Astronomical Society of India Meeting 2021

WS1 : Computational Astrophysics : An Emerging Avenue for Indian Astronomy Community

(Date : February 18, 2020   Mode : ONLINE)

Time	Speaker	Title of the Talk
9:15-9:30	Welcome Address	
SESSION 1 : Code Development Strategies		
9:30-9:55	Sanjay Wandhekar (CDAC, Pune)	Emerging trends in HPC technologies and programming environments for the Exascale HPC Systems
9:55-10:20	Prateek Sharma (IISc)	Idealized simulations of the multiphase circumgalactic medium
10:20-10:45	Shravan Hanasoge (TIFR)	Using machine learning to discover new solar physics
10:45-11:00	Session Summary (Moderated by Dipanjan Mukherjee, IUCAA)	
SESSION 2 : Numerical Simulations for Solar and Stellar Physics		
11:15-11:40	Dibyendu Nandi (IISER Kolkata)	Star Planet Interactions: Space Weather to Exoplanets
11:40-12:05	Piyali Chatterjee (IIA)	Solar atmospheric dynamics through MHD simulations
12:05-12:30	Nishant Singh (IUCAA)	Self-consistent formation of sunspot-like magnetic flux concentrations
12:30-12:55	Sourav Chatterjee (TIFR)	Numerical Modeling of Large-N Star Clusters
12:55-13:15	Session Summary (Moderated by Bhargav Vaidya, IIT Indore)	
SESSION 3 : Simulations on Galactic and Extragalactic Scales		
14:30-14:55	Robi Banerjee (Uni. Hamburg)	Star formation triggered by magnetic fields
14:55-15:20	Kinsuk Acharya (PRL)	The Universe as a Giant Laboratory : The Making of Complex Molecules from Atoms.
15:20-15:45	Jasjeet Bagla (IISER Mohali)	The significance of a mathematical model and the art of approximation
15:45-16:10	Girish Kulkarni (TIFR)	Cosmological Radiative Transfer Simulations
16:10-16:30	Session Summary (Moderated by Sharanya Sur, IIA)	
SESSION 4 : Astrophysical Relativity		
16:45-17:10	Sukanta Bose (IUCAA)	Comprehending nature's densest objects with gravity's messengers
17:10-17:35	Indranil Chattopadhyay (ARIES)	Numerical simulation of accretion and jets around compact objects
17:35-18:00	Prayush Kumar (ICTS)	New Computation paradigms in Astrophysical Relativity.
18:00-18:15	Session Summary (Moderated by Dipanjan Mukherjee, IUCAA)	
18:15-18:30	Conclusion and Thanks	

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ABSTRACTS

Speaker : Sanjay Wandhekar (CDAC, Pune)
Title : Emerging trends in HPC technologies and programming environments for the Exascale HPC Systems
Abstract:
The talk first will cover brief about typical HPC system architecture, Building blocks of HPC and Programming environments for developing parallel programs. Current trends in various HPC technologies like CPUs, memories, accelerators, network, storage, etc. and programming environments which may scale to exascale will be covered.

Speaker : Prateek Sharma (IISc)
Title : Idealized simulations of the multiphase circumgalactic medium
Abstract:
Cosmological galaxy formation simulations have come a long way in their ability to simulate galaxy formation over the past two decades. The state of the art cosmological simulations have ~100 pc resolution for a global box size of ~50 Mpc and include fundamental physical processes such as cooling, AGN/stellar feedback, and magnetic fields. Simultaneously, observations of galactic outflows and circumgalactic/intracluster medium (CGM/ICM) show the ubiquitous presence of multiphase gas of diverse origins. The length scales associated with radiative cooling, the fundamental cause of multiphase gas, can be smaller than ~ pc, still far beyond the resolution of cosmological galaxy formation simulations. We highlight the importance of idealized simulations - radiative cloud crushing, thermal instability-driven condensation, multiphase turbulence, etc.- in understanding the multiphase CGM. These studies can not only help us understand trends in cosmological simulations and observations but also shed light on some of the fundamental physical processes.

Speaker : Shravan Hanasoge (TIFR)
Title : Using machine learning to discover new solar physics
Abstract:

Machine learning is a powerful tool with which to build correlations between disparate quantities, and is therefore well adapted to discover patterns in datasets and discover new physics. Heliophysics data in particular, which are vast and comprise many different observables, are an excellent fit for these methods. Solar magnetism is the cause of violent phenomena such as flares and eruptions, responsible for space weather and potentially significant Earth- and space-based infrastructure damages. However, processes responsible for the emergence of new sunspots as well as dynamics preceding events such as powerful flares and coronal mass ejections are poorly understood. Space-based telescopes such as the Solar Dynamics Observatory make available terabytes of high-resolution and high-cadence data of photospheric magnetic field, velocity field and atmospheric intensity. I will describe how deep learning can be used to

probe these large datasets to reveal characteristic pre-emergence and pre-flare signatures and shed light on the underlying physics.

Speaker : Dibyendu Nandi (IISER Kolkata)
Title : Star Planet Interactions: Space Weather to Exoplanets
Abstract:
The activity of stars such as the Sun influences planetary environments. The consequence of stellar activity ranges from creation of space weather – impacting satellites and space-reliant technologies, to forcing of planetary atmospheres – impacting atmospheric evolution and the habitability of planets. In our own solar system, the dynamic activity of the Sun, interactions of solar wind and magnetic storms with planetary atmospheres with or without magnetospheres, provide an opportunity to study the physics of star-planet interactions. Understanding these phenomena – which occurs over a range of length- and time-scales – require complex, computationally intensive numerical modelling. In this talk, I shall review this exciting area of interdisciplinary research, and highlight computational modelling efforts at CESSI, IISER Kolkata which seeks to generate a comprehensive understanding of star-planet interactions in solar and exoplanetary systems.

Speaker : Piyali Chatterjee (IIA)
Title : Solar atmospheric dynamics through MHD simulations
Abstract:
The extremely dynamic solar atmosphere presents us with several grand challenge problems in the area of Plasma physics. We will focus on two of those through the lens of MHD simulations guided suitably by observations, namely - 1) The million degree Kelvin kinetic temperature of the solar coronal plasma and, 2) Prediction of eruptive phenomena on the Sun like the solar flares and the coronal mass ejections. We will elaborate on the intricacies of such radiative-MHD models including solving radiative transfer alongside MHD equations, anisotropic Spitzer conductivity along magnetic field lines and semi-relativistic Boris correction to account for large Alfven speeds and the physical processes behind the scene.

Speaker : Nishant Singh (IUCAA)
Title : Self-consistent formation of sunspot-like magnetic flux concentrations
Abstract:
An important goal of solar physics is to understand the mechanism of sunspot formation on the photosphere. In our recent high resolution simulations of turbulent magneto-convection, we find that the sunspot-like magnetic flux concentrations form on the surface in a self-consistent manner. I will highlight some details of these simulations and will share some new insights on the possible mechanism involved in formation of such concentrations in simulations.

Speaker : Sourav Chatterjee (TIFR)
Title : Numerical Modeling of Large-N Star Clusters
Abstract:
Dense and massive star clusters, such as globular clusters, nuclear clusters, and young super star clusters are efficient factories for the creation of a plethora of stellar exotica including gravitational wave sources, tidal disruption events, X-ray binaries, millisecond pulsars, cataclysmic variables, and blue straggler stars. The recent observational breakthroughs, especially by Gaia and MUSE collaborations, are providing unprecedented kinematic constraints on star cluster members making detailed dynamical modeling of star clusters more relevant than ever. The large number of stars and old ages of many of these systems ensure intricate interplay between single and binary stellar evolution and dynamical processes. The large

ranges of length and timescales involved in this problem makes this computationally expensive. I will talk about various types of gravitational N-body systems and the relevant physical processes. I will briefly discuss the different existing methods to solve this problem. I will focus on a highly successful method, Hénon-type Monte Carlo, and talk about our recent results from star-by-star models of globular clusters using a code, CMC, based on this method.

Speaker : Robi Banerjee (Universität Hamburg)
Title: Star formation triggered by magnetic fields
Abstract:
Magnetic fields are ubiquitous on all astrophysical scales and objects. They also permeate entire galaxies, where the energy density of magnetic fields is comparable or even larger than the thermal energy. Hence magnetic fields have a wide impact on the dynamics of the interstellar medium (ISM). In this talk, I'll discuss how stars are formed in galaxies in the presence of strong magnetic fields due to Parker Instability

Speaker : Kinsuk Acharyya (PRL)
Title : The Universe as a Giant Laboratory: The Making of Complex Molecules from Atoms
Abstract:
Molecules are found in a wide variety of astronomical conditions, ranging from star-forming regions to the outer envelopes of carbon stars, and from objects in our own solar system to distant metal-poor galaxies. Complexity of these molecules range from simple diatomic molecules to amino acids such as glycine. Their association with various phases of star and planet formation are of particular interest, they can serve as building blocks of more complex molecules and can provide an insight into the primordial composition of our planet Earth, thereby addressing the issue "how life originated on Earth". Besides, they are useful probes of the physical conditions of their environment and related to the lifetime of the sources. There are many molecules which are not found in the terrestrial conditions are of interest for what they tell about the build up of molecular complexity throughout the Universe. Therefore, the study of the formation of these molecules is of paramount importance. In this talk, I will discuss how the formation of these molecules can be studied using numerical simulations in diverse astrophysical sources.

Speaker : Jasjeet Bagla (IISER Mohali)
Title : The significance of a mathematical model and the art of approximation
Abstract:
I will use three examples to show that having a mathematical model is essential to understand weaknesses of any algorithm, and that it is critical to make suitable approximations in order to make the computation tractable. The examples I will use are: The cosmological N-Body problem, The Bondi accretion and population III stars, and non-linear clustering with dark energy.

Speaker : Girish Kulkarni
Title : Cosmological Radiative Transfer Simulations
Abstract:
Radiation plays an outsized role in the large-scale properties of the Universe. It is radiation that couples the small-scale astrophysics of stars and black holes within galaxies to the large-scale thermal state of the Universe. In recent years, increasing precision of cosmological data have therefore made cosmological radiative transfer simulations indispensable. This trend is expected to further strengthen in the coming decades with data expected from facilities such as SKA, TMT, and JWST. Interestingly, cosmological radiative transfer also still remains an open problem in computational astrophysics with no consensus on

what algorithm is best. In this talk, I will describe the current landscape of research in cosmological radiative transfer simulations and recent science results that have been enabled by them. I will highlight some surprises revealed by these simulations and how new technologies such as GPUs have driven progress in this area. Finally, I will comment on open issues and what the future may bring.

Speaker : Sukanta Bose (IUCAA)
Title : Comprehending nature's densest objects with gravity's messengers
Abstract:
With several compact object mergers already in its trove, gravitational-wave astronomy is now at the cusp of widening its net for more diverse observations. This quest is partly fueled by the curiosity for probing how extreme some of nature's relativistic solutions can beand supported by ever-improving data analysis and computational techniques and algorithms. I will discuss what it has taught us about the densest form of matter in the recent years and project what more we may learn in the coming ones.

Speaker : Indranil Chattopadhyay (ARIES)
Title: Numerical simulation of accretion and jets around compact objects
Abstract:
Matter falling onto or ejecting out of the environments around compact objects like blackholes or neutron stars may be moving with relativistic speeds, or the constituent particles may be zigzag around with relativistic random speed. The thermodynamics of a gas whose particles may posses relativistic random speed, should be described by relativistic equation of state (EoS). We obtained a number of exact solutions for various Riemann problem using a relativistic EoS, which acts as checks for various numerical codes. We then developed a numerical code based on TVD scheme and study matter falling onto black holes, as well as, radiatively driven outflows. We match various accretion solutions with theoretical steady state solutions and then impose conditions to study various time dependent phenomena in accretion. We also study radiatively driven jets, and investigate how oscillations in the accretion disc might affect the jets.

Speaker : Prayush Kumar (ICTS)
Title: New computation paradigms in astrophysical relativity
Abstract:
General relativistic simulations of astrophysical phenomena is a computationally challenging task as the relevant equations are often nonlinear partial differential equations that couple vastly different spatial and temporal-scales. Our algorithms for tackling these problems have essentially remained unchanged for the past several decades. In this talk, I will introduce a new relativistic astrophysics code, SpECTRE, that combines the quasi-locality of discontinuous Galerkin (DG) methods with a task-based model for parallelizing computation. The robustness of the DG method allows for the use of high-resolution shock capturing methods in regions where (relativistic) shocks are found, while exploiting high-order accuracy in smooth regions. A task-based parallelism model allows efficient use of the largest supercomputers for problems with a heterogeneous workload over disparate scales. SpECTRE's goal is to achieve more accurate solutions for challenging relativistic astrophysics problems such as compact binary mergers and core-collapse supernovae.