Ultra-cold dwarfs & transiting exoplanets

- Ultra-cold dwarf stars (UCDs) (M6-M9) are the smallest, dimmest, coolest and most abundant stars in our galaxy
  \[ M = 0.07 - 0.10 \, M_\odot, \quad R = 0.09 - 0.15 \, R_\odot \]
  \[ T_{\text{eff}} = 2,000 - 2,600 \, \text{K}, \quad \text{log} g = 5.0 - 5.5 \]
- High probability of detecting small planets
- Studying the host star sets the physical constraints for exoplanets and for the potential to spark life
- The SPECULOOS project will search for transiting exoplanets
- This is a survey targeting the nearest UCDs with four 1-m robotic telescopes at Paranal, Chile
- This concept has been tested with the Trappist-South and North telescopes

Trappist-1 system

- Seven earth-sized planets orbiting a M8 dwarf at 12 pc
- Kepler-2 mission data-analysis from the K2 campaign 12
  - 7-planet resonant chain
  - Trappist-1 h period confirmed: 18.77 days
  - No additional planets detected
  - 3-body orbital-resonance

Kepler-2 data. Long cadence (temp = 30 min) 

Stellar models for UCDs and the Trappist-1 star

- CLES Code Liégeois d’Évolution Stellaire: Sufiaine et al. 2008
- Stellar evolution code developed at the University of Liege

Updated CLES

- Recently adapted to account for low-mass stars
  - Include meaningful equation of state \([1, 2]\)
  - Adapt public atmosphere model grid: BT-Settl \([3]\)
  - Able to choose different metallicities, other than solar
  - Compared with low-mass stellar evolution code (BHAC15) \([4]\) with the same input physics (differences less than 1%)
  - Testing with M7 binary: [5]: M (dynamical) \(= 0.088 \pm 0.001 \, M_\odot \)
    - M (CLES & [6]) \(= 0.078 \pm 0.05 \, M_\odot \) (with [Fe/H] = 0.0)
    - M (BHAC15) \(= 0.045 \pm 0.012 \, M_\odot \)

Stellar luminosity and density for CLES and BHAC15 evolution models for 0.08 \(M_\odot\) and 0.09 \(M_\odot\) with various metallicities, compared to luminosity and density measured for Trappist-1. If Trappist-1 star was ‘young’: \(M_\star = 0.08 \, M_\odot\) would agree with observations

Testing new age

- Trappist-1 is not a young-star
- Indications of a middle-aged star has recently been constrained in \([7]\) to 7.6 ± 2.2 Gyr
- New-mass from stellar models
  - \(M_\star = 0.09 \, M_\odot\), with CLES and also confirmed by BHAC15 for measured luminosity
  - Need to increase the metallicity to further account for the stellar density derived from transits

Conclusion and what is next

- UCDs are excellent targets for searching transiting earth-sized planets
- Trappist-1 system was discovered while surveying UCDs
- CLES stellar evolution code is ready to carry-on studies with UCDs
- To account for an age > 7 Gyr for Trappist-1, the stellar models suggest a revision of the stellar mass which has an affect on planetary-star relations
- New discoveries made with the SPECULOOS project are potential targets for the Extremely Large Telescopes and the JWST/NASA with further studies on atmospheric characterisation and searching biosignatures
- Continuing work on improving stellar evolution models for low-mass stars

References


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