The JCMT after 2014

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1. Introduction

The JCMT is the largest single-dish submillimetre telescope on the planet. Its workhorse continuum instrument SCUBA-2 is designed for mapping and operates simultaneously at 450 and 850 um, with 5000 pixels at each wavelength. SCUBA-2 represents a two order of magnitude increase in mapping speed over the previous continuum instrument SCUBA. Three heterodyne spectroscopic instruments are also available. HARP, the world's first array receiver operating at 345 GHz, has sixteen individual receptors for enhanced mapping of molecular lines (e.g. CO 3-2). RxWD provides access to higher frequencies (690 GHz) during optimal dry weather conditions while venerable RxA3 allows for lower frequency (230 GHz) observing during poor weather conditions. Two Canadian-made ancillary instruments for SCUBA-2 are still in the commissioning stages: a Fourier Transform Spectrometer (FTS-2) providing low to moderate spectral resolution and a dual-wavelength polarimeter (POL-2).

The flagship program at the JCMT over the last few years has been the JCMT Legacy Survey (JLS), comprising seven individual investigations spanning nearby debris disks, star formation, galaxy structure, and cosmology. The SCUBA-2 component of the JLS was awarded almost 3490 hours, while the HARP component received 962 hours. By the end of September 2014, the HARP component of the JLS had been completed and the SCUBA-2 component was almost 80% finished. With the four month extension of JCMT operations (under STFC ownership) through to the end of January 2015, the overall completion is expected to be >90%. As of the end of November 2014, four of the surveys had reached completion, leaving only the cosmology, Gould's Belt (star formation), and Galactic Plane surveys with time remaining. We discuss some key science results from two of the largest JLS surveys below

The SCUBA-2 Cosmology Legacy Survey (S2CLS) is a blank-field survey with the key strength of being able to find sources which are too rare to appear in small-area interferometer surveys. It was allocated 1778 hours of observing time and uses a two-tier strategy covering well-known fields to observe ~5 deg2 at 850um, and ~0.15 deg2 at 450um, in each case to a 1sigma sensitivity of 1.2mJy. S2CLS is a `factory' for detecting dusty starbursts at z>1. Excellent ancillary data (e.g. CANDELS) allows for probing stellar emission, redshifts, and morphologies in the detected submm galaxies (SMGs). ALMA then offers HST-matched resolution allowing the direct comparison of dust and gas to stellar emission on sub-galactic scales. Highlights of major results include a Cycle 1 ALMA follow-up of S2CLS sources at sub-arcsec resolution, for the first time constraining the size distribution of the 850um emitting regions of SMGs, resolving dynamics and star formation on sub-kpc to kpc scales in the most luminous starbursts (Simpson et al., 2015). S2CLS has also made the first measurement of 450um number counts (Geach et al. 2013). Other key directions have been the identification of rare objects (Geach et al. 2014) , the average 850um properties of Lyman-break galaxies (Coppin et al. 2015), and the discovery of a cluster of SMGs (Smail et al., 2014).

The Gould Belt Survey (GBS) is studying the early phases of star formation by observing dust and gas emission from all major star-forming molecular clouds within 500 pc observable from Hawaii (Ward-Thompson et al. 2007). It was awarded 412 hours with SCUBA-2 and 250 hours with HARP. The ultimate goal is to provide a complete census of the dense star-forming cores and filaments in these nearby clouds, and determine the conditions and kinematics by which such structures form. This goal can only be achieved once all the data have been acquired. Until then, the GBS has undertaken a series of ‘first-look’ analyses of some of the data acquired so far. For example, HARP data of Serpens revealed this compact region to be a “burst” of star-forming activity due to the collision of two separate smaller clouds (Graves et al. 2010). SCUBA-2 data of Perseus NGC 1333 have shown how local heating from recently formed young stars can promote the formation of higher-mass stars by increasing the local Jeans mass (Hatchell et al. 2013). SCUBA-2 data also enabled a recent analysis of cores and filaments in Orion A, confirming the Salpeter-like character of the core mass function at higher values but also a surprising variety of filament column density profiles (Salji et al. 2014a,b).

The JCMT currently operates through a Telescope System Specialist supported scientifically by a visiting astronomer. The 12 hour nighttime shift is limited by safety regulations on the length of stay at the summit. To make use of good observing conditions that often continue well into the morning, extended observing takes place remotely from Hilo when the weather permits. All observations are undertaken using an observatory management program which schedules and executes individual observing blocks in priority order, dependent on the availability of instruments, the accessible night sky, and the atmospheric weather conditions. Completed observations are automatically ingested into the JCMT Science Archive at the CADC and the relevant PI is informed via email. In general all data remain proprietary for one year from the completion of the semester during which they are observed.

2. The new JCMT collaboration

(Caveat: many of the details in this section are still under discussion, including such important issues as the precise contributions (financial and in-kind) by the various partners, the division between PI and survey science time, etc. This section provides a snapshot of the current state of affairs.)

The current target for the legal transfer of JCMT operations from the STFC to the new collaboration led by the East Asia Observatory (EAO) is 31 January 2015. EAO is the lead and majority partner of the new collaboration, with contributions from a consortium of UK universities and a consortium of Canadian universities. The collaboration will establish a new JCMT Board with representatives from all the major partners, including the University of Hawaii. The membership of the new Board has not been finalized; the first Board meeting is expected to occur by the end of 2014.

- EAO is a partnership between observatories from Taiwan, China, Japan, and Korea. Paul Ho (formerly the director of ASIAA in Taiwan) has been named as the first director of EAO.
- The consortium of UK universities is led by Cardiff University; Professor Walter Gear is the PI on the proposal to STFC. The UK universities have raised funding of 290,000 pounds/yr for 3 years and their successful application to STFC has raised 250,000 pounds/yr for 3 years. STFC will also support UK observer travel to the telescope separately.
- The consortium of Canadian universities is led by McMaster University; the other participants are University of Alberta, University of Lethbridge, University of Waterloo, Western University, and Dalhousie University. The total funds committed by the Canadian consortium are $107,000 ($Cdn) per year for two years.

Within Canada, the JCMT collaboration will be established by two agreements: (1) an agreement establishing the Canadian consortium signed by all 6 universities; and (2) a Canadian-EAO agreement signed by EAO and by McMaster University on behalf of the Canadian consortium. At the time of writing both agreements are in an advanced stage but neither has been signed.

In addition to the cash contributions from the 6 Canadian universities, there is also a commitment to keep the JCMT archive at CADC open and ingesting new data for at least the first 2 years. Keeping the archive open provides important support for the first generation of the JLS, which will continue to acquire new data up until the handover to the new collaboration. Canadian astronomers are full and active participants in the JLS and are expected to play active roles in the second generation of surveys which will begin in 2015. There have already been several meetings (Tokyo, London, Nanjing) to begin discussion of the surveys and a wiki has been set up to facilitate the discussion http://jcmt.asiaa.sinica.edu.tw/do/view/JCMTTwiki/WebHome . The new JCMT consortium is also very interested in completing the commissioning of POL-2 and FTS-2.

Although the details remain to be confirmed by the Board, the current working model for operations assumes that observing time will be 50% PI time and 50% large surveys. Partners contributing cash for operations will gain access to both PI and survey time. PI time allocations are expected to be generally proportional to the fraction of total cash contributed by a given partner. In-kind contributions gain only access to survey time. However, there may be a third category of "cash-equivalent" contributions, that is, an "in-kind" contribution which contributes directly to operations by removing the need for cash to do a specific task. Whether the Canadian archive commitment will count as "in-kind" or "cash-equivalent" remains to be negotiated with the new JCMT board.

How these rules translate into Canadian access to the JCMT depends on many of the final details. At a minimum, astronomers at the 6 universities that make up the Canadian consortium will be able to propose for PI projects and participate in the surveys. The consortium's position in discussions with our partners is that contribution of the archive gains access to observing time for *all* Canadian astronomers (not just those at the 6 universities). Whether astronomers across Canada will be able to lead PI proposals depends on the status negotiated for the archive contribution. Depending on this negotiation (as well as the final operating budget of the JCMT), Canadian access to PI time could be as little as 2% of the total (3 nights per year in a 50:50 PI:survey model) or as much as 7% of the total.

The new EAO director is strongly encouraging extended visits to the JCMT by individual scientists and their postdocs and students. These visits will be important for increasing the "science culture" at the JCMT headquarters, helping to cement collaborations among individuals from the different regions, and so on. For example, Scott Chapman has a new graduate student who is planning to spend a year in Hilo; Chris Wilson is planning a few week visit in summer 2015 around the Honolulu IAU meeting.

3. Complementarity with ALMA

Observational submillimetre astronomy is becoming dominated by the new results from ALMA. This new international observatory has been a clear success, making several new discoveries in the Early Science phase while clearly being on track to fulfill its key science goals. Furthermore, the JCMT and ALMA are excellent complements for each other. This complementarity comes from the natural connection between single-dish facilities and interferometers. The JCMT and its multi-pixel HARP and SCUBA-2 receivers, in particular, provide the means for efficiently surveying large areas on the sky to show where interferometers should invest observing time. The synergy between facilities naturally provides a good connection between large-scale and small-scale phenomena. Overall, the JCMT provides a well matched aperture to ALMA while having a good set of instrumentation that overlaps with the most heavily used ALMA frequency bands.

Many ALMA Early Science and Key Science projects have been founded on the observational legacy of the JCMT. Looking to the future, the JCMT provides essential leverage for ongoing ALMA projects. Where they overlap with the sky accessible to ALMA (65% of the sky), JCMT data provide essential wide-area maps for ALMA. As the mosaicking capabilities of ALMA develop, these JCMT data will become essential for combining with ALMA survey data. For PI proposals, short JCMT projects provide signal strength measurements for making more compelling observing proposals. Additionally, access to the JCMT provides personnel training and expertise in submillimetre observing techniques for our students since the JCMT remains one of the few facilities where students can participate in observing. While ALMA is driving a rapid evolution of the submillimetre landscape, the JCMT remains an essential part of that evolution.

4. The JCMT after 2017 and complementarity with CCAT

In addition to the JCMT, the other two submillimetre facilities currently in operation are the Atacama Pathfinder Experiment (APEX; 12 m) and the Caltech Submillimeter Observatory (CSO; 10 m). CCAT is planned to be a new 25 m diameter telescope located on a superb site at 5500 m elevation in northern Chile near ALMA (see CCAT White Paper by M. Fich). A CFI proposal for construction funding led by the University of Waterloo was submitted in June 2014; results are expected around March 2015. Participation in CCAT would remove the necessity for the Canadian community to continue to be involved in the JCMT in the long term. With its larger diameter, focal plane, and better site, CCAT will be a much more powerful observatory than the 15 m JCMT when used at the same wavelength.

JCMT access is currently assured for two years, through the end of January 2017. This two year commitment was thought to be easier to obtain from individual universities while providing a long enough period of funding to carry us through the results from the CFI competition that includes CCAT and a bit beyond. However, it is worthwhile to consider what might happen after the initial 2 years. Even if CCAT achieves first light in early 2020, there would be a 4 year gap in our community's access to a big single-dish telescope. In the event that the CFI grant for CCAT is unsuccessful, JCMT access becomes even more important in the short term.

- Regardless of our ability to make cash contributions, Canadians might continue to have some JCMT access through participation in the large surveys. This access would depend largely on the goodwill of our EAO and UK collaborators; therefore it is important to show ourselves to be good partners and collaborators in these first two years.
- There is the possibility of going back to the universities for additional funds for another 1-3 years. This option would provide better bridging to CCAT in the event that the CCAT CFI grant is successful and could be very important if CCAT is not successful. Depending on the status of CCAT, it might be possible to add additional university partners at this time. The dollar amounts requested per university are quite small (<$30,000/yr). For this option, it will be important to show value for money in these first two years.
- The on-going availability of the JCMT archive at the CADC after the first 2 years (except as a passive archive of old data) cannot be guaranteed. However, if the cost of maintaining the archive open is relatively small and the funding climate for astronomy improves, this could remain a viable option, especially if it provides a clear benefit to the Canadian university community.
- Although JCMT operations funding was ruled ineligible by CFI for their Major Science Initiatives 2014 competition, it is not clear that the JCMT would necessarily be ineligible in a future competition once the facility is more distant from being an NRC-operated facility. It will be important to monitor upcoming competitions that might be used to provide operations funding e.g. through CFI, NSERC, etc.

5. Summary

Continued Canadian access to the JCMT appears to be secure until 31 January 2017. This access is primarily via participation in large surveys (to which the entire community will have access) as well as a small amount of PI time (which may only be accessible to astronomers at universities in the Canadian consortium). Decisions on extending our involvement in the JCMT will depend on a number of factors, including continued community interest, the success or failure of the CCAT proposal to CFI, and the ability to raise operating funds from our universities and funding agencies.

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