Accretion and luminosity bursts across the stellar mass spectrum

Online workshop

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Abstract booklet

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"Reviewing recent observations of accretion bursts in HMYSOs"

A wealth of new theoretical and observational evidence supports now the idea that episodic accretion is a fundamental and common phenomenon across mass and time in star formation. In particular, the most recent discovery and follow-up of four accretion bursts from high-mass young stellar objects (HMYSOs) (S255IR NIRS3, NGC 6334I-MM1, G358.93-0.03 MM1 and G323.46-0.08) have been key to link low- and high-mass star-formation mechanisms to the common ground of disk-mediated accretion. In this talk we will review the main observables of such events and compare their physical properties (e.g. in terms of accreted mass, released energy, and length of the burst) with respect to their low-mass counterparts. Besides the classical direct outburst tracers, such as multi-wavelength light-curves and spectroscopy, our data also reveal that other important tracers, such as CH3OH and H2O maser flares or radio jet bursts, can provide fundamental information on these events.

Yaroslav Pavlyuchenkov (INSASN, Moscow)

“Evolution of a Viscous Protoplanetary Disk with Convectively Unstable Regions”

The role of convection in accretion disks around young stars is studied. The evolution of a disk is modeled using the Pringle equation, which describes the time variations of the surface density. The main factor governing evolution of the disk in this model is the dependence of the viscosity coefficient on the radial position within the disk. To evaluate this coefficient we take into account the background viscosity providing the continuous accretion of the gas and the convective viscosity, which depends on the parameters of the convection at a given radius. In order to identify convectively unstable regions and determine convective viscosity, the vertical structure of the disk

is reconstructed. The vertical structure is derived assuming that the disk is hydrostatically stable and heated by stellar radiation, interstellar radiation, and by viscous dissipation.
Within this model, the accretion history is analyzed at different rates and areas of matter inflow from the envelope onto the disk. It is shown that the burst-like regime occurs in a wide range of parameters. The long-term evolution of the massive disk is also modeled, including the decrescent matter inflow from the envelope. It is demonstrated that the disk becomes convectively unstable and maintains burst-like accretion onto the star for several million years. Meanwhile, the instability expands to an area of several tens of astronomical units and gradually decreases with time. It is also shown that at early stages in the disk evolution, conditions arise for gravitational instability in the outer parts of the disk and for dust evaporation in the convectively unstable inner regions. The general conclusion of the study is that convection can serve as one of the mechanisms of episodic accretion in protostellar disks, but this conclusion needs to be verified using more consistent hydrodynamic models.

Philip Lucas (U. of Hertfordshire)

"Very high amplitude protostellar eruptions discovered by VVV and WISE"

We present the Delta Ks>4 mag sample of variable stars discovered by 9.5 years of monitoring the inner Milky Way with VVV/VVVX. This complements the slightly lower amplitude (~2 to 4 mag) VVV sample presented by Dr Guo. Aside from transients, YSOs are the most numerous group in the sample. Most of the YSOs display episodic accretion events characterised by a slow rise on a timescale of 2 to 3 years, in contrast to the fast rise of classical FUors. Very deep extinction events are also seen in other YSOs. There is considerable variety in eruptive light curve morphologies, suggesting that multiple processes can cause episodic accretion. However, periodic accretion is very rare at the highest amplitudes, though it is more common in the lower amplitude sample. We also present a small sample of eruptive YSOs found in WISE/NEOWISE and we briefly summarise the remarkable 8 mag eruption of WISE 1422-6115.

Zhen Guo (U. of Hertfordshire)

"Spectroscopic follow-ups of near-infrared eruptive objects discovered from the VVV survey"

A large number of near-IR variables have been detected by the decade-long Vista Variables in the Via Lactea (VVV) survey. In this talk, I will present a statistical view of our spectroscopic follow- up study of 61 high amplitude variable YSOs ($\Delta K > 1$ mag). By applying mid-infrared light curves from

WISE, we found the relative scale between ΔK and ΔW2 can effectively distinguish extinction and accretion dominated variations. We found FUor-like outbursts have duration longer than one decade, and multi-year-long extinction dips are also seen on FUor-like objects. On the other hand, almost all long-term and high-amplitude variations are outbursts, and most of them (10 out of 14) are still controlled by magnetospheric accretion. Long term periodic and quasi- periodic variations are seen in 13 spectroscopic confirmed YSOs. This suggests that dynamic interactions with a companion may control the accretion rate in a substantial proportion of eruptive systems, although star-disc interactions should also be considered. In other periodic variables, extinction by asymmetric disc structures are involved.

Ágnes Kóspál (Konkoly Observatory, Budapest)

"Photometric and spectroscopic studies of old and new eruptive stars"

The Gaia astrometric mission has been issuing alerts for objects that display sudden large brightness variations. We have been doing photometric and spectroscopic follow-up work for the most promising candidates to discover new young eruptive stars. I will present interesting unpublished results from this project and our first published discovery of a new FUor among the Gaia alerts, Gaia18dvy. Parallel with this, we also revisit some long-known classical FUors to determine their current accretion state. From this project, I will show results on V1057 Cyg using our new optical and infrared photometric and spectroscopic monitoring data.

Tamara Molyarova (INASAN, Moscow)

"Chemical Signatures of the FU Ori Outbursts"

Luminosity outbursts of FU Ori-type objects strongly affect the thermal structure and radiation field in the surrounding protoplanetary disk, thus changing its chemical composition. Using a physical-chemical model ANDES, we study the impact of the FU Ori outburst on the disk chemical inventory. We identify gas-phase molecular tracers of the outburst activity that could be observed during and after the outburst. We find that H2CO and NH2OH remain in the gas phase for ∼10-1000 yr after the end of the outburst and could be used as indicators of the previous outbursts in the post-outburst FU Ori systems. We also consider observational perspectives for H2CO.

Kundan Kadam (U. of Western Ontario, Canada)

“Episodic Accretion in Low Metallicity Environments”

A protoplanetary disk typically forms a magnetically dead zone in its midplane at the distance of a few au from the central protostar. Accretion through such a layered disk is not steady but intrinsically unstable and can exhibit powerful FUor and EXor outburst events. In this talk, I will present the results of the first investigation into the effects of low metallicity environment on the dead zone and the associated outbursting behavior of the protoplanetary disk. I will elaborate on the details of the model and show that the low metallicity can have profound effects on both the disk's structure as well as its evolution in terms of episodic accretion. Most notably, a metal poor disk accumulates much more mass in the innermost regions and the duration of the burst phase is reduced significantly, confining it to the early, mostly embedded stages.

Vardan Elbakyan (U. of Leicester, SFedU)

“Distinguishing between different mechanisms of FU-Orionis-type luminosity outbursts”

It is generally agreed that FUors are caused by a sudden in-crease in the mass accretion rate from the disk on the protostar. However, the mechanisms that trigger such an increase are uncertain. In this talk I will consider accretion bursts triggered by three distinct mechanisms: the magnetorotational instability in the inner disk regions, clump infall in gravitationally fragmented disks and close encounters with an intruder star. I will show that the circumstellar disks featuring accretion bursts can bear kinematic features that are distinct for different burst mechanisms, which can be useful when identifying the burst origin.

Fernando Cruz-Saenz de Miera (Konkoly Observatory, Budapest)

“The jets, outflows and chemistry of the FUor-like L1551 IRS 5”

Here I will present our ongoing and future projects for the well known FUor-like protobinary L1551 IRS 5. These include our projects to analyze the jets emanating from the two protostars, in both radio and optical. I will present our ALMA observations which show outflow and envelope emission in CO, and the detection of several molecules, which showcase how eruptive young stars can be used to study the chemistry of young disks. Finally, I will compare our results with those from both quiescent and eruptive young stars.

Michael Kueffmeier (U. of Virginia, MPE)

"Infall: crucial, yet underrated "

Star and disk formation is commonly thought of in the framework of a collapsing gaseous sphere that is completely detached from its protostellar environment. However, stars and disks are embedded in Giant Molecular Clouds and stars may undergo infall events. At early times, such events can lead to feeding and replenishing of the disk with fresh material as shown in MHD zoom-in simulations. Apart from that, recent models indicate that stars, in particular more massive ones, may undergo substantial infall at t > 1 Myr after star formation. As shown in independent hydrodynamical AREPO simulations, such a late infall can explain arc- and tail-like structures associated with disks around Herbig stars. Interestingly, an encounter event of gas with an existing star can lead to the formation of a second-generation disk significantly after the initial protostellar collapse phase. Additionally, observations of shadows in disks can be well described by a configuration of misaligned inner and outer disk, such that the inner disk casts a shadow on the outer disk. Our models demonstrate that a second-generation disk with large misalignment with respect to an existing primordial disk can easily form if the infall angle is large. The second-generation outer disk is more eccentric, though the asymmetric infall also triggers eccentricity of the inner disk of e ≈ 0.05 to 0.1. Retrograde infall can lead to the formation of counter-rotating disks and enhanced accretion. As the angular momentum of the inner disk is reduced, the inner disk shrinks and a gap forms between the two disks. The resulting misaligned disk system can survive for ∼ 100 kyr or longer without aligning each other even for low primordial disk masses given an infall mass of ∼ 10-4 M. Apart from illustrating the tail-like structures in dust polarization, synthetic images of our models reveal shadows in the outer disk similar to the ones observed in multiple transition disks that are caused by the misaligned inner disk. We conclude that late infall events can be responsible for observations of shadows in at least some transition disks.

Carlos Contreras Pena (U. of Exeter, U of Hertfordshire)

"The Relationship between Mid-Infrared and Sub-Millimetre Variability of Deeply Embedded Protostars"

We study the relationship between the mid-infrared and sub-mm variability of deeply embedded protostars using the multi-epoch data from the Wide Infrared Survey Explorer (WISE/NEOWISE) and the ongoing James Clerk Maxwell Telescope (JCMT) transient survey. Our search for signs of stochastic (random) and/or secular (roughly monotonic in time) variability in a sample of 59 young stellar objects (YSOs) revealed that 35 are variable in at least one of the two surveys. This variability is dominated by secular changes. Of those objects with secular variability, 14 objects (22% of the sample) show correlated secular variability over mid-IR and sub-mm wavelengths. Variable accretion is the likely mechanism responsible for this type of variability. Fluxes of YSOs that vary in both wavelengths follow a relation of $\log_{10} F_{4.6}(t) = n \log_{10} F_{850}(t)$ between the mid-IR and sub-mm, with $n = 5.53 \pm 0.29$. This relationship arises from the fact that sub-mm fluxes respond to the dust temperature in the larger envelope whereas the mid-IR emissivity is more directly proportional to the accretion luminosity. The exact scaling relation, however, depends on the structure of the envelope, the importance of viscous heating in the disc, and dust opacity laws.

Dominique Meyer (U. Potsdam)

"The burst mode of accretion in massive star formation"

The burst mode of accretion in star formation is a paradigm that describes how stars acquire their mass during the birth of young stellar objects. One particular scenario proposes that the stars grow in mass via episodic accretion of fragments migrating from their gravitationally unstable circumstellar discs and it naturally explains the existence of observed pre-main sequence bursts from high-mass protostars. We will review the foundations of the burst mode of accretion is star formation, explicit the differences/similitudes between low-mass and high-mass star formation in the context of the recent observations of the high-mass star S255 NIRS 3.

Dimitris Stamatellos (U. of Central Lancashire)

"The effect of episodic radiative feedback on the properties of young discs"

Stars are born with discs that during their initial stages of formation are relatively massive, asymmetric and they are being fed with material from their parent clouds. The properties of these discs set the initial conditions for planet formation. We will present radiative hydrodynamic simulations of discs around young stars and examine how radiative feedback from the host star affects the disc properties and the associated observational signatures. We will also examine how episodic outbursts affect the development of gravitational instability in massive discs.

Hau-yu Baobab Liu (ASIAA, Taipei)

"Properties of the FU Ori disk within the inner 10 au radii"

Based on the VLTI/GRAVITY, Spitzer, Herschel, ALMA, and JVLA observations of dust continuum, we have previously considered that the inner 10 au (or larger) region of the FU Ori disk may be predominantly heated due to viscous heat dissipation. In addition, we obtained tentative evidence of the presence of ~2 millimeter sized dust grains, which has vertically settled closer to the mid-plane as compared with the distribution of the smaller grains. To confirm this, we have observed the radio continuum spectra at X, Ku, K, Ka, and Q bands (~8-50 GHz) in the summer of 2020. In this presentation I will show the preliminary observational results and compare them with our previous hypotheses.

Sheng-Yuan Liu (ASIAA, Taipei)

"The Mass Accretion/Infall in Massive Star Formation - A Case Study"

Characterizing the mass accretion phenomenon immediately surrounding the central young star remains particularly as an active research area for our understanding of the formation processes of massive stars. From the theoretical perspective, circumstellar discs around young stellar objects play a vital role in gauging the accretion as well as launching the jets and molecular outflows, through which angular momentum can be transported out and removed. Such disc-outflow interaction has been commonly observed in low mass protostellar systems. Do massive stars thus form like a scaled-up version of their low-mass counterpart? I will present our observational study on this subject with a case study toward the massive star forming core S255IR SMA1, a region which has been recently observed also with a luminosity burst.