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I. INTRODUCTION

The discoveries of both steady and bursting X-ray sources in globular clusters have made them as interesting for high energy astrophysics and X-ray astronomy as they were for unlocking galactic structure in Shapley's day. Globular clusters are massive ($\sim 10^5\ M_\odot$) spherical clusters of primarily low mass ($\lesssim 0.8\ M_\odot$) evolved stars and may be the oldest systems in the Galaxy. Thus when several globular clusters were tentatively identified as containing X-ray sources (Giacconi et al. 1974), it was apparent that either dynamical or evolutionary processes must be occurring among the ancient stars in globular clusters to produce the relatively short-lived X-ray sources. The existence of these X-ray sources has prompted considerable discussion as to their origin, since they exist with ~ 100 times the probability per unit mass in globular clusters as in the Galaxy as a whole (Katz 1975; Clark 1975). They may be yet another example of X-ray binaries (e.g., Clark 1975; Fabian et al. 1975) or be due to accretion onto a single collapsed object (black hole) at the center of the cluster (Bahcall and Ostriker 1975; Silk and Arons 1975). At present both of these classes of models are possible and generally consistent with the data, though each has its particular difficulties. We shall review the observational data and then the models in an effort to point out the present balance of evidence for the binary vs. black hole models as well as the most promising directions for future work. Given the possibly high incidence of X-ray bursters in globular clusters, our discussion will refer to both observations and recent models for bursters. While this review will primarily address the X-ray sources in globular clusters, it is obvious that their eventual understanding will contribute much to studies of globular clusters in general and will prompt future studies in particular areas.

II. SUMMARY OF PRESENT DATA

A. Characteristics of the X-ray Sources. Three globular clusters were tentatively identified by *Uhuru* as containing X-ray sources (Giacconi et al. 1974).

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[The reference to a fourth cluster (M92) was erroneous.] The small (~1 arcmin) Uhuru error box for 3U1820-30 has been further refined to be within ~40 arcsec of the core of NGC 6624 by SAS-3 (Jernigan 1976). This source was the first identified globular cluster burster (Grindlay et al. 1976a). The X-ray sources 3U1747-37 and 3U2131+11 had larger positional uncertainties (~0.1° and ~1°) but included the clusters NGC 6441 and NGC7078 (M15) in their error boxes. Grindlay et al. (1976b) used the X-ray detectors on ANS to reduce the error box for 3U1746-37 by a factor of 3. The new source location region (~16 arcmin × 4 arcmin) includes the core of the (~6 arcmin diameter) globular cluster NGC 6441 but also still includes an interesting peculiar variable star (P-K 353 4° 1) outside the cluster for which Liller (1976a) has found a long-term optical brightening and a high excitation spectrum. While this star cannot yet be excluded, the probability of a globular cluster being in the X-ray source error box by chance (applying the empirical relationship given by Clark et al. 1975) is only $\sim 6 \times 10^{-4}$. We shall assume that NGC 6441 is the correct source identification, though we note the chance probabilities for cluster association given here may be too low if there are significant numbers of additional clusters in the galactic plane (see below). Finally, the positional uncertainty of 3U2131+11 has been reduced to be within ~1 arcmin of the core of NGC 7078 by a preliminary result from SAS-3 (Jernigan 1976).

Two additional sources apparently associated with the globular clusters NGC 1851 and NGC 6440 were discovered by the X-ray detectors on OSO-7. The first, MX 0513-40 = NGC 1851, was detected as a weak source with (probably) a flat spectrum in the range 1-10 keV (Clark et al. 1975) error box 0.18 deg^2 and source position suggest the probability of a chance association with the globular cluster is only $\sim 10^{-4}$. This source was subsequently found in the Uhuru data at comparably low and variable levels of persistent emission though a possible X-ray burst was also observed (Forman and Jones 1976). The source MX 1746-20 = NGC 6440 (Markert et al. 1975) was also detected by Uhuru and an improved source error box (0.06 deg^2) yielded a probability for chance cluster association of $\sim 3 \times 10^{-3}$ (Forman et al. 1976). A sixth persistent X-ray source was discovered by Ariel V near the globular cluster NGC 6712 (Seward et al. 1976). An improved source position and X-ray flare were reported by the Uhuru observers (Cominsky et al. 1976). The X-ray position was further refined by ANS (Grindlay et al. 1976c) to be 4 ± 3 arcmin south of the core of NGC 6712. However the combined (with Uhuru and Ariel V) 90% confidence error box is an ellipse of dimensions ~13 × 5 arcmin that includes the southern half of the (< 6 arcmin diameter) cluster NGC 6712. Although the probability for chance coincidence with the cluster is again only $\sim 10^{-4}$, the new error box still contains several irregular variable stars in the crowded field outside the cluster and is thus reminiscent of the identification of NGC 6441 mentioned above. The final globular cluster X-ray source to be identified with high probability is the highly reddened exteded object discovered by Liller (1976b) near the position of the rapid bursting X-ray source MXB 1730-335 (Lewin et al. 1976a). An improved position for the X-ray burster was obtained by ANS (Heise et al. 1976) and SAS-3 (Jernigan 1976) such that the combined (ANS - SAS-3) error box of $\sim 3 \times 2$ arcmin contained "Liller 1", implying a chance coincidence probability of $\lesssim 10^{-4}$. Recent infrared observations of this object by Kleinman et al. (1976) have confirmed that this object is, very probably, in fact a highly reddened and centrally-condensed globular cluster.

The key parameters describing these seven X-ray sources and their probable globular cluster counterparts are listed in Table 1. Few parameters are common to all seven sources, but we note that for each the "steady" (i.e., not in bursts) X-ray emission is variable by factors of at least 3-10 over time scales of minutes to months. Despite the large variations in X-ray flux, none of the sources in Table 1 shows any evidence for regular eclipses or pulsations. For NGC 6624 there is no periodic modulation (> 10%) for periods from ~ 6 hrs to 8 days (Canizares and Neighbours 1975), though a preferred time scale for flux changes may be ~ 1 day. Similar limits on periodicities have been found for 3U 1746-37 and A 1850-08 (Grindlay et al. 1976b, c). The variability of MX 1746-20 is extreme and resembles that of a "transient source" (Forman et al. 1976) as it was detected only for a ~ 1-month period in January 1972. The steady emission luminosities for the seven sources are all in the range $\lesssim 8 \times 10^{35}$-$3 \times 10^{37}$ erg s^{-1} and thus in the lower luminosity group of galactic sources as defined by Seward et al. (1972). This point has only now become clear with the detection of the weaker and highly variable cluster sources not in the 3U catalogue and the revision (Liller and Liller 1976) of the distance estimate for NGC 6624. Thus it is not correct to link the cluster sources with the "GX sources" (strong sources in galactic bulge) on the basis of high luminosities (Canizares 1975). Although the globular cluster X-ray luminosities may suggest similarities to the Sco X-1 or Cyg X-2 type sources, their high range of intensity variability and spectra do suggest similarities to the high luminosity GX sources. The time variations of NGC 6624 (at least) are also reminiscent of Cyg X-1, with long-term "high" and "low" (bursting) states (Grindlay et al. 1976a; Clark et al. 1976), ~ 10 min flares (Canizares and Neighbours 1975) and ~ 1 sec bursts. No millisecond variability has yet been detected from 3U1820-30 (Grindlay 1976), however.

The spectra of most of the steady sources listed in Table 1 are similar and reasonably well-described by exponentials with $kT \cong 5$–8 keV and low energy cutoffs consistent with (only) interstellar absorption (see refs. in Table 1). These generally lower temperature spectra are distinct from the higher temperatures ($kT \gtrsim 10$–15 keV) associated with the eclipsing or pulsing X-ray binaries (Jones 1976). The steady source MX 0513-40 may be an exception with a significantly harder spectrm (Clark et al. 1975) [though the burst was fit by $kT \cong 7.5$ keV (Forman and Jones 1976)]. The same (harder spectrum vs. soft flare) may also apply to A 1850-08 (Grindlay et al. 1976c); better measures of the steady-source spectra are needed for both of these weak sources.

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TABLE 1

PARAMETERS OF X-RAY SOURCES AND ASSOCIATED GLOBULAR CLUSTERS

X-ray Source and Glob. Cluster	2-10 keV Flux Range (10^{-10} ergs /cm^2 s)	Loc. Uncert. (arcmin)	Core and Clus. Diam. (arcmin)	Cluster Dis. (k_{pc})	L_x range (10^{36} erg/s)	Core Dens. (10^4 M_o/ pc^3)	Escape Veloc. (km/s)	Relax Time (10^7 y)	Int. Sp	ℓ^{II} b^{II} (deg)	Refs.
MX 0513-40 NGC 1851	<0.5 ~4.2 (105)	~25	0.3 11	11	<0.6 ~ 5 (125)	8.5	35	3.7	F7	244.5 -34.9	1,2 3,4 5
MX 1746-20 NGC 6440	<0.6 ~32	~15	0.2 6	10?	<0.5 ~36	30	≲48	≲3	G5	7 +3	1,2 3,6
3U 1746-37 NGC 6441	5.4 ~18	~ 5	≲0.4 6	9.3	5.3 ~17	10	42	5	G2	353.6 -5	1,2 4,7
3U 1820-30 NGC 6624	9 ~49 (1000)	< 1	0.3 4	6	3.7 ~20 (400)	5	28	2.8	G5	2.8 -7.9	1,2 8
A 1850-08 NGC 6712	<1.3 ~8 (32)	~ 8	1.6 ≲6	6.8	<0.7 ~ 4 (16)	0.15	20	35	G5	27 -5	1,3 9
3U 2131+11 NGC 7078	0.7 ~2.9	< 1	0.3 9	10	0.8 ~3.3	9	37	3.6	F2	65.6 -21.1	1,4 14
MXB 1730-335 Liller 1	<3 (200)	< 2	0.2 >1	10	< 3 (200)	40	60	4	?	354.8 -0.1	10,11 12,13

<u>Notes</u>: Maximum fluxes and luminosities in bursts given in parentheses. Cluster diameters are from Arp (1965) are max. apparent diameter, not tidal diameter. The location uncertainty θ is the approximate uncertainty in the source offset from the core given the error box of area θ^2.

<u>References</u>: (1) Arp (1965); (2) Bahcall and Hausman (1976); (3) Grindlay *et al.* (1976e); (4) Clark *et al.* (1975); (5) Forman and Jones (1976); (6) Forman *et al.* (1976); (7) Grindlay *et al.* (1976b); (8) Clark *et al.* (1976); (9) Peterson and King (1975); (10) Lewin *et al.* (1976a); (11) Heise *et al.* (1976); (12) Liller (1976a); (13) Kleinman *et al.* (1976); (14) Jernigan (1976).

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B. Characteristics of the Globular Clusters. The proposed globular cluster identifications are all, with the exception of NGC 6712, among the most centrally-condensed (and with highest escape velocities, shortest relaxation times) of the ~125 globulars known thus far in the Galaxy (Arp 1965; Peterson and King 1975). This correlation has been noted in many previous discussions (e.g., Clark 1975; Bahcall and Hausman 1976) with the previous more limited cluster sample. The anomaly of NGC 6712 suggests three possibilities: 1) the source A 1850-08 is not in NGC 6712 [the 90% error box of Grindlay et al. (1976c) includes an irregular field variable as well as the core]; 2) the central density is usually high for globular cluster sources and A 1850-08 is an extreme case; and 3) the source is in NGC 6712, but either the source or the globular cluster has undergone different evolution from the other cluster sources. This could arise if metal-rich globular clusters in the galactic plane (vs. the bulge, and NGC 6712 is at $\ell^{II} = 27^{\circ}$) are somehow disrupted - perhaps by tidal stripping such that eventually only whatever massive remnants there are in the core remain (Grindlay 1976). The absence of short-period (0.3-0.44^{d}) RR-Lyrae stars in metal-rich globulars (including NGC 6712) and their abundance as field stars in the galactic plane has suggested a "missing class" of disrupted globular clusters originally formed in the plane (Sandage et al. 1966). Thus perhaps NGC 6712 has lost a significant mass fraction and was formerly of higher density. Alternatively, metal-rich clusters with high initial mass function could evolve many more white dwarfs and other remnants at the cluster center such that the cluster M/L ratio, and hence central densities, would be much larger than the values assumed (M/L ~ 1) by Peterson and King (1975). This could be tested by actually measuring the velocity dispersion in the cluster core.

Accepting the identification of NGC 6712 as probably correct, it is also striking that 5 of the 7 globular clusters in Table 1 are within 8° of the galactic plane. Though the numbers are not yet compelling, this is already suggestive of the clustering about the galactic plane of galactic X-ray sources in general (Giacconi et al. 1974) and bursters (Lewin 1976), although 4 of these 5 X-ray clusters are within ~11° of the galactic center. There is an established correlation between galactic latitude and the integrated spectral type or metallicity of the cluster (see Arp 1965 for references). Indeed, the spectral type is G or later for the four clusters in Table 1 near the plane and this is probably consistent with the spectral data of Kleinman et al. (1976) for the fifth cluster, Liller 1, as well. Thus, high metallicity seems to be a common feature of most of the globular clusters containing X-ray sources. The metallicities of both NGC 6441 (Hesser and Hartwick 1976) and NGC 6624 (Liller 1976a) are, in fact, among the highest known. Of the two clusters in Table 1 with spectral types earlier than G (and $|b^{II}| > 20^{\circ}$) NGC 1851 has intermediate metal abundance while NGC 7078 (M15) is metal poor relative to other globular clusters.

C. Searches For Additional Globular Cluster Sources. Given these X-ray and optical characteristics of the known globular cluster sources, it is likely that additional sources may be found. Several X-ray surveys have been already carried out. Ulmer et al. (1976) analyzed Uhuru data from 125 days in 1971 on a sample of 35 nearby globulars and found no new sources; the search is being extended to all Uhuru data by Julien and Grindlay (1976). Johnson et al. (1976) have searched for both X-ray and radio emission from NGC 1904 with upper limits ($L_X < 1.5 \times 10^{36}$ erg s^{-1}) in each case. Finally, Grindlay et al. (1976c) have observed 15 clusters, most with high central densities, in March-April 1976 with the X-ray experiments on ANS. No new sources were found, and upper limits were typically $L_X \lesssim 10^{36}$ erg s^{-1}. Given the observed flux ranges (Table 1), however, it is clear that all these upper limits may be time-dependent. A survey with at least an order of magnitude more sensitivity is needed to test whether there are other sources (like NGC 6440?) that are emitting at a low level though they may also sustain high luminosities for limited periods.

There are several possible recently reported sources of steady or burst X-rays that may have globular cluster identifications, though none of these is as compelling as those in Table 1. The OSO-8 X-ray burst source reported by Becker et al. (1976) includes in its $\sim 6^\circ$ error box several globular clusters, notably NGC 6626 which has high central density and late spectral type. Babushkina et al. (1975) and Sagdeev (1976) have given positions for the three hard X-ray bursters seen by Kosmos 428 which include the condensed clusters NGC 6388 ($\sim 1^\circ$ box), NGC 6541 ($\sim 2.5^\circ$ box), and NGC 5904 ($> 10^\circ$ box). Pye et al. (1976) have reported a large (4°) error box for a new "steady" X-ray source which includes the globular clusters NGC 6293, 6304, and 6316, which are either centrally-condensed, or late spectral type, or both. Finally, there have been efforts to find new clusters optically at the positions of X-ray sources or bursters. Liller (1976a) now reports the near-IR discovery of possible cluster objects near the error boxes for the Norma burster (Grindlay and Gursky 1976) and MXB 1906+00 (Lewin et al. 1976b). However, both of these objects require considerable additional optical/IR study to establish their reality as new globulars, and better X-ray positions are required.

III. SUMMARY OF MODELS FOR GLOBULAR CLUSTER X-RAY SOURCES

The data described above suggest that the globular cluster X-ray sources are powered by accretion onto a neutron star or black hole at rates $\dot{m} \sim 10^{-9}$–10^{-7} $M_\odot$ yr^{-1}. White dwarfs can probably be ruled out by the X-ray luminosities which would then require a much higher $\dot{m}$ and hence total number of binaries than are observed in globular clusters (Canizares and Neighbours 1975).

A. Binary Models. The existence of X-ray sources in globular clusters was interpreted by Gursky and Schreier (1974) to imply the sources were extreme Population II binaries that would then involve Roche lobe overflow from low mass primaries onto neutron stars as in Sco X-1 or Cyg X-2. Clark (1975) has suggested

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that primordial binaries would either no longer contain a nuclear burning member to supply the accretion flow or would have been expelled from the cluster during the (presumably supernova) formation of the compact member. Silk and Arons (1975) have noted that the latter difficulty, originally pointed out by Katz (1975), is not relevant since the escape velocities in the X-ray clusters (Table 1) generally exceed those expected in the neutron star formation. We infer then that if the sources are relatively close separation (short period) primordial binaries in which collapse of one member has recently occurred, they may be at large separation from the cluster center in contrast to the capture binary models (Clark 1975; Fabian et al. 1975) favoring high stellar densities and formation in the cluster core. A short period primordial binary model may be attractive if a better refined X-ray position for the NGC 6712 source confirms that it is indeed offset from the cluster core (but still in the cluster).

While two-body tidal interaction should enhance stellar capture and form binaries in the high density cores of clusters (Fabian et al. 1975), the number of these containing compact components is dependent on the poorly-known densities of collapsed objects in globular clusters. Trimble (1976) finds the number of novae (3) and U-Gem stars (2-3) known in all globular clusters is higher than expected for these binaries, which contain white dwarfs. Thus, either white dwarfs are more numerous than expected in globulars [and King and Illingworth (1976) have some evidence for this] or a more efficient binary capture mechanism is needed (Trimble 1976) with fewer neutron stars (or stellar black holes) available to conserve the number of the X-ray sources. However, if the collapsed stars in the cluster are free, then (Silk and Arons 1975) they are more likely to capture each other rather than lower mass nuclear burning stars. This problem could be avoided if a (heavy) compact remnant collides (as would be favored) with a (heavy) binary of two normal stars. Such a "star exchange" process has been suggested by Hills (1975) and seems to be the most viable binary model for the globular cluster sources. Short periods would be usually expected.

The binary models are difficult to test optically since the capture or star-exchange binaries are formed in the core and are less probable in low density cores where observations are possible. No core binaries have been found in any cluster, and they have been searched for in NGC 6712 (Sandage et al. 1966) and NGC 6809 (Trimble 1976). Obviously the binary models would be established if X-ray eclipses or pulsations were observed. Periods of a few hours, such as expected from close binaries, are difficult for satellite experiments (with comparable orbital periods). However, Fabian et al. (1975) estimate an eclipse probability of ~ 0.4 for such sources, so that the lack of observable eclipses in 7 sources may be significant. It is reasonable to conclude that if the sources are binaries, they are probably surrounded by a cloud (or the neutron star orbits through and heats an extended corona of the primary) such that the radiation is scattered rather uniformly throughout the orbital phase.

B. Black Hole Models. Bahcall and Ostriker (1975) and Silk and Arons (1975) independently suggested the globular cluster X-ray sources may be due to accretion of free gas in the cluster core onto a central massive ($\sim$100-1000 $M_\odot$) black hole. The principal reasons for considering these models include 1) the differences between the X-ray properties of the cluster sources, including 2-3 bursters, and known binary sources; no bursters have been identified with known binaries; 2) the problems discussed above with creating sufficient X-ray binaries in clusters; and 3) the high central densities in the X-ray globulars suggest they may have undergone core collapse (e.g., Ostriker et al. 1972) and that these clusters will retain some gas for accretion in their central potential wells. However, recent calculations (Lecar 1976) indicate that the core collapse may proceed to $\sim$infinite density but $\sim$zero mass resulting in only a central hard binary. Further calculations are needed that include evolution of the cluster stars rather than treating them as mass points.

The gas available for accretion on a massive black hole could come from normal mass loss from stars in the cluster core (Silk and Arons 1975) and/or tidal breakup of stars near the hole (Bahcall and Ostriker 1975; Frank and Rees 1976). The first of these sources of supply alone, however, would not give rise to the large and rapid intensity variations observed in the steady flux, and this has been one of the principal observational difficulties with a massive black hole model. Instead, the gas flow must be modulated by a source closer to the hole. One possibility is a star in the central cusp orbiting close to the hole. Frank and Rees (1976) estimate a $\sim$50% probability that any central hole would have a close companion - a main sequence star would be capture in a $\sim$6 hour orbit and a giant or horizontal branch star in an orbit with larger separation. It is not necessary for any such captured star (which could be a neutron star) to supply the accretion gas. Instead the star could simply modulate an otherwise spherical accretion flow by the bow shock that would accompany its supersonic motion ($\gtrsim 10^8$-10^9 cm s) through the gas. In fact, the "steady" source luminosity limit ($\lesssim 3 \times 10^{37}$ erg s^{-1}) observed (Table 1) and generally small low energy absorption suggests the source is usually "starved", not "choked", as it could well be (Bahcall and Ostriker 1975) for cluster gas. Another possibility for modulating the accretion flow has been discussed by Grindlay (1976). If the X-ray burster and steady source in NGC 6624 (and perhaps bursters in general) is a massive ($\gtrsim 100$ $M_\odot$) black hole, then X-ray heating of the gas can modulate the flow. If the accretion flow exceeds a thermal limit, an accretion surge must follow which could account for the X-ray (and gamma-ray) bursts, limit the X-ray luminosity of the source to $\lesssim .01$ the corresponding Eddington limit, and expel high velocity hot gas from the system. It was then suggested (Grindlay 1976) that two-stream instabilities of this gas flowing through the cold infalling gas would modulate the accretion and steady X-ray flux.

IV. OBSERVATIONAL TESTS AND CONCLUSIONS

The hypothesis that the globular cluster X-ray sources are not intrinsically different from most galactic sources and are X-ray binaries would be strongly supported by: 1) observations of ~1 millisecond flux variations, or stable pulsations of the steady (or bursting) globular cluster X-ray sources; eclipses alone would be suggestive but not conclusive as an orbiting star near a central massive black hole could modulate the flux periodically; 2) establishing that all globular cluster sources are alike and some are significantly offset from the cluster cores; 3) identifying (optically) an X-ray burster with a (low mass) binary system outside a globular cluster; or 4) finding evidence for large numbers of collapsed remnants of stellar mass (white dwarfs and neutron stars) in the cores of globular clusters. Thus far none of these tests is positive [except possibly (4)], though this does not yet at all rule against binaries.

On the other hand, the association of globular cluster X-ray sources with massive black holes (assuming negative results above) would be strengthened by: 1) finding that many more centrally-condensed (and usually metal-rich) globular clusters contain (at least sporadic) X-ray sources; 2) finding evidence for free gas in the cores of globular clusters that could contribute to accretion on the central hole; 3) finding a cusp in the density of stars inside the cluster core as would arise from a central object (Bahcall and Wolf 1976); 4) establishing that X-ray bursters are always found in globular clusters or are (black hole) remnants (in interstellar clouds) of cores of disrupted clusters; 5) demonstrating theoretically that massive black holes can indeed be formed in the collapse of globular cluster cores.

The first point could still suggest capture binaries, though high metallicity would indicate more rapid evolution that might favor a black hole (Silk and Arons 1975). Point (2) is being explored by optical studies of Grindlay and Liller (1976). Preliminary results show that condensed cluster cores are generally redder than the cluster, which is expected from more massive cluster stars concentrating in the core. Both narrow-band photometry and direct spectra show evidence for weak H_α in emission, probably time variable, in the cores of several condensed globulars including the X-ray objects. The apparently high velocity of the emitting gas may argue against this being a direct mass loss from stars; additional optical studies are needed. Point (3) has been discussed by Bahcall and Wolf (1976), and density cusps would seem to be unobservable given present upper limits on black hole masses. Nevertheless Newell et al. (1976) have reported evidence for a possible cusp in M15, Point (4), the identification of bursters with globular clusters (e.g., Liller 1976b), is currently being studied. The black hole cores (in galactic plane clouds)(Grindlay 1976) of the "missing class" of metal-rich globulars suggested by Sandage et al. (1966) may account for some of the bursters and GX sources. Finally, point (5) will ascertain whether massive black holes in globular clusters could result from core collapse or must be primordial.

We conclude that massive black holes are at least as consistent with all the data for globular cluster X-ray sources as are low-mass binaries. It is possible that studies now in progress may settle this exciting question relatively soon.

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DISCUSSION

P. Mészâros - In the X-ray burst model described, involving spherical accretion on a black hole, the only heating mechanism considered is Compton heating of the electrons by outcoming radiation. It is very likely that viscous dissipation which should be present in spherical flows as well as in disks (e.g. Mészâros, Astron. & Astrophys. 44, 59 (1975)), provides a more important heating, and therefore would change the speakers estimates of timescales and luminosities to a significant degree.

J. Grindlay - Turbulent heating, as discussed by Mészâros, was in fact invoked in the present model to provide the hard X-ray flux from the central source. However, in the surrounding scattering cloud with a Compton scattering optical depth of ~ 1, Compton cooling by the steady flux from the optically thick accretion disk or core (intermediate be-

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tween the inner hard photon source and the scattering cloud) will cool the cloud somewhat below the temperatures calculated by Mészâros. Compton heating by the hard photons during a burst will expel the cloud and limit the burst luminosity.

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