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Stellar Population Synthesis of Bright X-ray Point Sources in NGC 1399

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Abstract

We present the stellar population synthesis (SPS) of X-ray point sources in NGC 1399 with an aim to investigate the dependence of X-ray characteristics on the dynamical properties of the sources. Our sample includes 22 bright X-ray sources ($L_x \geq 10^{38}$ erg/sec) in NGC 1399, of which two are ultra-luminous X-ray sources (ULXs). Using the SPS code of Bruzual and Charlot 2003 (BC03) and magnitudes in four Hubble space telescope (HST) filters, we estimate the possible ages and masses of these sources. We find that their X-ray luminosities are anti-correlated with the derived stellar masses excepting the two ULXs, the Spearman's rank correlation coefficient being -0.62 with a significance greater than 99%. As the optical counterparts are definitely multiple sources (most likely globular clusters), the strong trend exhibited by X-ray sources suggests the possibility of existence of multiple sources for the production of X-rays as well. Further, SPS also shows that the brighter X-ray sources are in general older. This analysis also suggests that the energy production mechanism in ULXs may be different from other non- ULX sources in our sample, as they are not following the correlation.

Keywords: Stellar populations, ultra-luminous X-ray sources, X-ray point sources, NGC 1399, globular clusters.

Introduction

Unresolved stellar populations in distant galaxies encapsulate significant information regarding the structure and evolution of parent galaxies. They appear as luminous compact objects in the photometric images of galaxies. Many of such sources were found to be X-ray emitting objects including ULXs which emit X-rays at super-Eddington rates (10^{39} –10^{41} erg/sec). Various studies were performed on such sources with an aim to investigate their X-ray to optical association.

Extensive studies performed on the nature of X-ray point sources in nearby galaxy NGC 1399 reveal that the majority of these sources reside in globular clusters. NGC 1399 is a prominent member of Fornax galaxy cluster and is the central cD galaxy of the cluster[1]. Spectroscopic studies show that it is located at a distance of about 19 Mpcs from our galaxy[2].

Globular cluster system of this galaxy was particularly well studied and it was found to exhibit colour-metallicity non linearity[3,4]. Major sources of X-ray emission in this galaxy were found to be low mass X-ray binaries (LMXBs)[5,6]. The X-ray point sources as well as the globular clusters were subjected to various multiband studies[7,8,9]. ULXs detected in the galaxy also proved to be interesting objects and their nature was investigated[10,11].

Though several studies were aimed at unveiling the dependence of X-ray point sources on the optical properties of their hosts, there is still scope for a stellar population synthesis (SPS) of these sources as such an approach is expected to provide dynamical properties of the system such as star formation history, ages, stellar masses etc. SPS is an effective tool in tapping the information hidden in the spectral energy distributions (SEDs) of unresolved star clusters. In the present study, we carry out SPS analysis of X-ray point sources in NGC 1399.

Data Reduction

Sample: Devi *et al.* carried out X-ray analysis of point sources ina sample of 30 nearby galaxies among which 13 were ellipticals[12]. Chandra advanced CCD imaging spectrometer (ACIS) observations were used in this analysis. They chose sources with net X-ray counts ≥ 60 for the study as it is the minimum requirement to perform spectral fit using two-parameter model. The spectra of 36 X-ray point sources in NGC 1399 were fitted with a two-parameter model- an absorbed power law and a disk blackbody. We selected this sample for our analysis.

Identification of optical counterparts: The optical properties of the bright X-ray sources reported by Devi *et al.* were investigated by Jithesh *et al.*[13]. Their study was based on the optically dark counterparts of these sources. 22 of these 36 sources were found to have genuine optical counterparts. We adopted this optical data for our analysis. They had performed aperture photometry in four different Hubble Space Telescope (HST) filters namely F475W, F606W, F814W and F850LP. The source identification was performed with the help of the package *source extractor* (SExtractor) and the galaxy was modelled using IRAF/STSDAS task *ellipsefit*[14].

Stellar population synthesis: The stellar population synthesis code of Bruzual and Charlot (BC03) was used for the analysis. The code computes the photometric and spectroscopic evolution of stellar populations across the wavelength range 320 nm to 950 nm[15]. The library GALAXEV, which is a part of the code, includes models for a wide range of ages and metallicities. The method of isochrone synthesis is used to compute the stellar spectral evolution in this code. Isochrones synthesis is based on the concept of simple stellar populations (SSPs). Isochrones specify the single age and single metallicity regions in the Hertzsprung-Russel (HR) diagram[16]. SSPs are believed to be formed at around the same time and with same initial elements. The evolution of such populations is computed in the code based on stellar spectral libraries and theories of stellar evolution.

We computed the absolute magnitudes and broadband colours assuming a distance modulus of 31.46. We adopted an average metallicity of 0.004 as suggested by Ostrov *et al.*[17]. The *Padova 1994* tracks were used for the analysis as recommended by the code. The *Chabrier* initial mass function (IMF) was used to generate the models.

The code computes the evolution from ages 1×10^5 to 2×10^9 years. The stellar populations of NGC 1399 are believed to be old populations with most of them identified as globular clusters[3]. We used star formation rates of the order of 0.1 solar mass per year and early cut offs (0.001Gyrs). All four magnitudes (F475W, F606W, F814W and F850LP) and broadband colours (F475W-F606W, F475W-F814W and F475W- F850LP) were extracted from the code. The magnitudes were in AB system as to make it easier to compare with the data.

After extracting the models, the data was fitted with the model with the help of a minimisation algorithm. The masses and ages were found using the best fitting values of the model parameters.

Results and Discussion

Results: We obtained the ages and masses of all the 22 sources by carrying out their SPS. The masses were found to be of the order of 10^5 solar masses. The ages of these clusters were found to be lying in the range 10^7 to 10^9years. Stellar masses for five sources in our sample were previously determined by Humphrey *et al.*[18]. Our results agree with their estimations with a slight deviation as expected as they have only considered magnitudes in two filters whereas our study involves four magnitudes.

We observed an anti-correlation between the stellar masses and X-ray luminosities as shown in figure-1. Excepting the two ULXs and an outlier, the Spearman's rank correlation is found to be -0.62 with significance greater than 99%. Also, we observe that brighter X-ray sources are older sources. It is to be noted that the two ULXs included in the study are not following both the relations.

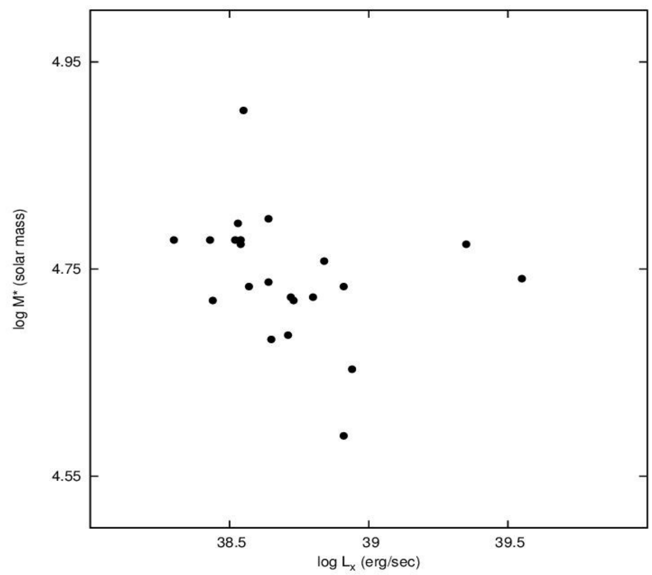

Figure-1
Plot of X-ray luminosity vs. stellar mass. It shows an anti-correlation except the two ULXs at the extreme right of the plot and an outlier with the highest mass

Conclusion

Figure-1 shows that the stellar mass is decreasing with increasing X-ray luminosities in the range 10^{38} to 10^{39} ergs/sec. Though this is an interesting result, its existence is not unexpected. It may be explained on the basis of basic stellar evolution theory. Unresolved stellar populations are believed to contain a large number of stars (of the order of 10^5) which contribute to the total optical light[19]. As all these stars evolve over time, it is expected that many of them will reach the final stages of stellar evolution such as white dwarfs, neutron stars or black holes, which in turn can contribute greatly to the X-ray brightness. The possibility of such a situation is supported by the observation that the X-ray luminosity is increasing with the age of the population. In addition to the high variability in X-rays showed by these compact sources, the large scatter observed in the trend may be attributed to the roles played by other factors such as metallicities, star formation rates etc. and comparatively large uncertainties in X-ray observations[20].

Further, the X-ray point sources in nearby galaxies were reported to be highly variable. This also suggests that in order to show such a correlation, there must be sufficient number of X-ray emitting objects to minimise the variability. As there are a number of optical sources, such a correlation demands a number of X-ray sources (which could be much smaller than the number of optical sources) also to be present in the clusters. In fact the presence of 5-100 stellar mass black holes were predicted in

Milky Way globular cluster M22[21]. This supports the possibility of such a situation in nearby galaxies also.

The lower limit of X-ray luminosity is constrained by the criteria imposed on X-ray counts whereas the upper limit to which the relation extends, is an element of interest. 10^{39} erg/sec is the Erdington limit for an accreting compact object. As ULXs are not following this relation, it is possible that their nature is completely different from the other sources of the sample. As to what could be the number and nature of X-ray emitting objects in ULXs, further studies involving more number of such objects need to be carried out. Our sample is not sufficient to draw conclusions in this regard. However, further attempts in this direction may be aided by such a correlation.

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References

1. Drinkwater M.J., Gregg M.D., Colless M., Substructure and Dynamics of the Fornax Cluster, *ApJ.*, **548**(**2**), L139-L142 (**2001**)
2. Richtler T., Dirsch B., Gebhardt K., Geisler D., Hilker M., Alonso M.V., Forte J.C., Grebel E.K., Infante L., Larsen S., Minniti D. and Rejkuba M., The Globular Cluster System of NGC 1399.II. Kinematics of a Large Sample of Globular Clusters, *ApJ.*, **127**, 2094-2113(**2004**)
3. Blakeslee J.P., Cho H., Peng E.W., Ferrarese L., Jordan A. and Martel A.R., Optical and Infrared Photometry of Globular Clusters in NGC 1399: Evidence for Color - Metallicity Nonlinearity, *ApJ.*, **746(1)**, 88-103 (**2012**)
4. Angelini L., Loewenstein M. and Mushotzky R.F., The X-ray Globular Cluster Population in NGC 1399, *ApJ.*, **557**, L35–L38 (**2001**)
5. Kundu A., Zepf S.E., Hempel M., Morton D., Ashman K.M., Maccarone T.J., Patig M.K., Puzia T.H. and Vesperini E., The Ages of Globular Clusters in NGC 4365 Revisited with Deep HST Observations, *ApJ.*, **634 (1),** L41-L44 **(2005)**
6. Bassino L.P., Faifer F.R., Forte J.C., Dirsch B., Richtler T., Geisler D. and Y. Schuberth, Large Scale Study of the NGC 1399 Globular Cluster System in Fornax, *A&A*, **451(3)**, 789-796 (**2006**)
7. Paolillo M., Puzia T.H., Goudfrooij P., Zepf S.E., Maccarone T.J., Kundu A., Fabbiano G. And Angelini L., Probing the GC-LMXB Connection in NGC 1399 : A Wide Field Study with the Hubble Space Telescope and Chandra, *ApJ.*, **736(2),** 90-106 (**2011**)
8. Shalima P., Jithesh V., Jeena K., Misra R., Raveendranath S., Dewangan G.C., Ravikumar C.D. and Babu B.R.S., Mid-infrared and X-ray Luminosity Correlations of X-ray Point Sources in NGC 1399, *MNRAS*, **434(2),** 639-651 (**2013**)
9. Kim H.S., Yoon S.J., Sohn S.T., Kim S.C., Kim E., Chung C., Lee S.Y. and Lee Y.W., Wide Field Multiband Photometry of Globular Cluster Systems in the Fornax Galaxy Cluster, *ApJ.*, **763**(**1**), 40-61(**2013**).
10. Kaaret P., Prestwich A.H., Zezas A., Murray S.S., Kim D.W., Kilgard R.E., Schlegel E.M. and Ward M.J., Chandra High Resolution Camera Observations of the Luminous X-ray source in the starburst galaxy M82, *MNRAS*, **321**, L29-L32 (**2000)**
11. Swartz D.A., Ghosh K.K., Tennant A.F., Wu K., The Ultraluminous X-ray Source Population from the Chandra Archive of Galaxies, *ApJS.*, **154**, 519-539 (**2004**)
12. Devi A.S., Misra R., Agrawal V.K. and Singh K.Y., The dependence of the estimated luminosities of ultra-luminous X-ray sources on spectral modes, *ApJ.*, **664**, 458-466 (**2007**)
13. Jithesh V., Jeena K., Misra R., Ravindranath S., Dewangan G.C., Ravikumar C.D. and Babu B.R.S., Black hole mass limits for optically dark X-ray bright sources in elliptical galalaxies, *ApJ.*, **729**, 67-70 (**2011**)
14. Bertin E. and Arnouts S., Sextractor : Software for Source Extraction, *A&AS.*, **117**, 393-404 (**1996**)
15. Bruzual G. and Charlot S., Stellar population synthesis at the resolution of 2003, *MNRAS*, **344**, 1000-1028 (**2003**)
16. Conroy C., Modeling the panchromatic spectral energy distributions of galaxies, *Annu. Rev. Astron. Astrophys.*, **51,** 1-66 **(2013)**
17. Ostrov P., Geisler D. and Forte J.C., The metallicity gradient and distribution function of globular clusters around NGC 1399, *AJ.,* **105(5**), 1762-1778 (**1993**)
18. Humphrey P.J. and Buote D.A., Low mass X-ray binaries and globular clusters in early-type galaxies.I. Chandra observations, *ApJ.*, **689**, 983-1004 (**2008**)
19. Heinke C.O., X-ray Sources in Galactic Globular Cluster, *AIP Conf. Proc.*, **1314**, 135-139 (**2010)**
20. Zhang Z., Gilfanov M. and Bogdan A., Dependence of the LMXB Population on Stellar Age, *A&A,* **546**, A36-A48 **(2012)**
21. Strader J., Chomiuk L., Maccarone T.J. and James C.A., Two stellar mass black holes in the globular cluster M22, *Nature*, **490**, 71-73 (**2012**)