SEARCH FOR HIGH PROPER MOTION WHITE DWARFS

J.T.A. DE JONG, K.H. KUIJKEN & M.J. NEESER
Kapteyn Astronomical Institute, Postbus 800, 9700 AV Groningen, The Netherlands

Recent results of microlensing surveys, show that 10-20 % of the dark halo mass of the Milky Way consists of compact objects. The masses of these compact objects range from 0.1 to 1 solar mass. New theoretical cooling models for white dwarfs, and the detection of faint blue high proper motion objects, imply that ancient white dwarfs might make up part of this population.

In this pilot project, using data from the C and D patches of the ESO Imaging Survey and data obtained at CTIO, we attempted to find such halo white dwarfs in the solar neighbourhood. With a time baseline of approximately one year between data sets and a limiting I-band magnitude of 23, we can find these high proper motion objects up to distances of 85 parsecs. In the 2.5 deg² studied so far we have found three high proper motion candidates.

1 Introduction: dark matter and white dwarfs

It is generally accepted that the Milky Way and most external galaxies contain more mass than observed directly. What makes up this so-called ‘dark mass’ is, however, not so clear. This mass is often assumed to be distributed in an isothermal halo, which means that dark matter would also be present in the solar neighbourhood. Recent results from galactic microlensing experiments like MACHO indicate that 10 to 20 % of the dark halo mass of the Milky Way may be in compact objects.

Recent number counts of faint blue objects in the Hubble Deep Fields North and South and the detection of high proper motion objects indicate the presence of a population of faint blueish compact objects in the galaxy. Furthermore, new cooling models for white dwarfs show that they are much bluer than was previously believed. The above suggests that the galactic dark halo might, at least partially, consist of very old white dwarfs.

In the project presented here we try to find faint high proper motion objects in the solar neighbourhood, which are likely to be dark halo white dwarfs (see the table on the right). For this purpose we use the C and D patches of the ESO Imaging Survey (EIS) Wide and a smaller survey done with the CTIO 4m telescope. These data serve as a pilot project for a larger survey.
for which we plan to observe the complete C and D patches of the EIS Wide survey with a larger temporal baseline.

2 Data and Method

The data that are being used for the current project consist of two overlapping sets. The first data set is taken from the C and D patches of the EIS Wide survey, which are 6 deg² each. These data were obtained between July 1997 and March 1998 in the I-band with individual exposure times of 300 seconds. The second data set was obtained with the 4m telescope at CTIO. This survey covers almost 2 deg² of both the EIS C and D patches, making up a total area of nearly 4 deg². The CTIO data were taken in the R-band with single pointing exposure times of 2000 seconds. As this second survey was performed in December 1998, we have a time baseline of approximately one year for the high proper motion search.

To find high proper motion objects from the data we use a straightforward method. First, the CTIO data are transformed to the EIS coordinate system. The EIS pixels are smaller than the CTIO pixels, so in this way we do not lose information. Following this, objects are matched within a 2 arcsecond radius. Objects that seem to be offset are selected with a magnitude dependent cutoff. Finally the resulting outliers are visually inspected to filter out close objects, cosmic rays, extended sources, etc. With the time baseline of ~ 1 year we are sensitive to proper motions of 0.5 to 2.0 arcsecond per year.

3 What can we find?

A high proper motion search can be very efficient in finding halo objects because of their large velocities with respect to the solar standard of rest. While the sun follows the galactic rotation, the halo does not. Therefore, halo objects have typical velocities of 200 km/s.

In the event that we find an object with a high proper motion, how do we know whether it’s part of the dark halo? In table 1 we compare the chances of finding objects belonging to the galactic components present in the solar neighbourhood. Our sensitivity to proper motions of 0.5 to 2.0 arcseconds, together with the typical velocities of the objects w.r.t. the sun, gives the distance range where we can find these objects. With these densities we can calculate the average number of objects per square degree. This shows that when we find a high proper motion object, it is most likely part of the dark halo. According to cooling models by Saumon & Jacobsen, white dwarfs as cool as 3000 K have $M_I \sim 16$; easily detectable in our survey to distances of 85 pc.

There are, however, some issues that should be mentioned. The two data sets are in different bands (R and I), and have different noise properties because of the different exposure times. Other possible explanations for apparent object motion include close (variable star) binaries, distant supernovae and even Kuiper belt and Oort cloud objects. The motions on the sky of

| Population     | $v$ (km/s) | distances (pc) | $\rho$ ($M_\odot pc^{-3}$) | objects (deg⁻²) |
|----------------|------------|----------------|----------------------------|-----------------|
| pop.II halo    | 200        | 20-85          | $5 \times 10^{-5}$        | 0.001           |
| thin disk      | 30         | 3-13           | 0.05                       | 0.03            |
| thick disk     | 60         | 6-25           | 0.003                      | 0.01            |
| dark halo      | 200        | 20-85          | 0.01                       | 2               |

Table 1: Calculated estimates of the average number of high proper motion objects one will find for different galactic populations. For these calculations, objects of 0.3 $M_\odot$ are assumed.
the Kuiper and Oort objects are dominated by parallax, but because our temporal baseline is ∼ 1 year this possibility can not be excluded with our current data. All of these problems can be solved by doing a third observation run.

4 Results

We have now analyzed 5/8 of the nearly 4 deg² of data, and have found three promising candidates for dark halo objects. These are shown in the figures 1 to 3. The first two candidates are located in the C patch of the EIS Wide survey while the third one is in the D patch.

The objects are very faint, which is a further indication that they are not normal stars. Both candidate 1 and 2 have an apparent I-band magnitude of 22. The third candidate is even fainter, around $m_I \sim 23$. It is also striking that the two C patch objects move approximately in the same direction. This direction is consistent with it being due to the galactic rotation of the sun. The same is true for the motion of the D patch candidate.

5 Future

The recently discovered population of faint, high proper motion objects which may be part of the galactic dark halo needs to be studied in detail. For this purpose, a large number of objects is necessary. Therefore, we see the current project as a pilot project for a larger survey. The most efficient way of increasing the chances of finding these objects is to increase the field of view. For the candidates we have so far, further observations need to be done to confirm the proper motions and to get more color information and/or spectra.

References

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Figure 1: Candidate 1. The two images show the same 16x16 arcsec patch of the sky (located in the EIS Wide C field). On the left is the EIS I-band image, on the right the CTIO 4m R-band image, which was transformed to the EIS coordinate system. The apparent shift of the image is $\sim 1$ arcsec.

Figure 2: Candidate 2. The shift of this candidate is also $\sim 1$ arcsec. This candidate is also located in the EIS Wide C patch and seems to be moving approximately in the same direction as candidate 1. This direction is consistent with it being due to the galactic rotation of the sun.

Figure 3: Candidate 3. This candidate has an apparent shift of $\sim 0.5$ arcsec and is near our brightness and proper motion detection limits. The direction of motion of this object is also consistent with it being due to the galactic rotation of the sun. This candidate is located in the EIS Wide D patch.