brighter field star and unresolved by the NTT/SUSI (Mignani et al. 1997). As in that case, high-resolution imaging of the region with the HST would be the only way to pinpoint the pulsar.

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The First X-ray Emitting Brown Dwarf

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The increasing number of brown dwarfs discovered in the last few years is rapidly opening the possibilities of studying a wide range of their properties and the ways in which these depend on essential parameters, such as the mass, the age, the rotation, or the environment. One of these properties is the magnetic field, which in principle should be expected to be important in fully convective objects such as brown dwarfs. The chromospheric X-ray emission, widely observed in M-type dwarfs (Neuhäuser 1997), has its origin in this magnetic activity. As such, it offers an observational tool to probe the interior of these objects, the mechanisms for the generation and maintenance of their magnetic fields, and the way in which the magnetic activity is affected by the basic parameters of the object. The detection of X-ray emission from brown dwarfs is thus of great importance to extend our understanding of the properties of stellar magnetic fields to the substellar domain, as well as to ascertain to what extent a small, substellar mass, and the consequent lack of a permanent nuclear energy source, can have an impact in the production and the evolution of a magnetic field.

Until recently, no conclusive evidence for X-ray emission from brown dwarfs had been found, as shown by an extensive search in ROSAT archive observations near the position of known bona-fide and candidate brown dwarfs (Neuhäuser et al. 1999). However, a newly identified member of the Chamaeleon I star form-

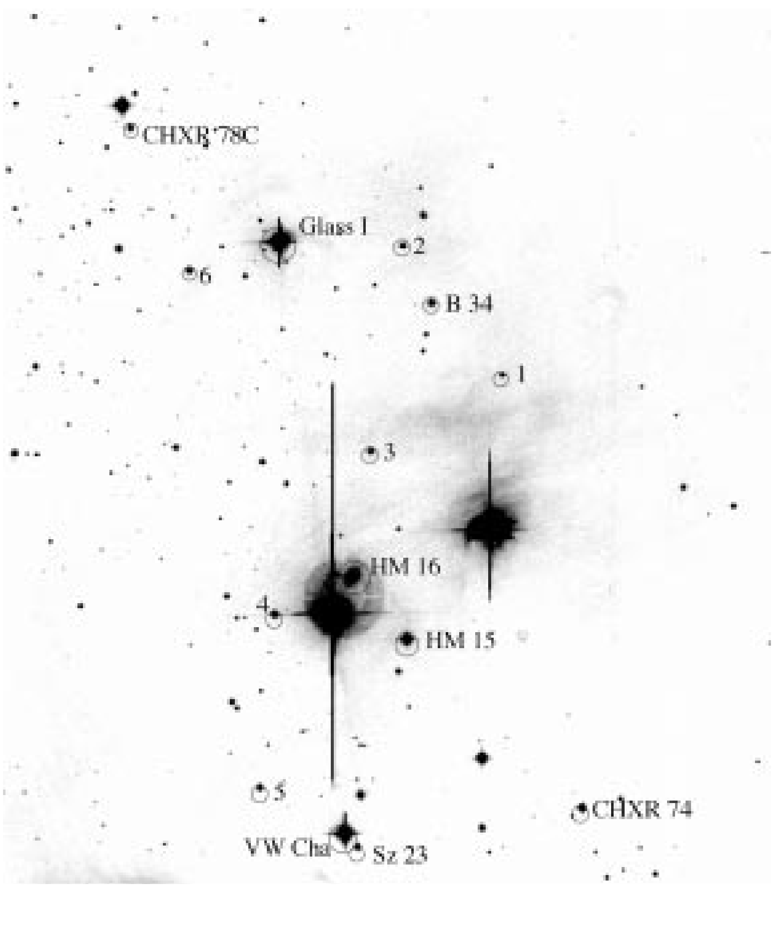

Figure 1: A 13′ ×13′ image of the centre of the Chamaeleon I aggregate in the I band. Labels identify previously known members of the aggregate, and numbers 1 to 6 denote the low-mass members newly found in the Hα survey by Comerón et al. 1999, i.e. Cha Hα 1 to 6. This image was obtained using DFOSC at the 1.5-m Danish telescope on La Silla, and includes the area surveyed in the infrared using IRAC2b at the ESO-MPI 2.2-m telescope. The area covered by the X-ray and ISOCAM observations is considerably larger.

ing cloud, whose temperature and luminosity clearly identify it as a brown dwarf younger than one million years, is clearly detected by a deep ROSAT observation with a 9σ detection significance (Neuhäuser & Comerón 1998). This object is only the second bona-fide brown dwarf to be detected in a star-forming region (Luhman et al. 1997), and the first one known to emit in X-rays.

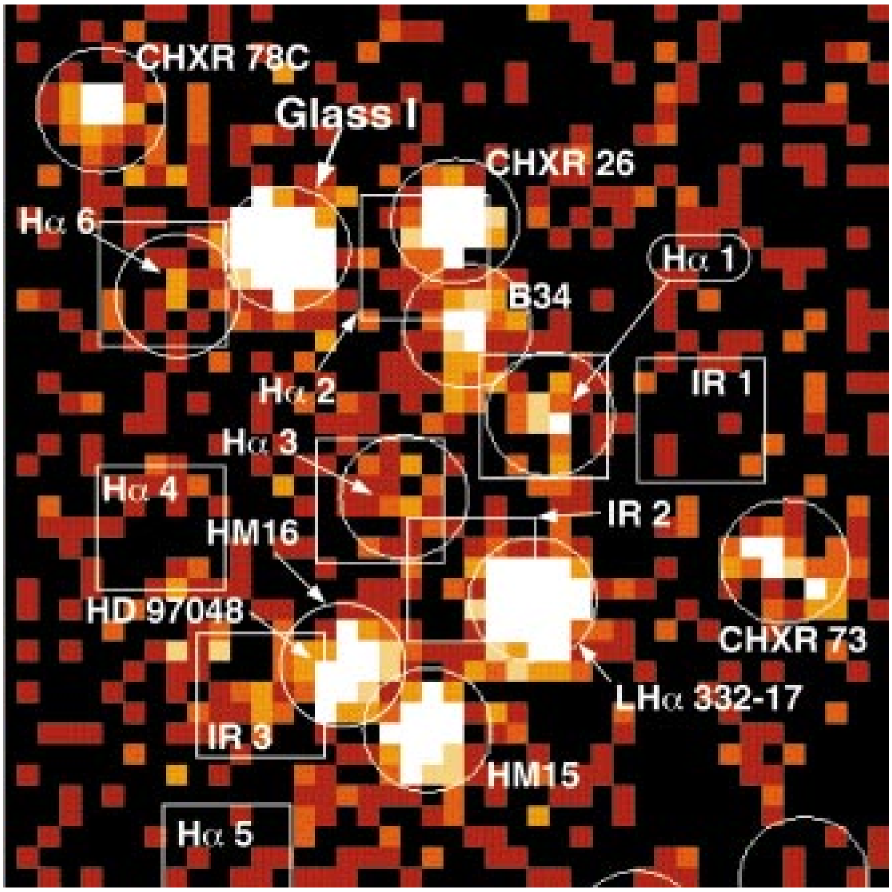

Figure 2: Deep ROSAT X-ray image of the centre of the Chamaeleon I aggregate, covering an area similar to that of Figure 1. The position of all the known and newly identified members is indicated.

The identification of the X-ray emitting brown dwarf in Chamaeleon I, hereafter referred to as Cha Hα 1, is the result of three parallel efforts aimed at finding brown dwarfs in this star-forming region by means of different characteristics typical of low-mass young stellar objects. The first of them was a research on deep observations in the ROSAT archive, amounting to 37.8 ksec of effective observing time at the position of Cha Hα 1, looking for faint, previously unidentified Chamaeleon I members revealed by their X-ray emission. The second one consisted of the combination of a JHK survey of 100 arcmin^2 of the centre of the aggregate, carried out with IRAC-2b at the ESO-MPI 2.2-m telescope on La Silla in May 1997, and an objective-prism survey of approximately the same field using DFOSC at the 1.5-m Danish telescope, also on La Silla, in March 1998. The aim in this case was to identify new faint members by means of their possible near-infrared excess or by their emission in Hα. A third set of observations came from a large-area star-formation survey carried out with ISOCAM at 6.7 and 14.3 µm (Nordh et al. 1996). The aim of this survey was to identify young stellar objects by means of their mid-IR excess in the colour index [14.3/6.7] and obtain a more complete census of the young stellar population for IMF studies. From an empirical correlation between the flux at 6.7 µm of the excess sources and bolometric luminosities (Prusti et al. 1992) extrapolated to faint sources, as well as adopting the median age of T Tauri stars of 3 10^6 yr (Lawson et al. 1996) as a common age for these, the theoretical models of D'Antona & Mazzitelli (1997) predict that about 25% of the ISOCAM selected young stellar objects in Cha I are substellar (Olofsson et al. 1998), a result that must be confirmed spectroscopically.

Cha Hα 1 is identified in all these surveys. Figure 1 shows it in an I-band image of the field surveyed in Hα, obtained also with the 1.5-m Danish telescope. Also indicated are the previously known members of the aggregate (e.g. Lawson et al. 1996), as well as five other new members identified by their Hα emission whose masses are near, and possibly below, the limit separating stars from brown dwarfs (Comerón et al. 1999). The X-ray image of the same field is shown in Figure 2. The initial spectrum of Cha Hα 1 from the DFOSC survey revealed a prominent emission at Hα and a late M spectral type, but given the faintness of the object in the Hα region, it was not possible to precisely determine the spectral subtype, an essential element to ascertain its temperature and therefore its mass. For this reason, additional spectroscopic observations at visible and near-infrared wavelengths were carried out in May 1998 using EMMI and SOFI at the NTT.

The visible spectrum of Cha Hα 1 obtained with the NTT is shown in Figure 3, where it is compared to late M spectral standard stars. The overall appearance of the spectrum clearly indicates a late M type, as confirmed as well by several indicators which measure the strengths of temperature-sensitive spectral features.

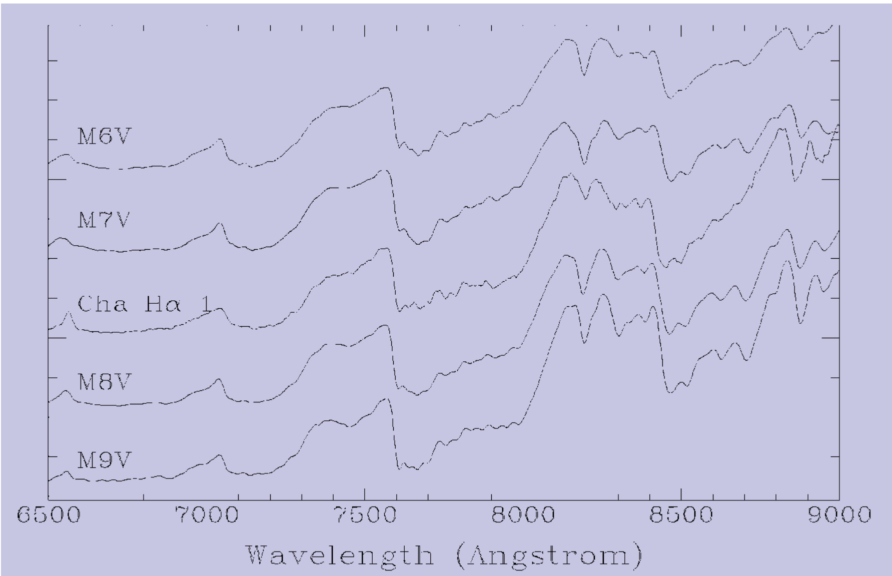

Figure 3: The visible spectrum of Cha Hα 1 obtained with EMMI at the NTT. The M6V comparison spectrum is that of Gl 406; M7V, of vB 8; M8V is the combination of LHS 2243, LHS 2397 A, LP 412-31, and vB 10; and M9V, of BRI 1222–1222, LHS 2065, LHS 2924, and TVLM 868–110639. The spectral classification of the standard stars is from Kirkpatrick et al. 1995.

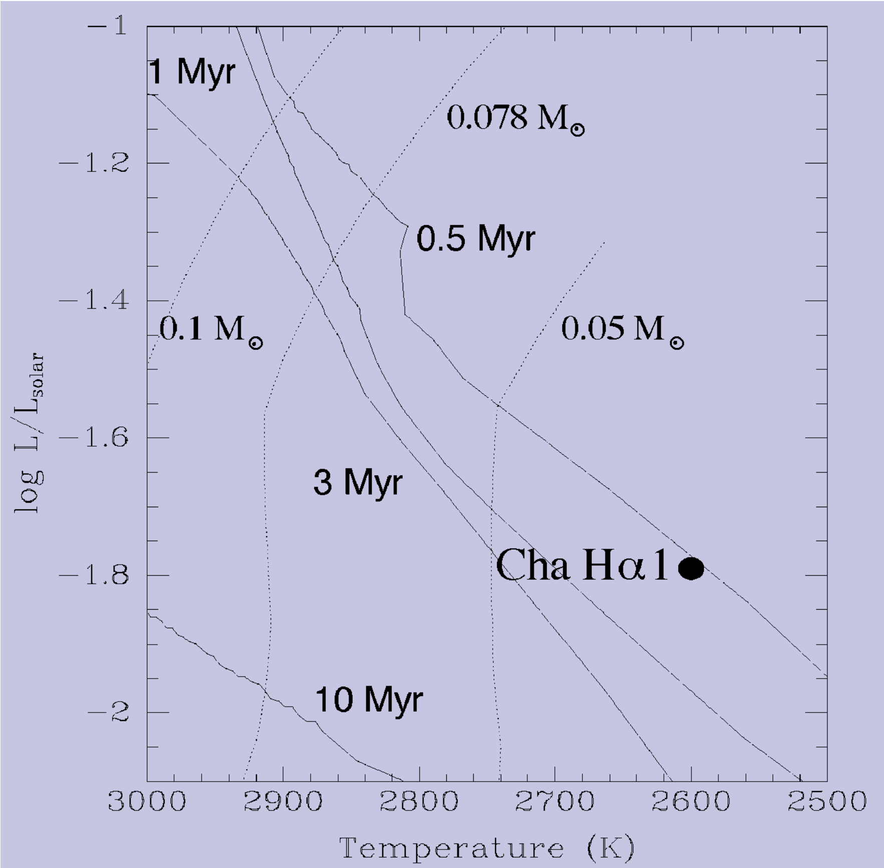

Figure 4: H-R diagram showing the position of Cha Hα 1. The lines give the position of the isochrones (solid lines) and lines of equal mass (dotted lines) for late M spectral types according to Burrows et al. 1997. The line labelled as 0.078 $M_\odot$, separates brown dwarfs from low mass stars.

Based on these elements, we classify Cha Hα 1 as M7.5–M8. Some differences with the standard field M dwarfs are apparent as well: the principal one is the smaller depth of the Na I absorption feature at 8190 Å, which is known to be sensitive to gravity. The smaller depth is in fact a confirmation of the youth of Cha Hα 1, as an object in the early stages of contraction should have a surface gravity intermediate between that of a dwarf (where Na I is strong) and a giant (where Na I is weak).

The precise spectral classification obtained from the NTT visible spectrum makes it possible to derive the surface temperature of Cha Hα 1, using existing spectral type-temperature calibrations (Leggett et al. 1996). In this way, we obtain a temperature of 2600 K. On the other hand, the luminosity can be determined from the visible and near-infrared photometry obtained with our DFOSC and IRAC2b observations respectively: we adopt for Cha Hα 1 the distance of 160 pc to Chamaeleon I recently derived from Hipparcos data and extrapolate to M7.5 the bolometric corrections and intrinsic colours of Kenyon and Hartmann (1995) in order to find the reddening-corrected luminosity of the object. In this way, we obtain $\log L(L_\odot) = -1.79$. The derived temperature and luminosity allow the direct comparison with the results of pre-main-sequence evolutionary tracks, thus allowing an estimate of the age and mass of Cha Hα 1. Using pre-main-sequence tracks by Burrows et al. (1997), we obtain a mass of 0.03 $M_\odot$ and an age of 5×10^5 years. The position of Cha Hα 1 in the H-R diagram, and the lines of equal mass and age in that diagram predicted by the isochrones, are shown in Figure 4. The results are essentially unchanged by using tracks by D'Antona & Mazzitelli (1997), whose main difference is the allocation of a somewhat younger age for our objects, $\sim 3 \times 10^5$ years. Strictly, the temperature scale adopted is valid only for field dwarfs, whose surface gravities are higher; M giants of the same spectral subtype tend to be hotter, what may imply that our temperature for Cha Hα 1 is actually an underestimate. However, even allowing for a total underestimate of 200 K which would include errors due to surface gravity effects and uncertainties in the temperature calibrations through model-atmosphere fitting, Cha Hα 1 still remains safely in the substellar realm, with a mass below 0.06 $M_\odot$.

Cha Hα 1 displays most of the typical signatures of youth commonly associated with low-mass young stellar objects. The X-ray luminosity derived from the ROSAT observations is $\log L_X(\mathrm{erg\ s^{-1}}) = 28.3 \pm 0.1$, implying an X-ray to bolometric luminosity ratio of $\log(L_X/L_{bol}) = -3.44$, well within the range occupied by low-mass stars in young clusters. This result suggests that there is no essential difference in the X-ray emission properties of very young stellar objects when crossing the threshold separating stars from brown dwarfs. The prominent Hα emission, with an equivalent width of 59 Å, is also typical of classical T Tauri stars. On the other hand, and unlike in the case of higher-mass members of Chamaeleon I and other young aggregates, this strong Hα emission is not accompanied by a noticeable excess emission in the K near-infrared band; excess emission is nevertheless observed at 6.7 and 14.3 μm, as revealed by the ISOCAM measurements. The ISOCAM colour index [14.3/6.7] = 0.15 corresponds to $\alpha_{ISO} = -0.55$ ($\alpha = d\log(\lambda F_\lambda)/d\log\lambda$), which is in agreement with it being a Class II object. This colour is in rough agreement with theoretical models of flared circumstellar disks (Kenyon & Hartmann 1995). Excess is also found in the K – m(6.7μm) colour index. In principle, the lack of excess in the K band is to be expected: neither viscous heating at the presumably low rates of accretion on a very low mass object like Cha Hα 1, nor the irradiation by such a cool central star, should produce in a circumstellar disk any significant emission in the K band, although such excess emission could become important at longer wavelengths. However, we note that other very low mass objects with comparably low temperatures do display emission of circumstellar origin in the K-band (Comerón et al. 1998, Wilking et al. 1998).

Our discovery of X-ray emission from Cha Hα 1, while revealing brown dwarfs as a new class of X-ray emitting objects, seems to suggest that the transition from the stellar to the substellar domain does not imply a dramatic change in the properties of very young low-mass, fully convective objects. This seems to be reinforced by the very recent identification of X-ray emission from GY 202 (Neuhäuser et al. 1999), one of the probable brown dwarfs found in the ρ Ophiuchi cluster by Comerón et al. (1998 and references therein), whose substellar character has received recent support by spectroscopic observations by Wilking et al. (1998). The characteristics of this object (mass, age, $\log(L_X/L_{bol})$) seem to be very similar to those of Cha Hα 1. The magnetic properties of massive young brown dwarfs may therefore be simply an extension of those already well studied in their more massive counterparts, M-dwarf stars. Nevertheless, a number of questions remain open: why no X-ray emission is seen from other, more evolved brown dwarfs, despite the availability of observations (Neuhäuser et al. 1999) that put rather severe limits on the $\log(L_X/L_{bol})$ ratios of some of them? Is X-ray emission a feature restricted to the very early stages of the evolution of brown dwarfs, perhaps decreasing at later times as a consequence of the lack of a stable source of energy in their interiors? What is the dependence of X-ray emission of brown dwarfs on parameters such as the mass, the age, the luminosity, the rotation, or the existence of circumstellar material? More detailed studies of objects such as Cha

Hα 1, and better constraints on the X-ray emission of other brown dwarfs, will be necessary to answer these questions.

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CALL FOR IDEAS FOR FUTURE PUBLIC IMAGING SURVEYS

Based on the experience gained with EIS, and to prepare for the full exploitation of future imaging facilities such as the VST, ESO is ready to co-ordinate efforts to provide the community with imaging survey data taken at the La Silla Telescopes (2.2-m and NTT).

To this end, and following the recommendation of the Working Group for Surveys (WGS), ESO is issuing the present CALL FOR IDEAS for future public imaging surveys.

Scientists in the community are invited to fill out the form available in the ESO EIS Web page with their suggestions for future surveys (http://www.eso.org/science/eis/eis_ideas/wfi2.2_form.html). The compiled responses will be forwarded to the chairman of the WGS (Joachim Krautter, J.Krautter@lsw.uni-heidelberg.de).

DEADLINE FOR SUBMISSION: FEBRUARY 15, 1999

In elaborating their suggestions interested scientists should consider the following guidelines.

A Public survey should primarily be aimed at the maximisation of the scientific outcome of the VLT, and should consist of observations not likely to be covered by "private" proposals.

Public surveys should also have a broad scientific goal, provide data that could be fruitfully used by astronomers working in different astronomical areas, e.g. solar system, stellar populations, observational cosmology, etc., and should be easily complemented by 'private' proposals aimed at more specific scientific goals. As a consequence, in general, public surveys may concentrate on broad-band imaging, leaving e.g. narrow-band follow up or second-epoch observations to 'private' proposals.

The Working Group will collect the submitted ideas, and elaborate one or more detailed proposals to be submitted to the OPC, including a description of the survey products, distribution policy and schedule.

It is expected that a Survey Team, following the model of the EIS team, will be charged to execute the survey, combining in it ESO scientists and Visiting scientists from the community. In the future, as standard survey tools become available throughout the community, one may also envisage public surveys being conducted by Teams assembled in a member state institute with demonstrated experience and required infrastructure. Shortly after OPC approval of a survey, ESO will issue an announcement of opportunity for the recruitment of the Visiting Scientists who will participate in the effort.

Please read also the EIS Working Group Recommendations regarding future surveys.