Time Variability of Thermal Molecular Emission in IRC+10216

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INTRODUCTION IRC+10216 is a Mira variable with a long period of ~1.75 years and an amplitude in K of 2 mag. Being a relatively nearby source (110-170 pc), it is one of the brightest infrared objects and richest molecular sources (>80 molecules detected) in the sky. The excitation of the rotational levels of most molecules is mainly collisional and there is no hint of time variability in the millimetre domain (e.g. Cernicharo et al. 2000). However Herschel/HIFI observations separated by several months have revealed drastic changes in line intensities of several species, while others were found to be very stable. This finding was followed-up by subsequent epochs and motivated the study presented here.

For complementary details please listen to the companion talk given by J. Cernicharo. See also M. Groenewegen's poster for a study of the variability in the SPIRE continuum.

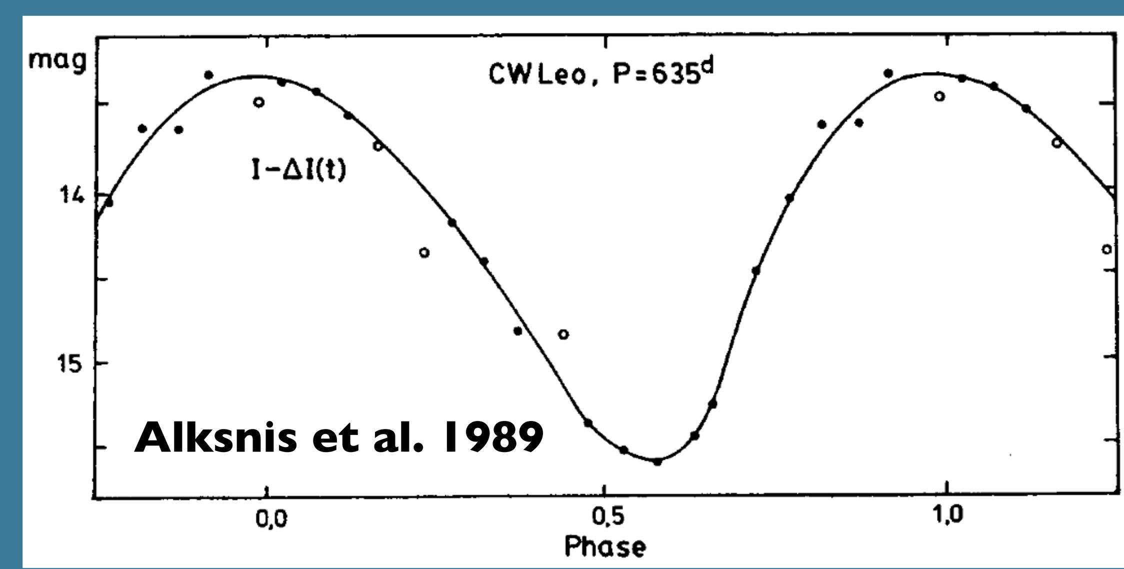

FIGURE 1: Measured light-curve of IRC+10216 in photographic Infrared I(0.81), with a period of 635 days

HERSCHEL OBSERVATIONS

We have conducted a monitoring of the thermal molecular emission of more than a hundred lines in IRC+10216 using all three Herschel instruments. About 80 selected lines of CO, ^{13}CO, HCN, HNC, H^{13}CN, CS, water, SiO and SiS among others, were observed over up to 7 epochs with HIFI, while full range scans were collected with PACS and SPIRE for up to 8 epochs. A complementary programme is currently being performed at the 30-m telescope to cover lower level transitions of these molecules.

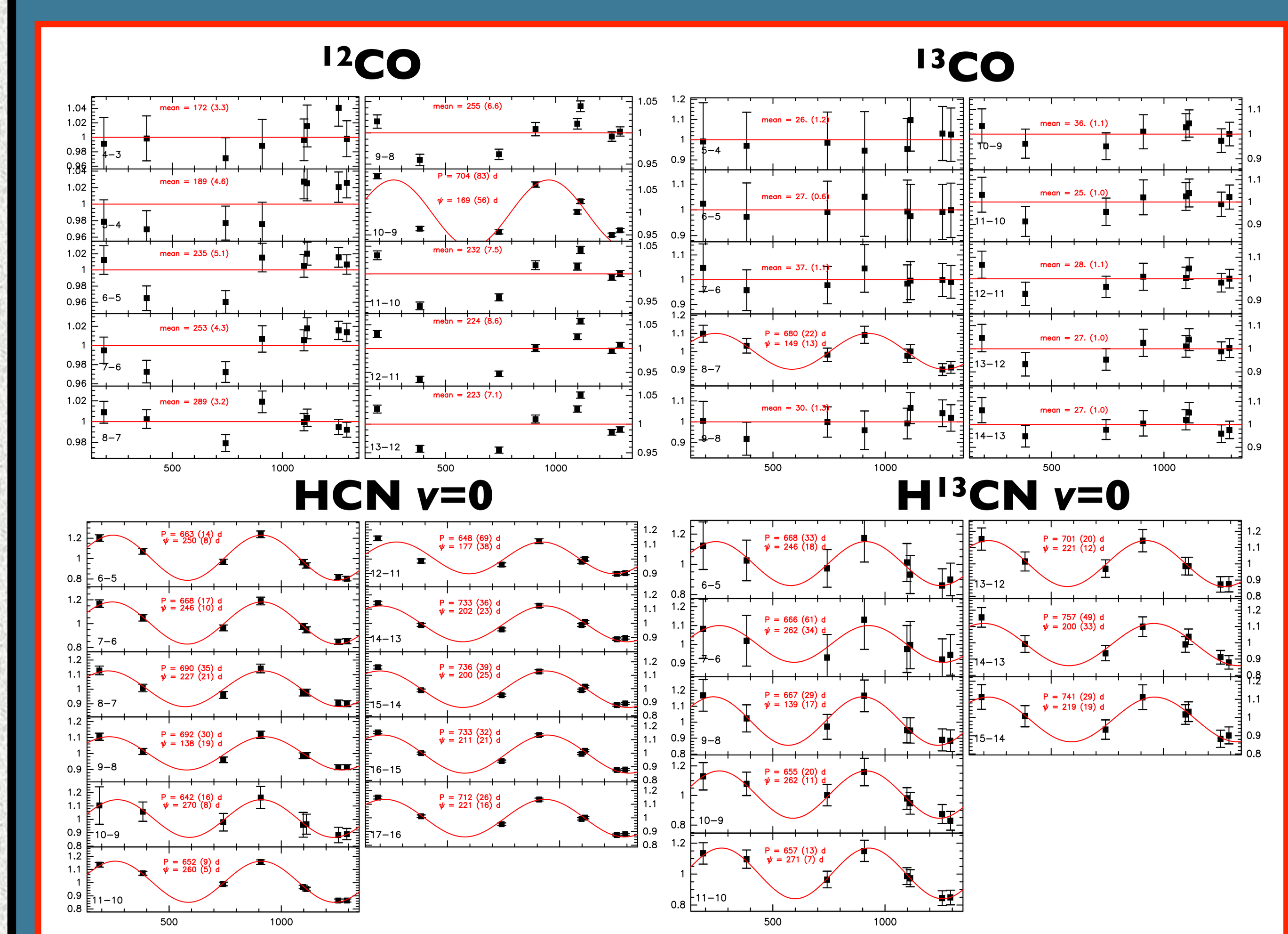

FIGURE 3: SPIRE fitted intensities over various epochs for a selection of molecules and transitions, together with the best fitted sine wave or mean intensity when no fit could be achieved (red curve). The fitted epoch and phase (with errors in brackets) are also shown.

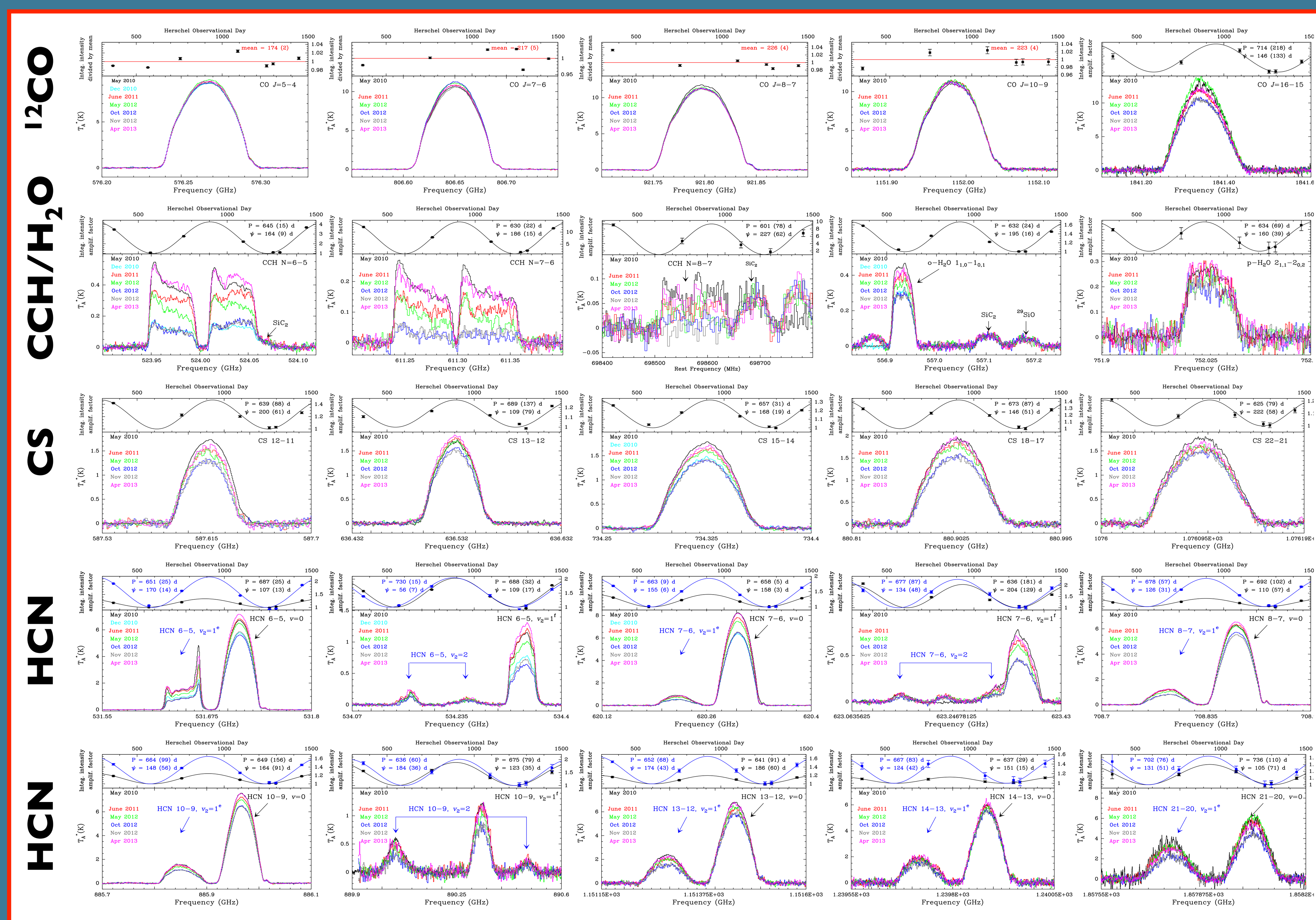

FIGURE 2: HIFI spectra at various epochs for a selection of molecules and transitions. The upper panels of each plot displays the integrated intensity computed at each epoch (black and blue squares), together with the best sine wave fit (black and blue curves), normalized to the minimum of the fitted function. The fitted epoch and phase (with errors in brackets) are also shown. When no decent fit is found, a straight line in red shows the average.

DATA ANALYSIS

Fig. 2 gives an overview of some of the transitions probed with HIFI, and displays the spectra compiled over the various epochs. For each molecule and transition, we have extracted the integrated line intensities (*sinc* function fit for the SPIRE data) of each epoch and fitted a sine wave function as first-order approximation of the equivalent "light-curve". This is shown in the upper panels of each sub-plots for Fig.2 and in Fig. 3 for some of the SPIRE data. The PACS analysis is still on-going.

- Basically all lines but CO and ^{13}CO (except at high-*J*) exhibit noticeable intensity variation with time. The largest excursion occurs with CCH (variation in excess of 1000% !)
- In general all variable lines can be fitted with a sine wave function having a period in the range ~600-700 days
- The modulation amplitude increases at higher vibrational levels, and is particular stronger in the bending mode (v_2) of HCN – see Fig. 4

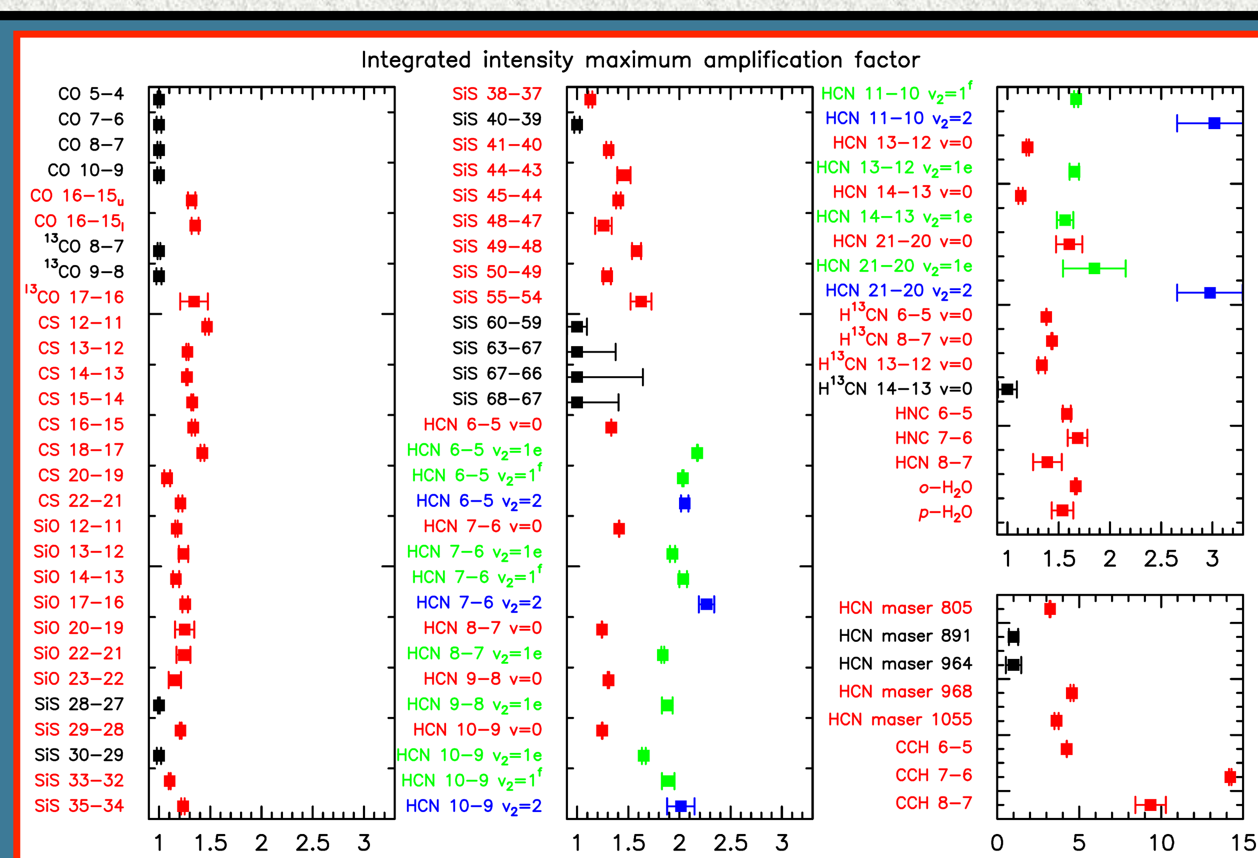

FIGURE 4: Overview of the maximum amplification factor inferred from the HIFI integrated line intensity modulations. Black boxes indicate cases with no decent sine wave fit.

THE ROLE OF IR-PUMPING

The IR radiation field is expected to most affect molecules with strong vibrational transitions. Fig. 4 confirms this trend and shows that the intensity modulation increases together with the vibrational levels at a given *J* level (e.g. HCN). It is also observed that the effect typically increases at higher rotational levels (e.g. CO, CS, SiS). This shows that the IR radiation field and its variation with time has to be included in any radiative transfer model of circumstellar envelopes if one wants to derive an accurate physical and chemical structure of the envelope. Each molecule will be a particular case and the complete ro-vibrational structure has to be considered.

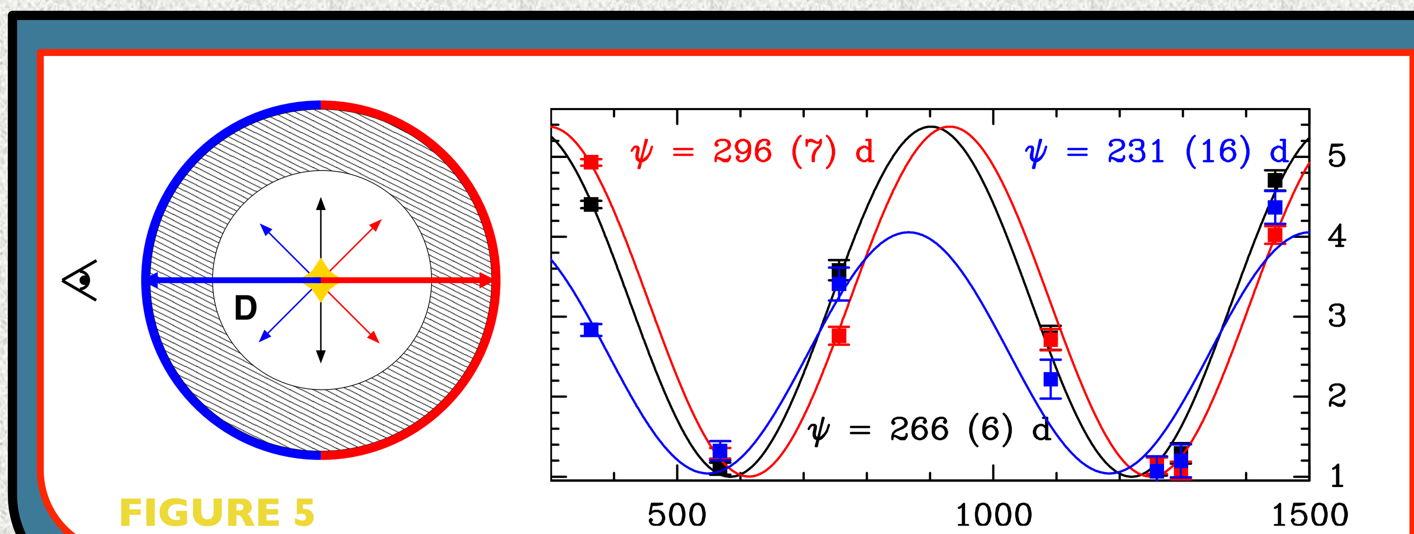

FIGURE 5

DISTANCE ESTIMATE

Because of the light travel time, the effect of IR-pumping in a given spectrum will manifest at different time lags in different layers of the envelopes. This means that the rear (red-shifted) and front (blue-shifted) parts of the envelope should have a time delay of 2D/c, with D the distance to the star of the zone contributing to the observed line. If one then knows the size of this zone in arcsec, the distance to the star could be inferred. Fig. 5 shows an example of possible time lag difference in the light-curve of various velocity ranges (red-shifted, central in black, and blue-shifted) in CCH 6-5. The distance inferred here would be ~370 +/-120 pc, i.e. a factor ~3 too large compared to the current assumption for IRC+10216. Note that this approach does not consider any sophisticated distribution of the envelope layers contributing to the velocity ranges considered in the fitting and might lead to larger uncertainties.