Astrometric search in SDSS Stripe 82 for wide compact binaries

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Wide Compact Binaries?

• Only close compact binaries known so far!
• Are there neutron star or black hole companions to M-dwarfs with orbital periods of several years?
• What could be the formation process for such systems?
  • Can the components evolve together, i.e. can the M-dwarf/the system survive the SN explosion of the massive component
  • Are such binaries a result of capture processes
Data set

- $20^h<\text{RA}<4^h$, $-1.25^\circ<\text{DEC}<1.25$
- 4 million stars and galaxies, repeatedly measured
- Providing photometric & astrometric measurements
- Mean positional uncertainty for stars: 35 mas
- For some objects spectra are available from the SDSS online database
Proper motions uncertainties provided by Bramich et al. (2008) catalogue are model errors $\rightarrow$ systematic features.
General selection criteria

- For saturated or too faint objects proper motion uncertainty systematically larger → magnitude cut
- First sample only contains well measured stars, i.e. objects not showing outliers in motion curve
- Aim to find neutron stars or black holes to low-mass stars → light dominated by low-mass component → only consider apparently isolated stars
- Astrometric signal should exceed the positional uncertainties → nearby objects
We need nearby objects! Preferably within 100pc → Proper motion > 50mas/yr

Binaries with larger mass ratio show larger astrometric signal → the most interesting ones
Two approaches to identify

1) Companion increases proper motion uncertainty ($\Delta \mu$) and the standard deviation of the positional residuals ($\sigma_{\text{Res}}^2$) → comparison to values of similar objects (No. of Epochs ± 5, r-mag ± 0.5)

2) Binaries are periodic systems → Lomb-Scargle periodograms and sine curve-fitting in each coordinate → period equal in both coordinates

→ Do both approaches lead to the same result?
First approach: SDSS J2341-0114

Spectral type: M2 dwarf
Distance: ~80 pc
$\mu_{\text{total}}$: 179 mas/yr
$i$ mag: 13.4 mag
$M_i$ mag: 8.9 mag
Proper motion uncertainty vs. $r$ magnitude

- $26 < \text{No. of Epochs} < 36 \quad \sigma$ of distribution (mas/yr): 0.815
- $13.929 < r\text{-mag} < 14.929 \quad \text{Difference to median (mas/yr): } 1.786$

Number of similar objects: 17

Standard deviation of positional residuals vs. $r$ magnitude

- $26 < \text{No. of Epochs} < 36 \quad \sigma$ of pos. residuals (mas): 8.432
- $13.929 < r\text{-mag} < 14.929 \quad \text{Difference to median } \sigma \text{ (mas): } 19.966$

Number of similar objects: 17
Lomb-Scargle periodogram in both coordinates

Sine-curve fitting in both coordinates

- Fitted Amplitude: 0.0545±0.0123 arcsec
- Fitted Period: 532.5496±8.8097 days
- Fitted starting time: 1658.2599±13.2409 days

- Fitted Amplitude: 0.0498±0.0121 arcsec
- Fitted Period: 661.1038±6.7702 days
- Fitted starting time: 0.0000±0.0000 days

Reduced $\chi^2$-value: 2.5394

Reduced $\chi^2$-value: 2.7432

Maximum peak at period of 532.32955 d
70% significance level: 8.21037

Maximum peak at period of 664.34344 d
70% significance level: 8.21037
Second approach: SDSS J2325-0026

Spectral type: M4 dwarf
Distance: \(~80\) pc
\(\mu_{\text{total}}\): 124 mas/yr
\(i\) mag: 15.5 mag
\(M_i\) mag: 10.8 mag
Sine-curve fitting in both coordinates

Lomb-Scargle periodogram in both coordinates

Maximum peak at period of 260.27571 d
70% significance level: 7.41811

Maximum peak at period of 286.98646 d
70% significance level: 7.41811
Proper motion uncertainty vs. r magnitude

Standard deviation of positional residuals vs. r magnitude
Open questions and future work

- Why do candidates show either good sine fit or are outliers in $\Delta \mu$ and $\sigma_{\text{Res}}^2$?
- Are the determined periods really significant?
- Resulting periods are different from sine-fit and lomb-scargle periodogram! Why?
- Orbit fit for best candidates
- Expanding data with online catalogue
- Own observations to confirm candidates
Thank you!

Artist impression by Mark Garlick (Space-Art)