DIGITAL AGE

Collected and edited by Prof. Zvi Kam,
Weizmann Institute, Israel

21st CENTURY CHALLENGES

Environmental sciences – consumable and sustainable energies,
clean energies (solar, wind, geothermal), air pollution and global warming
Biological diversity and extinction of species.
Medicine – life quality and life span, aging, cure to diseases, infections and
bacterial antibiotic resistance, virus caused epidemies and vaccines
personalized (precision) medicine, genes repair,
stem cells and organ replacement
Robotics, artificial intelligence - replacement to human labor and decision making
Big data – storing, retrieving and analysis. Privacy.
Computer technology - faster, larger memory, computer-human interface
Nanotechnology and application in material sciences, medicine and computers
Life in space

21st CENTURY NOTABLE EVENTS

2001 The first draft of the human genom sequence
2001 Keneth Matsumura apply self-curing materials for organ recovery
2002 **James Thomson** "reverse differentiation": convert skin cells into stem cells
2003 **Gregoiri Perelman** Proved Poincare's conjecture
2006 **Shinya Yamanaka** cloned stem cells from skin cells
2010 **J. Craig Venter Institute** synthesized bacteria genome
2010 Genetic prove for mating between neanderthal and nonAfrican man
2012 The predicted Higgs boson discovered in CERN
2012 Photonic molecules discovered in MIT
2014 Exotic hadrons discovered in CERN large hadron collider
2015 Discovered Kepler438b a star with properties similar to earth
2015 Water traces on Mars
Experiments give hope for quantum computers breaking light speed of information transfer
2016 LIGO crew detected gravitation waves from two circling black holes
2017 10 planets at many light year distances identified with potential to have life

21st CENTURY DEVELOPEMENTS

Artificial heart, gut imaging via a small pill, robotic limbs controlled by body nerves, implanted retina to recover vision.

Personalized genetic sequencing at $100, CRISP-Cas to edit and repair genes

Electric cars, fuel cells, autonomous car driving

Self Learning programs, Deep learning from big data bases, Artificial Intelligence (AI), computers play games (Chess- deep blue, Go).

Humanized computer-user interfaces (e.g. Siri)

Operating systems for computers, cellphone, tablets etc. Expert systems.

Wider band Cellular networks (5G). Optical fiber and free space communication.

Communication and social networks (Skype, Facebook, YouTube, Tinder, TicTac, …)

Virtual reality, 3D motion tracking (Google glass, Kinect3D, …) computer games

Web brausers

Faster computers, quantum computers, highly parallelized processors, (e.g. GPU).

Detectors (optical, radar, magnetic, lasers, imaging detectors) and applications in computerized systems

Lab on a chip for home medical diagnostics (microfluidics, …)

Solar cells, wind generators, geothermal generators.

TRENDS AND SEARCHES

New methods for oil and gas drilling and retrieval (deep undersee, shales oil, …)
Is lower gas prices good or bad?

Increasing salary gaps in capitalism and concentration of wealth, vs. degradation of communism – what is the preferred economic system?

Governmental regulation, welfare and economic security net, health systems: what is the best model

Increasing polarity and extremism – reasons and results.

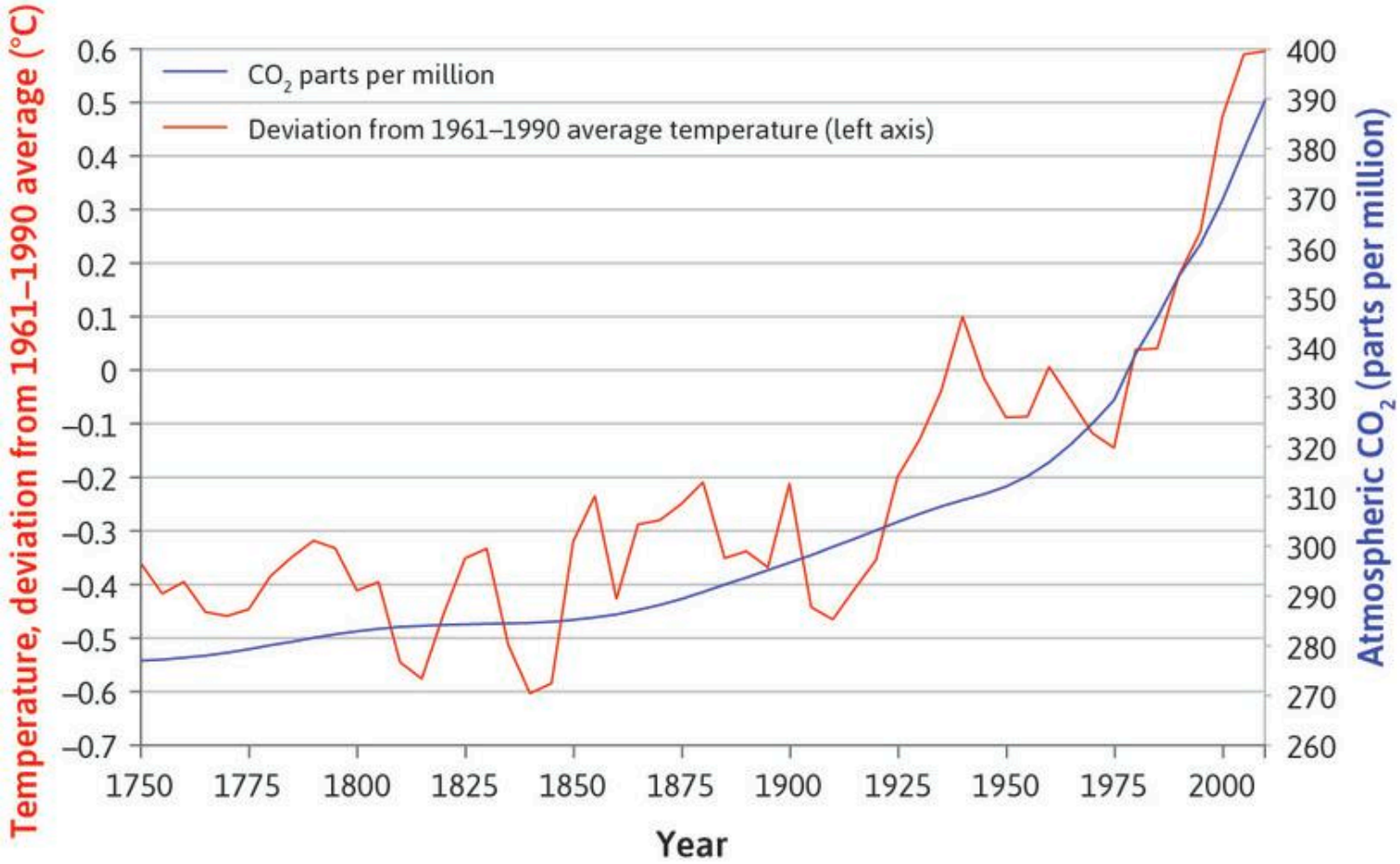
How to recruit technology development for better human life quality. Despite expectations, atomic energy did not free us from exhausting remains of energies accumulated during half a million years, modern medicine fail to cure increasing number of cancer patients in our polluted environment, excess use of antibiotics for humans and live stock for meat industry promote expansion of resistive traits at a pace that is faster than invention of new antibiotics, virus caused epidemics catch us unready without vaccines, despite extended life span, there is grossly failure to prevent or cure aging related diseases, making quality of life for the elderly fragile.

The global economy and good transportation induce fast development of weak economies with cheep labor costs, but turn the strong economies to service based societies.

And most importantly, technological development did not prevent wars, and increased the pressures in modern life. Maybe the fast spread of virtual reality gadgets serve to replace the unrewarding real world…

The expansion of agricultural products for animal feeding and energy (alcohol from cord) drive cutting of the tropical Amazon forestry causing less CO_2 absorption, and destruction of life diversity. This is instead of paying tropical countries to preserve their forests.

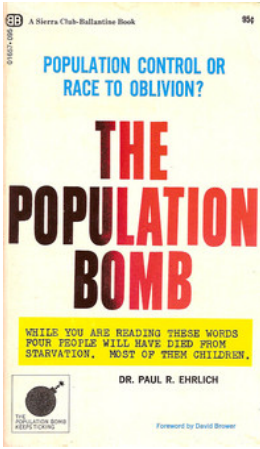
Atmospheric CO_2 increased from 0.028% to 0.04& and at the same rate will reach in the next decades 0.06% . A direct relation between global warming and CO_2 levels is displayed below:



RESEARCH AREAS

Editing genes in stem cells (e.g. Gero Huetter)
Single cell gene sequencing, for cancer mutations not common to healthy body cells.
Stem cell for organ recovery, blood cell treatments and more.
Molecular biology, biodiversity, space biosphere
Human microbiome – role of bacteria in our body
Environmental monitoring technologies
Environmentally safer batteries, energy storage methods (raise water, pressured air).
Technologies to harvest solar energy – efficient and cheep solar cells, catalytic hydrogen generation from water.
New materials: carbon fiber, carbon nanotubes, complex alloys,
Unification of all physical theories: superstrings ?
Cybernetic (Norbert Wiener), cyberspace, virtual worlds, artificial lives, cellular automata
Adaptive and self learning computerized systems. Fuzzy logics.
Weather forecast predicting hurricanes and earthquakes.
Faster and highly parallel computing, Teraflop processors.
Analysis & characterization of complex systems: chaos, fractals, punctuated equilibrium.
Earth-like life in other stars – via search for water, oxygen and carbon dioxide.
Possible other forms of “life” (defined by self reproduction).
Fertilizers to increase agricultural production without accumulative damage to soil
Genetic improvement of produce reduce diversity increase fragility.
Economic theories do not give answers to many problems.
Energy from controlled nuclear fission. Supervise or stop nuclear weapon proliferation.

EARTYH ECOLOGY



Human population exponential growth in the third world.
Start of 19th century: Thomas Maltus: resources only grow linearly, therefore our environment will collapse.
1968 Paul Ehrlich published "The Population Bomb"
1972 Meadows published "Limitation of Growth" – dynamic simulations
2009 Rockström, **2015 Steffen** "Limitations of our planet" discussing atmosphere chemistry, climate, resources, ecological systems, biological diversity, chemistry of ocean acidity and sweat water reservoirs, soil pollution by fertilization.
40% of land is cultivated.
The only valid solution: balance usage and renewal.
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SOCIAL INEQUALITY

Gatherers and hunters society was probably equalitarian and democratic (at least between females). Agriculture separated between farmers and rullers. Administration of tax collection and policing army created myths of godly kings and religions.

The industrial revolution exploited illegally workers, but unions in urban areas created political power to workers and welfare rights. At the beginning of the 20th century workers voted for left-wing parties, and rich supported right-wing. But post-materialistic society raised left-wing support among rich and well to do intellectuals. Workers turned right due to cultural factors (sectorialism, religion and emigration).

Globalization destabilized workers power, and the information revolution gave birth to the winning few and increased inequality between rich and most citizens in developed countries, while decreasing the inequality towards the third world. China and India close the gap, mainly due to good education, but not Africa.

Agricultural workers decreased from 55% of the population at 1850 to 2% at 1980. Industial workers increased from 15% to 25%. Decreased need due to robotics was balanced by increasing need in service workers, today 80%. Hi-Tech professions are expected to expand and pull economies, but today it is still small, and service workers without education stabilized. Increase in national produce does not reflect increasing salaries of service worker (gardeners, waiters, nannies, supermarket workers and cashiers), not even of professionals (doctors, lawyers, engineers and scientists), but meteoric increase in salary and benefits of managing layer, that increase from 20 to 300 times the average salary. The capitalistic “classical” excuse of “market forces” collapses facing the frustrated population majority and the resulted loss of motivation.

The main problem in making changes is the split ideas and wide variability of proposals carried by the left-wing politicians: Taxation of rich, deeper regularization, religion and education, privatization of national resources, health system and welfare.

The world war caused more equalitarian policies and social commitment, and mainly the understanding that poverty is not the individual to be blamed, and especially not his children. Thus health and education should be available to all. But the fall of communism strengthen extreme capitalistic policies. ”Equal opportunities” that lie at the basis of capitalism and generate the economic motivation, is replaced by preferred opportunities to powerful companies and their managing layer, and hindered rights to emigrators, the main driving force of economies now replaced by “outsourcing” labor to the third world.

The problematics in establishing “ideal” political system is the high complexity of a world where countries do not fully control their economy, and citizens cannot fully understand the huge amount of data and news, often badly distorted (“fake news”), and polarized so that the social media one is exposed to does not reflect balanced information.

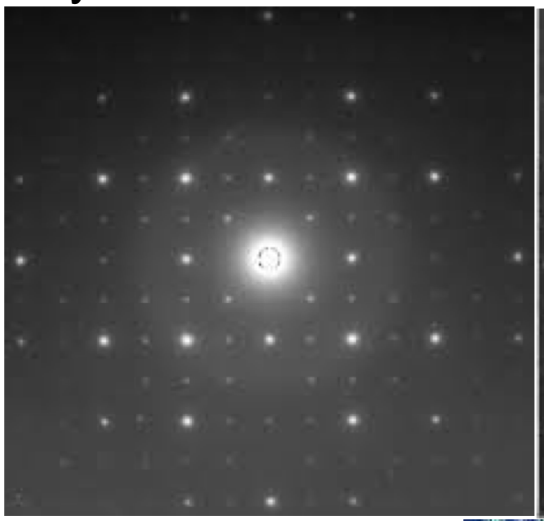
EMIGRATION

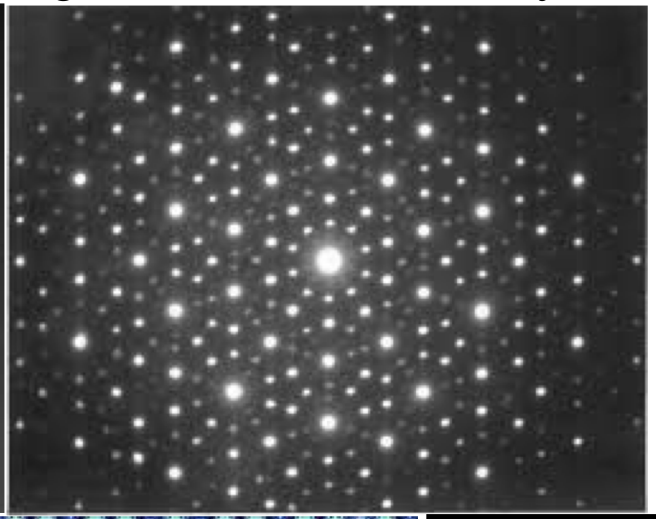
Migration of populations, opposite claimed of right-wing nationalists, lined all human history:

60,000 years ago – humans migrated from Africa
50,000 years ago Aboriginal ancestors migrated to Australia
40,000 years ago humans settled in Europe
30,000 years ago, the ice age pushed populations back south
18,000 years ago hunters-gatherers moved from the middle east to Europe
15,000 years ago hunters-gatherers moved from Asia to America
8,000 years ago farmers moved from Anatolia to Europe
4,800 years ago tribes from the preries of middle Asia evaded Europe and Asia
3,200 years ago the Mediteran people settled on the coast of Israel
2,500 years ago Celtic tribes evaded England and Spain
1,800 years ago Anglo-Saxon evaded Britany
1,500 years ago Germanic (Barbarian) tribes evaded Europe, pulled the Romans and mixed with the Celts
1,000 years ago Vikings settled in coast areas of Europe
800 years ago Mongols conquered most of Asia, middle east and east of Europe
500 years ago Europeans started a massive emigration to America

NEW CONCEPTS – QUAZI CRYSTALS

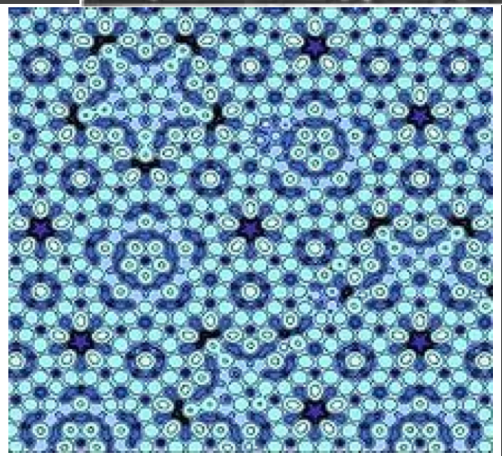
19th century mathematicians showed that there is a small number of symmetries that can fill two-dimensional wall-paper patterns: 14 Bravais lattices
This was extended to three-dimensions: 32 symmetries with 230 possible ”unit cells”.
The point symmetries possible are only 1,2,3,4,6
With the discovery of x-rays and their crystal diffraction pictures, such symmetries were clearly seen when the x-ray beam direction was aligned with one of the crystal symmetry axes.

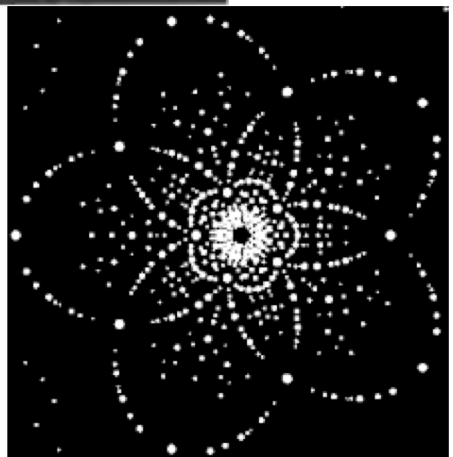




Dan Shechtman demonstrated that there are structures maintaining long range directionality, but break the translational Periodicity, providing a way to “pack” “forbideen” symmetries such as 5.

Nobel 2011

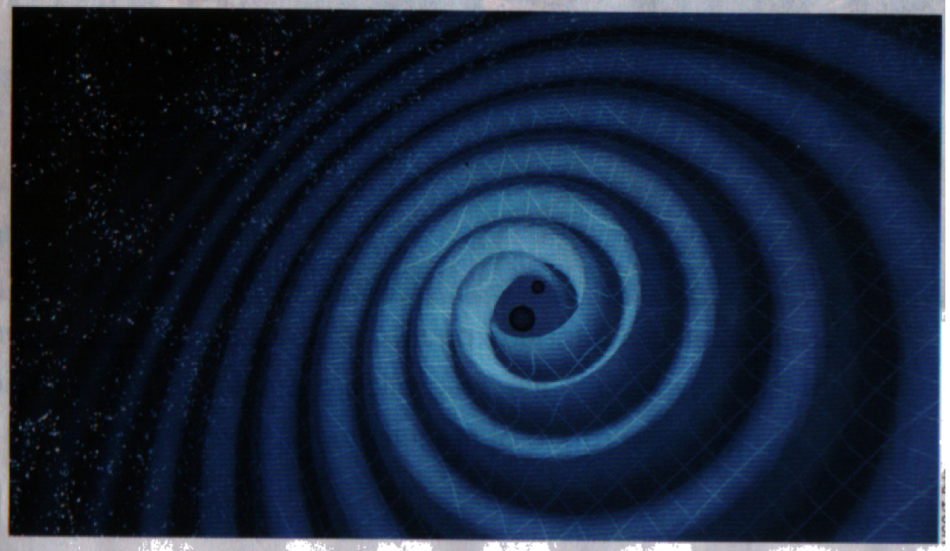




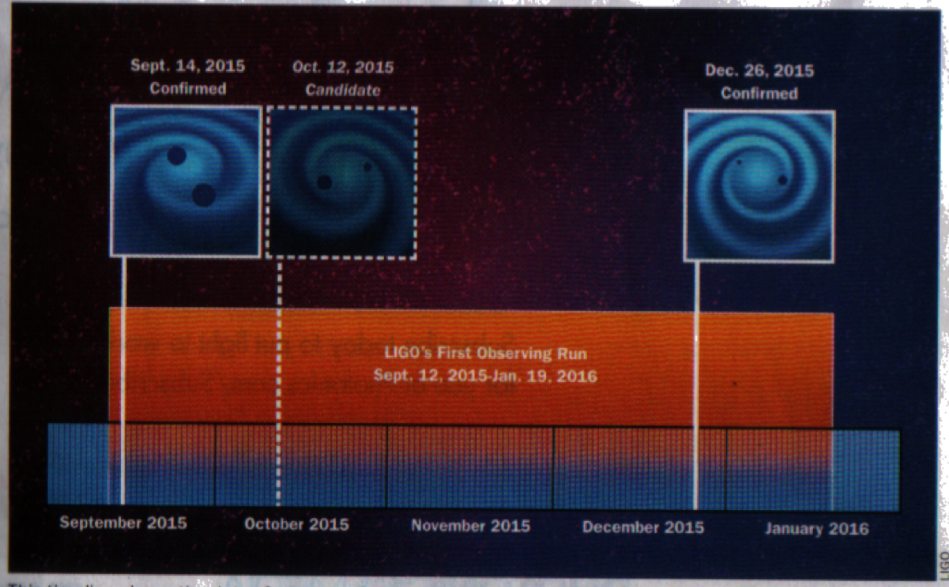
GRAVITY WAVES

גלי כבידה (גראויטציה)

Nobel 2017

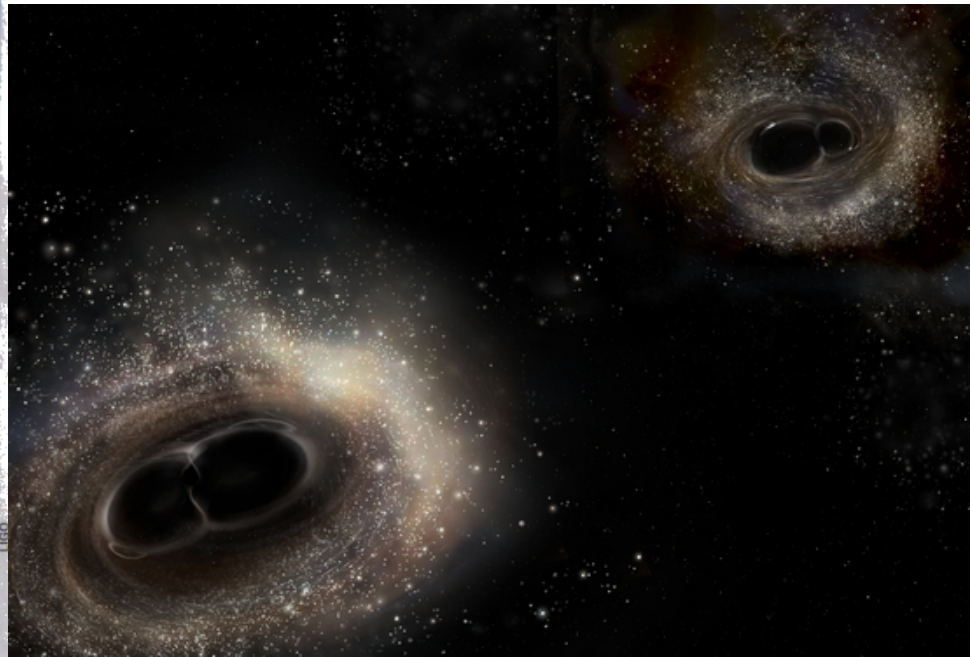


This illustration shows the merger of two black holes and the gravitational waves that ripple outward as the black holes spiral toward each other. The black holes — which represent those detected by LIGO on Dec. 26, 2015 — were 14 and 8 times the mass of the sun, until they merged, forming a single black hole 21 times the mass of the sun. In reality, the area near the black holes would appear highly warped, and the gravitational waves would be difficult to see directly.



This timeline shows the dates for two confirmed gravitational-wave detections by LIGO and one candidate detection, which was too weak to unambiguously confirm. All three events occurred during the first four-month run of Advanced LIGO — the upgraded, more-sensitive version of the facilities.

The “voice” of two black holes circling around each other before they unite.

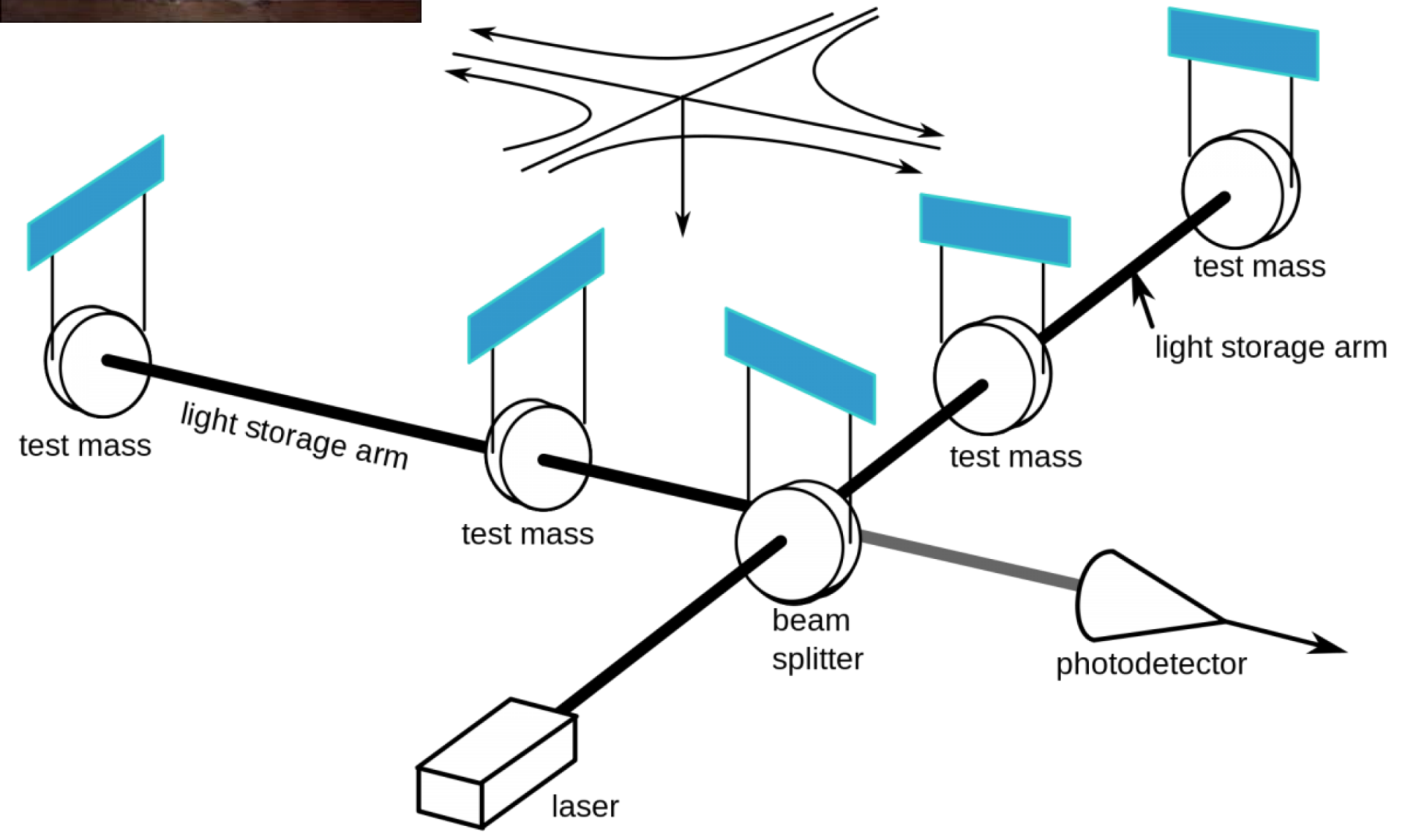


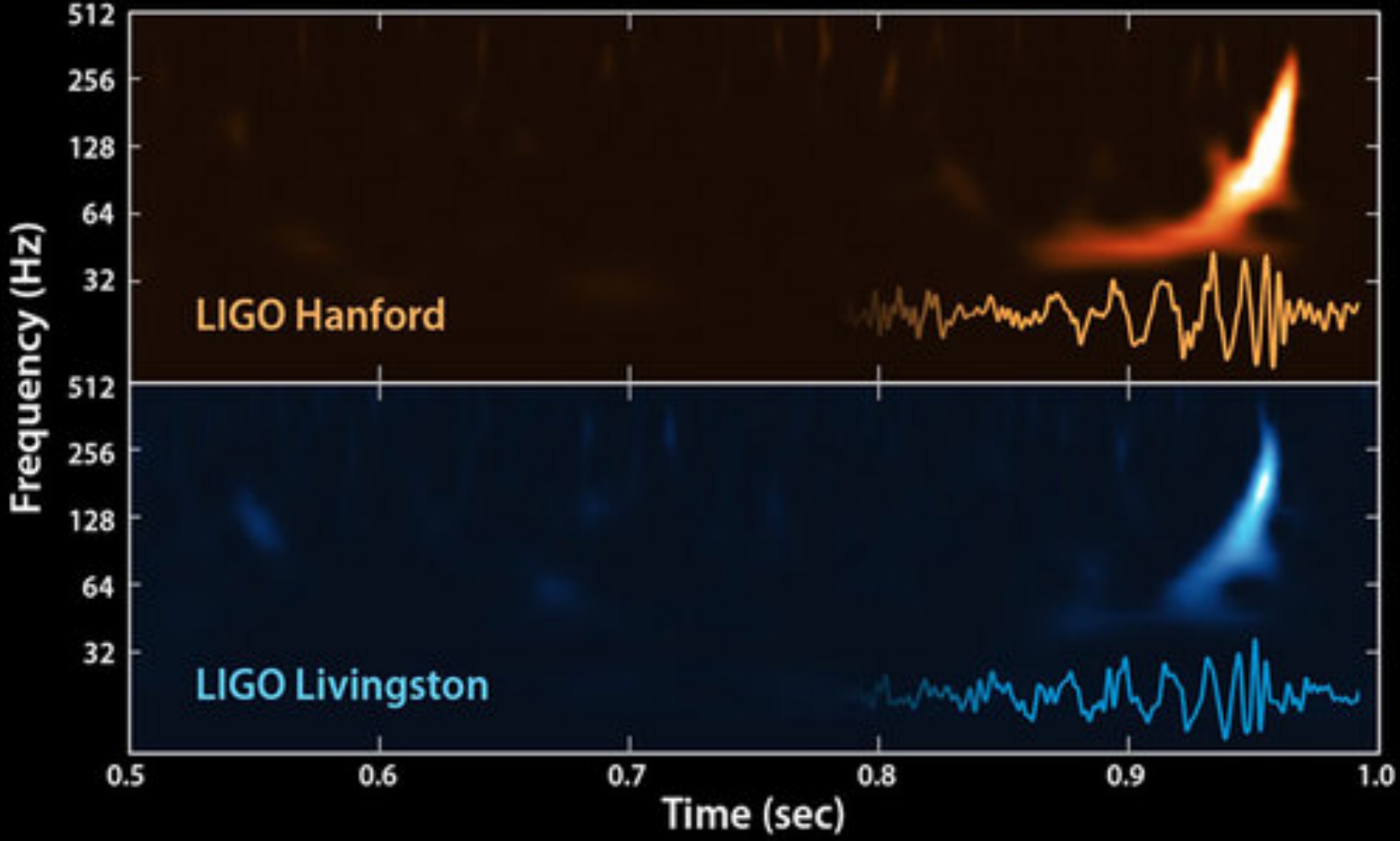
LIGO Laser Interferometer Gravitational wave Observatory

Two stations, 3000 km apart, in Washington state and in Louisiana, measure vibrations by interfering laser beams. Due to their distance, they would sense gravity at time delay (up to 10 milliseconds). The delay also provide the direction in space where the gravity source is by triangulation.

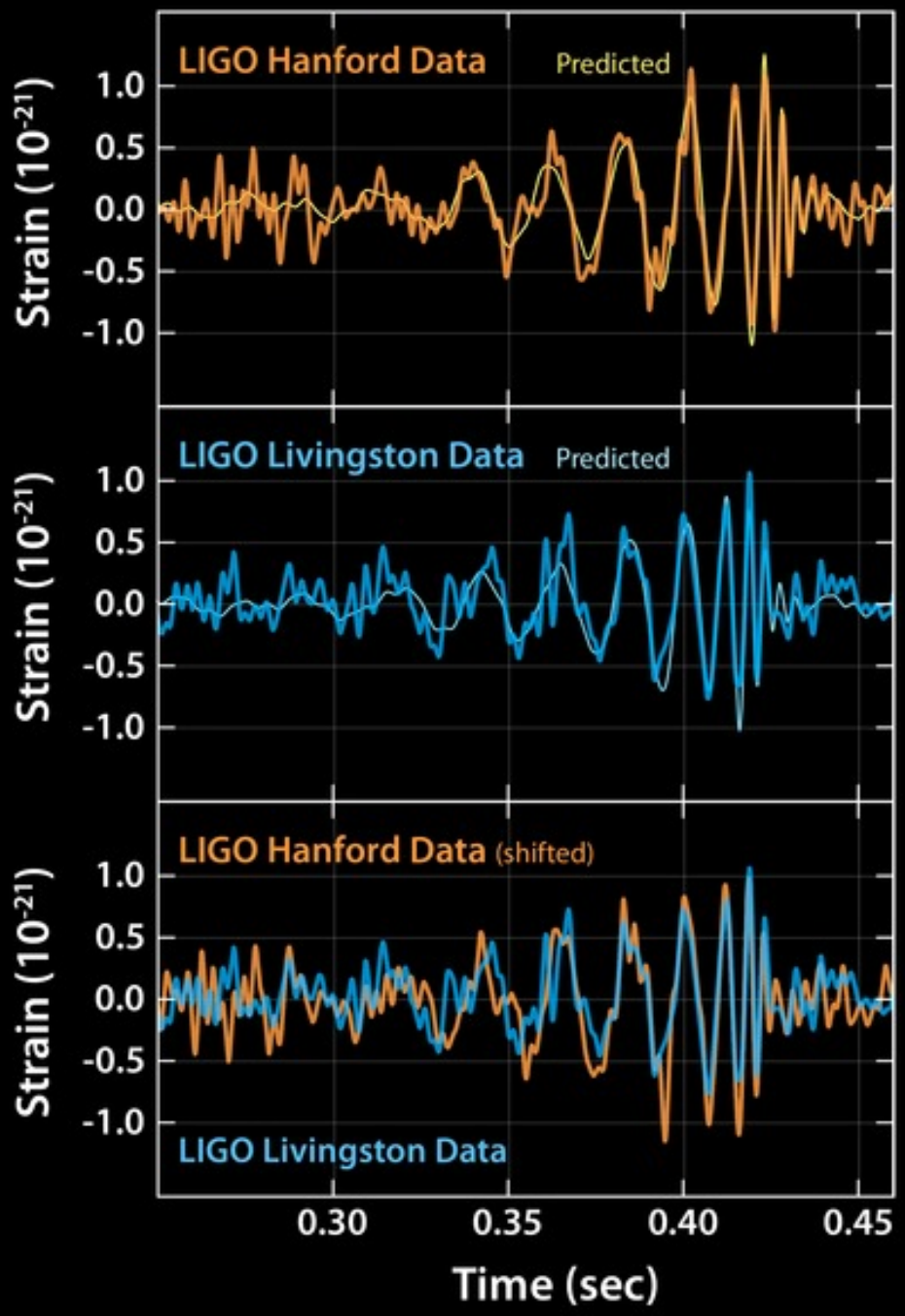
How LIGO operates?

Similar to Michelson-Morley interferometer. Every arm is 4km long, Gravity affects the two arms differentially, and cause changes in the interferometric intensity.





The time-frequency distribution of the gravity waves from the two LIGO interferometers



The data is filtered to obtain only the frequency of the black-holes rotation, Then the time delay is best fitted.

APPENDIX :

21-st century
Copley Medal
Of the British Royal Academy

2000 **Alan R. Battersby** "In recognition of his pioneering work in elucidating the detailed biosynthetic pathways to all the major families of plant alkaloids. His approach, which stands as a paradigm for future biosynthetic studies on complex molecules, combines isolation work, structure determination, synthesis, isotopic labelling and spectroscopy, especially advanced NMR, as well as genetics and molecular biology. This spectacular research revealed the entire pathway to vitamin B12”

2001 **Jacques Miller** "For his work on the immunological function of the thymus and of T cells, which has revolutionised the science of immunology. Professor Millers work is paving the way for designing new methods to improve resistance to infections, producing new vaccines, enhancing graft survival, dealing with autoimmunity and even persuading the immune system to reject cancer cells" —

2002 **John Pople** "For his development of computational methods in quantum chemistry. His work transformed density functional theory into a powerful theoretical tool for chemistry, chemical physics and biology”

2003 **John Gurdon** "For his unique range of groundbreaking discoveries in the fields of cell and developmental biology. He pioneered the concept that specialised cells are genetically equivalent and that they differ only in the genes they express not the genes they contain, a concept fundamental to modern biology”

2004 **Harry Kroto** "in recognition of his seminal contributions to understanding the fundamental dynamics of carbon chain molecules, leading to the detection of these species (polyynes) in the interstellar medium by radioastronomy, and thence to the genesis of a new era in carbon science”

2005 **Paul Nurse** "for his contributions to cell biology in general, and to the elucidation of the control of cell division.”

2006 **Stephen Hawking** "For his outstanding contribution to theoretical physics and theoretical cosmology. ”

2007 **Robert May** "for his seminal studies of interactions within and among biological populations that have reshaped our understanding of how species, communities and entire ecosystems respond to natural or human created disturbance.”

2008 **Roger Penrose** "for his beautiful and original insights into many areas of mathematics and mathematical physics. Sir Roger has made outstanding contributions to general relativity theory and cosmology, most notably for his work on black holes and the Big Bang.”

2009 **Martin Evans** "for his seminal work on embryonic stem cells in mice, which revolutionised the field of genetics.”

2010 **David Cox** "for his seminal contributions to the theory and applications of statistics."

Tomas Lindahl "for his seminal contributions to the understanding of the biochemistry of DNA repair."

2011 **Dan McKenzie** "For his seminal contributions to the understanding of geological and geophysical phenomena including tectonic plates."

2012 **John Walker** "For his ground-breaking work on bioenergetics, discovering the mechanism of ATP synthesis in the mitochondrion."

2013 **Andre Geim** "For his numerous scientific contributions and, in particular, for initiating research on two-dimensional atomic crystals and their artificial heterostructures."

2014 **Alec Jeffreys** "For his pioneering work on variation and mutation in the human genome."

2015 **Peter Higgs** "For his fundamental contribution to particle physics with his theory explaining the origin of mass in elementary particles, confirmed by the experiments at the Large Hadron Collider."

2016 **Richard Henderson** "In recognition of his fundamental and revolutionary contributions to the development of electron microscopy of biological materials, enabling their atomic structures to be deduced."

NOBEL PRIZES in Physics

PHYSICS

2000-Zhores I. Alferov and **Herbert Kroemer** "for developing semiconductor heterostructures used in high-speed- and opto-electronics"

2000-Jack S. Kilby "for his part in the invention of the integrated circuit"

2001-Eric A. Cornell, **Wolfgang Ketterle** and **Carl E. Wieman** "for the achievement of Bose-Einstein condensation in dilute gases of alkali atoms, and for early fundamental studies of the properties of the condensates"

2002-Raymond Davis Jr. and **Masatoshi Koshiba** "for pioneering contributions to astrophysics, in particular for the detection of cosmic neutrinos"

2002-Riccardo Giacconi "for pioneering contributions to astrophysics, which have led to the discovery of cosmic X-ray sources"

2003-Alexei A. Abrikosov, **Vitaly L. Ginzburg** and **Anthony J. Leggett** "for pioneering contributions to the theory of superconductors and superfluids"

2004-David J. Gross, **H. David Politzer** and **Frank Wilczek** "for the discovery of asymptotic freedom in the theory of the strong interaction"

2005-Roy J. Glauber "for his contribution to the quantum theory of optical coherence"

2005-John L. Hall and **Theodor W. Hänsch** "for their contributions to the development of laser-based precision spectroscopy, including the optical frequency comb technique"

2006-John C. Mather and **George F. Smoot** "for their discovery of the blackbody form and anisotropy of the cosmic microwave background radiation"

2007-Albert Fert and **Peter Grünberg** "for the discovery of Giant Magnetoresistance"

PHYSICS

2008-Yoichiro Nambu "for the discovery of the mechanism of spontaneous broken symmetry in subatomic physics"

2008-Makoto Kobayashi and **Toshihide Maskawa** "for the discovery of the origin of the broken symmetry which predicts the existence of at least three families of quarks in nature"

2009-Charles Kuen Kao "for groundbreaking achievements concerning the transmission of light in fibers for optical communication"

2009-Willard S. Boyle and **George E. Smith** "for the invention of an imaging semiconductor circuit – the CCD sensor"

2010-Andre Geim and **Konstantin Novoselov** "for groundbreaking experiments regarding the two-dimensional material graphene"

2011-Saul Perlmutter, **Brian P. Schmidt** and **Adam G. Riess** "for the discovery of the accelerating expansion of the Universe through observations of distant supernovae"

2012- Serge Haroche and **David J. Wineland** "for ground-breaking experimental methods that enable measuring and manipulation of individual quantum systems"

2013- François Englert and **Peter W. Higgs** "for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider"

2014- Isamu Akasaki, Hiroshi Amano and **Shuji Nakamura** "for the invention of efficient blue light-emitting diodes which has enabled bright and energy-saving white light sources"

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PHYSICS

2015- Takaaki Kajita & Arthur B. McDonald "for the discovery of neutrino oscillations, which shows that neutrinos have mass"

2016- **David J. Thouless, F. Duncan M. Haldane & John M. Kosterlitz** "for theoretical discoveries of topological phase transitions and topological phases of matter"

NOBEL PRIZES in CHEMISTRY

https://en.wikipedia.org/wiki/List_of_Nobel_laureates_in_Chemistry

CHEMISTRY

2000-Alan J. Heeger, **Alan G. MacDiarmid** and **Hideki Shirakawa** "for the discovery and development of conductive polymers"

2001-William S. Knowles and **Ryoji Noyori** "for their work on chirally catalysed hydrogenation reactions"

2001-K. Barry Sharpless "for his work on chirally catalysed oxidation reactions"

2002-Kurt Wüthrich "for his development of nuclear magnetic resonance spectroscopy for determining the three-dimensional structure of biological macromolecules in solution"

2002-John B. Fenn and **Koichi Tanaka** "for their development of soft desorption ionisation methods for mass spectrometric analyses of biological macromolecules"

2003-Peter Agre "for the discovery of water channels"

2003-Roderick MacKinnon "for structural and mechanistic studies of ion channels"

2004-Aaron Ciechanover, **Avram Hershko** and **Irwin Rose** "for the discovery of ubiquitin-mediated protein degradation"

2005-Yves Chauvin, **Robert H. Grubbs** and **Richard R. Schrock** "for the development of the metathesis method in organic synthesis"

2006-Roger D. Kornberg "for his studies of the molecular basis of eukaryotic transcription"

2007-Gerhard Ertl "for his studies of chemical processes on solid surfaces"

2008-Osamu Shimomura, **Martin Chalfie** and **Roger Y. Tsien** "for the discovery and development of the green fluorescent protein, GFP"

2009-Venkatraman Ramakrishnan, **Thomas A. Steitz** and **Ada E. Yonath** "for studies of the structure and function of the ribosome"

CHEMISTRY

2010- Richard F. Heck, **Ei-ichi Negishi** and **Akira Suzuki** "for palladium-catalyzed cross couplings in organic synthesis”

2011-Dan Shechtman "for the discovery of quasicrystals"

2012- Robert J. Lefkowitz and **Brian K. Kobilka** "for studies of G-protein-coupled receptors"

2013- Martin Karplus, Michael Levitt and **Arieh Warshel** "for the development of multiscale models for complex chemical systems"

2014- Eric Betzig, Stefan W. Hell and **William E. Moerner** "for the development of super-resolved fluorescence microscopy"

2015-Tomas Lindahl, Paul Modrich and **Aziz Sancar** "for mechanistic studies of DNA repair"

2016-Jean-Pierre Sauvage, Sir J. Fraser Stoddart and **Bernard L. Feringa** "for the design and synthesis of molecular machines"

NOBEL PRIZES
in
PHYSIOLOGY & MEDICINE

PHYSIOLOGY & MEDICINE

2000-Arvid Carlsson, **Paul Greengard** and **Eric R. Kandel** "for their discoveries concerning signal transduction in the nervous system"
2001-Leland H. Hartwell, **Tim Hunt** and **Sir Paul M. Nurse** "for their discoveries of key regulators of the cell cycle"
2002-Sydney Brenner, **H. Robert Horvitz** and **John E. Sulston** "for their discoveries concerning genetic regulation of organ development and programmed cell death’”
2003-Paul C. Lauterbur and **Sir Peter Mansfield** "for their discoveries concerning magnetic resonance imaging"
2004-Richard Axel and **Linda B. Buck** "for their discoveries of odorant receptors and the organization of the olfactory system"
2005-Barry J. Marshall and **J. Robin Warren** "for their discovery of the bacterium *Helicobacter pylori* and its role in gastritis and peptic ulcer disease"
2006-Andrew Z. Fire and **Craig C. Mello** "for their discovery of RNA interference - gene silencing by double-stranded RNA"
2007-Mario R. Capecchi, **Sir Martin J. Evans** and **Oliver Smithies** "for their discoveries of principles for introducing specific gene modifications in mice by the use of embryonic stem cells"
2008-Françoise Barré-Sinoussi and **Luc Montagnier** "for their discovery of human immunodeficiency virus"
2008-Harald zur Hausen "for his discovery of human papilloma viruses causing cervical cancer"

PHYSIOLOGY & MEDICINE

2009-Elizabeth H. Blackburn, **Carol W. Greider** and **Jack W. Szostak** "for the discovery of how chromosomes are protected by telomeres and the enzyme telomerase"
2010-Robert G. Edwards "for the development of in vitro fertilization"
2011-Bruce A. Beutler and **Jules A. Hoffmann** "for their discoveries concerning the activation of innate immunity"
2011-Ralph M. Steinman "for his discovery of the dendritic cell and its role in adaptive immunity"
2012- Sir John B. Gurdon and **Shinya Yamanaka** "for the discovery that mature cells can be reprogrammed to become pluripotent"
2013- James E. Rothman, Randy W. Schekman and **Thomas C. Südhof** "for their discoveries of machinery regulating vesicle traffic, a major transport system in our cells"
2014- John O'Keefe, May-Britt Moser and **Edvard I. Moser** "for their discoveries of cells that constitute a positioning system in the brain"
2015- William C. Campbell and Satoshi Ōmura "for their discoveries concerning a novel therapy against infections caused by roundworm parasites"
2016- Yoshinori Ohsumi "for his discoveries of mechanisms for autophagy"

TURING PRIZES in COMPUTER SCIENCES

http://amturing.acm.org/byyear.cfm

2000 Andrew Chi-Chih Yao In recognition of his fundamental contributions to the theory of computation, including the complexity-based theory of pseudorandom number generation, cryptography, and communication complexity.

2001 Ole-Johan Dahl and Kristen Nygaard For ideas fundamental to the emergence of object-oriented programming, through their design of the programming languages Simula I and Simula 67.

2002 Ronald L. Rivest, Adi Shamir and Leonard M. Adleman For their ingenious contribution for making public-key cryptography useful in practice.

2003 Alan Kay For pioneering many of the ideas at the root of contemporary object-oriented programming languages, leading the team that developed Smalltalk, and for fundamental contributions to personal computing.

2004 Vinton G. Cerf and Robert E. Kahn For pioneering work on internetworking, including the design and implementation of the Internet's basic communications protocols, TCP/IP, and for inspired leadership in networking.

2005 Peter Naur For fundamental contributions to programming language design and the definition of ALGOL 60, to compiler design, and to the art and practice of computer programming.

2006 Frances E. Allen For pioneering contributions to the theory and practice of optimizing compiler techniques that laid the foundation for modern optimizing compilers and automatic parallel execution.

2007 Edmund M. Clarke, E. Allen Emerson and Joseph Sifakis For [their roles] in developing model checking into a highly effective verification technology, widely adopted in the hardware and software industries.[8]

2008 Barbara Liskov For contributions to practical and theoretical foundations of programming language and system design, especially related to data abstraction, fault tolerance, and distributed computing.

2009 Charles P. Thacker For his pioneering design and realization of the Xerox Alto, the first modern personal computer, and in addition for his contributions to the Ethernet and the Tablet PC.

2010 Leslie G. Valiant For transformative contributions to the theory of computation, including the theory of probably approximately correct (PAC) learning, the complexity of enumeration and of algebraic computation, and the theory of parallel and distributed computing.

2011 Judea Pearl For fundamental contributions to artificial intelligence through the development of a calculus for probabilistic and causal reasoning.[9]

2012 Shafi Goldwasser / Silvio Micali for transformative work that laid the complexity-theoretic foundations for the science of cryptography, and in the process pioneered new methods for efficient verification of mathematical proofs in complexity theory.

2013 Leslie Lamport For fundamental contributions to the theory and practice of distributed and concurrent systems, notably the invention of concepts such as causality and logical clocks, safety and liveness, replicated state machines, and sequential consistency.

2014 Michael Stonebraker For fundamental contributions to the concepts and practices underlying modern database systems.

2015 Diffie, Whitfield & Hellman, Martin For inventing and promulgating both asymmetric public-key cryptography, including its application to digital signatures, and a practical cryptographic key-exchange method.

Fields Medal in MATHEMATICS

2002 Laurent Lafforgue For proving the global Langlands correspondence for function fields, a major advance toward the realization of the "Langlands Program," which deals with the deep connections between number theory, analysis, and group representation

Group theory | Number theory

Vladimir Voevodsky For developing a new cohomology theory for algebraic varieties, which represents an important advance in number theory and algebraic geometry

2006 Grigory Perelman For his contributions to geometry and his revolutionary insights into the analytical and geometric structure of the Ricci flow. His results provide a way of resolving two outstanding problems in topology: the Poincaré Conjecture and the Thurston Geometrization Conjecture. The mathematical community is in the process of checking his work to ensure that it is entirely correct and that the conjectures have been proved.

Geometry | Topology

Andrei Okounkov For his contributions bridging probability, representation theory, and algebraic geometry. | Algebraic geometry | Group theory | Probability

Terence Tao For his contributions to partial differential equations, combinatorics, harmonic analysis, and additive number theory. | Combinatorial theory | Differential equation | Fourier series and transforms | Number theory

Wendelin Werner For his contributions to the development of stochastic Loewner evolution, the geometry of two-dimensional Brownian motion, and conformal field theory.

Brownian movement | Conformal mapping | Stochastic process

2010 Elon Lindenstrauss For his results on measure rigidity in ergodic theory, and their applications to number theory. | Number theory | Topological dynamics

Ngô Báo Châ For his proof of the Fundamental Lemma in the theory of automorphic forms through the introduction of new algebra-geometric methods.

Group theory | Number theory

Stanislav Smirnov For the proof of conformal invariance of percolation and the planar Ising model in statistical physics. | Ising model | Mathematical physics | Statistical mechanics

Cedric Villani For his work proofs of nonlinear Landau damping and convergence to equilibrium for the Boltzmann equation | Entropy | Plasma (physics) | Thermodynamic principles

2014 Artur Avila Cordeiro de Melo For his profound contributions to dynamical systems theory, which have changed the face of the field, using the powerful idea of renormalization as a unifying principle.

Manjul Bhargava For developing powerful new methods in the geometry of numbers, which he applied to count rings of small rank and to bound the average rank of elliptic curves.

Martin Hairer For his outstanding contributions to the theory of stochastic partial differential equations, and in particular for the creation of a theory of regularity structures for such equations.

Maryam Mirzakhani **F**or her outstanding contributions to the dynamics and geometry of Riemann surfaces and their moduli spaces

2018

Abel prizes in MATHEMATICS

http://www.abelprize.no

נוסד ע״י הממשלה הנורווגית ע״ש המתמטיקאי הנורווגי **Niels Henrik Abel** (1802–29)

2003 **Jean-Pierre Serre** Collège de France
"for playing a key role in shaping the modern form of many parts of mathematics, including topology, algebraic geometry and number theory”

2004 **Michael Atiyah**; British;
Isadore Singer United States American University of Edinburgh; MIT
"for their discovery and proof of the index theorem, bringing together topology, geometry and analysis, and their outstanding role in building new bridges between mathematics and theoretical physics”

2005 **Peter Lax** United States American Courant Institute
"for his groundbreaking contributions to the theory and application of partial differential equations and to the computation of their solutions”

2006 **Lennart Carleson** Sweden Swedish Royal Institute of Technology
"for his profound and seminal contributions to harmonic analysis and the theory of smooth dynamical systems”

2007 **S. R. Srinivasa Varadhan** India, United States American Courant Institute
"for his fundamental contributions to probability theory and in particular for creating a unified theory of large deviation”

2008 **John G. Thompson**; United States American; University of Florida;
J**acques Tits** Belgium France French Collège de France
"for their profound achievements in algebra and in particular for shaping modern group theory”

2009 **Mikhail Gromov** Russia Institut des Hautes Études Scientifiques Courant Institute
"for his revolutionary contributions to geometry"

2010 John Tate United States American University of Texas at Austin
"for his vast and lasting impact on the theory of numbers"

2011 John Milnor United States Stony Brook University
"for pioneering discoveries in topology, geometry, and algebra"

2012 Endre Szemerédi Hungary US Alfréd Rényi Institute and Rutgers University
"for his fundamental contributions to discrete mathematics and theoretical computer science, and in recognition of the profound and lasting impact of these contributions on additive number theory and ergodic theory"

2013 Pierre Deligne Belgium Institute for Advanced Study
"for seminal contributions to algebraic geometry and for their transformative impact on number theory, representation theory, and related fields"

2014 Yakov Sinai Russia US Landau Institute for Theoretical Physics Princeton University
"for his fundamental contributions to dynamical systems, ergodic theory, and mathematical physics"

2015 John F. Nash, Jr. US (Nobel prize for economics for game theory)
Louis Nirenberg Canada US Princeton University Courant Institute
"for striking and seminal contributions to the theory of nonlinear partial differential equations and its applications to geometric analysis"

2016 Andrew J Wiles British -> US Princeton
"for his stunning proof of Fermat's Last Theorem by way of the modularity conjecture for semistable elliptic curves, opening a new era in number theory."

NOBEL PRIZES in ECONOMY

ECONOMY

2000-James J. Heckman "for his development of theory and methods for analyzing selective samples"

2000-Daniel L. McFadden "for his development of theory and methods for analyzing discrete choice"

2001-George A. Akerlof, **A. Michael Spence** and **Joseph E. Stiglitz** "for their analyses of markets with asymmetric information"

2002-Daniel Kahneman "for having integrated insights from psychological research into economic science, especially concerning human judgment and decision-making under uncertainty"

2002-Vernon L. Smith "for having established laboratory experiments as a tool in empirical economic analysis, especially in the study of alternative market mechanisms"

2003-Clive W.J. Granger "for methods of analyzing economic time series with common trends (cointegration)"

2003-Robert F. Engle III "for methods of analyzing economic time series with time-varying volatility (ARCH)"

2004-Finn E. Kydland and **Edward C. Prescott** "for their contributions to dynamic macroeconomics: the time consistency of economic policy and the driving forces behind business cycles"

2005-Robert J. Aumann and **Thomas C. Schelling** "for having enhanced our understanding of conflict and cooperation through game-theory analysis"

2006-Edmund S. Phelps "for his analysis of intertemporal tradeoffs in macroeconomic policy"

ECONOMY

2007-Leonid Hurwicz, **Eric S. Maskin** and **Roger B. Myerson** "for having laid the foundations of mechanism design theory"

2008-Paul Krugman "for his analysis of trade patterns and location of economic activity"

2009-Elinor Ostrom "for her analysis of economic governance, especially the commons"

2009-Oliver E. Williamson "for his analysis of economic governance, especially the boundaries of the firm"

2010-Peter A. Diamond, **Dale T. Mortensen** and **Christopher A. Pissarides** "for their analysis of markets with search frictions"

2011-Thomas J. Sargent and **Christopher A. Sims** "for their empirical research on cause and effect in the macroeconomy"

2012- Alvin E. Roth and **Lloyd S. Shapley** "for the theory of stable allocations and the practice of market design"

2013-Eugene F. Fama, Lars Peter Hansen and **Robert J. Shiller** "for their empirical analysis of asset prices"

2014-Jean Tirole "for his analysis of market power and regulation"

2015-Angus Deaton "for his analysis of consumption, poverty, and welfare"

2016-Oliver Hart and Bengt Holmström "for their contributions to contract theory"

DAVY MEDAL
In CHEMISTRY

2000 **Steven Victor Ley** "In recognition of his invention of new synthetic methods applied to the synthesis of complex natural products including those from insects, micro-organisms and plants. Among his most outstanding successes have been the synthesis of avermectin B1a, tetronasin, the milbemycins and indanomycin as well as his important development of short, practical syntheses of oligosaccharides"

2001 **Alastair Ian Scott** "For his pioneering contributions to the understanding of biosynthetic pathways, and in particular for his work on vitamin B12. He is a world leader in his area and the impact of his discoveries are likely to have a significant effect on the way natural product chemistry progresses into the future"

2002 **Neil Bartlett** "For his research exploring the highest oxidation limits of the less oxidizable elements, primarily using elemental fluorine. [*sic] He has exposed the new chemistry of the noble gases and new procedures for attaining high oxidation state limits across the elements of the periodic table"*

2003 **Roger Parsons** "For his distinguished career in electochemistry. [*sic] He developed the method of preparing, for the first time, clean and well-defined metal surfaces and putting them into contact with the electrolyte without contamination"

2004 **Takeshi Oka** "For his many and varied contributions to molecular spectroscopy and its applications, particularly to astronomy"

2004 **Chris Dobson** "For his work on the application of NMR and other structural methods for studying protein folding and misfolding, especially the formation of amyloid fibrils, leading to novel insights on protein structure and folding"

2006 **Martin Pope** "For his pioneering work in the field of molecular semiconductors which has now become a large and important area of semiconductor science and technology"

2007 **John Simons** "For his many innovative experimental contributions to a broad area of chemical physics, including molecular reaction dynamics, molecular spectroscopy and most recently, biophysical chemistry"

2008 **James Fraser Stoddart**"For his contributions in molecular technology”

2009 **Jeremy Sanders** "For his pioneering contributions to several fields, most recently to the field of dynamic combinatorial chemistry at the forefront of supramolecular chemistry”

2010 **Carol Robinson** "For her ground-breaking and novel use of mass spectrometry for the characterisation of large protein complexes.”

2011 **Ahmed Zewail** "For his seminal contributions to the study of ultrafast reactions and the understanding of transition states in chemistry, and to dynamic electron microscopy.”

2012 **Fraser Armstrong** "For his pioneering protein film electrochemistry allowing exquisite thermodynamic and kinetic control of redox enzymes, exemplified by hydrogenases, key in energy technology.”

2013 **Graham Hutchings** "for the discovery of catalysis by gold and for his seminal contributions to this new field of chemistry”

2014 **Clare Grey** "for further pioneering applications of solid state nuclear magnetic resonance to materials of relevance to energy and the environment”

2015 **Gideon John Davies** "for his work in determining the reaction chemistry of enzyme-catalysed carbohydrate transformations”

2016 **Stephen Mann** "for distinguished contributions to the chemistry of bio-mineralization and for pioneering the bio-inspired synthesis and self-assembly of functional nanostructures and hybrid nanoscale objects”