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LETTERS

Do Globular Clusters Harbor Black Holes?

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Abstract It has been firmly established that there exists a tight correlation between the mass of the central black hole and velocity dispersion (or luminosity) in elliptical galaxies, "pseudobulges" and bulges of galaxies, although the nature of this correlation still remains unclear. We explore the possibility of extrapolating such a correlation to less massive, spherical systems like globular clusters. In particular, motivated by the apparent success in the globular cluster M15, we present an estimate of the central black hole mass for a number of globular clusters with available velocity dispersion data.

Key words: black hole physics – globular clusters: general – galaxies: general

1 INTRODUCTION

Supermassive black holes have been convincingly detected in the centers of some nearby galaxies (Kormendy & Richstone 1995). Kormendy & Gebhardt (2001, hereafter KG2001) gave a comprehensive review of recent black hole discoveries made with the *Hubble Space Telescope* (*HST*). A tight correlation between black hole mass and bulge velocity dispersion is confirmed. They noticed that the black hole mass correlates with the luminosity of "pseudobulges" in disk galaxies, elliptical galaxies and the bulges of disk galaxies, but is independent of the luminosity of galaxy disks. The correlation strongly suggests a causal connection between the formation and evolution of the black hole and the bulge, but the nature of this connection remains unknown.

It is interesting to check whether this correlation still applies to both larger and smaller spherical systems. We may even speculate whether the correlation extends to systems with dispersion as low as that of globular clusters, since the globular clusters are also self-gravitating spherical systems similar to galactic bulges. Using the $M_{\rm BH} - \sigma$ correlation, a crude estimate for the possible black hole mass in globular clusters can be obtained. For a typical massive globular cluster having a dispersion of the order of 10 $\rm km\,s^{-1}$, a black hole mass of about $2\times 10^3\,M_\odot$ is expected. In certain galaxies, the black hole directly reveals itself through its associated accretion and activity. Such activity can hardly happen in globular clusters due to shortage of gas. However, recent X-ray observations of several starburst galaxies (e.g. M82, NGC 4038/39)

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reveal the existence of intermediate-mass black holes in starburst regions which are related to the formation of globular clusters (Kaaret et al. 2001; Matsumoto et al. 2001; Fabbiano, Zezas & Murray 2001). The presence of a black hole in a globular cluster affects the stellar density profile and the central stellar dynamics. With the dynamical detection sensitivity currently available, black hole mass as low as 1000 $M_\odot$ can hardly be identified (van der Marel 2001). So far, the only example was presented by Gebhardt et al. (2000) for M15 which may possibly host a black hole of the order of $10^3\,M_\odot$.

2 CONSTRAINT ON THE $M_{\rm BH}-\sigma$ CORRELATION BY M15

Gebhardt et al. (2000) inferred the projected velocity dispersion profile from ~1800 member stars in M15 with known line-of-sight velocities. Assuming isotropic velocity distribution, a constant stellar mass-to-light ratio $(M/L)_V = 1.7$ and no rotation, the best spherical dynamical model that matches the data contains a $2000\,M_\odot$ black hole (see fig. 15 in Gebhardt et al. 2000). However, other models also explain the data, such as the models presented by Gebhardt et al. (2000). To draw a firm conclusion on this issue, further studies are needed.

If the globular clusters are eventually found to possess central black holes, as hinted in Gebhardt et al. (2000), it is interesting to investigate the correlation between black hole mass and velocity dispersion among globular clusters. Taking the projected velocity dispersion at effective radius as $9.0 \pm 0.7\,{\rm km\,s^{-1}}$ and assuming a black hole with mass of $2000\,M_\odot$, M15 can be plotted in the $M_{\rm BH}-\sigma_e$ diagram. In Fig. 1, the solid line defined by

$$M_{\rm BH} = (1.26 \pm 0.07) \times 10^8\,M_\odot \left(\frac{\sigma_e}{200\,{\rm km\,s^{-1}}}\right)^{3.42\pm0.08}$$

is the best fit to the galaxies. Within the uncertainties, M15 is perfectly sitting on the lower extension of the fit! Adding M15 to the KG2001 data, a robust $M_{\rm BH}-\sigma_e$ correlation in a much larger range can be given as

$$M_{\rm BH} = (1.27 \pm 0.07) \times 10^8\,M_\odot \left(\frac{\sigma_e}{200\,{\rm km\,s^{-1}}}\right)^{3.50\pm0.04},$$

which is shown by dash line in Fig. 1. Should the globular clusters and galaxies follow a similar physical process of black hole formation, they would exhibit the same correlation between black hole mass and velocity dispersion. Based on the data of both globular clusters and galaxies, the determination of the $M_{\rm BH}-\sigma$ correlation would be improved significantly.

3 BLACK HOLE MASS ESTIMATE IN GLOBULAR CLUSTERS

Bearing in mind that the black hole mass correlates only with velocity dispersion or luminosity of the self-gravitating spherical system, a bold speculation arises that the formation and growth of black hole can be linked with a certain potential physical process that is universal for such systems, and hence various sizes of self-gravitating systems satisfy the same correlation. With this speculation, the same $M_{\rm BH}-\sigma$ correlation should be found over a wide range of dimensions going from stellar globular clusters to galaxies. The black hole mass measurement by Gebhardt et al. (2000) shows that the globular cluster M15 is remarkably consistent with the $M_{\rm BH}-\sigma$ correlation derived from galaxies. This implies that the speculation might be applicable at least for globular clusters.

Adopting such a universal $M_{\rm BH} - \sigma$ correlation, the mass of the black hole in globular clusters can be estimated from the velocity dispersion. In Table 1, the parameters of 22 Galactic and 9 M31 globular clusters are tabulated. According to the relation between the black hole mass and central velocity dispersion of galaxies, given by Equation (5) in Merritt & Ferrarese (2001), the mass of black holes in those globular clusters is estimated. The results are listed in column (6) of Table 1. The uncertainties are given following those of the velocity dispersion data.

Table 1 Parameters of Some Globular Clusters

ID name (1)	M_B (2)	σ_0 (3)	$\log M_{\rm BH}$ (4)	ID name (1)	M_B (2)	σ_0 (3)	$\log M_{\rm BH}$ (4)
Galactic Globular Clusters[a]							
NGC 104	−8.66	$10.0^{+4.8}_{-2.6}$	$1.97^{+0.80}_{-0.62}$	NGC 6266	−9.46	$15.4^{+7.4}_{-4.0}$	$2.86^{+0.80}_{-0.62}$
NGC 362	−7.78	$6.2^{+3.0}_{-1.6}$	$0.99^{+0.81}_{-0.61}$	NGC 6284	−7.75	$6.8^{+3.4}_{-2.0}$	$1.18^{+0.83}_{-0.71}$
NGC 1851	−7.63	$11.3^{+2.5}_{-1.8}$	$2.22^{+0.41}_{-0.36}$	NGC 6293	−8.08	$8.2^{+4.2}_{-2.5}$	$1.57^{+0.85}_{-0.75}$
NGC 1904	−7.24	$3.9^{+2.2}_{-1.9}$	$0.04^{+0.92}_{-1.37}$	NGC 6325	−8.45	$6.4^{+3.3}_{-2.5}$	$1.06^{+0.85}_{-1.02}$
NGC 5272	−8.27	$4.8^{+2.4}_{-1.4}$	$0.47^{+0.83}_{-0.71}$	NGC 6342	−6.61	$5.2^{+2.6}_{-1.5}$	$0.63^{+0.83}_{-0.70}$
NGC 5286	−8.47	$8.6^{+4.3}_{-2.5}$	$1.66^{+0.83}_{-0.70}$	NGC 6441	−9.56	$19.5^{+9.4}_{-5.1}$	$3.34^{+0.81}_{-0.62}$
NGC 5694	−7.40	$6.1^{+1.3}_{-1.3}$	$0.96^{+0.40}_{-0.49}$	NGC 6522	−7.95	$7.3^{+3.5}_{-2.0}$	$1.33^{+0.80}_{-0.66}$
NGC 5824	−8.49	$11.1^{+1.6}_{-1.6}$	$2.19^{+0.28}_{-0.32}$	NGC 6558	−6.71	$3.5^{+1.8}_{-1.2}$	$-0.18^{+0.85}_{-0.86}$
NGC 5904	−8.18	$6.5^{+3.2}_{-1.8}$	$1.09^{+0.82}_{-0.66}$	NGC 6681	−6.61	$10.0^{+4.8}_{-2.6}$	$1.97^{+0.80}_{-0.62}$
NGC 5946	−7.98	$4.0^{+2.9}_{-2.9}$	$0.09^{+1.12}_{-2.65}$	NGC 6752	−7.19	$4.9^{+2.4}_{-1.4}$	$0.51^{+0.82}_{-0.69}$
NGC 6093	−7.95	$14.5^{+7.0}_{-3.8}$	$2.73^{+0.81}_{-0.62}$	NGC 7099	−6.92	$5.8^{+2.9}_{-1.7}$	$0.86^{+0.83}_{-0.71}$
Globular Clusters in M31[b]							
G58	−8.30	10.6± 0.4	$3.46^{+0.06}_{-0.01}$	G219	−9.00	7.1 ± 1.8	$2.82^{+0.36}_{-0.08}$
G73	−9.04	15.3± 0.5	$4.04^{+0.05}_{-0.01}$	G272	−8.87	16.3± 0.8	$4.14^{+0.08}_{-0.01}$
G105	−7.58	10.2± 1.7	$3.40^{+0.24}_{-0.04}$	G280	−9.26	26.9± 0.5	$4.93^{+0.03}_{-0.00}$
G108	−8.29	8.7 ± 0.5	$3.14^{+0.09}_{-0.02}$	G319	−8.06	9.1 ± 0.5	$3.22^{+0.08}_{-0.01}$
G213	−9.15	21.9± 1.3	$4.61^{+0.09}_{-0.01}$				

[a] Column (2): Harris 1996; column (3): Dubath et al. (1997).

[b] Column (2) and (3): Dubath & Grillmair (1997).

(1) Name of globular cluster;

(2) Absolute B-band magnitude (cluster luminosity);

(3) Projected central velocity dispersion in km s^{-1};

(4) Logarithm of black hole mass in solar mass.

For galaxies, black hole mass also correlates with bugle luminosity. Such a correlation is expected also to be present in globular clusters. The luminosity of globular clusters is plotted against black hole mass in Fig. 2. The solid line gives the best fit of galaxies by KG2001. The globular clusters fall around the solid line with a considerable scatter. This consistency reinforces the possibility that the globular clusters harbor black holes and satisfy the same $M_{\rm BH}$ – σ correlation as do the galaxies.

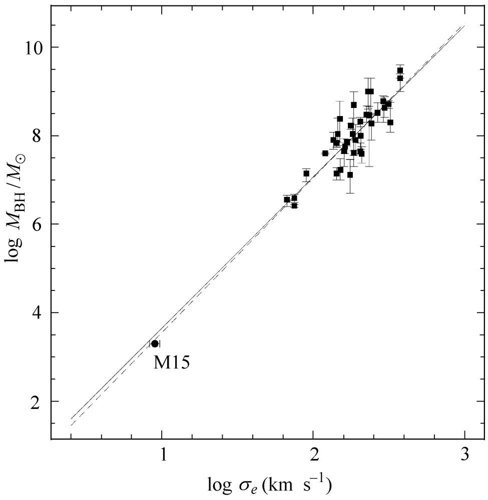

Fig. 1 Correlation of black hole mass with the mean velocity dispersion within the effective radius of the bulge of galaxies (squares, KG2001). The globular cluster M15 (solid circle) possibly contains a black hole of 2000 $M_\odot$, consistent with the correlation derived from galaxies.

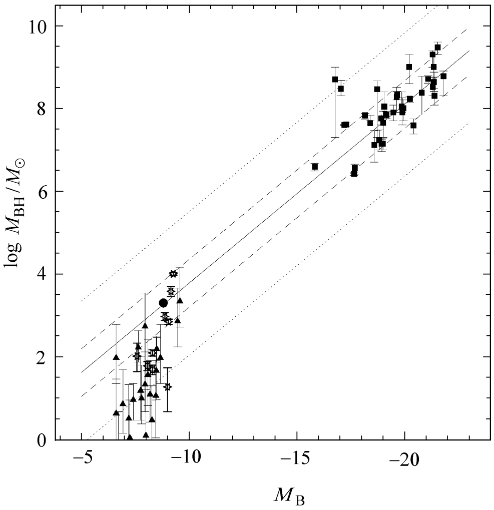

Fig. 2 Correlation of black hole mass with the absolute B-band magnitude for the bulge component of the host galaxy (squares, KG2001) and globular clusters (triangles for Galactic ones and asterisks for ones in M31). The circle is M15. The solid line gives the best fit of galaxies by KG2001. The dash and dotted lines show 1 σ and 3 σ confidence limits respectively.

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