WHERE'S THE CUSP? (OR CCD PHOTOMETRY OF GLOBULAR CLUSTER CORES)

Phyllis M. Lugger and Haldan Cohn
Department of Astronomy
Indiana University
Swain Hall West 319
Bloomington, IN 47405

Jonathan E. Grindlay
Harvard-Smithsonian Center for Astrophysics
60 Garden Street
Cambridge, MA 02138

ABSTRACT. UBVR CCD surface photometry for a sample of 11 globular clusters has been obtained at the Kitt Peak National Observatory (KPNO) #1 0.9 m telescope as part of a major study of globular cluster core structure. These data are being used to test for the presence of central cusps in the surface brightness profiles, which are expected to be present in clusters which have already undergone core collapse (Cohn and Hut 1984).

1. INTRODUCTION

Cohn and Hut (1984) have recently predicted that a significant fraction of high central concentration globular clusters have already undergone core collapse. While massive black holes can produce post-collapse expansion, it now appears rather unlikely that clusters do in fact harbor massive central black holes (Hertz and Grindlay 1984). Post-collapse expansion is instead expected to be driven by energy release from hard binaries (Inagaki 1984). Recent theoretical studies of binary driven post-collapse evolution (see e.g. Heggie elsewhere in this volume) predict that the central mass density profile should be characterized by a singular isothermal $\rho \propto r^{-2}$ or surface brightness $\sigma \propto r^{-1}$. Thus, the surface brightness in a post-collapse cluster should continue to increase with decreasing radius, in contrast to the behavior of a King profile which flattens out inside of the core radius. Therefore, central surface brightness cusps are predicted even in the absence of black holes.

The electronographic surface photometry of the cluster M15 reported by Newell and O'Neil (1978) indicates the presence of a central cusp that has been confirmed by the photographic photometry of Hertz and Grindlay (1984), the CCD photometry of Djorgovski and Penner (elsewhere in this volume), and the CCD photometry reported here. A

J. Goodman and P. Hut (eds.), Dynamics of Star Clusters, 89–92.

cusp has also been detected in NGC 6624 in these latter three studies. Djorgovski and King (1984) and Djorgovski and Penner (elsewhere in this volume) report cusps in NGC 6342, NGC 6642, NGC 6681, and NGC 7099.

2. THE SAMPLE

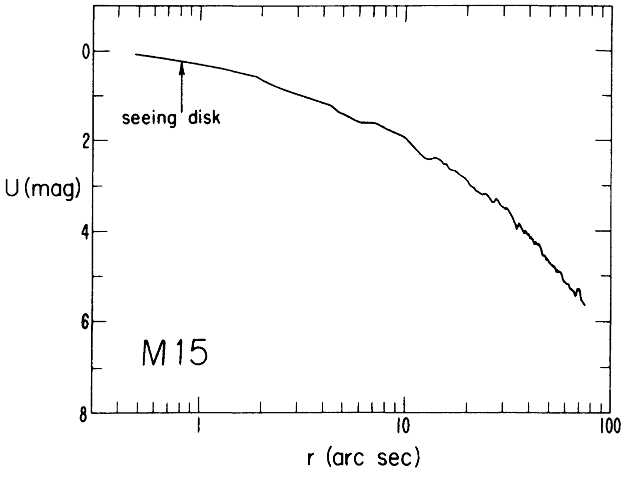
To determine how widespread the cusp phenomenon is, a major study of the core structure of globular clusters is being carried out by obtaining UBVR surface photometry for a total sample of 28 northern clusters using the CCD direct camera at the #1 0.9 m telescope at KPNO. Data for 11 of these clusters were obtained during a 21-24 May 1984 observing run. These clusters are NGC 4147, NGC 5024 (M53), NGC 5272 (M3), NGC 5904 (M5), NGC 6229, NGC 6254 (M10), NGC 6341 (M92), NGC 6517, NGC 6624, NGC 6760, and NGC 7078 (M15). Additional data will be obtained at KPNO and also at the Cerro Tololo Interamerican Observatory (CTIO) in a related study of a large sample of southern globular clusters. A scheduled 4 night run on the CTIO 4 m PFCCD in July 1984 was unfortunately snowed out.

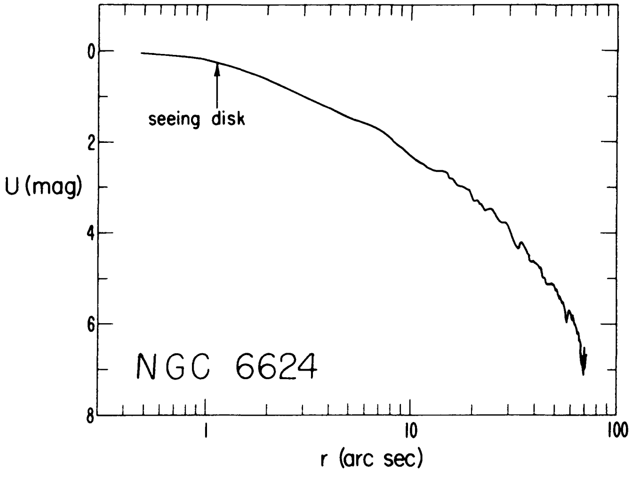
Data from the northern and southern samples will be used (1) to test for the presence of central cusps (i.e., luminosity excesses over normal King core surface brightness profiles), and (2) to investigate the dependence of core structure on galactic position and cluster core metallicity. The results of these studies will be of fundamental importance to our developing understanding of cluster dynamical evolution.

3. PRELIMINARY RESULTS

The U-band CCD frames obtained at KPNO for M15 and NGC 6624 have been analyzed using the SURFBRT routines on the KPNO Interactive Picture Processing System (IPPS). These routines were developed by Karen and Steve Strom for analyzing surface brightness profiles of elliptical galaxies. The core structure of globular clusters can best be studied in the U-band where the effects of individual red giants are minimized. As can be seen in Figures 1a and 1b, both M15 and NGC 6624 exhibit cusp structure. In both cases the surface brightness profiles rise as a power law into the seeing disk. The indicated seeing disk radii are the measured HWHM of stellar images from the same CCD frames as the cluster cores.

While no detailed fits to the cluster profiles have as yet been carried out, the power law portions of the profiles for $r_{seeing} < r < 10''$ have slopes $d \ln \sigma / d \ln r \approx -0.75$. As discussed by Cohn elsewhere in this volume, core collapse in a cluster in which the heaviest stars are nonluminous remnants can result in a slope such as that estimated from these data, which is flatter than the slope predicted for a single mass component cluster. Surface brightness profiles will be obtained for all 11 clusters using software developed by Hertz and Grindlay (1984). These profiles will be used to place limits on the seeing deconvolved central slopes of the profiles.





Figures 1a and 1b. U-band CCD surface brightness profiles of M15 and NGC 6624. The curves shown represent data points connected by straight line segments. Arrows indicate HWHM of the seeing profile. The zero point of the magnitude scale corresponds to the central value of the surface brightness.

The data obtained in this study will be used to investigate the dependence of core structure on galactic position (and hence tidal shocking rate) as well as on metallicity (and hence initial mass function). The question of whether the bulge clusters (which contain 7 of 9 of the high luminosity cluster X-ray sources) have evolved any differently than clusters farther out in the halo will be addressed. These data will also facilitate the construction of detailed, realistic models for evolving clusters using the Fokker-Planck methods developed by Cohn (1979, 1980).

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https://doi.org/10.1017/S007418090014728X Published online by Cambridge University Press