Report from the event supported by RadioNet

TITLE	**SUBMILLIMETRE SINGLE-DISH DATA REDUCTION AND ARRAY COMBINATION TECHNIQUES**
DATE:	*15-16 MARCH 2018*
LOCATION:	*GARCHING, GERMANY*
MEETING WEBPAGE:	*https://www.eso.org/sci/meetings/2018/SingleDish2018.html*
HOST INSTITUTE:	*EUROPEAN SOUTHERN OBSERVATORY*
RADIONET BENEFICIARY / NO:	*ESO / 13*

Report:

1. SCIENTIFIC SUMMARY

Single-dish submillimetre facilities such as the Atacama Pathfinder EXperiment (APEX) 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.

The workshop began with a general overview by Thomas Stanke of 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 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 1); the BOlometer Array analysis software (BoA); and the Interactive Data Language IDL pipeline using the map-making software Scanamorphos for ArTéMiS data (Figure 2). All of these packages are freely available from either the Institut de Radioastronomie Millimétrique (IRAM) website for the Grenoble Image and Line Data Analysis Software (GILDAS[2]; Pety, 2005), or the APEX ArTéMiS pages.

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 links to the example data are linked from the workshop web page https://www.eso.org/sci/meetings/2018/SingleDish2018.html with the talks the presentations hosted on Zenodo and github repositories[5] that were updated throughout the workshop.
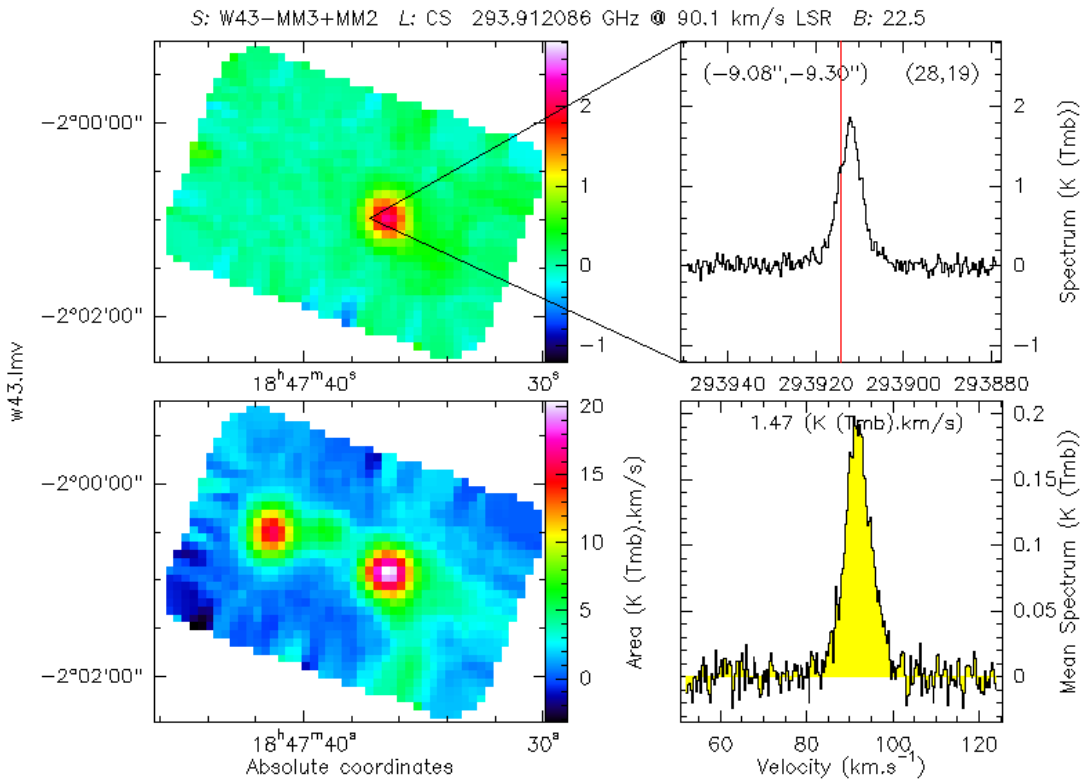
Figure 1.
Example from CLASS tutorial: an on-the-fly data cube of the giant molecular cloud W43 observed in CS with the Swedish Heterodyne Facility Instrument (SHFI) on APEX.
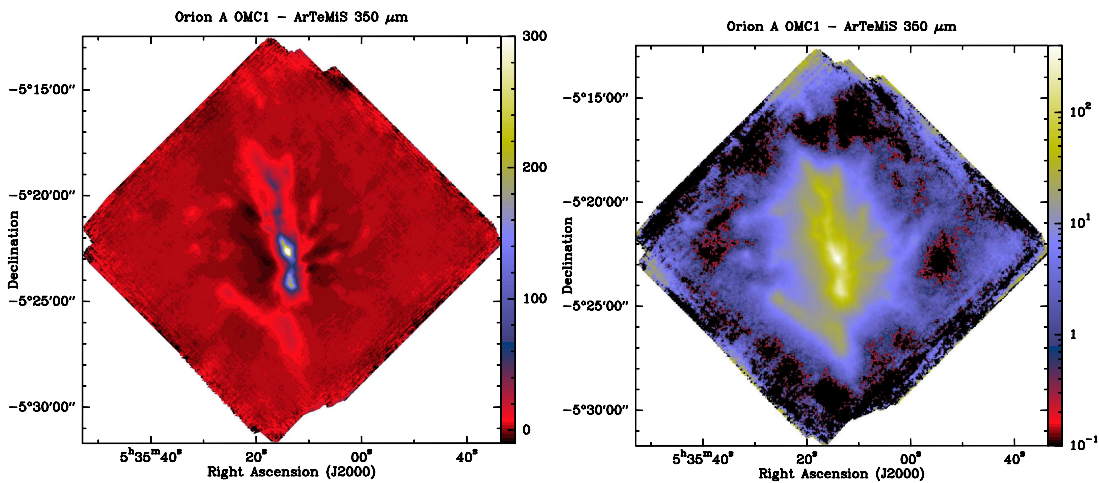

Figure 2.
Example from the ArTéMiS data reduction tutorial. The image on the left shows the image after running through the basic ArTéMiS IDL pipeline. Note the negative bowls next to the bright emission, which are due to the over-subtraction of the sky signal. The image on the right shows the full reduction using the Scanamorphos pipeline, which uses the full redundancy of the data.

2. AGENDA OF THE EVENT

Day 1, Thursday 15 March 2018

Session 1	Plenary talks	Room: Telescopium
08:45 - 09:00		Welcome
09:00 - 09:30	Thomas Stanke (ESO, DE)	Overview of submm single dish: from theory to observations (DOI 10.5281/zenodo.1204990)
09:30 - 09:45	Martin Zwaan (ESO, DE)	Overview of ALMA capabilities (including total power and ACA) (DOI 10.5281/zenodo.1204992)
09:45 - 10:00	Carlos De Breuck (ESO, DE)	Overview of APEX capabilities (heterodyne and bolometers) (DOI 10.5281/zenodo.1204978)
10:00 - 10:20	Dirk Muders (MPIfR, DE)	APEX observing strategies (DOI 10.5281/zenodo.1204980)
10:20 - 10:40	Andy Biggs (ESO, DE)	ALMA observing strategies (DOI 10.5281/zenodo.1204976)
10:30 -11:00	**Break**	
11:00 - 11:15	Dirk Petry (ESO, DE)	CASA (DOI 10.5281/zenodo.1204982)
11:15 - 11:30	Jérôme Péty (IRAM, FR)	CLASS (DOI 10.5281/zenodo.1205423)
11:30 - 11:45	Frederic Schuller (CEA, FR)	BoA (DOI 10.5281/zenodo.1204988)
11:45 - 11:50	Philippe André (CEA, FR)	The ArTéMiS IDL pipeline (DOI 10.5281/zenodo.1204974)
11:50 - 12:00	Hélène Roussel (IAP, FR)	Scanamorphos (DOI 10.5281/zenodo.1204984)
12:00 - 13:00	**Catered Lunch**	In front of Telescopium

Session 2	Tutorial	Room: Fornax
13:00 - 15:00	Tutorial 1	ALMA single dish data reduction in CASA
15:00 - 15:30	**Break**	

Session 3	Parallel tutorials	Rooms: Pictor+Sculptor and Fornax
15:30 - 17:00	Tutorial 2a	Bolometer data reduction in BoA, IDL and Scanamorphos (Room Pictor+Sculpor)
15:30 - 17:00	Tutorial 3a	Heterodyne data reduction in CLASS novice level (Room Fornax)
17:00	**End of Day 1**	

Day 2, Friday 16 March 2018

Session 4	Parallel tutorials	Room: Pictor+Sculptor and Fornax
08:30 - 10:30	Tutorial 2b	Bolometer data reduction in BoA, IDL and Scanamorphos (Room Pictor+Sculptor)
08:30 - 10:30	Tutorial 3b	Heterodyne data reduction in CLASS intermediate level (Room Fornax)
10:30 - 11:00		**Break**

Session 5	Plenary talk	Room: Telescopium
11:00 - 12:00	Peter Teuben	Combination of single dish and interferometry data (DOI 10.5281/zenodo.1204986)
12:00 - 13:00	Catered Lunch	

Session 6	Tutorial	Room: Fornax
13:00 - 15:00	Tutorial 4	Combination of single dish and interferometry data
15:00 - 15:30	**Break**	
15:30 - 17:00	Tutorial 4	Combination of single dish and interferometry data
17:00	**End of Day 2**	

3. PARTICIPANTS

The workshop was attended by 42 participants, 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.

The tutors were the experts developing the software for the APEX heterodyne instruments (Jérôme Péty from IRAM Grenoble, FR and Dirk Muders from MPIfR, Bonn, DE), the APEX bolometers (Frédéric Schuller and Philippe André from CEA, Saclay, FR and Hélène Roussel from IAP, Paris, FR), and the ALMA combination of single dish and interferometer data (Peter Teuben from Maryland, USA).

The full participants list: https://www.eso.org/sci/meetings/2018/SingleDish2018/participants.html

4. PUBLICATIONS

As this was a training event, there are no direct publications, but we did publish all presentations on a Zenodo repository: https://zenodo.org/communities/sd2018

5. RADIONET FINANCIAL CONTRIBUTION

The event received 3500€ Radionet fundin for organizational costs and individual funding of 5 attendees (users, tutors and experts).