# M Dwarf Eclipsing Binary Candidates from the SDSS-II Supernova Survey

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## Summary

**We use multi-band photometry collected by the SDSS-II Supernova Survey to identify M dwarf eclipsing binary candidates in SDSS Stripe 82 (RA between 22 h and 4 h, DEC between -1.27 deg and +1.27 deg). We use ensemble photometry to remove systematic effects caused by differences in photometric conditions from night to night, and generate differential magnitude light-curves of about 900,000 stars. About 520,000 of these are classified as M dwarfs using constraints in SDSS *r-i* and *i-z* colors. Finally, we search these objects for periodic variability.**

| | |
|---|---|
| Objects classified as stars | 884,049 |
| Objects classified as M dwarfs | 521,130 |
| Early M dwarfs (M0–M4) | 493,635 |
| Late M dwarfs (M5–M9) | 27,495 |
| Total stars processed to date | 115,803 |
| Total stars classified as M dwarfs | 76,978 |
| Early M dwarfs (M0–M4) | 72,570 |
| Late M dwarfs (M5–M9) | 4,408 |
| Processed M dwarfs tagged as variable | **40** |
| Tagged variable early M dwarfs (M0–M4) | **26** |
| Tagged variable late M dwarfs (M5–M9) | **14** |
| M dwarf eclipsing binary candidates | **4** |

Table 1: Summary of Data Reduction

## 4. Ensemble Photometry

- Variable photometric conditions produce systematic effects in light-curves that can be mistaken for variability
- Use ensemble photometry to mitigate these, and attempt to produce light-curves independent of such effects (Honeycutt 1992)
- Ensemble photometry uses all stars in the observed field to compute a differential magnitude for each target star
- Tags a target star as variable if RMS of the differential mag light-curve is greater (> 2 sigma) than the expected error in that differential magnitude bin

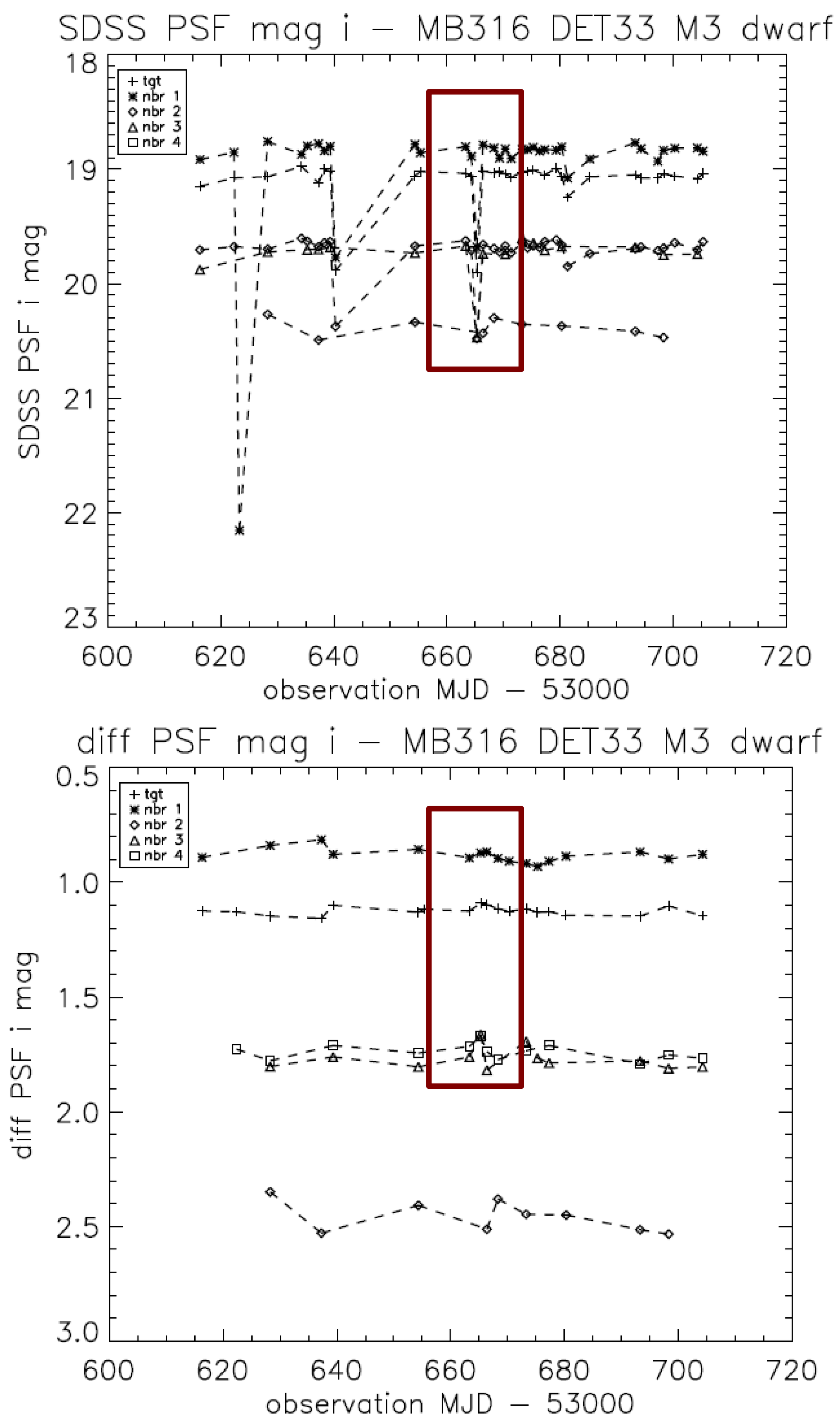



Figure 2: Ensemble Photometry in Action

## 1. M Dwarfs

- M Dwarfs are low-mass, low-temperature, long-lived stars on the main sequence
- By number, they are the most abundant type of star in the Galaxy, but are intrinsically faint, thus hard to see, which makes characterizing their properties difficult
- Photometric and spectroscopic observations of M dwarfs in eclipsing binary systems would provide high quality estimates of these stars' radii, masses, luminosities, temperatures, metallicities, and ages
- Theoretical models of very low mass stars disagree with observations of their radii (Ribas 2006, Chabrier 2007), leading to discrepancies in the mass-radius relation
- More observations of low-mass eclipsing binary systems would lead to better statistics, reconciling the predictions of theoretical models with the observed properties of these stars

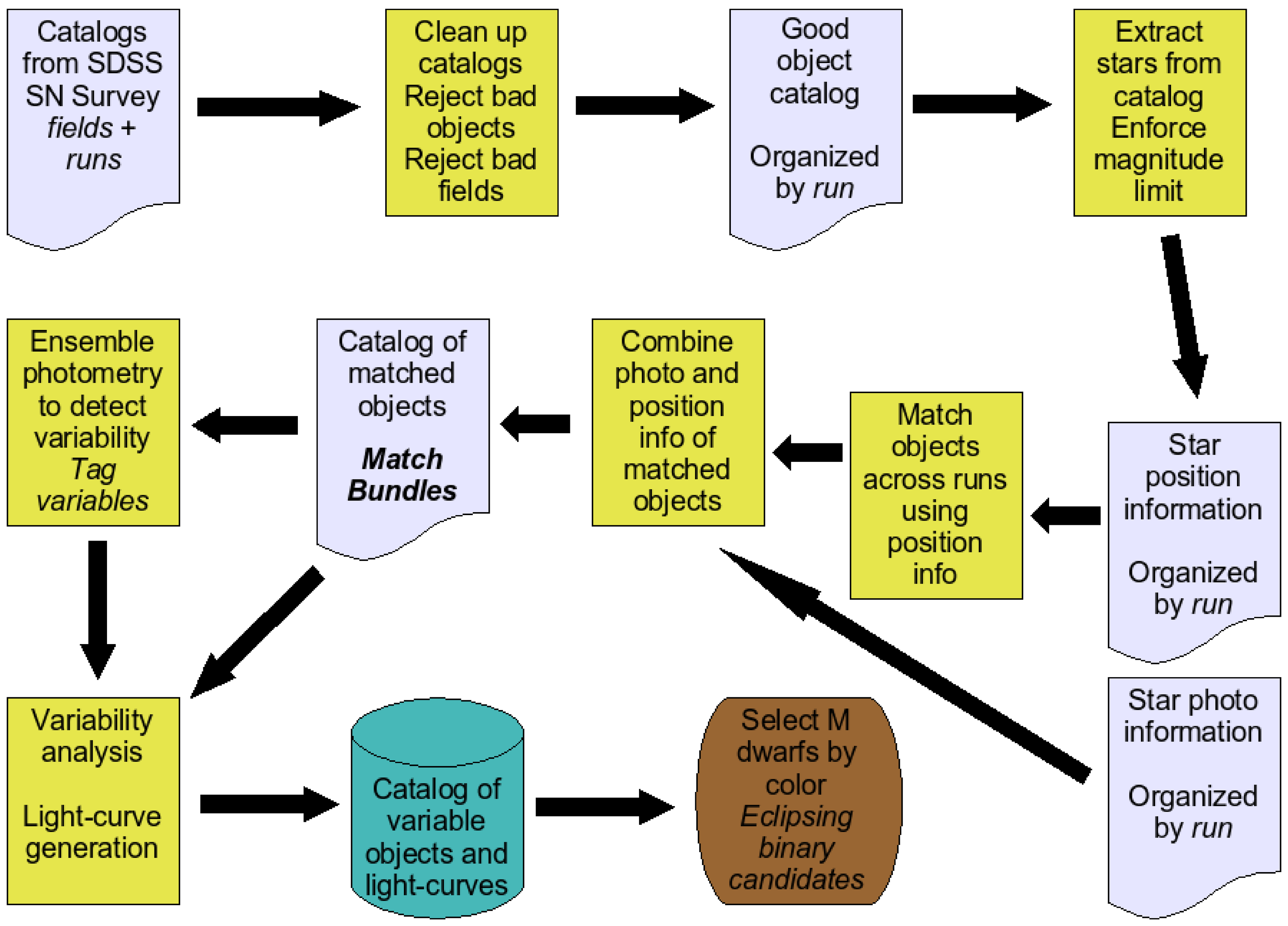



Figure 1: Data Reduction Pipeline Schematic

## 5. Eclipsing Binary Candidates

- Need to select for *periodically variable* objects, hard to do so given our time-sampling
- Pick out obvious variables in SDSS mag RMS vs mag plot: gives long-term variables, flare stars, etc.
- Apply ensemble photometry and look at tagged variable objects: selects non-obvious candidates
- Require good eclipsing binary candidates to have at least three equally-spaced *events* observed simultaneously in the SDSS *r*, *i*, and *z* bands
- Look at object light-curves with two *events* as well; these are possible candidates too

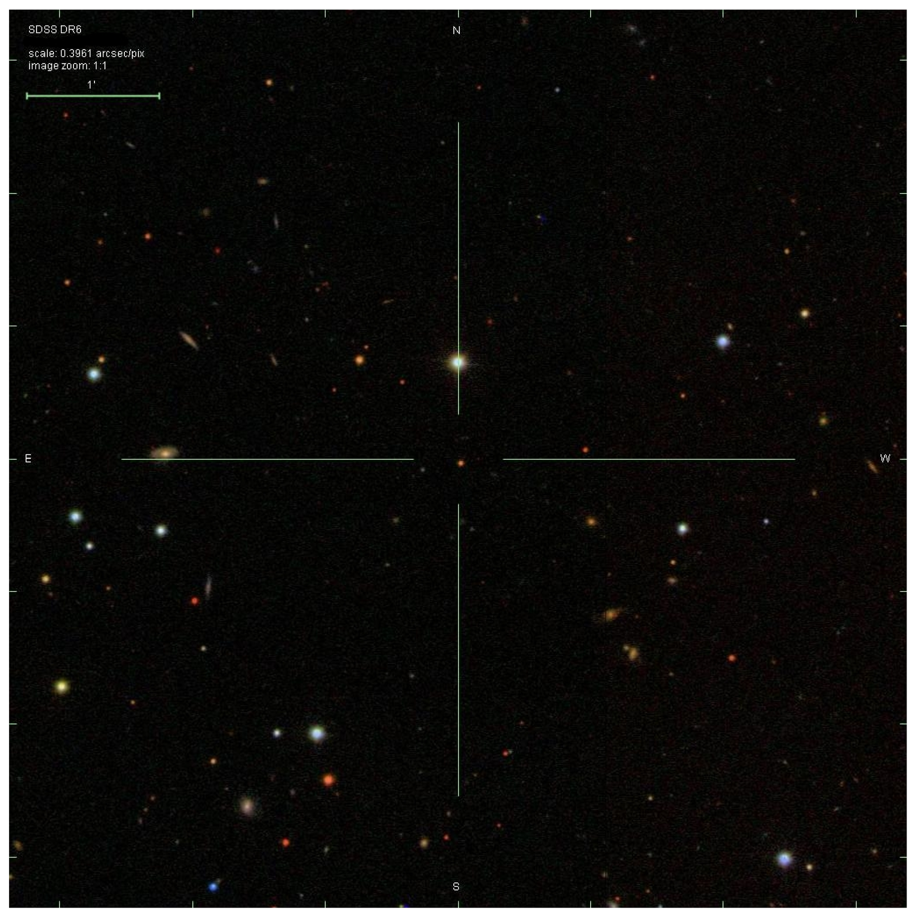



Figure 3: M Dwarf Eclipsing Binary Candidate MB6785, SDSS *r* mag: 19.45, SDSS *i* mag: 18.53, SDSS *z* mag: 18.02, M1

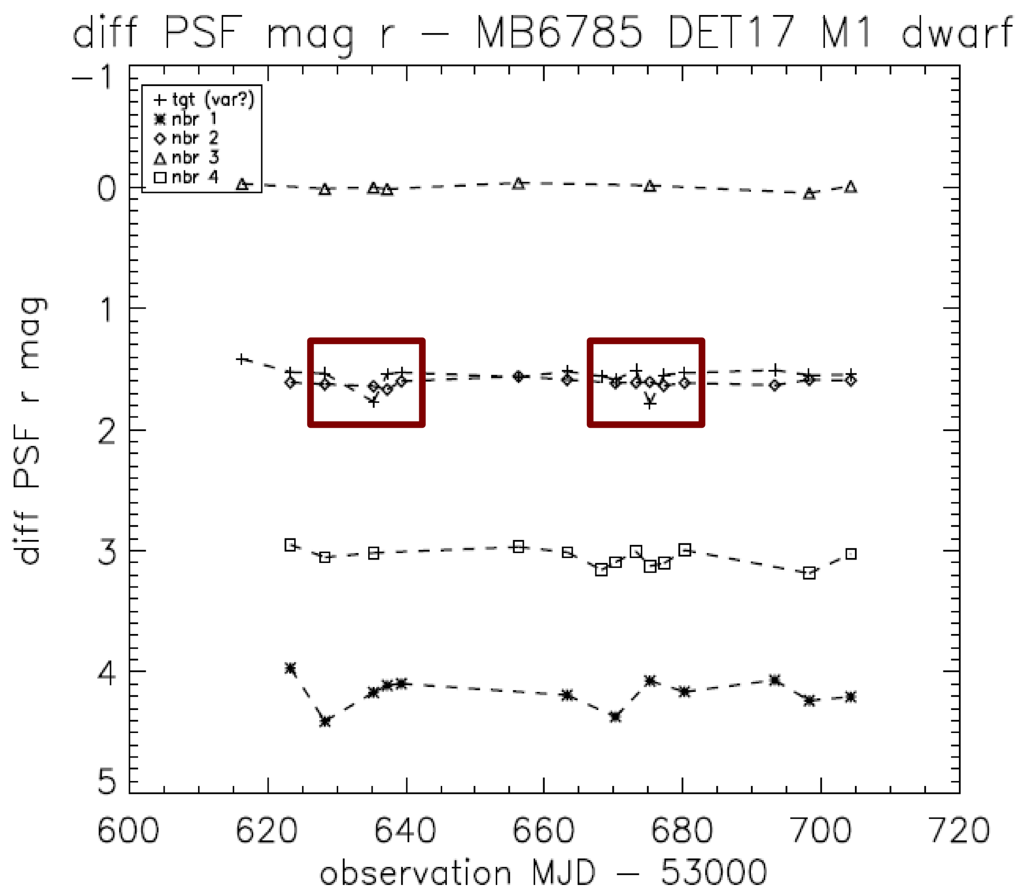


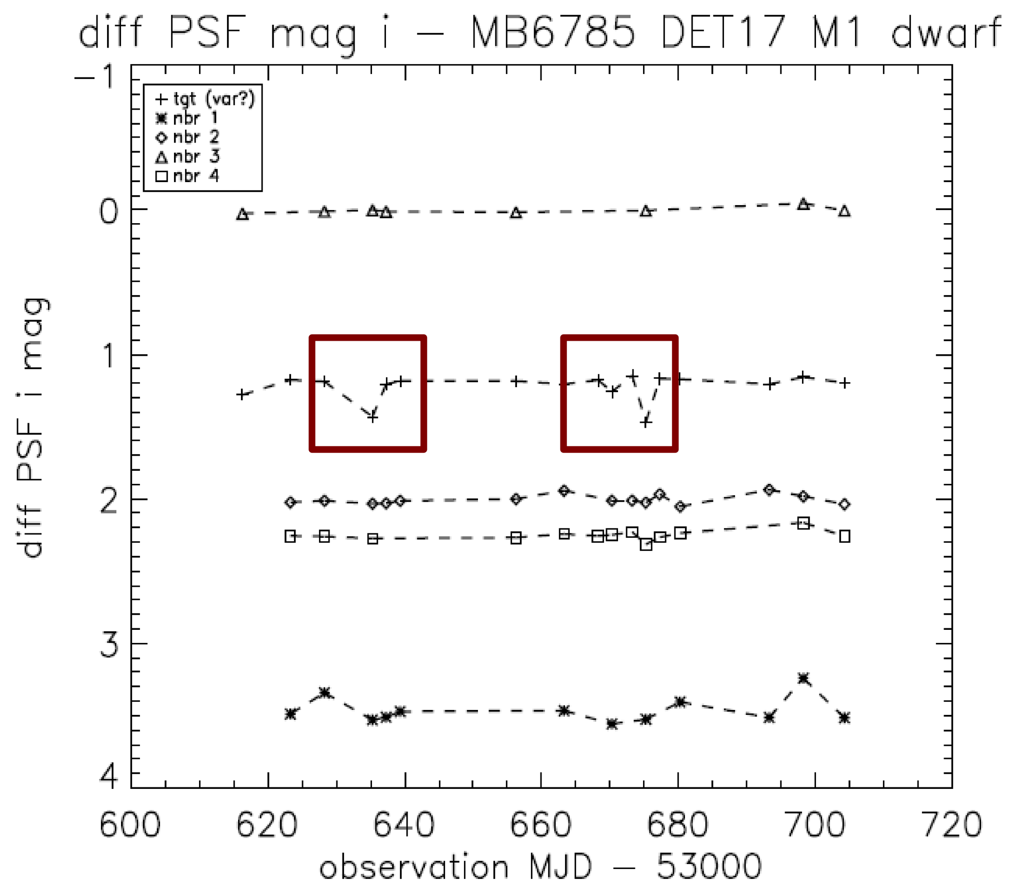

Figure 4: MB6785 ensemble light-curves *r* (above), *i* (top-right), *z* (bottom-right)

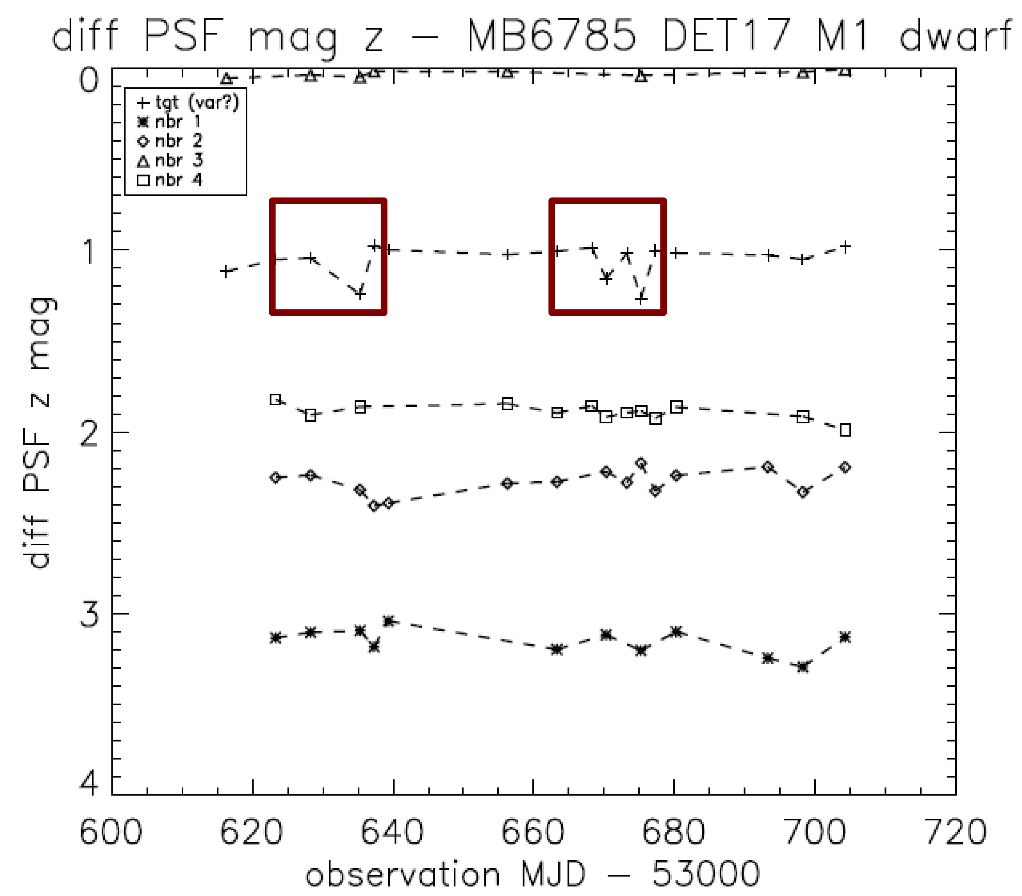
## 2. The SDSS-II Supernova Survey

- The SDSS-II SN Survey (Frieman, et al. 2008) is a multiple-epoch photometric survey using the APO 2.5-m telescope, searching for SNe in the Equatorial Stripe (Stripe 82 – RA between 22 h and 4 h, DEC between -1.27 deg and + 1.27 deg)
- 3 seasons of observing (2005-2007), about 60 nights per season, typically 2 nights between observations
- Survey carried out in widely varying photometric conditions, less strict than main SDSS, trading photometric uniformity for more temporal coverage
- We use photometric catalogs generated by the Survey for the 2005 observing season
- Need to clean up catalogs, separate stars and galaxies, apply quality and magnitude cuts
- About 900,000 stars observed at least 10 times over 60 nights, 520,000 of these are color-selected M dwarfs

## 3. Data Reduction Pipeline

- Catalogs from the SN Survey organized by night (*run*) and fields (13' x 10'); contain lists of objects detected, their type, position and photometric information, and associated quality flags
- Remove objects tagged as bad quality (saturated, incorrect photometric solutions, etc.), remove fields classified as incomplete or bad
- Get objects classified as stars from the catalog, apply a magnitude limit of SDSS $z = 21.0$
- Match stars across all 60 nights of the season, consolidate photo info for these multiply-observed objects into *match bundles*
- Select M dwarfs by using cuts on SDSS *r-i* and *i-z* colors following West, et al. 2005
- Characterize variability by using SDSS light-curves, and differential magnitude light-curves produced by ensemble photometry
- Finally, end up with catalog of possible variable objects, then check for periodicity

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