ALMA Science

What are some of the recommendations and best practices that I need to know if I am imaging very bright, resolved objects (e.g. planets)?

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Over the past several years, the imaging of bright solar system objects have led to recommendations that may be relevant to users that are looking to image these sources. If you are planning to use archival data or are planning your own observations using these types of sources, you should be aware of these recommendations and best practices when analyzing and/or preparing science observations.

1. Note that this applies only to sources that are both at least moderately resolved and have enough flux density per beam (are bright enough) to self-calibrate, after initial calibration.
2. Flux density (amplitudes) may be affected by primary beam resolution. If this is the case, it will affect the zero-spacing visibility and the shape of the planet on the sky. It effectively looks more limb-darkened than it is natively. A primary beam correction of the image is of course required and this is done and available in all imaging products generated by the pipeline.
3. Flux density (amplitudes) will be affected by all planets with enough flux density to affect Tsys, when off-target Tsys calibration scans were used (this includes all data taken before Cycle 8 2021). In this case, the absolute flux densities that are calculated will be low by some factor, which can be as much as a factor of 2 (even higher for the Moon or Sun). This factor can be calculated explicitly in many cases but that calculation has enough uncertainty that it is best practice to correct the flux densities so that they match the default models in CASA taking into account item (1) above
4. . Imaging these types of objects should include an initial model to mitigate the imaging artifacts seen due to missing short spacing data. This effect is smaller for more compact configurations, of course, but even in those configurations for large enough sources the effect can be significant. Imaging of a large bright object without setting a model will introduce small scale variations in the image due to the missing short spacing information. A simple disk model set before imaging (and preferably a disk model with limb darkening) will mitigate these imaging artifacts.
5. Further imaging artifacts, and notably those caused by uncalibrated trophspheric phase fluctuations, can be corrected by phase-only self-calibration. To properly phase-only self-calibrate a resolved planet, one should iterate, and get a decent

model which is more and more refined as the iterations proceed. This is much like self-calibration for any astronomical source, but it is absolutely critical that you start with at least a reasonable model, if the source is very resolved at all (see item 3 above). It doesn't have to be perfect, but it should have the about the right size, the right flux density, and at least something close to the right shape (the flux density is the least important, since this is phase-only self-calibration, and the shape is also not as important - uniform disk is good enough to start with in most cases). The normal steps are:

   1. Do a u-v fit to a limb-darkened model to find the fitted zero spacing flux density, size, and limb-darkening parameter (if the size is known, keep it fixed). If limb-darkened fits are not possible, use a uniform disk - again, it will likely be good enough as a starting model.
   2. Use that model as the first step in CLEAN, but don't CLEAN deeply at all (in fact sometimes I don't do any CLEANing, just use the model, for the first iteration). If you have to use a uniform disk, you may have to CLEAN a bit more deeply in the first iteration.
   3. Do phase-only self-calibration using the CLEAN components found for that image (which must include both the initial model, and any found by CLEANing), with a solution interval equal to the target scan duration.
   4. Repeat steps a-c, each step CLEANING more deeply, and shortening the self-calibration solution interval (see the following CASAGuide on the steps for proper self-calibration), until there are excessive failed solutions, the antenna phase solutions are starting to get very small (all of order 10 degrees or less), the image (and noise) isn't changing significantly, or the image is getting excessive artifacts (sometimes these are hard to quantify, but they're usually easy to see when monitoring CLEAN). Often a single phase-only, self-calibration iteration is enough. How many iterations depends on the flux density of the planet and the noise in the data, again like any other astronomical source (CASAGuide Reference).

6. Amplitude self-calibration on planets is usually not required and may introduce further unintended problems with the data. Amplitude fluctuations are almost always far smoother in time than phase fluctuations, and taken out quite well by normal calibration. In any case, amplitude self-calibration can potentially to do harm to planetary visibilities (depending on the details). The cause of this is poorly understood, but it is likely some combination of factors including flux density, a bright, sharply-bounded object on the sky, and the resulting visibility function (which has many nulls, if very resolved). These issues have never been quantified (or simulated) but rather this is based on experience with data processing and imaging of interferometric data taken on bright, resolved sources like planets.

Tags

ephemeris

solar system