

# HST/WFC3 spectroscopy of T dwarf candidates in young clusters

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## Abstract

We present HST/WFC3 spectra of the T dwarfs S Ori 70 and S Ori 73 located towards the Sigma Orionis cluster, and the peculiar object PLZJ 100 in the Pleiades. Both S Ori 70 and S Ori 73 are confirmed as T dwarfs, with spectral types similar to estimates previously reported in the literature. However, the spectra appear to be typical for T dwarfs, which reinforces the view derived from published proper motions that these are foreground objects, as opposed to cluster members (or ejected objects) with very low surface gravities and masses. The Pleiades object PLZJ 100 is marginally spatially resolved ( $\sim 0.2$  arcsec) indicating that it is an external galaxy. The extended nature of the source is probably responsible for the Pleiades-like proper motion that was previously reported at low signal to noise. This is a relatively new form of contamination that is likely to become more common as imaging surveys probe ever deeper for faint brown dwarfs and planets.

## Background

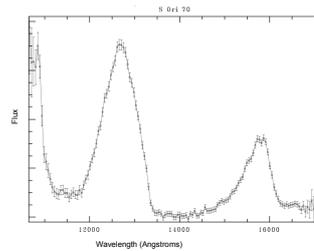
If bona fide T dwarfs can be identified in young clusters, they will be valuable benchmark systems with low surface gravities and planetary masses. Such systems would aid the development of model atmospheres for T dwarfs and exoplanets.

A few rather faint T dwarf candidates have previously been reported in young clusters, e.g. S Ori 70 and S Ori 73 in the  $\sigma$  Orionis cluster (Zapatero Osorio et al.2002;2008 (Z02,Z08); Bihain et al. 2009 (B09)) and PLZJ93 and PLZJ100 in the Pleiades (Casewell et al.2007).

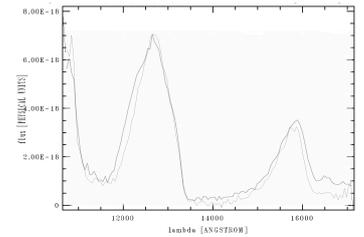
S Ori 70 was known to be a T4.5-T7 dwarf from low quality ground-based spectroscopy (Z02,Z08) and S Ori 73 was a good photometric candidate (B09) but their membership of the  $\sigma$  Ori cluster has long been uncertain. S Ori 70 has an unusually red (H-K) colour, which suggests low gravity and/or high metallicity. The Spitzer/IRAC [3.6]-[4.5] and [3.6]-[5.8] colours are also unusually red (Z08), although the reliability of these low S/N data have been disputed (Luhman et al.2008). At  $J=20.3$ , S Ori 70 is  $\sim 1$  mag brighter than expected for a cluster member but considerable scatter is often observed in the HR diagrams of clusters as young as  $\sigma$  Ori ( $\sim 3$  Myr). S Ori 73 ( $J=20.9$ ) has the right magnitude to be a cluster member but B09 noted that up to 3 foreground L5-T8 field dwarfs might be expected to contaminate the sample.

The Pleiades candidates were identified on the basis of sharing the cluster proper motion and indications from ZJHK colours, though these motions were only detected at the  $2$  to  $3\sigma$  level. Casewell et al.(2011) later found that methane imaging did not support T dwarf status but suggested that they might still be cool brown dwarfs that lack methane owing to an effect of low gravity on their atmospheres.

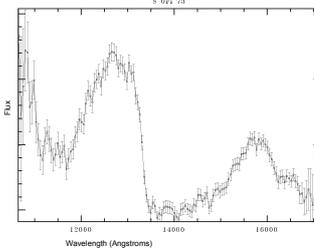
We obtained HST/WFC3 spectra of these systems in the hope that at least 1 of them would be confirmed as an ultracool cluster member.



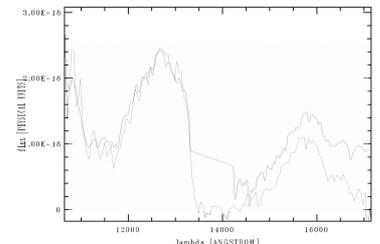
HST/WFC3 spectrum of S Ori 70 taken with the G141 grism. Individual data points and their error bars are plotted.



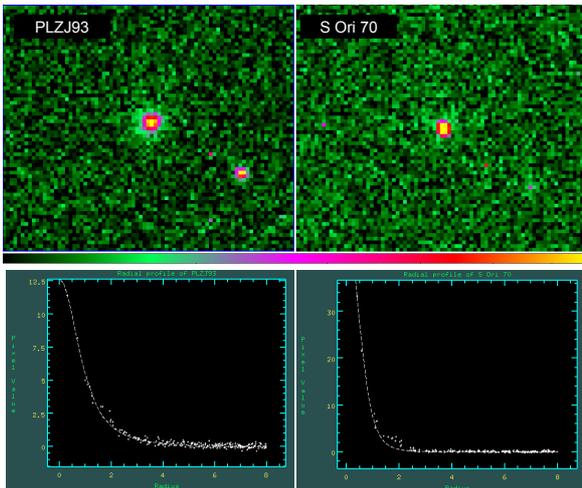
Comparison of S Ori 70 (thin line) with the spectrum of a field T6 dwarf 2MASS 0243-2453 (thick line) from the Burgasser T dwarf spectral library. The comparison suggests a similar or slightly later type for S Ori 70. There is no sign of large differences that might be expected in a low surface gravity object.



HST/WFC3 spectrum of S Ori 73 taken with the G141 grism. Individual data points and their error bars are plotted.



Comparison of S Ori 73 (thin line) with the spectrum of a field T3 dwarf 2MASS 1209-1004 (thick line) from the Leggett L and T dwarf data archive. The comparison suggests slightly later type (perhaps T3.5) for S Ori 73. The two spectra are similar at 1.1-1.4  $\mu$ m but S Ori 73 has a larger J/H peak ratio than 2MASS 1209, consistent with it's bluer J-H colour ( $J-H=0.1$  for S Ori 73 and  $J-H=0.3$  for 2MASS 1209).



HST/WFC3 F140W image and radial profile of PLZJ93 (left panels), formerly a candidate T dwarf or ultracool dwarf in the Pleiades. It is apparent that the spatial profile is broader than that of the point source S Ori 70 (right panels). This indicates that PLZJ93 is an external galaxy. The spectrum (not shown) is flat and featureless. Each pixel subtends 0.075 arcsec on the sky.

## Observations

Each target was observed for 1 orbit, consisting of an F140W image followed by 40 minutes of R-130 slitless spectroscopy at 1.08-1.70  $\mu$ m with the G141 grism. A 4 point dither was used to remove cosmic rays. Data were reduced with the aXe pipeline.

## Discussion

The image of the Pleiades candidate PLZJ93 shows a diffuse halo, demonstrating that it is not a T dwarf and it is likely to be an external galaxy. The Pleiades-like proper motion previously reported can now be understood as a consequence of the reduction in astrometric precision that occurs in extended sources, perhaps exacerbated by differential chromatic aberration. This tells us that external galaxies are a serious source of contamination that must increasingly be allowed for as surveys probe ever deeper for cold brown dwarfs and distant substellar cluster members. PLZJ100 also seems likely to be an external galaxy, given that its proper motion had even lower significance than that of PLZJ93.

Subsequent to our application for HST time, Peña Ramírez et al.(2011) published proper motions of for S Ori 70 and S Ori 73 that proved they are not members of the  $\sigma$  Orionis cluster. However, these authors argued that S Ori 70 might still be a very young, low gravity T dwarf ejected from another star formation region within Orion such as the LDN 1634 molecular cloud, which could explain the unusually red (H-K) and IRAC colours. In our view, the similarity of the spectrum of S Ori 70 to that of normal field dwarfs indicates that it probably is a slightly unusual field dwarf rather than a very young planetary mass object. Model atmosphere predictions for near IR spectra are evolving rapidly but we note that the 2010 generation of BT-SETTL models predicted that the effect of surface gravity on low resolution 1.1-1.7  $\mu$ m spectra depends strongly on temperature, with large effects at  $T_{\text{eff}} \leq 900$  K but little effect at 1000 K.

## References

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