CRIRES Science Verification Proposal

Title: H_3^+ and CO observation toward Superantennae

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Abstract:

We propose H_3^+ and CO observation toward Superantennae with CRIRES. Using the central luminous core as the background illumination, we will search for H_3^+ and CO in absorption on the continuum emission. The two molecular species make complementary physical probes in warm clouds. The observation will give new and quantitative look at the molecular torus around its nucleus which is ill-understood to date.

Scientific Case:

H_3^+ is the most fundamental ion molecule which plays pivotal role in the interstellar chemistry. It serves as a unique physical probe in space, for instance to directly measure the size of intervening cloud along its depth. H_3^+ has already proven its use by renewing the cosmic-ray ionization rate which is a key parameter to initiate the interstellar chemical network (McCall et al. 2003).

H_3^+ was first discovered in the ISM in 1996, in the heavily obscured line of sights toward dark clouds (Geballe & Oka 1996). Since then, the ion molecule is rapidly developing its frontier to the new fields, including unexpected detection in diffuse clouds with more than a order of magnitude higher abundance than the theoretical expectation (McCall et al. 1998; Geballe et al. 1999), and our detection of matastable H_3^+ which led to the discovery of a vast amount of warm and diffuse gas in the Central Molecular Zone of the Galaxy (Oka et al. 2005)

Recently H_3^+ reached for the first time outside our Galaxy. IRAS 08572+3915 is one of ultra luminous infrared galaxies with heavily obscured AGN and/or active starburst at their nucleus. The line of sight to the center of IRAS 08572+3915 shows heavy absorption of silicate as well as 3.4 μm hydrocarbon dust that guarantees abundant intervening material.

Geballe et al. (2005) discovered H_3^+ in absorption toward IRAS 08572+3915 NW along with the deep CO absorptions, using UKIRT and Subaru Telescope. The fundamental transition of CO shows a series of deep and broad absorption lines at 5 μm with large velocity dispersion as much $\pm$200 km/s. The line depth and the profile clearly uncovered the rich kinematics of warm gas inside the molecular torus (Shirahata et al. 2007).

The absorption survey of H_3^+ and CO in the torus around obscured AGNs is now in progress in the northern hemisphere. However, there are not so many prospective targets left undone that suffer heavy obscuration as much as IRAS 08572+3915 except Superantennae (IRAS F19254−7245). Superantennae is only observable from the southern hemisphere.

The project is unique to be done during the science verification time, since it gives rare opportunity to test the performance of CRIRES at the wavelength longer than nominal CO at 4.7 μm, and H_3^+ at 3.7 μm, because of its finite redshift $z = 0.062$.

1) McCall et al. Nature 422, 500 (2003)
2) Geballe & Oka Nature 384, 334 (1996)
3) McCall et al. Science, 279, 1910 (1998)
4) Geballe et al. ApJ 510, 251 (1999)
5) Oka et al. ApJ 632, 882 (2005)
6) Geballe et al. ApJ 644, 907 (2006)
7) Shirahata et al. ApJ submitted.

Required observing time

Target	RA	DEC	Wavelength Band	Magnitude	DIT	NDIT
Superantennae	19 31 21.4	−72 39 18	3853-3957 nm (14/-2/i)	L'=10.8	60	120
Superantennae	19 31 21.4	−72 39 18	4858-4994 nm (11/-2/i)	M'=9.1	10	360

We will observe one band at H_3^+ at L, and one band at CO v=1-0 transition at M, with priority on the H_3^+ observation.

The targeted transition of H_3^+ is a doublet of $R(1, 1)^u$ and $R(1, 0)$. The nominal laboratory wavelengths are 3.6681 μm and 3.6685 μm, respectively. Taking into account the redshift, observing wavelength should be centered at 3.896 μm with the margin larger than 200 km/s at both of the side, which is satisfied by one grating setting of 14/-2/i.

We assume same redshift of CO v=1-0. The fundamental transition of $R(0)$–$R(9)$ and $P(1)$–$P(4)$ will be covered by the grating setting 11/-2/i with a few lines missing between the abutting detectors.

The Superantennae has two major components, S and N, roughly aligned to the north to the south with 8" separation. The north core is starburst-dominated galaxy, and is not of our interest. The southern core, which harbors AGN, is a few times brighter than the north at the wavelength we are concerned. The southern core has two subcomponents within 1" separation. Both of them will be covered in the wide slit we will use.

In order to avoid the contamination by the north core, but still to put the slit along the elongation of the southern component, we will set the slit-orientation along PA=−45. Since the object is extended, and is expected to have large velocity dispersion, we will use the slit of 2" width in order not to lose the flux of the object. There is no contaminating sources within 1'×1' field of view in the 2MASS K band image except the northern galaxy. The spectrum should be recorded by dithering the telescope by half the length of the slit (∼20"). No need to go to separate blank sky to subtract the warm sky emission.

The target is faint, L'=10.8 and M'=9.1 (both from ISAAC spectrum of Risaliti et al. 2003. M' brightness is linearly extrapolated to ISOCAM photometry at 6 μm). The CRIRES ETC gives SNR = 1.9 and 1.1 for L' and M', respectively, with the integration times listed above. However, the numbers are for the SNR at one pixel integrated along the spatial direction. However, we will use 2" slit, which is 23 pixels in the spectral axis (0".087/pixel). After binning to R=10,000 (all 23 pixels), the expected SNR would be 9.1 at H_3^+, and 5.3 at CO, which was enough to call the detection of H_3^+ in Geballe et al. 2006 with their R=6,000 spectrum. In the case the SNR is still not sufficient, we will further bin the spectrum upto R=6,000.

The Superantennae is bright enough in visible wavelength to serve as a self-wavefront reference (R=14.5). The target is observable during the first half of the night.

The standard calibration is requested, with spectroscopic standard star, and the spectroscopic flat field with matched dark frames. We do not need photometric standard star to calibrate the absolute flux in the object spectrum, since we are only interested in the equivalent width of the absorption lines that can be measured with respect to the continuum flux.

The data will be reduced by two methods, one with standard CRIRES pipeline, and the other with custom-written IDL codes which have been developed for the search of H_3^+ and CO in the interstellar medium, and have been tested for years with data from different telescopes, including Subaru, Gemini South, UKIRT and IRTF. The resultant output spectra will be closely compared, so that if anything strange happened in or after the observation, it is swiftly recognized.

1) Risaliti et al. ApJ 597, L17 (2003)
2) Geballe et al. ApJ 644, 907 (2006)