

Annual Report of Academic Activity of Tapasi Ghosh (Mar07 - Feb08)

1. A brief Summary of Research and Scientific Activities :

Variation of Fundamental Constants - current status of the project:

(Collaborators: N. Kanekar (NRAO), J. Chengalur (NCRA, India)

Much of the interpretative work of the Arecibo data on this topic (project, A2123: 40-hour integration on the OH satellite lines in the associated absorber of PKS 1413+135) happened this year.

The result of the analysis so far imply, $[\Delta G/G] = (-1.9 \pm 1.1) \times 10^{-5}$ from the older WSRT data and, $[\Delta G/G] = (+1.94 \pm 0.66) \times 10^{-5}$ from the recent Arecibo data, where $G \equiv g_p [\alpha^2/\mu]^{1.85}$, a combination of the fine structure constant α , the electron-proton mass ratio $\mu \equiv m_e/m_p$ and the proton gyromagnetic ratio g_p . Combining the two results weighted by their errors yields, $[\Delta G/G] = (+9.5 \pm 5.6) \times 10^{-6}$. Both results are consistent with no evolution in α , μ or g_p from the redshift of PKS 1413+135, i.e. over a lookback time of ~ 2.9 Gyrs.

However, we note that the WSRT and the Arecibo results have similar magnitudes but opposite signs (eventhough, they are consistent with each other within the respective 3-sigma values). Hence, we are now investigating if the "discrepancy" could be due to an arithmatical error in one of the datasets. The WSRT observations were taken without any online Doppler shift, while Arecibo observations were taken with the Doppler shift applied as available at the observatory. The current effort is to use the same code (developed by us) to re-calculate the heliocentric velocity values from the observed (topocentric) frequencies for both data sets. Once this matter is settled, we would be able to submit the paper for publication.

A cm-wavelength spectral line Census of ARP 220:

(Collaborators: B. Catinella, M. Lebron, M. Lerner, R. Minchin, E. Momjian, C.J. Salter)

Together with a majority of the (then) Arecibo radio astronomy group (Drs. Catinella, Lebron, Lerner, Minchin, Momjian and Salter), I am participating in a project to make a spectral scan of the prototype ULIRG, Arp 220. This project uses the Arecibo receivers covering the 1.1 - 10 GHz band. The newly commissioned 800-MHz mode of the WAPP spectrometer is being employed. The aim of the study is to investigate the various atomic/molecular line transitions detectable from this ULIRG. The large number of radio recombination lines present can better constrain RRL emission models, while the molecular census will improve our understanding of how starbursts occur, and how the star formation rate is regulated. As well as "shaking down" the new WAPP mode, the Double Position Switching (DPS) mode of observing is a necessity for this project, and an optimized modified DPS approach has been developed. About one half of the observations took place in the spring of 2007.

These reveal a spectrum rich in molecular transitions, including the pre-biotic molecules, methanimine (CH_2NH) in emission, three $v_2=1$ direct l-type absorption lines of HCN, and an absorption feature from either 18OH or formic acid ($HCOOH$). Our results mark the first distant extragalactic detection of methanimine, a molecule with high relevance to the origins of life. In addition to detecting known absorptions lines of 6- and 5-cm excited OH, we have also revealed two, possibly three, absorption lines of $\lambda 4$ -cm OH not previously seen in Arp 220, and a probable absorption feature from the 6.668-GHz line of methanol. Possible emission lines of CH and formamide (NH_2CHO)

require confirmation. The first publication from this work has been submitted to A.J.

2. Observing/Research-support Proposals:

- Jun 2007: **Arecibo**; Salter, C.J., Ghosh, T., Catinella, B., Lebron, M., Lerner, M., Minchin, R., Momjian, E., “A Cm-wavelength Search for Prebiotic (and Other) Molecules in Arp 220-like Starburst Galaxies.”
- Oct 2007: **Arecibo**; Kanekar, N., Ghosh, T., Salter, C.J., “A Blind Survey for redshifted H₂CO 4.8 GHz Absorption towards a Radio-selected Sample.”
- Oct 2007:**Arecibo**; Arce, H.C., Lebron, M., Ghosh, T., Gibson, S., Lerner, L., Minchin, R., Momjian, E., Salter, C.J., “A Cm-wave Molecular Line Census for Three Representative Interstellar Regions.”
- Oct 2007:**Arecibo**; Zauderer, A., Momjian, E., Ghosh, T., Salter, C.J., “HI and Molecular Line Observations of the 2 Jy IRAS-NVSS Sample at L-Band.”
- Oct 2007 (and re-submitted Feb 08):**GBT**; Ghosh, T., Salter, C.J., Catinella, B., Lebron, M., Lerner, M., Minchin, M., Momjian, E., O’Neil, K., “A GBT Cm-wave Search for Prebiotic & Other Molecules in Arp220-like Galaxies.”
- Nov 2007:**MERLIN**; Ghosh, T., Salter, C.J., Momjian, E., Minchin, R., Lerner, M., Lebron, M., Catinella, B., “Mapping the Distribution of a Prebiotic Molecule, Methanimine, in Arp220.”
- Nov 07:**NSF Astronomy Grant Proposal**; Ghosh T., Lebron, M., Zauderer, L., “Cm-wavelength Studies of Prebiotic and High-density Tracer Molecules in Starburst/Megamaser/Ultraluminous IR Galaxies.”

3. List of Publications:

- Salter, C.J., Ghosh, T., Catinella, B., Lebron, M., Lerner, M.S., Minchin, R., Momjian, E., 2008, AJ, ”The Arecibo Arp 220 Spectral Census I: Discovery of the Pre-Biotic Molecule Methanimine and New Cm-wavelength Transitions of Other Molecules”, submitted.
- Kanekar, N., Chengalur, J. N., & Ghosh, T., “Probing Fundamental Constant Evolution with Redshifted OH Lines”, 2008, Princeton Series in Astrophysics, 109
- Ghosh, T., Catinella, B., Lebron, M., Lerner, M. S., Minchin, R., Momjian, E., & Salter, C. J., “The Detection of Prebiotic Molecules in the ULIRG Arp 220”, 2007, American Astronomical Society Meeting Abstracts, 211, #141.07
- Salter, C. J., Catinella, B., Ghosh, T., Lebron, M., Lerner, M. S., Minchin, R., & Momjian, E., “Excited-OH And Methanol Absorption In The ULIRG Arp220”, 2007, American Astronomical Society Meeting Abstracts, 211, #141.06
- Gupta, N., Salter, C. J., Saikia, D. J., Ghosh, T., & Jeyakumar, S., “Probing Radio Source Environments Using 21-cm Absorption”, 2007, The Central Engine of Active Galactic Nuclei, 373, 203
- Ghosh T. Salter, C.J., 2007, Galfacts Technical Memo No. 11, ”The ”Effects of Ionospheric Faraday Rotation on GALFACTS.”

4. Other Academic Activities:

- In 2006, Chris Salter, Emmanuel Momjian and I jointly supervised REU student, Maria Ximena Fernandez, in a project entitled, "A Radio Spectral Line Study of the 2-Jy IRAS-NVSS Sample". Ximena continued with the project for her final-year thesis at Vassar College, with "supervision from a distance", and an additional trip down to Arecibo in spring 2007. Her thesis was successfully submitted in May 2007.
- In Jun 2007, at the Green Bank NAIC/NRAO Single Dish Summer School, I lectured on VLBI techniques, supervised students' hand-on project of HI Galaxy search using the GBT in drift-scan mode, and also ran a demonstration of Arecibo observation and data reduction using the offline CIMA and a set of pre-observed data (as this was during the telescope down-time due to the ongoing platform painting).

5. VLBI related Technical Activities:

Between April 2007 and Dec. 2008, all observations were suspended due to painting of the platform. During that time, Chris Salter, Arun Venkataraman and I ran an eVLBI data transport experiment between Arecibo and JIVE using the UDP format over the existing OC3 connection. This was successful upto the data rate of about 105 Mbps. In Feb. 2008, we ran a realtime test, and was able to detect fringes for data rates of up to 128 Mbps.

We have also run three HSA/Global VLBI observations in February 2008. All of these have been successful. The observations represent; (1) a study of the Zeeman effects in compact components of ULIRGs using circular polarization observations of OH maser lines in these galaxies, (2) jet and counter-jet emissions in giant radio galaxy, NGC315, and (3) measuring the expansion velocity of SN 2008D associated with the transient X-ray source in NGC 2770 (a target of opportunity).

Post processing of the SEFD monitoring data were also performed by myself for all these projects and provided to the users.

During the year, I have also kept the FS software up-to-date by installing the package downloaded from the GSFC-VLBI Services group.

6. Meetings/Conferences/Official visitis

- June 07: Green Bank, NAIC/NRAO Single Dish Summer School.
- July 07: University of Calgary: To work with the GALFACTS team.
- Nov 07: The 3rd US-VLBI Technical meeting at Arecibo.
- Jan 08: AAS meeting at Austin.
- Feb 08: HI conference at Arecibo (presented a poster).

7. Academic Activities not covered Above:

- I have presentated two talks to the 2007 AUSAC and NAIC-VC committees.
- I have (co)authored two white-papers for the Sep. 2007, DC meeting, "Frontiers of Astronomy with the World's Largest Radio Telescope". These are: (1) Arecibo and High Resolution Astronomy, and (2) Probing Fundamental Constant Evolution with the Arecibo Telescope.
- I have compiled a VLBI-equipment upgrade request for this year's Program plan.

- I have organized the 3rd US-VLBI Technical workshop at Arecibo between 29th and 30th of November 2006.
- Jointly with Chris Salter, I have hosted a group of MIT-Alumni at Arecibo, arranging the logistics of the visit and the guided tour of the observatory.
- I have participated in the (remote, web-based) poster sorting session for the Jan08 AAS meeting at Austin.