Search and characterization of T-type planetary mass candidates in the σ Orionis cluster

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Abstract

We present new photometric and astrometric data available for S Ori 70 and 73, the two T-type planetary-mass member candidates in the σ Orionis cluster (3±2 Myr, d=~360 pc). S Ori 70 ($J \sim 19.9$ mag) has a spectral type of T5.5 ± 1.0 measured from near-infrared spectra, while no spectroscopic data are available for S Ori 73 ($J \sim 21$ mag). We estimate the spectral type of S Ori 73 by using J, H, and CH_{4off} ($\lambda_c = 1.575\mu m$, $\Delta\lambda = 0.112\mu m$) photometry and comparing the $H-CH_{4off}$ colors of S Ori 70 and 73 with the colors of field stars and brown dwarfs of spectral types in the range F to late T. The locations of S Ori 70 and 73 in the $J - H$ vs $H-CH_{4off}$ color-color diagram are consistent with spectral types T8±1 and T4±1, respectively. Proper motion measurements of the two sources are >2σ with respect to the proper motion of central σ Orionis star, in such a way the cluster membership of this two sources is uncertain.

Motivation

Knowledge of the low-mass end of the IMF is crucial to understand the formation mechanisms of substellar objects. In the σ Orionis cluster there are only two T-type planetary mass candidates S Ori 70 ($J \sim 19.9$ mag) has a spectral type of T5.5 ± 1.0 measured from near-infrared spectra (Zapatero Osorio et al. 2002), while no spectroscopic data are available for S Ori 73 ($J \sim 21$ mag).

We present new photometric and astrometric data, as well a spectral classification for this two candidates attempting To give new insights about the nature of T-Type planetary mass objects.

Observational data

Relevant observational data is presented in Table 1. HAWK-I and OSIRIS pointings were intended to image S Ori 70 and 73, covering areas of ~120 and ~220 arcmin², respectively. VISTA data covers all the σ Orionis cluster. Standard reduction and PSF photometry were carried on for HAWK-I and OSIRIS data, photometric calibration were made using the UKIDS DR7 database for the near-infrared data, and photometric standard stars from Smith et al. 2002 for the optical data.
In the VISTA case, science verification data were reduced by the Cambridge Astronomy Survey Unit (CASU), aperture photometry of 2" in diameter were performed.

Telescope	Instrument	Filter	Dates	Exp. Time [s]	Seeing [arcsec]	Completeness [mag]	Limiting [mag]
GTC	OSIRIS	i'	2009 October 15	3146	0.80	25.0	26.0
			2010 January 11	9360	1.10		
			2009 October 13,14,15	9438	0.70		
			2009 November 19	3198	1.10		
VISTA	VIRCAM	Z	2009 October 20,21	6084	0.80	22.6	23.2
		Y	2009 October 20	1008	0.90	21.0	21.4
		J	2009 October 19, 20	2112	0.90	21.4	21.8
		H	2009 October 20	288	0.90	19.6	20.0
		K_s	2009 October 20	288	0.70	18.6	19.1
UT4	HAWK-I	J	2008 September 19	160	0.64	22.4	23.4
		H	2008 December 8	8410	0.34	22.5	23.4
		CH_{4off}	2009 February 24	13500	0.52	22.5	23.1
			2009 March 28	13500			
UT4		J	2008 October 27	160	0.75	21.8	22.8
		H	2009 March 24	8410	0.52	20.5	21.8
		CH_{4off}	2009 March 16	13500	0.57	21.3	22.4
		J	2009 February 11	160	0.63	22.0	22.8
		H	2009 March 30	8410	0.75	20.8	21.6
		CH_{4off}	2009 March 29	12615	0.65	21.4	21.8

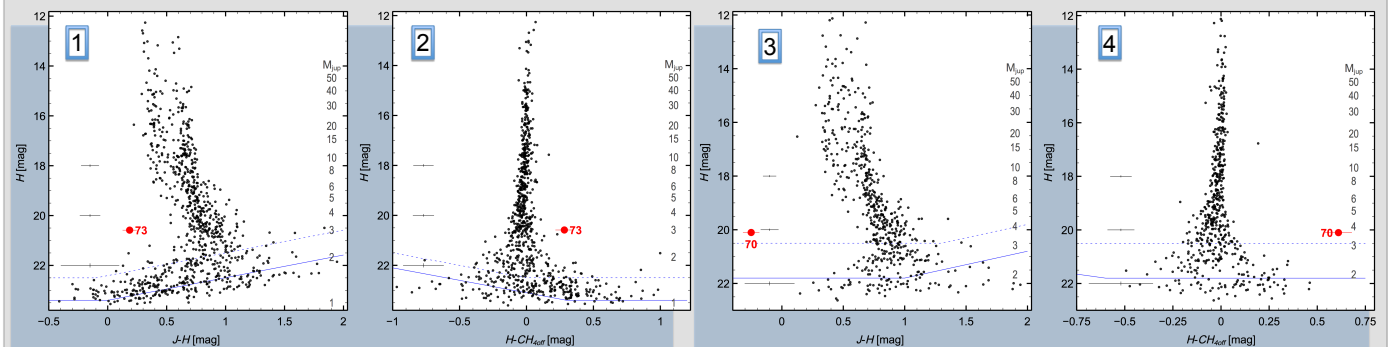**Table 1.** Observations log

Results

Fig. 1 Color-magnitude diagrams of the HAWK-I pointings that harbor S Ori 73 (1, 2) and S Ori 70 (3, 4) represented by red filled circles. Completeness and limiting magnitudes are indicated with a dashed and a solid line, respectively. Only point-like objects are plotted for clarity. Average error bars for intervals of 2 mag are indicated to the left. Masses are indicated to the right in units of Jupiter masses.
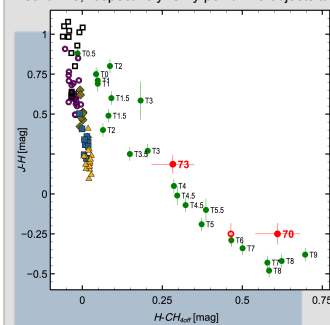
Instrument	Photometry	S Ori 70	S Ori 73
OSIRIS	i'	≥ 26.0	≥ 26.0
VIRCAM	Y	20.85 ± 0.13	
	J	19.84 ± 0.06	20.58 ± 0.10
HAWK-I	J	19.85 ± 0.05	20.77 ± 0.04
	H	20.10 ± 0.05	20.58 ± 0.05
	$H-CH_{4off}$	0.61 ± 0.07	0.28 ± 0.10

Table 2, 3: Photometric and proper motion data for S Ori 70 and 73

Candidate	Instruments	Δt [yr]	$\mu_\alpha \cos\delta$ [mas yr⁻¹]	μ_δ [mas yr⁻¹]
S Ori 70	Ω2000 (CAHA) / HAWK-I	3.41	37.9 ± 11.0	17.7 ± 8.0
	Ω2000 (CAHA) / VIRCAM	3.99	30.8 ± 21.5	10.4 ± 11.0
	NIRC (KECK I) / HAWK-I	7.23	25.5 ± 5.6	27.1 ± 5.1
	NIRC (KECK I) / HAWK-I	7.80	28.8 ± 7.0	17.7 ± 7.2
	Average		30.8 ± 11.0	18.2 ± 8.0
S Ori 73	ISAAC (VLT) / HAWK-I	6.98	38.6 ± 10.0	-0.6 ± 6.0
	ISAAC (VLT) / VIRCAM	7.85	52.7 ± 8.0	-10.0 ± 11.0
	Average		43.2 ± 10.0	-3.7 ± 7.0

Fig. 2 Color-color diagram (including the HAWK-I methane color) for T- (green), L- (black), M- (magenta), K- (olive green) G- (blue), and F- (yellow) type field sources. The photometry of S Ori 70 and 73 is plotted as red filled circles. The red open circle corresponds to the synthetic methane color of S Ori 70 derived from its Keck spectrum published in the literature.

Results and conclusions

• We estimate the spectral types of S Ori 73 and S Ori 70 by comparing the $J-H$ and $H-CH_{4off}$ colors with those of field dwarfs as T4 ± 1.0 and T8 ± 1.0. We confirm the "methane" nature of S Ori 73. The spectral classification of S Ori 70 is slightly cooler but marginally consistent with that derived from near-infrared spectra in the literature.

• Astrometric data for the two known T-type planetary mass candidates gives proper motion measurements for S Ori 70 (μ = 35.77 ± 14 mas yr⁻¹) and S Ori 73 ((μ = 43.36 ± 12.5 mas yr⁻¹). These proper motions values deviate from the Hipparcos motion of the sigma Orionis star by 2σ within the error bars, thus their cluster membership based on astrometric considerations is still uncertain.

• We developed a multi-wavelength photometric study using optical and near infrared data from HAWK-I in an area of ~120 arcmin² until completeness in H band. The selection criteria ($i'-J \geq 5$ mag, $Z-J \geq 2.5$ mag, $J-H \leq 0.5$ mag and $H-CH_{4off} \geq 0.15$ mag) did not gave us any additional candidate with colors of the T-type objects. No one candidate present red optical/IR colors except for two sources for which optical data is not restrictive due to they are close (4.2'' and 2.9'') to bright stars (~11-13 mag in H-band).

References

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