MOSAICING SYNTHESIS RADIO TELESCOPE IMAGES FOR THE CANADIAN GALACTIC PLANE SURVEY AT THE DOMINION RADIO ASTROPHYSICAL OBSERVATORY (DRAO)

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ABSTRACT

Major components of the Canadian Galactic Plane Survey are the radio images at 21cm and 74cm wavelengths. About 193 spectral data "cubes" and radio-continuum images at 21 cm have been mosaiced into large sub-images of the Milky Way covering altogether a region about 73 degrees long ($147.3 < l < 74.2$) and 9 degrees wide ($-3.6 < b < 5.6$). The original 21cm fields, observed with the DRAO Synthesis Telescope, are about 2 degrees wide with a resolution of about 1 arcmin. A computer program, SUPERTILE, combines the individual images into large mosaiced spectral data-cubes, suitable for astronomical interpretation.

INTRODUCTION

The Canadian Galactic Plane Survey (CGPS) [1] requires the mosaicing together of observations of many individual fields made with the Synthesis Telescope at the Dominion Radio Astrophysical Observatory. The individual fields are too small to be adequately interpreted from an astronomical perspective, because the Milky Way features that have been mapped often transit many fields. At the same time these features frequently contain fine structure at the limit of the telescope's resolution.

In this context, mosaicing refers to the combining of many adjacent, overlapping images into a single large image, taking into account that each individual (input) image has variable signal-to-noise ratio over the field, a general property of synthetic aperture telescopes. The variable signal-to-noise ratio is due to the method of aperture synthesis in which a high-resolution image is formed within the beam of individual small antennas in an array. Since mosaicing (in this case) is fundamentally a re-gridding process, it is useful to simultaneously provide the output data on a convenient sky-projection. Spectral line data observed with the telescope is 3-dimensional, in the sense that two of the dimensions are angular (on the sky), and one dimension is spectral. The 3-dimensional data is mosaiced as a series of images, one for each point in the spectrum.

This paper briefly describes the method and the software that carries out the mosaicing.

MOSAICING METHOD

The software tool used at DRAO to do this is SUPERTILE, part of the DRAO Export Software Package. The individual input datasets can be in different coordinate systems, although for the CGPS all input datasets are in the North Celestial Pole (NCP) coordinate projection. As well as producing a mosaiced output image or datacube, this program also outputs a "weight" image, which gives the weight of pixels in the mosaic. (For the CGPS, this image can be used to derive the noise distribution across the mosaic). Also produced are datasets giving the effective resolution across the mosaic. In its normal configuration, SUPERTILE can simultaneously mosaic up to 16 continuum images that are 1024 x 1024 pixels in size, or 16 datacubes that have spatial dimensions of 512 x 512 pixels. Special configurations for computers with large amounts of memory (512 Mbytes of RAM or more) can handle more or larger datasets.

The tiling operation is straight-forward but compute intensive. The J2000 equatorial coordinates are derived for each pixel in the desired projection of the output mosaic (a Galactic-coordinate grid for the CGPS). At each of these positions, a data-value and weight are interpolated from each of the input datasets. (For the CGPS, the weight is proportional to the square of the primary antenna response at the given point in the input image, and the radii of the input images are defined by the 10% level of the primary beam). Interpolation is "bi-cubic" in the spatial domain and linear in the spectral domain. The data value at the mosaic pixel is then the weighted sum of the input values. The software is designed so that, after a mosaic has been made, additional images or datacubes can be added to the mosaic at a later time. Other options provided by the software include the application of registration corrections (in position and intensity) to the input images, corrections to input images for primary-pattern attenuation, and corrections to datacubes for so-called "Doppler skew". The latter effect arises in Synthesis Telescope observations, where LSR velocity corrections are accurate only at the field center. Fig. 1 shows the fields used in creating an example λ21-cm mosaic.

Actual observing takes place in the Fourier transform plane of the images (the "*u-v* plane"), and in this case the *u-v* data-sampling coverage is very complete in each image, except for angular scales of about half the width of the image. Single antenna observations have been combined with the Synthesis Telescope observations to contribute structure on the largest of scales. The spacing of the fields, 112′ on a hexagonal grid, was determined as a compromise between complete sampling and uniform signal-to-noise in mosaiced images, and speed of sky coverage. Thus at λ21 cm there may be a very small range of spatial scales between the largest ones, observed with single antennas, and those corresponding to the smallest interferometer spacing, that are not fully sampled. No noticeable effect from this has been detected in the mosaiced images. Simultaneous CGPS observations were made at both λ21 cm and λ74 cm. At λ74 cm, the fields have very large overlap, and do not have any missing spatial information.

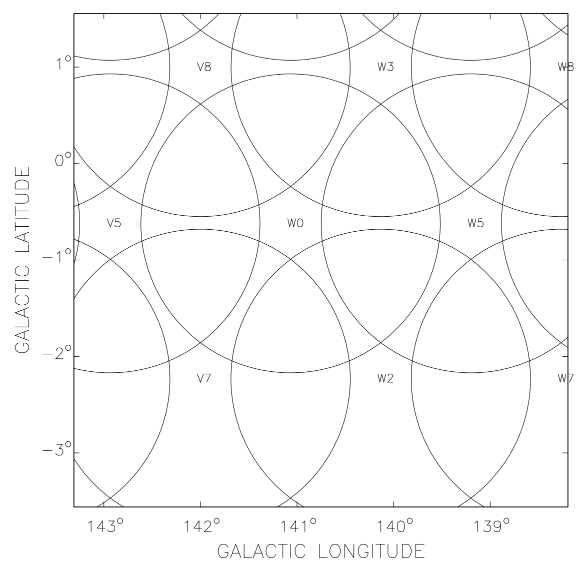
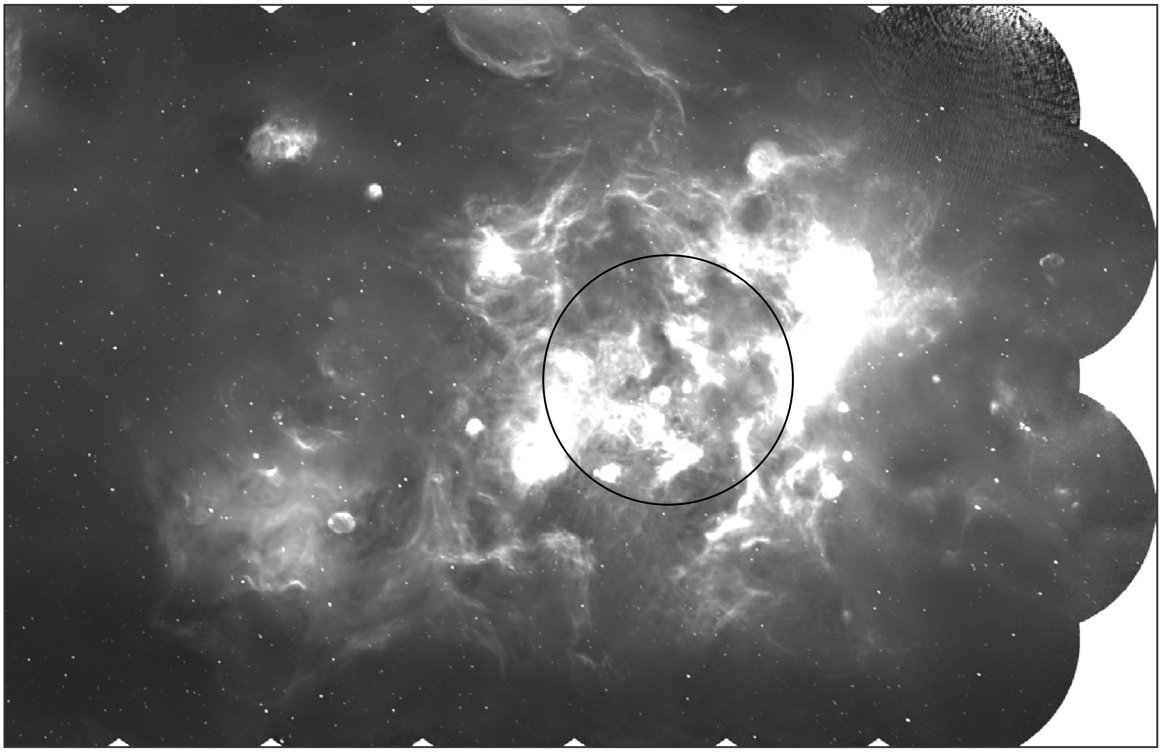


Fig 1. A schematic of the Synthesis Telescope field placements used in creating a CGPS mosaic. The radius of the fields is 93′, defined by the 10% cutoff of the primary antenna beam.

RESULTS

Fig. 2 shows a sample mosaiced result from the CGPS. The region shown is a part of the Milky Way known as the Cygnus region. In this region the line-of-sight is along one of the arms of the Milky Way, so that the many bright star-forming regions at different distances are superimposed on the sky. Radio waves readily penetrate dust that obscures much of this structure at optical wavelengths. The image shown is "burnt out" at the brightest levels to show the faint extended emission. One of the component fields of the mosaic is also shown in Fig. 2. The image shown in Fig. 2 is the Stokes I (total radio intensity) image. Similar mosaiced images of the (polarized) Stokes Q and U emission are being made in the same way. The data "cubes" (i.e. 3-dimensional images) referred to above are spectral-line images of the HI atomic hydrogen line. The spectra reveal the line-of-sight components of Doppler shift of the moving hydrogen gas.



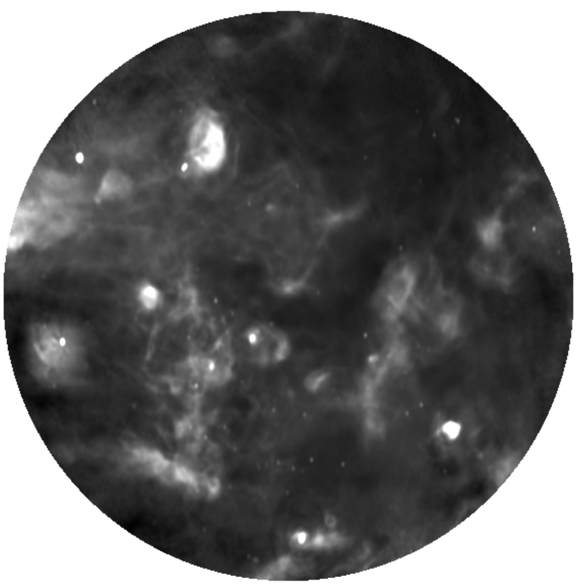


Fig. 2: A mosaiced region of the CGPS survey showing the λ21-cm continuum image of the Cygnus region of the Milky Way. The top image is a Galactic latitude and longitude projection in which the Galactic equatorial plane passes horizontally on the page near the center of the image. The angular width of the image is about 9°.

The image at the left is an example of a single field from which the mosaic at the top is made. Note that the brightest parts of the top image have been allowed to saturate, whereas this has not been necessary in the individual image. This field is in Right Ascension and Declination coordinates. The circle shows the position of this field in the mosaic above. (A rotation of about 45° is needed for the image on the left to be seen in the image above.)

REFERENCES

[1] A. R. Taylor, S. J. Gibson, M. Peracaula, T. L. Landecker, C. M. Brunt, P. E. Dewdney, S. M. Dougherty, A. D. Gray, L. A. Higgs, C. R. Kerton, L. B. G. Knee, R. Kothes, C. R. Purton, B. Uyaniker, B. J. Wallace, A.G. Willis, D. Durand, "The Canadian Galactic Plane Survey", unpublished.