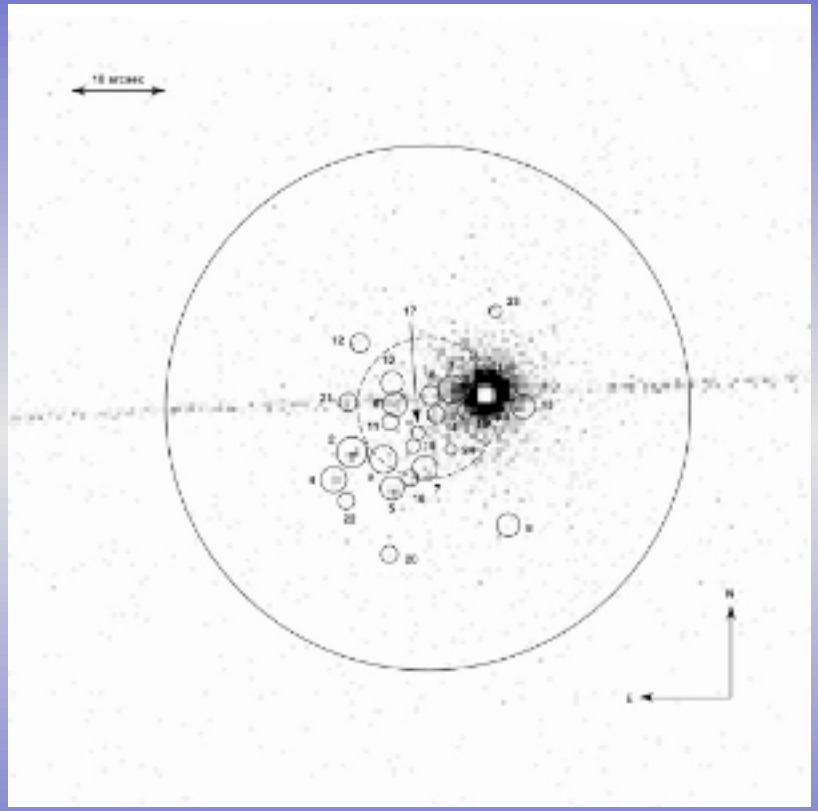
NGC 6440
Identification of the Transient LMXB

July 4, 2000



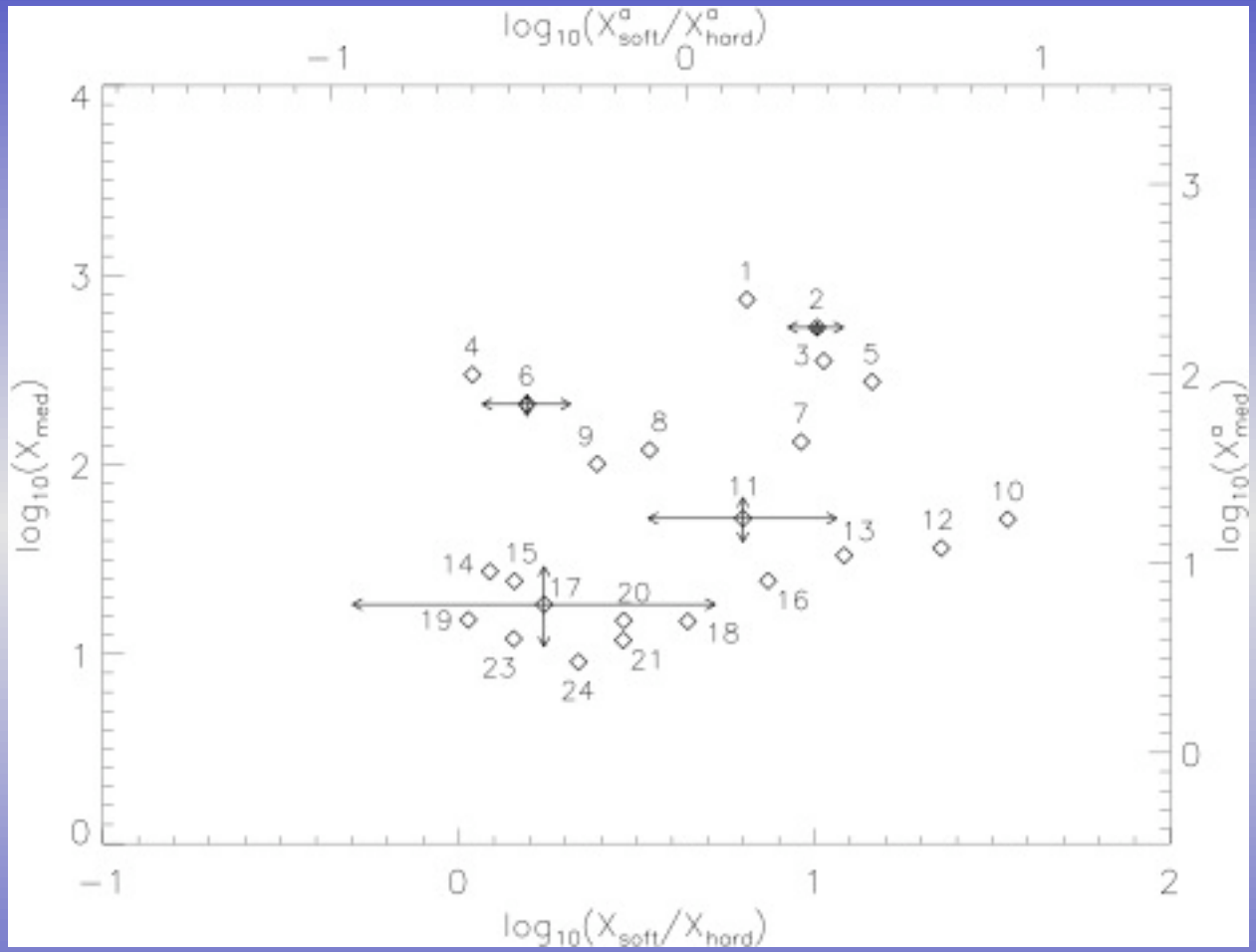
23 ksec

August 18, 2001

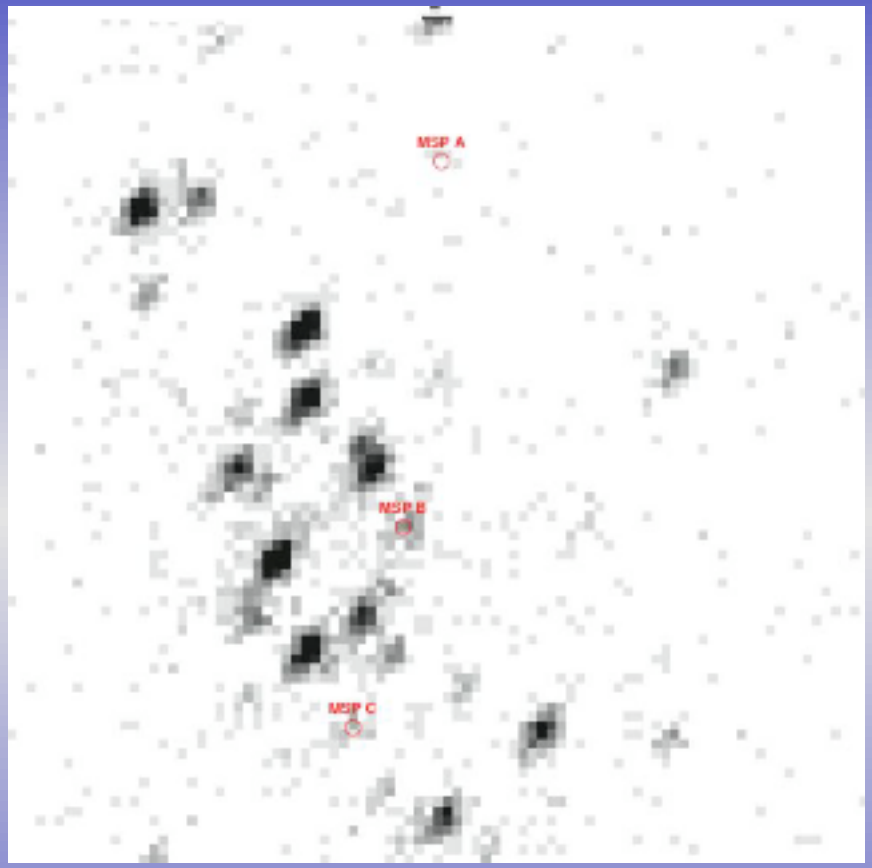


2.6 ksec

NGC 6440
Identification of the Other LMXBs



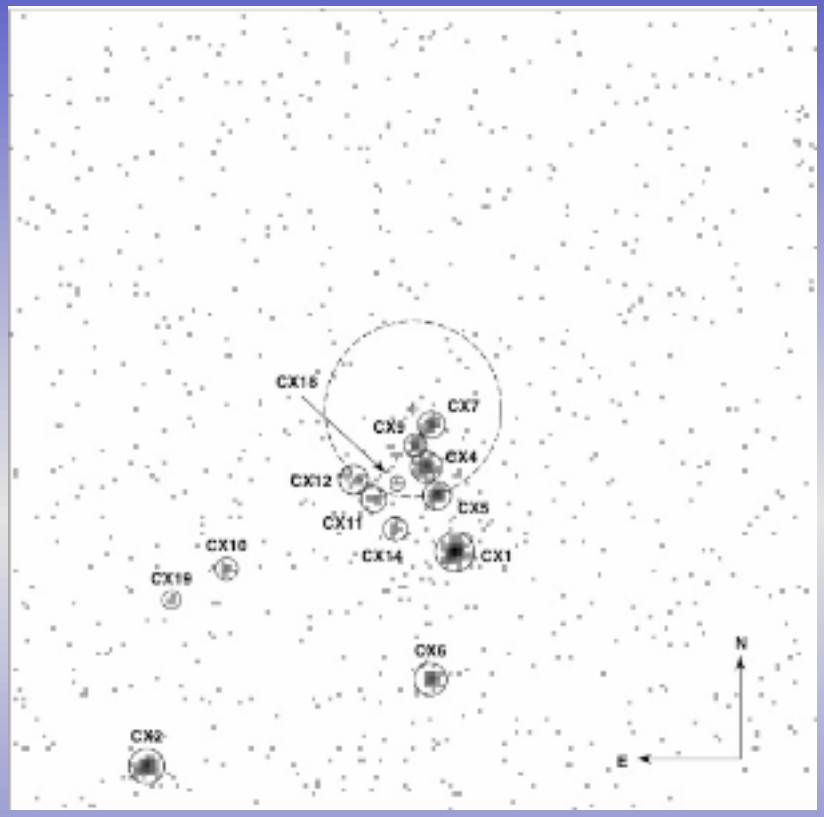
NGC 6266
Identification of the MSPs



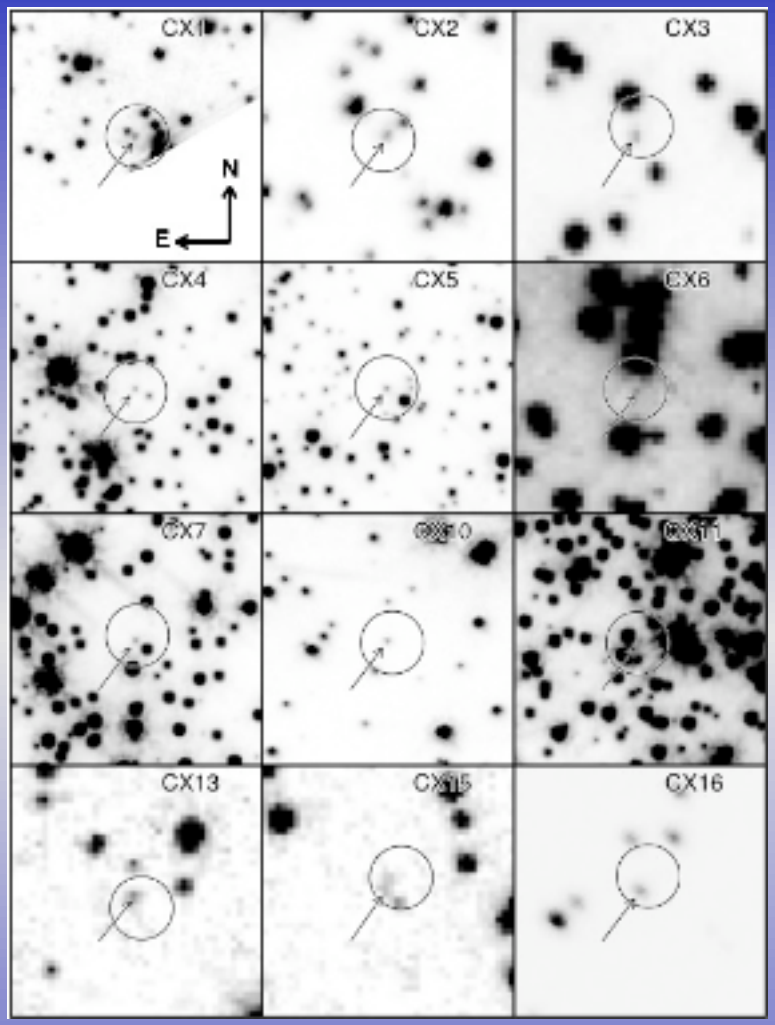
NGC 6752

Hubble

Chandra

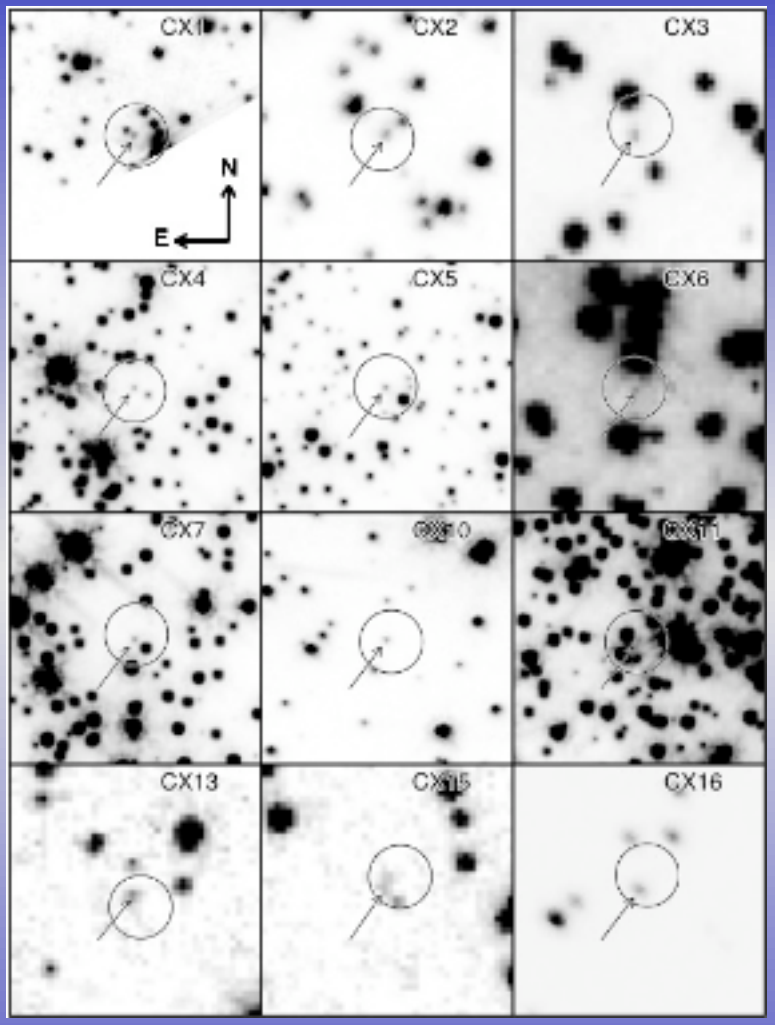


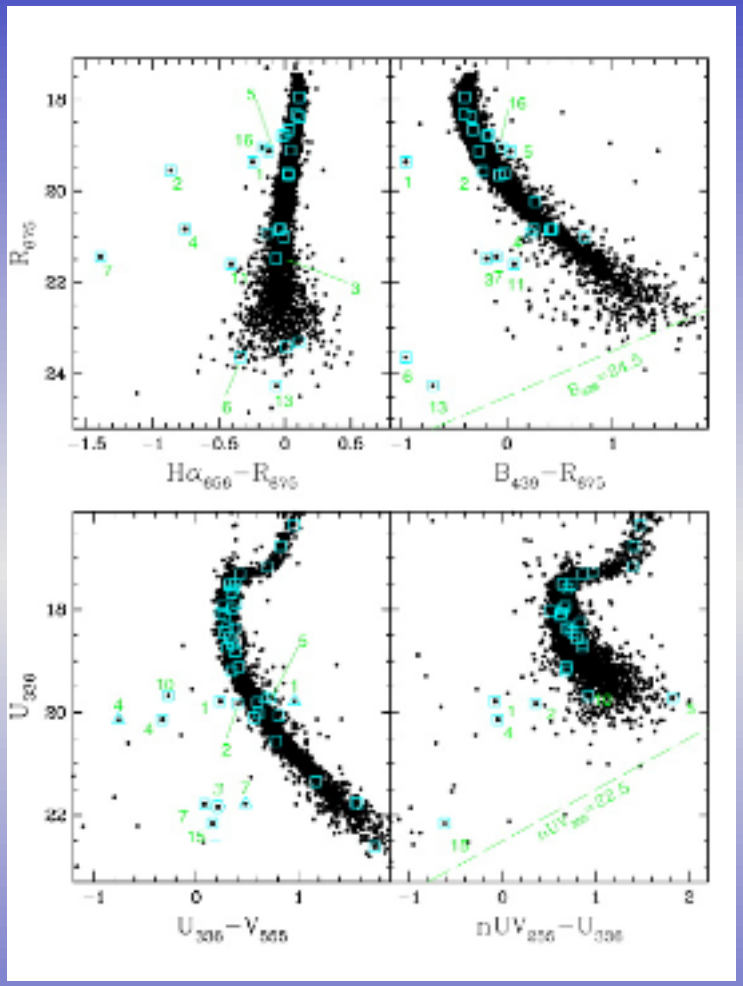
Central 1.6' x 1.6'
(10.5"core radius indicated)



4" x 4" finding charts

NGC 6752


CX1
CX2
CX3
N
E
CX4
CX5
CX6
CX7
CX10
CX11
CX13
CX15
CX16


R_{675}
$H\alpha_{656}-R_{675}$
$B_{439}-R_{675}$
U_{336}
$U_{336}-V_{555}$
$nUV_{255}-U_{336}$

Globular Cluster X-ray Binaries
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XRB Workshop
Nov 14, 2002

	47 Tuc	□ Cen	NGC 5904	NGC 6093	NGC 6121	NGC 6266
LMXBs	2	1	?	?	?	?
MSPs	20 (16-40)	0	2 (0)	?	1 (1)	6 (3)
CVs	13	2?	?	?	?	?
RS CVn	5	?	?	?	?	?
Unclassified	~60	~35	13	~20	25	32

	NGC 6366	NGC 6397	NGC 6440	NGC 6626	NGC 6752	NGC 7099
LMXBs	?	1	4-5	?	0	?
MSPs	?	1 (1)	0	?	5 (3)	?
CVs	?	8	?	?	10-13	?
RS CVn	?	2	?	?	1-3	?
Unclassified	3	1	~20	?	6	4

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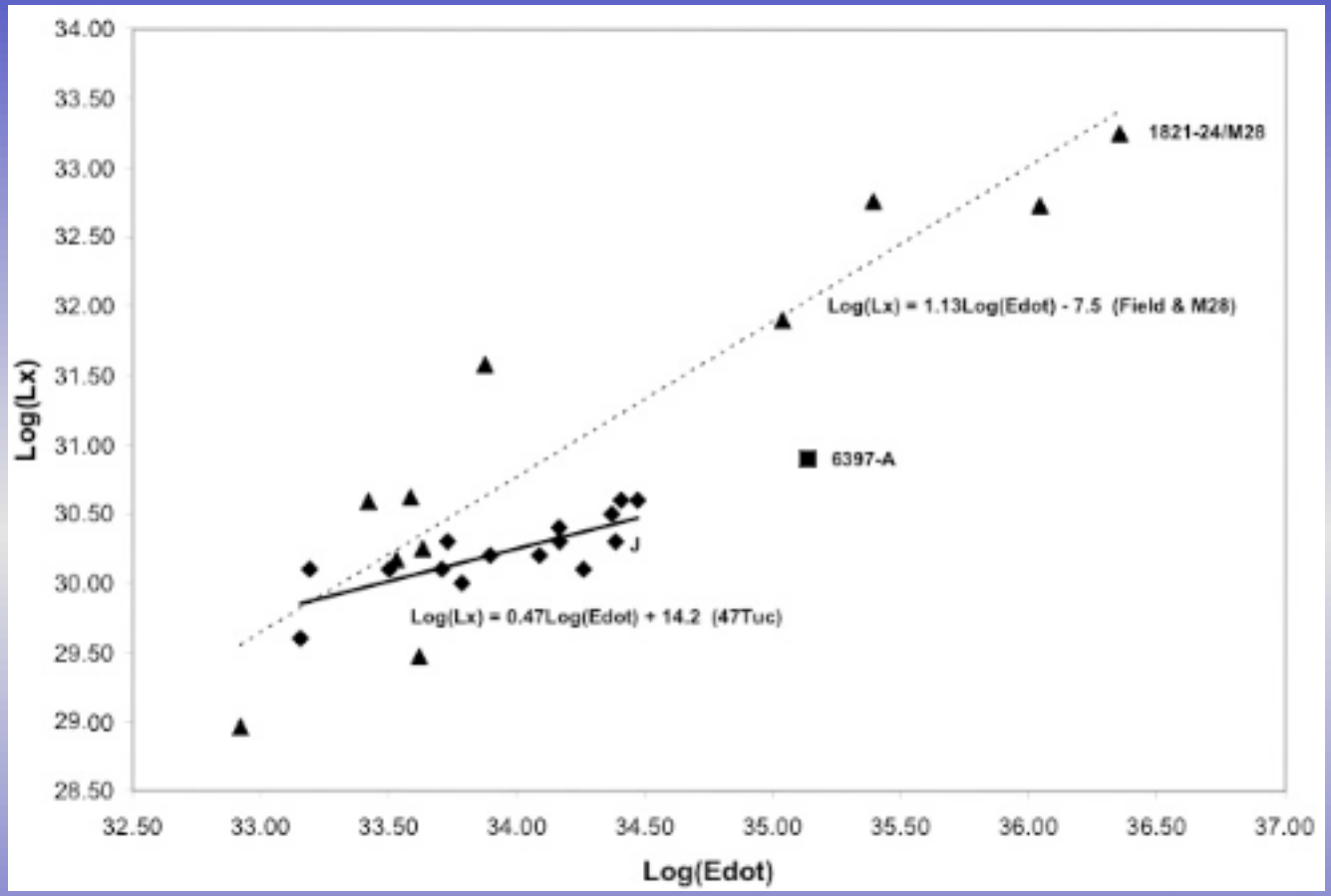
- Verbunt et al. (1996): $L_X \sim 10^{\square 3} \dot{E}$
- Possenti et al. (2002): $L_X \sim \dot{E}^{1.3}$
- Grindlay et al. (2002): $L_X \sim \dot{E}^{1.1}$ for the field & M28
  $L_X \sim \dot{E}^{0.5}$ for 47 Tuc & NGC 6397
  - Polar cap heating models (Harding & Muslimov 2002)
  - Altered surface magnetic field configurations
  - Neutrons stars are more massive or more compact

MSPs: the L_X – $\dot{E}$ Relation



Grindlay et al. (2002)

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- Use H or He atmosphere fits to X-ray spectra
- Accurate distance to cluster elimates one source of uncertainty

NS Radii from qLMXBs in Globular Clusters

□ Cen: $R_{NS} = 14^{+2.5}_{-2.5}$ for H atm (Rutledge et al. 2001)

NGC 6397: $R_{NS} = 4.9^{+14}_{-1}$ for H atm (Grindlay et al. 2001)
$R_{NS} = 12^{+3}_{-7}$ for He atm

NGC 6440: $R_{NS} = 19^{+29}_{-8}$ for H atm (in 't Zand et al. 2001)

BUT both N_H and M_{NS} are fixed in all fits:

- N_H can have uncertainties as large as 40%
- M_{NS} of 1.8 M_{sun} rather than 1.4 M_{sun} would give ~20% larger radii


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