ALMA OT Tutorial with solutions

Practise setting up the following observations, answering the questions as you go
For the purposes of this tutorial you can set each up as one or more Science Goals in the same proposal.

[0. Register with the ALMA Science Portal and download the OT]
I. Enter the basic information for your proposal
II. Attach the supporting material (any pdf up to 4 pages will do)
III. Create a Science Goal

Science Goal 1: NGC 3256 mosaic

1) In the Field Setup editor, resolve NGC 3256 from SIMBAD

2) Enter the Expected Source Properties. For the purposes of this exercise you can assume the following values:
- the total integrated CO 3-2 line flux of this source is 5700 Jy km/s
- the FWHM of the CO 3-2 line is 300 km/s, the other line of interest (see below) has a FWHM of 50 km/s
- the total continuum flux of the source is 150 mJy
What is the peak line flux density per synthesised beam of 1x1"? [~16 mJy]
What is the peak continuum flux density per 1x1" beam? [~0.13 mJy]
Hint: do an image query using the default image server. For this exercise you may assume that the spatial extent of both the line and continuum emission are well represented by the brightest emission in the (optical) image (extent ~30x40"). You will need to convert the integrated line flux to a peak line flux, and correct the total source flux for the number of resolution elements it will be spread over in the ALMA image, assuming a uniform flux distribution of the source. You may want to check the Knowledgebase for help!

3) Configure the spectral setup. You want to fully resolve the CO 3-2 v=0 line profile, and secretly hope to detect alien life emitting Formaldehyde (H2CO), which you believe has a FWHM of 50 km/s and a peak line flux equal to the CO 3-2 line. Your preference is for the lowest frequency line(s) observable with the defined spectral setup. You also want to measure the continuum emission.
What are the central frequencies of your basebands? [CO: 342.6 GHz on sky, Formaldehyde 329.1 and 340.1 GHz on sky, PLUS TDM continuum window, e.g. at 330.6 GHz]
Which correlator configuration(s) do you choose? [for the CO want bandwidth >400 MHz, for the Formaldehyde BW >117 MHz. To optimise continuum sensitivity can put BW=1875 MHz for CO and 320.1 GHz Formaldehyde, 937.5 MHz for 340.1 GHz Formaldehyde]
How many H2CO lines can you observe together with the CO 3-2 line, while keeping the bandwidths of the spws appropriate for the spectral line widths? [2]
What is the representative frequency? [329.1 GHz - this is the line with the worst atmospheric transmission]

Hint: for the representative frequency keep in mind that the atmospheric transmission varies with frequency!

4) Set up your pointing pattern in the Field Setup editor as a Rectangular mosaic.
How many (12-m) pointings do you need? [~18]

5) Enter the Control & Performance parameters. You want to achieve an angular resolution of 0.08", while the Largest Angular Scale is given by the spatial extent of the source.
Can this be set up in one Science Goal? [no. You need long baselines + compact config + ACA]

6) For now, you decide to just make a lower resolution map with an angular resolution of 1.0". You scientific objective is to fully resolve both lines (>5 resolution elements per line) with at least 5 sigma per resolution element.
What sensitivity and bandwidth for sensitivity do you enter? [~3 mJy, ~ 10 km/s]
Do you need the ACA? [yes. Both 7-m and TP]
How much time will the observations need? [1.35 h for the 12-m SB, total time of 6.76 h including ACA]

7) Look at the information in the Technical Justification editor and write a justification text for each section.
Can you reliably detect the continuum? [no. The S/N is ~ 1]
How long would it take you to detect the continuum (assuming this corresponds to the aggregate bandwidth, i.e. ignoring the lines) at 5 sigma? [To work this out, put bandwidth = aggregate and ask for a sensitivity of 0.13 mJy / 5 = 0.026 mJy. Needs 1.21 d on the 12-m config and 6.05 d total incl ACA)
How high is the data rate for the 12-m array? [if no spectral averaging has been used, the three spectral line widows are TDM and continuum FDM: 18.51 MB/s.]
Hint: check out the Tool menu item for help

8) Run a validation check
Do you get any errors/warnings? [should get high data rate warning if datarate is as mentioned above.]
How can you address these? [can set CO spw to TDM and/or spectrally average]

Extra exercise:
9) In order to get the high angular resolution (0.08") observations, you decide to define a second Science Goal. *Hint: you can copy and paste Science Goals*
Assuming the same total source flux as above and a uniform spatial distribution, what is the expected peak line flux per synthesised beam? [~0.1 mJy]
Luckily, the Formaldehyde you want to detect on these angular scales is strongly concentrated in clumps, and you can assume a peak line flux per synthesised beam of 3.5 mJy. The CO, which you also want to detect, is a little less clumped, with a peak flux density per synthesised beam of 2 mJy.
What sensitivity and bandwidth do you request (again assuming you want a 5 sigma detection, this time with 3 resolution elements per line width), and what is the time estimate? [Sensitivity requirement is driven by the Formaldehyde, since

the line width is much narrower. Requesting 3.5 mJy / 5 = 0.7 mJy over 3 spectral resolution elements = 16.7 km/s gives a time estimate ~21.2 hours. Doing the same calculation with the CO would have given 10.92 h]

Science Goal 2: monitoring very narrow spectral lines in an AGB star

1) In the field setup editor, define and resolve the AGB star W Hya. For the Expected Source Properties, you can assume a peak line flux per synthesised beam of 0.5 Jy and a line width of 0.25 km/s for all lines.

2) Experiment with the spectral setup, using the 'Select lines to overlay' button. You absolutely want to observe in Band 6, because 6 is your favourite number. Search for molecules commonly found in AGBs.
How many SiO lines do you find? [6]

3) You decide you really want all the SiO 5-4 transitions and set this up in terms of spectral windows.
How many of these lines can you fit in one baseband? [2]
What bandwidth/resolution do you choose? [58.6 MHz BW]

4) In addition to SiO, you want to observe as many transitions as possible of Cyanoacetylene. Try and fit 3 of these lines into the same spectral setup already defined.
What is the minimum number of basebands you need, taking into account that you want to resolve the lines (~three resolution elements minimum per FWHM)? [3]

5) Finalise the field setup.
How many pointings do you need to cover the sources at ~constant sensitivity? You may assume that you are mapping the emission visible in the default image query (optical) image. [3]

6) In the Control & Performance section, request the coarsest angular resolution possible, corresponding to the synthesised beam of the most compact configuration.
What is this AR? [~1.6"]
What is the maximum scale you can recover without requesting the ACA? [~12"]
Enter this as the LAS.
What sensitivity and bandwidth for sensitivity do you request to get a S/N of 10 in the lines? [50 mJy, BW should be ~finest resolution ~ 0.06 MHz or 0.08 km/s]

7) You would like to monitor W Hya at 3 epochs with an arbitrary start date, but each visit spaced ~3 months apart. This is because you are expecting some variability on the time scale of a few weeks.
What is the total time required for the Science Goal? [1.4 h]

8) Go to the Technical Justification editor.
Do the values reported back seem reasonable? [everything should be fine]

Fill in the text boxes for the sensitivity, imaging and correlator setup justifications.
Are there any extra choices to be justified? [high datarate & time constraints]
Can you justify them? [can justify high data rate because you really need the full spectral resolution, monitoring can be justified anyway]

9) Run a validation check.
Do you get any errors or warnings? [should get non-standard warning for narrow aggregate bandwidth, also for high data rate, but that should have been justified]
Can you "solve" any of these? [yes, just add continuum spw in BB4]