Spectrophotometric investigations of hot subdwarf stars in the Plato field with Gaia DR3

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Abstract

The Plato mission will provide high-precision light curves to study extrasolar planets and their host stars. However, data for all type of stars will become available. The aim is to characterize the population of hot subdwarfs in the Plato field. Hot subdwarfs are evolved stripped stars formed in binaries via mass transfer or mergers and, therefore, testbeds for binary star evolution. The third Gaia data release is used to select candidates. Combining parallaxes with multi-filter photometry allow to derive effective temperatures and radii and to place the stars in the HRD, as well as to identify composite systems with main sequence companions. This is a first step towards testing the diverse formation mechanisms of hot subdwarf stars.

Overview

Goal
To characterize hot subdwarfs in the Plato field with stellar parameters and to identify MS companions

Why
To test and refine binary evolution scenarios and place hot subdwarfs into context

Path
Gaia DR3 data selected candidates and was combined with spectrophotometric analysis of SEDs

Quantity
About 700 hot subdwarf candidates followed

Background

Hot Subdwarf Stars

- Belong to the **E**xtreme **H**orizontal **B**ranch
- Helium burning cores of red giants
- Loss of hydrogen envelope
- Binary evolution required

Radius	0.1 ~ 0.3 $R_\odot$
Mass	0.5 $M_\odot$
Temperature	20.000 ~ 100.000 K
Luminosity	10 ~ 100 $L_\odot$
Surf. gravity	4.5 ~ 6.5 cgs

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not explained by standard stellar evolution

Diverse Formation Mechanisms

e.g. White dwarf mergers → Single stars

e.g. Roche lobe overflow → Binary systems

Plato mission

PLAnetary **T**ransits and **O**scillations of stars (PLATO)

- Launch by the end of 2026
- Wide-field search of mainly rocky planets orbiting within the habitable zone
- High photometric precision
- Target list driven

→ Need information about the hot subdwarfs in the field

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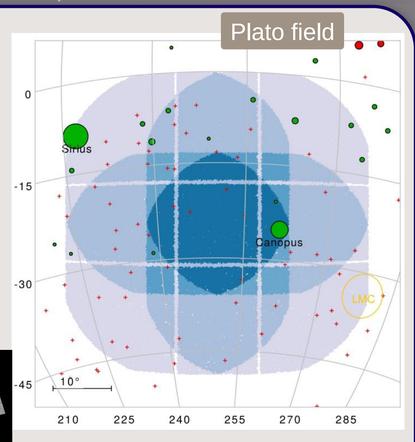


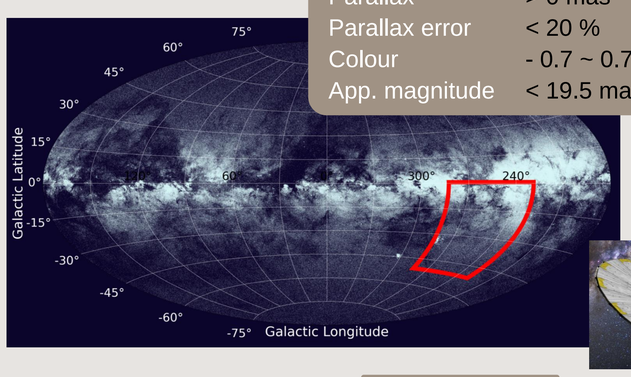
Sample

Gaia DR3 for search for stars

- Extensively mapped more than a billion stars
- Provides distance information by parallax measurement
  → Stellar populations via position in the color-magnitude diagram
  → Catalogues for different stellar objects

Constraints

Gal. Longitude	230.9° ~ 280.9°
Gal. Latitude	- 49.6° ~ - 9.6°
Parallax	> 0 mas
Parallax error	< 20 %
Colour	- 0.7 ~ 0.7 mag
App. magnitude	< 19.5 mag



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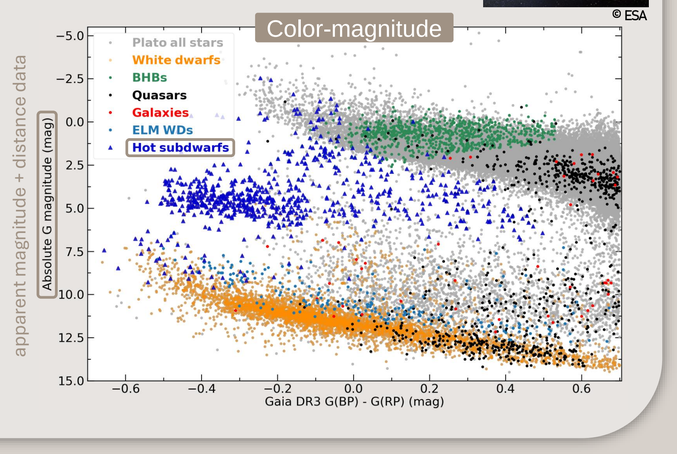
Comparison to catalogue objects

Sample

- Known hot subdwarfs (Geier, 2020 + Culpan, 2023)
- Candidate hot subdwarfs (Geier, 2019 + Culpan, 2023)

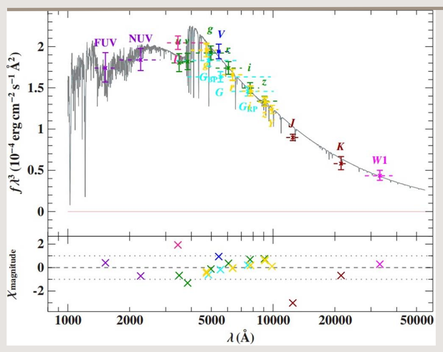
→ ~ 700 stars for SED analysis

Color-magnitude



Data Analysis

SED fits - Spectral Energy Distribution



- Photometry from various surveys
  → $T_{\rm eff}$
  → Angular diameter Θ
  → Reddening $E(\mathrm{B-V})$

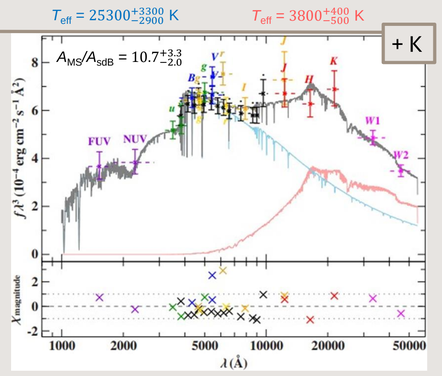
Methodology for stars in the Plato field

Need initial values for:
- $T_{\rm eff}$ → Literature or Gaia DR3
- log g → $T_{\rm eff}$ - log g relation predicted by hot subdwarf evolutionary theory

Binary SED fits

- Hot subdwarf + MS companion
- Surface ratio $A_{\rm MS}/A_{\rm sdB} \geq 3$ → Binary system

Parameters for the companion star:
- $T_{\rm eff}$ → 2.3 ~ 7 kK
- log g → (4.5 ± 0.1) cgs



Results

Binary identification

Total binary fraction: 31.3 %

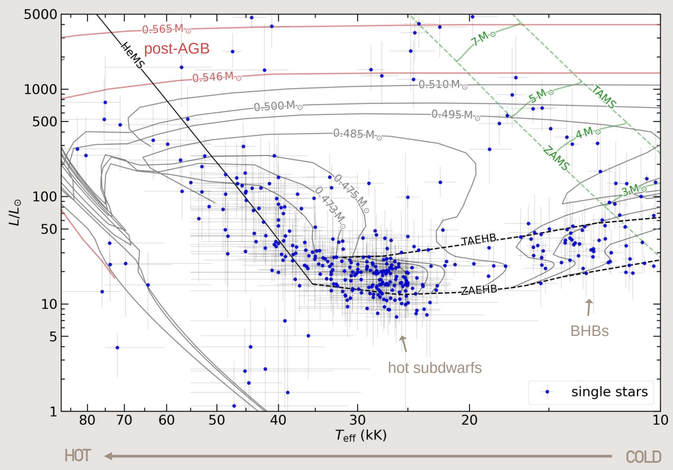
- sdB/OBs and sdOs
  → Interlinked evolutionary stages
- hot subdwarfs and BHBs
  → Different nature

Luminosity

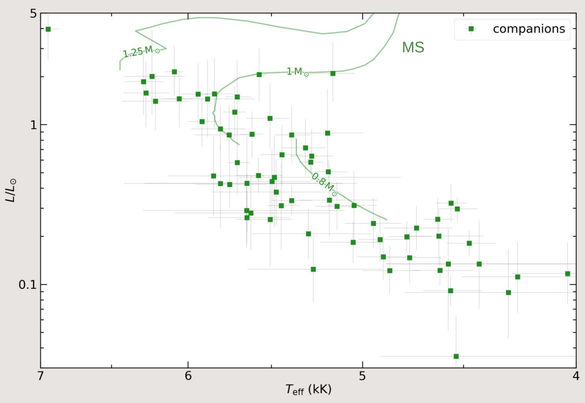
angular diameter Θ + 

parallax ϖ → $L \propto \left(\frac{\Theta}{2\varpi}\right)^2 T_{\rm eff}^{\,4}$ → Luminosity

- The primary star



- The main-sequence companion



+ Properties are in good agreement with expectations

− Description of the gap between hot subdwarfs and BHBs and characterization of companions still present a challenge

Literature

Gebhardt A. (2024). “Spectrophotometric investigations of hot subdwarfs stars in the Plato field with Gaia DR3”. Bachelor`s thesis. FAU Erlangen-Nürnberg.

Outlook

- Next step: Spectroscopy to derive the surface gravity
- Use of Newtons law to determine the stellar mass from radius and gravity

Future
- New data provided by Gaia will improve research
- New large spectroscopic surveys like 4MOST will detect much dimmer stars

Design by Anna Gebhardt