Mopra OTF mapping specs (PAJ)

As a guide to the discussion of future Mopra surveys, it is useful to have some quantitative information on mapping speeds, sensitivity etc.

For 3-mm, we have the sensitivity calculator
http://www.narrabri.atnf.csiro.au/mopra/sensitivity_mopra_otf.html
This uses the basic sensitivity scaling

$T_a^*{}_{rms} = C\, T_{sys}/(t_{int}\, \Delta f)$

and calculates OTF line spacing, scan speed etc.
However, it is not explicit on all its assumptions.

Here are some numbers for mapping speed, and sensitivity, from experiece in recent Mopra projects, and extrapolated to a couple of 'strawman' surveys, to spark discussion.

Experience with CMZ

For the Central Molecular Zone (M170), we used 2 sec samples, 4 arcsec/sec scanning (making 8 arcsec per sample along the line), and 10 arcsec separation between lines, taking around 80 minutes per 5 x 5 arcmin field, including pointing and slewing overheads.

This agrees fairly well with the sensitivity calculator time for 110 GHz (66 mins on mapping + 13 min overheads) at the top end of the 3-mm band. We deliberately chose finer spatial sampling than Nyquist for our 89 GHz CMZ observations, closer to the grid assumed for 110 GHz.

Our T_{rms} was around 0.098 K (for broadband 0.84 km/s pixels), compared to 0.075 K predicted by the sensitivity calculator (2 passes).

Experience with other 3-mm mapping

For some other 3-mm projects (e.g. M303, using zoom mode data), we also find that, in practice, our T_{rms} was a factor around 1.5 greater than that predicted by the sensitivity calculator.

This does make a significant difference, as it changes the integration time needed to reach a given T_{rms} by a factor ~ 2

Possibly the average T_{sys} is greater than that assumed, the factor C order unity is not correct (eg. noise in quotient from on and off, has factor root 2) or there are subtle definition differences (is Δf the channel width, or twice the channel width, assuming Nyquist sampling ?)

Note - also usually want T_{mb} not T_a^*, so include antenna efficiency

- T_{sys} changes rapidly around 115 GHz, so found $T_{rms}(^{12}CO) \sim 2\, T_{rms}(^{13}CO)$

Current mapping speeds

From the CMZ (and DQS) mapping, at 3-mm, of say 80 minutes per 5 x 5 arcmin field, we obtained up to 9 fields per 12-hour day (down to 30 deg. elevation), but averaged around 6 good fields per day, when loss due to bad weather etc considered.

This is around 0.04 square degrees per day (1 pass), or 0.02 square degrees per day (2 passes)

eg. 2007 and 2008 the CMZ covered (2 passes) an area of 0.80 square degrees (2.42 x 0.33 deg.) or 232 fields, taking order 40 days

This is fine for selected areas, but much too slow to cover a large fraction of the Galactic plane

On the other hand, the HOPS at 12-mm aims to cover 90 square degrees (90 x 1 deg.) at 4 hours per 0.25 square degree area (2 passes) observing 12 - 15 hours per day (~ 0.8 square degrees per day), reaching rms 0.5 - 1.5 Jy

(From web site : Andrew will have more quantitative details)

'Strawman' fast 3-mm CO Survey - speed

If the readout time could be reduced from 2 sec to 0.2 sec, then scanning would be 10 times faster, in area, or (at 3-mm) 0.4 square degrees per day (1 pass).

This would probably best be done by extending the area in the scan direction, making say 5 x 50 (60 ?) arcmin areas, so as to keep the 'off source - scan line' cycle the same, and not start and stop too much. The rate would be of order 40 arcsec (1 beam) per second.

Note, the telescope driving would need to be smooth. (Recall the problems of mismatch between correlator timestamps and telescope drive timestamps, requiring position interpolation, which was a problem even for 2 sec sampling initially).

Even at this rate, not a full area Galactic plane survey ?

The 90 square degree HOPS area would take ~225 days for 1 pass, or ~550 days for 2 passes (and we might like even more area covered)

'Strawman' fast 3-mm CO Survey - sensitivity

Scaling from previous observations (or sensitivity calculator, with fudge factor) the $T_a^*{}_{rms}$ would be around 3.2 K and 2.0 K for ^{12}CO and ^{13}CO with zoom mode (0.09 km/s channels, 1 pass), or as $T_{mb,\,rms}$ (including efficiency factor) 7.6 K and 4.6 K

In comparison the NANTEN CO surveys had rms 0.5 K for 0.1 km/s resolution ? unclear whether this is T_a^* or T_{mb}
(taken from Moriguchi et al., 2001, PASJ, 53, 1025, for Vela obs.)
- does Erik have more complete specs ?

The Dame, Hartmann & Thaddeus (2001) surveys (combination of different data sets) had T_{mb} rms ~ 0.25 to 0.31 K for 0.26 km/s channels, for the southern (Chilean) data

'Strawman' 7-mm Survey - speed

We (actually Michael) have made test observations at 7-mm, of the CMZ area (Sgr B2) with a simple scaling of the 3-mm strategy, by a factor 2 in scan rate (8 arcsec per second) and line spacing (20 arcsec), giving 10 x 10 arcmin blocks, in the same time (still about 80 minutes, including overheads), giving a factor of 4 in area
ie rate = 0.16 square degrees per day (1 pass)

This makes a survey of selected areas feasible (e.g. 0.80 square degrees of CMZ in 10 days with 2 passes), but still not very large continuous areas.

Since the 7-mm lines are weaker than CO, it is probably appropriate to consider surveys, with the present 2 second integration, to get the sensitivity.

'Strawman' 7-mm Survey - sensitivity, lines

The test data reached T_{rms} (broad band 0.25 MHz channels, 1 pass) ranging from 0.055 K to 0.11 K (increasing with frequency consistent with the rise of T_{sys} from ~ 70 K at 42 GHz to ~120 K at 50 GHz) BUT the test data were taken in very poor weather (when 3-mm observing was abandoned) so we expect more like 0.03 to 0.06 K in average weather

We detected strong extended lines from thermal SiO (43.424 GHz), HNCO (43.963 GHz), CH_3OH (44.069 GHz), HC_3N (45.490 GHz), CH_3OH (48.374 GHz) and CS (48.991 GHz),

... plus several more weaker lines (but these were only good in the extraordinary Sgr B2 complex).

We also found SiO masers (42.821 and 43.122 GHz) in 2 spots

Talking points - not conclusions !

System parameters are important for discussing trade-offs (sensitivity and time per area covered) of different proposed surveys. I may have some of these numbers wrong, but the quantitative performance is important, preferably from test observations

3-mm - even with 10 times faster 3-mm scanning, suggest we would be looking at the brighter CO areas, not the whole southern Galactic plane (sensitivity and speed)

7-mm - with present system, selected areas in CS etc are quite feasible, but still not a large fraction of the southern Galactic plane

12-mm - HOPS is covering a large fraction of the southern Galactic plane, so scaling makes 12-mm already quite feasible !