How can I estimate the Peak Flux Density per synthesised beam using flux measurements in Jy or K from other observatories?

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In the 'Expected Source Properties' section of the 'Field Setup' editor you are required to enter an estimate for the continuum and/or line peak flux density per synthesized beam for each source defined. These fluxes will guide your choice of requested sensitivity and are used by the OT to calculate the S/N achieved. Therefore, it is important that they are as reliable as possible.

In many cases, measurements of your sources will already exist based on data from other observatories. Here, we assume these measurements are peak fluxes/temperatures reported in Jy or K - for information on how to interpret line-integrated fluxes given in Jy km/s or K km/s, please see How do I convert flux measurements given in Jy km/s or K km/s into the peak flux density required by the OT? You should first check the observing frequency of these observations and if necessary adjust the measurements to your ALMA observing frequency using a spectral index or more detailed spectral model of your source. You will then need to consider the angular size and spatial distribution of the source.

In the OT, the fluxes must be entered in Jy/beam, i.e. you must provide the peak flux density of the source estimated within one synthesised ALMA beam. This means that if the source is resolved with ALMA you will need to correct the previously measured peak flux (in Jy) of the source by the ratio of the area of the source to the area of the synthesised beam. A source is considered resolved if the angular resolution requested is smaller than the largest angular scale of the emission, and the synthesised beam should be assumed to be the angular resolution requested.

For example, suppose you have a JCMT observation of a sub-mm galaxy, and have measured a flux density of 32 mJy within the JCMT beam (where of course the galaxy is spatially unresolved). From other evidence you believe that the angular size of the galaxy is about 2”, and you’d like to observe it with ALMA at an angular resolution of 0.5". That 2” wide galaxy would be spread over $(2''/0.5'')^2$=16 ALMA beams in area. The expected flux density in the ALMA beam would thus be only 32 mJy/16 = 2 mJy/beam. It is this value that should be entered in the Expected Source Properties and be used to estimate the sensitivity required. In this example, a 5 sigma detection of the source would require a sensitivity of 0.4 mJy per pointing. Note that you may need to correct existing flux measurements even if they come from previous ALMA data, since the synthesised beam was quite likely different due to a different configuration and/or a different observing frequency.

The situation is more complex if your previous measurements are given in terms of brightness temperature in Kelvin, which is often the case of measurements from single dish telescopes. The simplest way to use an antenna temperature to estimate an ALMA flux density is to first convert the antenna temperature into a source flux density. The flux density S_ν is then given by

$S_\nu = 3514\ T_{SD} / (\nu_a * D^2)$ Jy,

where ν_a is the aperture efficiency (you should be able to find this in the documentation for the single dish telescope in question), D is the diameter of the single dish telescope in m, and T_{SD} is the brightness temperature measured from the single dish telescope in Kelvins.

Now you need to consider the spatial distribution of your source, and the number of synthesised (ALMA) beams within the single dish beam, $n_B = (\mathrm{beam}_{SD} / \mathrm{beam}_{ALMA})^2$, where beam_{SD} and beam_{ALMA} are the beam size of the single dish telescope and the ALMA synthesised beam, respectively. If your source is unresolved with ALMA, the peak flux per beam will simply be S_ν in the beam that contains the source (and zero everywhere else). If, at the other extreme, the source flux is evenly distributed in the single dish beam, the peak flux per ALMA synthesised beam will be S_ν / n_B. In many cases, the peak flux expected with ALMA will lie between the two extremes, i.e.

$S_\nu / n_B <$ (peak flux / ALMA synthesised beam) $< S_\nu$

Let’s try an example. Suppose we have an IRAM single dish observation of a protostellar envelope that has a surface brightness of 1 K. IRAM has an antenna diameter of 30m and, checking the IRAM website, an aperture efficiency of 0.6 at 93 GHz. This gives a flux density of 6.5 Jy per IRAM SD beam. Let’s observe it with ALMA at an angular resolution of 1”. What flux density would we expect in a 1” ALMA synthesised beam? As we found before, that depends on how large the source is. In the worst case, the emission is spread evenly over the 26” IRAM beam, or over $(26/1)^2=676$ ALMA beams. In this case the expected flux density would be about 10 mJy per beam. Conversely, if the source is much smaller than the 1” beam, then the expected flux density would be 6.5 Jy per ALMA synthesised beam. If the source size is similar to the 1" beam size then the flux per ALMA synthesised beam depends on the exact source structure.

If you need more precise values consider running simulations using CASA.