1.4 THz Receiver

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I. Abstract

With the new technology of hot electron bolometers (HEB) low-noise heterodyne observations at THz frequencies are now possible and observations of high frequency molecular transitions as well as ionized material will allow us a detailed study of the far-infrared universe.

We are in the process of constructing such a THz receiver covering the two atmospheric windows at 1.3 and 1.5 THz. Indeed the poor atmospheric transmission at THz frequencies is one of the major problems and astronomical observations will only be possible from the very best ground-based sites, or from airplanes and satellites. Therefore the instrument is design to be modular so that it can be used on different ground-based telescopes as well as the SOFIA airplane observatory. Principle scientific targets will be high-mass star forming regions, the warm ionized medium (WIM) especially in the Galactic ring and molecular cloud chemistry.

We are currently in the phase of detailed design and expect to assemble the receiver in 2004. First lab test are scheduled to take place in late 2004/early 2005 and first test observations by the middle of 2005.

II. Atmospheric transmission

The atmospheric transmission at THz frequencies is greatly effected by water vapor at discrete frequencies as well as a water "continuum" , i.e. continuously increasing absorption toward higher frequencies, possibly due to water dimers (Pardo, Wiedner, Serabyn, Cernichero 2003). The transmission can be measured with Fourier Transform Spectrometers (FTS). Fig. 1 shows one such measurement we obtained of the transmission above Mauna Kea on a particularly dry night (0.27mm PWV). The black curve shows the measurements, the dotted lines are fits using the Atmospheric Transfer Model (ATM, by Pardo et al, 20..) including water line (blue), water continuum (red) and lines from other molecules (green). The result is that the water "continuum" greatly effects the transmission in the THz, that the THz windows at 1.0, 1.3 and 1.5 THz are much more opaque than the windows at 690 and 850 GHz and that astronomical observation will only be possible from the driest sites under good weather conditions.

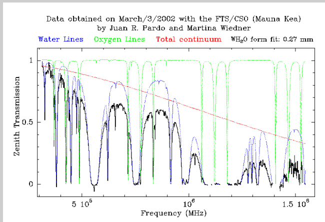


Fig.1 FTS measurement and model of atmospheric transmission in March 2002 on Mauna Kea, Hawaii.

III. Telescopes

Observations at THz frequencies are only possible from very dry sites. We are currently focusing on using the THz Receiver on two telescopes: the Stratospheric Observatory For Infrared Astronomy (SOFIA) and the Atacama Pathfinder Experiment (APEX).

Fig. 2 Stratospheric Observatory for Far-Infrared Astronomy (SOFIA)

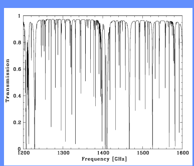


Fig. 3 Model of the atmospheric transmission for SIFIA at an altitude of 14km (2.3µm PWV).

SOFIA

SOFIA is an airborne 2.7m observatory for infrared astronomy that flies at an altitude of 10-14 km, above 99% of the water vapor (Becklin 1997). It has a resolution of 18" at 1.5 THz and will start general observations by the end of 2004. This 1.4 THz receiver will extend the observing range of the PI instrument GREAT (Güsten et al. 2000) to longer wavelengths.

Fig. 4 Model of the Attacama Pathfinder Experiment telescope located in the Atacama desert at 5000m elevation in Chile.

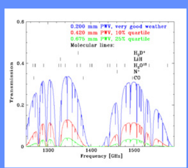


Fig. 5 Modeled atmospheric transmission for the lowest measured amount of PWV (blue) , the 10% quartile (red) and the 25% quartile of PWV.

APEX

APEX is a 12m telescope that is being constructed in the Atacama dessert in Chile at an altitude of 5000m (Schilke 2002). The telescope has a chopping secondary with which most of the atmospheric emission can be subtracted out. The telescope is expected to have first light in 2003.

IV. Astronomy

We are particularly interested in studying high mass star forming regions and the warm ionized medium in the galactic ring, for both of which the THz frequency band is ideally suited. In Fig. 5 the astronomically most important molecular lines between 1250 and 1600 GHz are indicated. The high CO transitions have upper energy levels between 430 and 580K and critical densities of a few times 10^6 cm^-3.

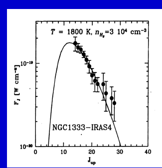


Fig. 6 CO transitions of the class 0 object NGC1333 measured by Giannini, Nisini & Lorenzeti (2001).

Massive Star Formation

The process of massive star formation might differ considerably from that of the formation of low mass stars. Not only are the molecular clouds bigger and denser, but also the temperatures higher. The high transitions of CO are thought to trace shocks as well as photo dominated regions (PDR). With a heterodyne receiver we will be able to determine the line width, which will allow us to distinguish between these two regions. Furthermore we will be able to map the objects and study the dynamics of the region, important to investigate the processes occurring in massive star formation. In order to prepare for these observations, we have already selected a small sample of 7 high mass star forming regions observable from Chile which we mapped in CO 3-2 and 2-1, see poster by Schmidt, Simon & Wiedner.

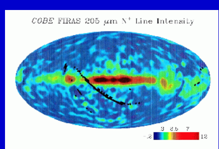


Fig. 7 N+ at 1496GHz is the third strongest emission line of the galaxy detected by COBE (Fixsen et al. 1999).

Warm Interstellar Medium (WIM)

The WIM is an important component of the interstellar medium, but its distribution and origin are not well understood. Petuchowski et al. (1994) suggest that the WIM appears in two phases, a low electron density phase (n_e~50cm^{-3}) making up 70% of the mass and a high electron density phase (n_e~100cm^{-3}). The latter might be at the rim of a plasma wind created by a starburst or alternatively the rim of a super bubble created by a SN. With the THz detector we will be able to map N^+ at high special and spectral resolution in order to compare its distribution with that of e.g. the 21cm line and Together with N+ observations at 2.46 THz electron densities can be determined.

V. THz Receiver

The THz Receiver will be build following the well-known design of heterodyne receivers (see Fig. 8). However, the local oscillator (LO) and the mixer for the THz frequency range are not standard components and are very challenging to produce. We have ordered a solid state oscillator with an output of at least 4µW at least at the line frequencies. Since the LO power is low, we cannot effort to lose much power in a beam splitter, but overlay the LO and the sky signal using a Martin-Puplett Interferometer. The mixer will probably be a phonon cooled Hot Electron Bolometer (HEB) build by KOSMA. Standard parts will be used for the IF amplification and possibly down- or upconversion. The receiver temperature is expected to lie around 1500K. Given the poor atmospheric conditions and the roughness of radio telescope dishes, the system temperature will be around 50000K (!) even under very dry weather conditions of 0.42mm PWV for observations from Chile, however, at a high resolution of 4". Complementary observations from SOFIA will have a resolution of 18" and a system temperature around 3000K.

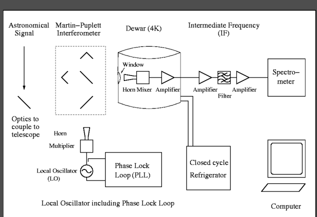
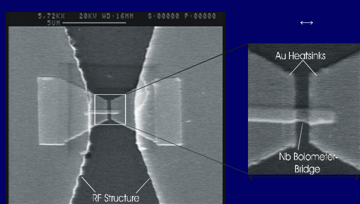


Fig.8 Schematic of the THz receiver

References:

E. E. Becklin 1997, in " The Far Infrared and Submillimeter Universe", ed. A. Wilson, ESA, 207
D. J. Fixsen, C .L .Bennett, & J. C. Mather 1999, ApJ 526, 207
T. Giannini, B. Nisini, & D. Lorenzetti 2001, ApJ 555, 40
R. Güsten et al. 2000, Proc. SPIE 4014, 23
J -R. Pardo, J. Cernicharo, & E. Serabyn 2001, IEE Trans on Ant. and Prop., 49/12, 1683
J., -R. Pardo, M. C. Wiedner, E. Serabyn, & P. Cernicharo 2003, ApJ in preparation
S. J. Petuchowski et al. 1994, ApJ 427, L17
P. Schilke 2002, conference contribution



Diffusion cooled Nb hot electron bolometer mixers:
dimensions: 160 x 130 x 10 nm
T_{rec}=1600 K @ 880 GHz
Jacobs, Honingh, et al.