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LkHα 262/263: the paradigm of multiplicity vs disk fraction in low-mass stellar systems.

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Abstract

The study of multiple systems and their link with the presence of discs around their components is key to understanding the evolution of low-mass pre-main sequence stars. Although there are indications that high-multiplicity systems are much more frequent among very young stars, until now, only a few of these young low-mass stellar systems have been confirmed. Here, we present high spatial resolution i band imaging of the system formed by LkHα 262 and LkHα 263, in the MBM12 cloud. It was obtained during the first commissioning period of the Adaptive Optics Lucky Imager (AOLI) at the 4.2 m William Herschel Telescope, using its Lucky Imaging mode. The multiple system LkHα 262/263 is composed of four low-mass very young M-type stars and some discs, including an edge-on disc around LkHa 263C. The AOLI data combined with previously available and newly obtained optical and infrared imaging show that the three components of LkHα 263 are co-moving, that there is orbital motion in the AB pair (0.41arcsec separation), and, remarkably, that LkHα 262-263 is a common proper motion system with a less than 1 mas/yr relative motion. According to BT-settl models the mass of each of the five components is close to 0.4 M and the age is in the range 1-2 Myr. We also give marginal evidence of a cooler companion to LkHα 262, at less than 0.15 arcsec, turning LkHα 262-263 into a five-component likely gravitationally bounded system. The presence of discs in some of the components offers an interesting opportunity to investigate the formation and evolution of discs in the early stages of multiple very low-mass systems.

1 Introduction

The formation and evolution of circumstellar disks is yet poorly understood, even given the fact that they are the consequence to the formation of stars after the core collapses. During the pre-main sequence phase, disks still remain surrounding the PMS stars as they go towards the main sequence meanwhile some processes change the disks properties and structure growing grains of matter and even planets. The way in which the material dissipates has important consequences not only on the central star but also on planet formation [21]. An unanswered question is whether the timescale for inner disk to survive optically thick is relatively longer (10^7 yr) than the timescale for small dust grains, which seem to be removed sooner (10^5 yr) [25]. A plausible answer to disks evolution is thought to come from the influence by companion stars as the disks in binary systems are expected to be disrupted by tidal effects (e.g [8]). However, studying the disks is not an easy issue, while edge-on disks are probably the best understood disks in 2-D images, their spectral energy distributions (SEDs) are still poorly characterized and modeled [29].

Multiple systems are key to understand the evolution of pre-main sequence (PMS) stars. Fortunately it appears that the existence of quadruple and quintuple systems among young stars is much more frequent than expected [4]. The search for multiple systems involving young stars in different evolution ages together with a near diffraction-limit study of their orbits and proper motions is needed to advance in this question.

2 The survey

We aim to study multiplicity existence in a dense group of stars (nearly 200 stars) from the Herbig-Bell catalog (1988), a catalog in where 735 pre-main sequence stars, members of the Orion Population are listed. Up to now, no systematic search with high resolution techniques has been done for the stars of this catalog, meaning that the multiplicity fraction of stars within this group remains unknown. A great effort is being done on the search for the presence of stellar and sub-stellar companions on later type stars. However, there is not yet any major study about the fraction of multiplicity presence in T Tauri stars. Thus, the stellar population present on the HB catalogue offers excellent conditions and an important opportunity for the study of stellar evolution at young stages via multiplicity surveys.

With an expected 20-30% of the population having companions, our goal consists not only to discover and resolve them but also to describe their orbital motion and main properties. This survey already started with FastCam at TCS and NOT with great success. We have selected from the HBC catalog those objects with a magnitude up to 14 in the I band, and with a declination bigger than -10 degrees, being observable with FastCam at NOT to reach the 19th magnitude (5σ) for the yet not observed possible companions.

The study presented here and widely developed in [27] shows important discrepancies between high-resolution astrometric measurements of the components in the optical, made with lucky imaging techniques, and in the infrared with adaptive optics. We strongly believe that the case of LkHα 262/263 (HBC8 and HBC9) described in [27] is not an isolated case.

Then, the optical study of those targets of the sample already measured with adaptive optics in the infrared will lead us to fully understand the nature of these discrepancies.

The survey is being done with the Lucky Imaging (LI) instrument FastCam, at TCS (OT) and NOT (ORM). Most relevant targets will be followed up with the new state-of-the-art instrument Adaptive Optics Lucky Imager (AOLI).

3 Method

The Lucky Imaging technique, as suggested by [12] and named by [7], was born as an alternative to Adaptive Optics (AO) to reach the diffraction limit in the optical bands. Images are taken at a very high speed in order to sample those intervals in which the atmosphere inside the collector tube through which the wavefront travels can be regarded as stable. If the best fraction of a bunch of images, those with smaller Strehl pattern, are stacked in a shift-and-add process, the equivalent to a near-diffraction limit observation is obtained, see [17]. The fraction of images selected for each target depends on the atmospheric conditions, see [1].

FastCam, jointly developed by the Instituto de Astrofísica de Canarias (IAC) and the Universidad Politécnica de Cartagena (UPCT), is described in [23]. FastCam, routinely reaches the diffraction limit in the optical I band, as shown in [6] and [15].

AOLI is a new instrument designed to combine AO and LI techniques to reach close to diffraction limited imaging in the visible range. A wide description of the instrument and its subsystems can be seen in [26], [20], [18], [3] and [28].

4 LkHα 262/263

Among the potential PMS quadruple systems in the literature, LkHα 262 and LkHα 263, shown in Figures 1 and 2, are particularly interesting because they contain at least three early M-type stars and evidence for the presence of disks around several of them.

LkHα 262 and LkHα 263, in the MBM12 cloud, are particularly interesting objects because they may be composed of four very young M-type stars and some of the components are known to host discs [11]. The MBM12 molecular cloud was thought to be the nearest one to the Sun, at a distance of 58–90 pc [10]. However, further studies by [19] have proposed a much greater distance at 275 pc, which we will assume in this paper.

LkHα 263 (02h 56m 8.433s, +20° 03' 38.63") is a triple T Tauri system with its primary and secondary stars tentatively classified as M-type [19], [22], and with a separation of 0.41 arcsec. The third fainter component C lies at 4 arcsec north-east from AB. This component C is an M0-type star hosting an optically thick edge-on disc, which was discovered with near-IR adaptive optics observations [14]. LkHα 262 (02h 56m 8.00s, +20° 03' 24.2"), is another T Tauri M0-type star [10], [13] 15 arcsec south-west of LkHα 263. The possibility of LkHα 262/263 being part of the same system was already discussed in [2], but it had not been demonstrated.

To investigate further the nature of LkHα 262/263 and, in particular, to study whether these two systems are linked, we performed optical high spatial resolution observations during the first commissioning of the Adaptive Optics and Lucky Imager (AOLI) at the 4.2-m William Herschel Telescope (Roque de los Muchachos Observatory, La Palma).

5 First results

The LkHα 262/263 system was observed on the night of September 24 with AOLI in the standard *i'* band (769.5 nm central wavelength, 137 nm full width at half-maximum). Both LkHα 262 and 263, were located within the FOV of the first 1024×1024 EMCCD detector of the AOLI science camera.

We obtained 4600 individual images with an exposure time of 50 ms, giving a total on-source observation time of 230 s. Using a standard LI algorithm [16], only 10 per cent of the images were selected for building the final image. In each frame both targets LkHα 262 and 263 were included. We chose the brightest pixel in the speckle of LkHα 262 for the shift-and-add algorithm as the contamination between LkHα 263 A and B due to their proximity renders them less adequate as LI reference stars. A very small fraction of individual frames exhibiting saturated pixels (due either to cosmic rays or spurious electronic events) was removed.

We have also combined this data with observations from other telescopes, performed by us or available at the archives.

Table 1: Photometric data and spectral classification of the LkHα 262-3 system.

Object	*i'*	*J*	*H*	K_s	*i'*-*J*	Spectral type
LkHα 262	12.5±0.1^a	10.5±0.1^c	10.3±0.1^d	9.6±0.1^d	2.0±0.1	∼ M0/M1^f
LkHα 263AB	12.6±0.1 ^{a}					
LkHα 263A	13.4±0.1 ^{b}	11.52^e	10.64^e	10.21^e	1.91±0.10	∼ M0-M1^g
LkHα 263B	13.2±0.1^b	11.25^e	10.51^e	10.34^e	1.95±0.10	∼ M1-M2^g
LkHα 263C	17.6±0.2^b	16.5±0.15^e	16.0±0.15^e	16.1±0.3^e	1.12±0.25	∼ M0^h

^{a}Photometry obtained with ALFOSC (NOT) on September 2014; ^{b}From delta magnitude photometry measured with AOLI on September 2013 and applied to ALFOSC photometry; ^{c}Photometry obtained with CAIN at TCS on November 2014; ^{d}From 2MASS [24]; ^{e}Photometric values from [14] with Gemini-N telescope using AO on December 2000; ^{f}AS Given by [22]; ^{g}Based on table 3 from [9] from *i'*-*J* values; ^{h}Given by [14].

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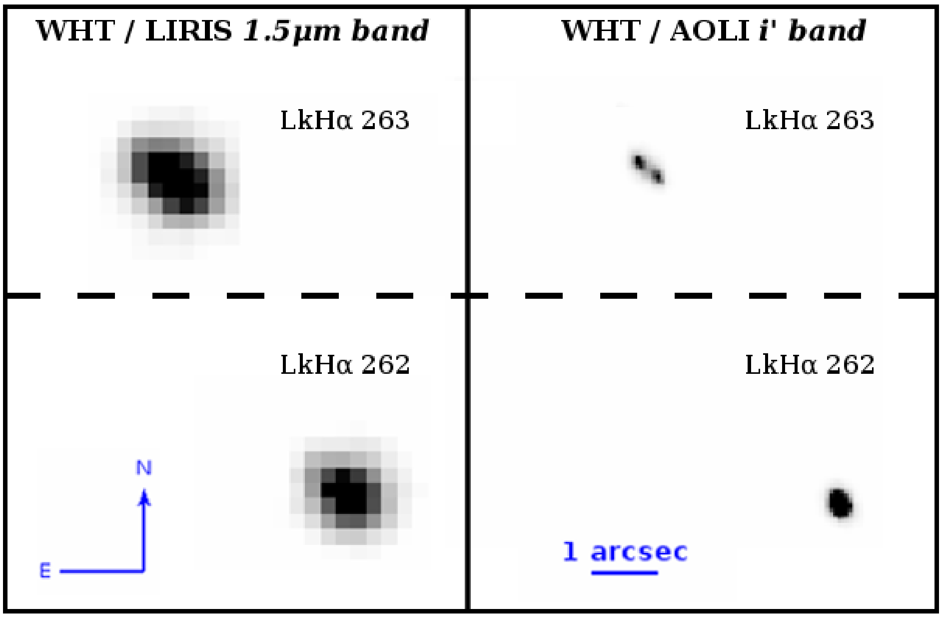

Figure 1: Left: LkHα 262 (south) and LkHα 263 (north) image taken with LIRIS at the WHT by PI B. Montesinos in 2009 in the 1.5 μ band (5 seconds integration time). Right: The same field as observed with AOLI. In this image, 10 per cent out of 4600 individual 50 ms frames were selected for lucky imaging processing. Components A and B of LkHα 263 are clearly resolved in the AOLI image. NOTE: Zig-zag line indicates that the empty space between LkHα 262 and 263 has been omitted. Scale has been preserved.

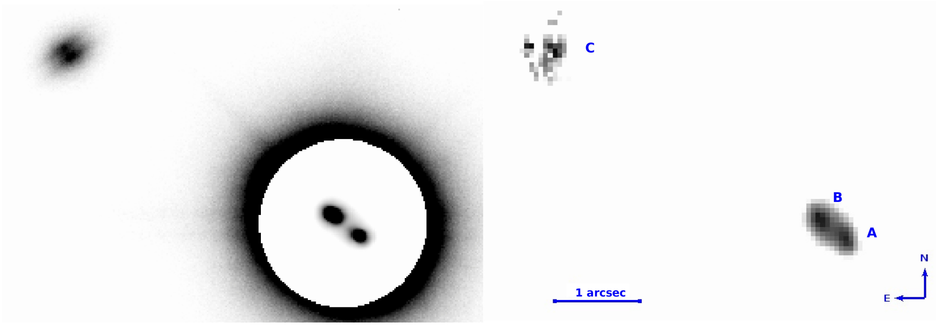

Figure 2: The LkHα 263 system. Left: image obtained by Jayawardhana et al. in 2000 (private communication). LkHα 263C is visible as a double disc. Right: image obtained with AOLI in 2013, LkHα 263C is visible together with LkHα 263AB. Both images are composites, the flux of component C has been enhanced while A and B have been lowered below the saturation level in order to show all three components in both epochs for a better comparison.