

First Brown Dwarfs in Globular Clusters

Roman **Gerasimov** (*Notre Dame*), Luigi **Bedin** (*INAF Padova*), Adam **Burgasser** (*UCSD*)

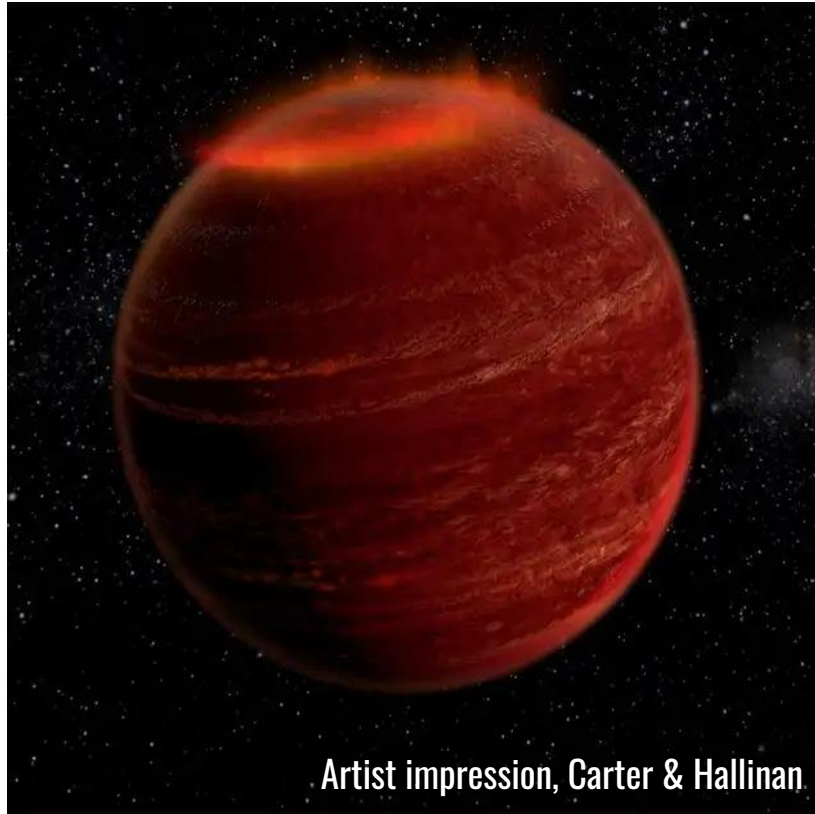
Background: NGC 6397, JWST NIRCam



Globular Clusters

Chemical composition?

Age?



Artist impression, Carter & Hallinan

Brown Dwarfs

- Mass \lesssim 8% solar
- No hydrogen fusion
- Cool down over time
- *Galactic chronometers*

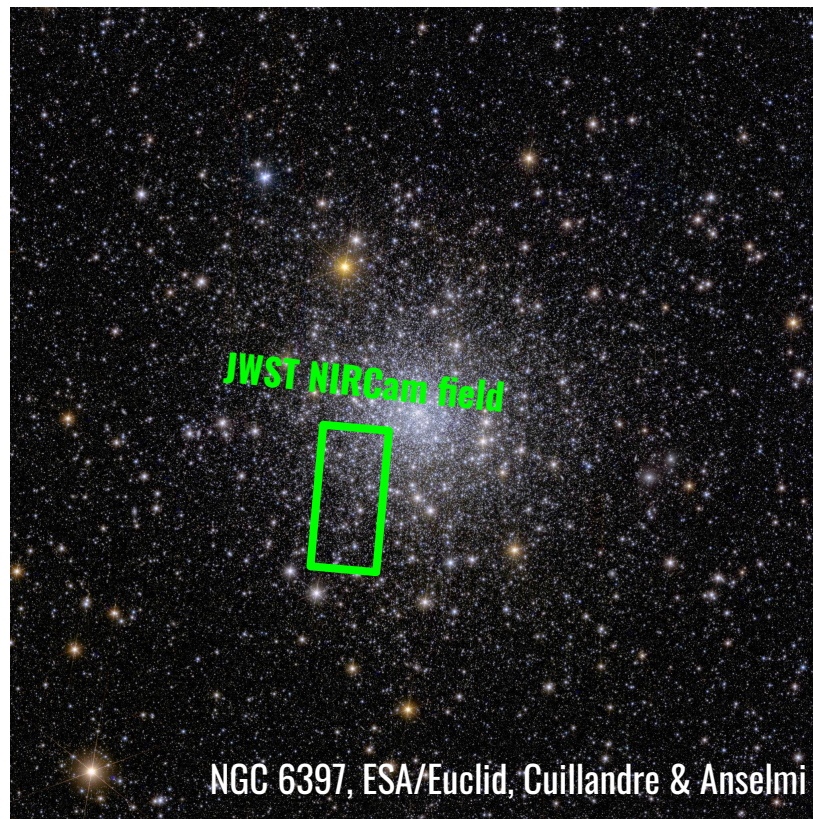
Brown Dwarfs in Globular Clusters are **cool and faint**

JWST NIRCам

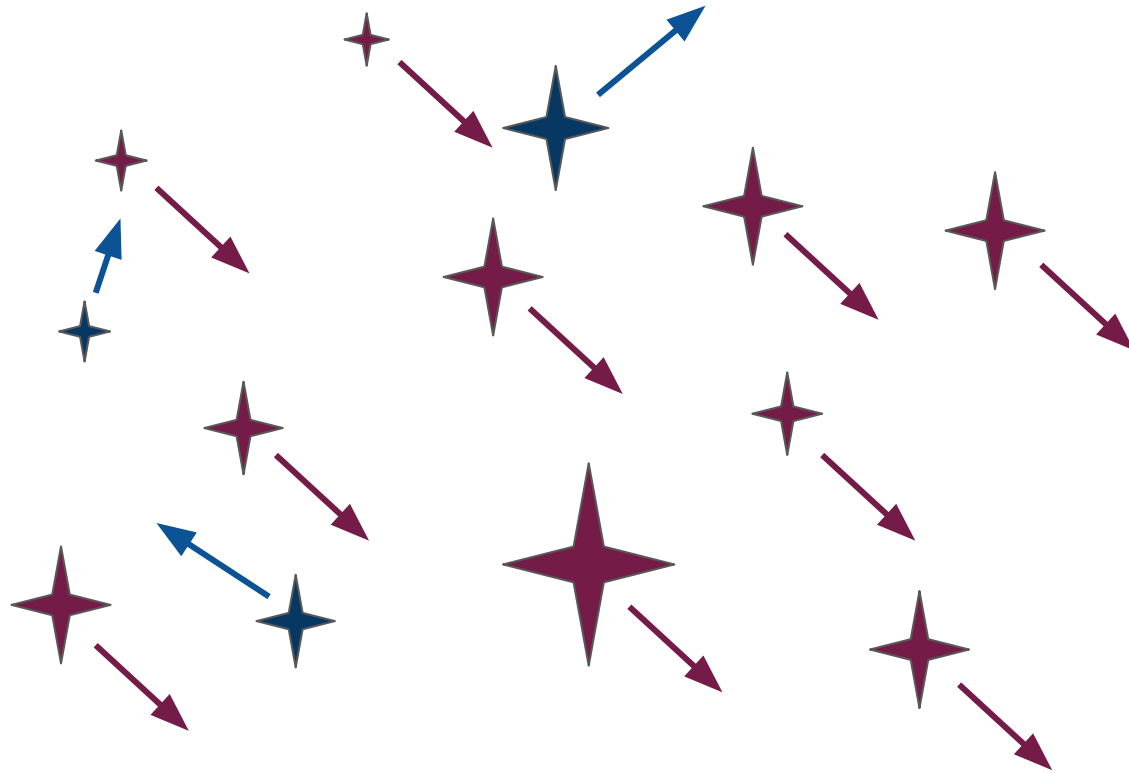
Program *GO-1979* (PI: **Bedin**)

Year: **2023**

Exposure: **2 hours**





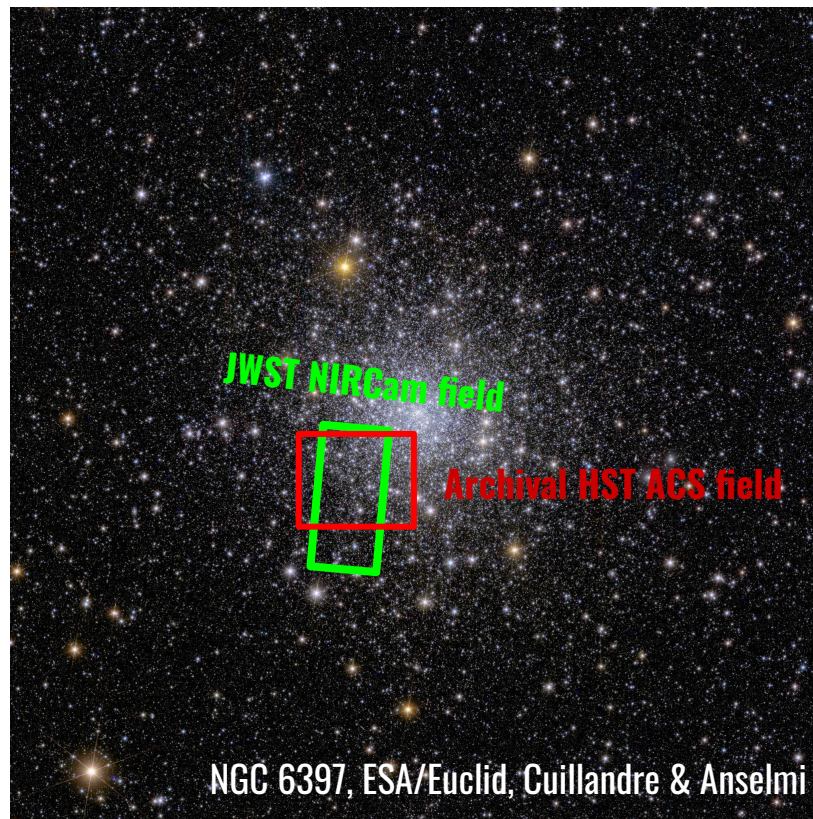


JWST NIRC*am*

Program *GO-1979* (PI: **Bedin**)

Year: **2023**

Exposure: **2 hours**



HST ACS

Program *GO-10424* (PI: **Richer**)

Year: **2005**

124 orbits

Measuring the Temperatures



Efrain Alvarado III

Probing the Early History of the Milky Way with New Models of Metal-poor Brown Dwarfs
 Efrain Alvarado III (1,3), Roman Gerasimov (2,3), Adam J. Burgasser (3), Hunter Brooks (4,3), Christian Aganze (5,3), Christopher A. Theissen (3)
 University of California, Berkeley (1); University of Notre Dame (2); University of California, San Diego (3); Northern Arizona University (4), Stanford University (5)

Abstract

Ultra-cool Dwarfs (UCDs) are stars and brown dwarfs with surface temperatures at 3000K, and masses ≤ 1 solar. The atmospheres of UCDs are dominated by molecular opacity and chemistry, rendering their spectra highly sensitive to element abundances. In combination with appropriate stellar models with non-solar chemistry, UCDs may be used as chemical tracers of stellar populations.

Metal-poor UCDs are particularly interesting, as they represent the poorly understood early phases of the chemical evolution of the Milky Way. However, few metal-poor UCD stellar models are available in the literature. We present Spectral Analog of Dwarfs (SAND) model atmospheres— and SANDee (evolutionary extension to SAND) for metal-poor UCDs. Our models were calculated using the PHENIX code, version 15, and include the Allard & Houriez treatment of clouds with gravitational settling. The atmosphere grid extends down to 700 K in effective temperature, and spans metallicity, [Fe/H], from -2.4 to 0.3 dex for multiple values of alpha-enhancement. The corresponding evolutionary models and synthetic lightcurves were calculated with the MESA code, using our model atmospheres as atmosphere-interior boundary conditions.

These new models will support studies of metal-poor UCDs discovered by deep surveys with the James Webb Space Telescope, the Nancy Grace Roman Space Telescope, and the Vera Rubin Observatory, as well as new photometric surveys of UCDs in globular clusters.

Models Atmospheres(SAND)

The Spectral Analog of Dwarfs (SAND) grid spans 700 K to Teff = 4000 K (100 K steps), $4.1 \log(g)$ s/c (in cm $\pm 2, 0.5$ steps), and $-2.4 \leq [Fe/H] \leq +0.3$ (solar scaled, variable step size). Abundance variations are parameterized through alpha enhancement, $[\alpha/Fe]$, with values chosen to sample the $[Fe/H]$, $[\alpha/Fe]$ distribution of Milky Way stars inferred from APOGEE spectra. We used PHENIX code version 15 to compute the model atmospheres.

SAND spectral sequence with Teff = 1900 K, $\log(g) = 5.0$, and varying metallicity and alpha enhancement.

To showcase these models, we include a figure (above) of varying metallicity and alpha enhancement and other varying Teff (below). In both figures, key molecular absorption bands (H₂O, CH₄, TiO), atomic lines of K, and the approximate wavelength range of collision-induced absorption by H₂ are highlighted. The spectra were downsampled to R = 1000 for clarity.

Evolutionary Models (SANDee)

The SAND grid was used as boundary conditions for stellar structures to develop the SANDee (evolutionary extension to SAND) grid. The SANDee grid was calculated using MESA (Modules for Experiments in Stellar Astrophysics) code, version 23.05.1.

Cooling curves for stellar and substellar objects with $[Fe/H] = 1.72$ and $[\alpha/Fe] = 0.3$. The hydrogen-burning limit (HBL) — indicated by black contours — divides the stellar objects (red contours) from the substellar objects (blue contours).

Figure 2 from Gerasimov 2024.

We calculated 24 different evolutionary models from the 24 different chemistries from the SAND grid. Each star started from the pre-main sequence phase until 13.5 Gyr. The lowest mass star was chosen from 0.05 M_☉ in the highest mass that would not exceed Teff = 4000 K, in 1 Gyr.

Implications

SAND models led to precise measurement of the effective temperature and metallicity of a metal-poor, spectrally L-subdwarf, J1249-3621 (Burgasser 2024, Submitted). It is biased toward the alpha-enhancement that this object came from an unknown globular cluster.

The spectrum of J1249-3621 was smoothed to a resolution of $\Delta\lambda/\lambda \approx 150$. The regression line is the best-fit model of the SAND grid. Figure 1 from Burgasser 2024 (Submitted).

SANDee models helped lead to the discovery of three brown dwarfs located in NGC 6397 using JWST data. This discovery made the first age estimate of a globular cluster from its substellar cooling sequence.

[ABSTRACT](#) [COMMENT](#) [REFERENCES](#) [CONTACT AUTHOR](#) [GET POSTER](#)



Temperature

1756 ± 111 K

1629 ± 102 K

1388 ± 123 K

Radius

77% Jupiter

75% Jupiter

72% Jupiter

Brown Dwarfs in Globular Clusters

- **BD 1756**, **BD 1682** and **BD 1388** are brown dwarf members of **NGC 6397**
- First confirmed brown dwarfs in a globular cluster
- Oldest known brown dwarfs with reliable ages: **~13.5 Gyr**
- *Hundreds more can be discovered with a second JWST visit*