I-TRAIN with the European ARC Network
Fitting visibility data with UVMultiFit – Q&As

• UVMultiFit parameters and fit uncertainties

Question: Do these parameters p[0], **,p[5] needed to be initially set?
Answer: It will help the fit convergence, and in case, prevent the fit to be stuck on a local minimum in the parameter space. So, as a good practice, it is always better to set the init values as close as possible to the expected solutions.

Question: In the case of a ring model, does major represent the inner radius of the ring?
Answer: The ring model consists in a mathematically ring with zero width (i.e., is non-zero only at the circumference of the ring). So there is no ambiguity on the radius. On the other hand, one can build a thick ring model with the combination of two discs, one with positive uniform intensity A and radius corresponding to the outermost radius, and another smaller disc with negative intensity -A and radius corresponding to the inner edge. The two disc models add up to form a thick ring model, empty in the center.

Question: In the spectral index fitting, does the module understand "nu" or do we need to provide it somehow?
Answer: The variable "nu" is a generic variable embedded in UVMultiFit, and can be used as is.

Question: I get different results between uvmultifit and CASAs uvmodelfit. In particular, the uvmultifit *uncertainties* have not been believable. Have you compared the performance between uvmultifit and uvmodelfit, and might you have example scripts or tests we can run on our datasets to check that the noise statistics in the UV domain are what we expect (e.g. Gaussian)?
Answer: We havent tested this. We would be happy to share your experience. Nota: The uncertainties in uvmultifit are rescaled to a reduced chi-squared of unity.

• Visibility fitting and S/N

Question: I remember reading on the GILDAS manual that uv fit makes sense if $S/N > 8$. Where does that come from?
Answer: It will depend on the complexity of the model. For a point source, with only three free parameters, and each relatively easy to constrain, there is no such strict requirement $S/N > 8$. As a rule of thumb, already with $S/N \sim 3$, one can fit for the flux of a point source by fixing the position, and with $S/N \sim 5$, one can also well fit the

positions as free parameters. For more complicated models, e.g., a combination of several source components, each with their own variables, it will be more difficult for the fit to converge, as in any least-square minimization, and good S/N are indeed preferable.

Question: When fitting each 'channel' individually, what S/N do you need per channel?
Answer: It depends on the complexity of the model. Roughly speaking, for a simple point source, a S/N of 3 should be enough to fit the flux (if the position is fixed), and with a $S/N > 5$ one can fit the positions and flux as free parameters.

• Visibility fitting and the "beam over-resolution", magic or not?

Question: How can you recover information for a source smaller than the beam? Shouldn't the fit also be limited by the resolution or is that just true for the imaging?
Answer: The beam resolution can be overcome in visibility fitting to some extent if the S/N is good enough. We are fitting a model (with an analytical or tabulated Fourier transform), and the choice of the model itself also input additional information. The fitted parameters, and their uncertainties, have to be interpreted in view of the chosen model. For example, let's imagine a source with a Gaussian intensity distribution (say with FWHM=λ/B_0 in the Fourier plane), observed with high S/N, then there is no need to have baseline lengths all the way to B_0 or more to fully constrain the Gaussian in the Fourier plane. Few datapoints at shorter spatial frequencies could be enough to fix the shape of the Gaussian. And in this case, the beam associated with the observations would have a size larger than the corresponding spatial frequency λ/B_0. In short, there is no contradictions, just the effect of high S/N and assumption of a correct model.

Question: At the beginning of the presentation you showed the modelling for a quasar pair with absorption lines. I know FT is magic, but how could you separate the spectra so cleanly even though the quasars are closer than the beam size?
Answer: There is no magic in there! Just mathematics! The visibilities carry the signal that the source is not just point-like. If the S/N is high enough, uv fitting can distinguish between the two sources, since their FT is not a single point source. See also the reply to the previous question.

• Visibility fitting and sources with extended structures

Question: Is there a way to deal with extended emission one doesnt want to fit but uvmultifit gets lost with? For instance, is it possible to give a uvrange to uvmultifit, to focus only on point-like sources, or maybe another solution?
Answer: If you have a proper model of you source, you better fit all visibilities at once with this model. An extended source will have a signal only on short baselines. For example, one can fix the total flux of the source in the model, to be the zero-spacing flux measured by a single-dish. Now sometimes, you do not care about the extended source structures (for example a small envelope from an evolved star located in the same line

of sight as a gigantic Galactic molecular cloud). Then, indeed, one could play with the filtering capability of the interferometer and select only long baselines with uvrange.

Question: Suppose you have both a compact and extended ALMA observation - you fit to the extended data set and then want to look for residuals of this fit in the compact ALMA observation, is this possible to do?
Answer: If you have a proper model of you source (for both extended and small scales), then better to fit the model to all data at once. A dirty trick could be to set the weight of compact observations to zero, then the fit would not take them into account, but would still subtract the model to obtain their residuals if asked for. By construction in uvmultifit, the model is analytical and it is thus defined for any spatial frequency (i.e., everywhere in the uv plane). The zero spacing value is the total flux of the source, which is a fit parameter.

Question: Following the previous question: UVmultifit can be then used also with highly resolved sources to measure the integrated flux density, provided that an image of the source is given as input to the code?
Answer: One can force the total flux of the model, and this is the zero-spacing value, i.e., the amplitude at uv location 0,0 (no need for an image). However, the choice of the model is a strong additional assumption: for example, if one has good reason to choose a Gaussian intensity distribution, then the zero-spacing flux is defined, mathematically as the amplitude of the Gaussian at uv =0,0. It is constrained by the behaviour of the visibilities at other, measured, locations in the uv-plane. In short, the total flux can be constrained, because of the analytical model function chosen as uv-fit model.

• Others

Question: How sensitive is the code to your phase center? Is it needed to have a shift in phase center before running the code?
Answer: No, the phase center is just a reference. On the other hand, if the source is close to the edge of the primary beam, one should in principle apply a primary beam correction (there is a dedicated option pbeam in UVMultiFit, it is a boolean, set it to true to activate the primary beam correction).

Question: For Multifit robustness fit check: How can we introduce systematic data error in the simulations?
Answer: UVMultiFit does not make difference between antennas, so it is difficult to account for antenna systematics. Otherwise, if one can construct a model to characterize the systematics, then it is possible to account for them (for example a frequency-gradient in the bandpass could be absorbed by fitting a spectral index).

Question: How to fit jets in UVMultifit?
Answer: Maybe a first try could be a thin and elongated Gaussian component? In general, however, sources with jets tend to have a complex morphology, and visibility fitting might not be the best method to analyze them. Note, however, that for marginally resolved jets observed with a spectral line, one could search for evidence of velocity gradients along the putative jet, e.g., a shift of the centroid emission w.r.t. to velocity.

Question: Does the module work with CASA 6 (Python 3)?

Answer: The version distributed via the Nordic ARC GitHub page will not work with CASA 6 (Python 3) right away. We have, however, made preliminary tests under Linux with a modified version. It appears to be working with the test cases that come with UVMultiFit. Please contact us at the Nordic ARC, if you are interested in trying this yourself.

Comment on memory leakage problem when running twice the call to the `runUVM_Ex1_line.py` script: I had the same issue with memory when I ran the line fit after the continuum fit - I got a flat spectrum.
Answer: Interestingly, I always got this strange behaviour before the tutorial, but it didnt come during it ! In any case, to avoid any bad surprise, the best solution is to exit/reopen a new casa session. And always have critical eyes on the results!