New Variable Stars in NGC 6652 and Its Background Sagittarius Stream

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Abstract

We conducted a variable star search on the metal-rich Galactic globular cluster NGC 6652 using archival Gemini-S/Gemini Multiobject Spectrograph data. We report the discovery of nine new variable stars in the NGC 6652 field, of which we classify six as eclipsing binaries and one as an SX Phoenicis star, leaving two variables without classification. Using proper motions from Gaia DR2 and Hubble Space Telescope, albeit with some uncertainties, we find that the cluster, the field, and the background Sagittarius stream each have three of these variables. We also reassess the membership of known variables based on the Gaia proper motions, confirming the existence of one RR Lyrae star in the cluster.

Key words: galaxies: individual (Sgr dSph) – globular clusters: individual (NGC 6652) – stars: variables: delta Scuti – stars: variables: RR Lyrae

1. Introduction

The study of variable stars is paramount to our understanding of the distance scale, as well as the stellar structure and evolution (e.g., Catelan & Smith 2015). The variable star content of star clusters is particularly relevant because it allows us to study ensembles of these stars at essentially the same distance, helping to understand the systematic errors that affect the different stellar distance indicators.

Stellar variability in Galactic globular clusters (GCs) is one of the oldest branches of astronomy (Pickering 1889; Bailey 1902), and by the mid 1990s it was thought that the census of their variable star content was almost complete (Suntzeff et al. 1991). This situation changed spectacularly with the introduction of image subtraction techniques (e.g., Alard & Lupton 1998), which resulted in hundreds of new variable stars found even in previously well-studied clusters (e.g., Kaluzny et al. 2004; Contreras et al. 2005). Even though stellar variability has now been studied using image subtraction techniques in many GCs (e.g., Salinas et al. 2005; Catelan et al. 2006; Arelanno Ferro et al. 2017), there are still GCs that have not been studied in this way, or where improved observational techniques have pushed even deeper into the cores of GCs (Skottfelt et al. 2013; Salinas et al. 2016). In this work, we focus on one of those understudied clusters, NGC 6652—with the unusual treat, for Galactic variability studies, of using data from a 8 m class telescope.

NGC 6652 (C 1832-330, R.A. = 18 35 45.6, decl. = −32 59 26.6) is a fairly metal-rich, ([Fe/H] = −0.96 and [Fe/H] = −0.85 in the Zinn & West 1984 and Carretta & Gratton 1997 scales, respectively), old Galactic GC (11.7 Gyr, Chaboyer et al. 2000), associated either with the inner halo (Chaboyer et al. 2000) or the outer parts of the bulge (Rossi et al. 2015). It has a heliocentric distance of 10 kpc, and a Galactocentric distance of 2.7 kpc (Harris 1996, 2010 edition). It has a core radius of 0.1 and a tidal radius of 6.3′ (Trager et al. 1993). This cluster has been a frequent subject of study, mainly because of the high number of X-ray sources it harbors (Predehl et al. 1991; Heinke et al. 2001; Coomber et al. 2011; Engel et al. 2012; DeCesar et al. 2015). Optical variability studies conducted by Hazen (1989) used photographic plates, and therefore were more sensitive to discovery in the outer parts of the cluster. More recent studies were conducted by Skottfelt et al. (2015), using EMCCD data restricted to the very inner 45° × 45° of the cluster. This means a significant portion of the cluster still has not been explored by modern techniques—and both studies were relatively shallow, leaving unexplored the variability below the main sequence turnover (MSTO).

NGC 6652 also lies in front of the Sagittarius dwarf spheroidal (Sgr dSph, hereafter Sgr) leading tidal arm, some 4 degrees away from the center of Sgr, and therefore deep imaging of the cluster has been frequently used to characterize the Sgr stream (Siegell et al. 2011; Sohn et al. 2015).

In this paper, we use archival Gemini imaging to conduct a search for variable stars in NGC 6652 and the background Sgr stream. Section 2 presents observation and data reduction, while Section 3 describes the search. Section 4 describes the found variables and reassesses the nature of the known variables, and we finish summarizing in Section 5.

2. Observations and Data Reduction

NGC 6652 was observed with the Gemini South telescope, located in Cerro Pachón, Chile, on the night of 2011 May 2 under Gemini program GS-2011A-Q-20 (PI: Heinke). Observations were taken with the Gemini Multiobject Spectrograph (GMOS, Hook et al. 2004) in imaging mode (then equipped with E2V detectors), taking alternatively undithered images in SDSS g′ and r′ filters (hereafter, g and r, for simplicity), with exposure times of 75 s in both bands. Observations were taken continuously for ~6 hr, for a grand total of 86 images in each filter. This cadence and time span are
particularly useful to detect short period variables such as SX Phoenicis (SX Phe) or δ Scuti stars, which have pulsation periods on the order of just a few hours. For other pulsating stars—such as RR Lyrae stars, which vary in timescales of around half a day—the cadence will not be enough to obtain a period, although the time span is enough to recognize them as variable stars. The GMOS FoV is 5.5 × 5.5 arcmin, with a pixel scale of 0′′146 when reading with a 2 × 2 binning.

These images were originally obtained to study the optical counterpart to the low-mass X-ray binary XB 1832-330 in NGC 6652 (Engel et al. 2012), but ignoring the rest of the cluster.

Raw science frames, along with their associated calibrations, were retrieved from the Gemini Observatory Archive. Bias subtraction, flat-fielding, and trimming of the unilluminated sections of the CCDs were done using the GMOS specific tasks in the IRAF/Gemini package. FWHM of the PSF was measured with the gemseeing task. Median FWHM of the complete data set are 0′′68 and 0′′61 for g and r, respectively.

3. Variable Star Search and Photometry

Variables stars were searched using the difference imaging program ISIS (Alard 2000). The process involves several steps made separately for each filter. First, all images are registered to one image that serves as an astrometric reference. This image is usually the one with the best image quality in the sample. A small set of the best images (best-behaved PSF, low background, no artifacts) are then combined to form a photometric reference. Next, ISIS finds a convolution kernel that, when applied to the reference frame, will match the PSF but also compensate for different exposure times, variations in background, and airmass in each individual image of the set. Once the PSF is matched, the subtraction is applied. The residual images are then combined, obtaining the mean of the absolute normalized deviations (a variance image), where variable residuals (e.g., genuine variable sources) will stand out.

Once this variance image is constructed, it is visually inspected in order to find intrinsic variations and discard blemishes that could produce similar signals (bad pixels, saturated stars, cosmic rays, etc.). Variable stars leave residuals that preserve a stellar-like shape and therefore can easily be separated from the residuals from ill-subtracted saturated stars or hot pixels. We have found that, in the extremely crowded regions of globular cluster cores, this visual inspection gives better results than applying a detection threshold to the variance image, which necessarily picks up a large amount of false positives. The success of our approach is best exemplified in the case of NGC 2808: there, using the same data set, Corwin et al. (2004) did not find any SX Phe stars, while Catelan et al. (2006) found four of these faint, low amplitude variables. We have applied this method in several publications with excellent results (Salinas et al. 2007, 2016, 2018). In the case of NGC 6652, our visual inspection revealed the existence of 14 candidate variable sources, which further inspection of their light curves narrowed down to nine (see below).

The final step of ISIS is to conduct PSF photometry over the selected candidates. This photometry is given in fluxes relative to the image chosen as reference. In order to transform these relative flux light curves to magnitudes, standard PSF photometry has to be performed over the reference images.

PSF-fitting photometry of the reference image was done using DAOPHOT/ALLSTAR (Stetson 1987), following standard procedures, including the selection of ∼50 bright isolated stars per filter to determine the PSF. For the variable sources discovered with ISIS, the relative flux light curves were associated with the ALLSTAR results to convert them to magnitudes using the procedure described in Catelan et al. (2013).

Calibration of the magnitudes to the standard system was achieved using the color terms given in the Gemini web pages, but the zeropoints derived by Engel et al. (2012) from standard stars observed the same night of the observations. The calibrated magnitudes of all stars in the GMOS field, together with the intensity-weighted magnitudes for the new variables, can be seen in the left panel of Figure 1. Saturation starts slightly above the horizontal branch, and it is unlikely that affects the search for RR Lyrae stars (see below). Additionally, Hubble Space Telescope (HST)/ACS photometry from Sarajedini et al. (2007) is shown in the right panel of Figure 1, where this time the magnitude of the variables comes from single exposures. HST photometry is expected to be mostly unaffected by blends and therefore give an independent measurement to assess the results from the GMOS photometry. Finally, periodicity in the light curves was searched using the phase dispersion minimization algorithm (Stellingwerf 1978) as implemented in IRAF, and the astrometry of all sources was established by cross-correlating with known 2MASS sources via SCAMP (Bertin 2006).

4. Known and New Variable Stars

4.1. Proper Motion Sources

As an aid to the classification of the discovered variables, we used proper motions from two sources: the HST proper motions from Soto et al. (2017) and the recent Gaia DR2 (Gaia Collaboration et al. 2016, 2018). Soto et al. (2017) released only coarse proper motions based on HST/ACS and HST/UVIS images of the cluster separated by 7.5 yr, with the advantage that observations are deeper than Gaia and can also identify stars in the very core of the cluster. As in Soto et al. (2017), we adopt the criterion of a proper motion relative to the cluster center of less than 0.35 pixel (2.3 mas) as an indicator of cluster membership. Because Soto et al. (2017) gave only proper motions relative to the cluster center, we used the NGC 6652 proper motion measured by Sohn et al. (2015) ($\mu_{R.A.} = 5.5$ mas yr$^{-1}$, $\mu_{Decl.} = -4.5$ mas yr$^{-1}$) to give a zero point to the HST proper motions. For variables outside the HST field of view, we have used complementary proper motions from the Gaia DR2 (Gaia Collaboration et al. 2016, 2018).

The right panel of Figure 2 shows Gaia proper motions for stars in the GMOS FoV (small black dots). The cluster of points around $\mu_{R.A.} = 5.5$ mas yr$^{-1}$ and $\mu_{Decl.} = -4.5$ mas yr$^{-1}$ shows the proper motion of stars in NGC 6652. The proper motion measured by Sohn et al. (2015) is shown with a green cross and has only a small offset with respect to the Gaia results. The proper motions for the discovered variable stars can be seen with black symbols corresponding to HST data, and red circles for Gaia. The circle centered at $\mu_{R.A.} = 2.9$ mas yr$^{-1}$ and $\mu_{Decl.} = -1.4$ mas yr$^{-1}$ displays the proper motion of the background Sgr field.

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5 https://archive.gemini.edu

6 http://www.gemini.edu/sciops/instruments/gmos/calibration/photometric-stds
measured by Sohn et al. (2015). Note that a couple of variables (V18 and V23) do not have proper motions because they are outside the \textit{HST} FoV and are too faint to be detected by \textit{Gaia}.

4.2. Known Variables outside the GMOS FoV

There have been several searches for variable stars in this cluster (Hazen 1989; Heinke et al. 2001; Skottfelt et al. 2015). The Clement et al. (2001) catalog (updated on 2015 January) lists a total of 14 variables, of which only V10 to V14 are within the GMOS field of view.
Gaia proper motions of all the bright population on the outskirts of the cluster permits us to reassess the membership of the known variables found by Hazen (1989). Table 1 shows the data for V1 to V9 discovered by Hazen (1989), as given by the Clement et al. (2001) catalog. Cross matching between the Gaia DR2 sources and the Clement et al. (2001) catalog was done with STILTS (Taylor 2006), using an archival wide-field Blanco/MOSAIC-II image of the cluster (proposal ID 2008A-0289) to check when multiple matches occurred. From the Gaia proper motions, all but one of these variables (V9) are non-members. V9 is a RRab variable with period of 0.63 day.

4.3. Known Variables within the GMOS FoV

Basic details for these variables are given in Table 1. V10 and V11 are LMXBs discovered by Heinke et al. (2001). Even though V10 shows no variability in our data, V11 leaves a positive residual, although is very close to a saturated star. Neither of them are found in the Gaia DR2 release.

V12, a cataclysmic variable (also discovered by Heinke et al. 2001) at only ~4′ from the cluster center, is in a zone of extreme crowding where again our data set fails to find a variable source. This variable is not found in Gaia, either.

V13 is an X-ray source for which Skottfelt et al. (2015) finds almost no variability, with the exception of small possible flare. This source, associated to an upper RGB star, appears saturated in our images. Their Gaia proper motions are consistent with cluster membership.

V14 was discovered by Skottfelt et al. (2015) (see details in Table 2). They found the light curve of this variable has the typical sinusoidal shape of an RRc, but its low luminosity would indicate a background star. Moreover, its period of 0.189845 day is very low for an RRL star, although not unheard of.7 As an alternative possibility, they mention this could be a blue straggler in an eclipsing system. Our observations confirm the period and give some support to its nature as an RRc variable. First, the light curve shows a hump before maximum light, a common feature in RRLs produced by shocks waves in the star’s atmosphere (e.g., Catelan & Smith 2015); second, its color and luminosity are consistent with the horizontal branch of the background Sgr stream (Figure 1, left panel). One puzzling feature is the sharp increase of luminosity near maximum light seen in both bands. Even though increased scatter at maximum light is well-documented for RRCs (e.g., Kaluzny et al. 2000), the amplitude of r ~ 0.07 mag of this feature is well above the expectations. A visual inspection of the images near maximum light reveals no issues at the position of this variable. The feature is also not visible in the Skottfelt et al. (2015) light curve. The final word for its classification comes from its proper motions. Not only do the Soto et al. (2017) proper motions put this variable as a cluster member, Simunovic & Puzia (2016), in their measurement of proper motions for blue stragglers in 38 globular clusters, also place it as a cluster member. Therefore, we conclude this variable is a member pulsating blue straggler, namely an SX Phe.

4.4. The Discovered Variables

The positions of the newly discovered variables are shown in Figure 2 (left panel). Data for the newly discovered variables are shown in Table 2, while light curves in g and r can be seen in Figure 3. We follow and extend the naming convention of the Clement et al. (2001) catalog. V15: this variable is located close to the the base of the red giant branch of NGC 6652, but with a color redder by about 0.1 mag. It has a small amplitude (Δ_v ~ 0.03) and a long period that cannot be constrained with the present data. Its membership cannot be established from the Soto et al. (2017) because it is located outside the HST FoV, but the Gaia proper motions put it far away from the proper motion of the cluster. Therefore, we define this star as a non-member with an unknown classification.

V16: also located close to the base of the RGB, but this time with a bluer color. It also has a very low amplitude (Δ_v ~ 0.01) and a possible period that cannot be constrained with the present data. Such a very low amplitude on this timescale would only be consistent with some long-period eclipsing binary. Gaia proper motions place it as field star.

V17: is a short-period variable with a well-defined period of 0.039 days. The light curve shape is typical for SX Phe and

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Table 1

Data for Known Variables, Excluding V14, in the NGC 6652 Field from the Clement et al. (2001) Catalog, Plus Proper Motions from Gaia

| ID  | R.A. (J2000) | Decl. (J2000) | Type | pm^Gaia^mas yr^-1 | pm^Gaia^mas yr^-1 | Member? |
|-----|-------------|---------------|------|-----------------|-----------------|--------|
| V1  | 18 35 41.43 | –32 55 47.5   | U    | 3.028 ± 0.199   | –6.302 ± 0.177  | N      |
| V2  | 18 35 26.79 | –32 54 31.3   | L    | –0.612 ± 0.263  | –1.261 ± 0.308  | N      |
| V3  | 18 35 19.10 | –32 58 56.8   | RRab | –0.076 ± 0.141  | –5.886 ± 0.127  | N      |
| V4  | 18 35 31.76 | –32 54 54.6   | U    | 8.768 ± 0.238   | –5.118 ± 0.212  | N      |
| V5  | 18 35 45.47 | –33 05 00.6   | RRab | –2.498 ± 0.087  | –5.819 ± 0.077  | N      |
| V6  | 18 35 27.39 | –32 59 04.1   | RRc  | 1.247 ± 0.156   | 1.327 ± 0.130   | N      |
| V7  | 18 35 32.99 | –32 57 23.3   | SR   | 2.887 ± 0.112   | –9.951 ± 0.094  | N      |
| V8  | 18 36 11.83 | –33 02 21.2   | E?   | –1.500 ± 0.103  | –5.675 ± 0.095  | N      |
| V9  | 18 36 19.84 | –32 56 40.6   | RRab | 3.967 ± 0.076   | –5.330 ± 0.068  | Y      |
| V10 | 18 35 43.65 | –32 59 26.8   | LMXB | —               | —               | ?      |
| V11 | 18 35 44.57 | –32 59 38.3   | LMXB | —               | —               | ?      |
| V12 | 18 35 45.75 | –32 59 23.5   | CV?  | —               | —               | ?      |
| V13 | 18 35 45.81 | –32 59 35.9   | U    | 3.538 ± 0.289   | –3.370 ± 0.265  | Y      |

Note. The classifications are as follows. CV: cataclysmic variable; E: eclipsing binary; L: long-period variable; LMXB: Low-mass X-ray binary; RRab/c: RR Lyrae, SR: semi-regular, and U: variable with unknown classification. The last column indicates cluster membership based on the Gaia Collaboration et al. (2018) proper motions. The long dash (−) indicates the star has not been found in Gaia, and therefore its membership is unknown (signified with a question mark, "?").
Table 2

Positions, Mean Magnitudes, Amplitudes, Periods, and Classification for the New Variables Discovered in the NGC 6652 Together with the Known Variable V14

| ID    | R.A. (J2000) | Decl. (J2000) | \(\langle g \rangle\)  | \(\langle r \rangle\) | \(A_g\)  | \(A_r\)  | \(P\)  | Type  | \(\text{pm}^{\text{Gaia}}_{\text{R.A.}}\) | \(\text{pm}^{\text{Gaia}}_{\text{Dec.}}\) | \(\text{pm}^{\text{HST}}_{\text{R.A.}}\) | \(\text{pm}^{\text{HST}}_{\text{Dec.}}\) | Member |
|-------|--------------|--------------|------------------------|------------------------|---------|---------|-------|-------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-------|
| V14   | 18 35 46.32  | −32 59 32.8  | 18.691                 | 18.422                 | 0.26    | 0.29    | 0.19  | SX    | —                           | —                           | —                           | 5.5                          | —     |
| V15   | 18 35 31.16  | −32 58 48.7  | 19.508                 | 18.733                 | 0.03:   | 0.02:   | >0.3  | U     | −0.086 ± 0.59               | −6.411 ± 0.51               | —                           | —                             | Field |
| V16   | 18 35 33.00  | −32 58 56.5  | 18.845                 | 18.269                 | 0.01:   | 0.01:   | >0.3  | E?    | 1.840 ± 0.39               | −7.259 ± 0.35               | —                           | —                             | Field |
| V17   | 18 35 39.50  | −32 59 56.3  | 20.415                 | 20.202                 | 0.12    | 0.08    | 0.039 | SX    | —                           | —                           | 2.90                         | —                             | Sgr   |
| V18   | 18 35 40.50  | −32 57 10.0  | 21.221                 | 20.521                 | 0.18    | 0.15    | >0.3  | E     | —                           | —                           | —                           | —                             | Cluster |
| V19   | 18 35 41.80  | −32 58 00.2  | 21.719                 | 20.466                 | 0.10    | 0.06    | ~0.24 | E     | —                           | —                           | —                           | −1.16                        | Field |
| V20   | 18 35 44.36  | −32 58 26.7  | 19.297                 | 18.902                 | 0.23    | 0.20    | 0.15  | E     | 4.625 ± 0.88               | −4.915 ± 0.73               | 5.5                          | −4.5                          | Cluster |
| V21   | 18 35 52.53  | −32 57 29.2  | 18.437                 | 17.619                 | 0.04:   | 0.03:   | >0.3? | U     | 4.781 ± 0.36               | −0.978 ± 0.32               | —                           | —                             | Sgr   |
| V22   | 18 35 52.61  | −32 59 19.9  | 18.686                 | 18.060                 | 0.02:   | 0.02:   | >0.3  | E?    | 2.339 ± 0.37               | −3.045 ± 0.32               | 2.17                         | −3.84                        | Sgr/Field |
| V23   | 18 35 54.78  | −32 59 08.8  | 23.100                 | 21.804                 | 0.36    | 0.24    | >0.24 | E     | —                           | —                           | —                           | —                             | Cluster |

Note. Uncertain amplitudes are indicated with a colon, while the > indicates lower limits for some periods. Classifications are as follows. SX: SX Phoenicis, RRL: RR Lyrae, E: eclipsing binary, and U: variable with unknown classification. The last column indicates cluster membership based on the Soto et al. (2017) and Gaia Collaboration et al. (2018) proper motions. The long dash (—) indicates the star lacks a measured proper motion. A question mark (?) signifies tentative membership and/or classification.
Delta Scuti pulsators. In Figure 2, we show an 11 Gyr isochrone from the Dotter et al. (2008) models with [Fe/H] = −1.3 shifted to the distance (and reddening) of the background Sgr stream. V17 appears in the extension of the background Sgr main sequence occupied by these variables. Even though is too faint to be observed by Gaia, Sgr membership is confirmed by the Soto et al. (2017) proper motions because it falls almost exactly at the Sgr proper motion calculated by Sohn et al. (2015) (see Figure 2, right panel). Because the Sgr tails are known to possess a population older than ~9 Gyr (e.g., de Boer et al. 2015) we can safely classify it as an SX Phe (a pulsating blue straggler) instead of a Delta Scuti.

SX Phe stars follow known period–luminosity relations (McNamara 1995). From a compilation of 77 SX Phe in Galactic GCs, Cohen & Sarajedini (2012) derive the PL relation: \( M_V = -1.640 - 3.389 \log P + 0.11 \pm 0.09 \). Using the dust maps of Schlafly & Finkbeiner (2011) and the Jester et al. (2005) transformations between SDSS and Bessell filters, we derive a true distance modulus of 16.84, or a distance of 23.4 ± 2.1 kpc. A shortcoming of the Cohen & Sarajedini (2012) PL relation is that it does not consider whether the SX Phe pulsate in their fundamental mode or any harmonic, nor the influence of metallicity. If we take the PL relations from Nemec et al. (1994), which take into account both the metallicity and the pulsation mode of the SX Phe, we find that if the measured period corresponds to the fundamental period, then the distance would be 19.5 kpc, while if the period corresponds to the first overtone (we can calculate the fundamental period following Santolamazza et al. 2001), then the distance would be 25.2 kpc. In both cases, we assume [Fe/H] = −1.3, corresponding to the bulk of the Sgr population. These results are significantly shorter than the Siegel et al. (2011) distance modulus of 17.42 (30.5 kpc) based on MS fitting of the Sgr stream population behind NGC 6652. One possibility is that this SX Phe has a significantly lower metallicity; for [Fe/H] = −2.0, the distance

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\text{Figure 3. Light curves in } g \text{ and } r \text{ for the newly discovered variables, plus the known variable V14. Upper panels indicate the } r \text{ time series photometry in Julian dates, while the central and lower panels for each panel show the } g \text{ and } r \text{ phased light curves, respectively. When only a lower limit period has been found, light curves are given phased to this period.}
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for a first overtone pulsator would be 28 kpc. Although there is no evidence that the metallicity of the Sgr tails is much different from the main Sgr body (e.g., Carlin et al. 2018), the Sgr body reaches metallicities as low as $-2.0$ (Mucciarelli et al. 2017). It is therefore unclear whether this short distance is the result of an unusual broadening of the stream or an uncertainty introduced in the calibration and/or transformation to the Bessell system, or if this SX Phe simply has a metallicity close to most metal-poor stars in Sgr.

V18: has a clear sinusoidal light curve shape with minima of different depths, which make it most likely a Beta Lyra-type eclipsing binary (or EB). It is located slightly above the NGC 6652 MS, which agrees with the position a binary member should have. Unfortunately, there are no HST nor Gaia proper motions to confirm this.

V19: another variable with sinusoidal shape and somewhat uneven minima, although not as pronounced as in V18. It could be eclipsing of the W Uma type, although a Beta Lyra is not excluded. The HST proper motions place it as member of the field.

V20: has a sinusoidal light curve very similar to an RRc, but its position in the CMD is close to the MSTO. With very similar minima, its classification is most likely a WUma eclipsing binary. Both Gaia and HST proper motions indicate it is a cluster member.

V21: presents a small clear variation with amplitude of $\sim 0.02$ mag in the measured period. If a member of NGC 6652, its position slightly above the MS will undoubtedly clarify the membership of the bright variable star content of the majority of GCs in our Galaxy.

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Facility: Gemini:South (GMOS).

Software: IRAF (Tody 1986), ISIS (v 2.1, Alard 2000), daophot/allstar (Stetson 1987).

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5. Summary and Conclusions

We have conducted a new variability study of the metal-rich GC NGC 6652 based on archival Gemini-S/GMOS gr data spanning six continuous hours. We discovered nine new variables. We classify seven of them as eclipsing binaries and one as a SX Phe, while the last remains unclassified. Together with Gaia DR2 and HST proper motions, we assign membership to these variables, finding that the cluster, the Sgr stream, and the field each have three of these variables. Using a PL relation for the SX Phe found in the Sgr stream, we estimate a distance of $23.4 \pm 2.1$ kpc to the stream. Finally, we reassess the membership of previously known variables in the cluster thanks to Gaia proper motions, finding that only one of the four candidate RRL would belong to the cluster. Gaia will undoubtedly clarify the membership of the bright variable star content of the majority of GCs in our Galaxy.
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