PROTOSTARS AND STARS IN THE CORONET CLUSTER: AGE, EVOLUTION, AND CLUSTER STRUCTURE*

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ABSTRACT

We present new optical spectroscopy with the FLAMES spectrograph at the Very Large Telescope (VLT), near-IR imaging with VLT/HAWK-I, and 870 \( \mu \)m mapping with APEX/LABOCA of the Coronet cluster. The optical data allow us to estimate spectral types, extinction, and the presence of accretion in 6 more M-type members, in addition to the 12 that we had previously studied. The submillimeter maps and near-IR data reveal the presence of nebular structures and high extinction regions, which are in some cases associated to known IR, optical, and X-ray sources. Most star formation is associated to two elongated structures crossing in the central part of the cluster. Placing all the 18 objects with known spectral types and extinction in an H-R diagram suggests that the cluster is younger than previously thought (<2 Myr, and probably ~0.5–1 Myr). The new age estimate is in agreement with the evolutionary status of the various protostars in the region and with its compactness (<1.3 pc across), but results in a conflict with the low disk and accretion fraction (only 50%–65% of low-mass stars appear to have protoplanetary disks, and most transitional and homologously depleted disks are consistent with no accretion) and with the evolutionary features observed in the mid-IR spectra and spectral energy distributions of the disks.

Key words: protoplanetary disks – stars: formation – stars: late-type – stars: pre-main sequence

Online-only material: color figures

1 INTRODUCTION

The Coronet cluster (also known as CrA) is an obscured star-forming region, located at 170 pc (Knude & Hog 1998), associated with the Herbig Ae star R CrA (Taylor & Storey 1984) and a dense molecular core (Loren 1979). Submillimeter, millimeter, IR, and optical surveys (Henning et al. 1994; de Muizien et al. 1980; Wilking et al. 1985; Marraco & Rydgren 1981) found a few Herbig AeBe and T Tauri stars (TTS), suggesting a modest young stellar population of ~1 Myr in age. X-ray surveys using Einstein, XMM-Newton, ROSAT, and Chandra (Walter 1986; Walter et al. 1997; Neuhäuser et al. 2000; Hamaguchi et al. 2005; Garmire & Garmire 2003; Forbrich & Preibisch 2007), less affected by extinction, identified more than 70 sources consistent with young stars, many of which are deeply embedded, all located within a region a bit smaller than 1 pc in diameter. The presence of very embedded sources, including Class 0 objects, suggested a very young region (Henning et al. 1994; Chen et al. 1997; Chini et al. 2003; Groppi et al. 2004, 2007; Nisini et al. 2005; Nutter et al. 2005). Optical studies also revealed an important population of low-mass stars, characterized by strong H\( \alpha \) emission (López Martín et al. 2005). The variety of sources makes the small Coronet cluster a very special place: containing Class 0, I, II, and III objects, it seems to be a relatively quiescent cluster, part of a larger molecular cloud where star formation has occurred only in the densest parts.

Spitzer IRAC/MIPS data and IRS spectra revealed more than 100 low and very low mass sources, mostly Class I, II, and Class III objects, some of them highly extincted, constituting a very young and relatively rich cluster (Sicilia-Aguilar et al. 2008, hereafter SA08; Currie & Sicilia-Aguilar 2011). Remarkably, the IRS spectra of the disks around M-type cluster members (which are the bulk of the cluster members) reveal features that are usually accepted as signs of disk evolution: lack of silicate emission, spectral energy distributions (SEDs) consistent with flattened/settled disks, and very low or absent near-IR excesses characteristic of optically thin inner disk/inner holes (SA08). In addition, the estimated disk fraction is lower than expected for a young, embedded cluster, with only two-thirds of the stars being surrounded by protoplanetary disks. Moreover, recent membership searches (López Martín et al. 2010) have found additional diskless low-mass members, which would reduce the disk fraction to about 50%, a number more consistent with 2–4 Myr old regions than with a 1–2 Myr old cluster (Sicilia-Aguilar et al. 2006; Hernández et al. 2007; Fedele et al. 2010).

Here we present new Very Large Telescope (VLT)/FLAMES optical spectroscopy, deep IR imaging with VLT/HAWK-I, and an 870 \( \mu \)m map taken with the APEX/Large Apex Bolometer Camera (LABOCA) of the Coronet cluster. The data provide spectral types and accretion constraints for most of the remaining low-mass cluster members with moderate extinction, as well as a detailed image of the structures and substructures in the region with associated Class 0/I embedded sources. The data sets and reduction techniques are discussed in Section 2. Spectral types, accretion, extinction maps, and the cluster structure and embedded members are presented in Section 3. In Section 4 we discuss the age of the Coronet cluster based on the identification of Class 0/I/II/III sources and cluster structure, and finally our conclusions are presented in Section 5.

2 OBSERVATIONS AND DATA REDUCTION

2.1 VLT/FLAMES Optical Spectroscopy

A large number of members and potential members had been already observed with FLAMES on VLT Unit Telescope 2 (see SA08). The remaining candidates were done as part of ESO program 083.C-0079, following a similar scheme to our previous observations. The data were taken during five nights (2009 May...
24, and 2009 June 3, 17, 18, and 19), using FLAMES together with the multifiber spectrograph GIRAFFE and the MEDUSA fibers, which allow us to take up to 130 spectra, covering both objects and sky positions. We observed one field centered near the cluster center with three different, intermediate-resolution ($R \sim 5600$–8600) gratings (L682.2, L773.4, L881.7). The resulting spectra thus cover a large wavelength range from 6440 Å to 9400 Å, which includes the main accretion features (Hα, Ca ii), the Lithium I 6708 Å absorption line (indicative of youth), and a large number of photospheric features and absorption bands, required for a spectral type classification of M-type stars. We obtained $3 \times 2700$ s exposures with each filter, which ensures good removal of cosmic rays.

The target list included the potential members detected via X-ray (Garmire & Garmire 2003) that had not been observed in our previous run, together with a large number of sky positions (more than 70 in each one of the filters) to ensure a good background subtraction in this region with variable nebular emission. In addition, we also assigned fibers to potential Herbig–Haro (HH) objects in the cloud (Wang et al. 2004) and to the objects that, having been detected in our previous FLAMES observations, presented low signal to noise which made a spectral type classification difficult (especially the disked stars G-85 and G-87). In total, 12 sources were detected (see Table 1). The lack of detections among the remaining X-ray candidates confirms their status as extragalactic or highly embedded sources, as presumed in SA08 (see Sections 2.2 and 3.3 for more detailed information on individual sources).

The spectra were reduced using standard tasks within IRAF.3 The data were bias corrected and then extracted with the help of corresponding dome flats, flat fielded, and calibrated in wavelength using the available ThAr lamp. Individual spectra were then combined. No flux calibration was performed due to the inherent difficulties of calibrating absolute fluxes with a multifiber spectrograph and because flux calibration is irrelevant for our science case. Since the sky emission is largely variable throughout the field, the sky subtraction was performed in several steps. First, we combined all the sky spectra for each filter and subtracted from all the objects. We then examined each object to determine whether this general sky subtraction properly removed nebular and sky lines. For the objects located in the brightest parts of the nebula (CrA-432, G-80, G-85, G-87, G-88, G-90, G-32, and G-48), for which the standard sky subtraction proved insufficient, we then selected the brightest sky spectra in the region (29 in total) and combined them in a new “bright” sky template, which provided an adequate removal of sky lines. Figure 1 shows the high- and moderate-signal-to-noise spectra, and Figures 2 and 3 provide more details on Hα emission and other accretion-related lines.

2.2. HAWK-I

Using the IR camera HAWK-I on VLT, we observed 11 $7.5' \times 7.5'$ fields in the Coronet cluster as part of our ESO program 083.C-0079. The location of the fields was determined by the presence of bright objects, given the minimum magnitude limits of HAWK-I ($K_s = 8.6$ mag, $H = 9.6$ mag, $J = 9.3$ mag). Due to these strong magnitude limitations, the central part of the cluster and most of the areas with strong star formation could not be observed with HAWK-I. Observations took place on six different nights, 2009 April 28 and 29, 2009 June 28 and 30, and 2009 July 12 and 16, under clear weather and variable seeing conditions (0.5–1.′′0).

The data were reduced using IRAF tasks within the ccdred package for bias correction and flat fielding. For each field and filter, we took six dithered images with offsets of 30′′ and NDIT = 20, with total exposure times of 40 s (J), 34 s (H), and 58 s (K). We used the IRAF daofind package to identify detections and apphot to perform aperture photometry, with 10 pixel aperture and 20–25 pixel sky annuli. The photometry was calibrated field by field and chip by chip as relative photometry by comparing it with Two Micron All Sky Survey (2MASS) objects present in the fields, typically using 20–120 stars for calibration. Typical calibration errors range from 1% to 5%, depending on the weather conditions. Therefore, signal to noise and background remain the main sources of uncertainty, especially for the fainter objects. The data are complete in a large dynamical range ($J = 11$–18.5 mag, $H = 11$–18.5 mag, $K = 10.5$–18 mag).

Table 2 lists the magnitudes of the previously known sources detected with HAWK-I. Two of the X-ray sources in Garmire & Garmire (2003) that had not been detected with Spitzer or FLAMES (G-116 and G-119) are now detected with HAWK-I. Their colors suggest that they are most likely extragalactic. Table 2 also includes a comment on the variability of the sources that are also detected in 2MASS. CrA-4107 and CrA-452 show some degree of variability (0.1–0.3 mag, depending on color) which is probably due to rotation and the presence of spots. The $J$ magnitude of G-32 appears more than 1 mag fainter in our observations than in the 2MASS catalog, but since the 2MASS magnitude is close to the detection limit of the survey, the HAWK-I data are more accurate.

2.3. APEX/LABOCA 870 μm Mapping

The 870 μm data were obtained with APEX using the LABOCA bolometer array as part of the ESO program

Figure 1. FLAMES spectra for the objects with enough signal to noise to derive a spectral type.
Table 1
Spectral Types, Extinction, and Main Lines

| Name      | ID/Coord.               | Spec. Type | $A_V$ (mag) | Hα  | Li $i$ | [N $ii$] | [S $ii$] | He $i$  | Ca $ii$ | K $i$ | Na $i^R$ | Na $i^I$ | Comments |
|------------|-------------------------|------------|-------------|-----|--------|----------|----------|---------|--------|-------|----------|----------|----------|
| CrA-4108   | 19020968-3646345        | M3.5 (+1.0)| 1.2 ± 1.1   | −7.6| 0.52   | ...      | ...      | −0.2   | 0.31/0.85/0.54 | 2.07/1.39 | 1.16/1.47 | 1.12/1.49 | NA       |
| CrA-432    | 19005974-3647109        | M4.0 (+1.0)| 2.7 ± 0.2   | −46 | ...    | ...      | ...      | −2.8   | −0.34/−0.59/−0.25 | 2.43/1.89 | 1.12/1.50 | 1.18/1.53 | A        |
| CrA-452    | 19004455-3702108        | M2.5 (+0.5)| 1.7 ± 0.2   | −2.6| 0.51   | ...      | ...      | 2.8    | 0.23/0.83/0.80 | 1.45/0.82 | 0.83/1.15 | 0.78/1.03 | NA       |
| CrA-468    | 19014936-3700285        | M3.5 (+0.5)| 0.6 ± 0.7   | −2.8| 0.53   | ...      | ...      | 2.8    | 0.5/0.7/0.7 | 1.77/1.07 | 0.99/1.28 | 1.02/1.26 | NA       |
| G-1        | 19022708-3658132        | M0.5 (+0.5)| 3.4 ± 0.2   | −3.8| 0.58   | ...      | ...      | 0.28   | 0.4/1.5/1.1 | 1.28/0.62 | 0.62/0.77 | 0.59/0.79 | A        |
| G-32       | 19015833-3700267        | ...        | ...         | −4: | ...    | ...      | ...      | ...    | ...    | ...   | ...      | ...      | NA       |
| G-48       | 19:01:49.8 -36:52:43    | ...        | ...         | −9: | ...    | ...      | ...      | ...    | ...    | ...   | ...      | ...      | Uncertain |
| G-80       | 19:01:35.7 -37:02:32    | ...        | ...         | −275:| −25/−83 | −170/−41 | ...      | ...    | ...    | ...   | ...      | ...      | HH       |
| G-85       | 19013385-3657448        | M0.5 (+1.5)| 19 ± 2     | −31 | ...    | ...      | ...      | −2.6   | −2.8/−2.1 | 2.27/1.06 | 0.72/0.98 | 0.76/0.98 | A        |
| G-87       | 19013232-3658030        | M1.5 (+1.5)| 16 ± 2     | −3: | ...    | ...      | ...      | 0.15   | 0.52/0.91 | 2.16/2.79 | 0.51/0.89 | 0.67/1.56 | A        |
| G-88       | 19:01:32.2 -36:51:20    | ...        | ...         | −13 | ...    | ...      | ...      | ...    | ...    | ...   | ...      | ...      | A        |
| G-90       | 19:01:31.4 -36:52:53    | ...        | ...         | −7.4| ...    | ...      | ...      | ...    | ...    | ...   | ...      | ...      | A        |

Notes. Lines observed in the FLAMES spectra. Uncertain values are marked by “−”. The field “ID/Coord.” provides the 2MASS IDs of the objects, or their coordinates in case they were not detected by 2MASS. The EW is given in Å, with negative values used for emission lines. The wavelengths of the listed lines are 6562 Å (Hα), 6708 Å (Li $i$), 6548/6584 Å ([N $ii$]), 6748/6784 Å ([S $ii$]), 6678 Å (He $i$), 8498/8542/8662 Å (Ca $ii$ IR triplet), 7665/7699 Å (K $i$), 8183/8185 Å (Na $i$). For the Na $i$ lines, we give two values measured in the L773 and L881 spectra (“R” for red, “I” for IR), respectively. The comments list the presence of accretion (A) or no evidence for accretion (NA), and Herbig–Haro objects (HH). The accretion classification is made taking into account the Hα EW, Hα profile, and presence of the Ca $ii$ in emission.

a The object CrA-468 is also known as G-49 (SA08).
Figure 2. Normalized spectra in the Hα region for the detected objects. For CrA-468 (G-49), we display as a dashed cyan line our previous FLAMES spectrum (SA08). (A color version of this figure is available in the online journal.)

Figure 3. Examples of other lines detected in the spectra. The presence of He I 5875 Å and the Ca II triplet in emission are indicators of accretion. Li I is a marker of youth.
3. ANALYSIS

3.1. Extinction Maps and Submillimeter Observations

We used the near-IR colors of the sources detected in the HAWK-I frames to calculate the dust extinction through the CrA cloud. In particular, we adopted the color-excess mapping method \texttt{nicer} (Lombardi & Alves 2001). In the following, we briefly describe the practical implementation of the method. For further details of the method we refer to Lombardi & Alves (2001) and Lada et al. (1994).

The observed colors of stars shining through a dust cloud are related to the dust extinction via the equation

\[ E_{i-j} = (m_i - m_j) - \langle m_i - m_j \rangle_0 = A_j \left( \frac{\tau_j}{\tau_{i-j}} - 1 \right), \]

where \( E_{i-j} \) is the color excess, \( A_j \) is extinction, \( \tau_j \) is optical depth, and \( \langle m_i - m_j \rangle_0 \) refers to the intrinsic color of stars, measured as the mean color of stars in a field that is free from extinction. We calculated the mean colors using stars in a HAWK-I frame close to (R.A., decl. J2000) = (19:02:50, -36:46:25), estimated to contain very little extinction based on our earlier, lower-resolution extinction map of the CrA region (Kainulainen et al. 2009). The mean colors in this field were \( \langle m_H - m_K \rangle = 0.47 \pm 0.15 \) mag. For the ratios of optical depths we adopted \( \tau_H/\tau_K = 1.67, \tau_J/\tau_H = 1.48, \) and \( \tau_V/\tau_K = 8.77 \) (Cardelli et al. 1989). Before calculating the extinction, we removed from the HAWK-I detections the previously known members of the CrA cloud, based on the identifications given by SA08, Forbrich & Preibisch (2007), and López Martí et al. (2005, 2010).

Observations in three broadband filters \((JHK_S)\) result in measurements of two-color excesses, namely, \( E_{H-K} \) and \( E_{J-H} \), toward each source. These two measurements were combined with

| Name     | R.A. (J2000) | Decl. (J2000) | R.A. (deg) | Decl. (deg) | J (mag) | H (mag) | K (mag) | Comments                  |
|----------|--------------|---------------|------------|-------------|---------|---------|---------|---------------------------|
| CrA-4107 | 19:02:54.64  | -36:46:19.1   | 285.72661  | -36.771973  | 12.577 ± 0.009 | 12.008 ± 0.015 | 11.631 ± 0.015 | Variable (0.1–0.2 mag) |
|         |              |               |            |             |         |         |         | Variable (~0.3 mag)       |
| CrA-452 | 19:00:44.55  | -37:02:10.8   | 285.18568  | -37.036343  | 11.853 ± 0.018 |         |         | ...                        |
| CrA-465 | 19:01:53.74  | -37:00:33.9   | 285.473907 | -37.009418  | 14.078 ± 0.079 | 13.479 ± 0.061 | 13.001 ± 0.070 | ...                        |
| CrA-468 | 19:01:49.36  | -37:02:28.5   | 285.45568  | -37.007915  | 12.508 ± 0.079 | 12.037 ± 0.061 |         | ...                        |
| G-14     | 19:02:12.01  | -37:03:09.3   | 285.550049 | -37.052582  | 13.453 ± 0.052 | 12.633 ± 0.029 | 12.200 ± 0.027 | ...                        |
| G-30     | 19:02:00.12  | -37:02:22.0   | 285.50048  | -37.039444  | 12.064 ± 0.079 |         |         | ...                        |
| G-32     | 19:01:58.33  | -37:00:26.7   | 285.493042 | -37.007416  | 18.134 ± 0.080 | 15.418 ± 0.061 | 13.650 ± 0.070 | ...                        |
| G-116    | 19:01:15.40  | -36:52:36.0   | 285.314178 | -36.876667  | 21.116 ± 0.167 | 18.962 ± 0.115 | 18.493 ± 0.068 | Prob. extragal.       |
| G-119    | 19:01:07.90  | -36:51:21.0   | 285.282928 | -36.855831  | 19.252 ± 0.039 | 18.347 ± 0.038 | 17.831 ± 0.040 | Prob. extragal.       |

Note. HAWK-I JHK magnitudes for the detected known Coronet members and potential members (based on \textit{Spitzer} and X-ray data). G-116 and G-119 are probably extragalactic sources.

081.C-0204(A). The data consist of 108 scans in raster map spiral mode, covering an approximate area of 30’ in diameter. This results in an integration time of 9.2 hr on target. The observations were carried out between 2008 June 21 and 2008 August 24. The opacity was determined with sky dips performed at the beginning and the end of the night, varying between \( \tau = 0.15 \) and 0.44, with a median value of 0.2. The flux calibration was estimated observing several sources per night, including Neptune, Uranus, and the secondary calibrators J1957–3845 and J1924–292.

The map was created and calibrated following the pipeline reduction of LABOCA data within the BoA package, especially developed for APEX bolometer data. BoA allows us to reduce sky dips to derive the opacity, reduce the calibrators, and make the maps. The 108 individual maps were reduced separately and then coadded to obtain the final map. In each map, the data affected by high acceleration were flagged, as well as the dead and very noisy channels (with rms larger than five times the median). Correlated noise was removed by comparing groups of channels. Finally, a linear baseline was fitted and subtracted from the data. The final maps were obtained using the weakmap option, which is optimized for weak sources and also provides the best result for the extended emission in the region. The final rms in the map center is \( -0.010 \) Jy, being higher near the brightest sources and the less integrated edges of the map. The resulting map is displayed in Figure 4.

The second step was to identify and extract the detected structures in the map and to measure the fluxes. The cluster contains a large, dense structure with several peaks as well as some elongated structures and isolated clumps (see Figure 4). The identification and extraction of clumps in the elongated and isolated structures was done using the 2D Clumpfind algorithm developed by Williams et al. (1994). The 2D Clumpfind algorithm works by contouring the data according to user-defined levels in order to determine the presence of structures. To efficiently detect the clumps in the different parts of the map, which have in general different sensitivity, we defined levels according to the local rms. The most noisy parts of the maps were removed before running Clumpfind. The clump identification was repeated five times with various sets of levels, and only clumps detected in three or more trials are considered to be real. Several sources appear as a single clump or as a collection of adjacent clumps depending on the search parameters. Given the uncertainty on the source boundaries and fluxes, they are listed as “multiple sources” with unique fluxes in Table 3, with names that indicate that they are composed of more than one peak or individual source (7+10+24, 8+22, 9+14, 13+25, 17+20+26, 18+21). The flux for each clump (or clump collection) was calculated with \texttt{clstats2d}, also within the 2D Clumpfind package. The errors in the final flux include the local rms as well as the standard deviation from the flux measured by the slightly different levels imposed for the source detection. The final clumps are listed in Table 3. In general, small, compact structures are detected in a very robust way, while the limits and subdivisions of more extended structures are less well constrained. Several of the submillimeter sources are associated to known IR sources and/or nebular structures (Figure 5).

See details in \url{http://www.astro.uni-bonn.de/boawiki/Boa}.
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Figure 4. Submillimeter 870 μm map obtained with APEX/LABOCA. The gray scale represents a logarithm scale between 0.030 and 1 Jy (approximately 3 × rms). The contours are in linear scale, from 0.030 to 1 Jy in steps of 0.050 Jy. The beam is displayed in the lower right corner. The numbers correspond to the clumps identified by 2D Clumpfind (see also Table 3). Right ascension and declination are in J2000.

Table 3

| Name | R.A. (J2000) | Decl. (J2000) | Extension (beam) | Integrated Flux (Jy) | Related Sources |
|------|--------------|---------------|------------------|----------------------|-----------------|
| 1    | 19:01:53.9   | −36:58:03     | 96 ± 8           | 33.3 ± 0.8           | COA2, Ch10,11,12, see Figure 5 |
| 2    | 19:01:42.5   | −36:58:39     | 6 ± 1            | 1.44 ± 0.02          | IRS2, Ch9       |
| 3    | 19:02:59.4   | −37:07:45     | 22 ± 7           | 3.40 ± 0.35          | Ch23, IRAS 18595-3712 |
| 4    | 19:03:07.9   | −37:13:04     | 10 ± 2           | 1.65 ± 0.07          | Ch24, VV CrA    |
| 5    | 19:01:39.5   | −36:53:29     | 35 ± 7           | 4.55 ± 0.43          | HD-176386B, Ch6,7,8 |
| 6    | 19:02:18.3   | −37:01:41     | 27 ± 20          | 2.1 ± 1.1            | Ch21            |
| 7+10+24 | 19:03:06.4 | −37:14:53     | 32 ± 5           | 2.40 ± 0.15          | COA4            |
| 8+22 | 19:00:55.4   | −36:55:27     | 29 ± 7           | 1.95 ± 0.28          |                 |
| 9+14 | 19:01:57.0   | −37:01:05     | 20 ± 5           | 1.43 ± 0.18          | Ch14            |
| 11   | 19:02:11.4   | −36:56:22     | 15 ± 7           | 1.08 ± 0.33          | G-17            |
| 12   | 19:02:13.7   | −36:57:26     | 7 ± 1            | 0.45 ± 0.05          | Ch19            |
| 13+25| 19:02:11.4   | −37:00:47     | 16 ± 2           | 1.15 ± 0.08          | Ch18            |
| 16   | 19:02:24.3   | −36:56:50     | 13 ± 4           | 0.73 ± 0.15          |                 |
| 17+20+26| 19:01:05.3 | −36:54:14     | 35 ± 13          | 1.88 ± 0.53          | Ch2,3,4         |
| 18+21| 19:01:13.7   | −36:54:23     | 27 ± 6           | 1.33 ± 0.03          | Ch5             |
| 19   | 19:02:33.5   | −37:02:08     | 13 ± 6           | 0.63 ± 0.03          |                 |
| 23   | 19:02:18.3   | −37:04:43     | 13 ± 5           | 0.48 ± 0.15          |                 |
| 27   | 19:01:09.1   | −36:57:26     | 6 ± 2            | 0.77 ± 0.02          | S-CrA, Ch1      |

Note. Clumps detected with 2D Clumpfind in the 870 μm map. When the identification of a structure as one or several clumps depends on the parameters used by 2D Clumpfind, we list it as a “multiple structure” (e.g., 7+10+24). The last column indicates whether the clump is associated with known sources or structures detected at different wavelengths. Millimeter clumps from Chini et al. (2003) are marked as Ch#. CO detections from Vilas-Boas et al. (2000) are marked as COA#. Uncertain values are marked with “:”. Note that the association to a source is merely the coincidence of coordinates; it does not mean that the submillimeter clump and the (optical, X-ray, CO) source are the same object (see the text for details).

to yield extinction values toward the sources following the formalism presented in Lombardi & Alves (2001). The derived extinction values were then used to produce a regularly sampled map by computing the mean extinction in regular intervals (map pixels) of 24″, using a Gaussian with FWHM = 48″ as a spatial weighting function. In this resolution, the maximum extinction in the resulting map reaches $A_V \approx 50$ mag, with $A_V \approx 20$ mag corresponding to one to two stars per pixel. The error in the map depends on extinction, with 3σ being about 0.8 mag at $A_V = 0$ mag and 7 mag at $A_V = 50$ mag.
Figure 5. Left: LABOCA contours for the detected clumps, plotted over the MIPS 24 μm image of the Coronet cluster. Right: a zoom in the densest part of the nebula. The scale bars assume a distance of 170 pc.

(A color version of this figure is available in the online journal.)

Figure 6. Extinction map and submillimeter structure (see the text). Right ascension and declination are in J2000. The scale bar for 1 pc assumes a distance of 170 pc. The color gradient represents the extinction in a log scale from $A_V = 0$ to 5 mag.

(A color version of this figure is available in the online journal.)

Figure 6 shows the resulting extinction map, combined with the 2MASS extinction map in the regions not included in our HAWK-I imaging. There is excellent agreement between the 870 μm clumps and the regions of high extinction. Nevertheless, the extinction map reveals large parts of the molecular cloud that are not detected in the LABOCA survey due to their lower column density. The most massive stars in the region are associated with the zones with the highest extinction and strongest submillimeter emission, as expected. The distribution of low-mass members with respect to the cloud is less clear, also due to the fact that the non-biased survey for low-mass members was done only in the central part of the cluster.

3.2. Spectral Types, Extinction, and Accretion

The FLAMES spectra allow us to determine spectral types for the objects with good signal to noise. We followed a similar scheme as used in SA08, using the spectral indices and bands from Martín et al. (1996), called PC1, PC2, PC3, and PC4, and the R1, R2, R3, TiO 8465 indices in Riddick et al. (2007). The additional indices VO 2 and VO 7445 from Riddick et al. (2007) were also used to refine the spectral types for objects M5 or later. Table 4 offers a list of the relevant indices and their valid spectral type ranges. A combination of spectral types and the available $JHK$ photometry allows us to estimate the extinction of the objects (see below). For the objects with intermediate to high extinction ($A_V > 3$ mag), we gave priority to the results derived from the indices PC1, PC2, R1, R2, R3, TiO 8475, VO 2, and VO 7445, which are derived from flux ratios in adjacent parts of the spectrum, thus being less sensitive to extinction. For objects like CrA-432 that have nearly no signal in the bluer part of the spectrum (L682.2), we used only the indices involving the longer-wavelength parts. For every object, the spectral types derived from each index were compared, and those that greatly deviated from the typical value were removed (deviating indices are usually affected by noise,
Table 4
Spectral Typing Indices

| Name  | λ Numerator | λ Denominator | Range   | Calibration                                  | Reference |
|-------|-------------|---------------|---------|----------------------------------------------|-----------|
| PC1   | 7030–7050   | 7525–7550     | M3–M9   | −0.06+2.95 X                                 | 1,2       |
| PC2   | 7540–7580   | 7030–7050     | M4–M8   | −0.63+3.89 X                                 | 1,2       |
| PC3   | 8235–8265   | 7540–7580     | M3–M9   | −8.01+14.08 X X−2.81 X²                     | 2         |
| PC4   | 9190–9225   | 7540–7580     | M3–M9   | −0.94+4.66 X X−0.52 X²                      | 2         |
| R1    | 8025–8130   | 8015–8025     | M2.5–M8 | 2.8078+21.085(X−1.044)−53.025(X−1.044)²+60.755(X−1.044)³ | 3         |
| R2    | 8415–8460   | 8460–8470     | M3–M8   | 2.9091+10.503(X−1.035)−14.105(X−1.035)²+8.5121(X−1.035)³ | 3         |
| R3    | (8025-8130)+ (8415-8460) | (8015–8025)+ (8460–8470) | M2.5–M8 | 2.8379+19.708(X−1.035)−47.679(X−1.035)²+52.531(X−1.035)³ | 3         |
| TiO 865 | 8405–8425   | 8455–8475     | M3–M8   | 3.2147+8.7311(X−1.085)−10.142(X−1.085)²+5.6765(X−1.085)³ | 3         |
| VO 2  | 7920–7960   | 8130–8150     | M3–M8   | 2.6102−7.9389(X−0.963)−8.3231(X−0.963)²+14.660(X−0.963)³ | 3         |
| VO 7445 | 0.5625(7350–7400)+0.4375(7510–7560) | 7420–7470     | M5–M8   | 5.0881+17.121(X−0.982)+13.078(X−0.982)²      | 3         |

Note. Indices used for spectral typing. The wavelengths are given in Å. In the calibration, X represents the index, and the resulting number indicates the M subtype. The lineal relations for PC1 and PC2 are obtained by fitting together the objects in references 1 and 2.

References. (1) Kirkpatrick et al. 1996; (2) Martín et al. 1996; (3) Riddick et al. 2007.
atmospheric features, and/or poor signal to noise in one of the bands). In general, between two and six indices were used for the classification of each star, depending on the spectral type, extinction, and signal to noise in the three spectral bands. The errors in the spectral types are calculated as the standard deviation of the values derived from each valid index. The classification scheme failed for the object G-1, which appears earlier than the rest. It was thus classified by comparison to solar-type T Tauri templates as we did for G-1 (see Figure 7). 

Two of the objects, G-85 and G-87, are highly extincted ($A_V > 14$ mag). After a tentative first classification, we used the preliminary $A_V$ value to de-redden the spectra (using IRAF task deredden within the onedspec package) before the final classification. Examination of two objects revealed that their spectral types are earlier than M2, a range for which the mentioned indices are not valid. We thus derived their spectral types using our solar-type T Tauri templates obtained from a combination of Hectospec/MMT observations in the Cep OB2 region (Sicilia-Aguilar et al. 2005).

Figure 7. De-reddened spectra of the low signal-to-noise objects G-85 and G-87, compared to our spectral type templates. (A color version of this figure is available in the online journal.)

valid for a standard galactic extinction law. For most sources, the agreement between $A_V$ obtained from the two different colors suggests that most of the extinction is due to foreground and cloud material, with no evidence of anomalous extinction that could be caused by processed grains in the circumstellar environment, despite the presence of strong disk emission in some of the objects. Only in the cases of CrA-4108 and CrA-468 did we find large differences between the extinction values derived from different colors, which could indicate the presence of anomalous extinction/scattering. In the case of CrA-468, the Spitzer data reveal it is located near substantial nebular material. CrA-4108 is out of our Spitzer field. 

The presence or lack of accretion was established by measuring the equivalent width and examining the profile and line width at 10% of the peak for the Hα line (see Figure 2). The lines were measured using IRAF tasks within the splot tool. We adopted the classification of White & Basri (2003) for the limiting EW of accreting and non-accreting stars, depending on their spectral type. Given that the line width is a more powerful tool than the EW to detect weak accretors (Sicilia-Aguilar et al. 2006), we consider an object to be accreting if its 10% line width exceeds 200 km s$^{-1}$ (Natta et al. 2005). In some cases, like G-1, the broad profile is evident, although the EW is much smaller than the canonical limit for accretion in an M0.5 object, so we list it as an accretor. The presence of accretion was also checked in other lines, like the Ca ii IR triplet and the 6678 Å He i line. The lack of Ca ii emission in G-1 suggests an accretion rate below $10^{-9} M_\odot$ yr$^{-1}$ (Muzerolle et al. 1998). All the spectral lines measured are listed in Table 1.

The new accretion determination, together with our previous measurements in SA08, confirms that most of the low-mass Coronet members have very low accretion rates, with CrA-432 and G-85 being the only exceptions. As we found in SA08, transitional and highly evolved disks (like G-87) do not show evidence of ongoing accretion (within the $10^{-10}$ to $10^{-11} M_\odot$ yr$^{-1}$ limit imposed by the FLAMES spectral resolution). This differs from the observations of solar-type stars, for which usually half or more of the transition disks are found to be accreting (Sicilia-Aguilar et al. 2006, 2010; Muzerolle et al. 2010; Fang et al. 2009). All objects without IR excesses are consistent with no accretion. For the objects out of the Spitzer fields (CrA-4108 and CrA-452), the spectroscopy reveals no evidence of accretion. CrA-4108 shows marginal emission that could belong to He i at 5875 Å, but the lack of Ca ii lines in emission suggests that the object is not accreting (see Figure 3). The HH object G-80 was reobserved in this program, confirming again its shock nature via [N ii], [S ii], and asymmetric Hα profile. Finally, three sources that were not detected with Spitzer (G-48, G-88, and G-90) are now marginally detected, with G-88 and G-90 displaying broad Hα emission that suggests they are very embedded Class I sources. Their condition as embedded sources is also consistent with their location within one of the strongest submillimeter structures.

3.3. Massive Disks, Protopsars, and Prestellar Condensations

As listed in Table 3, several of the detected 870 μm sources are related to known Class II and embedded sources in the region. Assuming a distance of 170 pc, the 18′ beam results in a ∼3000 AU size. Condensations 2, 3, 4, 5, and 27 are associated with the previously known sources IRS 2, IRAS 18595-3712, VV CrA, HD 176386b, and S CrA, respectively. In addition, condensations 3 and 4 also correspond to the millimeter emitting objects 23 and 24 from Chini et al. (2003). We combined the
Figure 8. SEDs of the unresolved sources detected with APEX/LABOCA. The SEDs include the data listed in Table 5. The data for S CrA is corrected for extinction, taking $A_V = 0.4$ mag (Currie & Sicilia-Aguilar 2011). A scaled black body emission for $T = 70$ K is plotted as a comparison for the long wavelength emission of IRAS 18595-3712.

Table 5

| Wavelength ($\mu$m)/Filter | IRS2 | IRAS 18595–3712 | VV CrA | HD 176386 | S CrA | References |
|---------------------------|------|-----------------|--------|-----------|-------|------------|
| 0.44/B                    |      |                 |        |           |       | SIMBAD     |
| 0.55/V                    |      |                 |        |           |       | SIMBAD     |
| 1.22/J                    | 0.0050 ± 0.0001 | 0.00007 | 0.179 ± 0.005 | 1.43 ± 0.10 | 0.828 ± 0.019 | 2MASS     |
| 1.63/H                    | 0.129 ± 0.004 | 0.005 | 0.729 ± 0.030 | 1.03 ± 0.10 | 1.54 ± 0.04 | 2MASS     |
| 2.19/Ks                   | 0.949 ± 0.023 | 0.0010 ± 0.0001 | 2.028 ± 0.040 | 0.89 ± 0.08 | 2.29 ± 0.05 | 2MASS     |
| 3.6                       |      | 0.00976 ± 0.00004 | 4.753 ± 0.017 | 0.2059 ± 0.0004 | 2.66 ± 0.01 | IRAC/Spitzer |
| 4.5                       |      | 0.0224 ± 0.0004 | 6.160 ± 0.022 | 0.1388 ± 0.0004 | 3.16 ± 0.01 | IRAC/Spitzer |
| 5.8                       |      | 0.0224 ± 0.0010 | 15.21 ± 0.05 | $^a$ | 3.81 ± 0.02 | IRAC/Spitzer |
| 8.0                       | 7.71 ± 0.02 | 0.0138 ± 0.0004 | ... | $^a$ | 4.17 ± 0.02 | IRAC/Spitzer |
| 9.0                       |      |                 | 24.12 ± 0.23 | ... | 4.41 ± 0.08 | AKARI     |
| 12                        | 13:  |      |                 | 31.9: | ... | ...         | IRAS      |
| 18                        | ... | 0.884 ± 0.026 | 39.7 ± 4.3 | ... | 7.19 ± 0.10 | AKARI     |
| 23.9                      |      | 2.474 ± 0.001 | ... | ... | ... | ...         | IRAS      |
| 25                        | 50: | 3.69: | 69.1: | ... | ... | ... | IRAS |
| 60                        | ... | 38.9: | 131: | ... | ... | ... | IRAS |
| 65                        | ... | ... | ... | ... | 13.8 ± 4.3 | AKARI    |
| 100                       |      |                 | ... | 95.2: | ... | ... | IRAS |
| 450                       | 12 ± 1 | ... | ... | ... | 3 ± 0.3 | Nutter et al. (2005) |
| 850                       | 2.0 ± 0.7 | ... | ... | ... | 0.7 ± 0.2 | Nutter et al. (2005) |
| 870                       | 1.44 ± 0.02 | 3.40 ± 0.35 | 1.65 ± 0.07 | 4.55 ± 0.43$^b$ | 0.77 ± 0.02 | This work |
| 870                       | 1.44 ± 0.02 | 3.40 ± 0.35 | 1.65 ± 0.07 | 4.55 ± 0.43$^b$ | 0.77 ± 0.02 | This work |
| 1200                      | 1.32 ± 0.70 | 0.672 ± 0.340 | ... | ... | 0.507 ± 0.260 | Gezari et al. (1999) |
|                           |       |                 | ... |     | 0.29 ± 0.15 | Chini et al. (2003) |

Notes. Multiwavelength fluxes for the sources in Figure 8. All the fluxes are in Jy. The data include 2MASS $JHK$ photometry and Spitzer data (Skrutskie et al. 2006; Currie & Sicilia-Aguilar 2011), IRAS observations (Wilking et al. 1992), AKARI data (9, 18, and 65 $\mu$m; Kataza et al. 2010), and millimeter/submillimeter points (Gezari et al. 1999; Chini et al. 2003; Nutter et al. 2005). The Spitzer data for VV CrA and IRAS 18595-3712 have not been published previously but were obtained as aperture photometry with MOPEX on the BCD mosaics using the same techniques and parameters exposed in Currie & Sicilia-Aguilar (2011). Uncertain values are marked by "$^a$".

$^b$ The emission is very extended and probably includes part of the molecular cloud, in addition to the source.

pre-existing data from Spitzer (see Currie & Sicilia-Aguilar 2011 for the data on IRS 2, S CrA, and HD 176386b, and the reduction procedures applied to the rest of the sources), AKARI (Kataza et al. 2010), and millimeter/submillimeter data (Gezari et al. 1999; Chini et al. 2003; Nutter et al. 2005) to trace the SEDs of these objects. Table 5 summarizes the available data for the SEDs shown in Figure 8.

The 870 $\mu$m flux from IRS 2 is in good agreement with previous submillimeter measurements of the source and consistent with an embedded Class I source. For S CrA, our data is also in
very good agreement with previous submillimeter observations, and its SED is consistent with a massive protoplanetary disk. Both IRS 2 and S CrA appear as marginally spatially extended, which suggests the presence of envelopes or surrounding cloud material. In both cases, the estimated size of the envelopes would be of the order of $\sim 5000$ AU (assuming a distance of 170 pc; Knude & Hog 1998). The emission associated with HD 176366b is extended and appears related to the warm cloud material detected in the Spitzer images.

To the south of the CrA region, two condensations, associated with the sources VV CrA and IRAS 18595-3712, are detected. The emission associated with the binary VV CrA is very compact and probably corresponds to the protoplanetary disk of the main source plus that of the disk and envelope of the embedded companion (Ratzka et al. 2008). The submillimeter emission around IRAS 18598-3712 appears slightly extended to the east, suggesting the presence of a larger envelope. The emission at longer wavelengths for this source is indeed consistent with a black body of $T = 70$ K (see Figure 8). The extinction map reveals substantial cloud material in this direction, which could also produce the extended emission near the source. The SED of this object suggests the presence of a large amount of material, which could include the source envelope plus contamination from the surrounding cloud.

Regarding the rest of clumps detected in the LABOCA maps, they correspond to more complex regions that include several embedded sources and to denser nebular material in the region, which is confirmed by the extinction maps. This is the case for clump 1, which includes the sources T CrA, R CrA, V710, and IRS 7e/w among others (see Figure 5, right). The peak of the emission appears to the southwest of IRS 7, which is consistent with the observations of Chini et al. (2003) and Nutter et al. (2005). The embedded X-ray source G-17 is associated with clump 12. Although the size of the clump is too large for it to be considered as the same and a single object, the presence of this X-ray source near the emission peak of clump 12 indicates that G-17 is most likely a very embedded low-mass protostar, as suggested by SA08. The star CrA-465 appears superimposed to clump 9, but the submillimeter emission is most likely due to background cloud material not related to the source, given both the size of the structure and the low extinction of CrA-465 ($A_V = 0.08 \pm 0.04$; SA08).

The strongest emission in the LABOCA map is thus associated with the largest concentration of intermediate-mass members, as would be expected. The most massive stars thus appear along the two arms (running in the HD 176386 to VV CrA direction and in the HD 176386 to S CrA direction, respectively) of the molecular cloud, clearly depicted in the extinction maps (Figure 6). It is not possible to establish a further correlation between the rest of structures with submillimeter emission and the distribution of cluster members in the region, since so far only the most central part of the cluster has been explored for membership in a systematic way.

4. THE AGE OF THE CORONET CLUSTER AND THE STAR-FORMING REGION

The age of the Coronet cluster has been subject to intense debate. While most observations suggested an age of 1–3 Myr (Meyer & Wilking 2009), the presence of a Class 0 source and several embedded objects are rather consistent with a younger cluster, $\sim 0.5$–1 Myr (Henning et al. 1994; Chen et al. 1997; Chini et al. 2003; Nisini et al. 2005; Nutter et al. 2005; Groppi et al. 2004, 2007). Nevertheless, both the disk frequency (\textasciitilde 50\%–65\%) and the disk characteristics among the low-mass, M-type population appear closer to the values observed in older regions than to a 1 Myr old cluster (SA08; López Martí et al. 2010; Currie & Sicilia-Aguilar 2011). On the other hand, the presence of substantial amounts of nebular material would be inconsistent with an age beyond 3 Myr (Hartmann et al. 2001; Ballesteros-Paredes & Hartmann 2007). Finally, spectroscopic data also reveal a low accretion fraction, with all the transition and settled/dust-depleted disks showing no evidence for accretion, which has been typically related to few Myr old regions (Muzerolle et al. 2010).

Few Myr age differences between cluster members are common in many regions, and many clusters include sequential star formation, which results in the presence of more than one star-forming event and thus two or more populations with different ages (e.g., Sicilia-Aguilar et al. 2005, 2006). Nevertheless, the Coronet cluster is special because of its compactness: the members studied here are located within the densest region of the CrA Nebula, which is less than 1.3 pc across (adopting a distance of 170 pc; Knude & Hog 1998). A strong correlation between the size of the region and the age dispersion of the cluster members has been observed in our galaxy and in the Magellanic Clouds (Elmegreen 2000): the age dispersion of cluster members is of the order of the crossing time in the region, which for the Coronet cluster is smaller than 2 Myr. In fact, regions similar to the Coronet cluster in size and stellar content (e.g., the $\eta$ Cha cluster) are usually found to be strongly coeval (Lawson et al. 2009).

We have thus estimated the age of the cluster by placing the known members in a color–magnitude diagram. A color–magnitude diagram is preferred to an H-R diagram since it involves less transformations of the original data that result in increased uncertainties. The effect of the data uncertainties is also easier to control and determine in a color–magnitude diagram, since it does not involve propagation of non-independent errors. Our knowledge of spectral types allows us to correct individually for the extinction, which is particularly important in regions with non-uniform cloud material. Figure 9 displays the near-IR color–magnitude diagram $\text{H}$ versus $J - \text{H}$ of the low-mass T Tauri members of the Coronet cluster, using their 2MASS and HAWK-I data, together with the isochrones from Baraffe et al. (1998) for the distances of 130 pc (only the 1 and 2 Myr isochrones) and 170 pc (1, 2, 5, and 10 Myr isochrones). These two distances correspond to the estimates given by Marraco & Rydgren (1981, 130 pc) and the more recent one by Knude & Hog (1998, 170 pc). Given that age and distance are degenerated, we consider both extreme values in order to ascertain the potential errors in the age determination. Table 6 summarizes the data of the sources used in the H-R diagram. The extinction of the objects has been corrected using their individual values in Figure 9. In addition to the photometric errors, we also display the uncertainties in the extinction, which are related to the uncertainties in the spectral types of the objects. Due to the fact that there is little spread for the lower-mass objects in the $J - \text{H}$ direction at these ages, it is hard to determine an age for the cluster from these objects. Nevertheless, the location of the isochrone “kink” for the early M-type stars is more consistent with a distance of 170 pc. In any case, for either a distance of 130 pc or 170 pc, and considering the limitations imposed by the small number of objects with early M-type in the cluster, the distribution in the color–magnitude diagram of the early M-type objects suggests that the population has an age in the range 0.5–2 Myr. For the most plausible distance of 170 pc, the
The age would be in the 0.5–1 Myr range. This is in agreement with the conclusions of Chen et al. (1997), based on the bolometric temperature and luminosity of young stellar objects (YSOs), who stated that the CrA region is younger than 2 Myr and most likely younger than Taurus, even assuming a distance of 130 pc.

This age estimate is also consistent with the presence of Class 0 and very embedded Class I sources in the region. Nevertheless, the relatively low disk fraction found among TTS (2/3 or lower; SA08, López Martí et al. 2010) is atypical for such a young region. The “evolved” features of the disks (lack of silicate emission as expected from disks with large grains, presence of disks with inner holes, and small dust-depleted disks, and SEDs consistent with strong dust settling; SA08, Currie & Sicilia-Aguilar 2011) are hard to understand for a 1 Myr old cluster. Some of the objects (CrA-205, CrA-4108, CrA-4109) are located at larger distances from the center of the cloud and may have thus a larger age difference compared with the main cluster. Nevertheless, the lack of spectral types and extinction (for CrA-205 and CrA-4109) do not let us test this hypothesis. Although the Coronet is younger than (or has a similar age to) Taurus, its median disk is younger than (or has a similar age to) Taurus, its median disk fraction is 10%. The lack of spectral types and extinction (for CrA-205 and CrA-4109) and the position of the source itself in a place where the isochrones are degenerated (for CrA-4108) do not let us test this hypothesis. Although the Coronet is younger than Taurus, its median disk fraction is 10%. The lack of spectral types and extinction (for CrA-205 and CrA-4109) and the position of the source itself in a place where the isochrones are degenerated (for CrA-4108) do not let us test this hypothesis. Although the Coronet is younger than (or has a similar age to) Taurus, its median disk fraction is 10%.

### 5. CONCLUSIONS

We present new multiwavelength data for the Coronet cluster, including optical spectroscopy obtained with the FLAMES multibber spectrograph at VLT, 870 μm mapping obtained with the LABOCA bolometer on the APEX telescope, and near-IR imaging from VLT/HAWK-I. The optical data allow us to derive spectral types, individual extinctions, and accretion status for the remaining X-ray members, completing the work started by SA08. The submillimeter data reveal the densest structures of the cloud, as well as the circumstellar disks and envelopes of some intermediate-mass and T Tauri members. The near-IR imaging provides photometry for some of the faintest members and allows us to derive extinction maps, which trace the cloud material in low-density regions that are not detected in the submillimeter. Both extinction and submillimeter maps reveal a large cloud where star formation has only occurred along

### Table 6

Summary of JHK Data for Sources in the H-R Diagram

| Name  | ID            | J  (mag)        | H  (mag)        | K  (mag)        | Sp. Type | A_v (mag) |
|-------|---------------|-----------------|-----------------|-----------------|----------|-----------|
| CrA-4108 | 19020968-3646345 | 12.580 ± 0.023  | 11.972 ± 0.023  | 11.634 ± 0.019  | M3.5     | 1.2 ± 1.1 |
| CrA-4110 | 19011629-3656282 | 12.954 ± 0.021  | 12.314 ± 0.021  | 11.897 ± 0.021  | M5       | 1.3 ± 0.4 |
| CrA-4111 | 19012083-3703027 | 13.233 ± 0.024  | 12.687 ± 0.023  | 12.402 ± 0.024  | M4.5     | 0.1 ± 0.5 |
| CrA-432  | 19005974-3647109 | 14.190 ± 0.026  | 13.333 ± 0.035  | 12.821 ± 0.030  | M4.0     | 2.7 ± 0.2 |
| CrA-452  | 19004455-3701208 | 11.571 ± 0.024  | 10.766 ± 0.025  | 10.447 ± 0.023  | M2.5     | 1.7 ± 0.2 |
| CrA-453  | 19010460-3701292 | 13.338 ± 0.024  | 12.524 ± 0.025  | 12.075 ± 0.023  | M4.5     | 0.4 ± 0.3 |
| CrA-465  | 19015374-3700339 | 14.084 ± 0.026  | 13.401 ± 0.033  | 13.015 ± 0.033  | M7.5     | 0.2 ± 1.0 |
| CrA-466  | 19011893-3655288 | 12.834 ± 0.024  | 11.245 ± 0.025  | 10.453 ± 0.021  | M2.0     | 8.1 ± 0.4 |
| CrA-468  | 19014936-3700285 | 12.498 ± 0.026  | 11.891 ± 0.025  | 11.603 ± 0.024  | M3.5     | 0.6 ± 0.7 |
| G-1      | 19022708-3658132 | 9.307 ± 0.024   | 8.292 ± 0.038   | 7.900 ± 0.016   | M0.5     | 3.4 ± 0.2 |
| G-14     | 19012101-3703093 | 13.408 ± 0.029  | 12.582 ± 0.029  | 12.145 ± 0.021  | M4.5     | 1.9 ± 0.1 |
| G-30     | 19020012-3702220 | 11.859 ± 0.026  | 11.238 ± 0.024  | 11.003 ± 0.026  | M3.5     | 0.1 ± 0.5 |
| G-65     | 19014041-3651422 | 13.898 ± 0.032  | 11.629 ± 0.023  | 10.481 ± 0.019  | M1.5     | 13.8 ± 0.5 |
| G-85     | 19013385-3657448 | 14.448 ± 0.030  | 11.910 ± 0.023  | 10.474 ± 0.019  | M0.5     | 19 ± 2    |
| G-87     | 19013232-3658030 | 14.853 ± 0.037  | 12.622 ± 0.029  | 11.432 ± 0.023  | M1.5     | 16 ± 2    |
| G-94     | 19012901-3701481 | 11.637 ± 0.024  | 10.956 ± 0.023  | 10.663 ± 0.021  | M3.5     | 0.6 ± 0.1 |
| G-95     | 19012872-3659317 | 10.828 ± 0.023  | 9.591 ± 0.025   | 9.002 ± 0.019   | M1.0     | 5.0 ± 0.4 |
| G-102    | 19012562-3704555 | 12.363 ± 0.023  | 11.654 ± 0.021  | 11.299 ± 0.023  | M5.0     | 0.7 ± 0.1 |

Note. Compilation of 2MASS magnitudes, spectral types, and extinctions of the members with known spectral types used in Figure 9.
two arms that contain the densest parts of the molecular cloud, resulting in a quite compact cluster.

By placing the extinction-corrected photometry of the known low-mass members in a near-IR color–magnitude diagram and comparing with the Baraffe et al. (1998) isochrones, we estimate the age of the cluster to be below 2 Myr, and probably within the 0.5–1 Myr range. This agrees with previous studies (suggesting an age <3 Myr; Meyer & Wilking 2009) as well as with the presence of substantial cloud material and highly embedded Class I and Class 0 objects, and it is also in agreement with the compactness of the region where most members are located. But a young age is in strong contrast with the relatively low disk fraction (~65%–50%; SA08; López Martí et al. 2010) and the evidence of disk evolution (inner holes, lack of silicate features, strong settling, and dust depleted disks; SA08; Currie & Sicilia-Aguilar 2011) observed among the lower-mass and M-type cluster members. Further observations will be required to examine the presence of other low-mass members in the region and determine whether the region contains more than one population.

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