Periodic Variability of Spotted M dwarfs In WTS

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Overview

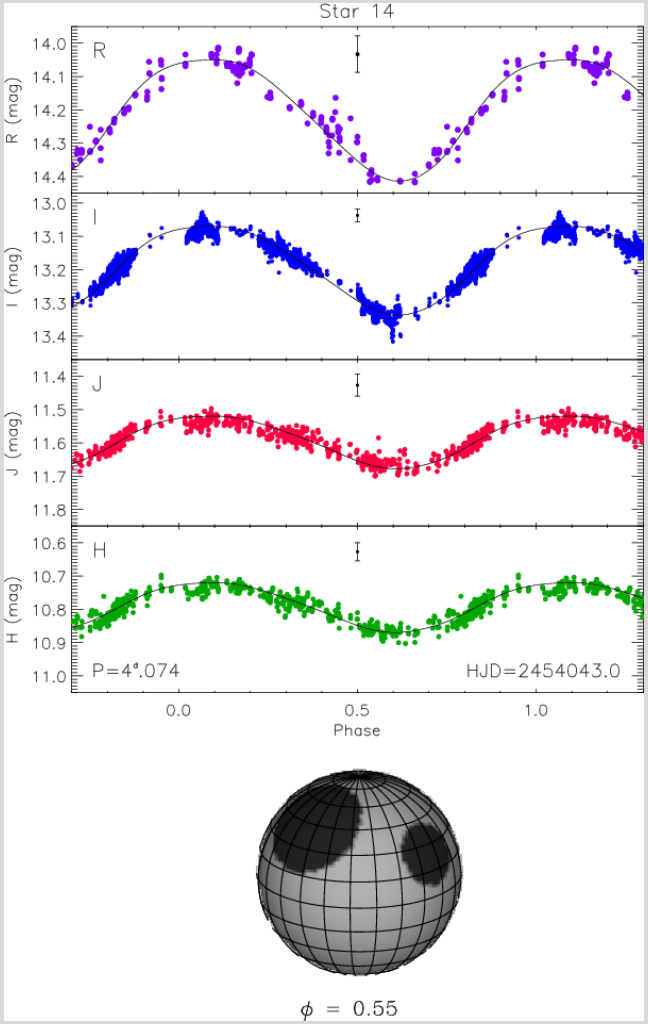
- Motivation
- Background
- Sample selection
- Sensitivity study
- Results
- Ongoing & future work

Motivation

- Characterisation of the M dwarf variability key to binary and planet parameterisation.
- Unique dataset for M dwarf variability study.
- Large sample of M dwarfs & long baseline of observations.

- Spots caused by flux tube emergence and coalescence in photosphere.
- In partially radiative stars, dynamo (α-Ω)driven by tachocline.
- Little differential rotation in M dwarfs (Barnes+ 2005)– alternative dynamo?
- Later than ~M3.5V are fully convective.
- Different dynamo mechanism (α^2).
- Both are primarily dependant on rotation with later types being more active (Reiners+ 2012).

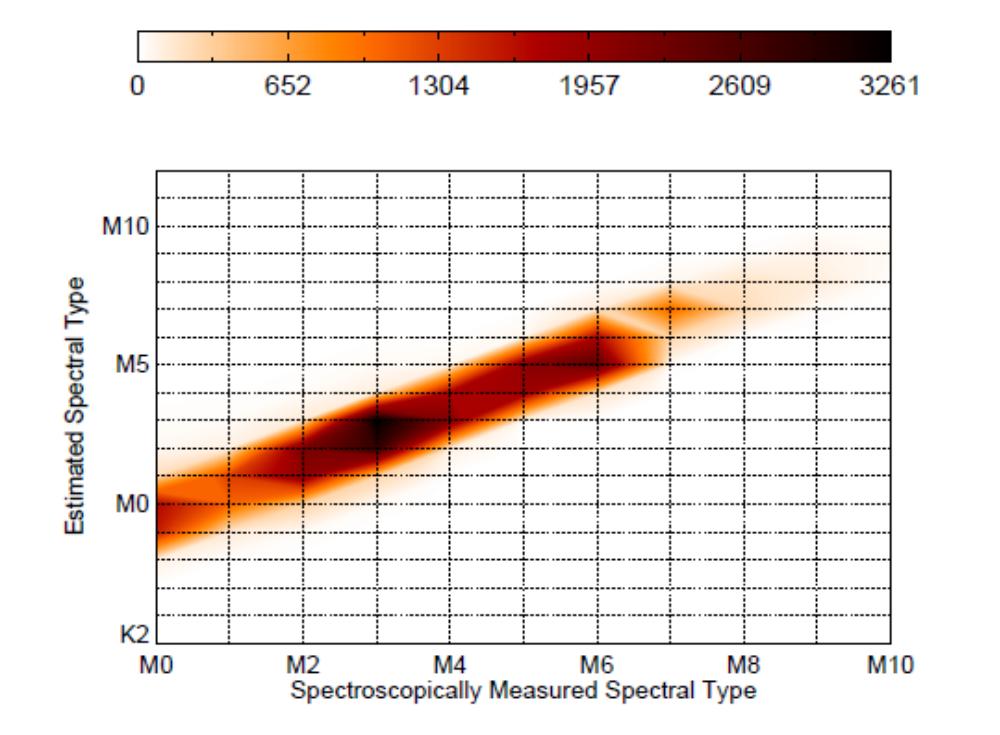
- Spot modulation traces rotation period.
- Angular momentum evolution in open clusters (e.g. Messina+ 2010) and in field stars (e.g. Irwin+ 2011).
- Starspot parameterisation (e.g. Frasca+ 2009, NIR).



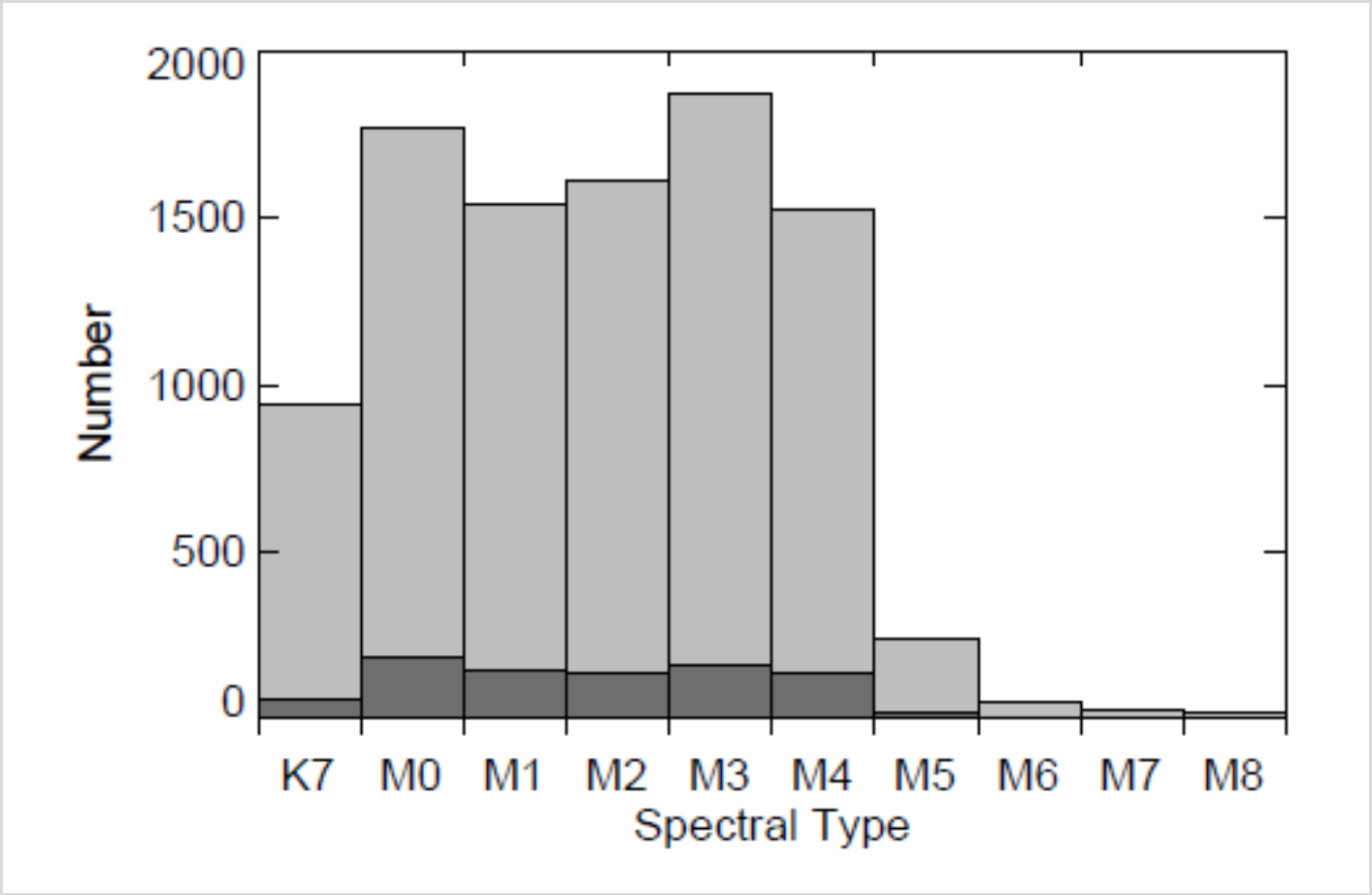
Selection

- Colour cuts (Plavchan+ 2008) to select M dwarfs.

- Type selection from colour-spectral type relations (Covey+ 2007, West+ 2011).



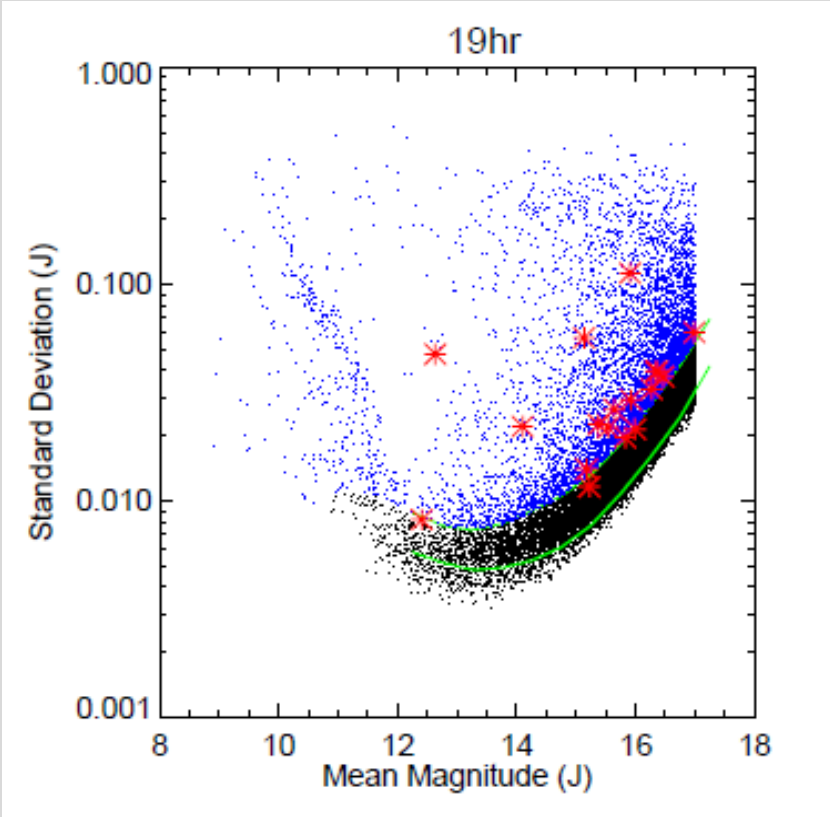
- Method finds 9600 M dwarfs (J<17)
- Earlier than M6



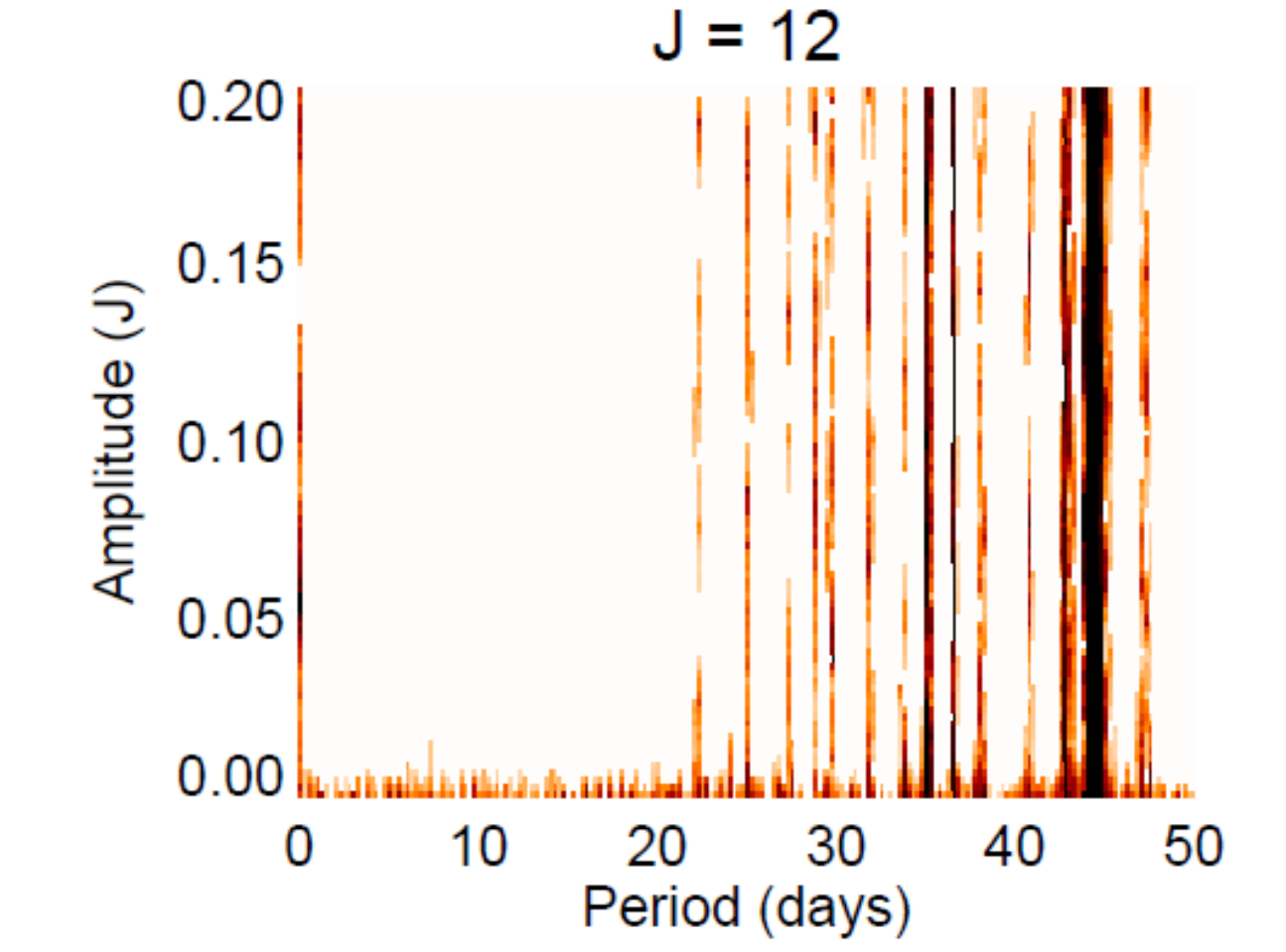
- Variability selection using Lomb-Scargle periodogram.
- 12000 Late time from colours 9600 → M dwarfs → ~3000 with apparent variability detected.
- Eliminate aliases, saturation, noise.
- Eliminate other variables, e.g. EBs, Miras.
- 3000 candidates → 68 variable M dwarfs

Sensitivity

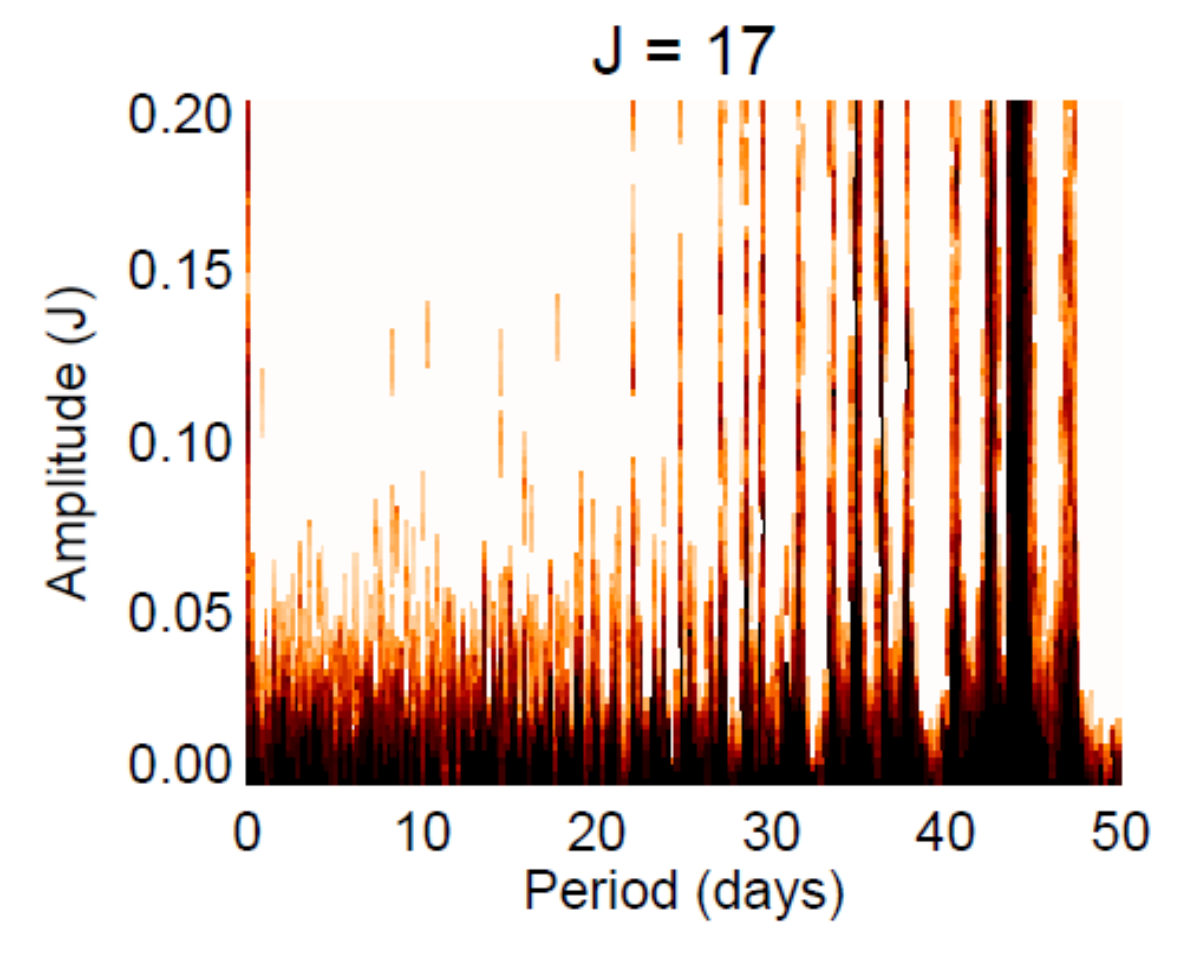
- Sample is noise limited in most complete bin ~8mmag
- Much less complete in more popular mag bins



- MC simulations to find recovering rate for sinusoids with amplitude and period



- Amplitude sensitivity ∝ noise
- Period sensitivity ∝ observations

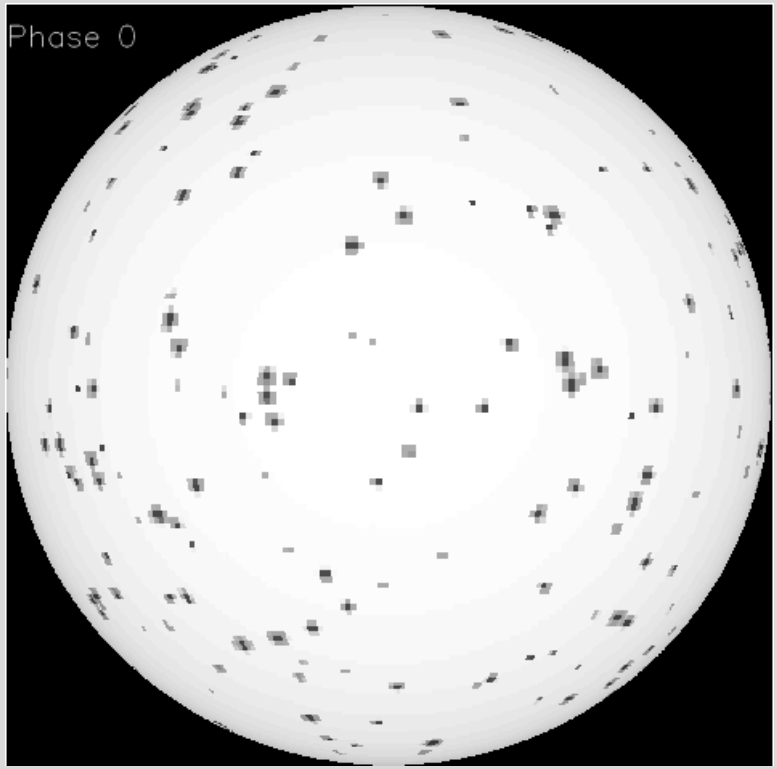


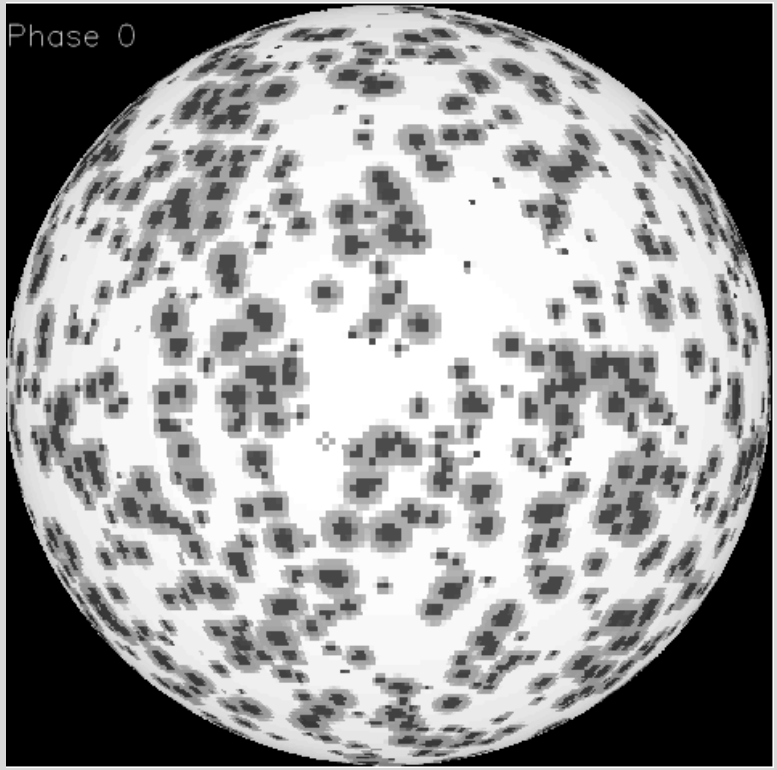
- 68 variables from 9600 stars = 0.7%
- Even in most complete magnitude bins = 2%
- Literature variability fractions...

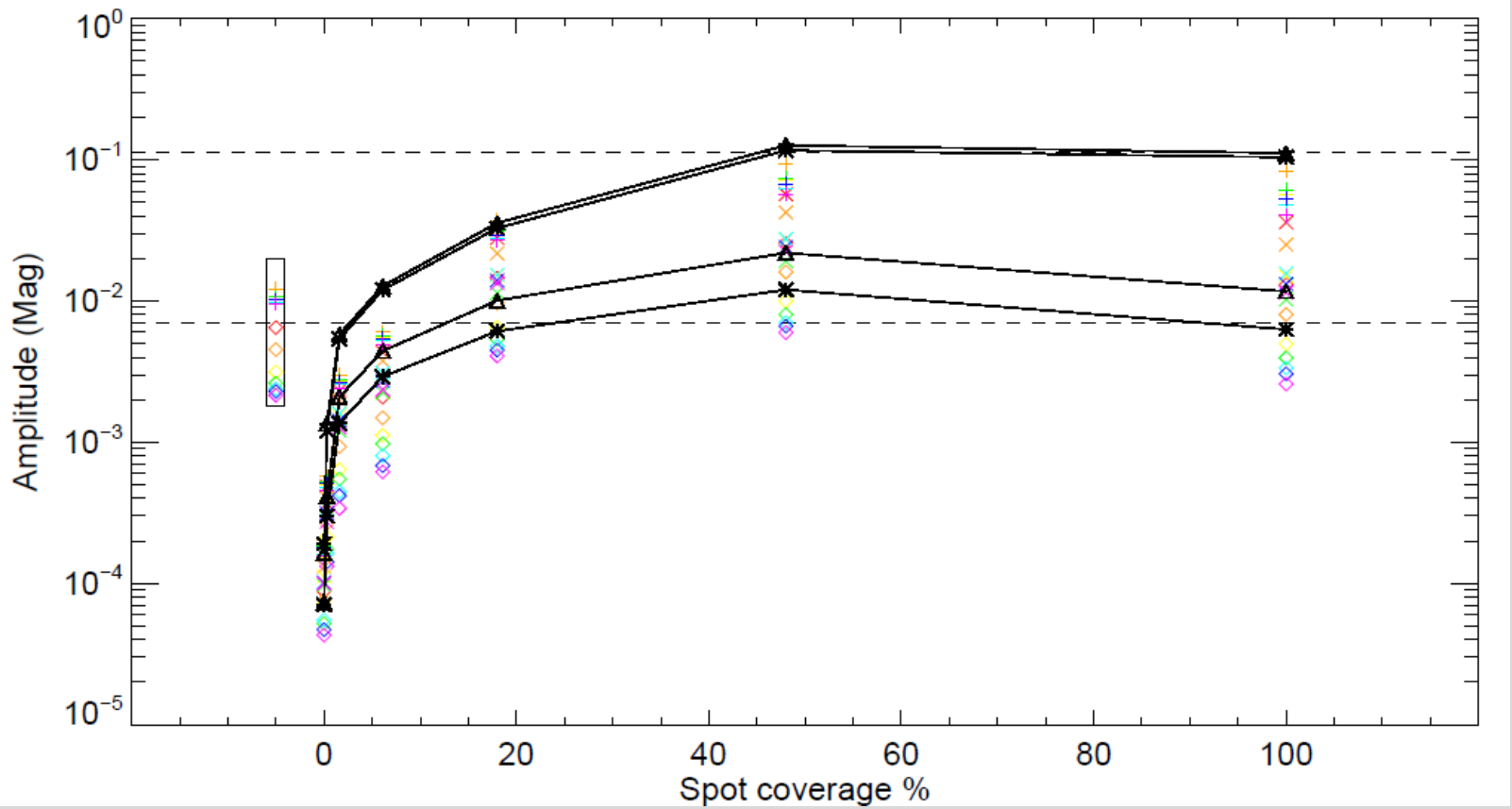
  - 36.7% (nonperiodic) in Kepler (I~B) (Ciardi+ 2011)
  - 21% in I/R/G (Rockenfeller+ 2006)
  - 5.7% in HATnet (I_c/R_c) (Hartman+ 2011)

- Why so few in WTS?

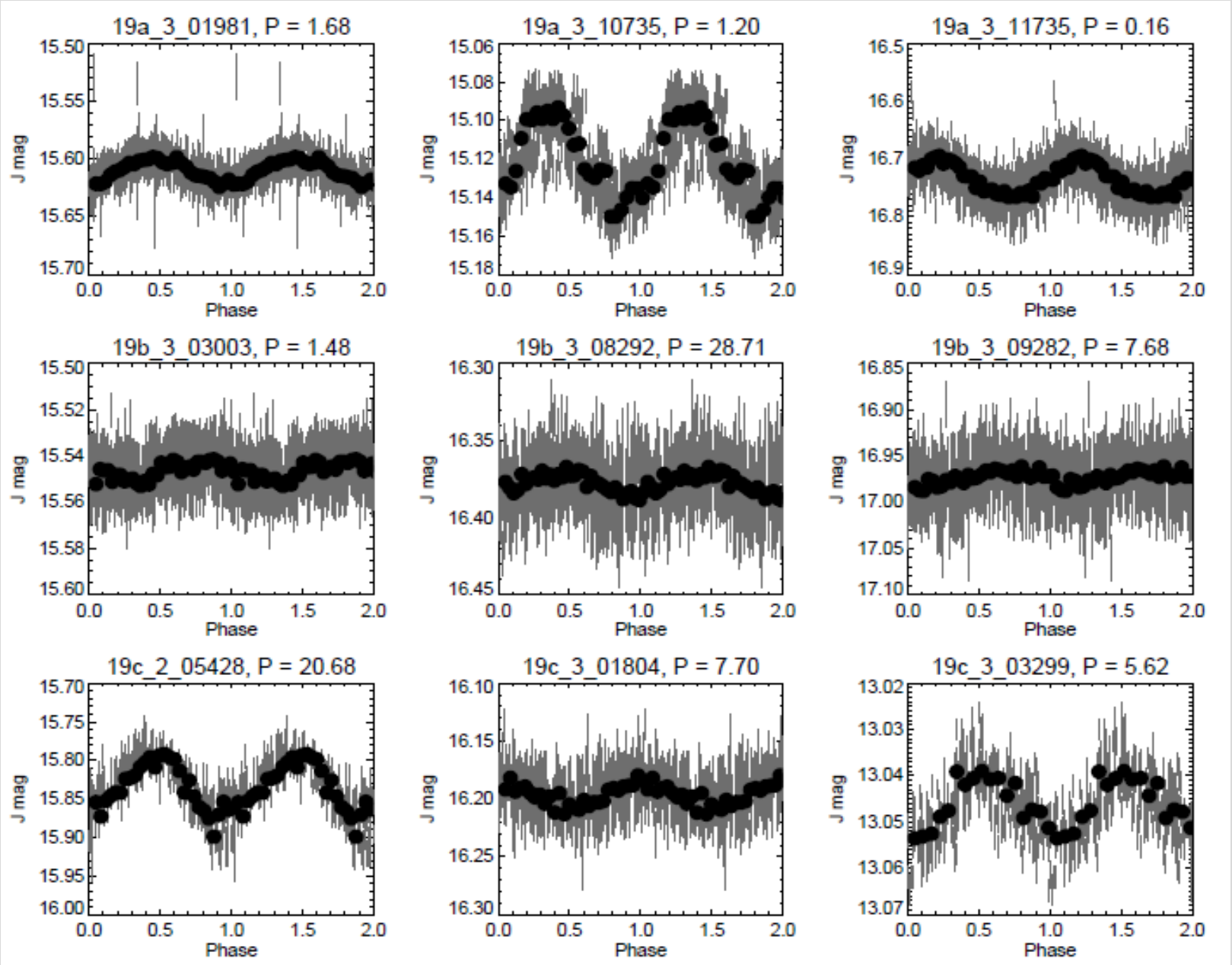
- Simulate spotted M dwarfs and observe at V, I an J bands using Doppler Tomography of Stars (DoTS) code
- Varying spot coverage



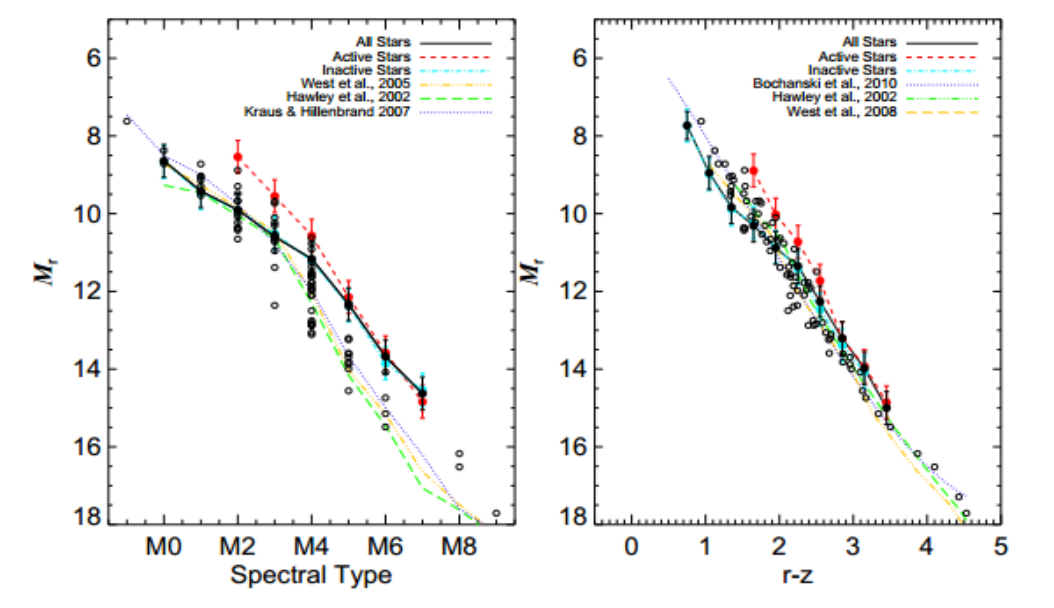




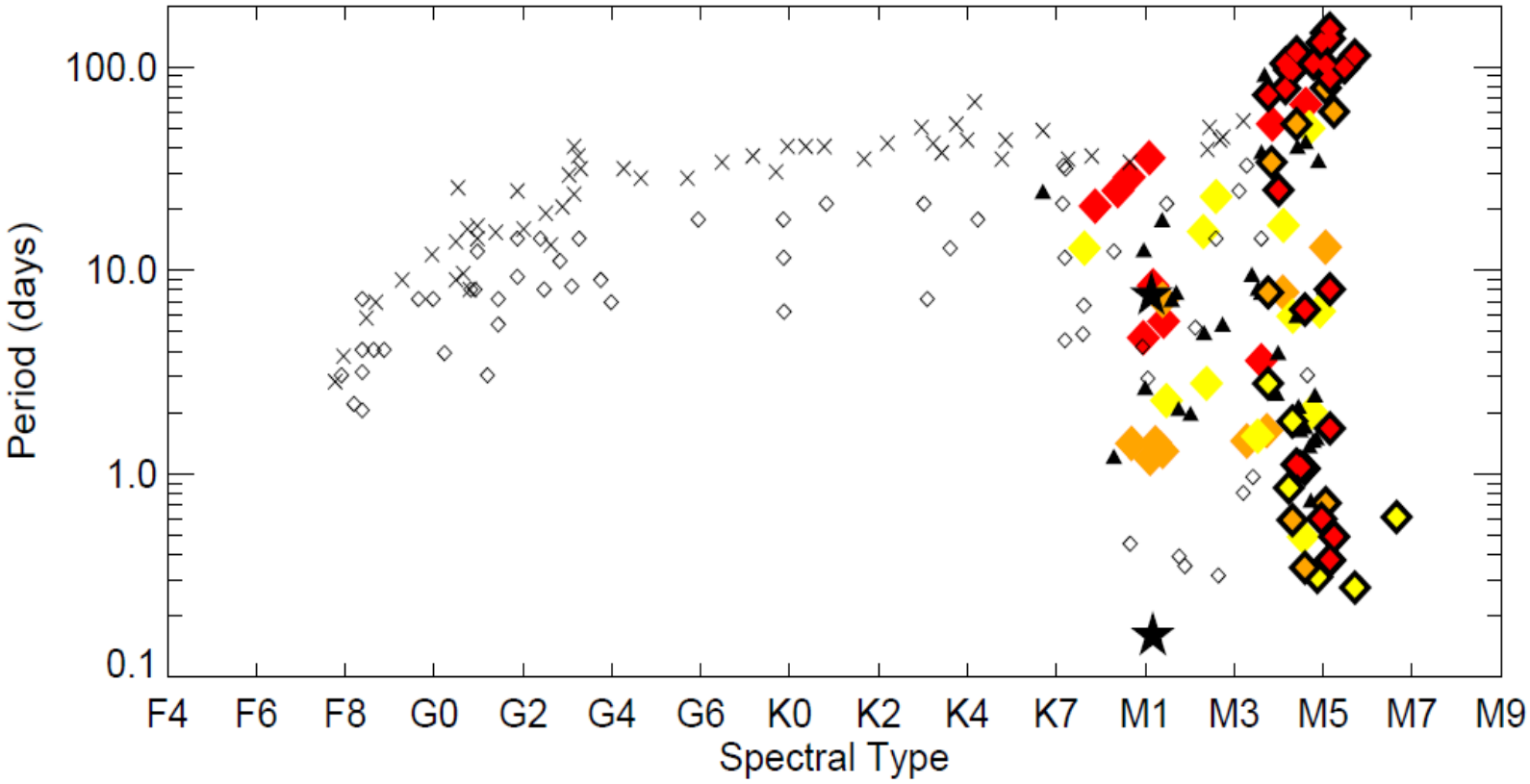
- Amp (J) = 0.44 Amp (V)
- Amp (J) = 0.55 Amp (I)
- Coverage ≳10% detected



- Photometric parallaxes (Bochanski+ 2011) and SDSSμ → v_{tan} to estimate populations (e.g. Reiners & Basri 2008)



- <15 km/s – Thin
  >30 km/s – Thick



◇ Irwin+ 2011 MEarth variables

◇ Literature thin disk variables

× Literature thick disk variables

◆ Thin disc

◆ Mid

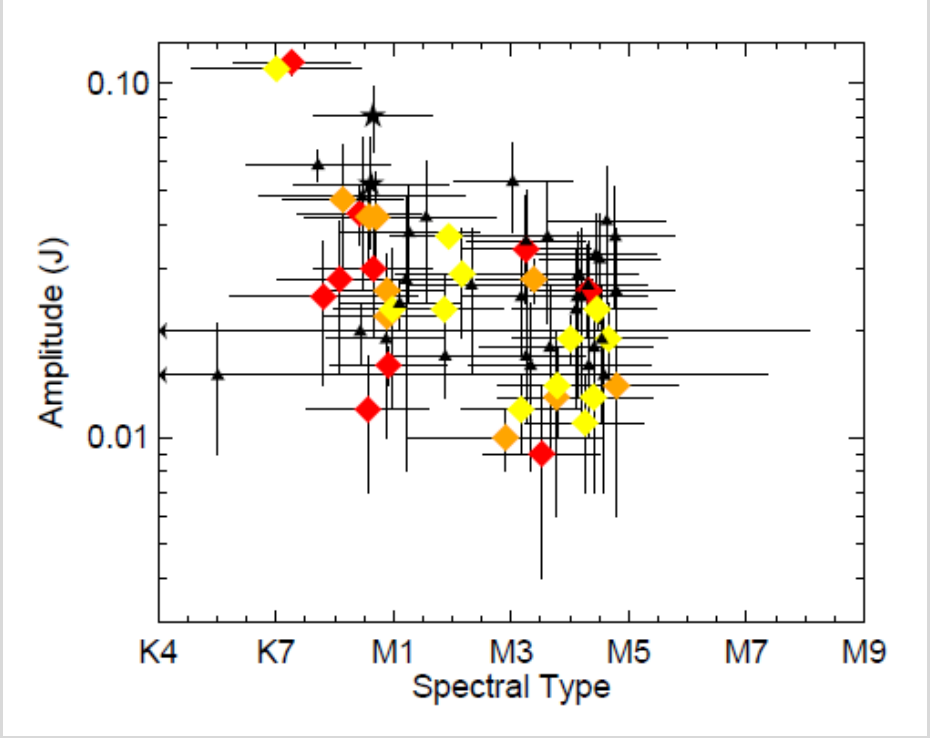
◆ Thick disc

★ Halo

Results

ST vs Amp

- R_S=-0.35
- Weak negative correlation



◆ Thin disc
◆ Mid
◆ Thick disc
★ Halo

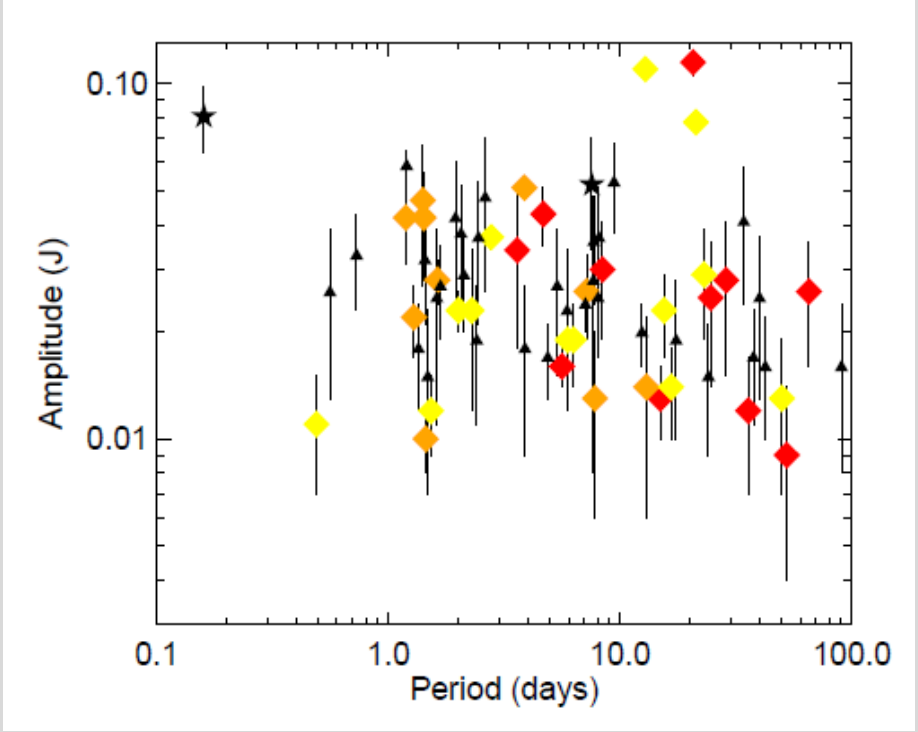
Results

ST vs Amp

- R_S=-0.35
- Weak negative correlation

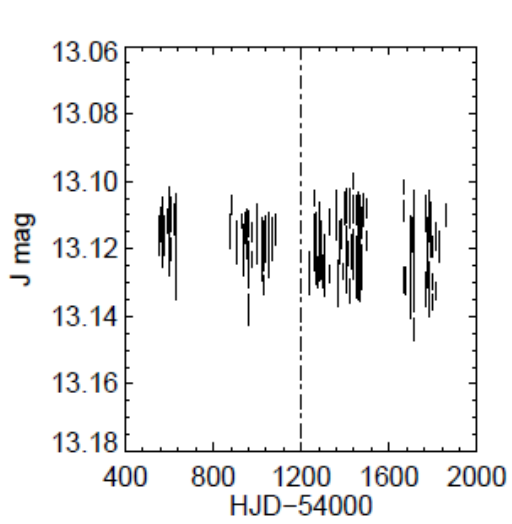
Period vs Amp

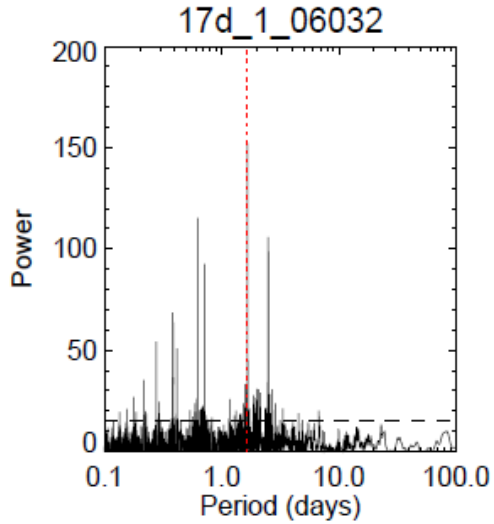
- R_S=-0.24
- Weak negative correlation

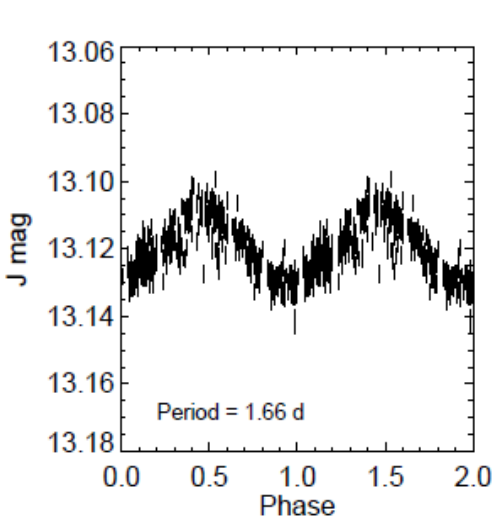


Thin disc
Mid
Thick disc
★ Halo

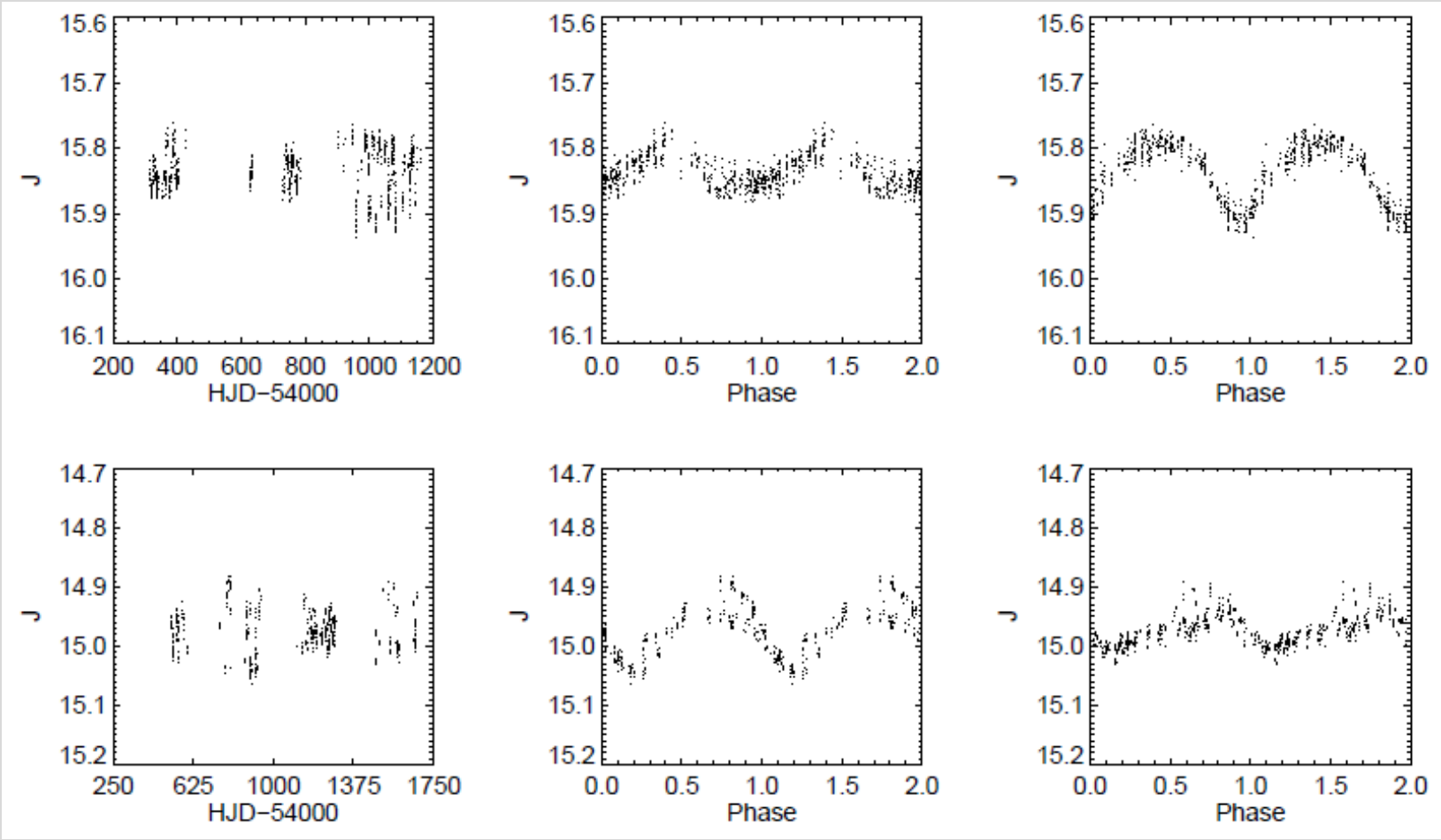
Star 17d_1_06032 shows activities that "switches on" midway through observations



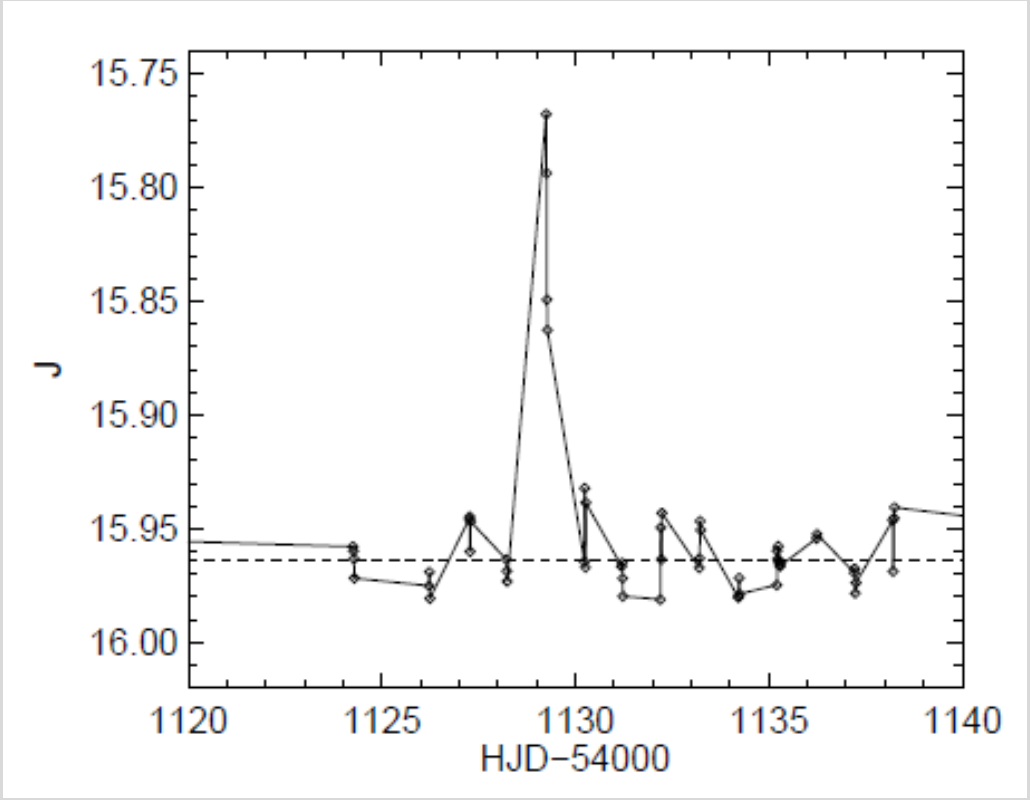




19c_2_05428, p=20.6d → morphology change
07_e_2 02466, p=12.86d → amplitude change



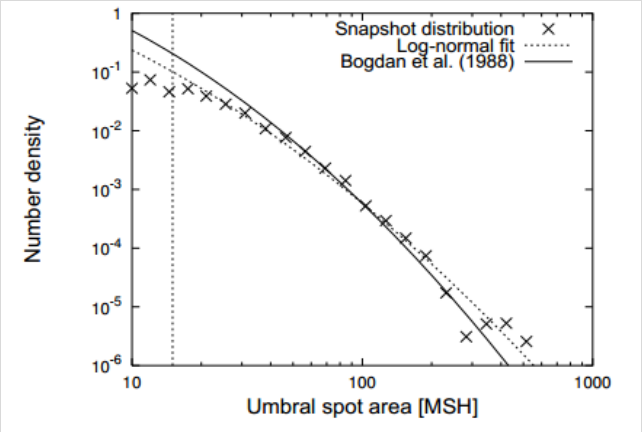
- Flare on 19d_1_12693
- 49 minutes
- Once a year (Tofflemire+ 2012)
- $\Delta J \geq 0.2$
- $\Delta u \gtrsim 6$



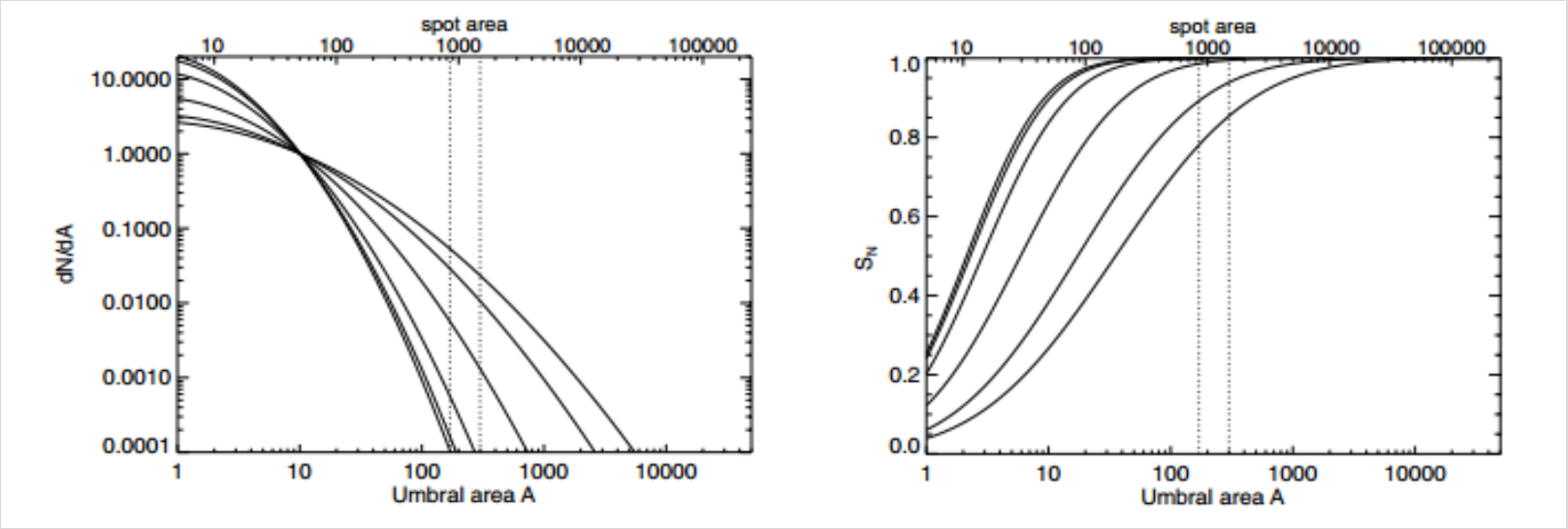
Ongoing & future work

- More comprehensive simulations of spotted M dwarfs
- Varying spot coverage to further understand results from WTS
- Understand stability of spot patterns and light curves for transit surveys
- Simulate transits using DoTS

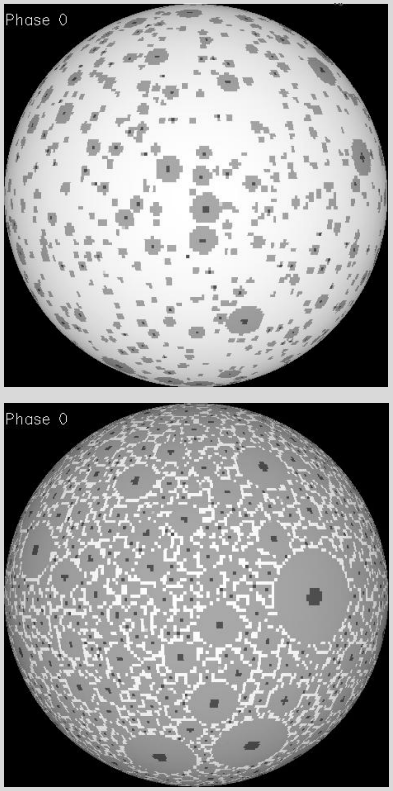
- Spot models created from extensions of solar spot distribution (Solanki 1999, Solanki & Unruh 2004, Baumann & Solanki 2005)

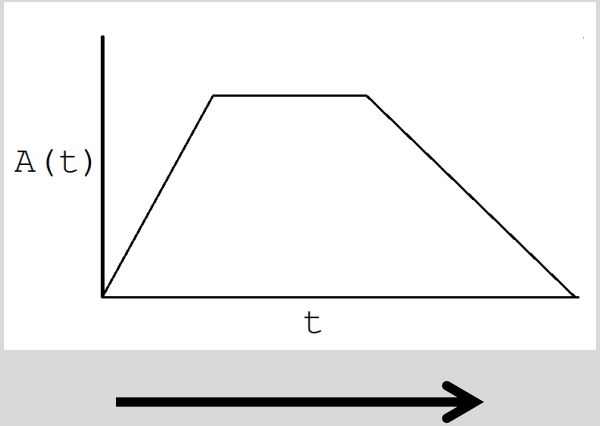


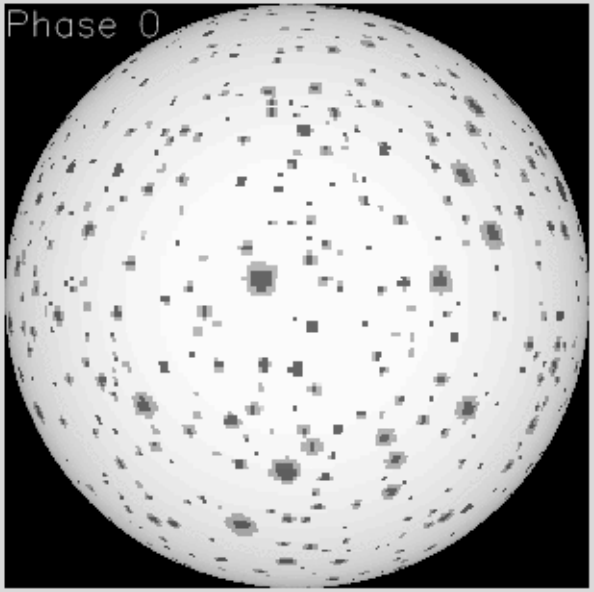
$$\ln\left(\frac{\mathrm{d}N}{\mathrm{d}A}\right) = -\frac{(\ln A - \ln\langle A\rangle)^2}{2\ln\sigma_A} + \ln\left(\frac{\mathrm{d}N}{\mathrm{d}A}\right)_{\max}$$



- Produce spot maps for varying spot coverages



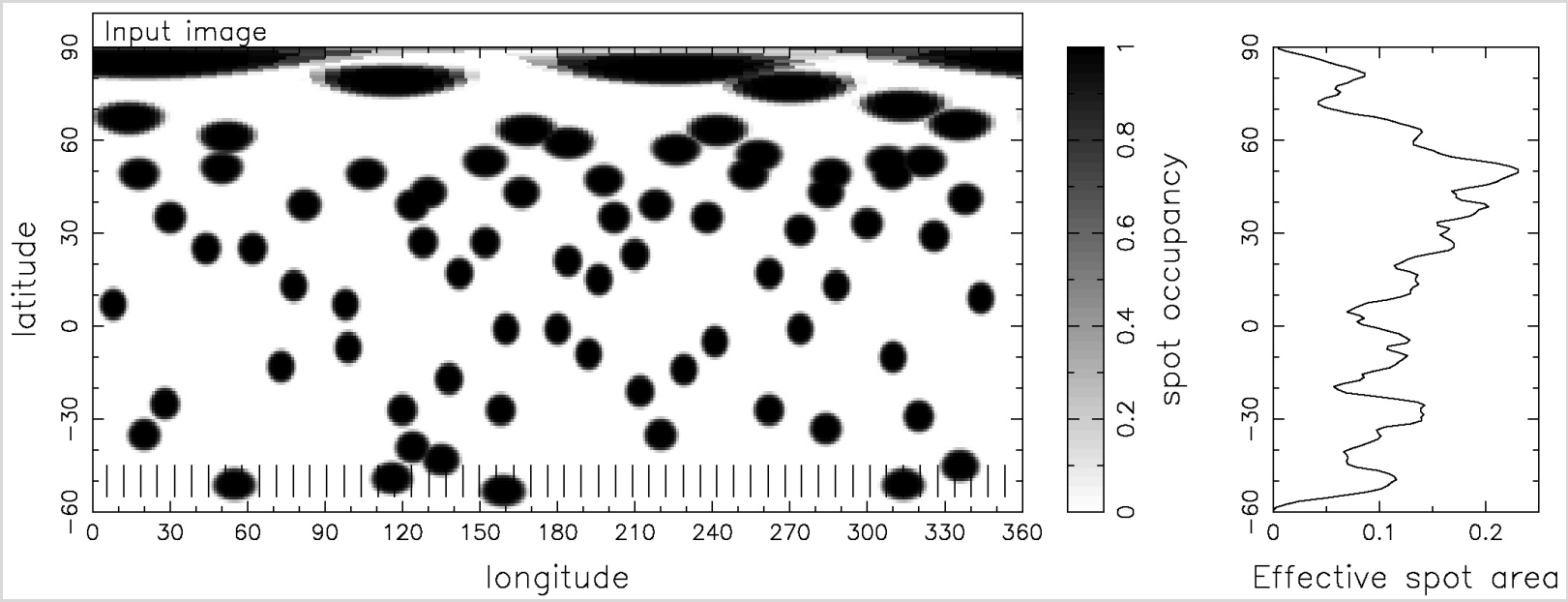


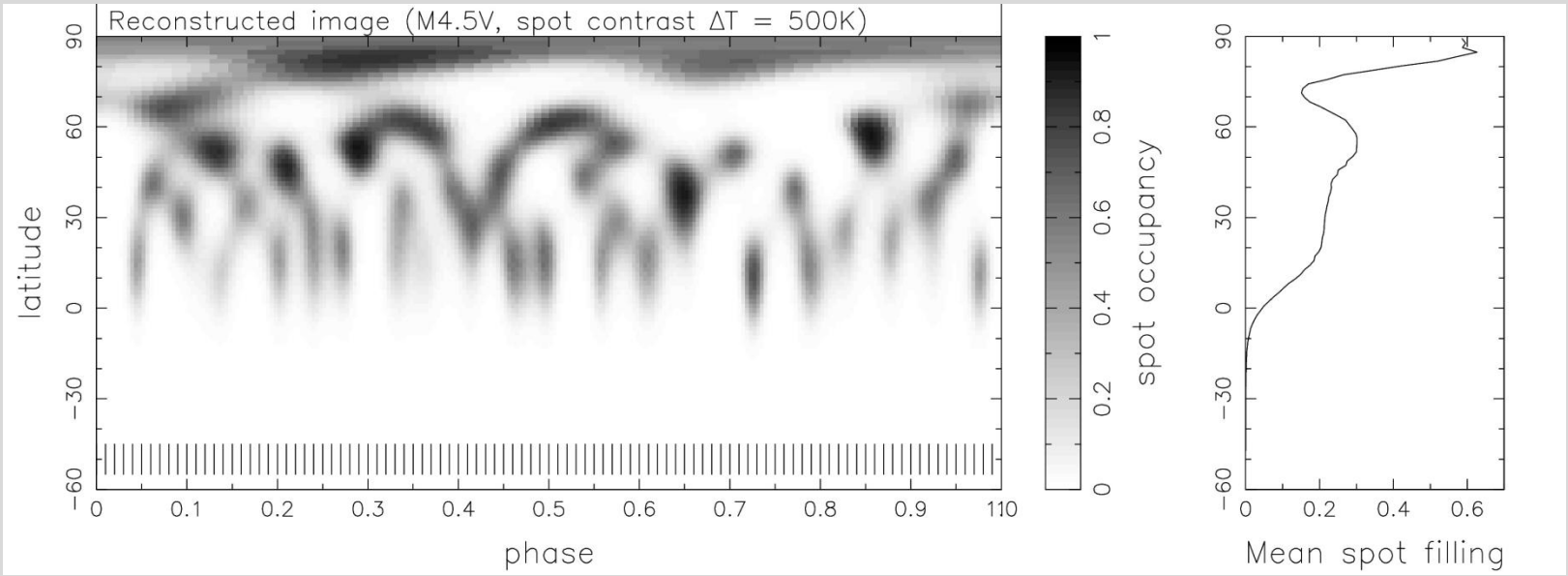


- Expand to MC simulation to explore fraction of stars with stable light curves.
- Expand to include spots with varying latitudes, polar spots, activity cycles.
- Introduce planet and measure detection rates (BLS) and parameter retrieval.

Other future work

- Looking at relation between Hα emission and spottedness from Doppler imaging
- Proposal submitted to use Hectochelle on MMT to follow up objects in Paper I.
- Proposal submitted to use UVES on VLT to Doppler image M4.5V and M9V – no spot maps currently exist for late M types.





Conclusions

- Limit placed on fraction of heavily (stably) spotted M dwarfs
- Stars generally behave as expected for their populations
- Changes in variability found on month-year time scales
- Very bright flare detected
- Future work to expand understanding of spot coverage and variability