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# Flows from young stars in the Serpens star forming region

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**Abstract.** We have surveyed an area of 3.15 □° in the Serpens star forming region with the Tautenburg Schmidt telescope in the [S II]$\lambda\lambda$6716,6730 lines searching for outflows from young stars. We find that the outflow activity is mainly concentrated on a region of about 15′ (1.3 pc) diametre around the Serpens Reflection Nebula (SRN). Here, we discovered six new groups of HH objects in addition to the already known HH 106/107, probably forming five or six independent outflows. Much further away from the SRN we observed two more outflows: a newly discovered object about 45′ south of the SRN near a group of nebulous stars, and the known HH 108/109, for which we present also near-infrared molecular hydrogen imaging. We discuss the potential exciting sources for the outflows in the Serpens dark clouds, and the connection between optical HH objects and molecular hydrogen knots observed in this region. We also note that there is only one parsec-scale flow seen among then HH flows in Serpens. We interpret this as the flows breaking rapidly out of their dense parental clouds into the very tenuous surroundings, in which no further shock excitation of the true terminal working surfaces can take place.

**Key words:** stars: formation – stars: winds, outflows – ISM: Herbig-Haro objects – ISM: jets and outflows

## 1. Introduction

Outflows from young stars are an important ingredient in the star formation process. Through their momentum input into the surrounding medium they may have a major impact on the evolution of their parental molecular clouds. They could support these clouds against further collapse, but in many cases more likely will even disperse them with time. It is therefore important to find out how many outflows are active in a certain cloud.

So far, most of the searches for outflows concentrated on single sources that were known to exhibit outflow signatures in their spectra (e.g., Mundt & Eislöffel 1998). Such searches among pre-selected sources are, however, highly biased in several ways. Therefore, surveys of whole star forming clouds are necessary for a better census of the outflow activity. Recently, several such surveys for outflows have been carried out, following two different approaches: some surveys have searched for molecular hydrogen emission from outflows in the near-infrared 1-0 S(1) line at 2.12 $\mu$m (NGC 1333: Hodapp & Ladd 1995; L1641N: Stanke et al. 1998). Other surveys have been done in the optical [S II]$\lambda\lambda$6716,6730 lines or H$\alpha$ (NGC 1333: Bally et al. 1996; the $\rho$ Oph dark cloud: Wilking et al. 1997, Gómez et al. 1998; L1641N: Reipurth et al. 1998).

While searches in the near-infrared are less susceptible to extinction, searches in the optical can cover larger areas more rapidly because of the vastly larger fields of view of optical wide field imagers as compared to near-infrared cameras. Moreover, even deeply embedded molecular $H_2$ outflows, like L1448 (Eiroa et al. 1994) or Cep E (Noriega-Crespo 1997) show optical [S II] emission at some distance from the source, where the extinction is lower.

Serpens is a nearby (310 pc, DeLara et al. 1991) star forming region, which has received considerable attention, because a large number of young and very young sources have been found there. Especially the striking Serpens Reflection Nebula (SRN) has attracted attention, and the stellar content of its embedded cluster has been studied at optical (Gomez de Castro et al. 1988), near-infrared (Eiroa & Casali 1992, Giovannetti et al. 1998), and mm-wavelengths (Chini et al. 1997; Reipurth et al. 1993). Recently, it has also been mapped with mm-interferometry (Testi & Sargent 1998). Apart from the stellar sources, a poorly defined molecular CO outflow has been found in the region of the SRN (Bally & Lada 1983). Subsequent observations at higher spatial resolution (White et al. 1995) showed that this is not a single flow, but in fact a superposition of several CO outflows. Consequently, the region around the SRN has also been mapped in the near-infrared 1-0 S(1) line of molecular hydrogen at 2.12 $\mu$m (Eiroa et al. 1997; Herbst et al. 1997; Huard et al. 1997), and a $H_2$ jet from the Class I source CK 8, as well as a large number of other $H_2$ emission features were found.

The region covered by these near-infrared observations also includes two other interesting objects: firstly, the enigmatic Serpens triple radio source (Rodríguez et al. 1980). This source consists of a VLA radio continuum source, and a remarkable non-thermal bipolar radio jet with knots moving at high proper motions (Rodríguez et al. 1989, Curiel et al. 1993). Secondly, a strongly variable young stellar object has been found about one

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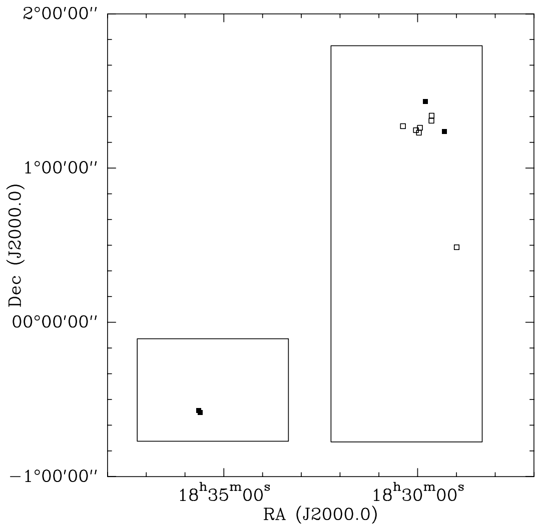


**Fig. 1.** Field of the survey region in Serpens. Newly found Herbig-Haro objects are marked by open squares, while previously known HH objects are marked by filled squares.

arcmin north of the radio source, which seems to have undergone an EXor outburst (Hodapp et al. 1996).

In a search on a red Schmidt plate and with follow-up CCD imaging in the H$\alpha$ line Reipurth & Eiroa (1992) found four Herbig-Haro objects HH 106 to 109 in Serpens, all situated further away from the SRN than the sources discussed so far. All this evidence for ongoing star formation and outflow activity has prompted us to carry out a large-scale search for HH objects and flows from young stars in Serpens.

Our observations are described in Sect. 2. In Sect. 3 we present the HH objects found in our survey, while in Sect. 4 we discuss possible sources for these HH objects and identify several extended flows.

## 2. Observations

Our survey observations of a 3.15 □° region in Serpens were carried out at the Tautenburg Schmidt telescope in June/July 1997. A CCD camera with a TEK TK1024A chip was installed in the Schmidt focus. With a sensitive area of 1024 × 1024 pixels of 24 $\mu$m on one side each, the CCD yielded a pixelscale of 1.233 arcsec/pixel and a field of view of 21.0 × 21.0 arcmin$^2$. For the survey, slightly overlapping exposures of 1200 sec were taken through a [S II]$\lambda\lambda$6716,6730 filter ($\lambda_c$ = 6729 Å, $\Delta\lambda$ = 100 Å). They were included between two exposures in the I-band of 180 sec each. The frames were reduced using standard procedures in IRAF, and mosaiced. The total field surveyed is shown in Fig. 1.

A higher-resolution image of HH 107 was obtained at the UH 88inch telescope with a tip-tilt secondary on 30. June 1997. Here, a TEK CCD with 2048 × 2048 pixels was employed, with 0.072 arcsec/pixel scale. An exposure of 3600 sec through a [S II] filter gave an image with a spatial resolution of 0.7 arcsec (FWHM).

**Table 1.** Coordinates of HH objects in our survey region in Serpens.

| Name | RA (J2000) | Dec (J2000) |
|---|---|---|
| HH 106 A | 18:29:18.8 | 1:14:17 |
| HH 106 B | 18:29:19.0 | 1:14:16 |
| HH 106 E | 18:29:18.7 | 1:14:10 |
| HH 106 F | 18:29:19.6 | 1:14:22 |
| HH 107 A | 18:29:47.7 | 1:25:52 |
| HH 108 A | 18:35:36.2 | −0:35:10 |
| HH 108 B | 18:35:36.6 | −0:35:10 |
| HH 108 C | 18:35:37.0 | −0:35:07 |
| HH 108 D | 18:35:36.8 | −0:34:59 |
| HH 108 E | 18:35:37.4 | −0:34:51 |
| HH 109 A | 18:35:38.9 | −0:34:22 |
| HH 109 B | 18:35:38.1 | −0:34:20 |
| HH 455 A | 18:30:22.7 | 1:16:18 |
| HH 455 B | 18:30:22.4 | 1:16:07 |
| HH 455 D | 18:30:20.8 | 1:16:01 |
| HH 455 E | 18:30:18.7 | 1:15:41 |
| HH 455 F | 18:30:18.5 | 1:15:36 |
| HH 458 A | 18:29:58.0 | 1:13:45 |
| HH 458 B | 18:29:58.1 | 1:13:42 |
| HH 459 A | 18:30:02.6 | 1:14:44 |
| HH 459 B | 18:30:02.7 | 1:14:48 |
| HH 460 A | 18:29:38.7 | 1:18:23 |
| HH 460 B | 18:29:38.6 | 1:18:31 |
| HH 460 C | 18:29:38.1 | 1:18:32 |
| HH 460 D | 18:29:39.2 | 1:18:19 |
| HH 476 | 18:28:59.5 | 0:29:13 |
| HH 477 | 18:29:38.3 | 1:20:24 |
| HH 478 A | 18:29:56.5 | 1:15:41 |
| HH 478 B | 18:29:56.7 | 1:15:34 |

The HH 108/109 region was also imaged in the 1-0 S(1) line of molecular hydrogen at 2.12 $\mu$m and in the K-band on 11. April 1993 at the ESO/MPI 2.2m telescope. We used IRAC-2, the facility IR camera with a Rockwell NICMOS3 HgCdTe detector of 256 × 256 pixels and a scale of 0.5 arcsec/pixel. A grid of 16 shifted exposures of 20 sec integration time each was obtained in the 1-0 S(1) line of $H_2$. After standard reduction these frames were mosaiced to a final depth of 320 sec around HH 108/109.

## 3. Results

In our survey for flows from young stars in Serpens we find that the outflow activity concentrates on three regions of dark clouds (see Fig. 1). Apart from the known HH objects 106 to 109 (Reipurth & Eiroa 1992), which are marked by filled squares in Fig. 1, we find seven new HH objects there (marked by open squares). Coordinates for many of the knots in all of these HH objects are given in Table 1. They should be accurate to about 1''.

The most active centre of outflow activity is situated in a region of about 15' diametre around the Serpens Reflection Nebula (SRN). A [S II] image of this region is shown in Fig. 2. Six of the new HH objects are found here, apart from the known HH 106 and HH 107. HH 477 is a faint elongated knot in a region of

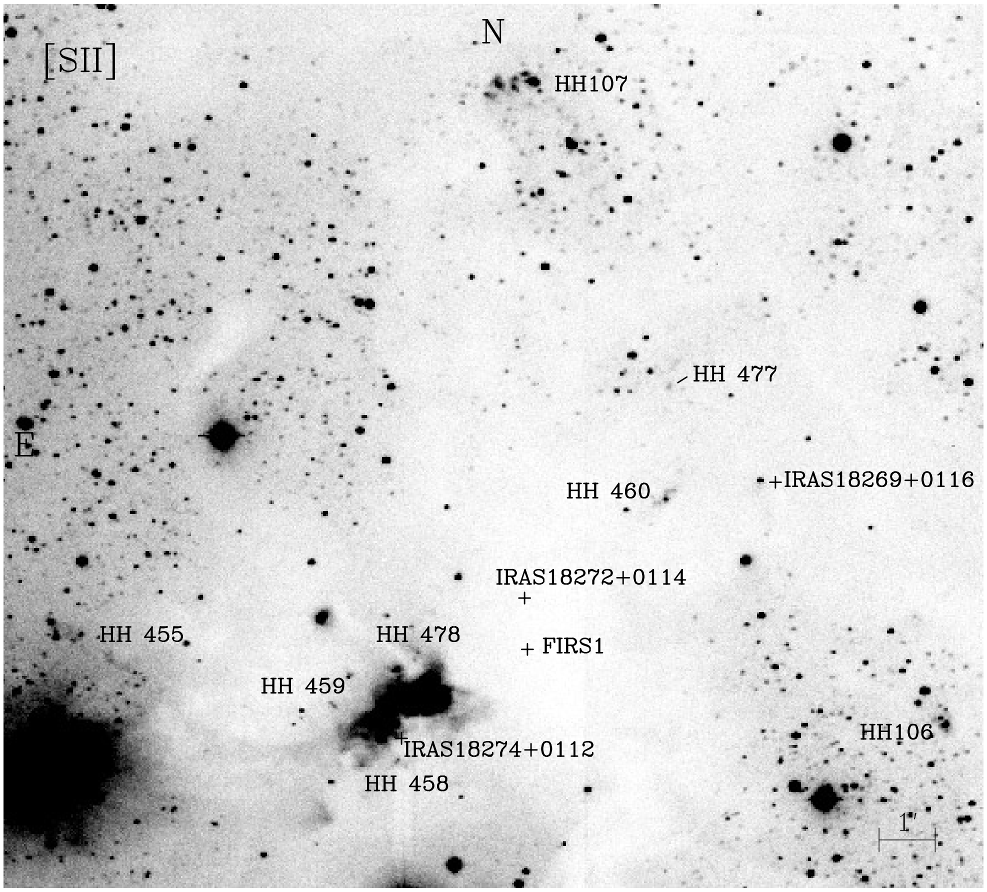


**Fig. 2.** Deep [S II] image of the field around the Serpens Reflection Nebula. Several new HH objects are found in this region of active star formation.

lower extinction. Its position roughly halfway between HH 106 and HH 107 could indicate that it belongs to a flow formed by these two objects. Without knowledge about its kinematics, it cannot be ruled out, however, that it is part of an independent flow.

HH 460 also is an elongated object. It consists of a bright central condensation (knot A) and three fainter knots southeast and northwest of it (see also Fig. 3). About 6.′5 southeast of HH 460 we find another object, HH 458, which consists of two concentrated knots that are in turn aligned with HH 460. In fact, several knots detected in molecular hydrogen by Eiroa et al. (1997) and Herbst et al. (1997), and marked S4, S6, S7 in Fig. 3 following the nomenclature of Herbst et al., are found on the axis through HH 460 and HH 458. The alignment of so many objects makes it very likely that they belong to a common source (see also below).

HH 478 is a group of two knots north of the SRN. These knots are separated about 10″, and are pointing in a northwesterly direction. They do not seem to be associated with any of the other objects around. HH 459 also consists of two knots northeast of the SRN, which point in a northeasterly direction.

HH 455 is a collimated flow east of the SRN. It appears at the edge of the dark cloud from a region of high extinction. Fig. 4 shows several condensations that stretch over at least 2 arcmin and end in the bright knot A in more detail. A faint filament seems to reach backwards from the point where the flow appears at the edge of the cloud towards a diffuse arc-shaped nebula, seen in the lower right corner of Fig. 4. Although our coadded mosaic has a total integration time of 200 min in [S II] and of 40 min in the I-band in this part of the image, its S/N is not high enough to decide with confidence if this faint filament is [S II] emission, and hence part of the flow pointing towards its origin, or if it is just a filament of the dark cloud.

In Fig. 5, we present a high resolution image of HH 107, and in the inset an image of HH 106. These two HH objects probably are the opposite terminal bow shocks of a single flow, as was already suspected by Reipurth & Eiroa (1992). HH 107 shows several concentrated and bright knots, especially in its western wing, as well as faint extended structures on its eastern side. It appears as a bow shock broken up due to instabilities, much like HH 2 (Hartigan et al. 1987; Solf & Böhm 1991; Eislöffel et al. 1994). HH 106, which appears to be the counter bow shock to HH 107, consists of several knots of greatly varying brightness. Note that its structure in our [S II] image (inset in Fig. 5) is somewhat different from the H$\alpha$ image presented by Reipurth & Eiroa (1992)(their Fig. 1). While the complex formed by knots A, B and C looks rather similar in [S II] and H$\alpha$, their bright H$\alpha$ knot D is not detected in [S II] at all. A star is visible in this place, however, in our deep I-band mosaic. Knot E, 6.″5 south of knot A, on the other hand, is much better seen in [S II], and also the faint [S II] knot F, about 13″ northeast of A was not detected in H$\alpha$.

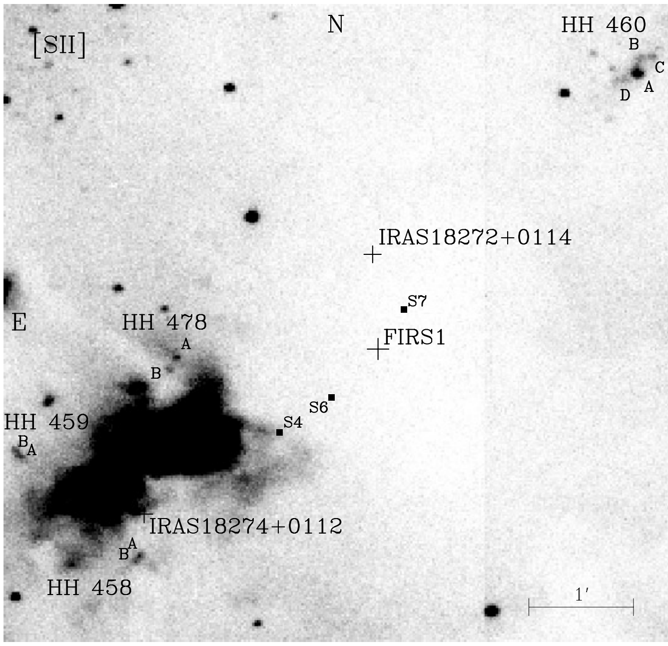


**Fig. 3.** Higher contrast [S II] image of the field around the Serpens Reflection Nebula. Newly discovered HH knots are named. Molecular hydrogen emission objects, which may form flows together with the optical knots, are marked by squares and Sx numbers (see also text).

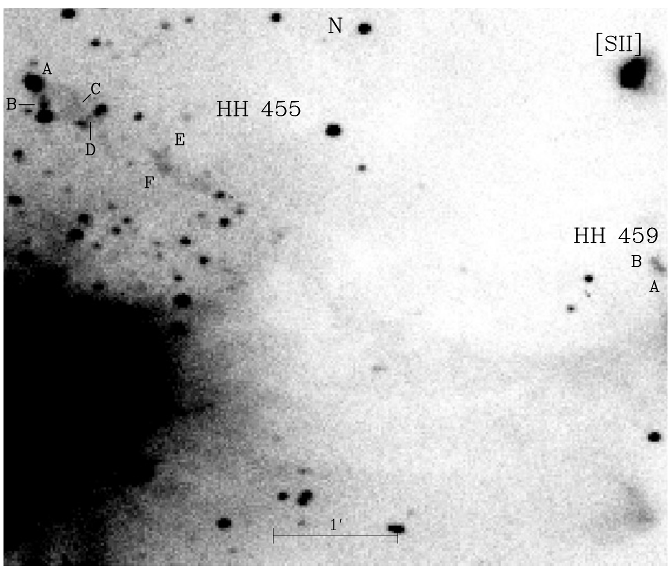


**Fig. 4.** Higher contrast [S II] image of the newly discovered HH 455 flow, east of the Serpens Reflection Nebula. The diffuse, arc-shaped nebula in the lower right corner might harbour the outflow source.

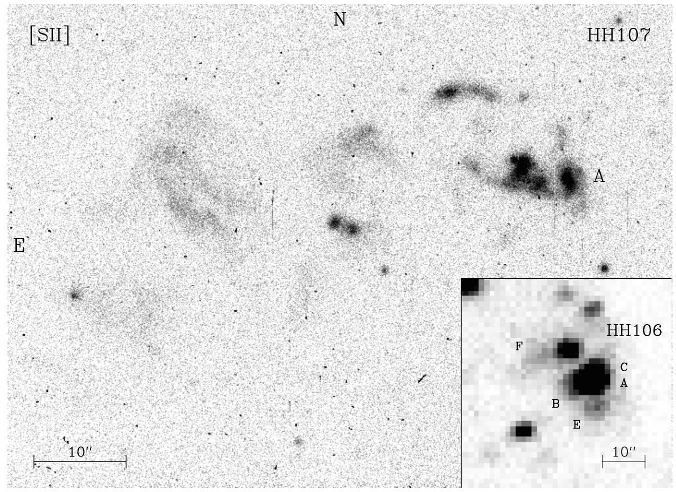


**Fig. 5.** Higher spatial resolution [S II] image of the HH 107 bow shock taken at the UH88inch telescope with a tip-tilt secondary. This bow shock has broken up into many condensations and filaments. The inset shows HH 106, the likely counter bow shock to HH 107 in [S II].

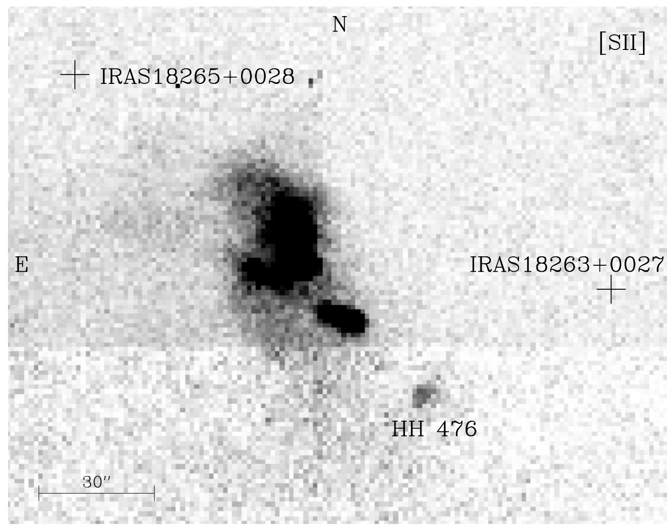


**Fig. 6.** [S II] image of the newly discovered HH object HH 476, which is situated southwest of a group af stars embedded in nebulosity.

A second region of outflow activity in our survey field is located about 45′ south of the SRN. Here, we find the new HH object HH 476 (Fig. 6). This bow-shaped object is located southwest of a group of stars embedded in nebulosity. A second, smaller such nebulosity about 2′ further east and two IRAS sources in this field may be further evidence for ongoing star formation in this region.

A filamentary dark cloud about 2° southeast of the SRN is the origin of HH 108 and HH 109(Fig. 7). These objects have already been observed by Reipurth & Eiroa (1992) in H$\alpha$. Here, we present images in the [S II]$\lambda\lambda$6716,6731 line and in the near-infrared 1-0 S(1) line of molecular hydrogen at 2.12 $\mu$m. In [S II], HH 108 consists of a group of bright knots A/B/C, which are followed by two much fainter knots D and E to the northeast. The optical knots A and C have counterparts in $H_2$, which are connected by a faint bridge of emission. As in the optical, knot A is much brighter than C also in $H_2$. The fainter optical knots of HH 108 are invisible in our $H_2$ image. In HH 109 two diffuse knots A and B are seen in [S II]. In $H_2$ also two knots are visible. The northern one is the brighter of the two, and is situated just south of a star. This star must suffer a high extinction, because it is visible only in the IR images, but not in our optical im-

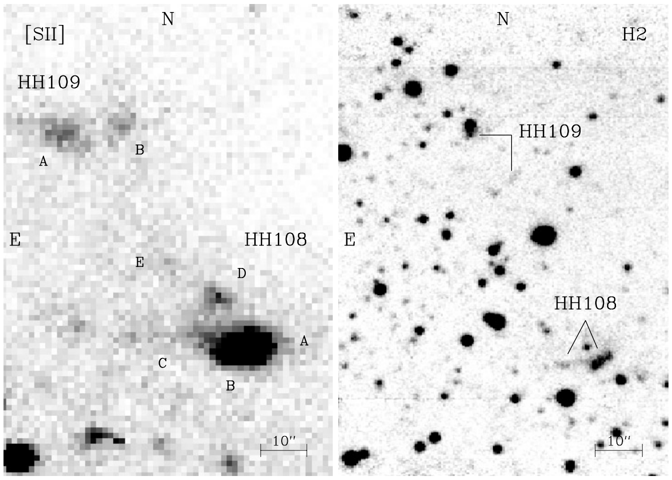


**Fig. 7.** *Left:* [S II] image of the bow shocks HH 108 and HH 109 in the southeastern part of our survey region. *Right:* The same region in the 1-0 S(1) line of molecular hydrogen at 2.12 $\mu$m. Here, the objects show a very different morphology.

ages. This northern knot turns out to be identical with the [S II] knot B. Consequently, the fainter southern $H_2$ knot is situated approximately half-way between HH 109 B and HH 108 D, and supports the notion that these two HH objects belong to the same flow. The optical knot A of HH 109 has no counterpart in $H_2$.

## 4. Discussion

### *4.1. Exciting sources*

For a discussion which of the newly found HH objects belong to what HH flows it may be important to look for their potential exciting sources first. Since these young stellar objects must possess active accretion disks and may still be deeply embedded they are interesting objects in their own right. At the distance of 310 pc to the Serpens dark clouds some of the exciting sources could have been detected as IRAS point sources. Therefore, we have plotted all those IRAS sources that could be potential exciting stars of outflows in our figures.

Turning to the HH objects near the SRN, we note that HH 460 and HH 458 are both in very good alignment with the molecular hydrogen knots S4, S6, and S7 (see Herbst et al. 1997). Also the Serpens triple radio source and the Serpens FIRS 1 source (IRAS18273+0113) are lying very close to this line. Therefore, it seems very likely that FIRS 1 is the exciting source of both HH objects, as well as of the radio jet and $H_2$ knots. The orientation of the two knots of HH 478 suggests that the source should be in the SRN. There, a molecular hydrogen jet emanating from the source CK 8 (= GEL 18 = EC 105) has been discovered recently by Eiroa et al. (1997), Herbst et al. (1997), and Huard et al. (1997). Indeed, the knots of HH 478 are lying on the axis of this jet and have a very similar position angle of about 340 °. Therefore, we consider it very likely, that CK 8 is also the source of HH 478. The orientation of the two knots in HH 459 again points to an origin of this flow in the southern part of the SRN. With a position angle of about 32° GEL 14 (= EC 92) and CK 6 (= GEL 15 = EC 117) are both not far away from the flow axis. Eiroa & Casali (1992) note that GEL 14 has an infrared excess, while for CK 6 they report that it is associated with nebulosity. Both notes would support the idea that the respective star could be an HH exciting source. Since the two knots in HH 459 are close to each other, and therefore their position angle is rather poorly defined, it is not possible from our data to decide which of these two young stellar objects is the outflow source, or if it is another embedded object in this region.

No IRAS source has been detected along the rather well-defined flow axis of the HH 455 flow. The arc-shaped nebula seen in the lower right corner of Fig. 4 lies, however, on this axis. Since many sources of HH flows have such arc-shaped nebulae around them, we suggest this object as a potential exciting source for HH 455.

The morphology of the two bow shocks pointing in opposite directions suggests that HH 106 and HH 107 may form a single flow, with their exciting source somewhere between them. IRAS18269+0116 is situated about halfway between the two HH objects, and has therefore been identifed as the potential exciting source by Reipurth & Eiroa (1992). It seems to be identical with the H$\alpha$ emission line star ESO H$\alpha$ 279 (Aspin et al. 1994). This source has an upper limit to its FIR luminosity of 5 $L_\odot$. It has been mapped by Chini et al. (1997) in the continuum at 1.3 mm, and has been found to be rather extended. We conclude that IRAS18269+0116 is indeed a very good candidate for the exciting source of HH 106/107.

For HH 476, there are two nearby IRAS sources, IRAS18265+0028 and IRAS18263+0027. They are about 2′ to the northeast and 1′ to the northwest of the HH object, respectively. Because of their small distance from each other, the IRAS 60 and 100 $\mu$m fluxes for both sources are confused, and the 100 $\mu$m flux is given as an upper limit. Therefore, the FIR luminosities of 12.6 $L_\odot$ and 11.4 $L_\odot$ are upper limits. We consider it more likely, however, that the exciting source of HH 476 is one of the stars in the nebulous cluster just northeast of this HH object. Infrared or mm-observations would be necessary to check our supposition.

Because of their morphology of aligned bow shocks, HH 108 and HH 109 probably belong to the same flow and have a common source. IRAS18327-0035, about 72″ northeast of HH 109 is lying on the axis through the two bows, and has already been suggested as the likely source by Reipurth & Eiroa (1992). Chini et al. (1997) have mapped the region around IRAS18327-0035 in the mm-continuum, and found two sources, however, a brighter one centred on the IRAS source and a fainter one 71″ to the northeast. Since both mm-sources are lying on the axis through the HH 108/109 bows it cannot be decided at the moment which of the two is the exciting source of this outflow.

For all new and known HH objects in Serpens potential outflow sources could be found (except for HH 477 in case it does not belong to the HH 106/107 flow). In some cases it is not possible to decide between several candidate sources from our data. Near-infrared observations of embedded $H_2$ knots, interferometric studies of the CO outflows in the vicinity of the sources, or kinematical studies in the optical will be necessary to uniquely identify the exciting sources for all the flows.

### 4.2. *Outflows in Serpens*

The comparison of our optical observations with $H_2$ imaging, and the search for potential exciting sources is allowing us now to study in more detail the outflows that our 7 new and the 4 known HH objects in Serpens may form. We think that in total we are seeing 7 or 8 different outflows now. One is formed by HH 106 and HH 107. Since it is lying close to the axis between these two bows, HH 477 could also belong to this outflow. The two sides of this flow from IRAS18269+0116 to the bows extend over 500″ to the north and 330″ to the south, or 0.75 pc and 0.49 pc at a distance of 310 pc to Serpens, respectively, making this the longest known flow in Serpens. The second longest flow, emanating from FIRS 1 seems to be formed by HH 460 on the northwestern side and HH 458 on the southeastern side. The Serpens non-thermal radio jet and the $H_2$ knots S4, S6, S7 (Herbst et al. 1997) also belong to this flow. It extends over 235″ to the northwest and 185″ to the southeast, or 0.35 pc and 0.28 pc, respectively. HH 478, as the bow shock of the CK 8 jet, brings this flow to a length of 100″ or 0.15 pc. For the four other flows, sources are not well established. The HH 108/109 flow could have a length of 145″ or 0.22 pc if IRAS18327-0035 was its exciting source, or of 210″ (0.31 pc) if it was emanating from the second mm-source found by Chini et al. (1997). The HH 455 flow, which is seen over 100″ (0.15 pc) could have a length on one side of 375″ (0.56 pc) if its source was at the tip of the bow-shaped nebula seen in the lower right corner of Fig. 4, and the HH 459 flow would stretch over about 70″ (0.10 pc), if its source was near CK 6 or GEL 14.

With one exception all the observed flows in Serpens have lengths of 0.1 to 0.5 pc on one side. Assuming an average jet velocity of 200 km $s^{-1}$, these lengths translate into kinematical ages of only 500 to 2500 years. Hence, they seem to be much younger than, e.g. the parsec-scale jets observed in Orion (e.g., Eislöffel & Mundt 1997). These jets reach kinematical ages of far more than 10000 years. Please note, that because of our very large survey area, we would not have missed optically visible bow shocks even if they were more than 15′ (1.4 pc) away from any of the HH objects discussed here. Therefore, the observation of mostly short jets could hint at very recent star formation in Serpens.

On the other hand, we note that most dark clouds and filaments in Serpens seem to be quite opaque and exhibit rather sharp edges. Almost all of the HH objects in Serpens appear (in projection) just beyond the edges of these clouds and filaments. It is therefore conceivable that the flows can neither be seen inside the clouds in the optical because of high extinction, nor can they be seen much beyond the sharp edges of the dark clouds, because the density of matter drops rapidly, and there is no material left further away from the surfaces of the clouds that could be shocked and light up the true terminal working surfaces of the outflowing gas. In this case the flows could be much longer and older than the kinematical ages from our optical observations indicate. Molecular CO mapping of the outflowing gas should be able to test this hypothesis, because outflowing bullets of CO gas can still be excited far beyond the cloud edges, as observed in HH 111 by Cernicharo & Reipurth (1996).

## 5. Conclusions

We have carried out a survey of 3.15 □° in the Serpens star forming region with the Tautenburg Schmidt telescope in the [S II]$\lambda\lambda$6716,6730 lines to search for outflows from young stars. We find a region of strong outflow activity centred on the Serpens Reflection Nebula (SRN), as well as two other outflows far away from the SRN. In a region of about 15′ (1.3 pc) diametre around the SRN, we discovered six new groups of HH objects in addition to the already known HH 106/107. Five groups of knots (HH 106/107, HH 460/HH 458, HH 478), together with several molecular hydrogen knots observed by other authors, we can assign to three independent outflows, and identify very likely exciting sources for them. For two more new groups of knots (HH 459, HH 455) from two other outflows we suggest more speculative exciting sources. Also for the two outflows far away from the SRN (HH 108/109, HH 476) no unique assignment of the source is possible so far.

Measuring the lengths of the HH flows in Serpens from their probable or potential sources, we find that with the exception of the parsec-scale flow HH 106/107 they all have lengths of 0.1–0.5 pc. Hence, their small kinematical ages of only 500 to 2500 years could hint at very recent star formation in Serpens. We suggest, however, that the flows are so short because they are rapidly breaking out of their dense parental clouds into very tenuous surroundings (as evidenced by the sharp edges of the dark clouds and filaments in Serpens), in which no further shock excitation of the terminal working surfaces of the flows can take place.

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## References

Aspin C., Reipurth B., Lehmann T., 1994, A&A 288, 165
Bally J., Lada C.J., 1983, ApJ 265, 824
Bally J., Devine D., Reipurth B., 1996, ApJ 473, L49
Cernicharo J., Reipurth B., 1996, A&A 460, 57
Chini R., Reipurth B., Sievers A., et al., 1997, A&A 325, 542
Curiel S., Rodríguez L.F., Moran J.M., Cantó J., 1993, ApJ 415, 191
DeLara E., Chavarria K.C., Lopez-Molina G., 1991, A&A 243, 139
Eiroa C., Casali M.M., 1992, A&A 262, 468
Eiroa C., Miranda L.F., Anglada G., Estalella R., Torrelles J.M., 1994, A&A 283, 973
Eiroa C., Palacios J., Eislöffel J., Casali M.M., Curiel S., 1997, IAUS 182, 103
Eislöffel J., Mundt R., 1997, AJ 114, 280
Eislöffel J., Mundt R., Böhm K.H., 1994, AJ 108, 1042
Giovannetti P., Caux E., Nadeau D., Monin J.-L., 1998, A&A 330, 990

Gómez M., Whitney B.A., Wood K., 1998, AJ 115, 2018
Gomez de Castro A.I., Eiroa C., Lenzen R., 1988, A&A 201, 299
Hartigan P., Raymond J., Hartmann L., 1987, ApJ 316, 323
Herbst T.M., Beckwith S.V.W., Robberto M., 1997, ApJ 486, L59
Hodapp K.W., Ladd E.F., 1995, ApJ 453, 715
Hodapp K.W., Hora J.L., Rayner J.T., Pickles A.J., Ladd E.F., 1996, ApJ 468, 861
Huard T.L., Weintraub D.A., Kastner J.H., 1997, MNRAS 290, 598
Mundt R., Eislöffel J., 1998, AJ 116, 860
Noriega-Crespo A., 1997, IAUS 182, 103
Reipurth B., Eiroa C., 1992, A&A 256, L1
Reipurth B., Devine D., Bally J., 1998, AJ 116, 1396
Reipurth B., Chini R., Krugel E., Kreysa E., Sievers A., 1993, A&A 273, 221
Rodríguez L.F., Moran J.M., Ho P.T.P., Gottlieb E.W., 1980, ApJ 235, 845
Rodríguez L.F., Curiel S., Moran J.M., et al., 1989, ApJ 346, L85
Solf J., Böhm K.H., 1991, ApJ 375, 618
Stanke T., Zinnecker H., McCaughrean M.J., 1998, A&A 332, 307
Testi L., Sargent A.I., 1998, ApJ 508, L91
White G.J., Casali M.M., Eiroa C., 1995, A&A 298, 594
Wilking B.A., Schwartz R.D., Fanetti T.M., Friel E.D., 1997, PASP 109, 549