SAMPARK

TIFR ALUMNI NEWSLETTER

March 2018

Volume 2/2

TAA requests its members to update their email ID by sending a mail to alumni@tifr.res.in or tifraa@gmail.com

From the TAA Presidents desk

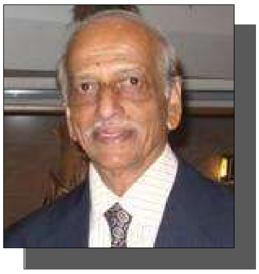
It is indeed a pleasure to extend my greetings to you all, as the President of the TIFR Alumni Association.
It has been our endeavor to make sure that those who graduate from here continue to be associated with the Institute through the TAA. We also encourage the current research scholars to become Associate members of TAA, which would then get converted to full-fledged membership when they graduate from here.
In the past year TAA was associated with a few activities.
We celebrated the National Science Day on 28th February by a lecture by Prof. B. Iyer, ICTS, TIFR on "the top scientific breakthrough in 2016: Detection of gravitational waves by LIGO" a very timely topic in the context of last year's greatest discovery on "detection of gravitational waves" which went to win the Nobel Prize in Physics in 2017.
TAA also organized the JRD Tata lecture on 3rd August by the eminent scientist, Prof. A. K. Sood, IISC. He charmed the audience in the packed Homi Bhabha auditorium by his lecture on "Fun Science with Inanimate and Living Bacteria: Flocking and Nano Heat Engine. ".
TAA was actively involved in Founder's Day celebrations on the 30th October. On this day we honoured some of our distinguished alumni and bestowed awards on the current scientists for their excellence in research and teaching and those who have obtained patents.
Starting this year, TAA will be organizing an annual lecture series "Aveek Guha Memorial Lecture" founded by Prof. S. Guha in memory of his son, Aveek Guha. The first lecture of this series was held on 16th November, 2017 and was given by Dr. Viral Acharya, Deputy Governor of RBI, India. He spoke on "Monetary Transmission in India:Why is it important and why hasn't it worked well?"
Though our membership is very limited, I believe that our members, many of whom are well established and respected in their profession, can be of immense help to the Institute. This can be done by their offering to help build linkages with other centers of excellence within and outside the country, by offering guidance to the senior research scholars in choosing appropriate places for post-doctoral research and those seeking employment in academia. We have just launched a website which we expect will become very helpful to our young members in this context and we appeal to senior members to provide valuable inputs so that the website may remain vibrant.
This year has been a year of many losses as the TIFR family lost many of its reputed scientists. We offer condolences to the family and well-wishers of Prof. Simha, Prof. Lagu, Prof. Srinivas and Prof. Yash Pal.
Finally, I would like to thank our editors for their effort in bringing out this issue which I trust our members would enjoy. It would be my attempt to persuade them to bring out, may be a slimmer version of the same, sometime in July as well. I also appreciate the help rendered in this connection by Mr. Kishore Menon .
We are indebted to TIFR administration and in particular to the Director, Prof. S. Trivedi for their help in connection with our activities.

Dipan Ghosh
TAA President
Former Professor IIT Bombay

From the editors desk

We are happy to bring this year's 2nd volume of the TAA Newsletter "SAMPARK" to our TAA members. As was decided from this year, we will bring out bi-annual editions. The first volume of 2017 was made online in August. We are happy to note that the online edition has gained excellent popularity among readers. It contains important TAA events such as Public Lectures by distinguished alumni, and also their life and work at TIFR.

We are happy to note that the TAA membership is increasing due to students' enrollment as TIFR deemed University is playing an important role in enhancing the future alumni. We also hope, the Newsletter would make a significant contribution in helping members to stay connected.



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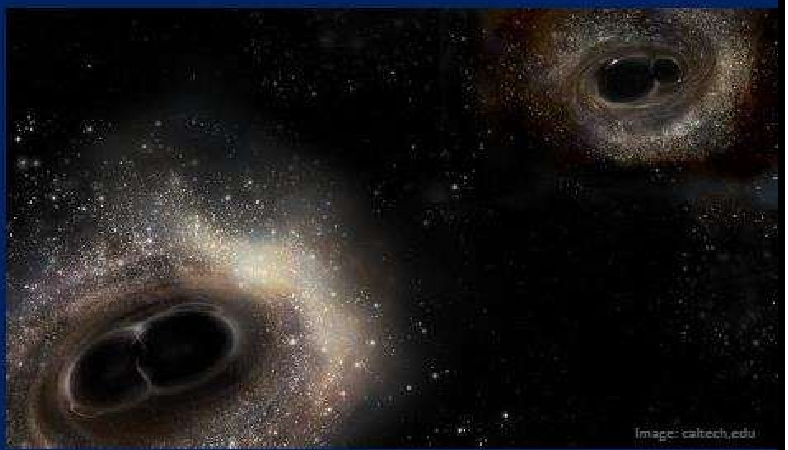
TAA PUBLIC LECTURES 2017

TAA NATIONAL SCIENCE DAY PUBLIC LECTURE
BY PROF. BALA IYER, ICTS, TIFR, BANGALORE.

TIFR ALUMNI ASSOCIATION
National Science Day Public Lecture

The top scientific breakthrough of 2016:
The detection of Gravitational Waves by LIGO
Prof. Bala Iyer, ICTS-TIFR

Bala Iyer, currently a Visiting Professor at ICTS-TIFR, Bengaluru, worked at the Raman Research Institute, Bengaluru during 1980-2014. Since 1990 he has worked on calculations of gravitational waves from binaries of neutron stars and black holes. He has been a Visiting Scientist in France, UK, Germany and the USA. He is a Fellow of American Physical Society and International Society on General Relativity and Gravitation.
He is the Chair of the IndIGO Consortium from its inception, Member of the Core team involved in the LIGO-India Proposal, and PI of IndIGO participation in the LIGO Scientific Collaboration (LSC). He is the Editor in Chief and Subject Editor on Gravitational Waves for the Online Journal `Living Reviews in General Relativity'. He actively participates in REAP (Research Education Advancement Program) at the Bengaluru planetarium for BSc students and public outreach activities on GW .



Predicted by Einstein a century ago, Gravitational Waves have eluded direct detection till recently. The first two detections of gravitational waves by Advanced LIGO in 2015 and the remarkable success in reconstructing the black hole binary source has been a long and fascinating journey pushing to limits both the experiment and the theory. The discovery is a sneak preview of what is possible in the coming decade with the new gravitational wave astronomy when LIGO-India joins the global gravitational wave detector network. This new window to the universe has implications for astrophysics, cosmology and fundamental physics. No wonder then that this figured as the top scientific breakthrough of 2016.

TAA PUBLIC LECTURES 2017

TAA JRD TATA PUBLIC LECTURE
BY PROF. AJAY SOOD, IISC, BANGALORE.

TIFR Alumni Association

TAA – JRD TATA PUBLIC LECTURE

Fun Science with Inanimate and Living Bacteria: Flocking and Nano Heat Engine

Prof Ajay Sood, Indian Institute of Science, Bengaluru

Thursday, August 3, 2017 at 5 p.m.

Lecture Theatre AG 66, Tata Institute of Fundamental Research

1 Homi Bhabha Road, Colaba, Mumbai 400005

This talk will bring out how nature inspires us to explore fascinating phenomena like flocking, a self-organized motion of vast numbers individuals of same species in a common direction is a common behavior in many animals like ants, locusts, birds, fishes etc. Flocks of birds flying every morning and evening or of ants crawling in one direction are a common sight. As physicists, we have tried to understand this beautiful phenomenon in the laboratory by working with inanimate polar granular objects made active by placing them on a rapidly vibrating surface amongst spherical beads. We discover that a small number of motile particles can coherently transport a large passive cargo which we suspect is potentially relevant to the understanding of flocking and other biological phenomena.

The conventional macroscopic heat engine, a device to convert thermal energy to mechanical energy, is a triumph of our understanding of classical thermodynamics over the last three centuries. In recent years, taking the heat engine concepts to microscopic scale, necessarily dominated by fluctuations, has led to the development of stochastic thermodynamics. In the second example, we show that a micrometer-sized active Stirling engine can be realized by periodically cycling a colloidal particle in a time-varying harmonic optical potential across bacterial baths at different activities Our experiments bring out a message towards the fundamental insights into the functioning of engines operating out of equilibrium.

Prof. Ajay Sood, FRS, is an Honorary Professor at Indian Institute of Science (IISc) and Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Bengaluru. He is a member of several science academies and has been bestowed with several honours and awards, some of which are - Fellow of the Royal Society, London (2015); Secretary General, The World Academy of Sciences (2013-2018); Shanti Swarup Bhatnagar Award in Physical Sciences (1990); TWAS Prize in Physics (2000).

TAA Aveek Guha Memorial Lecture

TATA INSTITUTE OF FUNDAMENTAL RESEARCH

Alumni Association

Dr. Viral Acharya obtained his B.Tech in Computer Science and Engineering from IIT Bombay in 2001 and PhD in Finance from the New York University Stern School of Business (NYU Stern). He is a Deputy Governor at the Reserve Bank of India (RBI) in charge of Monetary Policy, Financial Markets Operations and Regulation, Research and Statistics, and Human Resource Management. Prior to joining the RBI, he was the C V Starr Professor of Economics at the Department of Finance at New York University Stern School of Business. He has co-edited the books *Restoring Financial Stability: How to Repair a Failed System; The Dodd-Frank Act and the New Architecture of Global Finance; One Year On: NYU-Stern and CEPR*. He is also the co-author of the book *Guaranteed to Fail: Fannie Mae, Freddie Mac and the Debacle of Mortgage Finance*.

The First Aveek Guha Memorial Lecture

“Transmission of Monetary Policy in India: Why it matters and how it can be improved”

by Dr. Viral V. Acharya, Dy Governor, Reserve Bank of India

Thursday, November 16, 2017 at 5.15 p.m.
Homi Bhabha Auditorium
Tata Institute of Fundamental Research
1-Homi Bhabha Road, Navy Nagar, Mumbai 400005

Monetary Transmission in India:
Why is it important and why hasn’t it worked well?

Dr. Viral V Acharya, Deputy Governor, Reserve Bank of India

Inaugural Aveek Guha Memorial Lecture Thursday 16th November 2017

Homi Bhabha Auditorium, Tata Institute of Fundamental Research (TIFR)

When I travel from my residence in Vile Parle (W) to the Reserve Bank of India Central Office in Fort, I pass each way *Kenilworth* – the birth place of late Homi Jehangir Bhabha. It is a good way to start and end the day, being reminded not just of his immense intellect but also of his deep sense of service to India. I am thus grateful to Professor Dipan Ghosh, who was the Dean of Students during my time at IIT Bombay, for inviting me to speak today in the Homi Bhabha Auditorium, and to Dr Subhendu Guha, for having endowed this lecture series at the Tata Institute of Fundamental Research (TIFR) in memory of his dear son, Aveek Guha. “Aveek,” a beautiful Bengali name meaning “fearless”, is exactly how all research needs to be, taking on seemingly insurmountable challenges, fighting it out with grit, and along the way, dissecting, reflecting, and distilling truth to its essence until it is unearthed in some recognizable form from beneath its scratchy exterior. The TIFR is a daunting proposition for any researcher to speak at. I hope that I can progress some way towards meeting its highest standards in the form of this talk, by raising an issue that is germane to all of us in today’s forum and that is worthy of being tackled in due course – that of, *Monetary Transmission in India: Why is it important and why hasn’t it worked well?*

Let me start with some technical jargon and then explain from first principles the part of it I wish to focus on. With the amendment of the Reserve Bank of India Act in 2016, the “primary objective of the monetary policy is to maintain price stability while keeping in mind the objective of growth”. The Monetary Policy Committee (MPC) constituted under the amended RBI Act is mandated to determine the policy repo rate to achieve the specified medium-term inflation target of 4 per cent, within a band of +/- 2 per cent. For the Reserve Bank to achieve its mandate effectively, it is extremely important that an economic process referred to as “monetary transmission” works seamlessly. Any impediment to this process of monetary transmission hampers the achievement of our mandate. We, therefore, monitor and analyse monetary transmission on a regular basis, and undertake corrective steps to enhance its efficacy, if it seems broken or critically imperfect.

What is monetary transmission? It is essentially the process through which the policy action of the central bank is transmitted to the ultimate objective of stable inflation and growth. The policy action consists typically of changing the interest rate at which it borrows or lends “reserves” (in our case, Rupees) on an overnight basis with commercial banks. In other words, monetary transmission is the entire process starting from the change in the policy rate by the central bank to various money market rates such as inter-bank lending rates, to bank deposit rates, to bank lending rates to households and firms, to government and corporate bond yields, and to asset prices such as stock prices and house prices, culminating in its impact on inflation and growth. The transmission mechanism hinges crucially on how monetary policy changes influence households’ and firms’ behaviour. This change can take place through several channels. Studying these channels is a vast subject in finance and economics literature. Therefore, given the time constraint, I will only cover a few key aspects.

I will then explain how and why monetary transmission has, and more importantly, has *not*, worked in India, and touch also briefly upon how we could improve it.

Channels of Monetary Transmission:

Changes in the central bank's policy rate impact the economy with lags through a variety of channels, the primary ones being (i) *interest rate channel*, (ii) *credit channel*, (iii) *exchange rate channel*, and (iv) *asset price channel*.

Let us start with how the *interest rate channel* works. The immediate impact of a change in the monetary policy rate is on the short-term money market rates (such as call money rate, certificates of deposits, commercial papers, treasury bills), key financial markets (exchange rate, equity prices), and also on medium and long-term instruments (yields on dated government securities and corporate bonds). The impact is typically quick and broadly one-to-one from the policy rate to short-term money markets rates such as the call money rate which is the unsecured or uncollateralized inter-bank lending rate: A bank will be willing to part with its reserves overnight to another bank only if it earns at least the rate that it could earn by parking these funds with the central bank; and, if banks compete adequately for such lending, then the rate will in fact track closely the central bank's policy rate. The impact of the policy rate on other market rates varies across tenors and instruments depending upon the liquidity conditions and other factors such as how interest rates vary at different maturities.

In turn, the central bank's changes in its policy rate are expected to impact the banks' cost of funds, both the rates they would pay to depositors and the rates they would demand for making loans. For example, when a central bank reduces the policy repo rate with the intention to support aggregate demand in the economy, the expectation is that there would be a reduction in the banks' cost of funds and lending rates, and in the spectrum of market interest rates (and *vice versa* when the policy rate is increased). Lower lending interest rates of banks provide a boost to demand for bank credit from various segments of the society, for instance, from individuals and households for loans for consumer durables (such as automobiles) and for housing; and from entrepreneurs for new or increased investment in plant and machinery. An increased demand for automobiles, housing, and machinery generates increased demand for the inputs including labour in these industries, and hence, an increase in overall demand, incomes, and output in the economy. As this process continues, it eventually puts upward pressure on wages of labor and prices of inputs, and this way, raises inflation. A central bank mandated to maintain stable prices while taking account of growth thus faces a trade-off while lowering or raising its policy rate.

The implicit assumption here is that bank balance sheets are strong and in a position to step-up quickly the supply of credit in response to lower funding cost and higher demand for credit – the bank lending or the *credit channel* of transmission. Cross-country evidence indicates that monetary transmission is greatly hindered if bank balance sheets are weak in that they do not have much loss-absorption capacity to deal squarely with their problem loans – indeed, the evidence suggests that there might be ever-greening of bad loans, and increased 'zombie' lending, lending to distressed firms at subsidized rates to kick the can of loan defaults down the road, resulting in misallocation of resources, productivity losses and weak growth. This way, attempts to stimulate growth with aggressive policy rate cuts when there are bank balance-sheet problems get wasted and can even backfire in the form of mal-investments, creating false hopes of a growth boost and relaxing the pedal on deeper balance-sheet and structural reforms of the banking sector.[1] The effectiveness of this bank credit channel is a critical issue in the current juncture in India to which I will come back later.

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[1] Acharya, V.V., T. Eisert, C. Eufinger, and C.W. Hirsch (2016), '*Whatever it Takes: The Real Effects of Unconventional Monetary Policy*', Working Paper, New York University Stern School of Business.

Lower interest rates also boost asset prices such as housing and equity prices as these can now be purchased at cheaper borrowing costs. The resulting boost to household / corporate wealth and improved cash flows on the back of lower interest rates also add to the demand impulses. This is the asset price channel *of monetary transmission. Higher asset prices can enhance the value of the collateral or net worth of the borrowers, interacting with the bank lending or credit channel, enhancing the capacity to borrow more and at competitive rates, reinforcing the impulses to aggregate demand.*

Finally, lower domestic interest rates could lead to a depreciation of the domestic currency, on the one hand making exports more competitive in the global market and adding to domestic demand and economic activity, but on the other hand, could also have a direct upward impact on the domestic currency prices of imported inputs, making imports (for example, crude oil) costlier. This is the *exchange rate channel of transmission.*

All the channels that I have described above – the interest rate channel, the bank lending or credit channel, the asset price channel, and the exchange rate channel – are not stand alone channels; rather, these work at the same time, and may reinforce or interact with each other, so that their individual impact is difficult to disentangle. It also needs to be recognised that the transmission mechanism is complex. The speed and strength at which the central bank's policy rate changes travel to the rest of the economy could vary widely from country to country depending on the structure of the economy and the state of its financial system.

Monetary Policy Lags

The available empirical evidence for India suggests that monetary policy actions are felt with a lag of 2-3 quarters on output and with a lag of 3-4 quarters on inflation, and the impact persists for 8-12 quarters. Among the channels of transmission, the *interest rate channel* has been found to be the strongest.[2] Given that monetary policy impacts output and inflation with long (and often variable) lags, it is critical for monetary policy actions to be forward-looking, *i.e.,* monetary policy needs to respond to *expected* output and inflation developments. Of course, the expected evolution of output and inflation is uncertain, thereby rendering the transmission analysis even more challenging, adding to the complexity of the central bank's decision-making (and creating exciting opportunities for its critiques!). The key point is that if parts of the transmission machinery are broken, then monetary policy would be less effective.

Transmission from Policy Rate to Bank Lending Rates in India: Performance

The Indian financial system remains bank-dominated, though the share of non-bank finance companies (NBFCs) and markets (corporate bonds, commercial paper, equity, etc.) in overall financing of the economy is steadily rising. Hence, the overall efficacy of monetary transmission in India hinges critically on the extent and the pace with which banks, taking a cue from – and induced by – the changes in the policy repo rate, adjust their deposit and lending rates and meet adequately the economy's demand for credit. Overall, data suggests that the pass-through from policy rate changes to bank lending rates has been slow and muted. This lack of adequate monetary transmission remains a key policy concern for the Reserve Bank as it blunts the impact of its policy changes on economic activity and inflation.

[2] *Report of the Expert Committee to Revise and Strengthen the Monetary Policy Framework* (Chairman: Urjit R. Patel), 2014, Reserve Bank of India. The lags of 2-4 quarters that I just noted are the average lags over the sample periods of various studies, and the actual lags at any given point of time could be vastly different from these average lags, depending upon factors such as the stage of the domestic and the global business cycle, the domestic liquidity and financial conditions, the fiscal stance, the health of the domestic banking sector and the non-banking sector.

Since the deregulation of interest rates in the early 1990s, the Reserve Bank has made several attempts to improve the speed and extent of the monetary pass-through by refining the process of setting lending interest rates by banks, while at the same time imparting transparency to borrowers and flexibility to banks in the process of interest rate setting. We have transited from the *prime lending rate (PLR)* system (1994) to the *benchmark prime lending rate (BPLR)* system (2003), the *base rate* system (2010), and the present *marginal cost of funds based lending rate (MCLR)* system (2016). Let me explain these interest rate setting regimes briefly, before I turn to an assessment of the performance of the (legacy) Base Rate and (prevalent) MCLR systems.

In India, as in a number of other countries, a large proportion of loans is at floating rates, i.e., the interest rate charged to the borrower keeps changing depending on the reset periodicity. The floating rate is linked to some "benchmark rate" (which ideally varies over time in consonance with the changing macroeconomic and financial conditions and, in particular, the central bank's policy rate). Banks also charge a spread over the benchmark to factor in term premia and credit risk, among other factors. The actual lending rate is the benchmark plus the spread. The benchmark could be *internal* or *external*; an internal benchmark will be based on elements which are in part under the control of the bank such as cost of funds, while an external benchmark is outside the control of the bank (for example, it could be market determined rate such as Certificate of Deposit rate or Treasury Bill rate or Inter-Bank Offer Rate, or it could simply be the central bank's policy rate). The virtue of an external benchmark is that it is transparent, common across banks, and borrowers can compare various loan offers by simply comparing spreads over the benchmark (all else, such as maturity of the loan, being equal). As market rates normally move in line with the central bank's policy rate, an external benchmark is globally considered and adopted as more appropriate than an internal benchmark for transmitting monetary policy signals. In India, the Reserve Bank has provided the banks flexibility to use both the internal and external benchmarks, but the banks seem to have preferred internal benchmarks over external benchmarks on two key grounds: first, the internal benchmark reflects their cost of funds, and second, it has been perceived that there have not been until recently any robust and vibrant external benchmarks.

In October 1994, when the Reserve Bank deregulated lending rates for credit limits over ` 2 lakh, banks were required to declare their prime lending rates (PLR) - the interest rate charged for the most creditworthy borrowers - taking into account factors such as cost of funds and transaction costs. The PLR was, thus, expected to act as a floor for lending above ` 2 lakh. However, the experience with its working was not satisfactory mainly for two reasons: (i) both the PLR and the spread charged over the PLR varied widely, and inexplicably so, across banks; and perhaps more importantly, (ii) the PLRs of banks were rigid and inflexible in relation to the overall direction of interest rates in the economy.

In view of these concerns, the Reserve Bank advised banks in April 2003 to announce Benchmark PLRs (BPLRs), taking into account the cost of funds, operational costs, minimum margin to cover regulatory requirements (provisioning and capital charge), and profit margin. The BPLR system also fell short of its desired objective of enhancing transparency and serving as the reference rate for pricing of loan products, with a large part of the lending taking place at interest rates below the announced BPLRs. The share of sub-BPLR lending was as high as 77 per cent in September 2008, rendering it difficult to assess the transmission of policy rate changes of the Reserve Bank to lending rates of banks. The residential housing loans and the consumer durable loans were outside the purview of the BPLR. As such, sub-BPLR lending became a major distortion in terms of cross-subsidisation across borrower categories.

Next, the drawbacks of the BPLR system led to the introduction of the base rate system in July 2010. The base rate was also based, *inter alia*, on the costs of borrowed funds; an indicative formula for arriving at the base rate was also provided. The base rate was to be the minimum rate for all loans (except for some specified categories) with the actual lending rate charged to the borrowers being the base rate plus borrower-specific charge or spread. In practice, the flexibility accorded to banks in the determination of cost of funds – average, marginal or blended cost – caused opacity in the determination of lending rates by banks and clouded an accurate assessment of the speed and strength of the transmission. Moreover, banks often adjusted the spread over the base rate to benefit the new borrowers while leaving the transmission through the base rate weak for existing borrowers.

The weaknesses and rigidities observed with the transmission under the base rate system led to the present system, *i.e.,* the MCLR system effective April 1, 2016. With banks required to determine their benchmark lending rates taking into account the *marginal* cost of funds [unlike the base rate system where banks had the discretion to choose between the *average* cost or the marginal cost (or blended cost) of funds], lending rates were expected to be more sensitive to the changes in the policy rate under the MCLR system vis-à-vis its predecessor (the base rate). The actual lending rate is based on MCLR plus a spread (business strategy and credit risk premium). The base rate system was allowed to be in operation concomitantly for the loans already contracted, pending their maturity or a shift to the MCLR system at mutually agreeable terms between the bank and the borrower.

The expected benefits of the MCLR system – better transparency, more flexibility and faster transmission – have, however, continued to elude as documented in the Reserve Bank's recent study - "*Report of the Internal Study Group to Review the Working of the Marginal Cost of Funds Based Lending Rate System*" (Chairman: Dr. Janak Raj), the analysis wherein indicates that the transmission:

• has been *slow and incomplete* under both the base rate and the MCLR systems, although it has improved since November 2016 under the pressure of large surplus liquidity in the system post demonetisation (Table 1).

• was *significant on fresh loans, but muted for outstanding loans* (base rate and MCLR).

• was *uneven across borrowing categories*.

• was *asymmetric over monetary policy cycles – higher during the tightening phase and lower during the easing phase* – irrespective of the interest rate system.[3]

Transmission from Policy Rate to Bank Lending Rates: Some Issues

What explains the slow and incomplete pass-through from the policy rate changes to the lending rates? Two broad factors have dampened transmission to the lending rates.

First, a sizeable legacy loan portfolio of banks is still linked to the base rate (about 30 per cent of the outstanding bank loans). Lending rates under the base rate system are relatively stickier than the loans linked to MCLR. During the current easing cycle of monetary policy, as against 200 bps cumulative cut in the repo rate, the base rate has declined by about 80 bps. Since the introduction of the MCLR in April 2016, as against the cumulative cut in repo rate by 50 bps, the base rate has declined by just about 20 bps (Charts 1a and 1b). The Study Group's analysis suggested that banks deviated in an ad hoc manner from the specified methodologies for calculating the base rate and the MCLR to either inflate the base rate and MCLR or prevent the base rate and MCLR from falling in line with the cost of funds.[4]

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[3] For instance, the pass-through to outstanding loans from the repo rate was around 60 per cent during the tightening phase (July 2010 to March 2012), while it was less than 40 per cent during the subsequent easing phase (April 2012 to June 2013)

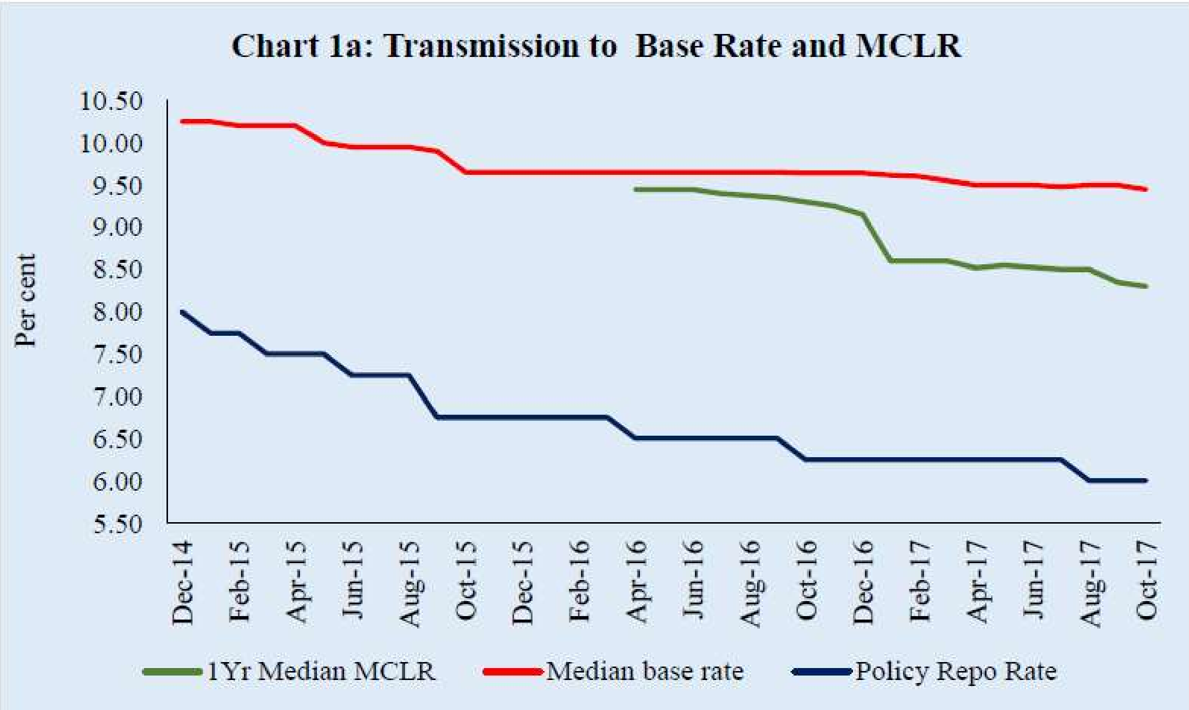
[4] The ad hoc adjustments included, inter alia, (i) inappropriate calculation of the cost of funds; (ii) no change in the base rate even as the cost of deposits declined significantly; (iii) sharp increase in the return on net worth out of tune with past track record or future prospects to offset the impact of reduction in the cost of deposits on the lending rate; and (iv) inclusion of new components in the base rate formula to adjust the rate to a desired level. The slow transmission to the base rate loan portfolio was further accentuated by the long (annual) reset periods.

Table 1: Transmission from the Policy Repo Rate to Banks' Deposit and Lending Rates

(Variation in percentage points)

Period	Repo Rate	Term Deposit Rates		Lending Rates			
		Median Term Deposit Rate	WADTDR	Median Base Rate	Median MCLR (1-year)	WALR - Outstanding Rupee Loans	WALR - Fresh Rupee Loans
October 2017 over end-December 2014	-2.00	-1.66	-1.99	-0.75	*	-1.39	-1.92
October 2017 over April 1, 2016	-0.75	-0.94	-1.08	-0.15	-1.15	-0.75	-0.94
Memo:							
Pre-Demonetisation							
January 2015 to October 2016	-1.75	-0.99	-1.26	-0.61	*	-0.75	-0.97
April 1, 2016 to October 2016	-0.50	-0.27	-0.35	-0.01	-0.15	-0.11	0.01
Post Demonetisation							
November 2016 to October 2017	-0.25	-0.67	-0.73	-0.14	-1.00	-0.64	-0.95

WADTDR: Weighted Average Domestic Term Deposit Rate.
WALR: Weighted Average Lending Rate.
MCLR: Marginal Cost of Funds based Lending Rate.
*: MCLR system was put in place in April 2016.
Latest data for WALRs and WADTDR pertain to September 2017.
Source: Reserve Bank of India.



Second, spreads charged by banks over MCLR were adjusted to offset the changes in MCLR, thereby impacting the overall reduction in lending rates. The spread over the MCLR could vary from bank to bank due to idiosyncratic factors. However, as the Study Group observed, banks adjusted the spread over the MCLR arbitrarily in several ways and the variations in the spreads across banks appeared too large to be explained based on bank-level business strategy and borrower-level credit risk.[5] The Study Group also observed that while the spread over the MCLR was expected to play only a small role in determining the lending rates by banks, it has turned out to be the key element in deciding the overall lending rates.

What explains the muted pass-through from policy rate to bank lending rates, either by banks not changing the benchmark rate or by adjusting the spread?

One plausible underlying reason is the rate rigidity on the liability side of banks caused by several factors. In India, about 90 per cent of total liabilities of banks are in the form of deposits. Bank deposits are predominantly at fixed interest rates, thereby imparting rigidity to the transmission process. Further, over 36 per cent of term deposits of banks have maturity of three years and above (Table-2), implying their rates get reset infrequently and with significant lags to policy rate changes. While the banks' marginal cost of funds may drop quickly with a cut in fresh deposit rates, the average cost of deposits comes down rather slowly, which weakens the transmission, especially in the case of the base rate system.

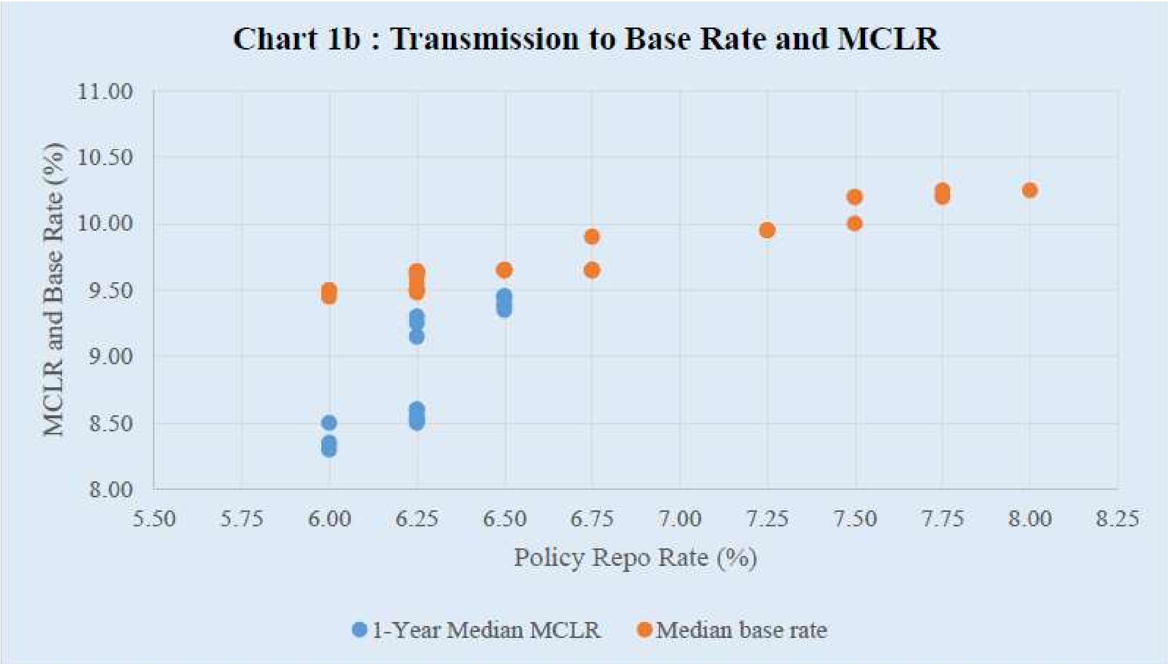


Table-2: Maturity Profile of term Deposits of Scheduled Commercial Banks

(% share in total Term Deposits)

End-March	Up to 90 days	91-days to 6 month	6-month to 1 year	1 year to 2 years	2 years to 3 years	3 years to 5 years	5 years and above
2005	13.9	10.5	15.0	23.4	10.7	18.1	8.4
2010	6.9	8.4	13.7	37.9	12.3	12.4	8.3
2015	7.5	4.1	12.6	40.4	10.1	11.4	13.9
2016	7.2	4.0	9.2	43.3	10.6	11.8	14.0

Source: Handbook of Statistics on the Indian Economy, RBI.

[5] For example, the Study Group found that: (i) large reduction in MCLR was partly offset by some banks by a simultaneous increase in the spread in the form of business strategy premium ostensibly to reduce the pass-through to lending rates; (ii) there was no documentation of the rationale for fixing business strategy premium for various sectors; (iii) many banks did not have a board approved policy for working out the components of spread charged to a customer; (iv) some banks did not have any methodology for computing the spread, which was merely treated as a residual arrived at by deducting the MCLR from the actual prevailing lending rate; and (v) the credit risk element was not applied based on the credit rating of the borrower concerned, but on the historically observed probability of default (PD) and loss given default (LGD) of the credit portfolio/sector concerned.

What is often not recognised is the large access our banks have to low cost Current and Savings Account (CASA) funds. CASA funds constitute about 40 per cent of aggregate bank deposits with the share of saving deposits at around 31 per cent. Importantly, banks are free to decide saving deposit interest rates since October 2011, but until recently, most of the banks chose to leave the saving deposit rate unchanged, ignoring completely monetary policy signals. For instance, the major banks kept their saving deposit rate unchanged at 4 per cent between October 2011 and July 2017, even as the Reserve Bank's policy rate moved significantly over this period from 8.5 per cent in October 2011 to 7.25 per cent in August 2013. It increased again to 8.0 per cent by January 2014, before declining to 6.0 per cent by August 2017.

Furthermore, the deterioration in banking sector health due to worsening of asset quality over the past 2-3 years and the expected loan losses in credit portfolios also seem to have induced large variability in spreads in the pricing of assets. With under-capitalized banks aiming to protect their net interest margins[6] (NIMs) – indeed, weak banks' NIMs have remained broadly unchanged in the face of large stressed assets – so as to maintain profitability in the short-term even at the expense of long-term profits as well as deposits and lending shares, the transmission to lending rates has been severely impacted. In effect, there has been a cross-subsidisation of corporate loan losses by lending rates in healthier sectors such as in retail.

Finally, the competition that banks face from alternative instruments of financial savings – such as mutual funds and small saving schemes – also seems to have made banks hesitant in varying the interest rates on term deposits in consonance with policy rate signals. Although bank deposits have some distinct advantages in the form of stable returns (*vis-à-vis* mutual fund schemes) and liquidity (*vis-à-vis* small saving schemes), bank deposits are in a disadvantageous position in terms of tax-adjusted returns in comparison with these schemes.

All of these factors have imparted rigidity to the liability side of banks' balance sheet with respect to policy rate changes, in turn inducing behaviour to make the rates on asset side of banks' balance sheet rigid too.

Improving Transmission: The Way Forward

Drawing from its comprehensive analysis, the RBI's Study Group has suggested a number of steps to enhance transparency and transmission from monetary policy signals to the actual lending rates. Their recommendations pertain to improving transmission based on the existing lending rate system as well as a fundamental reform of the interest rate setting process. Let me touch upon the four major recommendation by the Study Group.

In view of the less than desired transmission and transparency under the *internal* benchmark based lending rate systems – PLR, BPLR, base rate and MCLR – so far, the Study Group has recommended that there is need to shift to an *external* benchmark based lending rate system. The internal benchmark-based pricing regimes are not in sync with global practices on pricing of bank loans. Given the scope of arbitrariness under the MCLR system, the Study Group has recommended that the switchover to an external benchmark needs to be pursued in a time-bound manner. While recognising that no external instrument in India meets all the requirements of an ideal benchmark, and after analysing the pros and cons of 13 possible candidates, the Study Group has recommended that the Treasury Bill rate, the Certificate of Deposit (CD) rate, and the Reserve Bank of India's policy repo rate are better suited than other interest rates to serve the role of an external benchmark. The Study Group has recommended that all floating rate loans extended beginning April 1, 2018 could be referenced to one of the three external benchmarks selected by the Reserve Bank after receiving and evaluating the feedback from stakeholders.

[6] Net interest margin is defined as the difference between a bank's interest income (on its loans and assets) less its interest expenditure (on its deposits and other borrowings).

Second, the Study Group has recommended that the decision on the spread over the external benchmark could be left to the commercial judgment of banks, with the spread remaining fixed all through the term of the loan, unless there is a credit event (as per standardized or ex ante mutually agreed definition of "credit event").

Third, the periodicity of resetting the interest rates by banks on all floating rate loans, retail as well as corporate, be reduced from once in a year to once in a quarter to expedite the pass-through from the monetary policy signal to the actual lending rates.

Fourth, to reduce rigidity on liabilities side, banks be encouraged to accept deposits, especially bulk deposits, at floating rates linked directly to the selected external benchmark.

The common theme underlying these recommendations is to improve monetary transmission by ensuring that changes in the policy rate transmit quickly and adequately to banks' lending rates in a transparent manner without any cross-subsidisation and discrimination between existing and new borrowers. The idea is also to make banks' liability side more flexible so that the objectives of improving monetary transmission by the Reserve Bank and maintaining healthy net interest rate margins by banks are aligned.

The report of the Study Group, which was put in the public domain on October 4, 2017 has generated much interest and extensive feedback to the Reserve Bank from all stakeholders, not only banks, but also general public and media. We have received a number of useful suggestions and comments on the recommendations of the Study Group. These are being examined carefully and would help us to take a considered view, factoring in transition costs and providing a calibrated path to the desired benchmarking system.

Improving Monetary Transmission: Shoring up Bank Balance Sheets

As explained earlier, even as the Reserve Bank has reduced its policy repo rate by 50 bps since October 2016 and by a cumulative 200 bps since December 2014, the banking sector's credit growth has remained much muted. While weak demand for bank credit could be one of the factors leading to the observed slowdown in credit growth, a primary cause of the slowdown had also been the weak balance sheets of public sector banks in view of large. The dominance of the supply side factor has also been borne out by the fact that the credit growth of private sector banks (better asset quality and well-capitalised on average) remains robust, whereas there has been a sharp deceleration in the credit growth of public sector banks (especially the ones with high stressed assets). non-performing assets which seem to have made banks risk averse and induced them to reduce the supply of credit: under-capitalized banks have capital only to survive, not to grow[7].The dominance of the supply side factor has also been borne out by the fact that the credit growth of private sector banks (better asset quality and well-capital is on average) remains robust, whereas there has been a sharp deceleration in the credit growth of public sector banks (especially the ones with high stressed assets).

Against this backdrop, the enactment of the Insolvency and Bankruptcy Code (IBC) in December 2016, the promulgation of the Banking Regulation (Amendment) Ordinance 2017 (since notified as an Act), and the subsequent actions taken thereunder in the form of the Reserve Bank requiring banks refer the largest, material and aged non-performing assets (NPAs) to the IBC, have made the IBC a lynchpin of the new time-bound resolution framework for bank NPAs.

These initiatives will now be supported by the Government's decision to recapitalise public sector banks in a front-loaded manner, with a total allocation of Rs. 2.1 trillion, comprising budgetary provisions (Rs. 181 billion), recapitalisation bonds (Rs. 1.35 trillion), and raising

[7] Acharya, Viral V (2017), "The Unfinished Agenda: Restoring Public Sector Bank Health in India", 8th R K Talwar Memorial Lecture.

of capital by banks from the market while diluting government equity share (around Rs.580 billion).

The two steps together – asset resolution and bank recapitalisation – are expected to strengthen bank balance sheets significantly and improve banks' ability and willingness to lend at rates in consonance with policy rates and result in an improved monetary transmission.

Concluding Observations

In summary, efficient monetary transmission is a *sine qua non* for the successful pursuit of its objectives by any central bank. Over the past two decades, it has been the endeavour of the Reserve Bank to strengthen the monetary transmission process, but these efforts have yet not yielded the desired results. The transmission from the policy repo rate to bank lending rates, which is the dominant transmission channel in India, has remained a matter of concern. With the recent explicit objective of price stability mandated by the legislature, the issue of smooth monetary transmission has assumed an added significance.through market products such as interest-rate derivatives (swaps, in particular) and securitized products such as collateralized loan obligations (CLOs) will spring about, provided banks indeed have to manage the interest rate risk rather than have it as a matter of convenience to pass it onto borrowers.

Against this backdrop, we have recently put out a report by the Internal Study Group to address the weaknesses of the existing monetary transmission system. A key suggestion before us is to whether to shift the loan pricing system from an internal benchmark to an external benchmark. The Reserve Bank will take a considered view in the matter at an appropriate time.

In my view, there is a deeper economic issue at hand in the recommendation to move towards an external benchmark. The issue is: who should bear the interest rate risk in the economy – the borrower, or the depositor, or the bank? Who is likely to be better at managing the interest rate risk? Retail depositors and borrowers are unlikely to have efficient tools to manage the interest rate risk. Banks, however, should have the wherewithal to manage interest rate risk. Similarly, bulk depositors and large corporate borrowers can also be expected to be in a position to manage the interest rate risk. Non-bank financial institutions with less exposure to interest rate risk, such as insurance and pension funds, could also be good repositories of this risk. Foreign banks may be able to offset interest rate risk globally. A combination of interest-rate risk transfer mechanisms through market products such as interest-rate derivatives (swaps, in particular) and securitized products such as collateralized loan obligations (CLOs) will spring about, provided banks indeed have to manage the interest rate risk rather than have it as a matter of convenience to pass it onto borrowers.

Hopefully, I will focus sometime soon on these issues in a companion piece - *Monetary Transmission in India: How can it be improved?*

Photographs of the first Aveek Guha memorial lecture held on Nov, 16th 2017 at TIFR.

NOBEL PRIZE IN CHEMISTRY (2017): GIVING STRUCTURE TO SHAPELESS BLOBS (*WITH ANGSTROM RESOLUTION*)

Deepa Khushalani

Department of Chemical Sciences, TIFR

***Dr. Deepa Khushalani** is an Associate Professor at the Department of Chemical Sciences, TIFR. She did her BSc from the University of British Columbia, Canada in 1992 and Phd in 1997 from the University of Toronto. She was a post doctoral researcher in University of Toronto (1998) and University of Bristol, UK (1999-2000). From 2001 to 2003 she was a lecturer in Inorganic Materials Chemistry at the University of Kent at Canterbury, UK and thereafter joined TIFR as a faculty. She has won the DST (Nanomission) Young Career Award in Nanoscience and Technology in 2016 and the CRSI bronze medal in Chemistry in 2017. She is also the Fellow of the Royal Society of Chemistry (FRSC). Her research area lies in synthesis, characterization and application of a variety of inorganic structures such that (1) the morphology, phase, and size are carefully manipulated so that there is precise control over homogeneity and compositional purity, (2) the ensuing materials are applied in areas such as heterogeneous photocatalysis, biosensors, components in solar cells and in energy storage devices (such as batteries and supercapacitors) and also for drug delivery applications.*

She is also extensively involved in Science Outreach and actively promotes basic sciences within rural and economically deprived areas of India. She is involved in several workshops/lectures and mentoring sessions.

On October 4th 2017 the Nobel prize in Chemistry was announced by The Royal Swedish Academy of Sciences and it has been given to three male scientists working in three different institutes in the area of cryo-electron microscopy. They are Jacques Dubochet, Joachim Frank and Richard Henderson and the exact citation that was provided states that it is "*for developing cryo-electron microscopy for the high-resolution structure determination of biomolecules in solution*".[1]

It is an interesting observation to note that ever since the Nobel Prize awards were initiated in 1901, more than 21 Prizes in Chemistry (out of 109) have been awarded to a topic involving either structure determination, molecular structure elucidation or structure-property function. To elaborate, it can be stated that precise structure determination as a theme has been previously recognized by the academy and more importantly is continuing to do so. The academy is acknowledging the overwhelming notion that in Chemistry, determining the precise structure of any entity, be it of a small molecule (in solid, liquid or gas phase), peptide, protein, large mineral *etc*. are pivotal to the evolving the concepts of this fundamental science. Furthermore, it should also be noted that even though the prize has been given to “cryo-electron microscopy”, electron microscopy (EM) separately has already been awarded a Nobel Prize in 1986 (for Physics no less) to Ernst Ruska, Gerd Binnig and Heinrich Rohrer. Hence this makes this year's Nobel prize in Chemistry even more impressive as it suggests that the 'cryo' modification is a remarkable augmentation to the already established principle of EM that it needs to be recognized and appreciated separately, justifiably so if I might add.

Of the three scientists that have been noted for this impressive evolution of EM, the one that perhaps had the initial 'seed' idea is Richard Henderson who is currently the programme leader at Medical Research Council Lab of Molecular Biology, Cambridge. He has been a structural biologist for his entire career and initially started out using X-ray diffraction as the primary tool to solve the structures of biomolecules. Considering that for this technique, single crystals (preferably as large as possible) are mandatory, Prof. Henderson therefore spent a large part of his career post Phd in trying to grow single crystals of a variety of proteins. In the mid- 1970's, it has been stated that he got 'frustrated' with the constant preparation of large crystals as this was a very tedious process and more importantly did not allow the molecule to be investigated in its native environment. He was interested in solving the structure of a trans-membrane protein, namely Bacteriorhodopsin which, once removed from the membrane, rapidly unfolded thereby preventing crystallization. Mainly because of this problem, he chanced upon the seminal concept of evaluating the protein *while it was still embedded in the membrane*. Moreover, he was able to align a thin, protein loaded, membrane such that the protein molecules were at right angles to the electron beam thereby allowing ease of elucidation of the structure using *in situ* electron diffraction. He published the results of this work in 1975[2] and the structure had been elucidated up to 7 Å resolution which was the state-of-art at the time. This was seminal as it allowed electron microscopy to be used for more than just imaging and provided a route to structure elucidation of biomolecules in their native state.

The next pioneer contributor to cryo-electron microscopy is Jacques Dubochet who is currently Honorary Professor of Biophysics at University of Lausanne. His contribution was crucial to this technique as his discovery led to the principles from which the structure of all biomolecules can now be elucidated regardless of the native environment in which they are present. His discovery allowed the retention of the "hydration shell" of water molecules surrounding biomolecules such as proteins as it is crucial to the molecule's structure and motion.[3] Even though EM is done under vacuum conditions, Jacques's contribution allowed the biomolecules to be frozen rapidly, thereby preventing any form of denaturation to occur such that upon cooling the sample, the evaporation rate of water becomes negligible, and rapid freezing, at ideally a rate of 104 to 106 K/sec, prevents ice crystals from forming. This is the most crucial aspect and to achieve such rapid cooling, the sample cannot be simply plunged into liquid nitrogen. This process does not always freeze the specimen fast enough since at liquid N2 temperature, N2 actually boils and so the Leidenfrost effect occurs readily and ice crystals form.[4] However if first the specimen is plunged rapidly into liquid propane or ethane (ethane has been found to be more efficient), then the sample is cooled very close to the *melting* point of the liquid and so rapid cooling is more favourably observed and the sample then is found to be suspended in an amorphous ice matrix.

Finally, the last contributor that is being cited is Joachim Frank who is currently a Professor of Biochemistry and Molecular Biophysics and of Biological Sciences at Columbia University. He succeeded in developing a strategy that could calculate a three-dimensional image of the structure from a large number of two-dimensional high-resolution images of a SINGLE particle in an electron microscope.[4] To elaborate, in EM, the images are 2D projections of 3D structures. As such, in terms of generating a complete 3D structure it is imperative to collect many thousands of images of single particles at various tilt angles and then subsequently compile them using a variety of algorithms that allow the back-calculation of the 3D structure using FFT reconstruction. He was the first to develop the principles that allow the back-calculation of the 3D structure from the simple 2D projections by just using the intensity of the images as the paramount input to determine location and type of atoms constituting the single particle. His conceptual framework, although specifically centred around ribosomal structure, has now been extended to many other biomolecules.

In conclusion, it needs to be highlighted that currently there are three main techniques that are the most sought after for structure determination – X-ray diffraction, NMR and now Cryo Electron Microscopy. Although there are positive attributes to each technique, the main advantages that cryo-EM provides is now it is possible to get the structure of especially biomolecules in their *chemically active, native environment*. No longer is there any need to isolate the molecule and perfectly crystalize it (which XRD requires), no longer is it necessary that the molecule be soluble and in high concentrations (which NMR requires) and more importantly, no longer is it necessary to take the moiety out of its biologically or chemically active environment in order to study it. Cryo-EM has allowed scientists the flexibility to be able to, in principle, get the structure of molecules (e.g. proteins) that are undergoing dynamic alteration during a chemical reaction and be able to 'freeze' these intermediate stages and be able to study their structure at an angstrom level! This latter aspect is perhaps the most attractive property of cryo-EM and opening new frontiers for chemists and biologists.

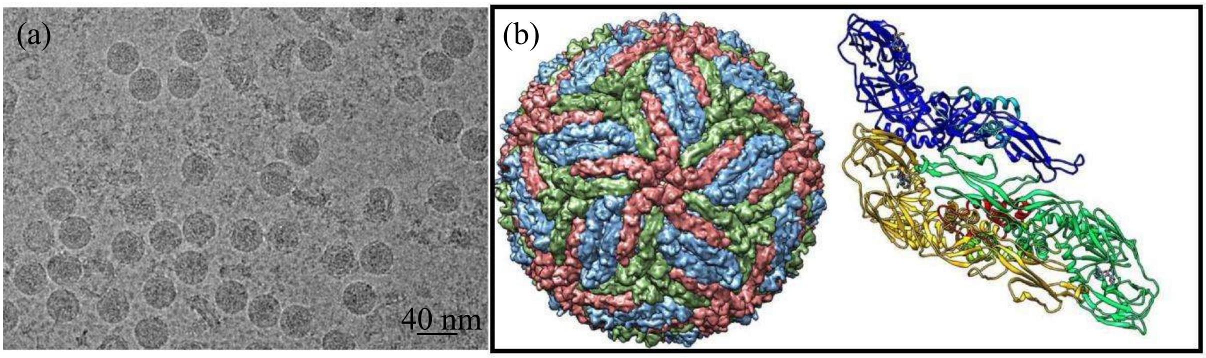


Figure 1. (a) Cryo-EM raw data of Zika Virus and (b) Virus Structure and Asymmetric Unit resolved at 3.8 Å resolution with Cryo EM using the raw data. This is being highlighted here for two reasons – A few years ago, when the Zika virus received large media attention due to its ill-effects as such, in the desire to find a vaccine for this virus, the structure needed to be solved and it was done so rapidly using the path-breaking technique of cryo-EM. The work was published in *Science* in 2016 and most importantly, for TAA readers, it is to be noted the first author of this work is an ex-TIFR student from DBS.[6]

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Nobel Prize in Physics (2017): The era of multi-messenger astronomy

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Abstract: *With several compact binary merger events being detected by LIGO-Virgo detectors since the first observational run of LIGO in 2015, the field of gravitational wave astronomy is rapidly evolving with new excitement of resolving older puzzles and posing new questions. To add to this excitement, this year's Nobel Prize in Physics isawarded to the pioneers of LIGO and for the first binary black hole merger discovery. The article talks about new LIGO-Virgo detections and the contribution of Nobel Laureats to this few decade long quest of gravitational waves.*

Keywords

Gravitational Waves-LIGO-Astronomy

Archana Pai did her PhD at Inter-Unievrsity Center of Astronomy and Astronomy at Pune in the field of Gravitational Wave Detection. Subsequently she was a Henri-Poincare Fellow at Observatoire de la Cote d'Azur, INFN Fellow at Lass Sapienza, Rome and post-doctoral position in Albert Einstein Institute, Germany and she has worked with various gravitational wave experiments. She is a member of LIGO Scientific Collaboration [1] and IndIGO consortium [2]. Her group works on developing detection schemes for compact binaries and with multiple detectors and astrophysical parameter estimation of gravitational wave sources.

Nobel Prize in Physics for the year 2017

On October 3rd, 2017, the Secretary General of the Royal Swedish Academy of Sciences, Professor Goran K. Hansson, announced the Nobel Prize in Physics as 'This year's prize is about the discovery which shook the world!' It was a moment to celebrate. The 2017 Nobel Prize is announced to the three pioneers of the field of gravitational wave research – Rainer Weiss, Massachussets Institute of Technology, Kip S. Thorne, California Institute of Technology, and Barry Barish from California Institute of Technology (Fig. 1) dividing one half of the prize to Weiss and rest amongst Thorne and Barish. The prize was awarded for the decisive contribution to the LIGO detector and observations of gravitational waves.

1. Nature of Gravitational Waves

Gravitational waves (GW) are ripples of space-time fabric which travel at the speed of light. According to general theory of relativity, any dynamic motion with non-spherical kinetic energy emits gravitational waves. For example orbiting, smashing, accreting objects, all of them produce gravitational waves. Unlike electromagnetic waves (with leading order dipolar in nature), the leading order contribution of gravitational waves is quadrupolar in nature. The source of EM waves are due to oscillating charges (hence due to microscopic motions) while sources of GW are due to dynamical systems with non-spherical kinetic energy (macroscopic bulk motion). The EM waves get absorbed and scattered, GW interact weakly with matter and hence are unaltered except (1=r) reduction in amplitude. Due to this property, it can unravel regions which are otherwise not accessible to EM waves such as dynamics in violent phenomenon like supernova explosion, binary star mergers, black hole (BH) dynamics etc. However, the flipside is that because of this weak interaction, it is very difficult to detect gravitational waves. Colloquilly, it is said that our space-time fabric is highly stiff and requires large amount of energy to stretch it. The strength of the gravitational waves in radiation zone is given by quadrupole formula as [3]

Figure 1. Rainer Weiss (Left most), born in 1932 in Berlin,Germany. Ph.D. 1962 from Massachusetts Institute of Technology, Professor of Physics, Massachusetts Institute of Technology, USA. Kip Thorne (Right most) is born 1940 in Logan, USA. Ph.D. 1965 from Princeton University. Feynman Professor of Theoretical Physics, California Institute of Technology. Barry Barish (Middle), born 1936 in Omaha, USA. Ph.D. 1962 from University of California,Berkeley. Linde Professor of Physics, California Institute of Technology

$$h \sim \frac{2\,G}{r\,c^4}\frac{d^2I}{dt^2} < \frac{2\,GM}{Rc^2}\frac{G\,M}{rc^2} \sim \alpha\frac{G\,M}{rc^2}$$

where I denotes the quadrupole moment of a given mass distribution and r is the distance to the source. The quantity $\alpha = 2GM/Rc^2$ is known as the compactness parameter (The M and R are the mass and the size of the system respectively.) The upper bound is obtained assuming virial theorem for gravitating bodies. It is clear from this expression that at a fixed distance, more compact system emits stronger gravitational waves. For example, consider a rod of one kg and length of one meter spinning with frequency of 10 cycles per second located on Moon. The gravitational wave amplitude from this rod will be of the order of 10^{-49} which will produce equivalent strain of that order on Earth! However, a binary system with two neutron stars (NS) located as far as 100 Mpc with orbital separation of 200km will emit gravitational waves of 10^{-23}. Thus, compact objects with NS and BH produce measurable GW.

2. Road to LIGO

The initial attempts to detect gravitational waves in 1960s were made by Joseph Weber using the metal bar detector [4]. In 1969, Weber announced the detection of gravitational waves with the aluminium bar. The idea was that the bar will resonate when the frequency of the incoming gravitational waves is close to its resonant frequency. Though the announcement created a lot of excitement, it was clear that the instrument did not have enough sensitivity to be able to detect gravitational waves from our galaxy. Though the claim was refuted, that triggered experimental efforts to detect gravitational waves. In 1957, in the coonference at Chappel Hill, Felix Pirani showed with a calculation that 'Observer by using light signal can determine coordinates of the neighbouring free test object'[6]. Young Rainer Weiss was excited with this idea and immediately thought that laser interferometers with mirrors as test masses (suspended mirrors are free masses) to detect gravitational waves. In 1972, he made detailed study and design of the suspended interferometer (see Fig. 2) which can act as gravitational wave antenna [5]. He did detailed calculations of the primary noise sources which can affect the performance of the instrument. They include laser frequency noise, seismic noise, thermal noise, radiation pressure noise, shot noise, gravity gradient noise etc and the concept of LIGO (Laser Interferometric Gravitational Wave Observatory) was born! This was the first detailed design of suspended interferometer to be used as a gravitational wave detector with its noise budget! Several novel ideas were explored on the prototypes by groups at Glasgow by Ronald Drever and Brian Meers, and the Garching group in late 1970's and 80's. In 1968, Kip Thorne started a new theoretical group that focused on astrophysics of gravitational wave sources especially for LIGO. In late seventies, he triggered an experimental group at Caltech and appointed Ronald Drever and Stan Whitecomb. Drever brought in a large number of sophisticated advanced schemes in the LIGO design which includes frequency stabilization scheme known as Pound-Drever-Hall scheme[8].

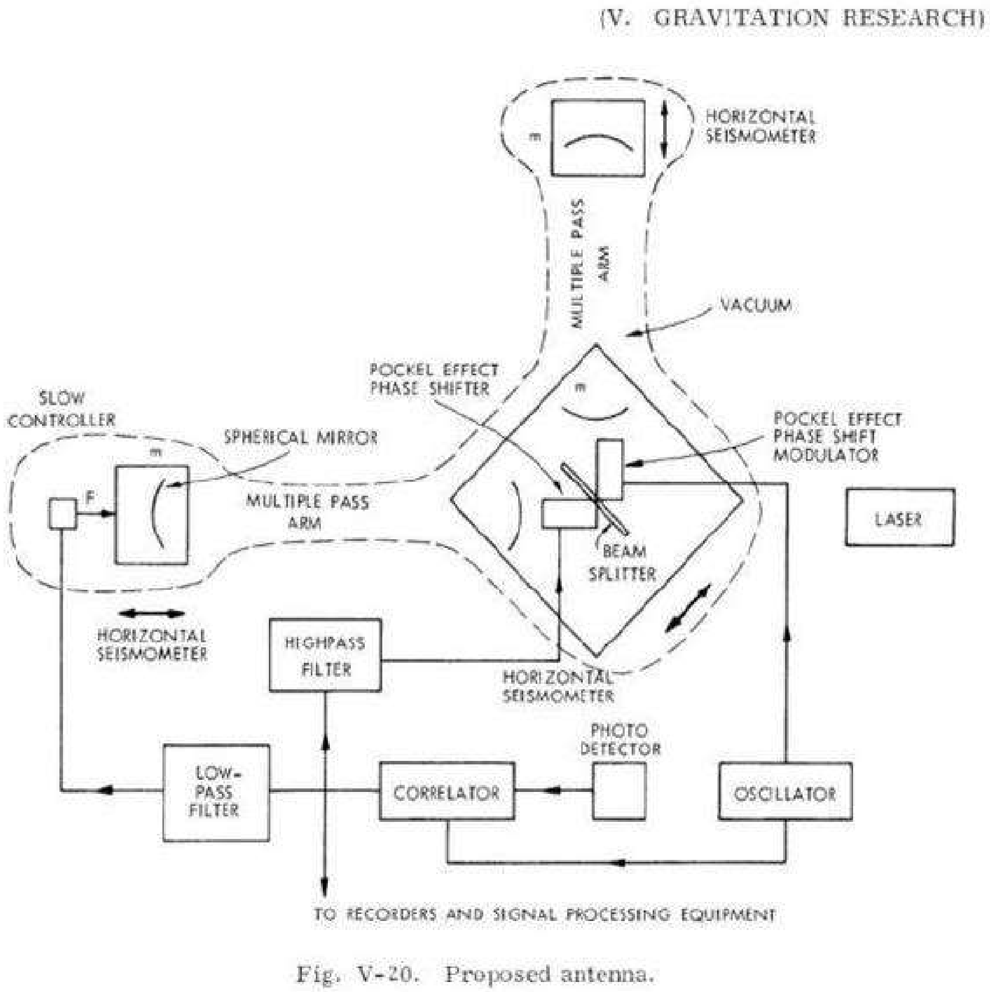

Figure 2. Rainer Weiss's design of suspended interferometer with Fabry Perot cavities as a gravitational wave detector [5]

[8] Ronald William Prest Drever (1931 – 2017) was a Scottish experimental physicist. He was a professor emeritus at the California Institute of Technology, co-founded the LIGO project, and was a co-inventor of the Pound–Drever–Hall technique for laser stabilization. This work was instrumental in the first detection of gravitational waves in September 2015. Source: LIGO news (url:http://www.caltech.edu/news/caltech-mourns-passing-ligo co-founder-ronald-w-drever-54336)

Further, with the Russian collaborator Vladimir Braginsky[9] Thorne's group recognized that the massive mirrors will act as a macroscopic quantum systems. Together Caltech and MIT put up a joint proposal for building the km arm-length suspended Michelson interferometer with optical cavities in the year 1989 [7] In the meanwhile, the astrophysical relativity group under Thorne set out to develop gravitational wave sources of LIGO. The primary sources identified for LIGO were categorized into bursts (merger of compact binaries with NS and BH, core collapse supernovae, accreting systems), periodic sources like rotating NS and stochastic background of GW from early universe. The study to develop the waveforms from these astrophysical sources was initiated. The classic reviews by Thorne contains more details [8] and [9].

In the year 1994, the construction of LIGO started at two sites namely Hanford, Washington and Livingston, Louisiana in USA and Barry Barish was appointed as a LIGO director. With his administrative expertise, and leadership qualities the LIGO project took off and went through phases of construction, installation and commissioning phase. He was the director between 1994 till 2006. The initial LIGO carried out six engineering runs between 2002 to 2006 which achieved the sensitivity level from h $3x10^{-21}$ to $3x10^{-23}$ per sqrt.Hz (See Figure 3).

The clear demonstration of achieving the target sensitivity of the initial LIGO respecting the initially estimated time-line was impressive. In fact, in some frequencies, the initial LIGO was performing better than the designed sensitivity! With this achievement, the project got approval for the advanced LIGO. The advanced LIGO is designed to improve the floor sensitivity over initial LIGO by a factor of 10 which translates into additional distance reach by a factor of 10 and in volume by 1000.

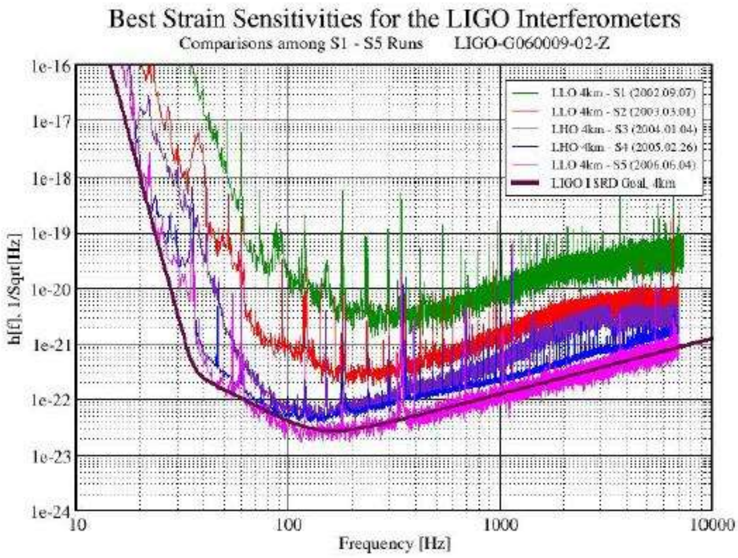

Figure 3. LIGO Science Runs: Improvement in sensitivity from science run 1 to science run 5. The solid curve represents the target sensitivity for initial LIGO. Credit:LIGO

3. First binary BH detection and more

In 1997, Barish conceived and led a crucial change in LIGO's organization by splitting into two: (1) The LIGO Laboratory at Caltech, MIT, Hanford and Livingston, responsible for LIGO operations and advanced interferometer research and development, and (2) the LIGO Scientific Collaboration, responsible for organizing and coordinating LIGO's technical and scientific research and data analysis, and for expanding LIGO to include scientists elsewhere. On 2015, just before the start of the first observation run, the LSC plus the Virgo collaboration was expanded to nearly 16 countries and more than 1000 scientists.

On September 14, 2015, the first binary black hole merger event was observed in both LIGO detectors aka GW150914. After several months of rigorous data analysis, the detection was announced to the world by LIGO-Virgo Scientific Collaboration on February 11, 2016

[9] Vladimir Borisovich Braginsky (3 August 1931 – 29 March 2016) worked in the areas of precision and quantum measurements, the detection of gravitational waves, systems with low dissipation, and fundamental thermodynamic fluctuations. Source: LIGO webpage (url:https://www.ligo.caltech.edu/news/ligo20160426)

[10].The event was an inspiraling of two compact BHs located at 1.3 billion light years away which merged in to a single BH. The two LIGO detectors observed the GW emitted from this system in its last fraction of a second of its life. As both the objects inspiral, the system emits gravitational waves bringing the two objects closer and thus emitting stronger and higher frequency gravitational waves. This is termed as a binary chirp signal. The observational features of this event were discussed in earlier issue of Physics News.

The detection of GW150914 was historic in many ways. It was the first binary black hole merger event observed by the terrestrial detectors. It gave a clear evidence of existence of BH greater than $25M_{sun}$. Till then, no candidate BH showed evidence of existence of masses above $25M_{sun}$. For the first time, using data from GW150914, the General theory of relativity was tested in strong regime and was shown to be consistent with Einstein's GR [11].

So far, LIGO detectors have conducted two observational runs. The first observational run; O1 was between September 2015-January 2016 and the second run; O2 was between

Event	Type	Detectors	Binary Masses in ($M_\odot$)	Remnant Mass in ($M_\odot$)	Distance in 10^6 light yrs.	Sky Location (deg.^{2})	Energy released in $M_\odot c^2$	Signal duration in seconds
GW150914[10]	BBH	LH	$\sim(36,29)$	~ 62	1300	600	2.5-3.5	0.2
GW151226[12]	BBH	LH	$\sim(14,7)$	~ 21	1400	850	0.8-1.1	1
GW170104[13]	BBH	LH	$\sim(31,19)$	~ 49	$1600-4300$	1200	1.3-2.6	0.25 - 0.31
GW170814[14]	BBH	LHV	$\sim(31,25)$	~ 53	$1100-1200$	60	2.4-3.1	0.26-0.28
GW170817[15]	BNS	LHV	$\sim(1.6,1.1)$	?	85-160	28	> 0.025	60

Table 1. Summary of all the GW detections so far. The name of the binary merger event is based on the date when the event is observed in the detectors i.e. in year-month-date format. BBH is binary black hole and BNS is binary neutron star. L, H and V stands for LIGO-Livingston, LIGO-Hanford and Virgo detector respectively. More details about the

November 2016 – August 2017. The European French-Italian 3 km arm length Virgo detector joined the LIGO O2 run and made joint observations. Together in O1 and O2, LIGO Virgo detectors have made four confirmed binary black hole merger events and one binary NS merger event. The table 1summarizes the LIGO-Virgo detections in terms of masses, detectors, distances, energy released etc.

Figure 4 shows the masses of stellar remnant measured both in EM window as well as GW window (by LIGO-Virgo detectors). In EM window, BH mass is estimated using X-ray and via accretion mechanism whereas rotating NS aka pulsars and emit in radio window. From this figure it is clear that using LIGO-Virgo observations, we are able to detect massive stellar BHs in binary systems and typically not found in the X-ray band.

Table 1 clearly shows that as expected from Eq.(1) that massive binaries will be able to detect much farther in the universe. The sky location column shows importance of multiple detectors in a

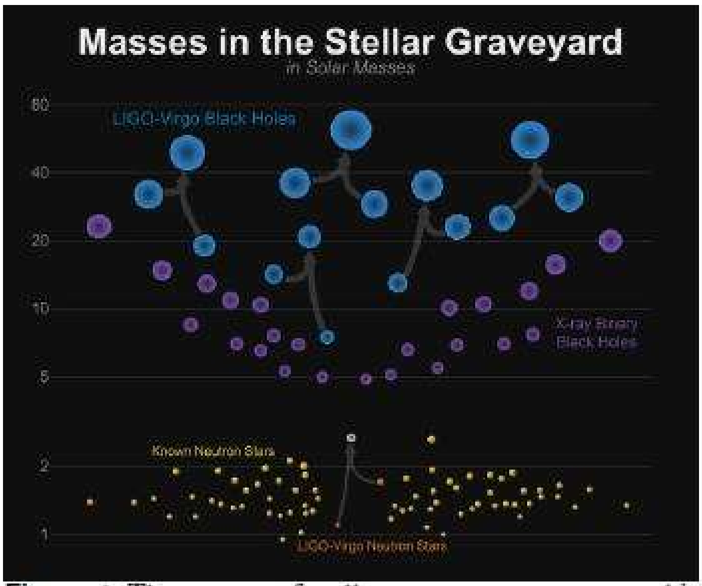

Figure 4. The masses of stellar remnants are measured in many different ways. This graphic shows the masses for black holes detected through electromagnetic observations (purple); the black holes measured by gravitational-wave observations (blue); neutron stars measured with electromagnetic observations (yellow); and the masses of the neutron stars that merged in an event called GW170817, which were detected in gravitational waves (orange). The remnant of GW170817 is unclassified, and labeled as a question mark. Credit: LIGO-Virgo/Frank Elavsky/Northwestern University

network. Using Virgo, the localization of GW170814 could be improved dramatically. Please note that the huge sky patch of 600 square degrees for GW150914 reduces to 60 sq. degrees for GW170814. Adding spatially separated interferometers improves the sky localisation immensely due to triangulation.
Using the BBH detections of LIGO-Virgo, Einstein's general theory of relativity was tested and was found to be consistent with the data. Additional tests such as Lorentz violation test as well as speed of gravitational waves was performed and obtained bounds on the same. No deviations from Einstein's GR is observed [14].

4. BNS detection opens up multi-messenger era

On August 17, 2017 at 12:41:04 UTC, the LIGO-Virgo gravitational wave detectors observed a gravitational wave chirp signal from the inspiral of two neutron stars [15].
Binary NS are known to be promising sources of GW and hence the detection of GW170817 itself was not a surprise. The scientists were expecting such an event in the advanced LIGO era. To recall, the most famous observation of Hulse-Taylor binary pulsar by radio astronomers for past few decades had provided indirect evidence of gravitational wave emission from such system. PSR1913+16 was first system of its kind and Hulse-Taylor duo received Nobel Prize for the year 1993[16]. Astronomers did find a dozen binary pulsars. However, this was the first binary NS merger event observed so far!
This event was special because just 1.7 seconds after the arrivel of the binary chirp, a gamma-ray burst known as GRB170817A of duration 2 sec. was detected by NASA's Fermi-GBM(Gamma ray Burst Monitor) satellite. The joint detection of this event in GW plus the gamma ray window marked the first GW multi-messenger discovery. This triggered a massive campaign to follow-up this event in the electromagnetic window over weeks that followed the event.
Within few hours, the Swope telescope located in Chile identified an optical transient (SSS17a) in the galaxy NGC 4993. Over the next two weeks, a network of ground-based telescopes and space-based observatories followed up the initial detections, spanning the entire EM spectrum right from ultraviolet (UV), optical (O), and near infrared (IR) wavelengths [17]. These observations carefully monitored the spectral energy distribution, revealing that this exceptional electromagnetic counterpart was a kilonova. The first detection of a kilonova was in 2013, in association with the short-duration GRB 130603B, where the faint infrared emission was observed by Hubble Space Telescope [18]. The joint observation of GW170817 showed a clear evidence supporting the idea that kilonovae result from the radioactive decay of the heavy elements formed by neutron capture during a BNS merger.
The discovery of BNS merger was another landmark historical event in the field of gravitational wave astronomy. Not only it is the first event of joint observation in GW and EM window but the observational data laid rest to some of the long standing puzzles about our universe. The joint observation of BNS merger and associated short GRB gives first evidence of the long standing puzzle of short GRB progenitors [19]. Gamma ray bursts are one of the most energetic events observed in Nature. They typically emit 1050 ergs per sec amount of energy. This is equivalent to amount of energy released by Sun throughout its 10 billion-year life span. They occur once a day and from any point in the sky. Based on the duration of the bursts, they are divided in to short GRB (less than 2 sec) and long GRBs (greater than 2 sec.) Long GRBs are caused by the core-collapse of rapidly rotating massive stars. Till August 17, 2017, astrophysists thought BNS or NSBH mergeres are plausible progenitors of short GRBs. The joint observation of GW170817 and GRB170817A gave clear evidence on this possibility.
The multi-messenger astronomy paper was a joint publication of LIGO-Virgo Scientific Collaboration and astronomers from various groups of observatories as well as collaborations.

In total, there are ~3000 scientists have authored the historic publication which marks the era of multi-messenger astronomy!

5. Indian contribution

The LIGO Scientific Collaboration and Virgo Collaboration now has 17 countries and more than 1000 scientists. The Indian participation in the LIGO Scientific Collaboration, under the umbrella of the Indian Initiative in Gravitational-WaveObservations (IndIGO), involves scientists from all over India. The recent detections have authors from - CMI Chennai, ICTS-TIFR Bengaluru, IISER-Kolkata, IISER-Trivandrum, IIT Bombay, IIT Chennai, IIT Gandhinagar, IIT Hyderabad, IPR Gandhinagar, IUCAA Pune, RRCAT Indore, TIFR Mumbai, and UIAR.

In 2009, IndIGO consortium was formed by a group of researchers with expertise in theoretical and experimental gravity, cosmology and optical metrology – keen to promote gravitational wave research in the country. The consortium pursued the dream of realizing an advanced GW detector in India - the LIGO-India project. The LIGO-India is a joint US-Indian gravitational wave detector project to set up an advanced LIGO detector in India. The nodal institutes are IUCAA, Pune, IPR, Gandhinagar and RRCAT, Indore. The details can be found at http://www.gw.iucaa.in/ligo-india/.

Indian groups within LVC collaboration have contributed to understanding the response of the detector to the terrestrial influences, bounding the orbital eccentricity, estimating the mass and spin of the final black hole and the energy and power radiated during merger, confirming that the observed signal agrees with Einstein's General Theory of Relativity, testing Lorentz invariance using the GW data, developing data analysis algorithms for compact binaries as well as stochastic background signals. In addition, in the BNS discovery, Indian astronomers were involved in the electromagnetic follow-up of the BNS event using AstroSat as well as GMRT (Giant Meter Radio Telescope). The group was also involved in extracting physics out of the joint observation and improving the source localization.

6. Conclusions

The GW detections of BBH as well as BNS merger events opens up a brand new era of multi-messenger astronomy. We expect that in the third observational run scheduled to start in 2018, the detectors will observe 8 times more volume in the sky and hence more number of events. Soon BBH and BNS detections will become a routine and can answer questions regarding the population of binary BH systems, mass distribution of BHs, equation of state of NS etc. Within a decade we expect the Japanese detector KAGRA and LIGO India will join the network. With more detectors especially located in different continents, we will be able to localize the source more accurately as well as probe much deeper in the universe. We have more open questions such as do NSBH binaries exists in our universe? Do intermediate mass BHs exists? How many are they? How are they formed? With new observations, new challenges will be faced and new questions to be answered in this era of multi-messenger astronomy.

7. Acknowledgement

This document has LIGO Document No LIGO-P1700402.

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In Memorium- *Prof. R. R. Simha (1937-2017)*

Professor Roddam Raya Simha was born on 3 December, 1937. He passed away in Bengaluru on September 30, 2017. It was quite unexpected for all who knew Simha to be quite healthy. Simha joined the School of Mathematics of TIFR on 25 July, 1958, and retired after almost thirty nine and a half years of very valuable service. Simha's main areas of interest were complex analysis of both one and several variables and complex analytic varieties. Necessarily for this he was an expert in other branches of analysis as well. In fact, he was very broad in his interests and knowledge of other branches of mathematics like Algebraic Geometry, Topology, Lie Groups.

In his research, he proved many important results like deformations of varieties of general type, set of critical values of holomorphic maps, Siu's characterization of domains of holomorphy, varieties biholomorphic to C X C*, hyperbolic complex spaces, simpler proofs of important theorems like Behnke--Stein theorem for Riemann surfaces, Uniformization Theorem for planar domains, etc.

Simha had a very good intuitive understanding of a lot of mathematics. His questions during colloquiums on wide range of topics made this amply clear. Simha's lectures were very clear, and he had a beautiful cursive handwriting.

During his career Simha was a Visiting Professor in many institutes and universities in Germany, U.S. and Canada, etc. After retirement from TIFR he taught for many years in the Mumbai University and the CEBS. He was very generous: Answering many a mathematics question by putting in a lot of time, effort and his wide knowledge.

Simha was a polyglot. In addition to his native Kannada he knew other Indian languages like Hindi, Marathi, Bengali, Sanskrit, Tamil, Telugu, Urdu, and several foreign languages like German, French, Russian, Spanish. Simha's excellent translation of Juergen Jost's book Riemann Surfaces from German to English was highly praised by the author himself.

Simha was very musical. As one of his friends said Simha had an extremely sharp sense of pitch. Simha is survived by his wife Dr. Mangala Simha and two daughters Gauri and Meera.

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In Memorium- ***Prof. R. G. Lagu (-2017)***

Dr. Raghunath Gopal Lagu joined the Tata Institute of Fundamental Research in 1957. He received a doctorate in Physics from the University of Poona for thesis titled "Positronium Lifetimes in Some Molecular Media" (1974). He was one of the founder members of the Homi Bhabha Centre for Science Education (HBCSE), Mumbai which began as a unit of the TIFR in 1974. He along with Prof's. B. M. Udgoankar and V. G. Kulkarni was instrumental in chalking out the road map for HBCSE. In the initial phases of the development of HBCSE, Dr. Lagu along with other HBCSE colleagues was involved in conducting rural education programmes at Khiroda near Jalgaon aimed at capacity building of rural school science teachers. One of the aims of this engagement was the development of school science experiments and demonstrations for students and teachers that could be conducted with the help of locally available resources and materials.

Dr. Lagu was a prolific writer and was instrumental in giving a boost to the materials development effort at HBCSE. Many of the early books of HBCSE for children were either authored, co-authored or edited by Dr. Lagu. These books published by Oxford University Press ran into a number of editions and were translated into many Indian languages. Some of these books are:

- Novel Experiments, Lagu, R. G., and Mhetre, S. B. (1977);
- Experiments are fun, Lagu, R. G. (Eds.) (1984);
- How and Why in Science: Junior Series Book 1, Lagu, R. G. (Eds.) (1981);
- How and Why in Science: Junior Series Book 2, Lagu, R. G. (Eds.) (1981);
- How and Why in Science: Senior Series Book 1, Lagu, R. G. (Eds., 1982);
- How and Why in Science: Senior Series Book 2, Lagu, R. G. (Eds.,1982);
- Ganitachya Gujagoshti, Lagu, R.G., and Tarey, D.T. (1987);
- Khudkan Hasu, Granthghar, Lagu, R.G. (1985).

According to Prof. Arvind Kumar (*ex*-Centre Director of HBCSE) these books for children were perhaps among the best of their kind written in our country (Reference: Current Science, http://www.currentscience.ac.in/Volumes/108/03/0445.pdf). Two of these books, were awarded the 'Haribhau Motey Award' in 1986 (R. G. Lagu and S. B. Mhetre, for "Abhinav Prayog" in Marathi) and 1988 (R. G. Lagu and D. T. Tarey for "Gunitachya Gujagoshti" in Marathi). All the books mentioned above have had a vast reach in sales figures and have contributed a great deal to popularising science and mathematics in the country. These books written in the late 70's and 80's are still popular and have greatly added to the prestige and recognizability of HBCSE. The Marathi version of "How and Why in

Science” named “Kuthoohal” has received the Maharashtra Rajya Wangmay Puraskar 1982-83 under the category general knowledge/hobbies and science (August 1985). Dr Lagu was also associated with Marathi Vidnyan Parishad, Granthali, National School of Banking, and Krishnamurti Foundation of India and was fond of cricket and music. I hope that Dr. Lagu's contributions to science education in India and the legacy of his writings continue to enlighten the generations to come.

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In Memorium- *Prof. S. Srinivasan (-2017)*

TIFR Alumni Association regrets to announce the sad demise of Dr. S. Srinivasan (fondly known to the TIFR community as Cheeni) in Chennai. He passed away 15 Dec morning following a heart attack in Chennai. He joined Theoretical Physics Group as a PhD student in 1974 and worked under the guidance of Prof. S.S Jha.

Post Ph. D., he was briefly working on project mode for the Indian Institute of Geomagnetism (IIG), then at Colaba, Mumbai. Having got into writing software, he was associated with the Indian Institute of Bank Management (IIBM), Pune, again on a software-related project. Later, he moved to New Delhi Delhi on a UNDP-sponsored project called Technology Information Pilot System (TIPS) being implemented by the Department of Science and Technology (DST). He got completely involved in software development and moved to Chennai to be associated with the Free and Open-source Software (FOSS) development projects at Anna University and later at C-DAC, Chennai.

He is survived by his wife Vidya and sister.

In memorium- **Prof. Yash pal (1926-2017)**

Prof. Yash Pal, cosmic ray physicist, space scientist, science communicator, and philosopher of education, passed away on 24 July 2017 at Noida (near Delhi) at the ripe age of 90. His coming of age coincided with India's independence so that his life is a chronicle of a new nation's achievements and aspirations, and towards the end disappointment over decreasing respect for, and interest in, science.

Early life[i]

Yash Pal was born on 26 November1926 to Lakshmi Devi and Ram Piyare Lal at Jhang (now in Punjab, Pakistan). His father was employed in the ordinance department of the defense ministry where he rose to be ordnance officer civilian; he retired in 1958.

Yash Pal's early schooling was in Quetta in Baluchistan where he remained till 1939 He passed the matriculation examination in 1942 from Jabalpur, and Intermediate from Government College Lyallpur in 1945, taking three years instead of two because of interruption caused by illness. Here, he met his future wife Nirmal Sharma who was an arts student. They would marry in 1953. Yash Pal enrolled at the prestigious Government College Lahore for B.Sc. Honours School in Physics. In this system, the bachelor's degree was awarded three years after Intermediate. M.Sc. Honours School degree, by dissertation, would then be just a year away. Yash's studies however were interrupted by the Partition that took place on 15 August 1947.

In the meantime, early 1947, Yash Pal's father had been transferred to Delhi, where he stayed in the Mess while his family remained in Lahore for the sake of children's education. He brought his family to Delhi in June 1947 which thus was spared the suffering that befell many who came later.

Lahore was the main centre of education in Punjab. Its loss caused institutional disruption that had to be immediately addressed. Physics and chemistry departments were temporarily housed in Delhi University. The arrangement lasted from September 1947 till 30 April 1949 after which the departments wereshifted to Government College Hoshiarpur. Yash Pal passed his B.Sc. Honours School in Physics in 1948 and enrolled for MSc. According to family sources, he used to travel sporadically from Delhi to Hoshiarpur for attending classes.

Career as a Researcher

When still a student of M.Sc., Yash Pal was selected as a research assistant at the recently established Tata Institute of Fundamental Research Bombay (TIFR) with Homi Bhabha at the helm. He formally obtained the University degree by submitting a dissertation from Bombay. Regrettably, but not surprisingly, neither a copy of the dissertation not any documentation of the University's action on it seems to have survived.

According to Yash Pal, when he joined TIFR, he went in kurta and jeans. A very senior person told him one day that he should not come to the institute in an informal dress as Dr. Bhabha did not like it. He retorted: 'My letter of appointment does not mention any dress code.' And that was the end of the controversy. 'Dr. Bhabha never raised any objections thereafter.'[ii]

An event of great importance in the early TIFR's scientific and cultural history was the arrival of Poland-born Bernard Peters already well-known as an uncommonly gifted cosmic ray physicist. Victim of McCarthyism in USA, Peters first came to TIFR on a four-month visit late 1950 on behalf of the University of Rochester. He returned to TIFR as a professor at the end of 1951 and remained here till his departure in 1959 for Neils Bohr Institute in Copenhagen. He remained in touch with his Indian colleagues even after leaving India and was honoured with the award of Padma Bhushan in 1985. Under his stewardship, the nuclear emulsion group became very productive and renowned. But Peters' influence on the work culture was far more significant. Being an outsider, he could undermine class, cultural, and linguistic differences. He chaired the all-important meeting of the board that interviewed candidates for selection as research scholars. He established close relation with each of his younger colleagues; respected individual opinions; encouraged open discussions, team work, and cooperation among groups. In 1953, Devendra Lal (another young researcher), Yash Pal, and Peters published a well-regarded paper in the prestigious *Physical Review*. Two things happened immediately. He was appointed to the faculty the same year, and he got married to his lady love (as already noted).

In 1954, he was deputed to Massachusetts Institute of Technology to do Ph.D. under the guidance of Bruno Rossi. On return in 1958, Yash Pal assembled a number of bright young scholars around him and brought out the best in them individually and collectively.[iii]

Space Scientist

Prof. Yash Pal's active research career came to an end in 1973 when he was appointed director of the newly opened Space Application Centre Ahmedabad. The appointment was made by the ISRO chairman Satish Dhawan at the instance of TIFR director M. G. K. Menon.[iv]

Yash Pal's own internationally respected credentials as a research scientist; felicity with instrumentation; his ability to enthuse and persuade people, Indira Gandhi downwards; his benevolent nature; his informal manner; and innate love for teaching; and commitment to nation building all combined to make the educational TV program a spectacular success.

His work on space application was nationally and internationally recognized. He was awarded Padma Bhushan in 1976, and the International Marconi Prize in 1980 for his 'wise and humane leadership in applying modern communications technology to meet the needs of isolated rural villagers in India'. He remained in office at SAC till 1981. He next served as the Secretary General of the Second United Nations Conference on Peaceful Uses of Outer Space, better known as UNISPACE82 (1981–82). He returned to TIFR from where he retired in 1983.

He was successively Chief Consultant, Planning Commission (1983-84); Secretary, Department of Science &Technology (1984-86); and Chairman, University Grants Commission (1986-91). Later he held Jawaharlal Nehru Chair in Technology, Panjab University (1997-1999).

Science Communication
In 1987 Government of India's National Council for Science and Technology funded an ambitious project for a 13-part TV serial called *Bharat ek Chhap*, on the history of science and technology on the Indian subcontinent. Yash Pal acted as an advisor for it. His next involvement was more direct. In the TV programme The Turning Point, whose telecast began in 1991, Yash Pal regularly explained complex scientific phenomena and also took up questions sent by viewers which he answered in simple language. The programme was sponsored by Doordarshan and received full cooperation from government agencies because of association of Yash Pal. A number of production houses were involved who all worked in a spirit of healthy competition. A total of about 150 episodes were telecast. Then in 1997 or 1998, Doordarshan withdrew its sponsorship and wanted the producers to find private backers. This did not quite work out and the once popular programme fizzled out.[v] The moral of the story is that the state should not abdicate its responsibility in the vital areas of science education and science communication.

In 2009, he was awarded UNESCO Kalinga Prize for Science Popularization, 'For his contribution to science communication in various forms over the decades'. As a fitting recognition of his contribution to various fields connected with science and education, he was awarded Padma Vibhushan in 2013.

A great man's life is greater than the biographical details. Yash Pal belonged to an era when nation building occupied top most place in individual and collective agendas and science was seen as the chief instrument of nation building and economic growth. Ironically today while the society's dependence on gadgetry is increasing sharply, respect for principles of science is decreasing even more sharply. Real tribute to Prof Yash Pal will not be to name a building after him or to institute an award or a lecture or a medal after him, but to revive national interest in and curiosity about science.

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[ii] Gauhar Raza: https://www.newslaundry.com/2017/07/26/yash-pal-obituary
[iii] For details of Yash Pal's scientific work see Cowsik, R. (2015) Yash Pal. Current Science 109(1):202-208; Cowsik, R. (2017) Yash Pal (1926-2017) Current Science 113(4): 804-807.
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[V] I thank Indraneel Kaul for useful conversations. His father Arun Kaul was one of the producers of The Turning Point and Indraneel was his assistant.

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AWARDS and HONOURS

The Homi Bhabha Award for Science Education has been made possible by an endowment from Prof Brij Arora, an Alumni of TIFR. The term science education will embrace mathematics, education, technology and related areas. Contribution to science education will be viewed in a broad and eclectic manner and the work may involve research or contributions to contemporary scholarship in popularizing science at the grassroots level. **Prof. Vivek Monetiro** is the recipient of the award this year.

Shri Ramakrishna Cowsik Medal and Smt. Saraswathi Cowsik Medal have been made possible by an endowment from Prof. Ramnath Cowsik, an alumni of TIFR. The medals are to be awarded to a member of TIFR - visiting, regular or otherwise - for his/her contribution to an outstanding paper in any field published in the three years prior to the award. This year, the recipients of the awards are:

Shri Ramakrishna Cowsik : Mr. Abhirup Ghosh (ICTS, Bangalore)
Smt. Saraswathi Cowsik: Dr. John Mathew (DCMP&MS, Mumbai)

TAA Excellence in Teaching Award was given to **Prof. Jaikumar Radhakrishnan** from the Department of Computer Science.

Best Thesis Awards
The Geeta Udgaonkar Award started in 1983 by an endowment by Prof. B. M. Udgaonkar, in memory of his daughter, Late Geeta Udgaonkar, in the year 1983. Initially the award was for the best Ph. D. thesis in Physics only. The Endowment Committee initiated the nucleation of the TIFR Alumni Association (TAA). One of the aims of TAA is to constructively involve the Alumni of TIFR in the activity of raising Endowments. TAA took the initiative to institute two new additional Best Ph.D Thesis Awards on the lines of the well-recognised TAA-Geeta Udgaonkar Award for best thesis in the school of Natural Sciences. In addition to the support received from the members of the TAA, the core amounts have been made available to the Endowment fund by the family members of the distinguished mathematician late Prof. Harish-Chandra and family member and colleagues of late Dr. Zita Lobo , a member of the Department of Biological Sciences at TIFR. Prof.Harish-Chandra had worked with Dr. Homi Bhabha during the formative years of the TIFR, before moving on to the Institute of Advanced Study, Princeton, U. S. A. The TAA-Zita Lobo Memorial Award is for the best Ph.D thesis in Biological / Chemical sciences and The TAA Harish-Chandra Memorial Award is for that in Mathematics and Computer Sciences.

Awards and Honors :

TAA best thesis awards 2016-2017

Name of the Award: TAA-Geeta Udgaonkar
Recipient : Dr. Joe Philip Ninan
Name of the Guide: Prof. D. K. Ojha

Honorable mention:
Recipient : Dr. Om Prakash
Name of the Guide: Prof. S. Ramakrishnan

Name of the Award: TAA – Zita Lobo Memorial Award
Recipient : Dr. Pankaj Dubey
Name of the Guide: Prof. Krishanu Ray

Honorable mention:
Recipient : Dr. Hemanth Giri Rao Vantharam
Name of the Guide: Prof. S. Gosavi

Name of the Award: TAA-Sasken Best Thesis Award
Recipient : Dr. Gugan Thoppe
Name of the Guide: Dr. V. S. Borkar
Jointly to:
Recipient : Dr. Swagato Sanyal
Name of the Guide: Prof. Prahladh Harsha

Name of the Award: TAA Harish Chandra Memorial Award
Recipient : Dr. Debabrata Karmakar
Name of the Guide: Professor Adimurthi and Professor Sandeep Kunnath.
Jointly to:
Recipient : Dr. Charanya Ravi
Name of the Guide: Prof. A. Krishna

Awards and Honors (Others)

Prof. D. Narasimha
Has been confirmed the title of "Best Scientist" of the year 2017 by the South Indian ASDF Awards (SIAA) 2017 Committee.

Prof.Pankaj Joshi
Awarded the first "Prof. A.R.Rao Research Award (2016)" by the Prof. A.R.Rao Foundation, Ahmedabad.

Prof. Prahladh Harsha
Awarded the "Swarna Jayanti Fellowship", by the Department of Science & Technology (DST).

Prof. R V Hosur
Elected as the Fellow of the "International Society for Magnetic Resonance (ISMAR)".

Prof. Arnab Bhattacharya
Awarded the "Indira Gandhi Prize for Popularization of Science (2017)" by the "Indian National Science Academy".

TAA Executive Committee 2016-2019

⇒ Patron	Prof. Sandip Trivedi (Director TIFR)
⇒ President	Prof. Dipan Ghosh
⇒ Vice-President	Prof. B.S. Acharya
⇒ Secretary :	Prof. G. Ravindra Kumar
⇒ Treasurer :	Dr. Kallol Mukerjee
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