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Letter to the Editor

The birth of massive twins in M 17

R. Chini[1], **M. Nielbock**[1], **and R. Beck**[2]

[1] Astronomisches Institut der Ruhr-Universität Bochum, Universitätsstrasse 150/NA 7, 44780 Bochum, Germany
[2] Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany

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Abstract. We have imaged the ultra-compact H II region M 17-UC1 at J, K, N, Q and 1.3 cm. A comparison with results from earlier epochs reveals an increase of the emitted flux both in the mid-infrared and radio continuum. Our N and Q images exhibit a second source of comparable strength $5''$ southwest of M 17-UC1. While M 17-UC1 is not visible at J, faint at K but very bright at 1.3 cm, the second southern source shows rather opposite characteristics, namely being very bright at infrared wavelengths but invisible in the radio continuum, probably due to self-absorption. The spectral energy distributions indicate that the sources are still surrounded by the remnants of their protostellar cocoons. The observed luminosities measured between 1.2 and 20.0 μm of about $10^3 L_\odot$ for both sources leads to the conclusion that they represent the youngest population of early type stars in M 17. The projected linear distance of 8900 AU between M 17-UC1 and its southern companion qualifies them to be a likely binary star system of O or early B-type stars.

Key words: stars: formation – stars: fundamental parameters – stars: binaries: general – stars: circumstellar matter – infrared: stars – radio continuum: stars

1. Introduction

The Omega Nebula (M 17, NGC 6618) is a prominent site of current sequential formation of high mass stars. The chain of discoveries goes back to the first UBVRI observations by Chini et al. (1980), who found heavily reddened stars of type O to A. Later on, Chini & Krügel (1985, hereafter CK) discovered a number of *cocoon stars* which were still embedded in the relics of their cradles of circumstellar matter. Felli et al. (1980, hereafter FJC) investigated a radio source at the interface of the H II region and the molecular cloud M 17 SW and classified it to be an ultra-compact H II region (UCHII) now generally known as M 17-UC1 (G15.04-0.68), with a B0 – B0.5 star as its ionizing source. Observations of this region by Felli & Stanga (1987, hereafter FS) in the near- and mid-infrared (NIR, MIR) revealed one bright source apparently coinciding with M 17-UC1 and another region of emission, interpreted as a more extended area heated by the outer radiation field from the nearby OB association. Our own NIR and MIR observations of a long term imaging project of M 17 also covers the M 17-UC1 area and leads to significantly different results. The same is true for our re-observations with the VLA. The morphological and photometric differences between the present and previous epochs are the topics of the present paper.

Send offprint requests to: R. Chini
Correspondence to: chini@astro.ruhr-uni-bochum.de

2. Observations and data reduction

The observations were made in 3 stages. The NIR data (J, K) was collected with the 2.2 m telescope on Calar Alto, Spain in June, 1998 with the IR camera MAGIC. A detailed description of the observation and data reduction will be published separately (Manthey et al., in prep.). The calibration is expected to be accurate within 0.05 mag. By interpolating the coordinates from 30 GSC stars in the field, we estimate the positional uncertainty to be below $1''$.

The MIR images at N (10.5 ± 5.0 μm) and Q (20.0 ± 5.4 μm) were obtained at the 2.2 m telescope on La Silla, Chile from June 28th to July 02nd, 1997 with the IR array camera MANIAC (Böker et al. 1997). M 17-UC1 was included in an extended survey of M 17 SW covering about $17\square'$ and resulting in a mosaic of 133 single frames. Every single frame with a field of view (FOV) of $43\farcs1$ was produced by using chopping techniques with a chopper throw of $26''$ and its direction set to 137°, parallel to the scanning path. Apart from the object frames, also sky frames were taken at the begin and end of an observing run in order to cope with the sky background and to produce proper flats. Frames of infrared standard stars (e.g. IRTF Photometry Manual 1990, Gehrz et al. 1974, Hanner et al. 1984, Tokunaga 1984, Rieke et al. 1985) were taken for calibration purposes resulting in an accuracy of 25 % in N and 10 % in Q. The data was reduced and analyzed with MOPSI[1], which resulted in two maps at N and Q from which the detailed images of M 17-UC1 have been extracted. Their positioning was obtained by superimposing various morphological IR features (in

[1] MOPSI is a software reduction package for infrared and radio mapping data written by Robert W. Zylka (ITA Heidelberg / MPIfR Bonn, Germany).

Table 1. Photometry of M 17-UC1 and IRS 5S.

Source	Flux density [mJy]				
	J	K	N	Q	1.3 cm
M 17-UC1	< 2	20 ± 4	23376 ± 714	177846 ± 1781	228 ± 11
IRS 5S	5 ± 1	126 ± 23	13548 ± 315	215161 ± 18107	< 1

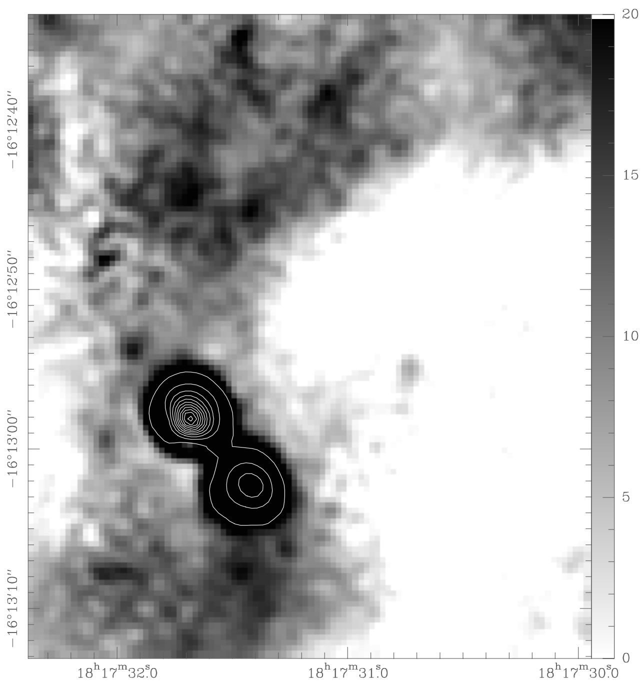

Fig. 1. M 17-UC1 at 10.5 μm. Contours indicate flux densities in steps of 10σ, beginning with 8σ.

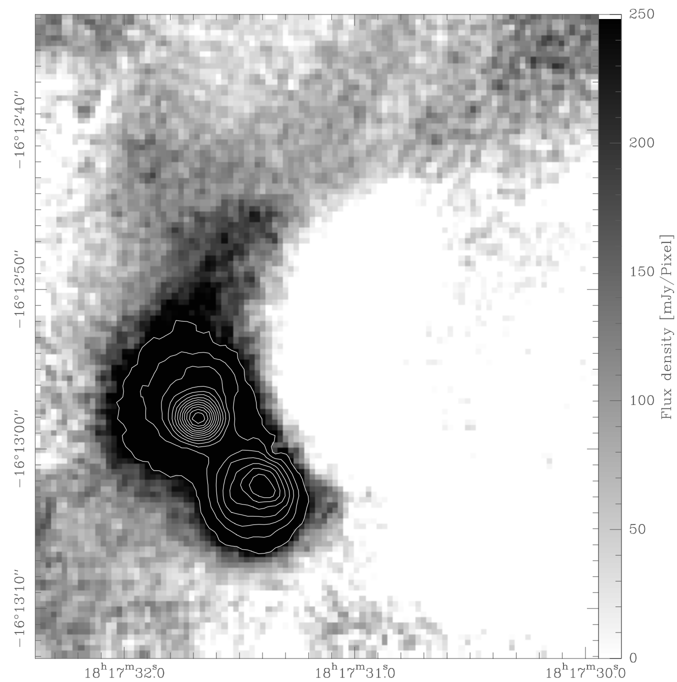

Fig. 2. M 17-UC1 at 20.0 μm. Contours indicate flux densities in steps of 5σ, beginning with 8σ.

particular the *Arc* as introduced by FJC) with the corresponding structures of the VLA map. From this procedure we can rule out almost any misalignment and estimate the position to be accurate by about $1''$.

The VLA observations were carried out on January 15$^{\rm th}$, 1999 in the C configuration at a wavelength of 1.3 cm. The HPBW of the synthesized beam is $1\farcs16 \times 0\farcs74$; the fit to M 17-UC1 yields $1\farcs17 \times 0\farcs78$, indicating that the source size is smaller than $0\farcs4$. The statistical errors of the flux calibration are below 1 %, the absolute uncertainty is 5%. Data reduction was performed with the AIPS software package.

As described in detail in Sect. 3, our MIR maps not only show M 17-UC1 but also another source orientated southwest from it which we call IRS 5S. The photometric results of these two sources are summarized in Table 1.

3. Morphology

Figs. 1 and 2 show the MIR images of the M 17-UC1 area at 10.5 and 20.0 μm and Fig. 3 the same region at 1.3 cm. An extended diffuse emission structure is visible in all images. It is referred to as *Arc* by FJC and FS. Apart from M 17-UC1 at $\alpha(1950) = 18^{\rm h}17^{\rm m}31\fs7$ and $\delta(1950) = -16°12'58''$, which is very faint at NIR wavelengths and clearly detected in the MIR and at 1.3 cm, we find a second compact IR source $5\farcs4$ to the southwest at $\alpha(1950) = 18^{\rm h}17^{\rm m}31\fs5$ and $\delta(1950) = -16°13'02''$, which is very bright at J,K, N and Q but does not have any counterpart in the VLA map (see Table 1). The described IR morphology differs significantly from the results of FS. While the diffuse emission region reported by FS is located approximately $5''$ southeast of M 17-UC1 our images clearly show a compact source $5\farcs4$ *southwest* of it. The relative orientation of M 17-UC1 and IRS 5S – our internal designation for the southern source – is indubitable correct and matches an early N-band image in 1995 with TIMMI at the 3.6 m telescope on La Silla and the ISOCAM images published by Crété et al. (1999).

In order to explain this discrepancy we may firstly assume that the diffuse structure to the SE of M 17-UC1 and IRS 5S are the same object and that the difference originates in a proper motion of the object between the epochs 1984 and 1997. With an adopted distance of M 17 of 1.6 kpc (Nielbock et al., in prep.) the displacement would run up to a linear distance of $1.3 \cdot 10^{14}$ m which implies an unrealistic velocity of $3\,100$ km/s. It is very striking that the morphology proposed by FS seems to appear mirrored in our images. The angular distances between the two southern sources and M 17-UC1 as well as their position angles

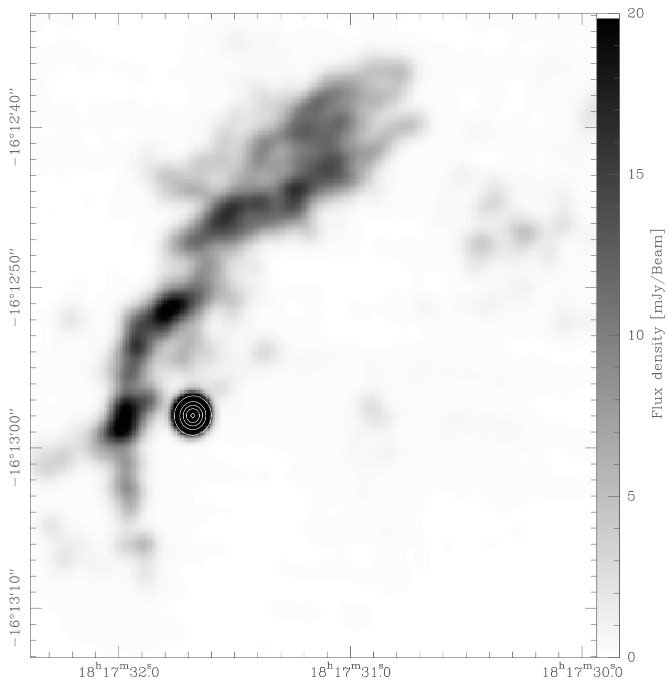

Fig. 3. M 17-UC1 at 1.3 cm. Contours indicate flux densities in steps of 50σ, beginning with 50σ.

are comparable. This might suggest that the difference could be simulated by an east-west flip of the MIR maps shown by FS. Unfortunately, an intensive discussion with Dr. Felli about this topic could not solve the problem because the original data cannot be accessed any longer.

The distance between M 17-UC1 and IRS 5S is only $8\,900$ AU (Figs. 1 and 2) and a sheer coincidence of their close position seems quite unlikely. We have mapped an area of about $17\Box'$ in total and did not find any similar strong MIR sources. Furthermore, extinction within M 17 SW of up to $A_V = 40$ mag (Chini & Wargau 1998, hereafter CW) rules out any background stars we might have picked up. Therefore, we suggest that both sources belong to a physically bound binary system of young high mass stars.

4. Properties

The evolutionary stage of the two sources can be estimated by calculating the infrared spectral indices $\alpha_{\rm IR}$ based on K, N and Q as proposed by Lada (1987). The derived values are listed in Table 2 and they qualify them to be Class I sources. The extreme positive numbers indicate a strong influence of circumstellar emission, i.e. both sources are still surrounded by cocoons and/or disks and therefore must be very young. The colour temperatures from N to Q derived by fitting a blackbody Planck-function vary between 140 and 165 K for both sources and agree well with dust shell model fits by Faison et al. (1998).

The observed luminosity for both sources is about $1000\ L_\odot$; however, due to the narrow spectral coverage and the unknown extinction the total luminosity must be considerably higher. FCM estimated from the measurements of the Lyman continuum photons that the ionizing source of M 17-UC1 should be a B0 – B0.5 star leading to a luminosity of $1.5 \cdot 10^4\ L_\odot$. This is consistent with the results of CK, who found that only 10 % of the total luminosity of the *cocoon stars* in M 17 is emitted below a wavelength of $20\ \mu$m. Faison et al. (1998) even fixed the corresponding stellar mass to $19.5\ M_\odot$ and radius to $8.3\ R_\odot$.

Table 2. Properties of the sources. Shown are spectral indices ($\alpha_{\rm K,N}$, $\alpha_{\rm K,Q}$), the observed luminosities between $\lambda = 1.2$ and $20\ \mu$m ($L_{\rm IR}$) and the linear dimensions of the sources at $\lambda = 10.5\ \mu$m adopting a distance of 1.6 kpc. Due to the diffraction limit, every feature with a linear extent below 2100 AU would appear as a point source.

Source	**Spectral Index**		$\mathbf{L_{IR}}$	**Morphology**
	$\alpha_{\rm K,N}$	$\alpha_{\rm K,Q}$	$[L_\odot]$	$D_{\rm maj} \times D_{\rm min}$ [AU]
M 17-UC1	3.52 ± 0.83	3.12 ± 0.32	< 960	3024×2560
IRS 5S	1.99 ± 0.34	2.37 ± 0.22	900	4480×4000

5. Brightness variations

In our J image we only see one point source coincident with IRS 5S, which was misinterpreted as M 17-UC1 in the past. So, the flux density measured in apertures of $3\farcs2$ and $7\farcs2$ by FS in 1984 of 4 mJy only refers to IRS 5S, which is comparable to the 5 ± 1 mJy derived by CW and was confirmed by recent observations in 1998. This leads to the conclusion that the southern source remained constant during the last decade.

Unsurprisingly, also at K IRS 5S was misidentified as M 17-UC1. FS derived 124 mJy ($3\farcs2$) and 134 mJy ($7\farcs2$), while CW measured a flux density of 146 ± 27 mJy in a $12''$ aperture. On our K images we can clearly discriminate between the sources and get 126 ± 27 mJy for IRS 5S and 20 ± 4 mJy for M 17-UC1. This demonstrates that the UCHII is very weak at NIR wavelengths, whilst its neighbour dominates the NIR emission with a constant flux density.

With this knowledge, we can now demonstrate the variability of M 17-UC1 at MIR wavelengths by comparing our results with previous ones. FS measured an N flux density of 10.6 Jy in a $3\farcs2$ aperture, while larger apertures increase that value considerably. In contrast, we derive 23.4 ± 0.7 Jy for M 17-UC1 in a $3\farcs2$ aperture, which means that the flux from the UCHII has doubled within 13 years! IRS 5S yields an N flux density of 13.5 ± 0.3 Jy.

Under the assumption that IRS 5S in our maps and the SE source in the maps by FS are identical we can perform another comparison by means of the slit scans done by FS. If we simply EW flip the maps by FS and normalize the scans to the southern source – a procedure that seems to be justified by the consistent NIR results – we find an increase of the peak flux of the UCHII by 50 % as shown in Fig. 4.

Similar arguments hold for the Q-band observations, although the waveband chosen by FS ($18.1 \pm 4.2\ \mu$m) does not match exactly ours. They measured 90.6 Jy in a $3\farcs2$ aperture centered on M 17-UC1, which doubles for a $7\farcs2$ aperture. We find 178 ± 1.8 Jy, again twice the value of FS; IRS 5S shows a Q-band flux density of 215 ± 18 Jy. By comparison with the

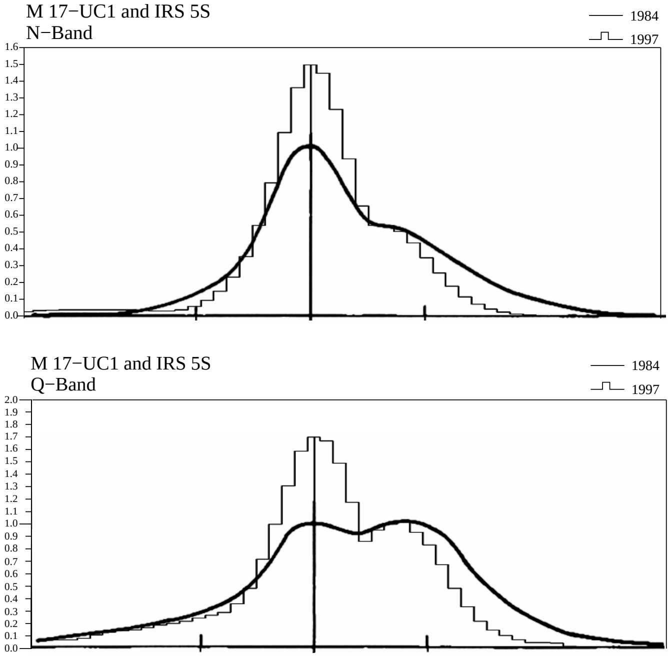

Fig. 4. Overlays of the slit scans by FS (bold curve, flipped in east-west direction) with cuts through our maps of the M 17-UC1 region (histogram). The flux densities are normalized to IRS 5S (located to the right).

slit scans of FS, the peak flux of the UCHII even increases by 70 % (see Fig. 4).

M 17-UC1 is a well studied object at radio wavelengths, especially at 1.3 cm. While FJC measured a flux density of 147 ± 7 mJy, a recent publication (Johnson et al. 1998) gives a value of 225 mJy which is almost identical with our result of 228 ± 11 mJy and implies an increase by 65 %. IRS 5S on the other hand does not show any radio emission.

The observed spectral appearance and the brightness variations may be explained by recent results of Testi et al. (1998). According to their scenario, IRS 5S is the youngest object in the region and most likely in its earliest stage of building an UCHII with an extent of $\ll 10^{-3}$ pc (200 AU). The hot dust accounts for the strong NIR emission but the radiation at radio wavelengths is strongly self-absorbed. When the source evolves towards a stage where the radius of the ionized volume becomes greater than $\approx 10^{-3}$ pc the dust temperature decreases as well as the NIR emission; simultaneously, the radio emission becomes detectable. Faison et al. (1998) determine an inner dust shell radius of $7.72 \cdot 10^{16}$ cm for M 17-UC1, which fits well into the present observations.

6. Conclusions

From infrared and radio observations we derive the following new results:

1. The ultra-compact H II region M 17-UC1 has significantly increased its emission at MIR and radio wavebands within the last 13 years. It is thus the first example of an ultra-compact H II region that shows an observable evolution.
2. M 17-UC1 does not seem to be an isolated massive star but is accompanied by an even younger high mass object (IRS 5S).
3. Both sources are in a similar stage of evolution, i.e. massive Class I sources, with IRS 5S being the younger twin of M 17-UC1 just beginning to create another ultra-compact H II region.

It will be interesting to monitor both sources at MIR and radio wavelengths in order to see the theoretically predicted evolutionary changes in flux and morphology.

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