IndIGO, LIGO-India and visit to EGO-Virgo

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Over two decades since early nineties, research in India in the areas related to gravitational waves (GW) mainly focussed on two significant fronts: source modeling at Raman Research Institute and data analysis at Inter University Centre for Astronomy and Astrophysics (IUCAA). In 2009, the IndIGO Consortium was formed to consolidate these efforts towards an integrated national participation in the LSC and more importantly extend this to participation in the global GW experimental efforts. In meetings under an Indo-Australian project on *Establishing Australia-India collaboration in GW Astronomy* at Kochi, Pune, Shanghai, Perth, Delhi over 2009-11 with ACIGA and the global GW community, IndIGO redefined, reoriented and responded to the global (GWIC) strategies for setting up the International GW Network. Thus it naturally evolved from participation in AIGO to collaboration in LIGO-Australia. In this period sub-system expertise for GW experiments in various DAE Labs, Research Institutes, IITs, IISERs, Universities, past projects were identified. Enthusiasm and consensus for participation in GW experiments was built and funding of 3m prototype at TIFR to be operational by 2014 happened. A multi-disciplinary IndIGO consortium currently consisting of eleven Indian institutions interested in GW experiments, related technology and GW Astronomy took shape and worked to convince the scientific community and funding agencies that with the first generation GW detectors achieving design sensitivity and the promise of GW astronomy in the coming decades, it was indeed the right time for Indian participation in the global GW detection efforts.

In 2011, the above efforts led to the LIGO-India proposal: the construction and operation of an Advanced LIGO Detector in India in collaboration with the LIGO Lab by relocating the third Advanced LIGO detector (H2) in India. LIGO-India is planned to achieve design sensitivity by 2020 and operated thereafter for 10 years as part of the LIGO (International GW) Network. The entire hardware components of the aLIGO detector along with designs and software is to be provided by LIGO-USA and its UK, German and Australian partners (costed at $120 M including R&D). The entire infrastructure including UHV, Labs and clean rooms as well as the team to build and operate will be the Indian responsibility ($250 M, 15 yrs). The geographical relocation of the second Hanford detector is strategic for GW astronomy. It leads to increased event rates, improved duty cycle, detection confidence, sky coverage, and determination of the two GW polarizations. More importantly, LIGO-India also leads to improved source location crucial for multi-messenger astronomy. A fourth site not in the plane formed by the two US LIGO sites and Virgo and far from them greatly improves source localization ability of the network. Inclusion of LIGO-India in the existing LIGO and Virgo network would improve angular resolution on an average by four times and in some directions by a factor of 10-20. With KAGRA in Japan scheduled to be operational in similar time frames, a global GW network will be realized in the coming decade.

Over the last year the LIGO-India proposal has made impressive progress on all the fronts required for its realization. On the Indian side, the project has been included in the list of Mega Projects under consideration by the DAE-DST consortium in the coming Five year plan. Three institutions from the Consortium, Institute of Plasma Research (IPR), IUCAA, Raja Ramanna Centre for Advanced Technology (RRCAT) have agreed to be the nodal leads for LIGO-India. LIGO-India has been discussed at the highest level in the

Department of Atomic Energy and is being referred to the Government of India for seeking in-principle approval and signing of MOUs. On the US side also the process has moved ahead. Four senior level visits from the LIGO-Lab to the LIGO-India lead institutions for technical assessment and discussions were followed by three in depth reviews by a NSF panel. All this culminated in a review by the National Science Board, USA, in August 2012 and the following resolution: *RESOLVED, that the National Science Board authorize the Deputy Director at her discretion to approve the proposed Advanced LIGO Project change in scope, enabling plans for the relocation of an advanced detector to India.*

I visited EGO during Sept 17-19, 2012 after the LVC meeting in Rome to share with colleagues in EGO the status of LIGO-India. Moreover, the aim was to take a guided tour of the Virgo site, detector infrastructure and experimental labs and make contact with colleagues in Virgo working on different aspects of the experiment and share their experience. Federico Ferrini kindly arranged a series of very useful meetings that allowed me to efficiently gather what I needed. Carlo Bradaschia provided a thorough visit to the facility and shared with me his insights on the facility. I met with the noise monitoring team of Elena Cuoco and Irene Fiori to get inputs on issues to pay attention to, during site selection. Carlo and Antonio Pasqualetti explained about issues related to the vacuum system. Franco Carbognani and his team showed me the various aspects of interferometer operations. Jean-Yves Vinet and Giovanni Losurdo discussed the complex project management aspects. Federico Fidecaro and Franco Frasconi showed me around the various labs at Pisa including the suspensions lab.

My discussions with Federico Ferrini and colleagues in EGO also explored potential areas of cooperation for mutual benefit and possible mechanisms to support it. An important area could be the assistance in the training of manpower for LIGO-India by hosting Phd students/Post-doctoral fellows/LIGO-India team members in aVirgo during its installation and commissioning taking advantage of the staggered LIGO-India time-line relative to aVirgo. There is a window of opportunity here with mutual benefits, and possible avenues to explore to facilitate mutual visits in connection with the International GW Network and research in associated technology. Some of these include (i) an Indo-Italian Exchange program, (ii) a joint annual fellowship at EGO, (iii) a collaborative Ph.D program, (iv) regular joint workshops on specific subsystems so that the Indian team can benefit from the experience of the EGO-Virgo collaboration and a knowledge network can be established for them to access when needed, (v) loaning/donating any equipment/setup or material (substrates/coatings) not being used or that can be spared.
Even from my brief visit, it was clear that interactions of the IndIGO team for LIGO-India with EGO-Virgo, (and similarly GEO, KAGRA) can play a useful mentoring role to the new Indian GW research program and provide multiple inputs to it on infrastructure, technology, management and outreach in the coming years.