Searching for hot subdwarf + dwarf M / brown-dwarf binaries in APOGEE data

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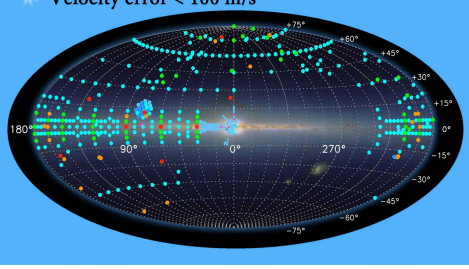
Abstract In this project, I aim to find hot subdwarf stars with late M-dwarf (brown-dwarf) companions. An inverse method will be applied for this: I will look at the APOGEE spectra of late type stars in order to find a trace of an sdB companion; not only because few hot subdwarfs are observed in APOGEE but also there has been some ancillary projects specifically for late type stars. More than two dozens of sd + dM systems are already known. Obtaining a high quality spectra for such systems would allow to learn the physical parameters of the companions by disentangling the spectra. Also the light curves of such systems can be obtained as follow-up observations and would help us to figure out the mass of the components. Despite there are many scenarios to form both single and binary hot subdwarf stars, binarity in these stars is not well understood, yet thought to be very common and there are theories being discussed in the favour of the idea that hot subdwarfs are essentially components of binary systems. Additionally, formation theories of these substellar components in such systems are still unknown, which makes the formation and evolution of hot subdwarfs in binary systems even more of a mystery.

The Apache Point Observatory Galactic Evolution Experiment

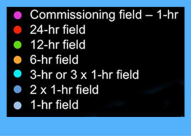
- Spring 2011 - Spring 2014
- 100,000 giant stars to magnitude H=12.2
- Resolution ~22,500
- Typical S/N > 100
- Wavelengths 1.51-1.70 μm
- Stellar parameters (including logg, T_{eff}, [Fe/H], [α/Fe])
- Abundance of 15 chemical species (C, N, O, Na, Mg, Al, Si, S, K, Ca, Ti, V, Mn, Fe, Ni) to 0.1 dex precision
- Velocity error < 100 m/s

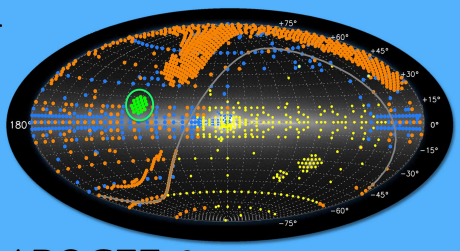


DR12 is the second spectroscopic release from the APOGEE.

- includes all APOGEE observations through July 2014 (encompassing all of SDSS-III).
- provides APOGEE's processed infrared spectra, as well as catradial velocities, stellar parameters, and abundances derived from these spectra.
- also includes spectra of ~900 stars that were obtained using the NMSU 1m telescope at Apache Point Obsevatory, using a fiber link to the APOGEE instrument.

By design, spectra for most of the survey stars are integrated over multiple visits, with at least one visit separated by at least one month, to enable the identification of binary stars through detection of radial velocity variations.

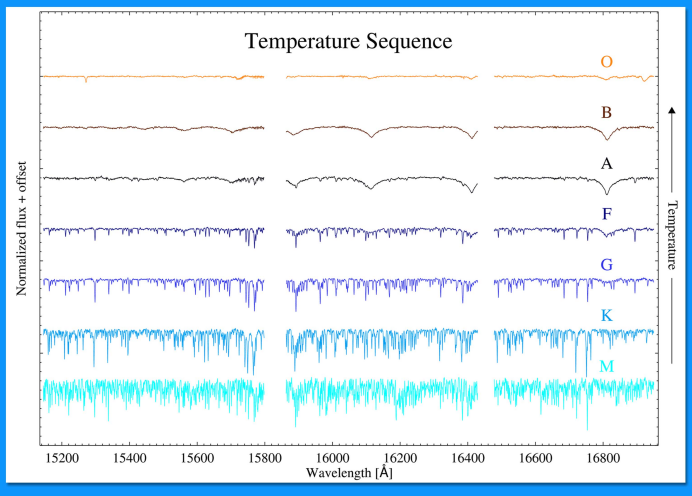




APOGEE-2

- Fall 2014 - Fall 2020
- Bright-time observations at APO (orange and green (Kepler)) and LCO (yellow)
- 300 fibers per 7 deg^2 plate (APO)
  3.5 deg^2 plate (LCO)
- Wavelength range & resolution same with APOGEE
- 300,000 stars with S/N > 100

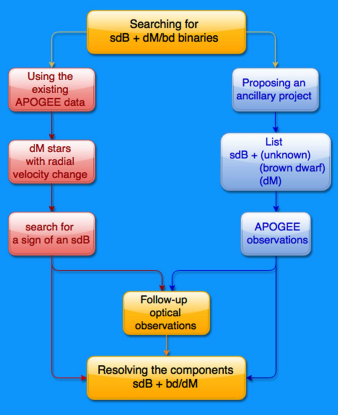
Method

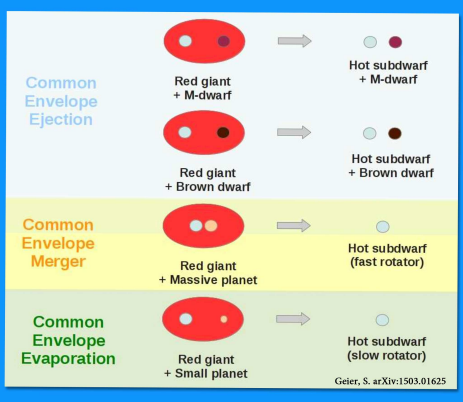


Two possible ways to explore these systems are considered:

- APOGEE Radial Velocity Survey of M Dwarfs (Desphande et al. 2013) can be used as an initial catalog to select the candidates. Fingerprints of a hot component will be searched at the composite spectum.
- Once the list of sdB+dM/bd/unknown binaries is made, a crossmatch between whole APOGEE database can be done. An ancillary project to APOGEE2 would be a better way to find these systems.

Follow up observations of the candidates in the optical region will reveal if there is really a companion and if it is an sdB or a wd or something else.





There are theories being discussed in the favour of the idea that subdwarfs are essentially a component of binary systems. Yet, producing a hot subdwarf with an M-dwarf companion is not very well understood, especially the mass limit to survive from a common-envelope evolution is still unknown. Kupfer et al. 2015 showed that the confirmed dM/bd companions are concentrated around 0.1M (light grey: wd companions, grey: dM companions, dark grey: unknown type). As an outcome of common-envelope ejection, finding more of such systems would allow to figure out the details of the formation and evolution theory of sdBs and help to learn the binary nature of sdB stars.