BLOOD TIES: THE REAL NATURE OF THE LMC BINARY GLOBULAR CLUSTERS NGC 2136 AND NGC 2137*

Alessio Mucciarelli1, Livia Origlia2, Francesco R. Ferraro1, Michele Bellazzini2, and Barbara Lanzoni1

1 Dipartimento di Astronomia, Università degli Studi di Bologna, Via Ranzani, 1-40127 Bologna, Italy; alessio.mucciarelli2@unibo.it, francesco.ferraro3@unibo.it, barbara.lanzoni3@unibo.it
2 INAF-Osservatorio Astronomico di Bologna, Via Ranzani, 1-40127 Bologna, Italy; livia.origlia@oabo.inaf.it, michele.bellazzini@oabo.inaf.it

Received 2011 November 29; accepted 2012 January 17; published 2012 January 30

ABSTRACT

We have used a sample of high-resolution spectra obtained with the multi-fiber facility FLAMES at the Very Large Telescope of the European Southern Observatory to derive the kinematical and chemical properties of the two young Large Magellanic Cloud (LMC) globular clusters NGC 2136 and NGC 2137. These two clusters represent a typical example of LMC cluster pair suspected to be bound in a binary system: indeed, the cluster centers of gravity have an angular separation of less than 1.4 arcmin in the sky. The spectral analysis of seven giants in NGC 2136 and four in NGC 2137 reveals that the two clusters share very similar systemic radial velocities, namely, \( V_r = 271.5 \pm 0.4 \text{ km s}^{-1} \) (\( \sigma = 1.0 \text{ km s}^{-1} \)) and \( V_r = 270.6 \pm 0.5 \text{ km s}^{-1} \) (\( \sigma = 0.9 \text{ km s}^{-1} \)) for NGC 2136 and NGC 2137, respectively, and they have also indistinguishable abundance patterns. The iron content is \([\text{Fe/H}] = -0.40 \pm 0.01 \text{ dex (}\sigma = 0.03 \text{ dex)}\) for NGC 2136 and \(-0.39 \pm 0.01 \text{ dex (}\sigma = 0.01 \text{ dex)}\) for NGC 2137, while the \([\alpha/\text{Fe}]\) ratios are roughly solar in both clusters. These findings suggest that the two clusters are gravitationally bound and that they formed from the fragmentation of the same molecular cloud that was chemically homogeneous. This is the first firm confirmation of the binary nature of an LMC cluster pair. The most likely fate of this system is to merge into a single structure in a timescale comparable with its orbital period.

Key words: globular clusters: individual (NGC 2136, NGC 2137) – Magellanic Clouds – stars: abundances – techniques: spectroscopic

1. INTRODUCTION

One of the most intriguing feature of the Large Magellanic Cloud (LMC) globular clusters (GCs) system is the large population of binary clusters that this galaxy harbors. The catalog by Dieball et al. (2002) includes a total of 473 candidate multiple (binary or triple) stellar clusters and associations with angular distances \( \lesssim 1.4 \text{ arcmin} \) (projected to a distance of 20 pc when a distance modulus of 18.5 mag is assumed) and ages less than \( \sim 1 \text{ Gyr} \). This sample corresponds to about 10% of the entire stellar clusters population in the LMC. Similar binary systems are observed also in other galaxies, like the Small Magellanic Cloud (SMC; Hatzidimitriou & Bhatia 1990), M31 (Holland et al. 1995), and NGC 5128 (Minniti et al. 2004). In contrast, in our Galaxy the only recognized case is the cluster pair NGC 869/NGC 884. There are some possible scenarios to explain the nature of the binary clusters: (1) two clusters at different distances appear as a binary system only due to projection effects, lying along the same line of sight; (2) the clusters were born independently from distinct molecular clouds (likely with different ages and chemical compositions) and subsequently became a bound system after a close encounter or a tidal capture; (3) the clusters were born from the same molecular cloud (hence with the same age and metallicity) and are gravitationally bound. Based on statistical arguments, Dieball et al. (2002) suggest that the LMC binary clusters population cannot be simply explained in terms of apparent pairs, but a relevant fraction must be bound systems.

While the large number of binary clusters among the young Magellanic globulars is a significant clue, the small projected distance on the sky between two clusters cannot guarantee the effective blood tie of the objects. Hints on binarity from the ages and photometric metallicities (with uncertainties at a level of 0.2 dex) have been provided for some tens of cluster pairs (see for instance Dieball & Grebel 1998; Hilker et al. 1995; Vallenari et al. 1998). However, a firm validation of that binarity can only be obtained from the combined information of age, chemical abundances from high-resolution spectra, and radial velocities (\( V_r \)) measurements in order to clarify if the system is gravitationally bound and unveil the possible common origin from the same molecular cloud. At present such a binarity validation has not been probed in any LMC cluster pair. This Letter is devoted to address the true nature of the cluster pair NGC 2136/NGC 2137. These are two young GCs with an angular separation of 1.34 arcmin (Bhatia et al. 1991), corresponding to a projected separation of \( \sim 19.5 \) pc, assuming a distance of 50 kpc (see the left panel in Figure 1). Previous studies stated that the two clusters have the same age (\( \sim 80–100 \) Myr; see Hilker et al. 1995; Dirsch et al. 2000) but no direct chemical and kinematical measurements are available to date.

2. OBSERVATIONS

Observations were performed with the multi-fiber facility FLAMES mounted at the ESO Very Large Telescope in the combined mode UVES+GIRAFFE. Data were acquired under a program devoted to investigate the chemical composition of the LMC GCs and their surrounding fields. The employed grating configuration includes the setups HR 11 and HR 13 for GIRAFFE and the 580 Red Arm for UVES. A total of five exposures of \( \sim 45 \) minutes each were secured on the same targets configuration. The reduction of the spectra (including bias subtraction, flat-fielding, wavelength calibration, and spectra extraction) was performed with the standard ESO pipelines. Typical signal-to-noise ratio per pixel of the final co-added spectra is of \( \sim 50–60 \). The FLAMES fibers were allocated on
giant stars of the two clusters NGC 2136 and NGC 2137 and of
the surrounding field. Targets in the innermost 2.5 arcmin from
the cluster center have been selected from the SofI near-infrared
catalog by Mucciarelli et al. (2006) while outermost objects
were chosen from the Two Micron All Sky Survey data set.

It is worth noting that the size of the clusters, their angular
separation, and the physical size of the FLAMES magnetic
buttons do not allow the allocation of a large number of fibers
on the area covered by two clusters. A total of 22 fibers were
finally allocated in the inner 3 arcmin (marked in the right panel
of Figure 1). Here, we discuss the kinematical and chemical
properties of these stars.

Interestingly enough, Hilker et al. (1995) suggest a possible
third component of the system, identifying a faint stellar
association located at a distance of \( \sim 2.4 \) arcmin from the main
cluster and embedded in a common stellar halo (the position
of this stellar association is highlighted in the left panel of
Figure 1). As apparent from the right panel of Figure 1, one
FLAMES fiber was allocated also on this loose clump of stars.

3. RADIAL VELOCITIES AND CHEMICAL ANALYSIS

Radial velocities were derived by using the DAOSPEC
code (Stetson & Pancino 2008) and measuring \( \sim 370 \) and
\( \sim 140 \) absorption lines of different elements in the UVES
and GIRAFFE spectra, respectively. Typical internal errors
(computed as \( \sigma/\sqrt{N_{\text{lines}}} \)) are of 0.05 for UVES and 0.15 km s\(^{-1}\)
for GIRAFFE. The accuracy of the zero point of the wavelength
calibration is checked by measuring several sky emission
lines and compared with their rest-frame positions listed by
Osterbrock et al. (1996); the uncertainty in the zero point has
been added in quadrature to the internal error.

Chemical analysis was performed by using the suite of
codes by R. L. Kurucz (see sbordone et al. 2004), aimed to
compute model atmospheres, abundances from the observed
equivalent widths, and synthetic spectra. The employed model
atmospheres were computed with ATLAS9, assuming plane-
parallel geometry, LTE for all the species, and no overshooting.

We used suitable line lists checked against spectral blending,
in order to include only transitions predicted to be unblended for
the corresponding spectral resolution and parameters. Oscillator
strengths are from the most recent version of the Kurucz/Castelli
line list.\(^3\) Equivalent widths were measured with DAOSPEC.

Atmospheric parameters were derived spectroscopically, by
requiring (1) no trend between excitation potential and iron
abundance to constrain the temperature, (2) no trend between
line strength and iron abundance to constrain the microturbulent
velocity, and (3) the same abundance from neutral and single
ionized iron lines to constrain the gravity.

We measured abundances for Fe, Ni, Mg, O, Al, Na, Si,
Ca, and Ti. Oxygen abundances are derived through spectral
synthesis of the forbidden line at 6300 Å. Na abundances were
derived from the doublet at 6154–6160 Å for all the stars
and also from the line at 5688 Å for the stars observed with
UVES; departures from LTE were corrected following Lind
et al. (2011). The total uncertainty for each abundance ratio was
computed by adding in quadrature the internal error (computed as \( \sigma/\sqrt{N_{\text{lines}}} \)) and the uncertainty arising from the atmospheric
parameters (the latter computed following the approach by
Cayrel et al. 2004).

4. RESULTS

The heliocentric radial velocity \( V_r \) distribution for all the
22 giants measured in the region of the two clusters is shown
in the upper panel of Figure 2. As can be seen, it is highly
peaked at \( V_r \sim 270 \) km s\(^{-1}\). The lower panel of Figure 2
shows metallicities and radial velocities for the stars with
\( V_r > 230 \) km s\(^{-1}\). A clear, well-defined clump of 11 stars
sharing virtually the same radial velocity (\( V_r \sim 270 \) km s\(^{-1}\)) and
metallicity ([Fe/H] \( \sim -0.40 \)) is visible. The main information
for these stars are listed in Table 1 and their position in the
SofI color–magnitude diagram is shown in the left panel of
Figure 3, together with portions of UVES spectra in the right

\(^3\) http://wwwuser.oat.ts.astro.it/castelli/linelists.html
Figure 2. Upper panel: the radial velocities distribution for the observed targets in the inner 3 arcmin from the center of NGC 2136 (see Figure 1). Lower panel: the distribution of the stars with $V_r > 230$ km s$^{-1}$ in the $V_r$-[Fe/H] plane; black circles are the stars of the cluster pair, the empty circles are the stars belonging to the LMC field, and the gray circle is the giant located in the possible third component of the system suggested by Hilker et al. (1995).

Figure 3. Left panel: SofI color–magnitude diagram of the field around NGC 2136 and NGC 2137; large gray points mark the spectroscopic targets. Right panel: UVES spectra of four stars. A few reference lines are marked.

4 Note that star 51 is located in the halfway between the two clusters and we decide to consider it member of NGC 2137.

5 If we attribute star 51 to NGC 2136 (instead of NGC 2137) the results change by $\sim 0.1$ km s$^{-1}$ only.
...stellar association is really bound to the other two clusters, hence we exclude it from the following discussion.

5. DISCUSSION

From the analysis of the kinematical and chemical properties of the two clusters we obtained two relevant findings.

1. All the measured stars share very similar \( V_r \); indeed, the difference between the average values in the two clusters is only \( \Delta V_r = 0.9 \) km s\(^{-1}\). Such a small value agrees well with the criterion by Van den Bergh (1998) for the gravitational link of two stellar systems. In order to compute the orbital velocity of the binary system, we first estimated the cluster masses. The SIMBAD database provides integrated \( V \) magnitudes of 10.70 and 12.06 for the main and secondary cluster, respectively, corresponding to \( L_V^{2136} = 1.13 \times 10^5 L_\odot \) and \( L_V^{2137} = 1.85 \times 10^4 L_\odot \). Adapting the mass-to-light ratio of \( M/L_V = 0.119 \), appropriate for a simple stellar population of 100 Myr, \( Z = 0.008 \), and solar-scaled chemical composition computed from the BaSTI database, we obtain masses of \( M_{2136} = 1.34 \times 10^3 M_\odot \) and \( M_{2137} = 0.22 \times 10^4 M_\odot \) (with a mass ratio of 0.16). With these mass values and by assuming a circular orbit and \( R_{3D} = \sqrt{3/2} R_p \), (where \( R_p \) is the...

http://albione.oa-teramo.inaf.it/

7 Note that McLaughlin & van der Marel (2005) derived a slightly higher mass for NGC 2136 by fitting the surface brightness profile: they obtained \( M_{2136} = 1.99 \times 10^3 M_\odot \), \( 2.19 \times 10^4 M_\odot \), and \( 2.09 \times 10^4 M_\odot \), adopting the King, power law, and Wilson model, respectively. Since no estimate was obtained for NGC 2137, in the following we will adopt the masses derived from the integrated \( V \) magnitudes.

...Solar reference abundances are from Grevesse & Sauval (1998), with the exception of the oxygen (Caffau et al. 2010).

This is the first clear-cut indication that stars in the two clusters are virtually indistinguishable both in terms of metallicity and radial velocity. Also, this is the first time that the real nature of a binary cluster is revealed.

Note that the star observed in the possible third component of the system (plotted as a black circle in the left panel of Figure 1) has \( V_r \) = 281.4 km s\(^{-1}\) and an iron content [Fe/H] = −0.54 dex, incompatible with the chemical and kinematical properties of the two clusters: this seems to exclude a link between this star and the two clusters. At present, we are not able to assess if...
projected distance, with $R_p = 19.5$ pc as a statistical proxy of the de-projected, three-dimensional distance, the orbital period can be easily inferred from Kepler’s third law, yielding a value of $P_{orb} \sim 87$ Myr. Finally, the orbital velocity (computed as $V_{orb} = 2\pi R_3D/P_{orb}$) turns out to be $V_{orb} \sim 1.7$ km s\(^{-1}\). This value indicates the maximum expected difference between the velocities of the two clusters. Such a small value is in excellent agreement with the observations and enforce our statement that the two objects are gravitationally bound.

2. The two clusters share the same chemical abundances and abundance pattern, in terms of iron and $\alpha$-elements, suggesting that they likely formed from the collapse of the same (chemically homogeneous) molecular cloud. Interestingly enough, the two clusters also show similar and homogeneous abundances of the light elements (Na, O, Mg, and Al), at variance with the old GCs in our Galaxy (see, e.g., Carretta et al. 2009) and in the LMC (Mucciarelli et al. 2009), which show clear spreads and some anti-correlations. Such a lack of abundance spread among light elements has been already found in a few other LMC GCs of young/intermediate ages (Ferraro et al. 2006; Mucciarelli et al. 2007, 2008) with metallicity similar to the NGC 2136/NGC 2137 pair. From this point of view, the LMC GCs younger than $\sim 3$ Gyr behave like the Galactic open clusters that do not show evidences of abundance anomalies (see, e.g., de Silva et al. 2009; Martell & Smith 2009).

This finding seems to indicate that while older globulars both in our Galaxy and the LMC self-enriched at the very early stage of their formation (in the age range between 20 Myr and 300 Myr; see Renzini 2008), and were much more massive in the past (see e.g., D’Ercole et al. 2008; Vesperini et al. 2010; Conroy & Spiergel 2011) to be able to retain the stellar ejecta, younger and less massive clusters did not undergo self-enrichment processes and their present-day mass should be very similar to their initial mass (see the discussion in Mucciarelli et al. 2011). Thus, the observational evidences presented here confirm the theoretical predictions that clusters with initial mass below $10^5 M_\odot$ should be chemically homogeneous (see Bland-Hawthorn et al. 2010). It is worth noticing that stellar clusters with ages of $\sim 100$ Myr and masses of $(1-5) \times 10^5 M_\odot$ are lacking in our Galaxy, the open clusters in the Milky Way being at least one order of magnitude less massive than the coeval LMC globulars. Hence, the study of such young LMC clusters appears to be particularly illuminating to understand the early evolution of the globulars.

Concerning the final fate of the NGC 2136/NGC 2137 system, there are two possible scenarios: (1) the two clusters will finally merge under the action of the dynamical friction, or (2) the mutual tidal forces will disrupt the less massive system, dispersing its stellar content (and probably leaving a weak stellar stream around the survived cluster).

The dynamical friction timescale, hence the time for the secondary cluster to spiral into the main cluster, can be estimated using Equations (7)–(26) of Binney & Tremaine (1987), assuming present-day conditions. We derive a merging timescale of $\sim 38$ Myr, comparable with the orbital period. However, this scenario is reliable only if the secondary cluster crosses the main cluster: McLaughlin & van der Marel (2005) derive for NGC 2136 a tidal radius of 30.9 pc by adopting a King model, larger than the projected distance between the two clusters ($\sim 20$ pc). Hence, we can consider realistic the occurrence of dynamical friction between the two objects. Alternatively, NGC 2137 will be destroyed by the tidal field of NGC 2136, in a timescale of $\sim 2$ Gyr, estimated by adopting Equation (1) of Gieles et al. (2007). Due to the uncertainty in the mass values and in the three-dimensional distance, these calculations should be considered to be a first-order estimation of the timescales.

The prospect of merging is quite interesting in light of the formation history of the LMC GCs. Numerical simulations by Makino et al. (1991), de Oliveira et al. (2000), and Bekki et al. (2004) predict that the final merger of a binary cluster would be indistinguishable from a genuine single-population GC, but with high values of ellipticity ($\epsilon = 0.25–0.35$), very similar to those observed in the LMC GCs (see, e.g., Geisler & Hodge 1980; Mucciarelli et al. 2007). In this framework, we cannot exclude that a fraction of the present-day single LMC clusters originated from the merging of twin objects (in terms of kinematics, age, and chemical composition).

6. CONCLUSIONS

The analysis of the kinematical and chemical properties of the pair NGC 2136/NGC 2137 presented in this Letter demonstrate that the two clusters share not only the same age (Hilker et al. 1995; Dirsch et al. 2000) but also the same chemical and kinematic DNA, unequivocally ensuring their common origin. This is the first firm validation of the true binary nature of an LMC cluster pair: the previous hints were in fact only based on their projected distances and photometric properties. From the obtained results we can also draw a general scenario for the formation and evolution of this binary system. Summarizing: (1) the two clusters formed from the fragmentation of the same molecular cloud; (2) the chemical composition of the clusters is about the same, without hints of self-enrichment or mutual chemical pollution; (3) the present-day orbital parameters suggest that the system will merge due to the dynamical friction in a timescale comparable with its orbital period (but see also the discussion in Portegies Zwart & Rusli 2007).

An important point to tackle is the different frequency of candidate binary clusters in the LMC and in the Milky Way. Theoretical models by Fujimoto & Kumai (1997) and Bekki et al. (2004) demonstrate that binary stellar clusters can be formed during high-velocity cloud collisions. Concerning the LMC, the rate of cloud collisions is mainly triggered by the mutual tidal interaction between the LMC and the SMC, and their close encounters (the last one occurring $\sim 200$ Myr ago; Bekki & Chiba 2005). On the other hand, the Galactic disk is less disturbed by the near tidal fields, at variance to the LMC (which suffers from the effects of the interaction with the Galaxy and SMC fields), and the rate of cloud–cloud collisions is less efficient, as demonstrated by the dearth of binary systems among the Milky Way open clusters. Thus, the occurrence of binary clusters is intimately linked to the star formation history of their parent galaxy and the interactions of the latter with near tidal fields.

Our findings indicate that other candidate cluster pairs in the LMC could be probed to be binary systems through the analysis of high-resolution spectra. Direct kinematical and chemical measurements of such systems (with both similar and different component clusters ages) are mandatory to assess the origin of these systems and enlighten on the cluster formation history in the Magellanic Clouds.

We warmly thank the anonymous referee for suggestions in improving the Letter. This research is part of the project
REFERENCES

Bekki, K., Beasley, M. A., Forbes, D. A., & Couch, W. J. 2004, ApJ, 602, 730
Bekki, K., & Chiba, M. 2005, MNRAS, 356, 680
Bhatia, R. K., Read, M. A., Hatzidimitriou, D., & Tritton, S. 1991, A&AS, 87, 335
Binney, J., & Tremaine, S. 1987, Galactic Dynamics (Princeton, NJ: Princeton Univ. Press)
Bland-Hawthorn, J., Krumholz, M. R., & Freeman, K. 2010, ApJ, 713, 166
Caffau, E., Ludwig, H.-G., Steffen, M., Freytag, B., & Bonifacio, P. 2011, Sol. Phys., 268, 255
Carretta, E., Bragaglia, A., Gratton, R. G., et al. 2009, A&A, 87, 335
Bekki, K., Beasley, M. A., Forbes, D. A., & Couch, W. J. 2004, ApJ, 602, 730
Bhatia, R. K., Read, M. A., Hatzidimitriou, D., & Tritton, S. 1991, A&AS, 87, 335
Binney, J., & Tremaine, S. 1987, Galactic Dynamics (Princeton, NJ: Princeton Univ. Press)
Bland-Hawthorn, J., Krumholz, M. R., & Freeman, K. 2010, ApJ, 713, 166
Caffau, E., Ludwig, H.-G., Steffen, M., Freytag, B., & Bonifacio, P. 2011, Sol. Phys., 268, 255
Carretta, E., Bragaglia, A., Gratton, R. G., et al. 2009, A&A, 505, 117
Cayrel, R., Degl'Innocenti, S., & Spite, M. 2006, A&A, 447, 139
Cole, A. A., Tolstoy, E., Gallager, J. S., III, & Smecker-Hane, T. A. 2005, AJ, 129, 1465
Conroy, C., & Spergel, D. N. 2011, ApJ, 726, 36
D'Ercole, A., Vesperini, E., D'Antona, F., McMillan, S. L. W., & Recchi, S. 2008, MNRAS, 391, 825
de Oliveira, M. R., Bica, E., & Dottori, H. 2000, MNRAS, 311, 589
de Silva, G. M., Gibson, B. K., Lattanzio, J., & Asplund, M. 2009, A&A, 500, 25
Dieball, A., & Grebel, E. K. 1998, A&A, 339, 773
Dieball, A., Müller, H., & Grebel, E. K. 2002, A&A, 391, 547
Dirsch, B., Richtler, T., Gieren, W. P., & Hilker, M. 2000, A&A, 360, 133
Ferraro, F. R., Mucciarelli, A., Carretta, E., & Origlia, L. 2006, ApJ, 645, L33
Fujimoto, M., & Kumai, Y. 1997, AJ, 113, 249
Geisler, D., & Hodge, P. 1980, ApJ, 242, 66
Gieles, M., Lamers, H. J. G. L. M., & Baumgardt, H. 2007, in IAU Symp. 246, Dynamical Evolution of Dense Stellar Systems, ed. E. Vesperini, M. Giersz, & A. Sills (Cambridge: Cambridge Univ. Press), 171
Girard, N., & Sauval, A. J. 1998, Space Sci. Rev., 85, 161
Hatzidimitriou, D., & Bhatia, R. K. 1990, A&A, 230, 11
Hilker, M., Richtler, T., & Stein, D. 1995, A&A, 299, L37
Holland, S., Fahlman, G. G., & Richer, H. B. 1995, AJ, 109, 2061
Lind, K., Asplund, M., Barklem, P. S., & Böhm, A. K. 2011, A&A, 528, L103
Makino, J., Akiyama, K., & Sugimoto, D. 1991, Ap&SS, 185, 63
Martell, S. L., & Smith, G. H. 2009, PASP, 121, 577
McLaughlin, D. E., & van der Marel, R. P. 2005, ApJS, 161, 304
Minniti, D., Rejkuba, M., Funes, J. G., & Kennicutt, R. C., Jr. 2004, ApJ, 612, 215
Mucciarelli, A., Carretta, E., Origlia, L., & Ferraro, F. R. 2008, AJ, 136, 375
Mucciarelli, A., Cristallo, S., Brocato, E., et al. 2011, MNRAS, 413, 837
Mucciarelli, A., Ferraro, F. R., Origlia, L., & Fusi Pecci, F. 2007, AJ, 133, 2053
Mucciarelli, A., Origlia, L., Ferraro, F. R., Maraston, C., & Testa, V. 2006, ApJ, 646, 939
Mucciarelli, A., Origlia, L., Ferraro, F. R., & Pancino, E. 2009, ApJ, 659, L134
Osterbrock, D. E., Fulbright, J. P., Martel, A. R., et al. 1996, PASP, 108, 277
Portegies Zwart, S. F., & Rasio, F. 2007, MNRAS, 374, 931
Renzini, A. 2008, MNRAS, 391, 354
Sbordone, L., Bonifacio, P., Castelli, F., & Kurucz, R. L. 2004, Mem. Soc. Astron. Ital., 75, 396
Stetson, P. B., & Pancino, E. 2008, PASP, 120, 1332
Vallenari, A., Bettoni, D., & Chiosi, C. 1998, A&A, 331, 506
Van den Bergh, S. 1998, AJ, 116, 1688
Vesperini, E., McMillan, S. L. W., D'Antona, F., & D'Ercole, A. 2010, ApJ, 718, L112