A Herschel [Cii] Galactic plane survey III: [Cii] as a tracer of star formation

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The [C ii] 158μm line is the brightest far–infrared cooling line in galaxies, representing 0.1 to 1% of their FIR continuum emission, and is therefore a potentially powerful tracer of star formation activity. The [C ii] line traces different phases of the interstellar medium (ISM), including the diffuse ionized medium, warm and cold atomic clouds, clouds in transition from atomic to molecular, and dense and warm photon dominated regions (PDRs). Therefore without being able to separate the contributions to the [C ii] emission, the relationship of this fine structure line emission to star formation has been unclear. We study the relationship between the [C ii] emission and the star formation rate (SFR) in the Galactic plane and separate the relationship of different ISM phases to the SFR. We compare these relationships to those in external galaxies and local clouds, allowing examinations of these relationships over a wide range of physical scales. We compare the distribution of the [C ii] emission, with its different contributing ISM phases, as a function of Galactocentric distance with the SFR derived from radio continuum observations. We also compare the SFR with the surface density distribution of atomic and molecular gas, including the CO–dark H_2 component. The [C ii] and SFR are well correlated at Galactic scales with a relationship that is in general agreement with that found for external galaxies. By combining [C ii] and SFR data points in the Galactic plane with those in external galaxies and nearby star forming regions, we find that a single scaling relationship between the [C ii] luminosity and SFR applies over six orders of magnitude. The [C ii] emission from different ISM phases are each correlated with the SFR, but only the combined emission shows a slope that is consistent with extragalactic observations. These ISM components have roughly comparable contributions to the Galactic [C ii] luminosity: dense PDRs (30%), cold Hi (25%), CO–dark H_2 (25%), and ionized gas (20%). The SFR–gas surface density relationship shows a steeper slope compared to that observed in galaxies, but one that it is consistent with those seen in nearby clouds. The different slope is a result of the use of a constant CO–to–H_2 conversion factor in the extragalactic studies, which in turn is related to the assumption of constant metallicity in galaxies. We find a linear correlation between the SFR surface density and that of the dense molecular gas.

Accepted by Astronomy and Astrophysics

1409.0537.pdf

SFR

$$\left[\frac{N_{\rm Lyc}(R_{\rm gal})}{\rm photons\ s^{-1}}\right] = \frac{1.25}{(1+y^{+})} 6.32\times10^{52} \left[\frac{T_{\rm e}}{10^4{\rm K}}\right]^{-0.45} \left[\frac{\nu}{\rm GHz}\right]^{0.1} \left[\frac{L_{\rm ff}(R_{\rm gal})}{10^{27}{\rm erg\ s^{-1}\ Hz^{-1}}}\right], \quad (14)$$

$SFR[M_\odot yr^{-1}] = 7.5 \times 10^{-54} N_{Lyc}[photons\ s^{-1}]$ estimated by Chomiuk & Povich (2011) assuming a Kroupa initial mass function (Kroupa & Weidner 2003)

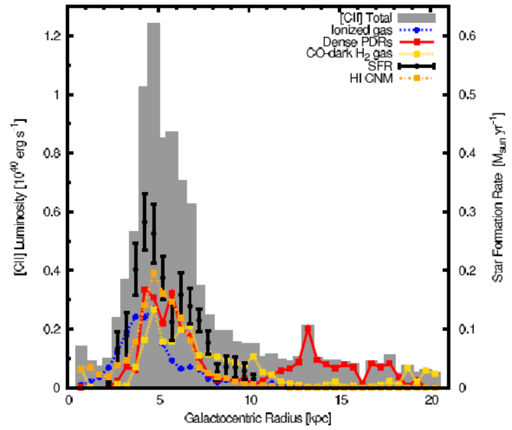

Fig. 2. The [C II] luminosity of the Milky Way as a function of Galactocentric radius. The estimated contributions to the [C II] luminosity from gas associated with dense PDRs, ionized gas, CNM H I gas, and CO–dark H_2 gas are also shown. Typical uncertainties are 5% for the total [C II] luminosity and the contribution from H I gas, 10% for the contribution from CO–dark H_2 gas, and we assume 30% for the contribution from ionized gas. The black dots (and error bars) represent the radial distribution of the star–formation rate derived in Section 2.

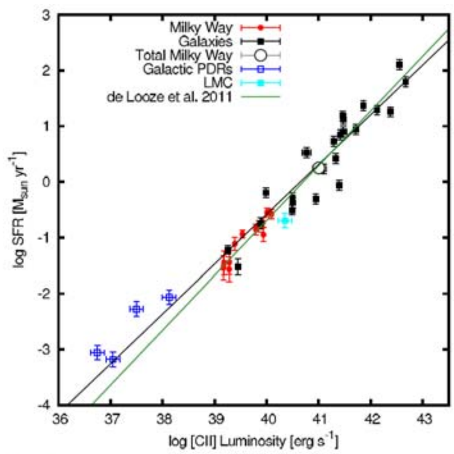

Fig. 4. Star formation rate as a function of [C II] luminosity for different rings in the Galaxy, the LMC, the galaxies studied by de Looze et al. (2011), and for individual Galactic photon dominated regions. The [C II] luminosity of the LMC is taken from Rubin et al. (2009) and the SFR from Harris & Zaritsky (2009). The Galactic PDR data points include Orion ($L_{[CII]}$ from Stacey et al. 1993 and SFR from Lada et al. 2010), M17 ($L_{[CII]}$ from Stacey et al. 1991 and SFR from Lada et al. 2010), Rosette ($L_{[CII]}$ from Schneider et al. 1998 and SFR from Chomiuk & Povich 2011), and Carina ($L_{[CII]}$ from Brooks et al. 2003 and SFR from Chomiuk & Povich 2011). The [C II] luminosities and SFRs for this sample are strongly correlated over 6 orders of magnitude.

Variable	$\log \mathrm{SFR} = m \log L_{[CII]} + b$		Dispersion	Spearman's rank coeff.	Total Luminosity
	m	b	dex		10^{40} erg s^{-1}
[C II] Total	0.98±0.07	-39.80±2.94	0.14	0.91	10.1
[C II] (PDRs)	0.74±0.07	-30.00±2.81	0.12	0.88	3.2
[C II] (Electrons)	0.91±0.06	-36.30±2.36	0.11	0.94	1.9
[C II] (HI CNM)	0.65±0.07	-26.50±2.75	0.14	0.86	2.5
[C II] (Dark Gas)	2.12±0.37	-84.10±14.30	0.21	0.84	2.5

$$\log \mathrm{SFR} = m \log L_{[CII]} + b, \qquad (17)$$

(1) the [Cii] luminosity and SFR are well correlated on Galactic scales with a relationship that is consistent with that found for external galaxies.

(2) dense PDRs (30%), cold Hi (25%), CO–dark H2 (25%), and ionized gas (20%).

(3) SF Regions in our Galaxy ~ nearby galaxies : log(SFR[M⊙yr-1])=(0.89±0.04)log($L_{[CII]}$[erg s-1])−(36.3± 1.5), applies over six orders of magnitude

Long-term photometric observations of pre-main sequence objects in the field of North America/Pelican Nebula

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To broaden the search and study stars in the early evolutionary phase, we investigated a sample of 17 pre-main sequence objects previously detected as either H_ emission-line pre-main sequence stars or T Tauri variables located in the field 32 of the North America/Pelican Nebula complex. Johnson-Cousins B, V,Rc, Ic magnitudes and mean color indices for the program stars are determined from more than 12400 measurements from archive photographic plates and from CCD data collected at 7 observatories covering the period of almost 60 years from 1954 up to 2013. We complemented previously rare insights on the photometry of the program stars and presented their photometric history, which for almost all program stars is the first long term photometric monitoring on a timescale of 6 decades. Eight program stars are found to be classical T Tauri stars of variability type II, while 6 program stars are weak-line T Tauri stars of variability type I. For the first time, periodicity is found for three stars: V1716 Cyg indicates a 4.15 day period, V2051 Cyg indicates a 384 day period, and V521 Cyg a period of 503 days.

Turbulence sets the initial conditions for star formation in high-pressure environments

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1409.0935.pdf

Despite the simplicity of theoretical models of supersonically turbulent, isothermal media, their predictions successfully match the observed gas structure and star formation activity within low-pressure (P=k < 10^5 K cm^{-3}) molecular clouds in the solar neighbourhood. However, it is unknown if these theories extend to clouds in high-pressure (P=k > 10^7 K cm^{-3}) environments, like those in the Galaxy's inner 200 pc Central Molecular Zone (CMZ) and in the early Universe. Here we present ALMA 3mm dust continuum emission within a cloud, G0.253+0.016, which is immersed in the high-pressure environment of the CMZ. While the log-normal shape and dispersion of its column density PDF is strikingly similar to those of solar neighbourhood clouds, there is one important quantitative difference: its mean column density is 1--2 orders of magnitude higher. Both the similarity and difference in the PDF compared to those derived from solar neighbourhood clouds match predictions of turbulent cloud models given the high-pressure environment of the CMZ. The PDF shows a small deviation from log-normal at high column densities confirming the youth of G0.253+0.016. Its lack of star formation is consistent with the theoretically predicted, environmentally dependent volume density threshold for star formation which is orders of magnitude higher than that derived for solar neighbourhood clouds. Our results provide the first empirical evidence that the current theoretical understanding of molecular cloud structure derived from the solar neighbourhood also holds in high-pressure environments. We therefore suggest that these theories may be applicable to understand star formation in the early Universe.

We obtained a 3'x1' mosaic of the 3mm (90 GHz) dust continuum and molecular line emission across G0.253+0.016 using 25 antennas as part of ALMA's Early Science Cycle 0.

within the inner 200 pc of our Galaxy (the Central Molecular Zone, CMZ)

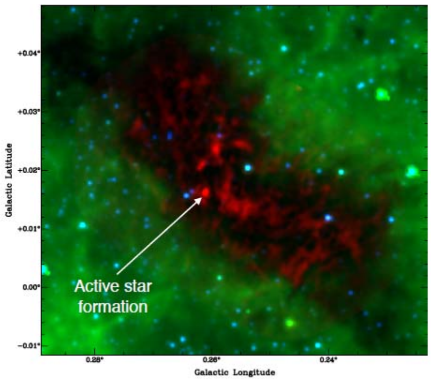

Fig. 1.— Three colour image of G0.253+0.016 (blue is *Spitzer* 3.6 μm emission tracing stars, green is *Spitzer* 8.0 μm emission tracing the bright Galactic background, while red is ALMA 3 mm emission tracing dust from the cloud's interior; the cloud has an effective radius of 2.9 pc). The position of a water maser is marked, which is evidence for active star formation. The cloud is so cold and dense that it is seen as an extinction feature against the bright IR emission from the Galaxy. Because ALMA sees through to the cloud's interior, we are now able to characterise its internal structure.

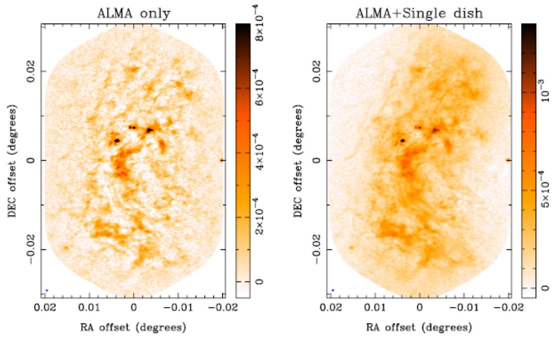

Fig. 2.— Images of the 3 mm dust continuum emission (in units of mJy beam^{-1}) toward G0.253+0.016 showing the emission detected in the ALMA-only image (left) and the recovery of the emission on the large spatial scales provided by the inclusion of the zero-spacing information (ALMA + single dish, right). These images are shown in equatorial coordinates: the (0,0) offset position in R.A. and Dec is 17:46:09.59, −28:42:34.2 J2000.

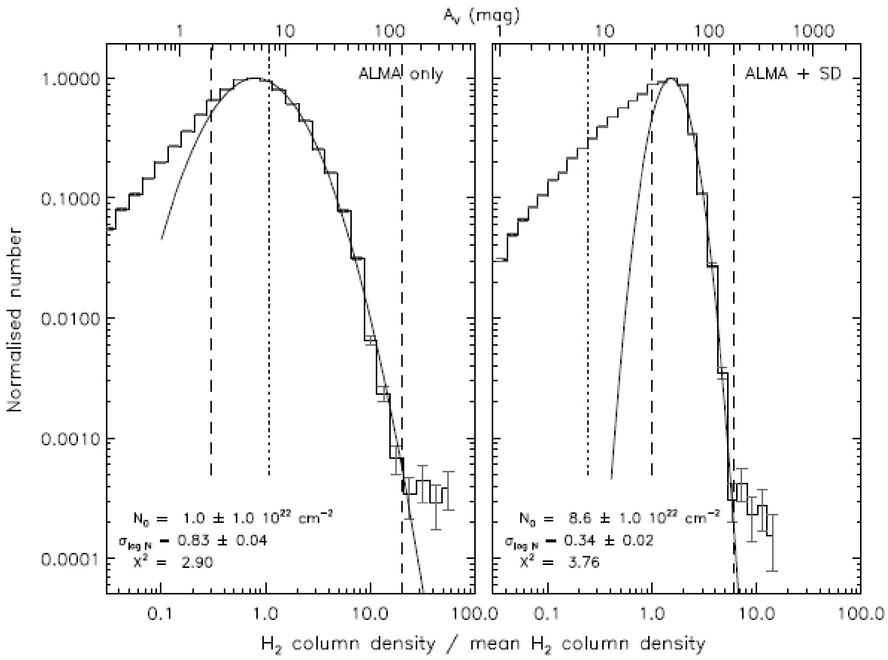

Fig. 3.— Normalised column density PDFs for G0.253+0.016 (histograms, *left:* derived using the ALMA-only image, *right:* derived using the combined image). The error bars show the $\sqrt{number}$ uncertainties. The solid curves are log-normal fits to the PDF: best-fit parameters are labeled. Vertical dashed lines show the fit range (the limits mark the approximate point at which the distributions deviate from log-normal). Vertical dotted lines mark $N(H_2)=1.4 \times 10^{22}\,cm^{-2}$. The small deviation at the highest column densities traces material that is self-gravitating and corresponds to the only location in the cloud where star formation is occurring.

Measured:			
Mean, column density PDF (N_0)	0.5–3.0$\times 10^{21}$ cm^{-2}	86 $\pm$ 20 $\times 10^{21}$ cm^{-2}	7, 8
Dispersion, column density PDF ($\sigma_{\log N}$)	0.28–0.59	0.34 $\pm$ 0.03	7, 8
Critical volume density (ρ_{crit})	10^4 cm^{-3}	$> 10^6$ cm^{-3}	3, 9, 8
Predicted (relative to solar neighbourhood clouds):			
Mean, column density PDF (N_0)	1	100	
Dispersion, volume density PDF ($\sigma_{\log \rho}$)	1	1.2	
Critical volume density (ρ_{crit})	1	10^4	10, 11, 5

Discovery of a companion candidate in the HD169142 transition disk and the possibility of multiple planet formation

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1408.0813.pdf

We present L′ and J-band high-contrast observations of HD169142, obtained with the VLT/NACO AGPM vector vortex coronagraph and the Gemini Planet Imager, respectively. A source located at 0”.156±0”.032 north of the host star (PA=7.4° ±11.3°) appears in the final reduced L′ image. At the distance of the star (~145 pc), this angular separation corresponds to a physical separation of 22.7±4.7 AU, locating the source within the recently resolved inner cavity of the transition disk. The source has a brightness of L′=12.2±0.5 mag, whereas it is not detected in the J band (J >13.8 mag). If its L′ brightness arose solely from the photosphere of a companion and given the J－L′ color constraints, it would correspond to a 28-32 $M_{Jupiter}$ object at the age of the star, according to the COND models. Ongoing accretion activity of the star suggests, however, that gas is left in the inner disk cavity from which the companion could also be accreting. In this case the object could be lower in mass and its luminosity enhanced by the accretion process and by a circumplanetary disk. A lower mass object is more consistent with the observed cavity width. Finally, the observations enable us to place an upper limit on the L′-band flux of a second companion candidate orbiting in the disk annular gap at ~50 AU, as suggested by millimeter observations. If the second companion is also confirmed, HD169142 might be forming a planetary system, with at least two companions opening gaps and possibly interacting with each other.

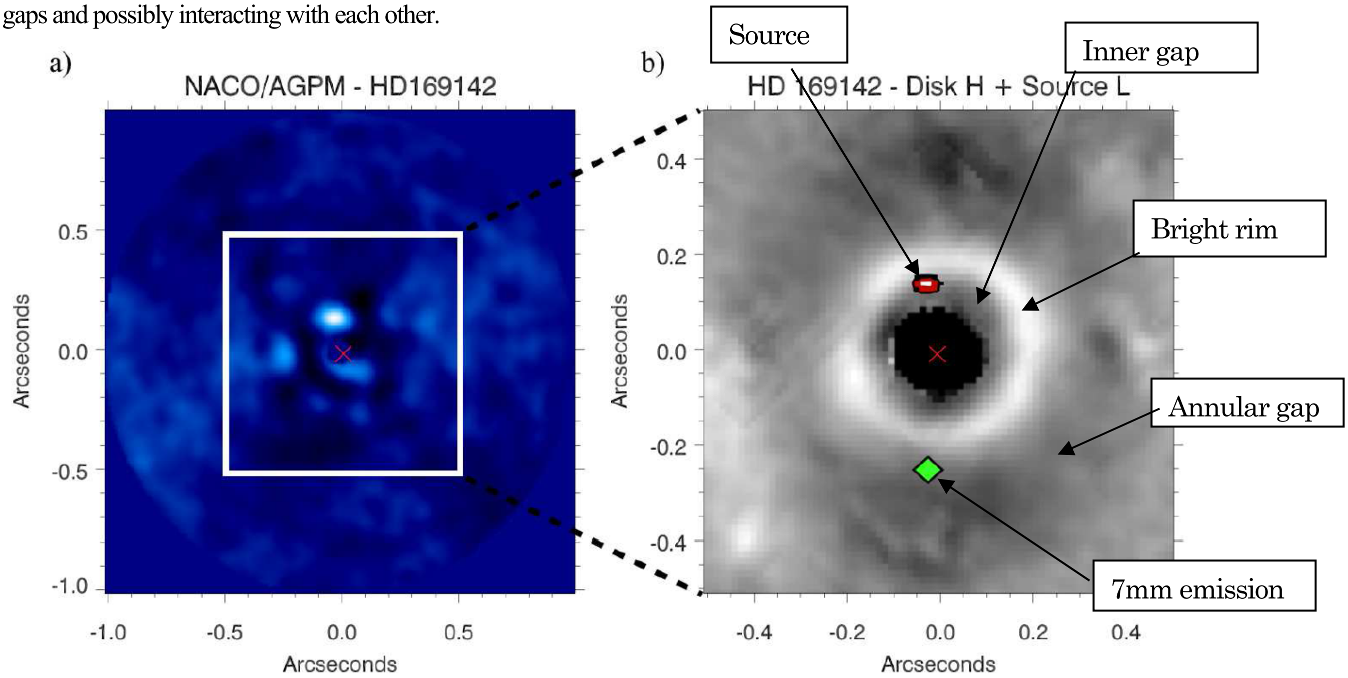

FIG. 1.— a) NACO/AGPM L' image of HD169142, using PYNPOINT with 20 PCA coefficients. A bright source is detected north of the central star. The image is scaled with respect to the maximum flux. b) H-band PDI image of the circumstellar disk of HD169142 (Quanz et al. 2013b). The inner cavity (<25 AU), the bright rim, and the annular gap (40-70 AU) are clearly visible. Overplotted in red contours is the detected L' source. The green diamond indicates the location of the compact 7-mm emission detected by Osorio et al. (2014).

可能性

1）ArfifactやBackground starやrimの可能性もあるが、

2）KH収縮中の星、the L′ luminosity suggests a mass of 35-80 $M_{Jupiter}$ for an age of 3-12 Myrs (Grady et al. 2007), according to the COND models (Baraffe et al. 2003). その場合はJband でJ=13.6-13.7 magで検出されるはずだが未検出。

a 28-32 $M_{Jupiter}$ object at 3 Myrs.ならよい。が、この質量では結構大きな54-59AU のギャップが生じるので、25AU程度なら10木星質量程度で良い。

３）形成中の惑星、降着luminosityによって明るくなる。

Annular gap中の天体はL,Jバンドでは見つかっていない。

An Ionized Outflow from AB Aur, a Herbig Ae Star with a Transitional Disk

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1408.7068v1.pdf

AB Aur is a Herbig Ae star with a transitional disk. Transitional disks present substantial dust clearing in their inner regions, most probably because of the formation of one or more planets, although other explanations are still viable. In transitional objects, accretion is found to be about an order of magnitude smaller than in classical full disks. Since accretion is believed to be correlated with outflow activity, centimeter free-free jets are expected to be present in association with these systems, at weaker levels than in classical protoplanetary (full) systems. We present new observations of the centimeter radio emission associated with the inner regions of AB Aur and conclude that the morphology, orientation, spectral index and lack of temporal variability of the centimeter source imply the presence of a collimated, ionized outflow. The radio luminosity of this radio jet is, however, about 20 times smaller than that expected for a classical system of similar bolometric luminosity. We conclude that centimeter continuum emission is present in association with stars with transitional disks, but at levels than are becoming detectable only with the upgraded radio arrays. On the other hand, assuming that the jet velocity is 300 km s^{-1}, we find that the ratio of mass loss rate to accretion rate in AB Aur is ~0.1, similar to that found for less evolved systems.

AB Aur is a Herbig Ae star at a distance of 144 pc

Fukagawa et al. (2004) revealed spiral arms of enigmatic origin in the disk.

Pi´etu et al. (2005) found that the dust disk is truncated at an inner radius of about 70 AU from the central star.

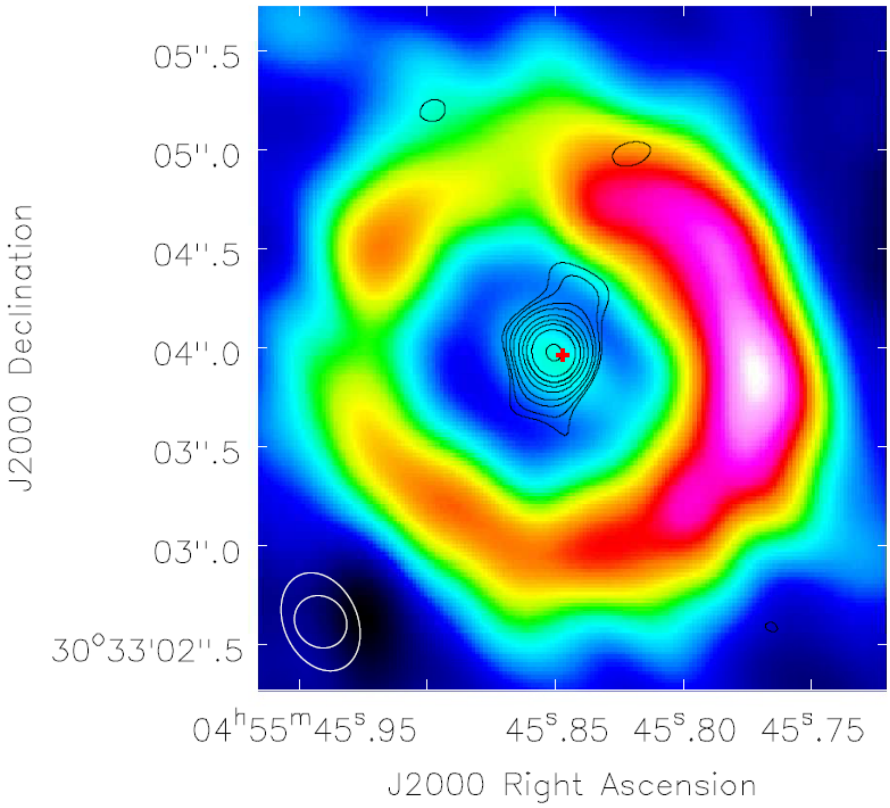

Fig. 1.— The VLA 3.3 cm continuum emission is shown in black contours overlaid on a color image of the 1.3 mm emission (Tang et al. 2012). The black contours are 8.6, 11.5, 17.3, 23.0, 34.6, 46.1, 57.6, 74.9 and 115.2 μJy beam^{-1}. The half-power contour of the synthesized beam of the 3.3 cm emission is shown as the smaller ellipse in the bottom left corner. The larger ellipse is the half-power contour of the synthesized beam of the 1.3 mm emission. The small red cross indicates the position of the star AB Aur, corrected for proper motions (van Leeuwen 2007).