European Organisation for Astronomical Research in the Southern Hemisphere

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APPLICATION FOR OBSERVING TIME

PERIOD: **96Z**

DDT

Important Notice:

By submitting this proposal, the PI takes full responsibility for the content of the proposal, in particular with regard to the names of CoIs and the agreement to act according to the ESO policy and regulations, should observing time be granted.

1. Title

Category: **X–0**

First exoplanet image

2. Abstract / Total Time Requested

Total Amount of Time:

The TW Hydrae association is a group of about 30 very young stars located 50 pc from Earth that are 5-10 million years old. The best studied members of this stellar association are TW Hydrae (nearest known accreting T Tauri star to the Earth), HR 4796 (an A-type star with resolved dusty debris disk; the most massive known group member), HD 98800 (a quadruple star system with debris disk) and 2M1207 (accreting brown dwarf with spectral type M8 of mass ≈25MJup and ≈8Myr age located ≈70 pc from Earth with a remarkable planetary-mass companion 2M1207b: a very red object at a close separation of ≈780 mas (≈55 AU) with a spectral type L5-L9.5). Different evolutionary models predict for the companion an object within the planetary regime with a mass of M=5±2 MJup and an effective temperature Teff=1250±200 K. The fact that the companion is a planet as well as the TW hydraee membership is still disputed and is the reason of our proposal.

3.

Run	Period	Instrument	Time	Month	Moon	Seeing	Sky	Mode	Type
A	96	NACO	1.5h	any	n	0.8	PHO	s	

4.

Number of nights/hours	Telescope(s)	Amount of time
a) already awarded to this project:	VLT	4h
b) still required to complete this project:	VLT	2.5h

5. Special remarks:

6. Principal Investigator: beevageeva

6a. Co-investigators:

G.	Chauvin	1096
C.	Dumas	1150

7. Description of the proposed programme

A – Scientific Rationale: We already have a few photometric and astrometric results from Two Micron All Sky Survey (2MASS) in bands: J , H , Ks (The transformations between the two filters Ks and K were found smaller than the measuring errors.) and from Keck telescope in L' band

The parent dwarf appears to be of spectral type M8 with magnitudes: 13.00(J), 12.39(H), 11.95(K), 11.38 (L') and the giant planet candidate: spectral type L5 - L9.5 with magnitudes: $\geq$ 18.5(J), 18.09 (H), 16.93(K), 15.28(L') (These values were obtained by comparison of its photometry with the infrared colors of field late-M, L and T dwarfs obtained by Leggett et al. (2001, 2002), Stephens et al. (2001), Golimowski et al. (2004) and Knapp et al. (2004) as seen in Fig 2)

We believe that **the parent dwarf is part of TW Hydrae association** first by observing its proper motion. The specter of the parent dwarf has already been measured and the radial velocity deduced from it is also consistent with the TW Hydrae membership. NaI absorption line at 8200 A which indicates low surface gravity and Hα emission line indicate a very young object. From isochrone fitting in the HR diagram we estimate its age to 10Myr and this is in concordance with the TW hydrae membership

It is not established yet the nature of the companion of the brown dwarf that we believe is a **giant planet**. Contamination by a foreground or background field L dwarf is still possible, though very improbable. The companion IR colors are consistent with that observed by Leggett et al. (2002) for late L field dwarfs, age of 15 Gyr; for example, an L8 field dwarf located at $\approx$ 60 pc or L5 field dwarf at $\approx$ 130 pc. Based on a number density of L dwarfs of $1.9 \times 10^{-3}/pc^3$ given by Burgasser (2001) and Cruz et al. (2003), the probability of finding a foreground or background L dwarf (located between 50 and 150 pc) in a region of 780 mas radius around 2M1207 is equal to 9×10^{-8}. Consequently, contamination by an L field dwarf is very improbable.

The signs of accretion onto the young dwarf: various He I and H I emission lines (Mohanty et al. 2003; Gizis 2002) and the $H\alpha$ line which is asymmetric and broad are also supporting the idea. Although L -band observations of Jayawardhana et al. (2003) did not reveal significant IR excess at 3.8 m, recent mid-IR observations of Sterzik et al. (2004, accepted) found excess emission at 8.7 m and 10.4 m and confirm disk accretion as the likely cause of the strong activity. New Chandra observations of Gizis & Bharat (2004) corroborates this disk-accretion scenario as they suggest that less than 20% of the Hα emission can be due to chromospheric activity.

We already used estimated age and distance and the measured magnitudes of the companion with evolutionary models which predict for the companion a mass M=5$\pm$2 MJup and an effective temperature Teff=1250$\pm$200 K which are appropriate for a giant planet. We used the non gray model of Burrows et al. (1997), for a distance of 70 pc and age of $\approx$ 510 Myr and we obtained a mass of 3 - 10 MJup and Teff 1000 - 1600 K, but we considered afterwards new generation models: the DUSTY and COND models. These can be seen as two extreme cases, to describe respectively brown dwarfs with an atmosphere saturated in dust, like late M and L dwarfs, and cool brown dwarfs or giant planets with the dust condensed in their atmosphere, like T dwarfs. We estimate the effective temperature and the mass of the companion by using the different color - magnitude diagrams using H, K and L bands or using the measured bolometric corrections $BC_K \approx 3.2$ for late-L dwarfs estimated by Golimowski et al. (2004)

B – Immediate Objective: The red object so close: at $\approx$ 780 mas from the brown dwarf is very intriguing. We need to repeat the photometric measurements using adaptive optics infrared wavefront sensing to acquire sharp images with bigger integration time and to obtain spectroscopic results (of the companion).

Spectroscopy reveals information about the atmosphere: whether the object is a candidate to support life. We can also estimate radial velocities.

More accurate photometry and spectroscopic results are better input parameters for evolutionary models which might not be very precise beacuse of the very young age.

If we can confirm the belief that the companion is a planet these would be **the first images of an exoplanet**. We also want to confirm that **the brown dwarf is a member of TW Hydrae association**.

7. Description of the proposed programme and attachments

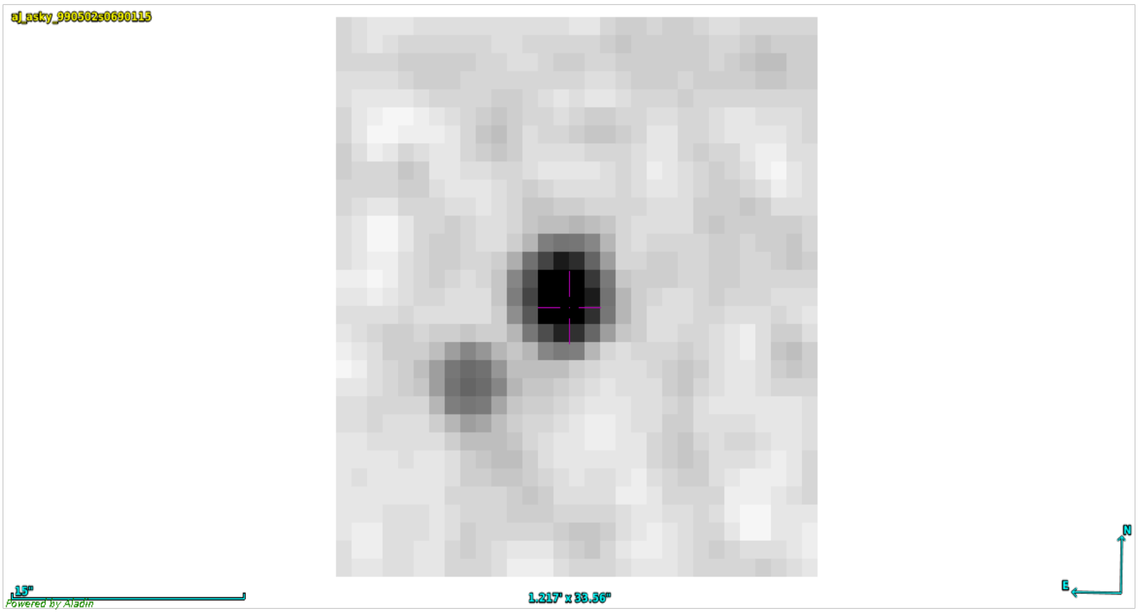

Fig. 1: image obtained from 2 mass centered on the parent dwarf: RA: 12h:07m:33.47s and dec: -39d:32m:54.0s, 30 arcsec

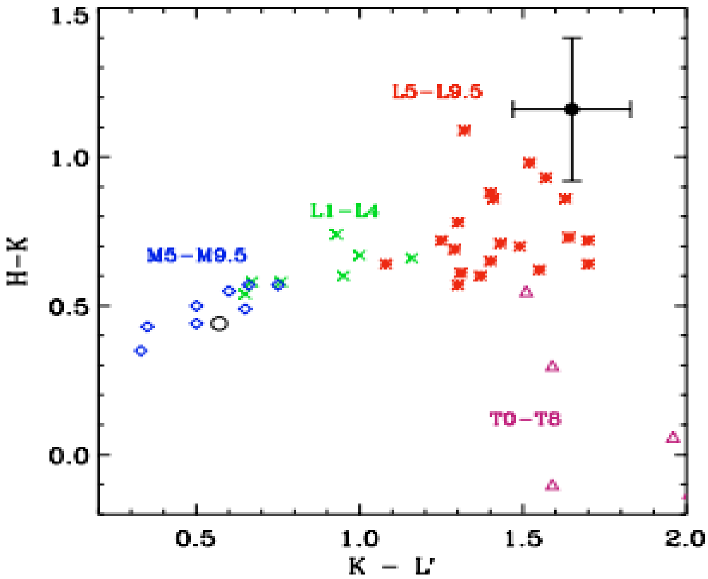

Fig. 2: Spectral type determined by comparison. Color - color diagram (H - K vs. K - L) for 2M1207 (open circle) and its faint GPCC (point shown with error bars). The observed infrared photometry for late-M dwarfs (diamonds), L1- L4 dwarfs (crosses), L5 - L9.5 dwarfs (asterisks) and T dwarfs (triangles) obtained by Leggett et al. (2002) and Stephens et al. (2001) are given for direct comparison.

8. Justification of requested observing time and observing conditions

Lunar Phase Justification: The object we want to observe is very faint

Time Justification: (including seeing overhead) **Band J**: *Target Setup*: Flux Distribution : Blackbody (Temperature : 1250.00 K), magnitude : J = 18.50, geometry : Point source,
Reference Source Setup (we use the parent dwarf as star reference for the AO which is fainter: magV = 20.15 than the maximum allowed in ETC: magV = 16.5, its angular distance from the planet we want to observe is less than 1 arcsec, much less than 5 arcsec so we set it to 0) Spectral Type : M6V, Reference Source magnitude : V = 16.50, Reference Source / Target Separation : 0.00 arcsec, Sky Conditions Airmass : 1.10, Seeing : 0.80 arcsec
Instrument Setup Neutral Density Filter : OUT, Wollaston Prism : OUT,
NAOS Dichroic : N90C10, CONICA Objective : S27/L27, Detector read-out mode : Double_RdRstRd(HighDynamic) (read-out noise 60.00 e-), (used for high intensity background) we set DIT to 30s
we get for input S/N = 13 NDIT = 8
For **band H** the same as for band J, we change the seeing (more easily achieved for longer wavelengths): to 0.60 arcsec and for an input S/N = 200 we get NDIT = 16
For **Band Ks** same as band H , but with an input S/N = 340 NDIT = 16
For **Band L'**: same as band Ks, we change NAOS Dichroic : JHK, Detector read-out mode : Uncorr(HighWellDepth) (read-out noise 60.00 e-), we set DIT to 0.175s and obtain for input S/N = 100 NDIT = 1312
Thus imaging total time is 240 + 480 + 480 + 229.6 = 1429.6s
Specter: *Sky Conditions* Airmass : 1.15, Seeing : 0.80 arcsec
Instrument Setup Dichroic : N90C10, Spectroscopic Mode : S54_4_SHK (Spectral domain: 1.30-2.60 microns, order 1, spatial scale: 54 mas/pixel, linear dispersion: 1.94, resolution: 550)
Slit Width : 0.086 arcsec, Detector read-out mode : FowlerNsamp(HighSensitivity), We set DIT = 300s and for S/N = 10 we get NDIT = 9 So we have total time 1430s (imaging) + 2700s (specter) = 4130s calculated without overheads we round it to 1.5h

8a. Telescope Justification:

VLT is the world's most advanced optical instrument, consisting of four Unit Telescopes with main mirrors of 8.2m diameter and four movable 1.8m diameter Auxiliary Telescopes. We want to use UT1 beacuse we want to use intrument NACO.
NACO = Nasmyth Adaptive Optics System (NAOS) + Near-Infrared Imager and Spectrograph (CONICA)
NACO has been contributing to major discoveries in different fields of astronomy: exoplanets, the Galactic centre of the Milky Way, young stellar objects, Solar System bodies, etc.
In order to split the beam for the adaptive optics we use the N90C10 dichroic (90% flux to the wavefront sensor of NAOS and 10% to the camera CONICA) for imaging in J, H and Ks band and for spectrography. This mode is dedicated to the sharp imaging of red sources V K $\geq$ 6 (M5 or later spectral type), but this cannot be used for L' filter where we use the JHK dichroic(90% flux to the WFS and 90% to CONICA).

8b. DDT Justification:

The only option was for cycle 96z(DDT cycle)

8c. Calibration Request:

Standard Calibration

9. Report on the use of ESO facilities during the last 2 years

September 2003, VLT(UT3) telescope with instrument ISAAC at Nasmyth A focus: Spectroscopic surveys of large numbers of young low-mass stars which are still deeply embedded in their parental clouds. Our infrared spectra show a rich variety of features due to ices and gas-phase molecules, each of which trace different aspects of the physical and chemical state of the objects.
We already published the data: Origin and Evolution of Ices in star-forming regions a VLT-ISAAC 35 μm spectroscopic survey

9a. ESO Archive - Are the data requested by this proposal in the ESO Archive (http://archive.eso.org)? If so, explain the need for new data.

No

9b. GTO/Public Survey Duplications:

There are some results from 2 mass survey that our research is based on. We want to repeat the observations in J, H, Ks and L' band using adaptative optics and a bigger integration time and to obtain its specter in order to determine the nature of the companion of the brown dwarf that appears faintly in the images from 2 mass.

10. Applicant's publications related to the subject of this application during the last 2 years

E. F. Van Dishoeck , E. Dartois, K. M.Pontoppidan, W. F. Thi, L. D'Hendecourt, A. C. A. Boogert, H. J.Fraser, W. A. Schutte, A. G. G. M Tielen: Origin and Evolution of Ices in star-forming regions a VLT-ISAAC 35 μm spectroscopic survey

11. List of targets proposed in this programme

Run	Target/Field	α(J2000)	δ(J2000)	ToT	Mag.	Diam.	Additional info	Reference star
A	2M1207	12:07:33.47	-39:32:54.0	1	13			2M1207

Target Notes: RA above given in h:m:s format and declination in d:m:s format and the magnitude are those of the parent brown dwarf(2M1207). We use as reference star for adaptive optics the parent brown dwarf because the Adaptive Optics System (NAOS) is designed to work with natural guide stars. The target(the companion) is slightly off the optical axis because the parent dwarf is used as reference source(the image is centered in the parent dwarf). This is particularly useful if the target is very faint. A reference image obtained from 2 mass (centered on the parent dwarf) is shown in Fig. 1 For spectroscopy we observe simultaneously the parent dwarf and its companion(2M1207b) at coordinates: RA: 12h:07m:34.01s, dec: -39d:32m:58.9s
We will use the following filters for imaging:

name	central wavelength(μm)	width(μm)	limit magnitude
J	1.265	0.25	24.05
H	1.66	0.33	24.05
Ks	2.18	0.35	23.35
L'	3.80	0.62	18.55

12. Scheduling requirements

This proposal involves time-critical observations, or observations to be performed at specific time intervals.

13. Instrument configuration

Period	Instrument	Run ID	Parameter	Value or list
96	NACO	A	IMG filters: J, H, Ks	N90C10 dichroic, Double RdRstRd(HighDynamic) detector mode (used for high intensity background), detector FOV: 27.6x27.6 arcsec
96	NACO	A	IMG filter: L’	JHK dichroic, Uncorr(HighWellDepth) detector mode, detector FOV: 27.6x27.6 arcsec
96	NACO	A	Spectroscopy	N90C10 dichroic,S54 camera with SHK filter , FowlerNsamp(HighSensitivity) detector mode, 86 mas slit width