A Preliminary Design Review of Band 10 was held recently. Hills circulated a document describing some sections of the report, along with the Sept 2001 ASAC discussion on the science drivers for Band 10. This document was discussed at the ASAC ANASAC and Science IPT telecons held in late May and at subsequent meetings in the US held in Pasadena at the AAS meeting in St. Louis and among the members ot the Science IPT/NA. This document summarizes that discussion.

Panel members at the review noted that the aggressive ALMA specifications pushed hard against technological capability in this band, suggesting the Project consider a possible tradeoff between sensitivity and radiofrequency bandwidth to provide the best attainable performance for the array. Hills posed three key questions:
1) Is it more important to have reasonable performance over the whole band or very good performance over some restricted part of the band?
2) If the latter, then which is the most important part of the band?
3) What is the minimum noise performance that would be acceptable to make the effort and expense of building these receivers worthwhile?

Science goals of Band 10
As identified by the ASAC in 2001, key science goals may be categorized as:

A. **The Excited [C I] fine structure line**
B. **Redshifted [C II] emission**
C. **High excitation lines of fundamental molecules**
D. **Dust continuum emission**

The Carbon line is the higher excitation of a pair of lines and is an important tracer of photoionized material, particularly isolating warmer and denser regions when compared to the lower frequency line at 492 GHz. Some external galaxies have been observed in the [C I] lines but extensive extragalactic studies await ALMA for scientific development. This line lies at 809 GHz; it may be observed to redshifts of z~0.03 within Band 10. It is obscured by atmospheric water until the redshift reaches z~0.15.

Observations of redshifted atomic lines, of which [C II] at 157 microns and [N II] at 205 microns are exemplars from more redshifted galaxies which are important targets for study. To date, the [C II] line has been detected in J1148 at z=6.42 (Maiolino et al. 2005) and in B1202 at z=4.69 (Iono et al. 2006). Recently, Stacy and co-workers detected the line in a galaxy at z=1.35 using ZEUS at the CSO (Lis, private communication). The [N II] line has not been detected in distant galaxies; in the Milky Way its luminosity is down by over an order of magnitude from that of [C II] (Wright et al 1991). Strong evolution in galaxies is observed near z~1; the [C II] line occurs in Band 10 at redshifts between 1 and 1.4. Furthermore, a Level One science goal for ALMA is the detection of the [C II] line in a galaxy of Milky Way luminosity at z=3 within 24 hours. The observed luminosity in the [C II] lines in J1148 and BR1202 is approximately that of the entire far infrared luminosity of the Milky Way; the FIR luminosity of those galaxies is of order 5000 times that of the line alone (in the Milky Way the ratio is about 300). Over the redshift range of interest, the observed flux of the Milky Way [C II] line in a 300 km s-1 line would range from 0.50 to 1.15 Jy. For the best 12.5% of ALMA weather ALMA's T_{sys} would be about 1000K. ALMA's sensitivity in one minute should be about 3.5 mJy over a 850 MHz bandwidth, which corresponds to 300 km/s. The [C II] lines from galaxies like the Milky Way at distances corresponding to z=1 to 1.4 should be readily detected in rather short integration times. The recent detection of a [C II] line with the CSO confirms the estimates of strength of the line, for the luminous galaxy which was detected. As the lines occur over the entire band, addressing this science would favor bandwidth over sensitivity. Note that for z=1.43 to 1.03, the 205 micron line of [N II] lies within ALMA Band 9. The intensity of this line is about one tenth that of the [C II] line. Although it has not yet been observed in distant objects, the ability to measure both of these lines in galaxies in the range 1.0 to 1.4 is an interesting science capability for ALMA.

We note that recently, Spitzer has detected strong molecular hydrogen emission from interacting galaxies. The S(0) line at 28 microns shifts into ALMA Band 10 at redshifts above z~10.2. It is premature to estimate the intensity of emission from galaxies at these redshifts.

The third area of interest is in the high excitation lines of fundamental molecules. Several of these cluster at the lower and at the higher end of the band, as may be seen from the figure, which shows atmospheric transmission as a function of frequency for the best 12.5% of the time for ALMA. As mentioned, the neutral carbon line presents a singular opportunity for exploring warm dense gas in photodissociation regions near the low end of the band. The ground state deuterated water line lies at 893 GHz; however several other lines are available for measuring HDO. The 795-850 GHz portion of the spectrum would appear to offer a slight advantage over the 850-905 GHz region of the spectrum in that the neutral carbon line lies in the former range.

The last key science area is that of dust continuum emission. Band 10 is the highest frequency accessible to ALMA. For galactic objects, measurements in Band 10 will help define the spectral energy distribution, and therefore the temperature, a key aspect of the scientific understanding of a dusty region. Band 10 lies near the peak of the spectral energy distribution of nearby and slightly redshifted galaxies, data important for determination of bolometric luminosities of these galaxies. At z~5, peak emission from a dusty distant galaxy will peak in Band 10. Furthermore, spatial resolution is highest at Band 10; high resolution is needed to image protoplanetary disks such as that in the S. Wolf simulation. Band 10 receivers will cover 8 GHz in instantaneous bandwidth. The best continuum sensitivity in Band 10 over 8 GHz lies near 850 GHz or a little higher, near 870 GHz. For best addressing dust continuum science, Band 10 should address these windows.

Note that a future upgrade improving bandwidth could result in an array for which some baselines might be temporarily unavailable, owing to mismatch in receiver bandwidths, until all Band 10 receivers could be upgraded. One might therefore favor covering as full a bandwidth as possible with the first complement of receivers.

In summary, while good performance over the whole band is necessary for observing redshifted lines, ALMA will be able to meet its immediate scientific goals by addressing a subinterval of the specified Band 10 window. Our detailed consideration of the science goals leads us to suggest that if performance were optimized over the range 790-860 GHz, ALMA would be able to meet most of its science goals.

With thanks to numerous correspondents, including Brogan, Lis, Bergin, Cernicharo, Testi, Hills, Emerson, and others; Al Wootten, 10 June 2008.

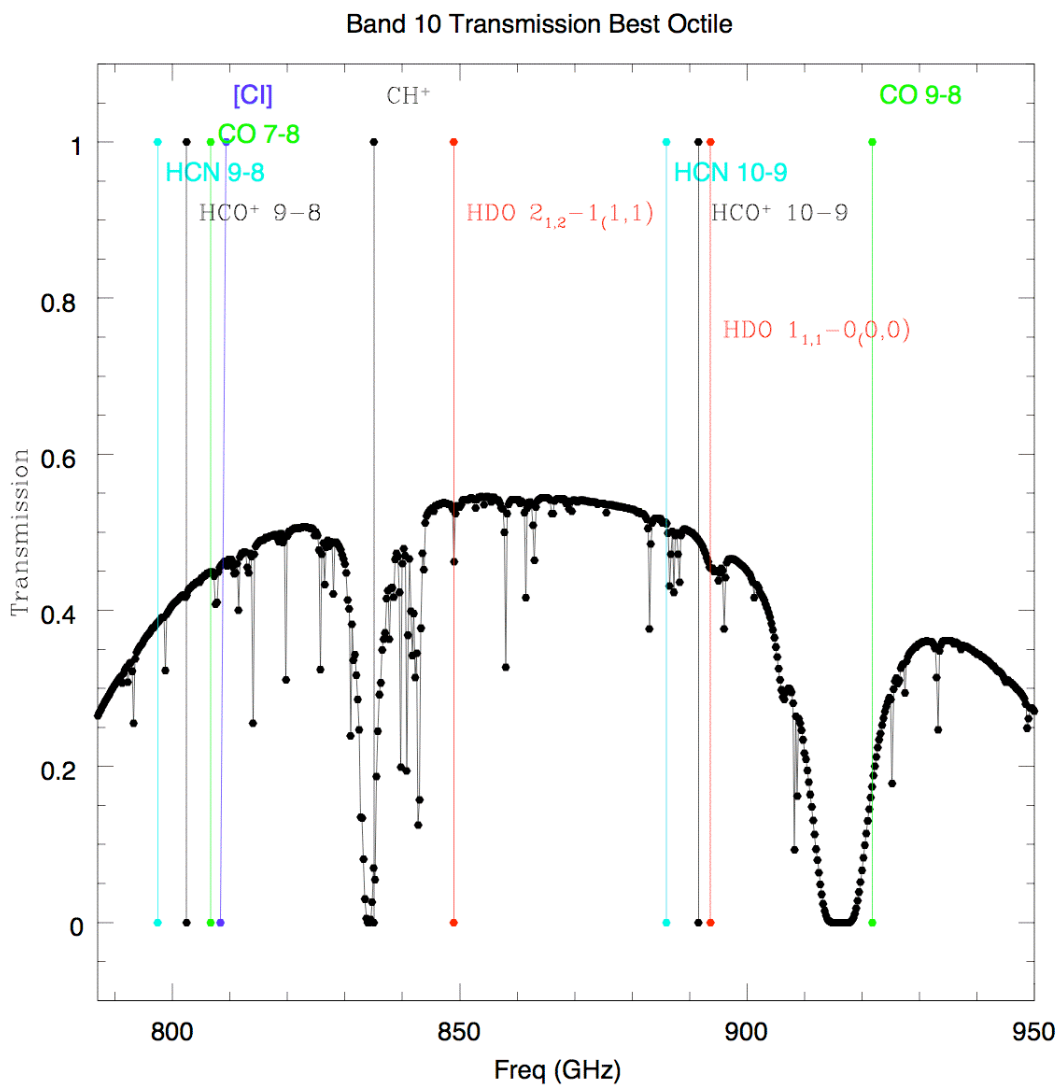

Figure 1 Atmospheric transmission for the best 12.5% of weather (PWV~0.5mm) at Chajnantor gives the transmission as a function of frequency shown. Lines mentioned in the text are flagged.

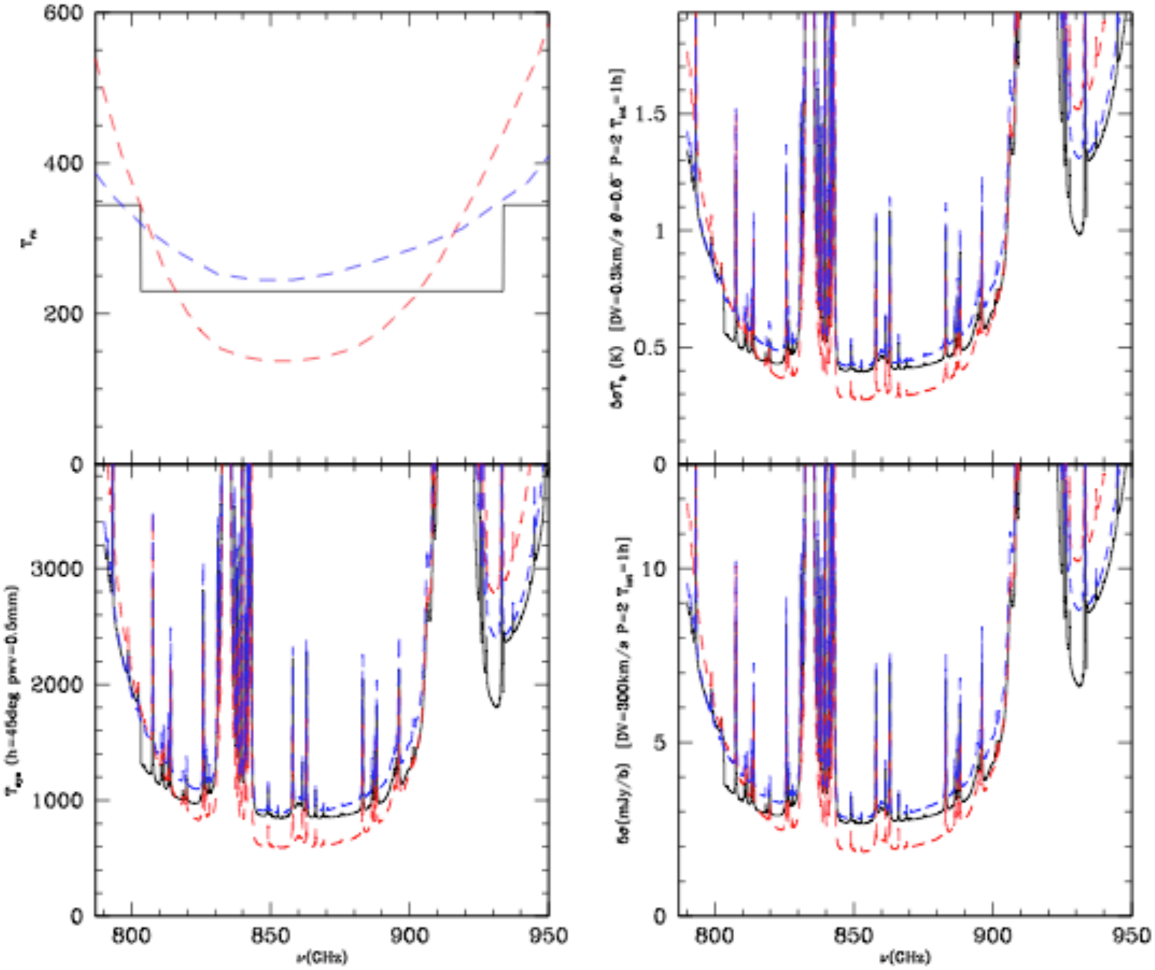

Figure 2 Top left: ALMA spec Band 10 receiver temp, overlaid with Hills' narrow and wide Tmixer curves. Bottom left: Tsys, for ZA=45, corrected for membrane and ohmic losses including antenna efficiency. Upper right 5 sig sensitivity for 1 hr, 2 plzn; 150m configuration. Figure courtesy L. Testi.