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"*Supernovae. Before, During and After the Explosion*"

Vasily Belokurov, University of Cambridge and Roman Zhuchkov, Kazan Federal University

Supernovae are spectacular events. They are the death throes of stars that can be seen across the Universe. They radiate across the whole electromagnetic spectrum from radio to gamma-rays, and often outshine their host galaxies. Being intrinsically bright they can be seen out to great distances; indeed, some types of supernovae have been used as relative distance indicators, leading to the startling result that the expansion of the Universe is accelerating.

Although they have been known to astronomers for centuries, many puzzles regarding the nature of the stars that explode, the explosion itself, and the type of remnant (neutron stars or black holes) that some explosions leave behind, remain; these areas are the subject of active current research.

10-20 years ago, typically only few supernovae were discovered per year, making systematic studies difficult. Over the last five years, the frontiers have been pushed forward dramatically with the advent of all-sky surveys with large field-of-view detectors. With this configuration, scanning the entire visible sky periodically, looking for anything that moves (e.g. asteroids) or flashes (e.g. supernovae) has become feasible, leading to hundreds of discoveries per year. Thus, for the first time in the history of transient research, astronomers will have access to large samples of different types of stellar explosions -- these can then be used to study the final stages of stellar evolution, the environments in which these explosions occur, and to measure the type and amount of nucleosynthesized material that is returned to the interstellar medium. This seed material will ultimately be recycled into the next generation of stars, planets, and complex molecules.

Although several surveys are currently ongoing, the symbiotic relation between professional searches and amateur supernova hunters continues to flourish.

'Entrapment and manipulation of molecules at nanoscale'

Andrei Khlobystov, University of Nottingham and Igor Mashkovsky, Zelinsky Institute of Organic Chemistry

The ultimate quest of chemical science is to control the behaviour of individual molecules, harness their functional properties and direct their reactions at the single-molecule level. One of the most powerful methodologies for achieving these goals is based on the confinement of individual atoms and molecules at the nanoscale. Entrapment and encapsulation enable the manipulation of molecules with atomic precision and provides a mechanism for the control of their physicochemical states.

Elena Bichoutskaia introduced the idea that confinement at nanoscale helps chemists to analyse structures of highly reactive and otherwise unstable guest-molecules by methods of spectroscopy and microscopy, thus affording a useful analytical tool. Importantly, the relative stabilities of confined molecules can be altered dramatically due to interactions with the host-structure, which can change pathways of chemical transformations. Chemical reactions that are unfeasible in bulk (solution, gas or solid phase) become possible inside nano-containers such as carbon nanotubes. New previously inaccessible products can be synthesised by conducting chemical reactions in confinement.

A number of host-structures based on hollow molecular cages, including cyclodextrines, calixarines and supramolecular cages, are currently available for encapsulation. Prof Michaele Hardie reported the latest advances in the construction of nanosized metallo-cages based on coordination interactions between organic ligands and transition metal ions. Polydentate multifunctional ligands are designed so that they click into place during the metallo-cage formation. The self-assembled hollow structures possess remarkable topology including a knot or catenane, and increasingly complex geometry and functionality.

Porous 3D materials, such metal-organic frameworks (MOFs) – also based on coordination interactions - can be engineered so that their pores match the size and shape of guest-molecules. Dr Danil Dybtsev described a study on a chromium terephthalate based MOF. This highly porous material (pore size *c.a.* 3.5 nm) is amenable to modifications, and exhibits excellent hydrogen storage capacity or proton transport characteristics when doped with inorganic clusters or strong acids respectively. One of the most exciting applications of this material is expected to concern fuel cells.

Nanoscale containers are clearly changing the way we make and study molecules.

'Climate change in earth's history'

Daniela Schmidt, University of Bristol and Anton Kolchugin, Institute of Geology, Oil and Gas Technology

For hundreds of years, we have tended to think of climate change as a gradual phenomenon, which will take place slowly over a long period of hundreds – or perhaps thousands – of years. In contrast, marine and terrestrial archives show that climate in the past changed rapidly between cold and warm states. Concerns about future rapid climate change due to increases of greenhouse gases make it paramount to improve our understanding of the climate system and its feedbacks on the Earth's system. The session constituted of three great talks addressing abrupt climate events in the past and what we can learn from these (Kirsty Edgar, Cardiff), using ocean temperature to understand climate evolution and extinction (Erin McClymont, Durham) and biological indicators of environmental change from lacustrine environments (Larisa Nazarova, Kazan).

All of the talks emphasised that the geological record is our "experiment" to quantify climate feedbacks and forcings in the ocean and on land. The multiple events in the geological past allow us to think about how/what/when climate changes happened and what their impacts are. In the absence of an Earth-like planet to experiment on, it is the main way to determine drivers of extinction and speciation, scaling of responses to greenhouse gases and susceptibility to different background conditions. These events inform climate models and provide datasets against which different hypotheses can be tested.

The discussion was very animated and wide ranging encompassing topics such as fidelity of the fossil record and precision of the dating of the record. Whilst the contributions to current and future climate change from anthropogenic activities are difficult to quantify, there was strong feeling that we understand some of the key feedbacks from the climate system in terms of ocean acidification and global temperature change.

'Long-term autonomous systems: from individuals to swarms'

Jon Timmis, University of York and Airat Khasianov, Kazan Federal University

Robotic systems have the potential to have considerable impact in areas such as environmental monitoring, agriculture and search and rescue. Robots might work on their own as individuals, or together as a 'swarm', collaborating together to achieve the task. A major issue, however, is how to control these robots and how to ensure their long-term operation without human intervention.

Researchers are concerned with issues ranging from computer vision, to planning the routes that robots might take to the distributed coordination of many robots to allow for effective collaboration between different types of robots. Research into path planning represents a major challenge in robotics research. The robot needs to create a map of its operational environment so that it can best calculate a suitable trajectory through the environment. Should the environment change, then recalculation is needed. This approach is called 'deliberative'. An alternative approach is not to plan a route, but to react to the environment only, according to a set of predefined behaviours. These behaviours interact to give rise to an overall emergent behaviour of the system. Such an approach is called 'reactive'. This is a very common approach when dealing with multiple robotic systems, or swarm robotic systems, that operate based on simple behavioural rules, often inspired by social insects.

Designs of swarm behaviours within robotic systems allow for the coordination of large numbers of robots, and crucially allow them to collaborate on tasks that a single robotic unit cannot perform. Examples of such activities include co-operative transport, where robots communicate with each other to allow a group of them to collaborate moving an object that a single robot cannot move on its own. A further example is the combined use of land and aerial robotic platforms, where robots of different types assist each other in the navigation of terrain and obstacles through the use of local communication.

Many challenges exist to achieve long-term operation of such systems and before they realize their full potential in the real world.

'Neurodevelopment'

Jacinta O'Shea, University of Oxford, Steven Chance, University of Oxford and Guzel Stidikova, Kazan Federal University

The main issue of the Neurobiology session concerned the fundamental principles of brain development and how abnormal development leads to brain disorders. During development, billions of neurons establish specific synaptic connections to produce our functional thinking brain. While the general map of synaptic circuits is encoded in our genes, early electrical activity plays an equally important role in brain development. The session began with an introduction to our current understanding of the cellular and network mechanisms of the specific activity patterns that emerge in the brain during early developmental stages in mammals.

Schizophrenia is a devastating and complex disorder that is believed to have its roots in abnormal brain development. Symptoms can include hallucinations, delusions and problems with social interaction. In addition to these core symptoms, patients also suffer from problems with attention, memory and decision making (collectively known as cognitive deficits). One of the leading hypotheses of how schizophrenia arises suggests that symptoms can be explained by abnormal dopamine levels in different brain regions. The presented data focused on the catechol-O-methyltransferase (COMT) enzyme, which breaks down dopamine, in healthy brain function and schizophrenia. The main finding of the research suggests that inhibiting COMT is a viable therapeutic strategy for treating the cognitive deficits suffered by patients with schizophrenia.

Finally, the application of advanced optogenetic technologies was described using mice expressing channelrhodopsin-2 to investigate the action of gamma amino butyric acid (GABA) in vivo. GABA is the main inhibitory neurotransmitter in adult brains. However it has an excitatory action in early life and the transition is yet to be fully understood.

The session concluded with a lively discussion of the value and costs of large-scale data gathering on neural activity, psychiatric assessments and gene expression to understand the brain.

'Quantum communications'

Alexey Kalachev, Zavoisky Physical-Technical Institute and Catherine Kendall, Cranfield University

The life of small physical systems, such as elementary particles, is governed by the laws of quantum mechanics, which were discovered in the early twentieth century. One interesting property of the quantum world is that elementary particles do not have a precise location or speed, as we would intuitively expect. An observer who would want to get information on the particle's location would destroy information on its speed (and vice versa), which is described by the famous Heisenberg uncertainty principle. The uncertainty principle is usually considered as an inconvenient limitation except in quantum information, where positive applications have been found. One of them is quantum key distribution (QKD). It enables two users, commonly named Alice and Bob, to produce a shared secret random bit string, which can be used as a key in cryptographic applications, by quantum communication with elementary particles such as single photons. Unlike conventional cryptography, where security relies on unproven computational assumptions, QKD promises unconditional security based on the fundamental laws of quantum mechanics. Following the uncertainty principle, an eavesdropper cannot perfectly copy quantum information stored in the photons. Any measurement of a quantum system will disturb it, and we can use this fundamental fact to detect the presence of an eavesdropper.

Quantum communications has recently matured from a purely fundamental research area of quantum physics to an applied multidisciplinary field of research and development. Developing deterministic sources of single photons and entangled photon pairs, elaborating effective quantum memories and bringing quantum communication into space are the frontiers of research in this field.