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Report on the ESO–Radionet Workshop

# Submillimetre Single-dish Data Reduction and Array Combination Techniques

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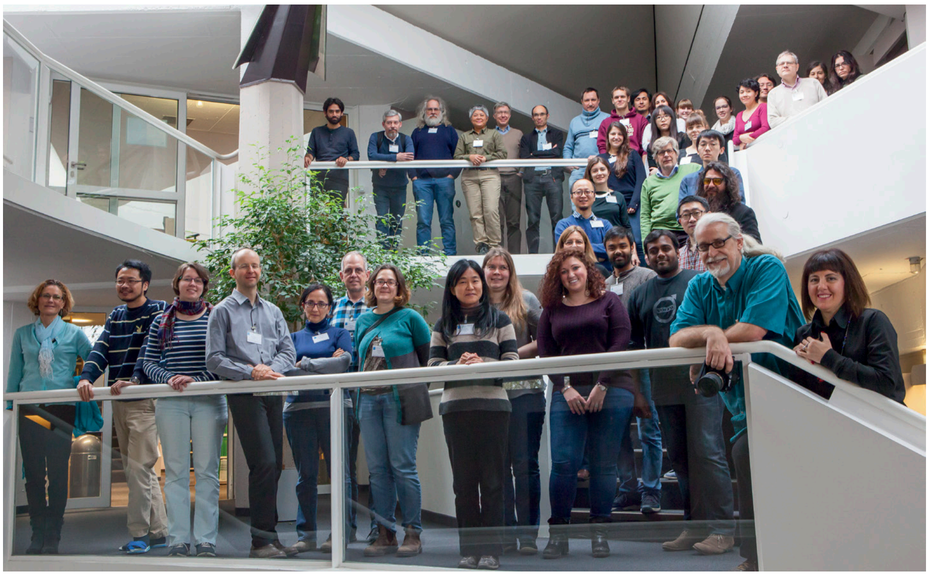
**Single-dish submillimetre facilities provide an essential complement to the Atacama Large Millimeter/submillimeter Array (ALMA) interferometry data, but require a set of special observing techniques and data reduction software that are different from those applied to radio and millimetre facilities. As there has not been a dedicated workshop to inform the ESO user community about these specific aspects, we decided to organise such a workshop, with the generous financial support of Radionet which made the workshop possible.**



ESO/L. Calçada

Figure 1. Workshop participants.

The workshop was attended by 42 participants (Figure 1), of whom 43% were women. The majority of the participants were PhD students or postdocs, likely reflecting those members of the wider community who are most actively working on this kind of data reduction[1].

The workshop began with a general overview by Thomas Stanke on the challenges of observing with single-dish telescopes at submillimetre wavelengths. In contrast to observing with interferometers, where the spatially extended sky signal is resolved, for single-dish telescopes, the sky dominates over the source signal by many orders of magnitude. Moreover, the sky signal varies significantly on timescales on the order of seconds. Most of the observing and data reduction techniques therefore need to concentrate on the removal of this bright sky emission. Additional challenges come from the atmospheric absorption bands and other instrumental effects. The subsequent lectures presented an overview of the ALMA and Atacama Pathfinder EXperiment (APEX) observing capabilities and observing strategies, followed by an introduction to the data reduction software used.

More than half of the time was reserved for (four) hands-on tutorial sessions. The first tutorial illustrated how to reduce ALMA total power data using the radio data processing package Common Astronomy Software Applications (CASA). Two additional tutorials showed how to reduce APEX heterodyne data using various alternative software packages: the Continuum and Line Analysis Single-dish Software (CLASS; see Figure 2); the Bolometer Array analysis software (BoA; Schuller, 2012); and the Interactive Data Language IDL pipeline using the mapmaking software Scanamorphos for ArTéMiS data (Roussel, 2013; Figure 3). All of these packages are freely available from either the Institut de Radioastronomie

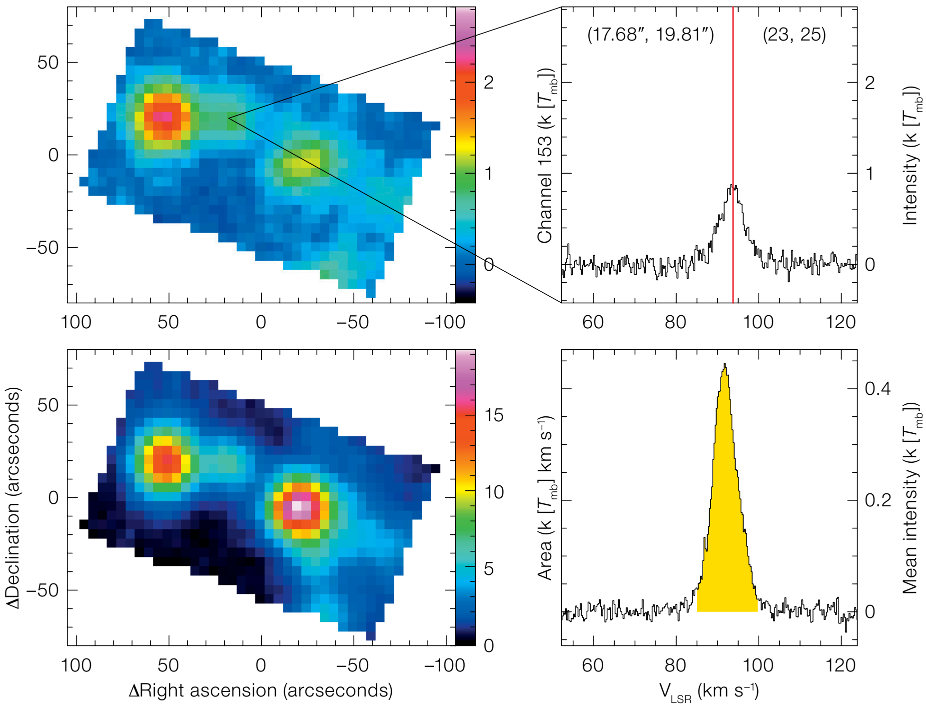



Figure 2. Example from CLASS tutorial: an on-the-fly data cube of the giant molecular cloud W43 observed in CS with the Swedish Heterodyne Facility Instrument (SHFI) on APEX. $T_{mb}$ is the main beam brightness temperature.

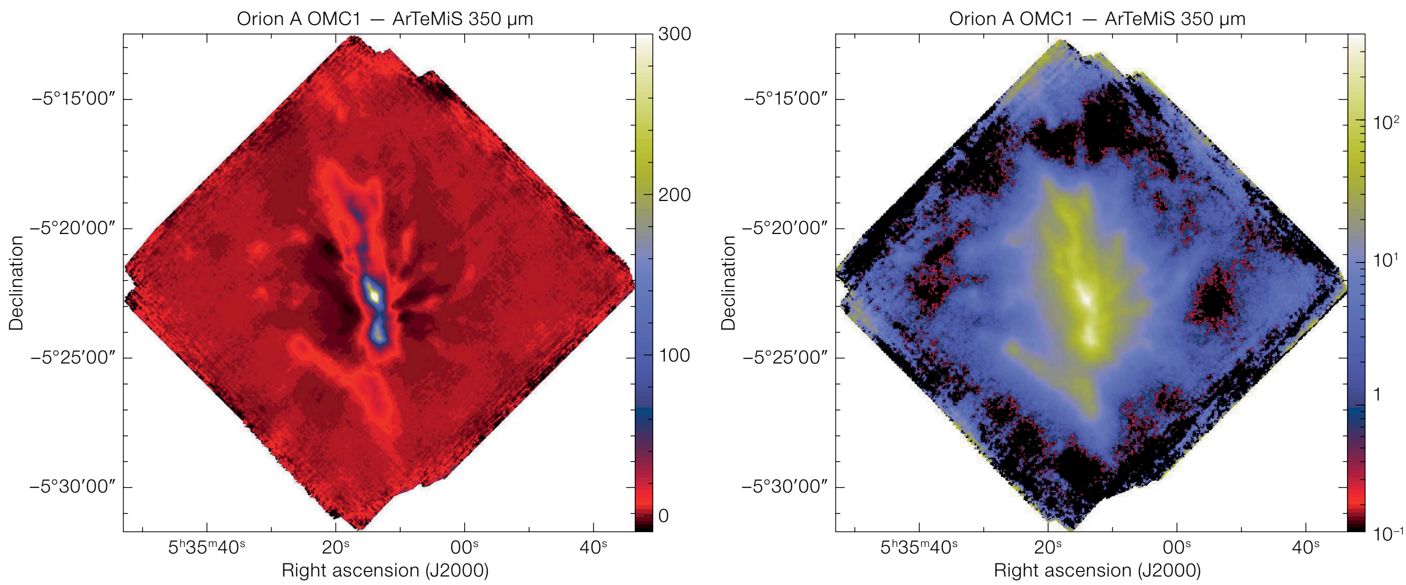



Figure 3. Example from the ArTéMiS data reduction tutorial. The image on the left shows the image after running through the basic ArTéMiS IDL pipeline. Note the negative bowls next to the bright emission, which are due to the over-subtraction of the sky signal. The image on the right shows the full reduction using the Scanamorphos pipeline, which uses the full redundancy of the data.

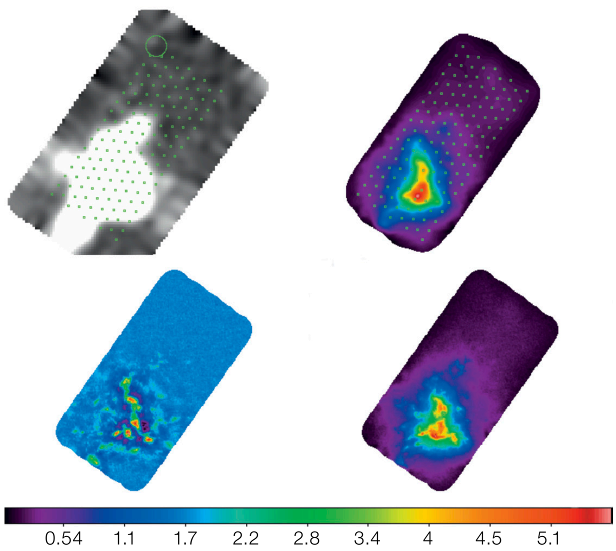



Figure 4. Top left: A channel from an ALMA total power observation of CO from a small region in the Small Magellanic Cloud. Overlayed on this greyscale are the pointing centres of the 12-metre array. For one pointing, the true extent of the 12-metre field of view is given as well with the larger green circle. Top right: The reconstructed total power map from the pseudo-visibilities generated from a virtual interferometer emulating the short spacings. Lower left: The pure interferometric map combining the 7- and 12-metre data. Lower right: Combining the total power visibilities with those of the 7- and 12-metre data recovers the large-scale flux as well as the fine scale structure. The size of each rectangle is ~ 5 × 3 arcminutes and the colour scale is in Jy/beam.

Millimétrique (IRAM) website for the Grenoble Image and Line Data Analysis Software (GILDAS[2]; Pety, 2005), or the APEX ArTéMiS pages[3].

One of the advantages of a single dish observation is that it can complement interferometric data by supplying information corresponding to short spacings that are filtered out by the interferometer, but that are necessary to recover the larger-scale emission. It is not uncommon to miss half of the flux in a more extended component when considering only interferometric data.

The majority of the second day in the workshop was spent on a number of techniques that have been developed and fine-tuned over the past 30 to 40 years, including a tutorial following the standard example of the M100 spiral galaxy using CASA, supplemented with two new techniques. The default method in CASA is called "feather", but two new techniques were also highlighted: Short Spacing Corrections (SSC) — which combines two images — and the Total Power to Visibility tool (TP2VIS) — which replaces the single dish map with pseudo-visibilities that can be used in a standard joint deconvolution method to create images.

Talk slides, example scripts and example data are linked from the workshop web page[1], the workshop Zenodo repository[4], as well as via a github repository[5] that was updated throughout the workshop.

## Acknowledgements

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## References

Pety, J. 2005, SF2A-2005, ed. Casoli, F. et al., EdP-Sciences, Conference Series, 721
Roussel, H. 2013, PASP, 125, 1126
Schuller, F. 2012, SPIE, 8452, 84521T

## Links

1 Meeting web page: https://www.eso.org/sci/meetings/2018/SingleDish2018.html
2 IRAM GILDAS website: https://www.iram.fr/IRAMFR/GILDAS/
3 APEX ArTéMiS pages[3]: http://www.apex-telescope.org/instruments/pi/artemis/data_reduction/
4 The workshop Zenodo web page: https://zenodo.org/communities/sd2018
5 Github repository for the material used in the meeting: https://github.com/teuben/sd2018