Observations of 42 Double Stars Near Messier 35

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Abstract

For this work we observed 42 stars near M35. Of these, 30 were first observed in 1926 and the remainder largely have a first observation in 1998. In most cases, plots of historical measurements are consistent with linear motion, although less than 1” of motion has been observed over this time, which makes interpreting these plots difficult. We used Gaia DR3 data to better understand the nature of these stars. Most of them are not physically associated with each other, however 26 are cluster members. We found that WDS06085+2414 is a cluster member and likely a true binary, while WDS06079+2435 is probably a binary, although it is not a cluster member.

Introduction

In this paper, we investigate 42 double stars located within and near the open cluster Messier 35 (Dias et al. 2021). This region was selected because of the abundance of double stars available within a single frame. The open cluster NGC 2158 (Poggio et al. 2021) is also nearby, although it is out of the field of view of our images, and none of the stars we observed appear to be members of this cluster. Our analysis involves the measurement of the stars’ astrometry (separation and position angle) and comparison of our measurements with historical data. Gaia DR3 (Gaia collaboration et al. 2016b, 2023j) parallax and proper motion measurements were also used to assess the physical nature of our observed systems. The Gaia data was also helpful in determining whether any of the systems are members of M35.

For 40 of the stars in our study, the most recent observation dates to 2015, while one is from 2016 and another dates to 2013. As for the first observation, 30 of the systems have an original observation date to 1926, with a single star having been first observed in 1894. The remaining 11 stars were first observed in 1998. Thus, we have a baseline of nearly a century for about three-fourths of the stars, while the remainder have an observational baseline of about 25 years.

Methods

We observed these systems using the Great Basin Observatory located in Great Basin National Park, Nevada. Technical specifications of the observatory and its instruments are provided in Anselmo et al 2018. This observatory is managed and maintained by a consortium consisting of Great Basin National Park and the Park's Foundation, Southern Utah University, and the University of Nevada-Reno. Twelve images of the selected region were taken on February 13th, 2023. The images were taken in the V filter and had an exposure time of 300 seconds to maximize the signal to noise of the star systems in the field of view, which is shown in Figure 1. The systems studied in this paper are indicated, with those systems having at least one star belonging to M35 shown as blue ovals, while systems whose Gaia DR3 parallax and proper motion are inconsistent with cluster membership are shown in red. The radius in which half of the cluster members are found (the r_{50}) is also shown (Cantat-Gaudin, Anders 2020).

AstroImageJ (Collins et al. 2017) was used to verify that the components of the systems were not overexposed. Several systems (06071+2429, 06087+2416, 06087+2412, 06088+2417) were found to be saturated and therefore unmeasurable,which left 42 systems for study. AstroImageJ was also used to reduce the images, which were dark, bias, and flat corrected. The images were then plate solved with http://nova.asrometry.net/ (Lang 2010). Finally, AstroImageJ was used to measure the separation (ρ) and position angle (θ) of the stars.

We have found that the aperture size affects the standard deviation of the measurements of a given system across several images. The effect is quite small (usually less than 0.1 arcsec), especially for well-resolved systems. However, it becomes more of an issue with more closely-spaced stars. This effect seems to be related to how AstroImageJ calculates the centroid within the selected aperture size. Generally, the suggested aperture size provided in the seeing profile will yield measurements with the smallest standard deviation. As we measured our stars, we varied the aperture size and noted how the different diameters affected the standard deviation for that system. We then recorded the separation and position angle that yielded the smallest standard deviations, and we report those values in Table 1.

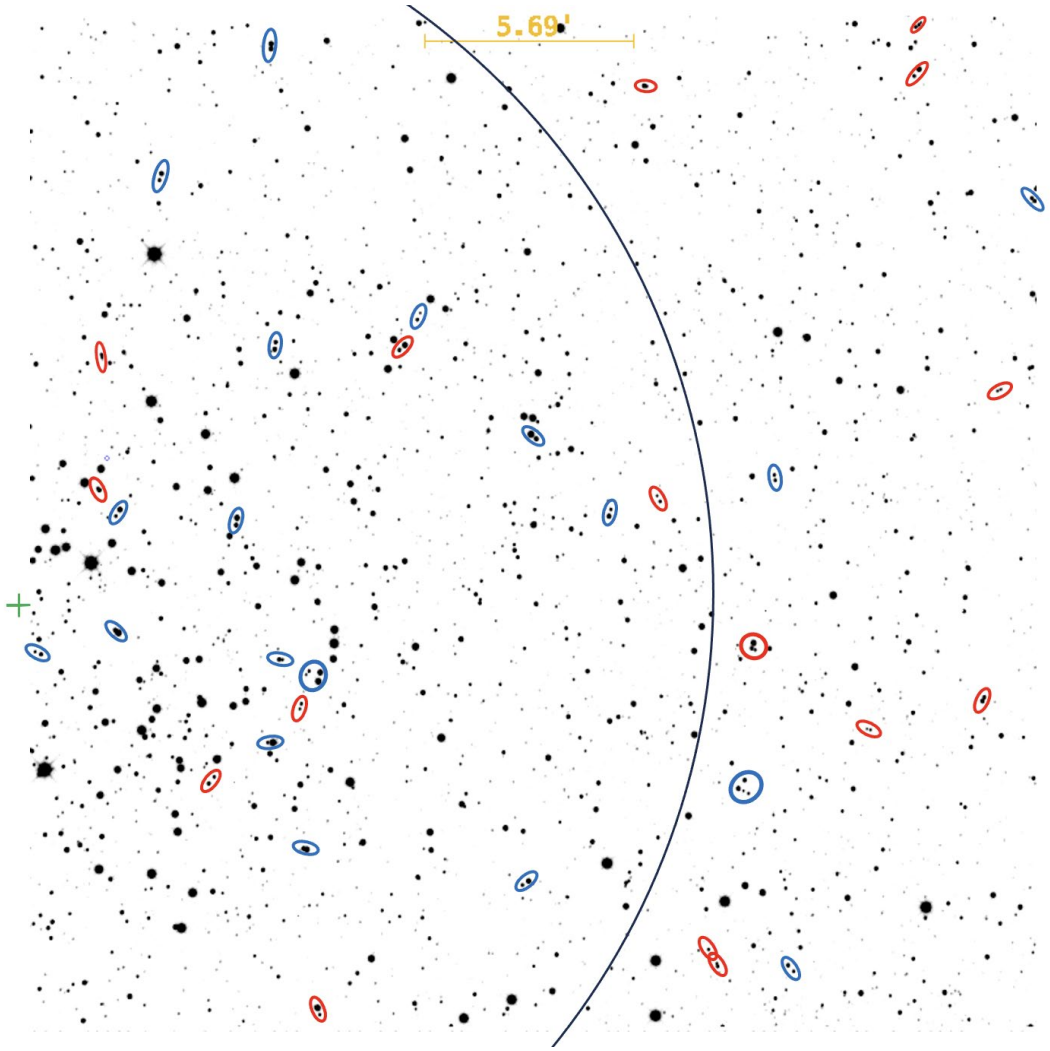

Figure 1 *Finder chart of the stars we imaged. The green cross indicates the center of M35, while the curved line shows the r_{50} (the radius which encloses half the cluster members) of the cluster. Blue marks denote systems whose Gaia observations indicate that at least one system member is also a cluster member, while red marks indicate systems whose Gaia measurements are inconsistent with cluster membership. Most of those systems within the angular extent of M35 have at least one cluster member, while those whose distance is greater than this are typically not members.*

Results

Our measurements of rho and theta for the 42 stars in this study are presented in Table 1. Additionally, we assessed cluster membership via proper motion and parallax information extracted from the Gaia DR3 database. Column 4 indicates those stars that are likely cluster members, and further details of the cluster membership criteria are provided in the Discussion.

WDS Identifier	Rho (Error)	Theta (Error)	Cluster, Binary
06071+2419	6.92 (0.04)	157.2 (0.21)	
06071+2427	5.88 (0.17)	296.2 (0.39)	
06071+2432	6.69 (0.02)	47.1 (0.18)	B
06073+2418	6.07 (0.06)	77.6 (0.29)	
06073+2435	13.69 (0.02)	146.6 (0.04)	
06073+2437	6.31 (0.05)	128.9 (0.28)	
06075+2411	13.34 (0.02)	224.1 (0.08)	B
06076+2411	8.72 (0.04)	37.00 (0.23)	
06076+2416AB	17.1 (0.04)	324.9 (0.08)	A
06076+2416AC	9.30 (0.03)	247.8 (0.12)	A
06076+2416CD	9.26 (0.06)	244.8 (0.39)	
06076+2420AB	9.16 (0.01)	162.6 (0.09)	
06076+2420BC	6.26 (0.04)	246.9 (0.33)	
06076+2424	8.81 (0.02)	10.8 (0.07)	A?
06077+2412	4.62 (0.22)	14.6 (0.75)	
06078+2424	10.42 (0.03)	29.6 (0.08)	
06079+2423	11.24 (0.02)	346.8 (0.07)	B?
06079+2435	4.16 (0.12)	264.4 (1.28)	Binary
06080+2413	11.96 (0.01)	126.8 (0.09)	B
06080+2425	11.55 (0.01)	232.1 (0.06)	A & B
06081+2422AB	12.53 (0.01)	206.7 (0.05)	
06081+2422AC	9.23 (0.02)	6.5 (0.07)	
06083+2428	12.09 (0.01)	133.2 (0.05)	
06083+2429	11.83 (0.03)	339.1 (0.11)	A
06084+2410	11.57 (0.03)	199.6 (0.09)	
06085+2414	5.7 (0.07)	75.9 (0.4)	A & B, Binary
06085+2417	8.57 (0.14)	94.1 (0.28)	A

06085+2418	8.83 (0.03)	166.5 (0.07)	
06085+2419AB	14.91 (0.01)	349.9 (0.02)	A & B
06085+2419AC	22.43 (0.02)	44.6 (0.06)	A
06085+2419CD	7.67 (0.04)	143.7 (0.16)	
06086+2419	5.63 (0.06)	269.4 (0.37)	B
06086+2423	11.96 (0.01)	176.0 (0.03)	A
06086+2427	11.83 (0.01)	355.7 (0.06)	B
06086+2436	8.28 (0.01)	182.0 (0.06)	B
06087+2415	13.88 (0.02)	323.0 (0.02)	B
06088+2432	11.41 (0.01	165.8 (0.05)	A
06089+2420	7.01 (0.04)	53.0 (0.20)	A
06089+2423	12.68 (0.02)	150.1 (0.05)	A
06089+2424	3.60 (0.3)	41.3 (2.15)	
06089+2427	4.2 (0.19)	194.3 (0.46)	
06090+2419	10.65 (0.02)	68.9 (0.13)	A

Table 1 Our measurements for rho and theta for the pairs observed. The 4th column indicates if either or both of the stars are members of the M35 open cluster. Systems that are true binaries are also here indicated.

Discussion

To investigate whether any of these systems are physical, we plotted our measurements together with the historical measurements provided by Matson (2023). These plots were generated with Plot Tool (Harshaw 2020) for all our observed systems. For 30 stars, the first observation dates from 1926, while the remainder generally have a first observation dating to 1998. In many cases, we found that less than 1" of motion has been observed, sometimes over the course of a century or so, which makes it difficult to assess the physicality of the systems from the historical measurements alone. We find that in general, the historical measurements from 2009 tend to be outliers. This may be because the 2009 measurements were taken by the space-based Wide-field Infrared Survey Explorer (WISE) mission (Wright et al. 2010), and it is

possible that there was some systematic offset in correlating the astrometry of that mission with ground-based astrometry.

Figure 2 shows plots of historical measurements, together with our new measurement, for 4 of the stars we observed. The top two panels, for WDS 06080+2425 and WDS 06073+2437, show linear relations for the motions of these stars over the course of the last century. Many of the systems we observed show such linear relations, although these relations may not mean much in cases where the observed motion is less than 1 arcsec.

In the bottom two panels we show examples of the plots where the motion is harder to interpret. WDS 06076+2416 AC shows several outliers, the most discrepant of which is the measurement from 2009. The bottom right panel for WDS 06078+2424 is typical of those whose reported measurements make it difficult to discern the actual motion of the star. The 2009 measurement again appears to be discrepant, as does the 2010 measurement. In these panels we again see an apparent motion of less than 1.” Clearly, the historical measurements alone would not be sufficient to characterize the nature of these systems.

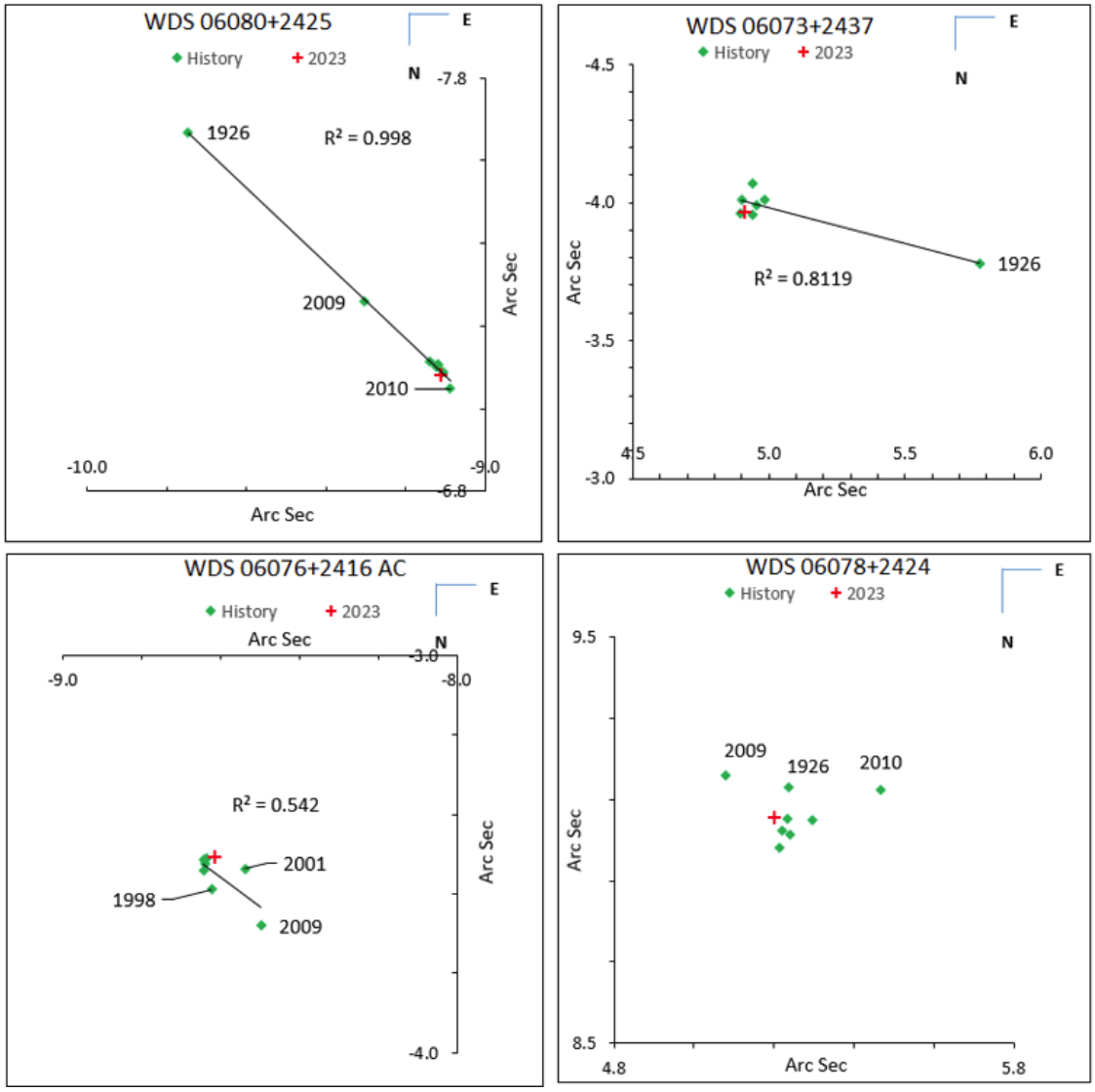

Figure 2 Plots of historical measurements (generated using Plot Tool) for 4 representative systems. Although the top two seem linear, they show less than 1" of motion over ~100 years. The bottom two are less clear, but again less than 1" of motion is seen.

To further assess whether our observed systems are physical, we extracted parallax and proper motion data from Gaia DR3. This was also used to examine whether the stars we observed are members of the M35 cluster. Several values for the parallax and proper motion of this cluster are provided in the literature. Dias et al. (2021) used Gaia DR2 data to derive a parallax of 1.127 with a measurement error of 0.07 mas, while Poggio et al. (2021) used Gaia EDR3 data to generate a parallax of 1.152 with a measurement error of 0.039 mas. As for proper motion, Dias et al. (2021) report a pm-ra of 2.299 (±0.567) and a pm-dec of -2.905 (±0.251), with Poggio et al. (2021) reporting a pm-ra of 2.256 (±0.201) and a pm-dec of -2.889 (±0.197). Based on these values, we have indicated in Table 1 probable cluster members stars whose parallax lie within the range 1.025 - 1.149 and whose pm-ra lies within the range 1.4 - 2.7 and whose pm-

dec is between -3.19 and -2.34. In the paragraphs that follow, we discuss the properties of each system in the context of the historical measurements, our new observation, and the Gaia parallax and proper motions. The “goodness” of the Gaia data is measured with RUWE (Lindegren 2018). For good measurements, the RUWE should be near 1. In the discussion that follows, all Gaia measurements are near this value, unless otherwise noted.

06071+2419

It is difficult to interpret the motions of this pair, as there are three apparent outliers in the data. The observations do not appear to be consistent with either orbital or linear motion. However, the system has seen less than 0.5” of motion over the past century, which is true for many of the systems in this field. The Gaia data clarify the nature of the system, with the A component at a distance of 1,600 pc and the B component at 2,700 pc. This would explain why so little motion has been seen, and would also indicate that this pair is not physical.

06071+2427

Past measurements of these stars are hard to analyze due to their scattered nature. Measurements from 2009 and 2010 appear to be outliers, and there is no strong linear relationship between the pair. However the Gaia data indicate that the stars are not physical, although the errors on the parallax are somewhat elevated, at 17% for the A component and 8% for the B component. The distances corresponding to these parallaxes are 4,400 - 6,200 pc for the primary and 1,600 - 1,900 pc for the secondary. This suggests that these stars are not physically related.

06071+2432

The historical observations are incredibly linear, with $R^2 = 0.95$. Our measurement fits well into this line of movement. It is unlikely that these two stars are related to each other, as the Gaia data indicate that the primary is at 1,750±75 pc away, while the secondary is at a distance of 872±17 pc. This distance and the proper motion are consistent with the secondary being a member of M35. However, this star is ~30’ from the center of the cluster, indicating that if it is indeed a cluster member it must be only weakly bound.

06073+2418

This system is faint, complicating measurement. Additionally, the measurements taken in 2001 and 2009 seem to be outliers. The system has seen less than 0.5” of motion in a century, so we turn to the Gaia data for help. The proper motions are dissimilar, and the stars appear to be quite distant, with the primary at 3,650±400 pc and the secondary at 5,500±1,100 pc. Clearly these parallax measurements have very large errors, although the RUWE for both stars is near 1. Nevertheless, it seems evident that these stars are not physical.

06073+2435

These stars are bright, meaning we can be more confident in the data we have collected. There are measurements starting in 1926, and including all data there is a moderate linear association (R^2 =0.51). However, 2001 and 2009 are both outliers, and once they are removed, the linear

association becomes very strong (R^2 = 0.95), and our data point sits at the end of this line. This isn't a very meaningful association, however, as there is less than 1 arcsec of motion in the last century. Parallax measurements tell us that the two stars are very far apart, with the primary star at 3,500 pc and the secondary at 1,500 pc. This, along with the great dissimilarity between the proper motions, confirms that the stars are not physically associated.

06073+2437

Because of the stars' brightness and location at the edge of our field of view, we have a somewhat elevated standard deviation in our measurements. There are no outliers in the plot of historical measurements, and there is a strong linear relation between them (R^2 = 0.81). Referring to the Gaia data, we see that the stars have dissimilar proper motions and parallaxes, with the primary star being at a distance of 4,000 pc, and the secondary at 1,600 pc. This tells us that the stars are probably not physically associated.

06075+2411

The plot for these two stars doesn't indicate a linear relationship, and our data point is in the middle of the measurements. Remarkably there has been almost no motion in the last century, with the separation varying by less than 0.25" since 1926. The Gaia data are helpful, which indicate that the primary is at a distance of 1,000 pc, and the secondary is at 870 pc. Clearly they are not physical, although the proper motions of the secondary indicate that it is a member of M35. However this star is 23' from the center of the cluster, suggesting that it is probably loosely bound.

06076+2411

These stars are faint, which resulted in marginally elevated standard deviations, especially for our measurement of $\boldsymbol{\theta}$. With such little movement in the separation over the last 100 years, it is hard to get a clear picture of the star's motion. The Gaia data suggest that the stars are not physical, as the primary is at a distance of 2,540±200 pc and the secondary is at a distance of 3,400±340 pc. The proper motions are dissimilar, which suggests that these stars are not physical.

06076+2416 AB

These stars have a nice baseline of observations dating to 1926. However there has been very little motion in that timespan, which makes it difficult to interpret the historical observations. The Gaia data is more helpful, as the primary is at a distance of 824±8 pc and the secondary is even closer at 730±7 pc. The parallax and proper motion of the primary are consistent with its membership in M35, although at nearly 20' from the center of the cluster it may be only loosely bound.

06076+2416 AC

As with the A and B components, there has been little change in $\boldsymbol{\theta}$ and $\boldsymbol{\rho}$ in the past century. The C component is at a distance of 2,035±184 pc, and is unrelated to the A component.

However, the RUWE for the C component is somewhat elevated, at 1.45. As noted above, the A component appears to be a member of M35.

06076+2416 CD
These stars are quite faint, leading to increases in our reported standard deviations. With little change in separation and position angle, it is hard to interpret the historical measurements. The Gaia data appear to be more straightforward though, as the C component is at a distance of 2,035±184 pc and the D component is at a distance of 571±6 pc. Along with this, their proper motions are dissimilar, indicating that these stars are not physically associated.

06076+2420 AB
This system was first observed in 1926, but there has been less than 0.1” of motion since then. The observation from 2009 seems to be an outlier, with the remaining data appearing very linear. This has little meaning however, in the context of such little movement. Looking at the Gaia data, we see that the distance between the stars is quite large, with star A being at 3,400 pc and star B at 1,700 pc. Along with this, their proper motions are quite dissimilar, so we can say that they are not physical.

06076+2420 BC
As with the AB components, these show very little motion, albeit over a smaller time span as the first observation of this pair dates to 1998. They are faint, which contributes to the higher errors we report. The Gaia parallax data suggests that they are not physical, with the B component at a distance of 1,740±52 pc and the C component at a distance of 1,027±31 pc. Their proper motions are quite different, consistent with this pair not being physical.

06076+2424
With less than 0.5” of motion over the course of a century, it is hard to interpret the historical observations. The Gaia data may not be of great help either, as the RUWE for the primary component is quite large, at 2.67. The Gaia distance to the primary is 728 pc and the secondary is 925 pc. Although the proper motion of the primary is consistent with it being a member of M35, its inconsistent distance and large RUWE prevent us from determining this with any certainty. Finally, if the A component is indeed a cluster member, it is quite near the edge of the cluster, 30’ from the center.

06077+2412
This pair is very close together and rather faint. This produced larger than ideal errors in our measurements, especially regarding the angle. As with the others, very little motion has been observed since the first measurement in 1998. The Gaia data suggests that they are well separated, with the primary at 3,700 pc and the secondary at 7,500 pc, although the errors on both are quite high.

06078+2424
Although first observed in 1926, this pair exhibited less than 0.1” of motion in that time. This makes it quite difficult to interpret the historical measurements. The Gaia data indicate that this

is not a binary, as the primary is at a distance of 864 pc while the secondary is at 1,640 pc. While this distance would suggest that the primary is a member of M35, the proper motion is inconsistent with cluster membership.

06079+2423
Less than 1” of motion has been observed for this pair since observations began in 1926. The Gaia parallax indicates that the A component is at a distance of 2,950 pc while the secondary is at 975 pc. This, together with the star’s very different proper motions, indicates that this is not a physical binary. The proper motion of the B component is consistent with M35 cluster membership, but its distance is somewhat larger than that of the cluster. This makes it difficult to say whether this is a cluster member.

06079+2435
These two stars are quite close together, which contributed to the uncertainty of our measurement. There has been little to no motion since the first observation in 1998. Happily, these stars are quite nearby, with Gaia-derived distances of 289±3 and 287±6 pc. They also have very similar proper motions, indicating that these are indeed a physical pair. A longer baseline of observation is clearly needed to observe the orbital motion.

06080+2413
Although this pair seems to show linear motion, it has moved less than 1” in a century. The distance derived from the Gaia parallax for the primary is 3,000±150pc, while the secondary is at 865±17 pc. The proper motion of the secondary, together with its parallax, is consistent with M35 cluster membership.

06080+2425
The plot for this pair is remarkably linear, with R^2=0.998. However there is less than 1” of motion, so this linearity must be interpreted with caution. The Gaia data suggests that both stars are cluster members, and may be a physical pair as well. The distance for the A component is 848±17 pc while the B component is at a distance of 862±9 pc. Their proper motions are also quite similar, with both stars having pm-ra = 2.1, while the DECcomponents are somewhat different, at -2.714 and -3.145. These differences in DEC suggest that they may not be physically bound, but are certainly members of M35.

06081+2422 AB
As is typical, little motion has been observed since the first observation, making it hard to interpret the stars’ motions. Still, what little motion that has occurred appears to be linear in nature. The Gaia data is somewhat helpful, indicating that the primary is at a distance of 2,500 pc and the secondary is at 2,100 pc. However, the RUWE for the secondary is quite large (5), which means that perhaps these measurements are not to be trusted. Taken together, this suggests that this pair is not physical.

06081+2422 AC

In contrast to almost every other star observed, this pair shows more than 6” of motion over the last 100 years. Perhaps the initial 1926 observation was in error, as the first reported separation was 3”, while the next observation, in 1998, was 9.2”. This is a greater change than seen for any other stars we observed. Still, the historical measurements are quite linear, with R^2=0.98. The Gaia data confirm that this pair is not physical, with the primary at a distance of 2,550±100 pc and the secondary at a distance of 940±19 pc. Their proper motions are also quite different.

06083+2428

Very little motion has been observed in the past century, making it hard to interpret the plot of historical measurements. Compounding the problem is the fact that the B component appears to be itself a double, and indeed there are two adjacent Gaia objects there. The proper motions of these two are similar, but their parallaxes suggest that they are not physical. In contrast the A component lies at a distance of only 575 pc, so we can conclude that it is not related to the B component.

06083+2429

These stars are somewhat faint, affecting our reported errors. With a first observation in 1926, there has been approximately 1” of motion since then. The 2009 observation may be an outlier, although a line fitted to the data has R^2=0.91. The Gaia data indicate that the A component is a member of M35, with a distance of 850 pc and proper motion consistent with that of the cluster. In contrast, the B component is at a great distance of 4,800±773 pc. Clearly these stars are not physical.

06084+2410

Unfortunately this pair was near the bottom edge of our frame, which may have affected our measurements. This pair has also shown little movement over the last 100 years, which makes it challenging to interpret the historical measurements. Nevertheless, our reported numbers are broadly consistent with them. Turning to the Gaia data, we see that the stars are probably not physical, as the primary is at a distance of 1,600 pc while the secondary is at a distance of 900 pc. The RUWE for the secondary is quite large, at 3.692, which means its parallax must be treated with some caution.

06085+2414

The first observation of this pair only dates to 1998, so little motion has been observed. It is not clear from these few historical measurements how the stars are moving. Furthermore they are close together, which has slightly elevated our reported errors. The Gaia data however indicates that both stars are cluster members, with the A component at a distance of 874±9 pc and the B component at a distance of 876±9 pc. Their proper motions are also quite similar, suggesting that in addition to being part of M35, this pair is probably physical.

06085+2417

Like many of the other stars we observed, this one has exhibited less than 0.5” of movement over the past century. There is no clear trend in the historical measurements over such a short time span. The Gaia data clarify the nature of this system, as the primary is at a distance of 922 pc while the secondary is at a distance of 1,800 pc. The proper motions suggest that the A component is a member of M35, and indeed this star is within 10’ of the cluster center.

06085+2418

The first observation for this system dates to 1998, and as with other such systems, there has been very little (<0.2”) motion since then. The Gaia data indicate that they are not physical, as the A component is at a distance of 490 pc and the secondary is much further away at 1,600 pc.

06085+2419 AB

There is a nice baseline of observations for this system, dating back to 1898. However, it is unclear from these observations how the stars are moving. The data don’t show a curved trend, nor are they linear. There has been less than 0.3” of motion since the first observation. Turning to the Gaia data, we see that these two are probably part of M35, as the primary is at a distance of 879±9 pc and the secondary is at 861±9 pc. Their proper motions are also consistent with cluster membership.

06085+2419 AC

With less than 0.25” of motion since the first observation in 1998, it is difficult to understand from the historical measurements alone the motion of this system. The Gaia data indicates that they are not physical, with the primary being at a distance of 879±9 pc and the secondary at a distance of 2,070±100 pc. Their proper motions are also unrelated, and it appears that the A component is a member of M35.

06085+2419 CD

These stars are rather faint, which resulted in larger errors in our reported measurements. The first observation was recorded in 1998, and there has been less than 0.25” of motion since then. The Gaia data suggest that the stars are at a similar distance, with the primary at 2,070±100 pc and the secondary at 1,980±80 pc. However their proper motions are quite dissimilar, so they don’t seem to be part of a moving group.

06086+2419

These stars are quite close together, which makes them hard to measure and has resulted in a somewhat elevated standard deviation for our reported $\boldsymbol{\theta}$ and $\boldsymbol{\rho}$. Unfortunately, the first measurement only dates to 1998, and there has been no reported change since then. The Gaia data suggest that they are not physical, as the proper motions are quite different, and the primary is at a distance of 1,700 pc and the secondary is at a distance of 925 pc. Based on its proper motion, it is likely that the B component is a member of M35.

06086+2423

Once again, less than 0.5” of motion has been seen for this pair in the last century. The data seems a bit scattered, but the Gaia data is helpful in that it indicates that the A component is at a distance of 830 pc and is a cluster member, while the B component is even closer, at 740 pc.

06086+2427
Like many of the other double stars in this field, this system has seen very little motion in the past century. Although the 2009 and 2010 observations appear to be outliers, it is hard to interpret the remaining data. Luckily, the Gaia data indicate that this pair is not physical, with the primary at a distance of 1,360 pc and the secondary at 900 pc. Based on this distance as well as its proper motion, we conclude that the secondary is a member of M35.

06086+2436
This system was first observed in 1926, and has 9 observations total. The measurements from 2010 and 2009 are outliers. If these are removed and a line is fitted, it has R^2=0.9. Nevertheless, there has been very little (<0.5”) motion in the past century, so the astrometry alone is not helpful. The Gaia data suggests that they are not physical, with the primary at a distance of 1,200 pc and the secondary at a distance of 875 pc. This distance, together with its proper motion, suggests that the B component is a cluster member.

06087+2415
This system has 9 observations dating to 1926. The data does not appear to have a clear trend, but there has been less than 0.5” of movement in the past century. The Gaia data indicate that the system is not physical, with the A component at a distance of 1,200 pc and the secondary at a distance of 880 pc. This distance, together with its proper motion, suggests that the B component is a member of M35.

06088+2432
The first observation for this star dates to 1926, and has 7 historical measurements in total. It seems that the observations dating to 2010 and 2009 may be outliers, and if they are removed and a line is fitted, that line has R^2=0.94. Looking at the Gaia data, we see that they are not physical, as the proper motions do not match and they are quite far from each other. The primary is at a distance of 876 pc, suggesting that it is a cluster member, and the secondary is at a distance of 2,800 pc.

06089+2420
This star has 11 historical measurements, although there is no clear pattern in the data. The 2009 measurement appears to be discrepant, as does two from 2015. Removing these gives a line with R^2=0.7. The Gaia data suggest that the stars are not physically associated, with the A component at a distance of 880 pc and the B component at a distance of 1,440 pc. This distance, together with its proper motion, suggests that the A component is a member of M35.

06089+2423
This system seems quite linear, although 2009 could be an outlier. If that observation is removed, then the R^2 becomes 0.997. The RUWE for the primary is quite poor at 8.9, although it is near 1 for the secondary. The Gaia parallax gives a distance of 880 pc for the primary, and a distance of 1400 pc for the secondary, indicating that this is not a physical system. However, based on its proper motion and parallax, the A component is probably a member of the M35 cluster.

06089+2424

These are quite close together (<4“) and faint, which produced a relatively large standard deviation. Still, our measurement appears to be in line with the historical measurements, except for 2009, which may be an outlier. The Gaia measurements suggest that the system is not linear, as the A component is at a distance of 1,400 pc while the B component is at 2,900 pc. However, the RUWE is somewhat high (1.6) for the A component. In any case, this is probably not a physical system.

06089+2427

This system is interesting because there are three stars in a line, which makes measuring difficult. This is compounded by the small separation (4”) and relative faintness of the stars. Still, our measurement appears to be linear with the previous ones, although 2009 seems to be an outlier. There are only 3 historical data points, the earliest of which dates to 1998. The Gaia data indicate that the A and B components are not physical, with the A component at a distance of 1,360 pc and the B component at a distance of 900 pc. The third C component is likely physical with the B component, as they are at a similar distance and have similar proper motions.

06090+2419

This pair is near the extreme left side of our images, and are also somewhat faint, which may affect the accuracy of our measurement. The plot suggests that 2009 is an outlier, but the measurements seem rather linear. However, the proper motions and parallaxes are quite different, with the primary at a distance of about 860 pc and the secondary much further away at 1,430 pc. The A component’s parallax and proper motion are consistent with it being a member of M35.

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