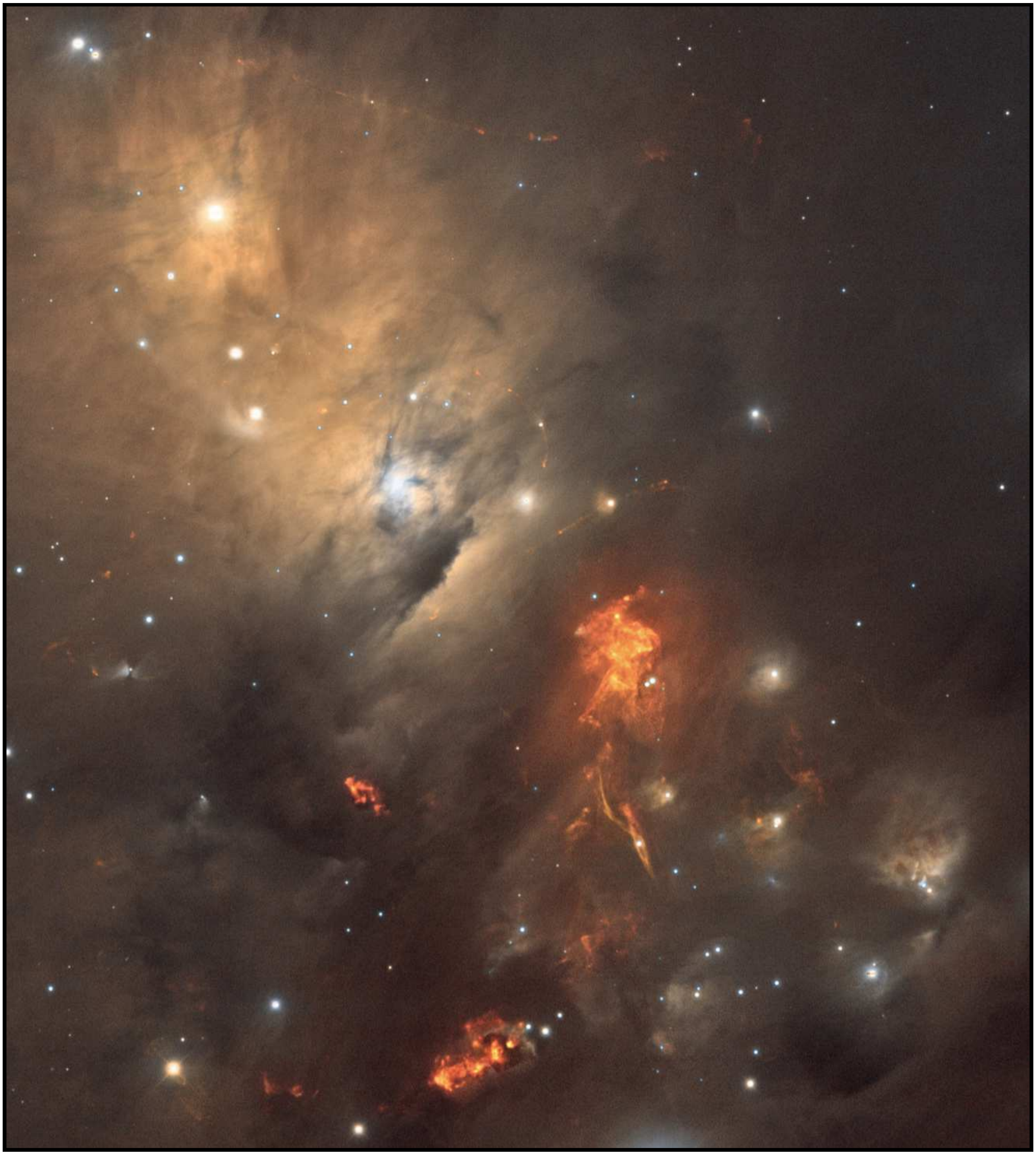
THE STAR FORMATION NEWSLETTER

An electronic publication dedicated to early stellar/planetary evolution and molecular clouds

No. 327 — 16 March 2020 Editor: Bo Reipurth (reipurth@ifa.hawaii.edu)



The Star Formation Newsletter

The Star Formation Newsletter is a vehicle for fast distribution of information of interest for astronomers working on star and planet formation and molecular clouds. You can submit material for the following sections: *Abstracts of recently accepted papers* (only for papers sent to refereed journals), *Abstracts of recently accepted major reviews* (not standard conference contributions), *Dissertation Abstracts* (presenting abstracts of new Ph.D dissertations), *Meetings* (announcing meetings broadly of interest to the star and planet formation and early solar system community), *New Jobs* (advertising jobs specifically aimed towards persons within the areas of the Newsletter), and *Short Announcements* (where you can inform or request information from the community). Additionally, the Newsletter brings short overview articles on objects of special interest, physical processes or theoretical results, the early solar system, as well as occasional interviews.

Newsletter Archive

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Cover Picture

NGC 1333 is a mini-starburst of low-mass star formation generating numerous Herbig-Haro objects. The large shocked region that dominates the image is HH 12, and the chain of knots at the bottom of the image is HH 7-11. The faint collimated jet at the top is HH 333, which is the HH jet with the highest collimation known. For identifications of other objects, see Walawender et al. Astron. J. 129, 2308, 2005. The color figure is a composite of Hα, [SII], and I-band images obtained at the Mayall 4m telescope.
Processing: Jon Talbot
http://www.starscapeimaging.com

Submitting your abstracts

Latex macros for submitting abstracts and dissertation abstracts (by e-mail to reipurth@ifa.hawaii.edu) are appended to each Call for Abstracts. You can also submit via the Newsletter web interface at http://www2.ifa.hawaii.edu/star-formation/index.cfm

Abstracts of recently accepted papers

Energy Optimization in Extrasolar Planetary Systems: The Transition from Peas-in-a-Pod to Runaway Growth

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Motivated by the trends found in the observed sample of extrasolar planets, this paper determines tidal equilibrium states for forming planetary systems — subject to conservation of angular momentum, constant total mass, and fixed orbital spacing. In the low-mass limit, valid for superearth-class planets with masses of order $m_\mathrm{p} \sim 10 M_\oplus$, previous work showed that energy optimization leads to nearly equal mass planets, with circular orbits confined to a plane. The present treatment generalizes previous results by including the self-gravity of the planetary bodies. For systems with sufficiently large total mass m_T in planets, the optimized energy state switches over from the case of nearly equal mass planets to a configuration where one planet contains most of the material. This transition occurs for a critical mass threshold of approximately $m_T \gtrsim m_C \sim 40 M_\oplus$ (where the value depends on the semimajor axes of the planetary orbits, the stellar mass, and other system properties). These considerations of energy optimization apply over a wide range of mass scales, from binary stars to planetary systems to the collection of moons orbiting the giant planets in our solar system.

Accepted by Monthly Notices of the Royal Astronomical Society

http://arXiv.org/pdf/2002.10661

Lithium-rotation connection in the newly discovered young stellar stream Psc-Eri (Meingast 1)

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Context. As a fragile element, lithium is a sensitive probe of physical processes occurring in stellar interiors. *Aims.* We aim to investigate the relationship between lithium abundance and rotation rate in low-mass members of the newly discovered 125 Myr-old Psc-Eri stellar stream. *Methods.* We obtained high-resolution optical spectra and measured the equivalent width of the 607.8 nm LiI line for 40 members of the Psc-Eri stream, whose rotational periods have been derived by Curtis et al. 2019. *Results.* We show that a tight correlation exists between lithium content and rotation rate among the late-G to early-K-type stars of the Psc-Eri stream. Fast rotators are systematically Li rich, while slow rotators are Li depleted. This trend mimics that previously reported for the similar age Pleiades cluster. *Conclusions.* The lithium-rotation connection thus seems to be universal over a restricted effective temperature range for low-mass stars at or close to the zero-age main sequence, and does not depend on environmental conditions.

Accepted by Astronomy & Astrophysics

http://arxiv.org/pdf/2002.10556

Dynamics of Planetary Systems Within Star Clusters: Aspects of the Solar System's Early Evolution

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Most planetary systems — including our own — are born within stellar clusters, where interactions with neighboring stars can help shape the system architecture. This paper develops an orbit-averaged formalism to characterize the cluster's mean-field effects as well as the physics of long-period stellar encounters. Our secular approach allows for an analytic description of the dynamical consequences of the cluster environment on its constituent planetary systems. We analyze special cases of the resulting Hamiltonian, corresponding to eccentricity evolution driven by planar encounters, as well as hyperbolic perturbations upon dissipative disks. We subsequently apply our results to the early evolution of our solar system, where the cluster's collective potential perturbs the solar system's plane, and stellar encounters act to increase the velocity dispersion of the Kuiper belt. Our results are two-fold: first, we find that cluster effects can alter the mean plane of the solar system by $\lesssim 1°$, and are thus insufficient to explain the $\psi \approx 6°$ obliquity of the sun. Second, we delineate the extent to which stellar flybys excite the orbital dispersion of the cold classical Kuiper belt, and show that while stellar flybys may grow the cold belt's inclination by the observed amount, the resulting distribution is incompatible with the data. Correspondingly, our calculations place an upper limit on the product of the stellar number density and residence time of the sun in its birth cluster, $\eta\tau \lesssim 2 \times 10^4$ Myr pc^{-3}.

Accepted by AJ

http://arxiv.org/pdf/2002.05656

Dynamical evolution of fractal structures in star-forming regions

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The Q-parameter is used extensively to quantify the spatial distributions of stars and gas in star-forming regions as well as older clusters and associations. It quantifies the amount of structure using the ratio of the average length of a minimum spanning tree, $\bar{m}$, to the average length within the complete graph, $\bar{s}$. The interpretation of the Q-parameter often relies on comparing observed values of Q, $\bar{m}$ and $\bar{s}$ to idealised synthetic geometries, where there is little or no match between the observed star-forming regions and the synthetic regions. We measure Q, $\bar{m}$ and $\bar{s}$ over 10 Myr in N-body simulations which are compared to IC 348, NGC 1333, and the ONC. For each star-forming region we set up simulations that approximate their initial conditions for a combination of different virial rations and fractal dimensions. We find that dynamical evolution of idealised fractal geometries can account for the observed Q, $\bar{m}$ and $\bar{s}$ values in nearby star-forming regions. In general, an initially fractal star-forming region will tend to evolve to become more smooth and centrally concentrated. However, we show that initial conditions, as well as where the edge of the region is defined, can cause significant differences in the path that a star-forming region takes across the $\bar{m}$–$\bar{s}$ plot as it evolves. We caution that the observed Q-parameter should not be directly compared to idealised geometries. Instead, it should be used to determine the degree to which a star-forming region is either spatially substructured or smooth and centrally concentrated.

Accepted by MNRAS

http://arxiv.org/pdf/2002.11140

Magnetorotational Instability in Diamagnetic, Misaligned Protostellar Discs

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In the present study, we addressed the question of how the growth rate of the magnetorotational instability is modified when the radial component of the stellar dipole magnetic field is taken into account in addition to the vertical component. Considering a fiducial radius in the disc where diamagnetic currents are pronounced, we carried out a linear stability analysis to obtain the growth rates of the magnetorotational instability for various parameters such as the ratio of the radial-to-vertical component and the gradient of the magnetic field, the Alfvenic Mach number and the diamagnetization parameter. Our results show that the interaction between the diamagnetic current and the radial component of the magnetic field increases the growth rate of the magnetorotational instability and generates a force perpendicular to the disc plane which may induce a torque. It is also shown that considering the radial component of the magnetic field and taking into account a radial gradient in the vertical component of the magnetic field causes an increase in the magnitudes of the growth rates of both the axisymmetric ($m = 0$) and the non-axisymmetric ($m = 1$) modes.

Accepted by MNRAS

http://arxiv.org/pdf/2002.02254

The origin of s-process isotope heterogeneity in the solar protoplanetary disk

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Rocky asteroids and planets display nucleosynthetic isotope variations that are attributed to the heterogeneous distribution of stardust from different stellar sources in the solar protoplanetary disk. Here we report new high precision palladium isotope data for six iron meteorite groups, which display smaller nucleosynthetic isotope variations than the more refractory neighbouring elements. Based on this observation we present a new model in which thermal destruction of interstellar medium dust results in an enrichment of s-process dominated stardust in regions closer to the Sun. We propose that stardust is depleted in volatile elements due to incomplete condensation of these elements into dust around asymptotic giant branch (AGB) stars. This led to the smaller nucleosynthetic variations for Pd reported here and the lack of such variations for more volatile elements. The smaller magnitude variations measured in heavier refractory elements suggest that material from high-metallicity AGB stars dominated stardust in the Solar System. These stars produce less heavy s-process elements compared to the bulk Solar System composition.

Accepted by Nature Astronomy

http://arxiv.org/pdf/2002.02155

Seeds of Life in Space (SOLIS).VII. Discovery of a cold dense methanol blob toward the L1521F VeLLO system

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The SOLIS (Seeds Of Life In Space) IRAM/NOEMA Large Program aims at studying a set of crucial complex organic molecules in a sample of sources, with well-known physical structure, covering the various phases of Solar-type star formation. One representative object of the transition from the prestellar core to the protostar phases has been observed toward the Very Low Luminosity Object (VeLLO) called L1521F. This type of source is important to study to make the link between prestellar cores and Class 0 sources and also to constrain the chemical evolution during the process of star formation. Two frequency windows (81.6–82.6 GHz and 96.65–97.65 GHz) were used to observe the emission from several complex organics toward the L1521F VeLLO. Only 2 transitions of methanol (A^+, E_2) have been detected in the narrow window centered at 96.7 GHz (with an upper limit on E_1) in a very compact emission blob ($\sim 7''$ corresponding to $\sim$1000 au) toward the NE of the L1521F protostar. The CS 2–1 transition is also detected within the WideX bandwidth. Consistently, with what has been found in prestellar cores, the methanol emission appears $\sim$1000 au away from the dust peak. The location of the methanol blob coincides with one of the filaments previously reported in the literature. The $T_{\rm ex}$ of the gas inferred from methanol is (10±2) K, while the H_2 gas density (estimated from the detected CS 2–1 emission and previous CS 5–4 ALMA obs.) is a factor >25 higher than the density in the surrounding environment ($n(H_2) > 10^7$ cm^{-3}). From its compactness, low excitation temperature and high gas density, we suggest that the methanol emission detected with NOEMA is either a cold and dense shock-induced blob, recently formed ($\leq$few hundred years) by infalling gas or a cold and dense fragment that may have just been formed as a result of the intense gas dynamics found within the L1521F VeLLO system.

Accepted by A&A

http://arxiv.org/pdf/2002.07004

Evolution of porous dust grains in protoplanetary discs – I. Growing grains

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One of the main problems in planet formation, hampering the growth of small dust to planetesimals, is the so-called radial-drift barrier. Pebbles of cm to dm sizes are thought to drift radially across protoplanetary discs faster than they can grow to larger sizes, and thus to be lost to the star. To overcome this barrier, drift has to be slowed down or stopped, or growth needs to be sped up. In this paper, we investigate the role of porosity on both drift and growth. We have developed a model for porosity evolution during grain growth and applied it to numerical simulations of protoplanetary discs. We find that growth is faster for porous grains, enabling them to transition to the Stokes drag regime, decouple from the gas, and survive the radial-drift barrier. Direct formation of small planetesimals from porous dust is possible over large areas of the disc.

Accepted by MNRAS

http://arxiv.org/pdf/2002.03204

ALMA chemical survey of disk-outflow sources in Taurus (ALMA-DOT) I. CO, CS, CN, and H_2CO around DG Tau B

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The chemical composition of planets is inherited by the distribution of the various molecular species in the protoplanetary disk at the time of their formation. As of today, only a handful of disks has been imaged in multiple spectral lines with high spatial resolution. As part of a small campaign devoted to the chemical characterization of disk outflow sources in Taurus, we report on new ALMA Band 6 observations with 20 au resolution toward the embedded young star DG Tau B. Images of the continuum emission reveals a dust disk with rings and, putatively, a leading spiral arm. The disk, as well as the prominent outflow cavities, are detected in CO, H_2CO, CS, and CN while they remain undetected in SO_2, HDO, and CH_3OH. From the absorption of the back-side outflow, we inferred that the disk emission is optically thick in the inner 50 au. This morphology explains why no line emission is detected from this inner region and poses some limitations toward the calculation of the dust mass and the characterization of the inner gaseous disk. The H_2CO and CS emission from the inner 200 au is mostly from the disk and their morphology is very similar. The CN emission significantly differs from the other two molecules as it is observed only beyond 150 au. This ring-like morphology is consistent with previous observations and the predictions of thermochemical disk models. Finally, we constrained the disk-integrated column density of all molecules. In particular, we found that the CH_3OH/H_2CO ratio must be smaller than 2, making the methanol non-detection still consistent with the only such a ratio available from the literature (1.27 in TW Hya).

Accepted by A&A

https://arxiv.org/pdf/2002.10195

A Novel Survey for Young Substellar Objects with the W-band filter II. The Coolest and Lowest Mass Members of the Serpens-South Star-forming Region

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Given its relative proximity (∼430 pc), compact size ($< 20'$), young age (~ 0.5 Myr) and rich number of young stellar objects, the Serpens-South star forming region is a promising site for studying young sub-stellar objects, yet the low-mass members of this region remain largely undiscovered. In this paper we report on a deep photometric survey using a custom 1.45 μm filter (W-band), as well as standard J and H near-IR filters, in order to identify candidate low-mass young brown-dwarfs in the Serpens-South region. We constructed a reddening-insensitive index (Q) by combining J, H and W-band photometry for survey objects, in order to identify candidate low-mass members of Serpens based on the strength of the water absorption feature at 1.45 μm in the atmospheres of mid-M and later objects. We then conducted spectroscopic follow up to confirm youth and spectral type for our candidates. This is the first survey to identify the very low-mass and coolest members of Serpens-South. We identify 4 low-mass candidate Serpens members, which all display IR excess emission, indicating the likely presence of circumstellar disks around them. One of the four candidate low-mass members in our list, SERP182918-020245, exhibits $Pa\beta$ and $Br\gamma$ emission features, confirming its youth and ongoing magnetospheric accretion. Our new candidate members have spectral types >M4 and are the coolest and lowest mass candidate members yet identified in Serpens-South.

Accepted by ApJ

https://arxiv.org/pdf/2002.02473.pdf

Mass constraints for 15 protoplanetary disks from HD 1-0

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Hydrogen deuteride (HD) rotational line emission can provide reliable protoplanetary disk gas mass measurements, but it is difficult to observe and detections have been limited to three T Tauri disks. No new data have been available since the *Herschel* Space Observatory mission ended in 2013. We set out to obtain new disk gas mass constraints by analysing upper limits on HD 1-0 emission in *Herschel*/PACS archival data from the DIGIT key programme. With a focus on the Herbig Ae/Be disks, whose stars are more luminous than T Tauris, we determine upper limits for HD in data previously analysed for its line detections. Their significance is studied with a grid of models run with the DALI physical-chemical code, customised to include deuterium chemistry. Nearly all the disks are constrained to $M_{gas} \leq 0.1\,M_{\odot}$, ruling out global gravitational instability. A strong constraint is obtained for the HD 163296 disk mass, $M_{gas} \leq 0.067\,M_{\odot}$, implying $\Delta_{g/d} \leq 100$. This HD-based mass limit is towards the low end of CO-based mass estimates for the disk, highlighting the large uncertainty in using only CO and suggesting that gas-phase CO depletion in HD 163296 is at most a factor of a few. The M_{gas} limits for HD 163296 and HD 100546, both bright disks with massive candidate protoplanetary systems, suggest disk-to-planet mass conversion efficiencies of $M_p/(M_{gas}+M_p) \approx 10$ to 40% for present-day values. Near-future observations with SOFIA/HIRMES will be able to detect HD in the brightest Herbig Ae/Be disks within 150pc with ≈ 10 h integration time.

Accepted by Astronomy & Astrophysics

https://arxiv.org/pdf/1912.11883

Model of a gap formed by a planet with fast inward migration

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A planet is formed within a protoplanetary disk. Recent observations have revealed substructures such as gaps and rings, which may indicate forming planets within the disk. Due to disk–planet interaction, the planet migrates within the disk, which can affect a shape of the planet-induced gap. In this paper, we investigate effects of fast inward migration of the planet on the gap shape, by carrying out hydrodynamic simulations. We found that when the migration timescale is shorter than the timescale of the gap-opening, the orbital radius is shifted inward as compared to the radial location of the gap. We also found a scaling relation between the radial shift of the locations of the planet and the gap as a function of the ratio of the timescale of the migration and gap-opening. Our scaling relation also enables us to constrain the gas surface density and the viscosity when the gap and the planet are observed. Moreover, we also found the scaling relation between the location of the secondary gap and the aspect ratio. By combining the radial shift and the secondary gap, we may constrain the physical condition of the planet formation and how the planet evolves in the protoplanetary disk, from the observational morphology.

Accepted by ApJ

http://arxiv.org/pdf/2002.08217

Distortion of Magnetic Fields in BHR 71

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The magnetic field structure of a star-forming Bok globule BHR 71 was determined based on near-infrared polarimetric observations of background stars. The magnetic field in BHR 71 was mapped from 25 stars. By using a simple 2D parabolic function, the plane-of-sky magnetic axis of the core was found to be $\theta_{\rm mag} = 125^\circ \pm 11^\circ$. The plane-of-sky mean magnetic field strength of BHR 71 was found to be $B_{\rm pos} = 8.8 - 15.0\ \mu$G, indicating that the BHR 71 core is magnetically supercritical with $\lambda = 1.44 - 2.43$. Taking into account the effect of thermal/turbulent pressure and the plane-of-sky magnetic field component, the critical mass of BHR 71 was $M_{\rm cr} = 14.5 - 18.7$ M$_\odot$, which is consistent with the observed core mass of $M_{\rm core} \approx 14.7$ M$_\odot$ (Yang et al. 2017). We conclude that BHR 71 is in a condition close to a kinematically critical state, and the magnetic field direction lies close to the plane of sky. Since BHR 71 is a star-forming core, a significantly subcritical condition (i.e., the magnetic field direction deviating from the plane of sky) is unlikely, and collapsed from a condition close to a kinematically critical state. There are two possible scenarios to explain the curved magnetic fields of BHR 71, one is an hourglass-like field structure due to mass accumulation and the other is the Inoue & Fukui (2013) mechanism, which proposes the interaction of the core with a shock wave to create curved magnetic fields wrapping around the core.

Accepted by Astrophysical Journal

https://arxiv.org/pdf/2002.12512

Stability and Solution of the Time-Dependent Bondi-Parker Flow

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Bondi (1952) and Parker(1958) derived a steady-state solution for Bernouilli's equation in spherical symmetry around a point mass for two cases, respectively, an inward accretion flow and an outward wind. Left unanswered were the stability of the steady-state solution, the solution itself of time-dependent flows, whether the time-dependent flows would evolve to the steady-state, and under what conditions a transonic flow would develop. In a Hamiltonian description, we find that the steady state solution is equivalent to the Lagrangian implying that time-dependent flows evolve to the steady state. We find that the second variation is definite in sign for isothermal and adiabatic flows, implying at least linear stability. We solve the partial differential equation for the time-dependent flow as an initial-value problem and find that a transonic flow develops under a wide range of realistic initial conditions. We present some examples of time-dependent solutions.

Accepted by MNRAS

https://arxiv.org/pdf/2002.09004

CS Depletion in Prestellar Cores

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The CS molecule is known to be adsorbed onto dust in the cold and dense conditions, causing it to get significantly depleted in the central region of cores. This study is aimed to investigate the depletion of the CS molecule using the optically thin $C^{34}S$ molecular line observations. We mapped five prestellar cores, L1544, L1552, L1689B, L694-2 and L1197 using two molecular lines, $C^{34}S$ ($J = 2-1$) and N_2H^+ ($J = 1-0$) with the NRO 45-m telescope, doubling the number of cores where the CS depletion was probed using $C^{34}S$. In most of our targets, the distribution of $C^{34}S$ emission shows features that suggest that the CS molecule is generally depleted in the center of the prestellar cores. The radial profile of the CS abundance with respect to H_2 directly measured from the CS emission and the *Herschel* dust emission indicates that the CS molecule is depleted by a factor of ~ 3 toward the central regions of the cores with respect to their outer regions. The degree of the depletion is found to be even more enhanced by an order of magnitude when the contaminating effect introduced by the presence of CS molecules in the surrounding envelope that lie along the line-of-sight is removed. Except for L1197 which is classified as relatively the least evolved core in our targets based on its observed physical parameters, we found that the remaining four prestellar cores are suffering from significant CS depletion at their central region regardless of the relative difference in their evolutionary status.

Accepted by ApJ

https://arxiv.org/pdf/2002.06857

Spiral structures in an embedded protostellar disk driven by envelope accretion

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Hydrodynamical simulations show that a pair of spiral arms can form in the disk around a rapidly growing young star and that the arms are crucial in transporting angular momentum as the disk accretes material from the surrounding envelope. Here we report the detection of a pair of symmetric spiral structures in a protostellar disk, supporting the formation of spiral arms in the disk around a forming star. The HH 111 VLA 1 source is a young Class I source embedded in a massive infalling protostellar envelope and is actively accreting, driving the prominent HH 111 jet. Previous observations showed a ring of shock emission around the disk's outer edge, indicating accretion of the envelope material onto the disk at a high rate. Now with ALMA observations of thermal emission from dust particles, we detect a pair of spiral arms extending from the inner region to the disk's outer edge, similar to that seen in many simulations. Additionally, the disk is massive, with a Toomre Q parameter near unity in the outer parts where the spiral structures are detected, supporting the notion that envelope accretion is making the outer disk gravitationally unstable. In our observations, another source, HH 111 VLA 2, is spatially resolved for the first time, showing a disk-like structure with a diameter of $\sim$26 au and an orientation nearly orthogonal to that of the HH 111 VLA 1 disk.

Accepted by Nature Astronomy

https://www.nature.com/articles/s41550-019-0905-x

Internal motions in OB-associations with Gaia DR2

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We study the motions inside 28 OB-associations with the use of Gaia DR2 proper motions. The average velocity dispersion calculated for 28 OB-associations including more than 20 stars with Gaia DR2 proper motion is $\sigma_v = 4.5$

km s^{-1}. The median virial and stellar masses of OB-associations are $M_{\rm vir} = 8.9 \times 10^5$ and $M_{\rm st} = 8.1 \times 10^3\ M_\odot$, respectively. The median star-formation efficiency in parent giant molecular clouds appears to be $\epsilon = 1.2$ per cent. Gaia DR2 proper motions confirm the expansion in the Per OB1, Car OB1 and Sgr OB1 associations found earlier with Gaia DR1 data. We also detect the expansion in Gem OB1, Ori OB1 and Sco OB1 associations which became possible for the first time now when analyzed with Gaia DR2 proper motions. The analysis of the distribution of OB-stars in the Per OB1 association shows the presence of a shell-like structure with the radius of 40 pc. Probably, the expansion of the Per OB1 association started with the velocity greater than the present-day expansion velocity equal to 5.0±1.7 km s^{-1}.

Accepted by MNRAS

http://arxiv.org/pdf/2002.05044

On the turbulence driving mode of expanding HII regions

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We investigate the turbulence driving mode of ionizing radiation from massive stars on the surrounding interstellar medium (ISM). We run hydrodynamical simulations of a turbulent cloud impinged by a plane-parallel ionization front. We find that the ionizing radiation forms pillars of neutral gas reminiscent of those seen in observations. We quantify the driving mode of the turbulence in the neutral gas by calculating the driving parameter b, which is characterised by the relation $\sigma_s^2 = \ln(1 + b^2\mathcal{M}^2)$ between the variance of the logarithmic density contrast σ_s^2 (where $s = \ln(\rho/\rho_0)$ with the gas density ρ and its average ρ_0), and the turbulent Mach number $\mathcal{M}$. Previous works have shown that $b \sim 1/3$ indicates solenoidal (divergence-free) driving and $b \sim 1$ indicates compressive (curl-free) driving, with $b \sim 1$ producing up to ten times higher star formation rates than $b \sim 1/3$. The time variation of b in our study allows us to infer that ionizing radiation is inherently a compressive turbulence driving source, with a time-averaged $b \sim 0.76 \pm 0.08$. We also investigate the value of b of the pillars, where star formation is expected to occur, and find that the pillars are characterised by a natural mixture of both solenoidal and compressive turbulent modes ($b \sim 0.4$) when they form, and later evolve into a more compressive turbulent state with $b \sim 0.5$–0.6. A virial parameter analysis of the pillar regions supports this conclusion. This indicates that ionizing radiation from massive stars may be able to trigger star formation by producing predominately compressive turbulent gas in the pillars.

Accepted by MNRAS

http://arxiv.org/pdf/2002.08707

Protostellar Outflows at the EarliesT Stages (POETS). IV. Statistical properties of the 22 GHz H_2O masers

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We wish to perform a statistical study of the location and motion of individual 22 GHz water maser cloudlets, characterized by sizes that are within a few au, with respect to the radio thermal emission from young stellar objects (YSO). For this purpose, we have been carrying out the Protostellar Outflows at the EarliesT Stages (POETS) survey of a sample (38) of high-mass YSOs. The water maser positions and three-dimensional (3D) velocities were determined through Very Long Baseline Array observations with accuracies of a few milliarcsec (mas) and a few

km s^{-1}, respectively. The position of the ionized core of the protostellar wind, marking the YSO, was determined through sensitive continuum Jansky Very Large Array observations with a typical error of 20 mas. The statistic of the separation of the water masers from the radio continuum shows that 84% of the masers are found within 1000 au from the YSO and 45% of them are within 200 au. Therefore, we can conclude that the 22 GHz water masers are a reliable proxy for the YSO position. The distribution of maser luminosity is strongly peaked towards low values, indicating that about half of the maser population is still undetected with the current Very Long Baseline Interferometry detection thresholds of 50–100 mJy beam^{-1}. Next-generation, sensitive radio interferometers will exploit these weak masers for an improved sampling of the velocity and magnetic fields around the YSOs. The average direction of the water maser proper motions provides a statistically-significant estimate for the orientation of the jet emitted by the YSO: 55% of the maser proper motions are directed on the sky within an angle of 30° from the jet axis. Finally, we show that our measurements of 3D maser velocities statistically support models in which water maser emission arises from planar shocks with propagation direction close to the plane of the sky.

Accepted by A&A

http://arxiv.org/pdf/2002.06871

Rocking shadows in broken circumbinary discs

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We use three dimensional simulations with coupled hydrodynamics and Monte Carlo radiative transfer to show that shadows cast by the inner disc in broken circumbinary discs move within a confined range of position angles on the outer disc. Over time, shadows appear to rock back and forth in azimuth as the inner disc precesses. The effect occurs because the inner disc precesses around a vector that is not the angular momentum vector of the outer disc. We relate our findings to recent observations of shadows in discs

Accepted by MNRAS Letters

http://arxiv.org/pdf/2002.02983

Episodic accretion constrained by a rich cluster of outflows

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The accretion history of protostars remains widely mysterious even though it represents one of the best ways to understand the protostellar collapse that leads to the formation of stars. Molecular outflows are here used to characterize the protostellar accretion phase in W43-MM1. The W43-MM1 protocluster host a sufficient number of protostars to statistically investigate molecular outflows in a single, homogeneous region. We used the CO(2–1) and SiO(5–4) line datacubes, taken as part of an ALMA mosaic with a 2000 AU resolution, to search for protostellar outflows, evaluate the influence that the environment has on these outflows' characteristics and put constraints on outflow variability in W43-MM1. We discovered a rich cluster of 46 outflow lobes, driven by 27 protostars with masses of 1–100 $M_{\odot}$. The complex environment inside which these outflow lobes develop has a definite influence on their length, limiting the validity of using outflows' dynamical timescales as a proxy of the ejection timescale in clouds with high dynamics and varying conditions. We performed a detailed study of Position-Velocity (PV) diagrams of outflows that revealed clear events of episodic ejection. The time variability of W43-MM1 outflows is a general trend and is more generally observed than in nearby, low- to intermediate-mass star-forming regions. The typical timescale found between two ejecta, about 500 yr, is consistent with that found in nearby protostars. If ejection episodicity reflects variability

in the accretion process, either protostellar accretion is more variable or episodicity is easier to detect in high-mass star-forming regions than in nearby clouds. The timescale found between accretion events could be resulting from disk instabilities, associated with bursts of inflowing gas arising from the dynamical environment of high-mass star-forming cores.

Accepted by A&A

http://arxiv.org/pdf/2002.05720

GG Tau A: gas properties and dynamics from the cavity to the outer disk

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GG Tau A is the prototype of a young triple T Tauri star that is surrounded by a massive and extended Keplerian outer disk. The central cavity is not devoid of gas and dust and at least GG Tau Aa exhibits its own disk of gas and dust emitting at millimeter wavelengths. Its observed properties make this source an ideal laboratory for investigating planet formation in young multiple solar-type stars. We used new ALMA ^{13}CO(3–2) and C^{18}O(3–2) observations obtained at high angular resolution ($\sim 0.2''$) together with previous CO(3–2) and (6–5) ALMA data and continuum maps at 1.3 and 0.8 mm in order to determine the gas properties (temperature, density, and kinematics) in the cavity and to a lesser extent in the outer disk.
By deprojecting, we studied the radial and azimuthal gas distribution and its kinematics. We also applied a new method to improve the deconvolution of the CO data and in particular better quantify the emission from gas inside the cavity. We perform local nonlocal thermodynamic equilibrium studies in order to determine the excitation conditions and relevant physical parameters inside the ring and in the central cavity.
Residual emission after removing a smooth-disk model indicates unresolved structures at our angular resolution, probably in the form of irregular rings or spirals. The outer disk is cold, with a temperature < 20 K beyond 250 au that drops quickly ($\propto r^{-1}$). The kinematics of the gas inside the cavity reveals infall motions at about 10% of the Keplerian speed. We derive the amount of gas in the cavity, and find that the brightest clumps, which contain about 10% of this mass, have kinetic temperatures $40 - 80$ K, CO column densities of a few 10^{17} cm^{-2}, and H_2 densities around 10^7 cm^{-3}.
Although the gas in the cavity is only a small fraction of the disk mass, the mass accretion rate throughout the cavity is comparable to or higher than the stellar accretion rate. It is accordingly sufficient to sustain the circumstellar disks on a long timescale.

Accepted by Astronomy & Astrophysics

http://arxiv.org/pdf/2001.08147

Planet induced spirals in the circumbinary disk of GG Tau A

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ALMA high angular resolution observations of the dust and CO emission have already revealed signatures of protoplanets embedded in protoplanetary disks. These detections are around single T Tauri stars while exo-planet surveys reveal that planets can also form in binary (or multiple) systems, either in circumstellar or circumbinary orbits. We searched for indirect evidence for planet formation in the multiple system GG Tau A that harbors the most massive circumbinary disk among T Tauri stars.
We performed CO(2–1) ALMA Cycle 6 observations of GG Tau A at $0.3''$ resolution. The images confirm the "hot spot" detected at higher frequencies, but also reveal prominent spiral-like features. We model these features by using the analytic prescription for the linear perturbation regime induced by low-mass planets.
The brightest spiral is well reproduced by a density wave excited by a protoplanet (GG Tau Ac) at the hot-spot location (290 au), just outside the dust ring. The absence of a clear gap (in gas or dust) at the planet location implies that its mass is significantly lower than that of Jupiter, i.e. of the order of the mass of Neptune or less. Furthermore, other prominent (trailing) spiral patterns can be represented by adding one (or more) planet(s) at larger orbital radii, with the most obvious candidate located near the 2:1 mean-motion resonance with GG Tau Ac.
The (proto-)planet GG Tau Ac appears to externally confine the ring in a stable configuration, explaining its high mass. Our results also suggest that planets similar in mass to Neptune may form in dense circumbinary disks orbiting (wide) binary stars. In the GG Tau case, orbital resonances appear to play an important role in shaping this multiple circumbinary planet system.

Accepted by Astronomy and Astrophysics (A&A Letters)

Chemistry Along Accretion Streams in a Viscously-Evolving Protoplanetary Disk

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The composition of a protoplanetary disk is set by a combination of interstellar inheritance and gas and grain surface chemical reactions within the disk. The survival of inherited molecules, as well as the disk in situ chemistry depends on the local temperature, density and irradiation environment, which can change over time due to stellar and disk evolution, as well as transport in the disk. We address one aspect of this coupling between the physical and chemical evolution in disks by following accretion streamlines of gas and small grains in the disk midplane, while simultaneously taking the evolving star into account. This approach is computationally efficient and enables us to take into account changing physical conditions without reducing the chemical network. We find that many species are enhanced in the inner disk midplane in the dynamic model due to inward transport of cosmic-ray driven chemical products, resulting in, e.g., orders-of magnitude hydrocarbon enhancements at 1 au, compared to a static disk. For several other chemical families, there is no difference between the static and dynamic models, indicative of a robust chemical reset, while yet others show differences between static and dynamic models that depend on complex interactions between physics and chemistry during the inward track. The importance of coupling dynamics and chemistry when modeling the chemical evolution of protoplanetary disks is thus depends on what chemistry is of interest.

Accepted by ApJ

http://arxiv.org/pdf/2002.04651

A Massive Young Runaway Star in W49 North

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We analyzed high-angular resolution 45.5 GHz images of the W49 North massive star-forming region obtained in 1998 and 2016 with the Very Large Array. Most of the ultracompact H II regions show no detectable changes over the time interval of the observations. However, subcomponents B1, B2, G2a, and G2c have increased its peak flux densities by values in the range of 3.8 to 21.4%. Most interestingly, the cometary region C clearly shows proper motions that at the distance of the region are equivalent to a velocity of 76±6 km s^{-1} in the plane of the sky. We interpret this region as the ionized bowshock produced by a runaway O6 ZAMS star that was ejected from the eastern edge of Welch's ring about 6400 yr ago.

Accepted by The Astrophysical Journal

http://arxiv.org/pdf/2002.02894

Proper Motions of the Radio Source Orion MR, Formerly Known as Orion n, and New Sources with Large Proper Motions in Orion BN/KL

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The infrared source known as Orion n was detected in 1980 with observations made with the 3.8-m United Kingdom Infrared Telescope. About two decades later, sensitive observations made with the Very Large Array revealed the presence of a mJy double radio source apparently coincident in position with the infrared source n. The radio source was assumed to be the counterpart of the infrared source. However, over the years it has been concluded that the radio source shows large proper motions to the south while the infrared source n is stationary. Here we reanalyze the proper motions of the radio source adding both older and newer VLA observations than previously used. We confirm the proper motions of the radio source that at present no longer coincides positionally with the infrared source. The solution to this problem is, most probably, that the infrared source n and the radio source are not the same object: the infrared source is a stationary object in the region while the radio counterpart is moving as a result of the explosion that took place in this region some 500 years ago and that expelled large amounts of molecular gas as well as several compact sources. Considering the paper where it was first reported, we refer to this double radio source as Orion MR. In addition, we use these new observations to fully confirm the large proper motions of the sources IRc23 and Zapata 11. Together with sources BN, I, Orion MR, and x, there are at least six compact sources that recede from a point in common in Orion BN/KL. However, IRc23 is peculiar in that its ejection age appears to be only ∼300 years. The relatively large number of sources rules out as a possible mechanism the classic three-body scenario since then only two escaping bodies are expected: a tight binary plus the third star involved in the encounter.

Accepted by The Astrophysical Journal

http://arxiv.org/pdf/2002.12513

Time-domain study of the young massive cluster Westerlund 2 with the Hubble Space Telescope. I

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Time-domain studies of pre-main sequence stars have long been used to investigate star properties during their early evolutionary phases and to trace the evolution of circumstellar environments. Historically these studies have been confined to the nearest, low-density, star forming regions. We used the Wide Field Camera 3 on board of the Hubble Space Telescope to extend, for the first time, the study of pre-main sequence variability to one of the few young massive clusters in the Milky Way, Westerlund 2. Our analysis reveals that at least 1/3 of the intermediate and low-mass pre-main sequence stars in Westerlund 2 are variable. Based on the characteristics of their light curves, we classified $\sim$11% of the variable stars as weak-line T-Tauri candidates, $\sim$52% as classical T-Tauri candidates, $\sim$5% as dippers and $\sim$26% as bursters. In addition, we found that 2% of the stars below 6 $M_\odot$ ($\sim$6% of the variables) are eclipsing binaries, with orbital periods shorter than 80 days. The spatial distribution of the different populations of variable pre-main sequence stars suggests that stellar feedback and UV-radiation from massive stars play an important role on the evolution of circumstellar and planetary disks.

Accepted by ApJ

http://arxiv.org/pdf/2002.04574

On the coexistence of the streaming instability and the vertical shear instability in protoplanetary disks

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The streaming instability is a leading candidate mechanism to explain the formation of planetesimals. Yet, the role of this instability in the driving of turbulence in protoplanetary disks, given its fundamental nature as a linear hydrodynamical instability, has so far not been investigated in detail. We study the turbulence that is induced by the streaming instability as well as its interaction with the vertical shear instability. For this purpose, we employ the FLASH Code to conduct two-dimensional axisymmetric global disk simulations spanning radii from 1 au to 100 au, including the mutual drag between gas and dust as well as the radial and vertical stellar gravity. If the streaming instability and the vertical shear instability start their growth at the same time, we find the turbulence in the dust mid-plane layer to be primarily driven by the streaming instability. It gives rise to vertical gas motions with a Mach number of up to $\sim 10^{-2}$. The dust scale height is set in a self-regulatory manner to about 1% of the gas scale height. In contrast, if the vertical shear instability is allowed to saturate before the dust is introduced into our simulations, then it continues to be the main source of the turbulence in the dust layer. The vertical shear instability induces turbulence with a Mach number of $\sim 10^{-1}$ and thus impedes dust sedimentation. Nonetheless, we find the vertical shear instability and the streaming instability in combination to lead to radial dust concentration in long-lived accumulations which are significantly denser than those formed by the streaming instability alone. Thus, the vertical shear instability may promote planetesimal formation by creating weak overdensities that act as seeds for the streaming instability.

Accepted by A&A

http://arxiv.org/pdf/2002.07185

Prevalence of Complex Organic Molecules in Starless and Prestellar Cores within the Taurus Molecular Cloud

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The detection of complex organic molecules (COMs) toward dense, collapsing prestellar cores has sparked interest in the fields of astrochemistry and astrobiology, yet the mechanisms for COM formation are still debated. It was originally believed that COMs initially form in ices which are then irradiated by UV radiation from the surrounding interstellar radiation field as well as forming protostars and subsequently photodesorbed into the gas-phase. However, starless and prestellar cores do not have internal protostars to heat-up and sublimate the ices. Alternative models using chemical energy have been developed to explain the desorption of COMs, yet in order to test these models robust measurements of COM abundances are needed toward representative samples of cores. We've conducted a large-sample survey of 31 starless and prestellar cores in the Taurus Molecular Cloud, detecting methanol (CH_3OH) in 100% of the cores targeted and acetaldehyde (CH_3CHO) in 70%. At least two transition lines of each molecule were measured, allowing us to place tight constraints on excitation temperature, column density and abundance. Additional mapping of methanol revealed extended emission, detected down to A_V as low as ∼3 mag. We find complex organic molecules are detectable in the gas-phase and are being formed early, at least hundreds of thousands of years prior to star and planet formation. The precursor molecule, CH_3OH, may be chemically linked to the more complex CH_3CHO, however higher spatial resolution maps are needed to further test chemical models.

Accepted by ApJ

http://arxiv.org/pdf/2002.02469

Planet gap opening across stellar masses

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Annular structures in proto-planetary discs, such as gaps and rings, are now ubiquitously found by high-resolution ALMA observations. Under the hypothesis that they are opened by planets, in this paper we investigate how the minimum planet mass needed to open a gap varies across different stellar host masses and distances from the star. The dependence on the stellar host mass is particularly interesting because, at least in principle, gap opening around low mass stars should be possible for lower mass planets, giving us a look into the young, low mass planet population. Using dusty hydrodynamical simulations, we find however the opposite behaviour, as a result of the fact that discs around low mass stars are geometrically thicker: gap opening around low mass stars can require more massive planets. Depending on the theoretical isochrone employed to predict the relationship between stellar mass and luminosity, the gap opening planet mass could also be independent of stellar mass, but in no case we find that gap opening becomes easier around low mass stars. This would lead to the expectation of a *lower* incidence of such structures in lower mass stars, since exoplanet surveys show that low mass stars have a lower fraction of giant planets. More generally, our study enables future imaging observations as a function of stellar mass to be interpreted using information on the mass vs. luminosity relations of the observed samples.

Accepted by MNRAS

https://arxiv.org/pdf/2002.11036

The Cloud Factory I: Generating resolved filamentary molecular clouds from galactic-scale forces

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We introduce a new suite of simulations, 'The Cloud Factory', which self-consistently forms molecular cloud complexes at high enough resolution to resolve internal substructure (up to 0.25 Msol in mass) all while including galactic-scale forces. We use a version of the AREPO code modified to include a detailed treatment of the physics of the cold molecular ISM, and an analytical galactic gravitational potential for computational efficiency. The simulations have nested levels of resolution, with the lowest layer tied to tracer particles injected into individual cloud complexes. These tracer refinement regions are embedded in the larger simulation so continue to experience forces from outside the cloud. This allows the simulations to act as a laboratory for testing the effect of galactic environment on star formation. Here we introduce our method and investigate the effect of galactic environment on filamentary clouds. We find that cloud complexes formed after a clustered burst of feedback have shorter lengths and are less likely to fragment compared to quiescent clouds (e.g. the Musca filament) or those dominated by the galactic potential (e.g. Nessie). Spiral arms and differential rotation preferentially align filaments, but strong feedback randomises them. Long filaments formed within the cloud complexes are necessarily coherent with low internal velocity gradients, which has implications for the formation of filamentary star-clusters. Cloud complexes formed in regions dominated by supernova feedback have fewer star-forming cores, and these are more widely distributed. These differences show galactic-scale forces can have a significant impact on star formation within molecular clouds.

Accepted by MNRAS

https://ui.adsabs.harvard.edu/abs/2020MNRAS.492.1594S/abstract

On the vortex evolution in non-isothermal protoplanetary discs

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It is believed that large-scale horseshoe-like brightness asymmetries found in dozens of transitional protoplanetary discs are caused by anticyclonic vortices. These vortices can play a key role in planet formation, as mm-sized dust — the building blocks of planets — can be accumulated inside them. Anticyclonic vortices are formed by the Rossby wave instability, which can be excited at the gap edges opened by a giant planet or at sharp viscosity transitions of accretionally inactive regions. It is known that vortices are prone to stretching and subsequent dissolution due to disc self-gravity for canonical disc masses in the isothermal approximation. To improve the hydrodynamic model of protoplanetary discs, we include the disc thermodynamics in our model. In this paper, we present our results on the evolution of the vortices formed at the outer edge of an accretionally inactive region (dead zone) assuming an ideal equation of state and taking PdV work, disc cooling in the β-approximation, and disc self-gravity into account. Thermodynamics affects the offset and the mode number (referring to the number of small vortices at the early phase) of the RWI excitation, as well as the strength, shape, and lifetime of the large-scale vortex formed through merging of the initial small vortices. We found that the inclusion of gas thermodynamics results in stronger, however decreased lifetime vortices. Our results suggest that a hypothetical vortex-aided planet formation scenario favours effectively cooling discs.

Accepted by MNRAS

http://arxiv.org/pdf/2002.02203

Variable Accretion onto Protoplanet Host Star PDS 70

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The PDS 70 system has been subject to many studies in the past year following the discovery of two accreting planets in the gap of its circumstellar disk. Nevertheless, the mass accretion rate onto the star is still not well known. Here we determined the stellar mass accretion rate and its variability based on TESS and HARPS observations. The stellar light curve shows a strong signal with a 3.03±0.06 days period, which we attribute to stellar rotation. Our analysis of the HARPS spectra shows a rotational velocity of $v \sin i = 16.0 \pm 0.5$ km s^{-1}, indicating that the inclination of the rotation axis is 50±8 degrees. This implies that the rotation axes of the star and its circumstellar disk are parallel within the measurement error. We apply magnetospheric accretion models to fit the profiles of the Hα line and derive mass accretion rates onto the star in the range of 0.6–2.2 $\times 10^{-10}$ $M_\odot$ yr^{-1}, varying over the rotation phase. The measured accretion rates are in agreement with those estimated from NUV fluxes using accretion shock models. The derived accretion rates are higher than expected from the disk mass and planets properties for the low values of the viscous parameter α suggested by recent studies, potentially pointing to an additional mass reservoir in the inner disk to feed the accretion, such as a dead zone. We find that the He I λ10830 line shows a blueshifted absorption feature, indicative of a wind. The mass-loss rate estimated from the line depth is consistent with an accretion-driven inner disk MHD wind.

Accepted by ApJ

http://arxiv.org/pdf/2002.07283

Analysis of membership probability in nearby young moving groups with Gaia DR2

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We analyze the membership probability of young stars belonging to nearby moving groups with Gaia DR2 data. The sample of 1429 stars were identified from 'The Catalog of Suspected Nearby Young Moving Group Stars'. Good-quality parallax and proper motion values were retrieved for 890 stars from Gaia DR2 database. The analysis for membership probability is performed in the framework of LACEwING algorithm. From the analysis it is confirmed that 279 stars do not belong to any of the known moving groups. We estimated the *U, V, W* space velocity values for 250 moving group members, which were found to be more accurate than previous values listed in the literature. The velocity ellipses of all the moving groups are well constrained within the "good box", a widely used criterion to identify moving group members. The age of moving group members are uniformly estimated from the analysis of Gaia Color-Magnitude Diagram with MIST isochrones. We found a spread in the age distribution of stars belonging to some moving groups, which needs to be understood from further studies.

Accepted by AJ

http://arxiv.org/pdf/2002.04801

VLT/X-shooter spectroscopy of massive young stellar objects in the 30 Doradus region of the Large Magellanic Cloud

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The process of massive star ($M \geq 8\ M_{\odot}$) formation is still poorly understood. Observations of massive young stellar objects (MYSOs) are challenging due to their rarity, short formation timescale, large distances, and high circumstellar extinction. Here, we present the results of a spectroscopic analysis of a population of MYSOs in the Large Magellanic Cloud (LMC). We took advantage of the spectral resolution and wavelength coverage of X-shooter (300-2500 nm), mounted on the European Southern Observatory Very Large Telescope, to detect characteristic spectral features in a dozen MYSO candidates near 30 Doradus, the largest starburst region in the Local Group hosting the most massive stars known. The X-shooter spectra are strongly contaminated by nebular emission. We used a scaling method to subtract the nebular contamination from our objects. We detect $H\alpha, \beta$, [O I] 630.0 nm, Ca II infrared triplet, [Fe II] 1643.5 nm, fluorescent Fe II 1687.8 nm, H_2 2121.8 nm, Brγ, and CO bandhead emission in the spectra of multiple candidates. This leads to the spectroscopic confirmation of ten candidates as bona fide MYSOs. We compare our observations with photometric observations from the literature and find all MYSOs to have a strong near-infrared excess. We compute lower limits to the brightness and luminosity of the MYSO candidates, confirming the near-infrared excess and the massive nature of the objects. No clear correlation is seen between the Brγ luminosity and metallicity. Combining our sample with other LMC samples results in a combined detection rate of disk features such as fluorescent Fe II and CO bandheads which is consistent with the Galactic rate (40%). Most of our MYSOs show outflow features.

Accepted by A&A

https://arxiv.org/pdf/2002.02690

Protostellar disk formation by a non-rotating, non-axisymmetric collapsing cloud: model and comparison with observations

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Planet-forming disks are fundamental objects thought to be inherited from large scale rotation, through the conservation of angular momentum during the collapse of a prestellar dense core. We investigate the possibility for a protostellar disk to be formed from a motionless dense core which contains non-axisymmetric density fluctuations. The rotation is thus generated locally by the asymmetry of the collapse. We study the evolution of the angular momentum in a non-axisymmetric collapse of a dense core from an analytical point of view. To test the theory, we perform three-dimensional simulations of a collapsing prestellar dense core using adaptative mesh refinement. We start from a non-axisymmetrical situation, considering a dense core with random density perturbations that follow a turbulence spectrum. We analyse the emerging disk comparing the angular momentum it contains with the one expected from our analytic development. We study the velocity gradients at different scales in the simulation as it is done with observations. We show that the angular momentum in the frame of a stellar object which is not located at the center of mass of the core is not conserved, due to inertial forces. Our simulations of such non-axisymmetrical collapse quickly produce accretion disks at the small scales in the core. The analysis of the kinematics at different scales in the simulated core reveals projected velocity gradients of amplitudes similar to the ones observed in protostellar cores, and which directions vary, sometimes even reversing when small and large scales are compared. These complex kinematics patterns appear in recent observations, and could be a discriminating feature with models where rotation is inherited from large scales. Our results from simulations without initial rotation are more consistent with these recent observations than when solid-body rotation is initially imprinted.

Accepted by A&A

http://arxiv.org/pdf/2002.02144

Intermittent planet migration and the formation of multiple dust rings and gaps in protoplanetary disks

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A key challenge for protoplanetary disks and planet formation models is to be able to make a reliable connection between observed structures in the disks emission, like bright and dark rings or asymmetries, and the supposed existence of planets triggering these structures. The observation of N dark rings of emission is often interpreted as evidence for the presence of N planets which clear dust gaps around their orbit and form dust-trapping pressure maxima in the disk. The vast majority of the models that studied the impact of planets on the dynamics of dust and gas in a protoplanetary disk assumed planets on fixed orbits. Here we go a different route and examine how the large-scale inward migration of a single planet structures the dust content of a massive disk. In many circumstances, the migration of a partial gap-opening planet with a mass comparable to Saturn is found to run away intermittently. By means of 2D gas and dust hydrodynamical simulations, we show that intermittent runaway migration can form multiple dust rings and gaps across the disk. Each time migration slows down, a pressure maximum forms beyond the planet gap that traps the large dust. Post-processing of our simulations results with 3D dust radiative transfer calculations confirms that intermittent runaway migration can lead to the formation of multiple sets of bright and dark rings of continuum emission in the (sub)millimeter beyond the planet location.

Accepted by MNRAS

http://arxiv.org/pdf/2002.02280

Architecture of three-planet systems predicted from the observed protoplanetary disk of HL Tau

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A number of protoplanetary disks observed with ALMA potentially provide direct examples of initial conditions for planetary systems. In particular, the HL Tau disk has been intensively studied, and its rings/gaps are conventionally interpreted to be a result of unseen massive planets embedded in the gaps. Based on this interpretation, we carried out N-body simulations to investigate orbital evolution of planets within the protoplanetary disk and after the disk dispersal. Before the disk dispersal, our N-body simulations include both migration and mass-growth of the planet coupled with evolution of the disk. By varying the disk parameters, we produce a variety of widely-separated planetary systems consisting of three super-Jupiters at the end of disk dispersal. We found the outer planet is more massive than the inner one, and the migration of the innermost planet is inefficient due to the accretion of outer planet(s). We also showed how the final configuration and the final planetary mass depend on disk parameters. The migration is found to be convergent and no planet-pair has a period ratio less than 2. After the disk dispersal, we switch to pure gravitational N-body simulations and integrate the orbits up to 10 Gyr. Most simulated systems remain stable for at least 10 Gyr. We discuss implications of our result in terms of the observed widely-separated planetary systems HR 8799 and PDS 70.

Accepted by ApJ

http://arxiv.org/pdf/2002.08036

GMC Collisions as Triggers of Star Formation. VII. The Effect of Magnetic Field Strength on Star Formation

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We investigate the formation of stars within giant molecular clouds (GMCs) evolving in environments of different global magnetic field strength and large-scale dynamics. Building upon a series of magnetohydrodynamic (MHD) simulations of non-colliding and colliding GMCs, we employ density- and magnetically-regulated star formation sub-grid models in clouds which range from moderately magnetically supercritical to near critical. We examine gas and star cluster morphologies, magnetic field strengths and relative orientations, pre-stellar core densities, temperatures, mass-to-flux ratios and velocities, star formation rates and efficiencies over time, spatial clustering of stars, and kinematics of the stars and natal gas. The large scale magnetic criticality of the region greatly affects the overall gas evolution and star formation properties. GMC collisions enhance star formation rates and efficiencies in magnetically supercritical conditions, but may actually inhibit them in the magnetically critical case. This may have implications for star formation in different Galactic environments such as the Galactic Center and the main Galactic disk.

Accepted by ApJ

https://arxiv.org/pdf/1911.03141.pdf

Constraining the Infalling Envelope Models of Embedded Protostars: BHR 71 and its Hot Corino

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The collapse of the protostellar envelope results in the growth of the protostar and the development of a protoplanetary disk, playing a critical role during the early stages of star formation. Characterizing the gas infall in the envelope constrains the dynamical models of star formation. We present unambiguous signatures of infall, probed by optically thick molecular lines, toward an isolated embedded protostar, BHR 71 IRS1. The three dimensional radiative transfer calculations indicate that a slowly rotating infalling envelope model following the "inside-out" collapse reproduces the observations of both hcop $J = 4 \rightarrow 3$ and CS $J = 7 \rightarrow 6$ lines, and the low velocity emission of the HCN $J = 4 \rightarrow 3$ line. The envelope has a model-derived age of 12 000±3000 years after the initial collapse. The envelope model underestimates the high velocity emission at the HCN $J = 4 \rightarrow 3$ and htcn $J = 4 \rightarrow 3$ lines, where outflows or a Keplerian disk may contribute. The ALMA observations serendipitously discover the emission of complex organic molecules (COMs) concentrated within a radius of 100 au, indicating that BHR 71 IRS1 harbors a hot corino. Eight species of COMs are identified, including CH_3OH and CH_3OCHO, along with H_2CS, SO_2 and HCN $v_2 = 1$. The emission of methyl formate and ^{13}C-methanol shows a clear velocity gradient within a radius of 50 au, hinting at an unresolved Keplerian rotating disk.

Accepted by Astrophysical Journal

https://arxiv.org/pdf/2002.01478

Rapid Evolution of Volatile CO from the Protostellar Disk Stage to the Protoplanetary Disk Stage

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Recent observations show that the CO gas abundance, relative to H_2, in many 1–10 Myr old protoplanetary disks may be heavily depleted, by a factor of 10–100 compared to the canonical interstellar medium value of 10^{-4}. When and how this depletion happens can significantly affect compositions of planetesimals and atmospheres of giant planets. It is therefore important to constrain if the depletion occurs already at the earliest protostellar disk stage. Here we present spatially resolved observations of $C^{18}O$, $C^{17}O$, and $^{13}C^{18}O$ J=2–1 lines in three protostellar disks. We show that the $C^{18}O$ line emits from both the disk and the inner envelope, while $C^{17}O$ and $^{13}C^{18}O$ lines are consistent with a disk origin. The line ratios indicate that both $C^{18}O$ and $C^{17}O$ lines are optically thick in the disk region, and only $^{13}C^{18}O$ line is optically thin. The line profiles of the $^{13}C^{18}O$ emissions are best reproduced by Keplerian gaseous disks at similar sizes as their mm-continuum emissions, suggesting small radial separations between the gas and mm-sized grains in these disks, in contrast to the large separation commonly seen in protoplanetary disks. Assuming a gas-to-dust ratio of 100, we find that the CO gas abundances in these protostellar disks are consistent with the ISM abundance within a factor of 2, nearly one order of magnitude higher than the average value of 1–10 Myr old disks. These results suggest that there is a fast, $\sim$1 Myr, evolution of the abundance of CO gas from the protostellar disk stage to the protoplanetary disk stage.

Accepted by ApJL

http://arxiv.org/pdf/2002.08522

Excess C/H in Protoplanetary Disk Gas from Icy Pebble Drift across the CO Snowline

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The atmospheric composition of giant planets carries the information of their formation history. Superstellar C/H ratios are seen in atmospheres of Jupiter, Saturn, and various giant exoplanets. Also, giant exoplanets show a wide range of C/O ratio. To explain these ratios, one hypothesis is that protoplanets accrete carbon-enriched gas when a large number of icy pebbles drift across the CO snowline. Here we report the first direct evidence of an elevated C/H ratio in disk gas. We use two thermo-chemical codes to model the $^{13}C^{18}O$, $C^{17}O$, and $C^{18}O$ (2–1) line spectra of the HD 163296 disk. We show that the gas inside the CO snowline ($\sim$70 au) has a C/H ratio of 1–2 times higher than the stellar value. This ratio exceeds the expected value substantially, as only 25–60% of the carbon should be in gas at these radii. Although we cannot rule out the case of a normal C/H ratio inside 70 au, the most probable solution is an elevated C/H ratio of 2–8 times higher than the expectation. Our model also shows that the gas outside 70 au has a C/H ratio of 0.1× the stellar value. This picture of enriched C/H gas at the inner region and depleted gas at the outer region is consistent with numerical simulations of icy pebble growth and drift in protoplanetary disks. Our results demonstrate that the large-scale drift of icy pebble can occur in disks and may significantly change the disk gas composition for planet formation.

Accepted by ApJL

http://arxiv.org/pdf/2002.08529

The VMC survey – XXXVI. Young stellar variability in the Large Magellanic Cloud

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Studies of young stellar objects (YSOs) in the Galaxy have found that a significant fraction exhibit photometric variability. However, no systematic investigation has been conducted on the variability of extragalactic YSOs. Here we present the first variability study of massive YSOs in a $\sim 1.5\,\mathrm{deg}^2$ region of the Large Magellanic Cloud (LMC). The aim is to investigate whether the different environmental conditions in the metal-poor LMC ($\sim 0.4 - 0.5\,\mathrm{Z}_\odot$) have an impact on the variability characteristics. Multi-epoch near-infrared (NIR) photometry was obtained from the VISTA Survey of the Magellanic Clouds (VMC) and our own monitoring campaign using the VISTA telescope. By applying a reduced χ^2-analysis, stellar variability was identified. We found 3062 candidate variable stars from a population of 362 425 stars detected. Based on several *Spitzer* studies, we compiled a sample of high-reliability massive YSOs: a total of 173 massive YSOs have NIR counterparts (down to $K_\mathrm{s} \sim 18.5\,\mathrm{mag}$) in the VMC catalogue, of which 39 display significant ($> 3\sigma$) variability. They have been classified as eruptive, fader, dipper, short-term variable and long-period variable YSOs based mostly on the appearance of their K_s band light curves. The majority of YSOs are aperiodic, only five YSOs exhibit periodic lightcurves. The observed amplitudes are comparable or smaller than those for Galactic YSOs (only two Magellanic YSOs exhibit $\Delta K_\mathrm{s} > 1\,\mathrm{mag}$), not what would have been expected from the typically larger mass accretion rates observed in the Magellanic Clouds.

Accepted by MNRAS

http://arxiv.org/pdf/2002.12291

Abstracts of recently accepted major reviews

Molecular jets from low-mass young protostellar objects

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Molecular jets are seen coming from the youngest protostars in the early phase of low-mass star formation. They are detected in CO, SiO, and SO at (sub)millimeter wavelengths down to the innermost regions, where their associated protostars and accretion disks are deeply embedded and where they are launched and collimated. They are not only the fossil records of accretion history of the protostars but also are expected to play an important role in facilitating the accretion process. Studying their physical properties (e.g., mass-loss rate, velocity, rotation, radius, wiggle, molecular content, shock formation, periodical variation, magnetic field, etc) allows us to probe not only the jet launching and collimation, but also the disk accretion and evolution, and potentially binary formation and planetary formation in the disks. Here I review recent exciting results obtained with high-spatial and high-velocity resolution observations

of molecular jets in comparison to those obtained in the optical jets in the later phase of star formation. Future observations of molecular jets with a large sample at high spatial and velocity resolution with ALMA are expected to lead to a breakthrough in our understanding of jets from young stars.

Accepted by Astronomy and Astrophysics Review

https://arxiv.org/abs/2002.05823

Impact of low-energy cosmic rays on star formation

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In recent years, exciting developments have taken place in the identification of the role of cosmic rays in star-forming environments. Observations from radio to infrared wavelengths and theoretical modelling have shown that low-energy cosmic rays (< 1 TeV) play a fundamental role in shaping the chemical richness of the interstellar medium, determining the dynamical evolution of molecular clouds. In this review we summarise in a coherent picture the main results obtained by observations and by theoretical models of propagation and generation of cosmic rays, from the smallest scales of protostars and circumstellar discs, to young stellar clusters, up to Galactic and extragalactic scales. We also discuss the new fields that will be explored in the near future thanks to new generation instruments, such as: CTA, for the γ-ray emission from high-mass protostars; SKA and precursors, for the synchrotron emission at different scales; and ELT/HIRES, JWST, and ARIEL, for the impact of cosmic rays on exoplanetary atmospheres and habitability.

Accepted by Space Science Reviews topical collection Star formation

https://arxiv.org/pdf/2002.10282

Planet formation: key mechanisms and global models

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Models of planet formation are built on underlying physical processes. In order to make sense of the origin of the planets we must first understand the origin of their building blocks. This review comes in two parts. The first part presents a detailed description of six key mechanisms of planet formation: 1) The structure and evolution of protoplanetary disks 2) The formation of planetesimals 3) Accretion of protoplanets 4) Orbital migration of growing planets 5) Gas accretion and giant planet migration 6) Resonance trapping during planet migration. While this is not a comprehensive list, it includes processes for which our understanding has changed in recent years or for which key uncertainties remain.
The second part of this review shows how global models are built out of planet formation processes. We present global models to explain different populations of known planetary systems, including close-in small/low-mass planets (i.e., super-Earths), giant exoplanets, and the Solar System's planets. We discuss the different sources of water on rocky exoplanets, and use cosmochemical measurements to constrain the origin of Earth's water. We point out the successes and failings of different models and how they may be falsified. Finally, we lay out a path for the future trajectory of planet formation studies.

To appear in Lecture Notes of the 3rd Advanced School on Exoplanetary Science

http://arxiv.org/pdf/2002.05756

Understanding Protostellar Jet Feedback on Disc and Cloud Scales

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Ph.D degree awarded: December 2019

Protostellar jets are a vital part of the star formation process. They are responsible for the removal of excess angular momentum critical to the growth of protostars, while feeding that angular momentum back into molecular clouds to regulate the formation of stellar cores and gravitational collapse. To better understand the origin and impact of protostellar jets, this thesis investigates the launching of protostellar disc winds and the driving of non-isothermal turbulence in the interstellar medium.

In the first part of this thesis, we explore how the structure of protostellar discs relates to the properties of the wind-launching region, which directly effects the large-scale properties of the jet. In order to study the launching of disc winds, we first design a 1+1.5D magnetohydrodynamic (MHD) model of the launching region in the [r,z] plane. We take into account the three diffusion mechanisms of non-ideal MHD (Ohm, Hall, and ambipolar) by calculating their contributions at the disc midplane and using a simplified, vertically-scaled approach for higher z. We observe that most of the mass launched by the wind is concentrated within a radially localized region a fraction of an astronomical unit (au) in width, in agreement with current observations. We find that the footprint radius and the wind efficiency, measured by the ratio of the wind mass-loss rate to the rate of material accreted onto the star, are a strong function of the model parameters, namely the mass accretion rate, magnetic field strength, and surface density profile of the disc. Understanding the structure of the wind-launching region has important

We subsequently improve the 1+1.5D models by removing the vertical scaling approximation to the non-ideal MHD terms and calculate the magnetic diffusivities self-consistently at all heights above the disc midplane. This results in increased field-matter coupling surrounding the midplane, increasing the poloidal magnetic field bending and compressing the disc via enhanced magnetic pressure gradients. It also shifts the wind-launching region to smaller radii,

decreases the overall wind mass-loss rate by an order of magnitude, and generates a radially symmetric wind mass-loss profile.

In the second part of this thesis, we investigate the properties of driven, turbulent, adiabatic gas. The density variance–Mach number relation of the turbulent interstellar medium is a key ingredient for analytical models of star formation. We examine the robustness of the standard, isothermal form of this relation in the non-isothermal regime, specifically testing ideal gases with diatomic molecular and monatomic adiabatic indices. Stirring the gas with purely solenoidal forcing at low wavenumbers, we find that as the gas heats in adiabatic compressions, it evolves along a curve in the density variance-Mach number plane, but deviates significantly from the standard isothermal relation. We provide new empirical and theoretical relations that take the adiabatic index into account and provide good fits for a range of Mach numbers.

Moving ... ??

If you move or your e-mail address changes, please send the editor your new address. If the Newsletter bounces back from an address for three consecutive months, the address is deleted from the mailing list.

Abstract submission deadline

The deadline for submitting abstracts and other submissions is the first day of the month. Abstracts submitted after the deadline will appear in the following month's issue.

Summary of Upcoming Meetings

Interstellar Shocks School
22 - 27 March 2020, Les Houches, France
https://www.sciencesconf.org/browse/conference/?confid=8899

Linking Dust, Ice, and Gas in Space
19 - 24 April 2020, Capri Islands, Italy
http://www.frcongressi.it/ecla2020/

AIP Thinkshop on Protoplanetary Disk Chemodynamics
11 - 15 May 2020, Leibnitz Institute for Astrophysics Potsdam, Germany
https://meetings.aip.de/event/1

Planet Formation: From Dust Coagulation to Final Orbital Assembly
1 - 26 June 2020, Munich, Germany
http://www.munich-iapp.de/planetformation

Cool Stars, Stellar Systems, and the Sun 21
21 - 26 June 2020, Toulouse, France
https://coolstars21.github.io/

The Physics of Star Formation: From Stellar Cores to Galactic Scales; 29 June - 3 July 2020, Lyon, France
http:/staratlyon.univ-lyon1.fr/en

Illuminating the Dusty Universe: A Tribute to the Work of Bruce Draine
6 - 10 July 2020, Florence, Italy
https://web.astro.princeton.edu/IlluminatingTheDusty Universe

The Early Phase of Star Formation
12 - 17 July 2020, Ringberg, Germany
http://www.mpia.de/homes/stein/EPoS/2020/2020.php

Star Formation: From Clouds to Discs - A Tribute to the Career of Lee Hartmann
17 - 20 August 2020, Malahide, Ireland
https://www.dias.ie/cloudstodiscs/

Star Formation in Different Environments 2020
24 - 28 August 2020, Quy Nhon, Vietnam
http://icisequynhon.com/conferences/sfde/

Planetary Science: The Young Solar System
6 - 12 September 2020, Quy Nhon, Vietnam
http://www.icisequynhon.com/conferences/planetary_science/

Wheel of Star Formation: A conference dedicated to Prof. Jan Palouš
14 - 18 September 2020, Prague, Czech Republic
https://janfest2020.asu.cas.cz

Conditions and Impact of Star Formation - Across Times and Scales
28 September - 2 October 2020, Chile
https://astro.uni-koeln.de/symposium-star-formation-2020.html

From Clouds to Planets II: The Astrochemical Link
28 September - 2 October 2020, Berlin, Germany
https://events.mpe.mpg.de/event/12/

The Aftermath of a Revolution: Planet Formation Five Years after HL Tau
7 - 11 December 2020, Chile
https://www.eso.org/sci/meetings/2020/hltau2020.html

Protostars & Planets VII
1 - 7 April 2021, Kyoto, Japan
http://www.ppvii.org

Short Announcements

In Fall 2020, the SOFIA Observatory anticipates offering a new, next generation, scientific instrument: the High Resolution Mid-Infrared Spectrometer (HIRMES). HIRMES will enable mid- to far-infrared spectroscopy (25 – 122 μm) with selectable spectral resolving powers of R $\sim$ 300-600, 12,000, and 50,000-100,000, covering the wavelength gap between JWST MIRI (28 μm) and Herschel PACS (55 μm). In its highest resolution mode, HIRMES is expected to provide 100x higher spectral resolution with similar or slightly better sensitivity compared with Herschel PACS. Thus, HIRMES is expected to enable a wide variety of science by spectrally resolving gas emission lines (including 63 μm [OI] and other fine-structure lines, HD 1-0, and many water lines) and providing access to a variety of solid-state emission features, including the elusive 43 μm solid-state water ice feature. Finally, HIRMES offers a fast spectral mapping mode for selected lines, including the 88.4 μm [OIII] and 121.9 μm [NII] lines.

The HIRMES Science Working Group is organizing a workshop for the astronomical community June 22-24, 2020 to be held at Space Telescope Science Institute on the campus of Johns Hopkins University. The goal of the workshop is to raise the community's awareness to the upcoming availability of HIRMES, discuss the science that could be enabled by this new capability, and provide technical support for attendees interested in submitting HIRMES proposals. The SOFIA project is enthusiastic about engaging the broader astronomical community and hearing about the science that HIRMES will enable. The project would like to support HIRMES observing by providing early opportunities to propose for telescope time if the community is interested. There are no fees associated with participating in the workshop. For more information, please go to https://www.hirmes.org/2020-workshop