SUBMILLIMETER SPECTROSCOPY OF HIGH REDSHIFT GALAXIES

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1 Introduction

Population of redshifted objects is a favored target for surveys in a wide range of wavelength, from the visible (HDF, Hubble Space Telescope), infrared (ISOCAM, ISO), far infrared (ISOPHOT, ISO), and submillimeter (SCUBA, JCMT). Identification of sources accross these surveys is a difficult task because of the very different angular scales of these observations, ranging from a fraction of an arcsecond for the HST up to ten and above arcseconds at longer wavelength. Many visible sources lies in the same infrared or submillimeter pixel, therefore visible follow-up observations of the sources detected at long wavelength is of very little help. Redshift determination of these sources relies mainly on photometry. Recent advances in the observational techniques at submillimeter wavelength bring new tools in the study of early galaxies. The submillimeter spectrometer developped for the ground based 10 m antenna of the CSO is one of these tools. Observing through the atmospheric windows at 350 μm and 450 μm allows the search for redshifted atomic and molecular lines lying in the far infrared in the rest frame.

2 FIBRE : Fabry-Perot Interferometer Bolometer Research Instrument

FIBRE original concept is described in Maffei et al, 1994. The spectrometer is based on a cryogenic scanning Fabry-Perot interferometer and a grating for sorting the orders of the Faby-Perot on a linear array of 32 bolometers. Thus a single scan of the Fabry-Perot allows to explore the entire atmospheric window selected for the run, either 350 or 450 μm. The large velocity distribution within the emitting objects produces line widths of many 100 km per second. The resolution of 1000 to 1500 achieved with this instrument is therefore well suited for their observation. Present design takes advantage of the latest developments in bolometric detectors at NASA-GSFC : TES (superconducting Transition Edge Sensors) bolometers and SQUID readout, operated between 300 and 400 mK. Operating temperature is achieved by mean of a 300 mK Torre-Chanin closed cycle 3He mini fridge. The cryostat is cooled by a Gifford-McMahon cycle cryorefrigerator complemented by a pumped helium bath to obtain the 2 K background environment for the spectrometer. This is needed to keep the photon noise of the thermal emission by the spectrometer components below the detectors noise. The spectrometer has been succesfully operated with a test bolometer array at 1.5 K. Integration of TES bolometers is in progress at NASA-GSFC, and the instrument first light at the focus of the 10 m antena of the Caltech Submillimeter Observatory is scheduled during the second semester of 2000.

3 Spectrometer performances

The spectrometer resolution measured with the monochromatic emission produced by a 80-110 GHz Gunn diode in serie with a doubler and a tripler is comprised between 1000 and 1500 depending on the wavelength. The expected sensitivity at the CSO is 8 10-18 Wm^{-2} (S / N=5, 1 hour, 5 spectral elements) or 2 10-17 Wm^{-2} (S / N=5, 1 hour, full spectrum). Table 1 summarizes the corresponding luminosities for galaxies that FIBRE could detect.

Table 1: Expected luminosities (1 hour, S / N=5) of galaxies that FIBRE could detect. The power in the CII line is assumed to be equal to 0.3% of the galaxy flux.

	Wavelength (μm)	Redshift (z)	Sensitivity ($L_{\odot}$)
Line Detection	350	1.2	3×10^{12}
	450	1.8	8×10^{12}
Full Spectrum	350	1.2	8×10^{12}
	450	1.8	2×10^{13}

4 Source selection for submillimeter spectroscopy

Continuum observations such as the ISOPHOT deep surveys (ie FIRBACK survey, Puget et al., 1999, Dole et al, 2000) has led to the detection of potentially high redshift sources : fluxes ranging from 100 mJy to 1 Jy at 170 μm correspond to a total luminosity of 10^{12} to 10^{13} solar luminosities at a redshift of one. SCUBA detection at the JCMT led to photometric redshifts 1.2 and 1.4 for 2 sources of the FIRBACK survey (Scott et al, 2000).

Modeled deep source counts compared to observations at 15, 170 and 850 microns is presently one of the best probe to test our understanding of galaxy evolution (Dole et al, 1999, Dole et al, 2000).

At larger redshifts, continuum observations of high redshift quasars (Benford et al) probe the the most extreme population . The positive detection of CO line in these objects (Guilloteau et al.) is a promising result for the FIBRE instrument.

References

1. Dole H., Gispert R., Lagache G., Puget J-L. *et al*, astro-ph / 0002283, proceedings of the Ringberg Conference “ISO view of a Dusty Universe”, Lemke, Stickel, Wilke Eds, november 1999
2. Dole H., Gispert R., Lagache G., Puget J-L., *et al*, 2000, Astronomy & Astrophysics, in preparation.
3. Guilloteau, S., Omont, A., Cox, P., McMahon, R. G., Petitjean, P., Dust and CO lines in high redshift quasars, 1999, Astronomy & Astrophysics, 349, 363
4. Benford, D., Cox, P., Omont, A., Phillips, T., McMahon, R., 350 Micron Dust Emission from High-Redshift Objects, 1999, Astrophysical Journal, 518-2, L65
5. Maffei B., F. Pajot, T. Phillips, D. Benford, E. Caux, R. Gispert, N. Halverson, T. Hunter, G. Jegoudez, M. Josse, J.M. Lamarre, J.P. Lepeltier, H. Moseley, A. Origne, S. Petuchowsky, M. Rabotin, J.C. Renault, C. Rioux, G. Serabyn, N. Wang, A medium resolution ground based submillimeter spectrometer, 1994, Infrared Physics & Technology 35, 321
6. Puget J-L., Lagache G., *et al*, 1999, Astronomy & Astrophysics, 345, 29