Resolving the Vela C ridge with P-ArTéMiS and Herschel\textsuperscript{1-3,4,5,6}

T. Hill\textsuperscript{1}, Ph. André\textsuperscript{1}, D. Arzoumanian\textsuperscript{1}, F. Motte\textsuperscript{1}, V. Minier\textsuperscript{1}, A. Men'shchikov\textsuperscript{1}, P. Didelon\textsuperscript{1}, M. Hennemann\textsuperscript{1}, V. Könyves\textsuperscript{1,2}, Q. Nguyen-Luong\textsuperscript{3}, P. Palmeirim\textsuperscript{1}, N. Peretto\textsuperscript{1}, N. Schneider\textsuperscript{1,4,5}, S. Bontemps\textsuperscript{4,5}, F. Louvet\textsuperscript{1}, D. Elia\textsuperscript{6}, T. Giannini\textsuperscript{6}, V. Revéret\textsuperscript{1}, J. Le Pennec\textsuperscript{1}, L. Rodriguez\textsuperscript{1}, O. Boulade\textsuperscript{1}, E. Doumayrou\textsuperscript{1}, D. Dubreuil\textsuperscript{1}, P. Gallais\textsuperscript{1}, M. Lortholary\textsuperscript{1}, J. Martignac\textsuperscript{1}, M. Talvard\textsuperscript{1}, and C. De Breuck\textsuperscript{1}

1 Laboratoire AIM, CEA/IRFU CNRS/INSU Université Paris Diderot, CEA-Saclay, 91191 Gif-sur-Yvette Cedex, France
2 Institut d’Astrophysique Spatiale, CNRS/Université Paris-Sud 11, 91405 Orsay, France
3 Canadian Institute for Theoretical Astrophysics – CIT, University of Toronto, 60 St. George Street, Toronto, Ontario, M5S 3H8, Canada
4 Université de Bordeaux, Bordeaux, LAB, UMR 5804, 33270 Floirac, France
5 CNRS, LAB, UMR 5804, 33270 Floirac, France
6 IAPS – Istituto di Astrofisica e Planetologia Spaziali, via Fosso del Cavaliere 100, 00133 Roma, Italy
7 European Southern Observatory, Karl Schwarzschild Str. 2, 85748 Garching bei Munchen, Germany

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Abstract

We present APEX/P-ArTéMiS 450 μm continuum observations of RCW 36 and the adjacent ridge, a high-mass high-column density filamentary structure at the centre of the Vela C molecular cloud. These observations, at higher resolution than Herschel/SPire camera, reveal clear fragmentation of the central star-forming ridge. Combined with PACS far-infrared and SPIRE sub-millimetre observations from the Herschel HOBYS project we build a high resolution column density map of the region mapped with P-ArTéMiS. We extract the radial density profile of the Vela C ridge which with a ~0.1 pc central width is consistent with that measured for low-mass star-forming filaments in the Herschel Gould Belt survey. Direct comparison with Serpens South, of the Gould Belt Aquila complex, reveals many similarities between the two regions. Despite likely different formation mechanisms and histories, the Vela C ridge and Serpens South filament share common characteristics, including their filament central widths.

Key words. ISM: individual objects: Vela C – ISM: individual objects: RCW 36 – submillimeter: stars – dust, extinction – stars: early-type – stars: protostars

1. Introduction

Independent of mass, the formation of a star is a key astrophysical process: while high-mass stars drive galactic formation and ecology, low-mass stars populate their host galaxy and are themselves likely hosts of planetary systems. Although the formation paradigm for low-mass stars has been relatively well established the formation scenario for high mass stars is less clear, as are the processes involved in their formation (McKee & Ostriker 2007; Zinnecker & Yorke 2007).

The Herschel Space Observatory (Pilbratt et al. 2010) is providing important observational insights into both low- and high-mass star formation in our Galaxy. In particular, two Herschel key projects focus on low- and high-mass star formation in relatively nearby star-forming complexes: the Gould Belt survey (HGBS, 130–500 pc; André et al. 2010) and HOBYS (700 pc–3 kpc; Motte et al. 2010), respectively. Combining these two projects will help us to examine the differences between low- and high-mass star formation.

\textsuperscript{1} This publication is based on data acquired with the Atacama Pathfinder Experiment (APEX) in ESO program 083.C-0996. APEX is a collaboration between the Max-Planck-Institut für Radioastronomie, the European Southern Observatory, and the Onsala Space Observatory.

\textsuperscript{2} Herschel is an ESA space observatory with science instruments provided by European-led Principal Investigator consortia and with important participation from NASA.

\textsuperscript{3} Figures 4, 5, and Appendix A are available in electronic form at http://www.aanda.org

\textsuperscript{*} Herschel observations in the far-infrared and submillimetre, the crucial regime for studying the birthplaces of stars, have revealed most star-forming complexes in our Galaxy to be comprised of filamentary structures (André et al. 2010; Molinari et al. 2010). Star formation proceeds in the densest (“supercritical”) of these filaments, which can be clustered into organised networks (nests) or into single dominating ridges (Hill et al. 2011). Arzoumanian et al. (2011) found that in low-mass star-forming regions these interstellar filaments could be characterised by a standard central width, or thickness, of ~0.1 pc.

The Vela C molecular cloud was recently observed with Herschel as part of the HOBYS project (Hill et al. 2011; Giannini et al. 2012; Minier et al. 2012). Vela C is known to house low-, intermediate- and high-mass star formation (Massi et al. 2003; Netterfield et al. 2009; Hill et al. 2011) and is thought to be at an early stage in its evolution (<10^6 yr). Running through the centre of Vela C is a ridge, a high-column density (~100 mag\textsuperscript{-1}) self-gravitating filament, which houses the majority of the high-mass dense cores in the cloud (Hill et al. 2011). Adjacent to this ridge, and at roughly the centre of the Vela C molecular cloud is the RCW 36 ionising star cluster. Minier et al. (2012) showed that the ridge results from the ionisation of an initial sheet of molecular gas. Located at 700 pc, Vela C is the closest complex in the HOBYS sample, which allows direct comparison with low-mass star-forming regions, such as those targeted by the HGBS project, at comparable spatial resolution.

Where N_{H_{2}} = 0.94 A_{V} \times 10^{21} cm^{-2} mag^{-1} (Bohlin et al. 1978).
Fig. 1. P-ArTéMiS 450 μm map of the RCW 36/Vela C ridge at 10′′ resolution. The contours are 3, 7, 11 Jy/10′′-beam and the rms noise level in the central part of the map is ~1 Jy/10′′-beam.

Here we present a study of the Vela C ridge and RCW 36 using the P-ArTéMiS camera\(^2\) at 450 μm on APEX. P-ArTéMiS is used here to complement the Herschel/ SPIRE bands in the submillimetre (250, 350, 500 μm), at a factor 2–3 higher resolution (e.g. 11.5′′ compared with 25′′ at 350 μm).

2. Observations and data reduction

The RCW 36 region of Vela C was observed using the P-ArTéMiS bolometer camera\(^2\) at 450 μm on APEX. P-ArTéMiS is used here to complement the Herschel/ SPIRE bands in the submillimetre (250, 350, 500 μm), at a factor 2–3 higher resolution (e.g. 11.5′′ compared with 25′′ at 350 μm).

3. Structural analysis

3.1. Column density and dust temperature maps

Multiple wave-band observations covering the far-infrared and sub-millimetre regime allow construction of column density (\(N_{\text{H}_2}\)) and dust temperature maps. The maps of these quantities for the Vela C ridge/RCW 36 region, derived from Herschel data, were drawn using pixel-by-pixel spectral energy distribution (SED) fitting according to a modified blackbody with a single dust temperature (cf. Hill et al. 2012). Only the longest four Herschel wavebands were used. In order to do this, the Herschel observations were first convolved to the resolution of the 500 μm band (36′′), and the zero offsets derived from Planck data were applied (see Hill et al. 2011). The quality of the SED fit was assessed using \(\chi^2\) minimisation. The corresponding column density map of the Vela C ridge and RCW 36 is given in Fig. 2 (left).

As our P-ArTéMiS data at 10′′ resolution have better resolution than that of all of the Herschel/ SPIRE bands, we devised a method to derive a higher resolution column density map of the Vela C ridge and RCW 36 region mapped by P-ArTéMiS. By combining the PACS 160 μm, SPIRE 250 μm and P-ArTéMiS 450 μm data we were able to derive a column density map at 11.5′′ resolution, i.e. the resolution of the 160 μm Herschel map. This method is similar to the one used by Palmeirim et al. (2012, submitted) for their higher resolution Herschel column density map of the Taurus B211 region, but adapted for P-ArTéMiS as outlined in Appendix A. Due to the area covered by our P-ArTéMiS observations, only ~1/3 of the full Vela C ridge detected by Herschel is measured in the higher resolution column density map, which shows clear fragmentation into a number of cores/clumps. These cores are clearly visible with P-ArTéMiS (see Fig. 1) but could not be previously identified from the lower resolution Herschel column density map (Fig. 2, left).

3.2. Filamentary structure

At the 36′′ resolution of the Herschel column density map, the RCW 36 region is characterised by a single dominating high-column density filament containing the Vela C ridge (see Fig. 2). The filamentary structure seen in our higher resolution column density map is consistent with that seen in the lower resolution map, with slight deviations as it traces the topological structure of the fragmented cores (see Fig. 2, right). The mean column density of the Vela C ridge, as measured from the higher resolution column density map, is ~9 × 10\(^{22}\) cm\(^{-2}\).

The mean radial density profile (\(\rho_r\)) of the Vela C ridge (Fig. 3) was derived by measuring cuts perpendicular to the crest of the filament at each pixel, and then averaging along the length of the filament (as detailed in Arzoumanian et al. 2011). In order to derive the characteristic parameters of the profile (e.g. central density, power law exponent), we assume a cylindrical filament model given by a Plummer-like function, which is a density profile that can be expressed in terms of column density. Accordingly,

\[
\rho_r(r) = \frac{\rho_c}{\left[1 + (r/R_{\text{flat}})^2\right]^{3p/2}}
\]

where \(\rho_c\) is the radial density at the centre of the filament, \(p\) is the exponent of the model function, and \(R_{\text{flat}}\) is the characteristic radius for the flat inner portion of the profile.

The Vela C ridge can be characterised by an inner radius \(R_{\text{flat}} \sim 0.05\pm0.02\) pc, and a deconvolved FWHM of 0.12±0.02 pc which is consistent with that seen in low-mass star-forming filaments (Arzoumanian et al. 2011). The Vela C radial density profile decreases at large radii as \(r^{-2.7\pm0.2}\). The filament outer radius ~0.4 ± 0.1 pc is defined from the deviation of the observed ( western side) profile from the Plummer fit (cf. Fig. 3). The eastern side of the profile, containing the OB star cluster, decreases up to a larger radius ~1–1.5 pc (see Fig. 4).
The Vela C ridge and Serpens South filament have a similar mass and length. We have extended our study of filamentary structures to the Serpens South filament, part of the Aquila star-forming complex at $d \sim 260$ pc (see Fig. 5). The Serpens South filament is particularly interesting as it, as one of the most extreme column density filaments of the HGBS, is comprised of high-column density material, similar to Vela C. Bontemps et al. (2010) detected seven Class 0 protostars, confirming that Serpens South is undergoing low- to intermediate-mass star formation, while Maury et al. (2011) used evolutionary tracks to estimate the lifetime of these Class-0 protostars and showed that Serpens South is at a very early phase of forming stars.

The column density map of Serpens South has been derived in the same manner as that of Vela C (see Sect. 3.1 and Könyves et al. 2010), with only the longest four Herschel bands. The 36" resolution of this map, at the distance of Serpens South, corresponds to a spatial resolution of 0.05 pc on the sky, comparable to that of Vela C when using our higher-resolution column density maps with P-ArTéMiS data (0.04 pc at 700 pc). These two regions – Serpens South, forming low- to intermediate-mass stars, and Vela C forming intermediate and potentially high-mass stars – provide a good comparative opportunity.

The crest shown in Fig. 5 (left) for the Serpens South filament is $\sim 1.2$ pc in length and has an average column density value of $6.4 \times 10^{22}$ cm$^{-2}$ (after subtracting a background of $3.7 \times 10^{21}$ cm$^{-2}$). The crest shown in Fig. 2 for the Vela C ridge is $\sim 0.8$ pc in length and is slightly more dense at $8.6 \times 10^{22}$ cm$^{-2}$. The Vela C ridge and Serpens South filament have a similar mass per unit length ($M_{\text{line}} = 320(\pm 75)$ or $400(\pm 85) M_{\odot}$/pc as measured from the integrated radial profile of 0.4 and 1.5 pc, respectively, after subtracting a background of $3.6 \times 10^{21}$ cm$^{-2}$.

4. Comparison with the Serpens South filament

Recent Herschel observations have revealed the prolificity of interstellar filaments in star-forming complexes, though only those filaments above an $A_V$ of $\sim 8$ mag are supercritical and capable of forming stars (André et al. 2010, 2011). Arzoumanian et al. (2011) showed that the filaments in low-mass HGBS regions tend to have inner widths of $\sim 0.1$ pc. With higher resolution P-ArTéMiS data at hand it is possible to check the application of such a characteristic filament width to more distant, higher mass regions, such as the Vela C complex at $d \sim 700$ pc. Here we have shown that, based on its radial column density profile, the Vela C ridge has a filament inner width consistent with the characteristic inner width suggested by Arzoumanian et al. (2011).
thus core surveys in Vela C are intrinsically biased toward more massive objects than those accessible in Serpens South.

5. Universality of star-forming filament profiles?

Star formation requires a reservoir of material, concentrated into a small volume, from which the burgeoning young star can accumulate mass. The idea of a minimum mass, or density requirement, for star formation inside molecular clouds is not surprising. Evans (2008) suggested that star formation is restricted to dense gas within molecular clouds, which also has a higher star formation efficiency than lower density gas. Comparing Spitzer inventories of young stellar objects with dust extinction ($A_V$) maps of nearby molecular clouds, both Lada et al. (2010) and Heiderman et al. (2010) suggested that star formation requires a minimum gas density (corresponding to $A_V = 8$ mag). Essentially the same column density threshold was recently found by André et al. (2010, 2011) from an analysis of the prestellar core population in the Aquila complex based on Herschel data (see also Sect. 1).

In addition to a minimum mass/density for core and star formation, a minimum threshold for high-mass star formation has also been suggested both theoretically (Krumholz & McKee 2008) and observationally (Kaufmann & Pillai 2010). According to these authors, low- and high-mass stars likely do not form in the same environments, with the latter requiring a minimum density, and the two modes of star formation (low- and high-mass) are distinct from each other.

In this Letter we have compared two nearby (<700 pc) regions undergoing clustered star formation. The Vela C molecular cloud is known as a low- to intermediate-mass star-forming molecular cloud. The Vela C ridge however is associated with a high-mass ionising star cluster (Minier et al. 2012), and hosts seven high-mass dense cores (Hill et al. 2011) each with the potential to form high-mass stars. Ridges are the extreme density filaments of high-mass star-forming regions whose large areas of influence suggest that they may have been formed through dynamic scenarios such as converging flows, filament mergers and/or ionisation pressure from nearby star clusters (Hill et al. 2011; Nguyen Luong et al. 2011; Hennemann et al. 2012; Minier et al. 2012). Comparatively, the Serpens South filament is populated by low- to intermediate-mass protostars (Gutermuth et al. 2008; Maury et al. 2011). Both of these filamentary star-forming clumps have supercritical masses per unit length and are thus likely to form more stars in the future.

Our analysis of the filamentary structure in the Vela C ridge and the Serpens South filament indicates that the two are quite similar with respect to their column density profile and mass per unit length, yet the Vela C ridge is a factor of ~2 longer and is slightly more massive than the Serpens South filament (see Sect. 4). The lack of known Class-0 protostars in Vela C may arise from sensitivity limitations, but the same cannot be said for the lack of high-mass dense cores in Serpens South.

While the Vela C ridge and Serpens South filament are likely to have formed in different environments, under different conditions, and to have experienced different histories (with, e.g., the strong ionizing effect of a massive star cluster in the case of Vela C, and no such effect in Serpens South), these two regions display a similar filament inner width ~0.1 pc which is also consistent with the characteristic inner width found for low-mass star-forming filaments by Arzoumanian et al. (2011). This suggests that supercritical filaments and ridges, regardless of their formation process, have the same inner width which may be characteristic across modes of star formation. These results advocate a high degree of commonality among star-forming filaments, independently of the masses of the stars they form, rather than the aforementioned idea of distinct environmental conditions for higher mass stars.

More work would be needed to establish the universality of star-forming filament profiles in the high-mass regime. Recently, Hennemann et al. (2012) used HOBYS data to show that the high-mass DR 21 ridge in the Cygnus X complex (d ~ 1.4 kpc) has an apparent mean central width of ~0.3 pc when observed at a resolution 0.17 pc. The flat inner portion of the DR 21 ridge was however only marginally resolved with Herschel observations. It should be stressed that higher mass star-forming ridges and filaments occur at greater distances than lower mass ones, and observations of these are thus subject to lower spatial resolution. At distances exceeding that of Vela C (>700 pc) a characteristic inner width of ~0.1 pc would remain unresolved, or at best marginally resolved with Herschel. Higher resolution observations of high-mass star-forming filaments and ridges, with for example the full ArTéMiS camera to be installed soon on APEX or the Atacama Large Millimetre Array (ALMA), over a greater number of regions are needed now to address the hypothesis of a characteristic inner width for interstellar filaments independently of the masses of the stars they form.

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References

André, P., Men'shchikov, A., Bontemps, S., et al. 2010, A&A, 518, L102
André, P., Men'shchikov, A., Könyves, V., & Arzoumanian, D. 2011, in IAU Symp. 270, eds. J. Alves, et al., 255
André, P., Minier, V., Gallais, P., et al. 2008, A&A, 490, L27
Arzoumanian, D., André, P., Didelon, P., et al. 2011, A&A, 529, L6
Bolton, R. C., Savage, B. D., & Drake, J. F. 1978, ApJ, 224, 132
Bontemps, S., André, P., Könyves, V., et al. 2010, A&A, 518, L85
Evans, H. N. 2008, in Pathways Through an Eclectic Universe, eds. J. H. Knapen, T. J. Mahoney, & A. Vazdekis, ASP Conf. Ser., 390, 52
Giannini, T., Elia, D., Lorenzetti, D., et al. 2012, A&A, 539, A156
Gutermuth, R. A., Bourke, T. L., Allen, L. E., et al. 2008, ApJ, 673, L151
Heiderman, A., Evans, II, N. J., Allen, L. E., et al. 2010, ApJ, 723, 1019
Hennemann, M., Motte, F., Schneider, N., et al. 2012, A&A, 543, L3
Hildebrand, R. H. 1983, QJRAS, 24, 267
Hill, T., Motte, F., Didelon, P., et al. 2012, A&A, 542, A114
Kaufmann, J., & Pillai, T. 2010, ApJ, 723, L7
Könyves, V., André, P., Men'shchikov, A., et al. 2010, A&A, 518, L106
Krumholz, M. R., & McKee, C. F. 2008, Nature, 451, 1082
Lada, C. J., Lombardi, M., & Alves, J. F. 2010, ApJ, 724, 687
Massi, F., Lorenzetti, D., & Giannini, T. 2003, A&A, 399, 147
Maury, A. J., André, P., Men'shchikov, A., et al. 2011, A&A, 535, A77
McKee, C. F., & Ostriker, E. C. 2007, ARA&A, 45, 565
Minier, V., Bergman, P., et al. 2009, A&A, 501, L1
Minier, V., Tremblin, P., Hill, T., et al. 2012, A&A, submitted
Molinari, S., Swinyard, B., Bally, J., et al. 2010, A&A, 518, L100
Motte, F., Zavagno, A., Bontemps, S., et al. 2010, A&A, 518, L77
Netterfield, C. B., Ade, P. A. R., Bock, J. J., et al. 2009, ApJ, 707, 1824
Nguyen Luong, Q., Motte, F., Hennemann, M., et al. 2011, A&A, 535, A76
Palmeirim, P., André, P., & Gould Belt consortium 2012, A&A, submitted
Filbratt, G. L., Riedinger, J. R., Passvogel, T., et al. 2010, A&A, 518, L1
Stark, J.-L., & Mart tah, F. 2006, Astronomical Image and Data Analysis (Springer-Verlag)
Távald, M., André, P., Le-Penne c, Y., et al. 2010, in SPIE Conf. Ser., 7741
Zinnecker, H., & Yorke, H. W. 2007, ARA&A, 45, 481
Fig. 4. Left: mean radial column density profile measured on the eastern side of the Vela C ridge in the 11.5′′ resolution column density map shown in Fig. 2 (right). This figure is complementary to Fig. 3 for the side containing the OB cluster. This profile has a p value of $2.3 \pm 0.5$ and $R_{\text{flat}} = 0.05 \pm 0.02$ pc. The error bars in yellow show the dispersion of the radial profile along the filament, while the lines on the plot are as per Fig. 3 and as indicated on the key. Right: comparison of the mean background-subtracted radial profiles measured on the western side of the Vela C ridge in the 11.5′′ resolution column density map (black curve and yellow error bars) and in the 36.3′′ resolution column density map (orange curve). The black and orange dash-dotted curves represent the effective 11.5′′ and 36.3′′ HPBW resolutions of the corresponding data, respectively.

Fig. 5. Left: column density map of the Serpens South filament (36′′ resolution) derived from HGBS data (see Könyves et al. 2010), with the corresponding topological filament identified overlaid in blue. Right: mean radial density profile (taken from both sides of the filament) measured perpendicular to the supercritical Serpens South filament (left) shown here in log-log format. Lines and colour coding are consistent with Figs. 3 and 4. The Gaussian fit to the inner part of the profile (dotted blue curve) has a deconvolved $\text{FWHM}$ width $0.10 \pm 0.05$ pc. The best Plummer-like model fit (dashed red curve) has an inner radius $R_{\text{flat}} \sim 0.03 \pm 0.01$ pc and a power-law index $p = 2.02 \pm 0.27$.

Appendix A: Deriving a high-resolution column density map with P-ArTéMiS and Herschel data

The P-ArTéMiS 450 μm map (Fig. 1) provides information on small-scales in the RCW 36 ridge but is not sensitive to large-scale structures because any emission at low spatial frequencies has been completely filtered out during the process of atmospheric skynoise removal. Conversely, the Herschel column density map produced by Hill et al. (2011) at 36′′ resolution contains little information on scales <36′′ but provides an accurate view of larger-scale features. In order to combine these two complementary data sets, we used the following procedure (inspired from Palmeirim et al. 2012, submitted).

Following the spirit of a multi-resolution data decomposition (cf. Starck & Murtagh 2006), the gas surface density distribution of the RCW 36 region, smoothed to the resolution of the Herschel/PACS 160 μm observations, may be expressed as a sum of four terms:

$$\Sigma_{160} = \Sigma_{500} + (\Sigma_{350} - \Sigma_{500}) + (\Sigma_{250} - \Sigma_{350}) + (\Sigma_{160} - \Sigma_{250}) \quad \text{(A.1)}$$

where $\Sigma_{500}, \Sigma_{350}, \Sigma_{250},$ and $\Sigma_{160}$ represent smoothed versions of the intrinsic gas surface density distribution $\Sigma$ after convolution.
with the Herschel beam at 500 μm, 350 μm, 250 μm, and 160 μm respectively, i.e.: \( \Sigma_{500} = \Sigma + B_{500}, \Sigma_{350} = \Sigma + B_{350}, \Sigma_{250} = \Sigma + B_{250}, \) and \( \Sigma_{160} = \Sigma + B_{160}. \)

The first term of Eq. (A.1) is simply the surface density distribution smoothed to the resolution of the Herschel/SPIRE 500 μm data. An estimate, \( \Sigma_{500}, \) of this term can be obtained in a manner similar to Hill et al. (2011) through pixel-by-pixel SED fitting to the lowest four Herschel data points, assuming the following dust opacity law, very similar to that advocated by Hildebrand (1983) at submillimetre wavelengths: \( k_\nu = 0.1 \times (\nu/1000 \text{ GHz})^\beta \times (300 \mu \text{ m} / \nu \text{ cm}^2 / \text{ g}) \), with \( \beta = 2. \)

The second term of Eq. (A.1) may be written as \( \Sigma_{250} - \Sigma_{500} \). This subtraction of scales larger than 50 μm (i.e., \( \Sigma_{250} \)) from \( \Sigma_{500} \) suppresses the effect of the RCW36 cluster and its uncertain location along the line of sight. Simple tests suggest that this effect leads to an additional 50% uncertainty in the radial density profile.

Likewise, the third term of Eq. (A.1) may be written as \( \Sigma_{250} = \Sigma_{350} + G_{250_350}, \) where \( G_{250_350} \) is a circular Gaussian with FWHM \( \sqrt{24.9^2 + 18.2^2} \approx 26.4^\circ. \) (To first order, the SPIRE beam at 500 μm is a smoothed version of the SPIRE beam at 350 μm, i.e., \( B_{500} = B_{350} \)).

The fourth term on the right-hand side of Eq. (A.1) is
\[
\begin{align*}
\Sigma_{160} &= \Sigma_{500} + (\Sigma_{350} - \Sigma_{500} \times G_{500_350}) \\
&+ (\Sigma_{250} - \Sigma_{350} \times G_{250_350}) + (\Sigma_{160} - \Sigma_{250} \times G_{250_160}).
\end{align*}
\]

The resulting 11.5″ resolution column density map \( \Sigma_{160} \) of the Vela C ridge is also more uncertain than that of the Serpens South filament owing to the strong heating effect of the RCW36 cluster and its uncertain location along the line of sight. Simple tests suggest that this effect leads to an additional 50% uncertainty in the absolute calibration of the column density map of the Vela C ridge but has little influence on the shape of the radial density profile.

Finally, we note that our column density map of the Vela C ridge is also more uncertain than that of the Serpens South filament owing to the strong heating effect of the RCW36 cluster and its uncertain location along the line of sight. Simple tests suggest that this effect leads to an additional 50% uncertainty in the absolute calibration of the column density map of the Vela C ridge but has little influence on the shape of the radial density profile.