Magnetic Fields and the Structure of the Filamentary Interstellar Medium

Magnetic Fields at Different Scales: Tuesday, June 22, 2021

Click on a presentation title to see the abstract.

Time (Pacific)	Speaker (Affiliation)	Presentation Title
7:00–7:05am	B-G Andersson (SOFIA/USRA), Chair	Welcome to the Workshop
7:05–7:45am	Christoph Federrath (ANU)	How Turbulence and Magnetic Fields Regulate ISM Structure and Star Formation
7:45–8:05am	Che-Yu Chen (LLNL)	The Scale-dependent Importance of Magnetic Field in Star Formation
8:05–8:15am	**Flash Contributed Talks** Dylan Michelson Paré: Characterizing Mechanisms Producing the Unusual Magnetic Field of the Galactic Center Radio Arc Amit Seta: Magnetic Filaments in the ISM due to the Small-scale Dynamo James Wurster: Magnetic Fields in the ISM and their Effect on Filaments, Stars & Discs Jin-Ah Kim: The Magnetic Field Geometry in the Halo of NGC891 Fatemeh Tabatabaei: Cloud-scale Radio Survey of Star Formation and Feedback in Triangulum Galaxy (CRASSFIT) Gina Panopoulou: The North Polar Spur Puzzle: Feedback Near versus Feedback Far Qilao Gu: A Comparison between Magnetic Field Directions Inferred from Planck and Starlight Polarimetry toward Gould Belt Clouds	
8:15–8:25am	10 minute break	
8:25–9:05am	Terry Jones (U. Minnesota)	Magnetic Fields at Multiple Scales as Seen In FIR-MM Polarimetry
9:05–9:25am	Sarah Sadavoy (Queen's University)	Polarization from Cores to Disks: Connecting Single-Dish and ALMA Dust Polarization
9:25–9:40am	Yue Hu (University of Wisconsin-Madison)	Multi-scale and Multi-wavelength Magnetic Fields in the Central Molecular Zone
9:40–9:50am	10 minute break	
9:50–10:05am	Patrick Koch (ASIAA)	Multi-Scale Picture of Magnetic Field and Gravity in High-Mass Star-Forming Region W51
10:05–10:15am	**Flash Contributed Talks** Yik Ki (Jackie) Ma: A GASKAP View of HI Filaments in the SMC: The Relationship with Magnetic Fields Yapeng Zhang: Anchoring Magnetic Fields in Turbulent Molecular Clouds. II. From 0.1 to 0.01 pc Paulo Cortes: Magnetic Fields in Massive Star-Forming Regions (MagMaR) II. Tomography Through Dust and Molecular Line Polarization in NGC 6334 Chat Hull: The Explosion in Orion-KL as Seen by Mosaicking the Magnetic Field with ALMA Fuda Nguyen: Modeling of CO Emission in Shocks of W 28 and IC 443 Philipp Girichidis: The Dynamical Impact and Orientation of Magnetic Fields in the Interstellar Medium Thuong Duc Hoang: Studying Magnetic Fields toward M17 Cloud using Dust Polarization Taken with SOFIA/HAWC+	
10:15–11:05am	Chat Hull (NAOJ/ALMA)	Discussion: Magnetic Fields vs All: Contribution at Different Scales

Magnetic Fields and the Structure of the Filamentary Interstellar Medium

Magnetic Fields and the Lifecycle of IRDCs Part I: Wednesday, June 23, 2021

Click on a Presentation Title to see the abstract.

Time (PDT)	Speaker (Affiliation)	Presentation Title
7:00–7:05am	Ian Stephens (Worcester State), Chair	Introduction
7:05–7:45am	Mordecai-Mark Mac Low (AMNH)	IRDC Structure: Magnetically Dominated Envelopes and Collapsing Cores
7:45–8:05am	Mika Juvela (University of Helsinki)	Simulations of Dust, Gas, and Magnetic Fields
8:05–8:15am	**Flash Contributed Talks** Jihye Hwang: The Distribution of Magnetic Field Strengths in the OMC-1 Region Daisei Abe: Classification of Filament Formation Mechanisms in Magnetized Molecular Clouds Felix Priestley: The Characteristic Widths of Magnetised Filaments Lars Bonne: The Role of the Magnetic Field in the Formation of the Musca Filament Dana Alina: The Monoceros OB1 East Filamentary Cloud and its Large-scale Magnetic Field	
8:15–8:25am	10 minute break	
8:25–8:40am	Mehrnoosh Tahani (DRAO – National Research Council Canada)	Reconstructing the Full 3D Morphology of Magnetic Fields Associated with Filamentary Molecular Clouds
8:40–8:55am	Lapo Fanciullo (Academia Sinica)	Disentangling Dust Properties, Grain Alignment and Magnetic Field Structure in NGC 2071 with SOFIA and JCMT
8:55–9:15am	Dan Clemens (Boston University)	NIR BSP, GPIPS, Gaia, and IRDCs
9:15–9:30am	Archana Soam (SOFIA Science Center, USRA, NASA Ames Research Center)	Magnetic Fields at Different Spatial Scales of a Filament G34.43+0.24
9:30–9:40am	**Flash Contributed Talks** Niko Zielinski: Magnetic Field Structure of OMC-3 in the Far-infrared Unveiled by SOFIA/HAWC+ Janik Karoly: Multi-wavelength Analysis of the Magnetic Field in Ophiuchus A using SOFIA/HAWC+ and JCMT/POL-2 Akanksha Bij: Magnetic Field Morphology in High-Mass Star Forming Filaments Pak Shing Li: Mapping the Magnetic Field in the Taurus/B211 Filamentary Cloud with SOFIA HAWC+ and Comparing with Simulation Shashwata Ganguly: SILCC-Zoom: the Effect of Magnetic Fields on the Morphology, Dynamics and Fragmentation of Molecular Clouds Dennis Lee: HAWC+/SOFIA Polarimetry in L1688: Relative Orientation of Magnetic Field and Elongated Cloud Structure	
9:40–9:50am	10 minute break	
9:50–10:05am	Jean-Sébastien Carrière (IRAP – CNRS/UPS)	Planck/Herschel Analysis of Correlations between Filamentary Structures and Magnetic Fields in Star Forming Regions
10:05–10:55am	Giles Novak (Northwestern University)	Discussion: Comparing Simulations/Observations: What do We Learn, What is Missing

Magnetic Fields and the Structure of the Filamentary Interstellar Medium

Magnetic Fields and the Lifecycle of IRDCs Part II: Thursday, June 24, 2021

Click on a Presentation Title to see the abstract.

Time (Pacific)	Speaker (Affiliation)	Presentation Title
7:00–7:05am	Simon Coudé (SOFIA/USRA), Chair	Introduction
7:05–7:45am	Thushara Pillai (Boston University)	Multi-wavelength Magnetic Field Observations in Infrared Dark Clouds
7:45–8:05am	Patrick Hennebelle (CEA)	What the Orientation of the Magnetic Field Tells Us and which Effects Should We Expect from the Magnetic Field?
8:05–8:15am	**Flash Contributed Talks** Derek Ward-Thompson: Some Insights from the JCMT BISTRO Surveys Eun Jung Chung: The Role of the Magnetic Field in the Evolution of the Hub-filament Structures in IC5146 Diep Pham Ngoc: BISTRO Survey: Dust Grain Properties from the Observation of Magnetic Fields Surrounding LkHa 101 Cornelia Pabst: How do Magnetic Fields Regulate Star Formation? The Case of 30 Doradus Woojin Kwon: BISTRO: Magnetic Fields in Serpens Main Adai Shomanov: Filaments Segmentation: Mask RCNN Approach Mike Chen: Relative Orientations between Velocity Gradients and Magnetic Fields in Perseus NGC 1333 Filaments Fuda Nguyen: Modeling of CO Emission in Shocks of W 28 and IC 443	
8:15–8:25am	10 minute break	
8:25–8:45am	Kate Pattle (NUI)	The JCMT BISTRO Survey: The Evolution of Magnetic Fields in Dense Filaments
8:45–9:00am	Qizhou Zhang (Center for Astrophysics | Harvard & Smithsonian)	Filaments, Clumps and Massive Star Formation
9:00–9:15am	Eswaraiah Chakali (National Astronomical Observatories of China)	Revealing the Diverse Magnetic Field Morphologies in Taurus Dense Cores with Sensitive Sub-millimeter Polarimetry
9:15–9:30am	Peter Barnes (Space Science Institute)	First Results from the CN-Bright Magnetic Fields Project
9:30–9:40am	10 minute break	
9:40–9:55am	Phil Myers (Center for Astrophysics | Harvard and Smithsonian)	Magnetic Properties of Star-Forming Dense Cores
9:55–10:45am	Josep Miquel Girart (CSIC-IEEC)	Discussion: The Markers of the Role of Magnetic Fields for Star Formation

Magnetic Fields and the Structure of the Filamentary Interstellar Medium

Characterizing B Fields from Observations: Friday, June 25, 2021

Click on a Presentation Title to see the abstract.

Time (PDT)	Speaker (Affiliation)	Presentation Title
7:00–7:05am	Arielle Moullet (SOFIA/USRA), Chair	Introduction
7:05–7:35am	Martin Houde (Western University)	The Davis-Chandrasekhar-Fermi Method, its Caveats and Areas of Application
7:35–7:55am	Brandon Hensley (Princeton University)	A Practical Guide to Grain Alignment Theory
7:55–8:05am	**Flash Contributed Talks** Ka Ho Yuen: Velocity Caustics as the Tracer of Magnetic Field and Turbulence Statistics in Interstellar Media Raphael Skalidis: Precession Galactic Magnetometry through Dust Polarization Jordan Guerra: Constructing Maps of Plane-of-Sky Magnetic Field Strength using FIR Polarimetric Data Thiem Hoang: Rotational Disruption and Alignment of Astrophysical Dust Le Ngoc Tram: Understanding Polarized Dust Emission from Rho Ophiuchi A in Light of Grain Alignment and Disruption by Radiative Torques Siyao Xu: Turbulence Anisotropy: a New Method for Measuring Magnetic Fields in Cold Interstellar Phases Jean-Mathieu Teissier: Magnetic Helicity Inverse Transfer in Supersonic Isothermal MHD Turbulence	
8:05–8:15am	10 minute break	
8:15–8:35am	Alex Lazarian (University of Wisconsin-Madison)	Measuring B-strength: Turbulence Theory Based Alternative to the Davis-Chandrasekhar-Fermi Approach
8:35–8:50am	Junhao Liu (Nanjing University)	Calibrating the Davis-Chandrasekhar-Fermi Method with Numerical Simulations
8:50–9:05am	Nguyen B. Ngoc (Vietnam National Space Center)	Testing the Grain Alignment and Rotational Disruption by Radiative Torques using Dust Polarization in Filaments
9:05–9:25am	Tom Troland (University of Kentucky)	Magnetic Field Measurements via the Zeeman Effect — Strengths and Limitations
9:25–9:45am	Stefan Reissl (University of Heidelberg)	The Imprint of Magnetic Fields on Polarization Observations
9:45–9:55am	10 minute break	
9:55–10:15am	Juan Diego Soler (MPIA)	Beyond Davis-Chandrasekhar-Fermi: Understanding the Magnetized Interstellar Medium Using Statistical Tools
10:15–11:05am	Crystal Brogan (NRAO)	Discussion: Application and Limitations of Observation and Interpretation Techniques

Peter Barnes (Space Science Institute)

Title: First Results from the CN-Bright Magnetic Fields Project

Abstract: The role of B fields in star formation is still mysterious due to observational challenges in measuring their strength and geometry. Eg, only 14 Zeeman field strength measurements exist using the dense gas tracer CN, limiting our tests of theory in the high-density regime; the important transition from magnetic to gravitational domination near densities ~300 cm−3 has not been clearly defined in a large cloud sample; and we lack systematic information connecting the GMC-scale (10s of pc) field geometry from Planck to the sub-pc scale of protostellar core fields, where cluster-forming clumps dominate star formation. SOFIA+ALMA provide an exciting opportunity to fill these gaps by enabling high quality field mapping in the cold, dense, star-forming gas. We have identified a complete sample of 45 massive molecular clumps which are sufficiently bright in CN to feasibly measure Zeeman field strengths with ALMA, while at the same time affording high-sensitivity field morphology mapping with the Goldreich-Kylafis effect in CO, plus in the continuum with both facilities. In this talk I present first results from this project from recent SOFIA+ALMA data. We are using various polarisation analysis techniques to construct systematic high-SDR maps of dust polarization, detailed mapping of field geometries and strengths, and leveraged by existing continuum & spectroscopic data on clumps' non-magnetic properties, statistical studies of all parameters across contiguous scales 0.1–10 pc.

Jean-Sébastien Carrière (IRAP - CNRS / UPS)

Title: Planck/Herschel Analysis of Correlations between Filamentary Structures and Magnetic Fields in Star Forming Regions

Abstract: Pre-stellar cores form in the dense interstellar medium, mostly within filaments. Magnetic fields are believed to play a key, albeit poorly understood, role in the whole sequence of structure formation, from interstellar filaments down to stars. It is, therefore, instructive to study the interplay between magnetic fields and filaments hosting cold cores in star forming regions under various conditions (density, evolutionary stage). This can be investigated by studying the relative orientation between filaments and magnetic fields using both Herschel and Planck maps towards various star forming regions. For this purpose, we have developed the new SupRHT method, based on an improvement of the Rolling Hough Transform (RHT), for the extraction of filamentary structures and the characterisation of their sizes and orientations. This new method is user friendly and is able to identify filaments automatically and robustly in any kind of environments. SupRHT thus allows us to analyse the relative orientation between magnetic fields and filaments over a broad range of size and density, from striations to dense filaments. We present the results obtained for a sample of Herschel fields from the 'Galactic Cold Cores' project, probing star formation in different Galactic environments. We find a whole range of relative orientations, with a tendency for filaments to be aligned either parallel or perpendicular to the magnetic field (generally depending on column density).

Eswaraiah Chakali (National Astronomical Observatories of China (NAOC))

Title: Revealing the Diverse Magnetic Field Morphologies in Taurus Dense Cores with Sensitive Sub-millimeter Polarimetry

Abstract: We have obtained sensitive dust continuum polarization observations at 850 μm in the B213 region of Taurus using POL-2 on SCUBA-2 at the James Clerk Maxwell Telescope (JCMT), as part of the BISTRO (B-fields in STar-forming Region Observations) survey. These observations allow us to probe magnetic field (B-field) at high spatial resolution (~2000 au or ~0.01 pc at 140 pc) in two protostellar cores (K04166 and K04169) and one prestellar core (Miz-8b) that lie within the B213 filament. Using the Davis-Chandrasekhar-Fermi method, we estimate the B-field strengths in K04166, K04169, and Miz-8b to be 38±14 μG, 44±16 μG, and 12±5 μG, respectively. These cores show distinct mean B-field orientations. B-field in K04166 is well ordered and aligned parallel to the orientations of the core minor axis, outflows, core rotation axis, and large-scale uniform B-field, in accordance with magnetically regulated star formation via ambipolar diffusion taking place in K04166. B-field in K04169 is found to be ordered but oriented nearly perpendicular to the core minor axis and large-scale B-field, and not well-correlated with other axes. In contrast, Miz-8b exhibits disordered B-field which show no preferred alignment with the core minor axis or large-scale field. We found that only one core, K04166, retains a memory of the large-scale uniform B-field. The other two cores, K04169 and Miz-8b, are decoupled from the large-scale field. Such a complex B-field configuration could be caused by gas inflow onto the filament, even in the presence of a substantial magnetic flux.

Che-Yu Chen (LLNL)

Title: The Scale-dependent Importance of Magnetic Field in Star Formation

Abstract: The role played by magnetic fields during the star-forming process has been long debated and is still an open question in astrophysics. Motivated by the recently-advanced polarimetric capabilities, our recent theoretical efforts utilizing 3D MHD simulations have provided new ways to characterize the 3D structure and the relative importance of the magnetic field in star-forming

clouds. At sub-pc scale, our previous investigations of magnetized core formation in turbulent clouds showed that magnetic effect is not critical during core growth because gas preferably flows along the field lines towards dense cores. Further examinations on the progression of magnetic field geometry from cloud to core scales also lend support to the anisotropic core formation model we proposed. Taken together, we suggest that the magnetic field is dynamically significant in regulating the star-forming process at intermediate scales, where the large-scale super-sonic/Alfvénic turbulence already cascaded but gravity has not yet taken over the control.

Dan Clemens (Boston University)

Title: NIR BSP, GPIPS, Gaia, and IRDCs

Abstract: Background starlight polarimetry (BSP) at optical wavelengths first revealed Galactic magnetic fields 70 years ago. Near-infrared (NIR) BSP enables probing magnetic fields through extinctions ranging from under one Av magnitude to about 60 Av magnitudes. Hence NIR BSP provides key magnetic field context for diffuse to dense ISM interfaces, atomic to molecular cloud phase changes, comparing magnetic energies to thermal and turbulent energies, and how clouds form cores and cores form stars. The Galactic Plane Infrared Polarization Survey (GPIPS) probed much of the Galactic mid-plane with unprecedented NIR BSP sensitivity and sampling, yielding over one million stars with high quality polarizations. Coupled with Gaia distances and proper motions, we now have the ability to begin 3-D tomography of the magnetic field in the Milky Way. GPIPS survey data and follow-up deeper Mimir observations towards several IRDCs reveal a surprisingly complex range of magnetic field properties, from highly ordered to highly disordered. How do these properties correlate with turbulence, star formation, and the effects of external coherent forces?

Lapo Fanciullo (Academia Sinica)

Title: Disentangling Dust Properties, Grain Alignment and Magnetic Field Structure in NGC 2071 with SOFIA and JCMT

Abstract: The thermal emission of interstellar dust is one of the most important tracers of interstellar environments. In particular, interstellar magnetic fields can be studied using polarized dust emission from grains aligned with the field lines. However, interpreting the polarization fraction in emission is a non-trivial task, since this quantity is determined by several degenerate factors: the orientation and structure of the magnetic field, the grain alignment efficiency and the optical properties of dust itself. Comparing polarized emission at multiple wavelengths is one possible way of breaking this degeneracy.

I will show the preliminary results of a multi-wavelength polarimetric analysis in the star-forming region NGC 2071, conducted at wavelengths of 850 µm (POL-2 observations from the BISTRO project at JCMT), 154 µm and 214 µm (HAWC+/SOFIA observations). The data show the potential for tracing variations of magnetic Field orientation with optical depth, and/or grain growth in the higher-density region of the cloud, although more detailed modelling is needed to conclusively distinguish the two scenarios. I will further discuss which analysis techniques do not transfer well across wavelength, and how including both short-wavelength (< 250 µm) and long-wavelength data (~ 1 mm) was key to obtaining our results.

Christoph Federrath (ANU)

Title: How Turbulence and Magnetic Fields Regulate ISM Structure and Star Formation

Abstract: Turbulence and magnetic fields are key players in the process of star formation. This is because they control the structure of the ISM on large scales, but also regulate processes such as angular momentum transport and jet launching inside protostellar discs where stars form. I will attempt to explain some of the theoretical models for how filaments may form in molecular clouds (in the Galactic disc and in the Galactic centre), and how the interplay of gravity, turbulence, magnetic fields and stellar feedback controls the star formation rate and the initial mass function of stars.

Patrick Hennebelle (CEA)

Title: What the Orientation of the Magnetic Field Tells Us and Which Effects Should We Expect from the Magnetic Field?

Abstract: Which role magnetic fields play within the interstellar medium has been the matter of intense research. Recently simulations and observations have been revealing that there is a preferred orientation between magnetic fields and density gradients which tend to be respectivelly perpendicular or parallel at low or high column densities. What does it physically mean ? Can we conclude that magnetic fields have a strong influence on the ISM ? Using a reformulation of the MHD equations, I will argue that the preferred magnetic field and density gradient orientation is a natural consequence of the transport equations. I will then discuss three cases where magnetic fields really quantitatively modify the picture, namely the formation of diffuse filaments, the fragmentation of a collapsing core and the formation of proto-planetary disks.

Brandon Hensley (Princeton University)

Title: A Practical Guide to Grain Alignment Theory

Abstract: The physics of grain alignment is a challenging problem, as evidenced by the decades between first observations of dust polarization in the 1940s and a theory capable of explaining its wavelength dependence in detail. In this talk, I will present the key ingredients of modern grain alignment theory, including radiative torques (RATs), paramagnetic dissipation, and thermal flipping, with emphasis on predictions for changes in grain alignment properties with interstellar environment. I will conclude with a discussion of some outstanding questions in grain alignment theory.

Martin Houde (Western University)

Title: The Davis-Chandrasekhar-Fermi Method, its Caveats and Areas of Application

Abstract: In this presentation I will be focusing on the well-known and widely used DCF equation due to Davis (1951) and Chandrasekhar & Fermi (1953) for estimating magnetic field strengths in the interstellar medium. I will summarize the assumptions underlying the derivation of the DCF equation and discuss its applicability to different environments. I will further emphasize the ensuing shortcomings of this method and discuss some approaches that have been devised to alleviate them. Finally, I will emphasize the need for alternatives to the DCF equation, some of which are discussed in this workshop.

Yue Hu (University of Wisconsin-Madison)

Title: Multi-scale and Multi-wavelength Magnetic Fields in the Central Molecular Zone

Abstract: Magnetic fields in the central molecular zone have attracted a vast of attention in recent years. To get an insight into the magnetic fields, we employ the Gradient Technique (GT), which is rooted in the anisotropy of magneto-hydrodynamic turbulence. Our analysis combines the data of multiple wavelengths, including molecular emission lines, radio 1.4 GHz continuum image, and Herschel 70μm image, as well as ionized [*Ne*2] and Paschen-alpha emissions, with the observations of Planck 353 GHz and HAWC+ 53μm polarized dust emissions. We will show wavelength-dependent magnetic fields in the overall central molecular zone, the radio arc, and the Sagittarius A* west region, accessing multi scales from the order of 10 pc to 0.1 pc. The magnetic fields towards the central molecular zone traced by GT are globally compatible with the polarization measurements, accounting for the contribution from the galactic foreground. This correspondence suggests that the magnetic field and turbulence are dynamically crucial in the galactic center. We will show that the magnetic fields associated with the arched filaments and the thermal components of the radio arc agree with the HAWC+ polarization. The measurement towards the non-thermal radio arc reveals the poloidal magnetic field components in the galactic center. For Sagittarius A* region, we will present the agreement between the GT measurement using [*Ne*2] emission and HAWC+ 53μm observation. We use GT to predict the magnetic fields associated with ionized Paschen-alpha gas.

Terry Jones (U. Minnesota)

Title: Magnetic Fields at Multiple Scales as Seen in FIR-MM Polarimetry

Abstract: Far Infrared and MM wave polarimetry of dust emission provides a unique tool for the study of magnetic fields in the interstellar medium over a wide range of physical scales. Observations of polarized dust emission are not affected by scattering as is the case at optical and NIR wavelengths, nor Faraday effects present in radio synchrotron observations. Current advances in both observations and analysis techniques are discussed for scales ranging from protostellar molecular cloud cores to entire galaxies. Current challenges for present and future application of FIR-MM wave polarimetry for the study of magnetic fields are discussed.

Mika Juvela (University of Helsinki)

Title: Simulations of Dust, Gas, and Magnetic Fields

Abstract: Star-formation studies require precise knowledge of the structure, kinematics, and magnetic fields of dense clouds. The magnetic fields are observationally the most challenging component but, since one only sees one projection of the medium, even density and velocity information is often hard to interpret. Simulations help to understand the relationships between the measurements and the three-dimensional reality in the clouds.

I will describe past studies where simulations were used to interpret Planck polarisation measurements of clumps (using random MHD cloud realisations) or to seek explanation for SCUBA POL-2 measurements of an IRDC (using toy models built for the individual source). I will also describe ongoing study of an IRDC-like object selected from a larger MHD simulation. The study will be based on a combination of synthetic observations of line emission and dust continuum emission and polarisation.

Patrick Koch (ASIAA)

Title: Multi-Scale Picture of Magnetic Field and Gravity in High-Mass Star-Forming Region W51

Abstract: We present a suite of dust polarization observations in the high-mass star-forming region W51. These observations image the magnetic (B-) field morphology with progressively higher-resolutions from the pc-scale envelope, to globally collapsing cores, to the fragments within cores, and down to a network of core-connection fibers with the currently highest resolution around 500au. These observations cover a range in resolution of about a factor 1,000 in area. Together with these scale-dependent B-field morphologies we analyze the gravitational vector field. We find recurring similarities in the magnetic field structures and their corresponding gravitational vector fields. These self-similar structures point at a multi-scale collapse-within-collapse scenario. At the highest resolution, we find B-field orientations that are prevailingly parallel to the core-connecting extensions and fibers. This key structural feature is analyzed together with the gravitational vector field. We derive a stability criterion that defines a maximum magnetic field strength that can be overcome by an observed magnetic field-gravity configuration. Equivalently, this defines a minimum field strength that can stabilize extensions and fibers against a radial collapse. We find that the detected fibers and extensions are stable, hence possibly making them a fundamental component in the accretion onto central cores.

Alex Lazarian (University of Wisconsin-Madison)

Title: Measuring B-Strength: Turbulence Theory Based Alternative to the Davis-Chandrasekhar-Fermi Approach

Abstract: I shall present a new way of measuring magnetic field strength distribution using polarization. The technique's foundation is the modern MHD turbulence theory. I will describe the advantages of the new approach compared to the Davis-Chandrasekhar-Fermi technique and provide numerical simulation that support these advantages.

Junhao Liu (Nanjing University)

Title: Calibrating the Davis-Chandrasekhar-Fermi Method with Numerical Simulations

Abstract: The Davis-Chandrasekhar-Fermi (DCF) method is widely used to indirectly estimate the magnetic field strength from the plane-of-sky field orientation. In this work, we present a set of 3D MHD simulations and synthetic polarization images using radiative transfer of clustered massive star-forming regions. We apply the DCF method on the synthetic polarization maps to investigate its reliability in high-density molecular clumps and dense cores where self-gravity is significant. We investigate the validity of the assumptions of the DCF method step by step and compare the model and estimated field strength to derive the correction factors for the estimated uniform and total (rms) magnetic field strength at clump and core scales. We find the DCF method works well in strong field cases. However, the magnetic field strength in weak field cases could be significantly overestimated by the DCF method when the turbulent magnetic energy is smaller than the turbulent kinetic energy. We investigate the accuracy of the angular dispersion function (ADF, a modified DCF method) method on the effects that may affect the measured angular dispersion and find that the ADF method correctly accounts for the ordered field structure, the beam-smoothing, and the interferometric filtering, but may not be applicable to account for the signal integration along the line of sight in most cases. Our results suggest that the DCF methods should be avoided to be applied below ~0.1 pc scales if the effect of line-of-sight signal integration is not properly addressed.

Mordecai-Mark Mac Low (AMNH)

Title: IRDC Structure: Magnetically Dominated Envelopes and Collapsing Cores

Abstract: Models of stratified, radiatively-cooing, magnetized, supernova-driven turbulent gas representative of sections of galactic disk have density enhancements that reach densities characteristic of giant molecular clouds (GMCs). However, in the absence of self-gravity, these objects have dynamics clearly distinct from observed GMCs, with velocity dispersions under a kilometer per second at all scales, and a diffuse morphology. Inclusion of self-gravity, however, produces dense filaments strongly reminiscent of IRDC morphology, with dynamics in broad agreement with observed dependences of velocity dispersion on column density and size of cloud. Detailed investigation of these clouds magnetic field structure reveals that, in agreement with observed clouds, they have strongly magnetized envelopes and gravitationally dominated cores that collapse at close to the free-fall timescale. Stellar feedback appears to terminate star formation and disperse gas quickly, leading to the low observed star formation rates.

Phil Myers (Center for Astrophysics | Harvard and Smithsonian)

Title: Magnetic Properties of Star-Forming Dense Cores

Abstract: We present and interpret magnetic and energetic properties of star-forming dense cores, based on observations of submm and near-infrared polarization of 17 low-mass dense cores. The observations are analyzed with the DCF model of Alfvénic fluctuations of polarization angle and gas velocity. They indicate (1) mass-to-flux ratios are slightly supercritical, with M/M_B= 1-3; (2) correlation between plane-of-sky field strength and column density

B_pos~N^p, with p=1.05±0.08, and (3) correlation between plane-of-sky field strength and density B_pos~ n^q, with q=0.66±0.05. These properties agree with earlier Zeeman studies (Crutcher et al. 2010), but have finer precision. They are interpreted by (1) the small range of M/M_B is due to the relation between virial and magnetic masses, and to selection of centrally concentrated, gravitationally bound cores with modest Alfvén amplitudes. (2) B~N because B~(M/M_B)N and because the range of M/M_B is less than the range of N, and (3) B~n^(2/3) because B~M^(1/3) n^(2/3) and because the range of M^(1/3) is less than the range of n^(2/3), for concentrated, bound, spheroidal cores. These results call for better models and simulations of core ensembles. They do not support spherical core evolution at constant mass (Mestel 1966), which predicts B~n^(2/3) but requires weak fields to maintain spherical shape. Instead these results describe cores close to equipartition, with gravitational binding that is centrally concentrated, and with fields that are nearly as strong as possible, among fields that allow gravitational contraction.

Nguyen B. Ngoc (Vietnam National Space Center)

Title: Testing the Grain Alignment and Rotational Disruption by Radiative Torques using Dust Polarization in Filaments

Abstract: Filaments are ubiquitous in the interstellar medium and play an important role in the star formation process. Dust polarization induced by alignment of dust grains with the magnetic field is widely used to study the magnetic field and its role in star formation. In this study, we use dust polarization data observed toward several filaments (Musca, Vela C, and Orion A observed by Planck, BLASTPol, JCMT/POL2, and SOFIA/HAWC+) to test the grain alignment and rotational disruption mechanisms by radiative torques. We found a general correlation of polarization fraction with dust temperature at low temperature and anticorrelation at high temperature. Our numerical modeling of the dust polarization degree simultaneously taking into account the dust alignment and disruption by RAdiative Torque mechanisms (RATs) successfully reproduces the observed variation of the dust polarization with dust temperature.

Kate Pattle (NUI)

Title: The JCMT BISTRO Survey: The Evolution of Magnetic Fields in Dense Filaments

Abstract: In this talk I will present results from the JCMT BISTRO (B-Fields in Star-Forming Region Observations) Survey, which has been using the POL-2 polarimeter to map magnetic fields in the dense structures of Milky Way star-forming regions. I will discuss the insights which these observations give into the transition to magnetically subcritical gas dynamics which takes place in dense filamentary structures within molecular clouds, and the first hints that we are getting about the effects of stellar feedback on magnetic fields in dense star-forming gas. I will present recent BISTRO Survey observations of several nearby molecular clouds, discussing the search for a characteristic size or density scale at which magnetic fields lose their dynamic importance in the evolution of a dense filament to gravitational instability.

Thushara Pillai (Boston University)

Title: Multi-wavelength Magnetic Field Observations in Infrared Dark Clouds

Abstract: Detailed measurements of magnetic fields in star-forming filaments in a state prior to the onset of star formation have just started to become available, and are even more scarce for high-mass star forming (HMSF) infrared dark clouds (IRDCs). Recent HMSF theories explore the effect of weak to strong magnetic fields on star formation and cloud evolution. I will present a review of the near and far-infrared polarimetric observations in IRDCs and how it informs us on the magnetic field topology at different stages of evolution. While the current data consistenly show evidence for strong magnetization in IRDCs, outstanding questions remain as to its implications for star-formation itself. I will briefly discuss these as well before opening up the forum for discussion.

Stefan Reissl (University of Heidelberg)

Title: The Imprint of Magnetic Fields on Polarization Observations

Abstract: Magnetic fields are the key ingredient in many astrophysical processes within the interstellar medium (ISM). Observations of aligned dust grains, line emission with Zeeman Effect, and the Faraday rotation measure (RM) are common tracer techniques to infer magnetic field properties. Driven by large sub-mm polarization capabilities, e.g. SOFIA/HAWC+, Planck, and ALMA, in this talk I focus on specific astrophysical problems that currently beg re-evaluation: Does grain alignment physics cause a detectable imprint on the polarization signal? What regions of the ISM are actually probed by the different tracers? What is the actual impact of the magnetic field morphology on the observed polarization signal?

In detail, I present selected results of past projects from my radiative transfer (RT) code POLARIS, which covers multiple facets of dust polarization, Zeeman Effect, and RM. Based on synthetic observations of post-processed large-scale numerical ISM simulations I statistically analyze the imprint of the magnetic field on polarized light. Especially, I discuss methods to distinguish between distinct magnetic field morphologies. Finally, I outline the caveats and numerical limitations of such RT post-processing techniques.

Sarah Sadavoy (Queen's University)

Title: Polarization from Cores to Disks: Connecting Single-Dish and ALMA Dust Polarization

Abstract: The field of star formation is rapidly changing with the development of high resolution and multi-wavelength instrumentation that can observe dust polarization at far-infrared and (sub)millimeter wavelengths. With these facilities, we are now able to probe dust polarization in protostellar environments on scales of 10-5000 au, and we can use those data to infer magnetic field structures down to the scales of disks. In this presentation, I will present an overview of magnetic fields traced by dust polarization from the scales of cores and filaments as observed by HAWC+ and POL-2 to the scales of disks around young stars as observed by ALMA. I will also discuss the difficulties in probing magnetic fields down to disk scales and the need for multi-scale and multi-wavelength observations to uncover their role in the formation of both stars and planets.

Archana Soam (SOFIA Science Center, USRA, NASA Ames Research Center)

Title: Magnetic Fields at Different Spatial Scales of a Filament G34.43+0.24

Abstract: As most of the molecular clouds are filamentary and elongated, the magnetic fields (B-fields) in these clouds are found either parallel or perpendicular to the main axes. In the talk, I will present the B-fields mapped in IRDC G34.43+0.24 (G34 now onwards) obtained with 850-micron polarized dust emission observed with POL-2/JCMT. We examined the magnetic field geometries and strengths in the northern, central, and southern regions of the filament. The overall field orientations are uniform at large (POL-2 at 14" and SHARP at 10") to small scales (TADPOL at 2.5" and SMA at 1.5") in the MM1 and MM2 regions. The SHARP/CSO observations in MM3 at 350-micron from Tang et al. show a similar trend as seen in our POL-2 observations. TADPOL observations demonstrate a well-defined field geometry in central region of G34 consistent with MHD simulations of accreting filaments. We obtained a plane-of-sky magnetic field strength of 470+/-190 micG, 100+/-40 micG, and 60+/-34 micG in the central, northern and southern regions of G34, respectively, using the updated Davis-Chandrasekhar-Fermi relation. The estimated value of field strength, combined with column density and velocity dispersion values available in the literature, suggests G34 to be marginally critical with criticality parameter values 0.8+/-0.4, 1.1+/-0.8, and 0.9+/-0.5 in the central, northern, and southern regions, respectively. The turbulent motions in G34 are sub-Alfvénic in the three regions. The observed aligned B-fields in G34 are consistent with theoretical models suggesting that B-fields play an important role in guiding the contraction of the cloud driven by gravity. I will also highlight our attempts to map B-fields at different spatial scales of some other filamentary clouds.

Juan Diego Soler (MPIA)

Title: Beyond Davis-Chandrasekhar-Fermi: Understanding the Magnetized Interstellar Medium using Statistical Tools

Abstract: Seventy years ago, Leverett Davis Jr. made the first estimations of the interstellar magnetic field strength in the Milky Way using starlight polarization observations and what is now known as the Davis-Chandrasekhar-Fermi method. Today, we have an unprecedented amount of observations of the interstellar magnetic fields in the form of synchrotron polarization, Faraday rotation, Zeeman splitting, Goldreich-Kylafis (GK) effect, starlight polarization, and dust polarized emission. This plethora of observations calls for new statistical tools that integrate large volumes of data, compare them to the physical phenomena in numerical simulations, and provide insight into the cycles of matter and energy in the interstellar medium. I will review some of these techniques, mainly focusing on those applied to the analysis of dust polarized emission observations in and around star-forming clouds by SOFIA, Planck, BLASTPol, and other millimeter- and submillimeter-wavelength observatories.

Mehrnoosh Tahani (DRAO - National Research Council Canada)

Title: Reconstructing the Full 3D Morphology of Magnetic Fields Associated with Filamentary Molecular Clouds

Abstract: We present a new approach to study the complete 3D morphology of magnetic fields, including their direction, associated with filamentary molecular clouds. We considered the Perseus, California, and Orion A filamentary molecular clouds, which previously showed a line-of-sight magnetic field reversal across them (Tahani et al. 2018). We analyzed velocity and Galactic magnetic field information of these regions and compared them with models and magneto-hydrodynamics simulations. We found that the observational data in the Perseus cloud matched the models that predict a bow-shaped magnetic field morphology, indicating a high likelihood for this magnetic morphology associated with the cloud. Using Galactic magnetic field and velocity information, we then reconstructed the 3D bow-shaped magnetic field morphology in this region, with its concave side pointing toward us and its plane-of-sky projection pointing in the decreasing longitude direction.

For the Orion A and California clouds the limitations in the observations restricted us from comparing their consistency with the bow-predicting models. However, using previous studies and observations we constructed the 3D morphology of the magnetic fields in the Orion A cloud. The method suggested in this work enables us to construct the complete three-dimensional large-scale magnetic field morphologies and vectors. More specifically, the technique

allows us to map the signed direction of magnetic fields in the plane of the sky (without the 180 degree ambiguity).

Tom Troland (University of Kentucky)

Title: Magnetic Field Measurements via the Zeeman Effect — Strengths and Limitations

Abstract: Nature is exceedingly devious in hiding her secrets of the interstellar magnetic field. Each method we have to reveal these secrets obscures some of them, and the radio frequency Zeeman effect is no exception. The Zeeman effect offers the only method to measure interstellar magnetic field strengths directly. It can even reveal field strengths independently in multiple velocity components along the line-of-sight. However, the Zeeman effect only reveals the line-of-sight field strength. The effect is very weak, requiring long integration times per measurement. It can be susceptible to maddening instrumental effects. And the Zeeman effect can only be applied to the radiation from a very few interstellar species. In particular, (non-maser) Zeeman effect measurements to date have been made with spectral lines of HI (21 cm), OH (18 cm), and CN (1 and 3 mm). Fortunately, each species samples a different density regime, providing field strength information in a wide range of interstellar environments. High spatial resolution Zeeman effect measurements are especially needed in dense, star forming environments. ALMA observations of the CN Zeeman effect, discussed in this conference, likely offer the best opportunity to make these measurements.

Qizhou Zhang (Center for Astrophysics | Harvard & Smithsonian)

Title: Filaments, clumps and massive star formation

Abstract: Massive protostars and protostellar clusters are often found at intersections of filamentary molecular clouds. How cloud materials condense and fragment from filaments to form dense cores and a cluster of stellar objects remains an unsolved problem in astrophysics. We investigate the role of magnetic fields in this process using polarimetric observations of polarized dust emission from mm/submm interferometers such as SMA and ALMA, as well as from single dish telescopes such as JCMT and SOFIA. The angular scales probed by these telescopes enable investigations of the dynamic role of magnetic fields during the collapse and fragmentation of parsec-scale clumps and the formation of <0.1 pc dense cores. In this talk, I will present polarimetric surveys of protocluster forming molecular clumps obtained from the SMA and ALMA, and a multi-scale analysis of magnetic fields in conjunction with data from JCMT and SOFIA. We found compelling evidence of a strong magnetic field influence on the gas dynamics during the formation of cores in protoclusters.

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Tuesday, June 22

Paulo Cortes (ALMA/NRAO)

Title: Magnetic Fields in Massive Star-Forming Regions (MagMaR) II. Tomography Through Dust and Molecular Line Polarization in NGC 6334

Abstract: We will report ALMA detections of polarized emission from dust, CS (J = 5 →4), and C33S (J = 5 → 4) toward the high-mass star-forming region NGC6334I(N).A clear "hourglass" magnetic field morphology was inferred from the polarized dust emission which is also directly seen from the polarized CS emission across velocity, where the polarization appears to be parallel to the field. By considering previous findings, the field retains a pinched shape which can be traced to larger length-scales (2 pc) from the scales traced by ALMA (3 mpc), suggesting that the field is dynamically Important across multiple length-scales in this region. The CS total intensity emission is found to be optically thick (τCS = 32 ± 12) while the C33S emission appears to be Optically thin (τC33S = 0.1 ± 0.01). This suggests that sources of anisotropy other than large velocity gradients, i.e. anisotropies in the radiation field, along with interferometric filtering, are required to explain the polarized emission from CS seen by ALMA. By using four variants of the Davis-Chandrasekhar-Fermi technique and the polarization position angle dispersion function methods, we estimate a magnetic field strength onto the plane of the sky of Bpos i = 16 ± 8 mG from the dust and Bpos i ~ 2 mG±1 mG from the CS emission, where each emission traces different molecular hydrogen Number densities. This effectively enables a tomographic view of the magnetic field within a single ALMA observation.

Philipp Girichidis (Institute for Theoretical Astrophysics, University of Heidelberg, Germany)

Title: The Dynamical Impact and Orientation of Magnetic Fields in the Interstellar Medium

Abstract: Magnetic fields are ubiquitously observed in the interstellar medium (ISM) with dynamically relevant energy densities. Using 3D-MHD simulations of the supernova-driven ISM we investigate the dynamical impact of magnetic fields on the formation of molecular gas out of the atomic gas, GMCs and filaments. We show how magnetic fields delay the formation of H2 and help preventing the gas from forming stars too efficiently. The simulation covers a box of 500 pc and resolves scales down to sub-parsec, which allows to investigate the magnetic field strength and orientation from scales of the galactic disk down to the densest and self-gravitating parts of the molecular clouds. We also correlate the orientation of the magnetic field with respect to gas structures and gas velocities with the density and the degree of importance of contracting gravitational forces. We also illustrate why the orientation of the field is well identified locally in 3D simulations but might be hard to observe because of the short correlation lengths of the density structures and the magnetic fields and the resulting line of sight integration effects.

Qilao Gu (Shanghai Astronomical Observatory)

Title: A Comparison between Magnetic Field Directions Inferred from Planck and Starlight Polarimetry toward Gould Belt Clouds

Abstract: We compare the magnetic field (B-field) orientations inferred from Planck 353 GHz thermal dust polarization and starlight polarimetry data and study the cloud-field alignment based on these two tracers within Gould Belt clouds, which show good agreement with each other. Furthermore, we analyze two fundamentally different alignment studies—global (cloud scale, ~10–100 pc) cloud-field alignment, which compares mean fields and global cloud orientations, and local (pixel size scale, ~0.1–1 pc) structure-field alignment, which compares this relation pixel by pixel—and find the connection between them.

Thuong Duc Hoang (University of Science and Technology of Hanoi)

Title: Studying Magnetic Fields toward M17 Cloud Using Dust Polarization Taken with SOFIA/HAWC+

Abstract: Understanding the role of magnetic fields in the evolution of dense clouds and star formation process is a challenge in modern astrophysics. This study reports the observation of magnetic fields in the plane-of-sky of the M17 cloud using SOFIA/HAWC+ polarimetric data at 154 µm wavelength. Using the Davis-Chandrasekhar-Fermi technique, we found the presence of strong magnetic fields (326 and 839 µG in lower-density and higher-density regions, respectively). The mean values of the field strengths are used to determine the sub-Alfvénic Mach numbers (i.e. 0.02-0.004) which are the results of The well-aligned magnetic fields morphology. Sub-critical values of the mass-to-flux ratios (i.e. 0.21-0.55) are in agreement with the lack of massive stars formed in M17. We also study the relationship between the dust polarization degree and dust temperature to explain the effect of grain alignment and rotation disruption by radiative torques.

Chat Hull (NAOJ/ALMA)

Title: The Explosion in Orion-KL as Seen by Mosaicking the Magnetic Field with ALMA

Abstract: We present the first linear-polarization mosaicked observations performed by the Atacama Large Millimeter/submillimeter Array (ALMA). We mapped the Orion-Kleinmann-Low (Orion-KL) nebula using super-sampled mosaics at 3.1 and 1.3 mm as part of the ALMA Extension and Optimization of Capabilities program. We derive the magnetic field morphology in the plane of the sky by assuming that dust grains are aligned with respect to the ambient magnetic field. At the center of the nebula, we find a quasi-radial magnetic field pattern that is aligned with the explosive CO outflow up to a radius of approximately 12" (~5000 au), beyond which the pattern smoothly transitions into a quasi-hourglass shape resembling the morphology seen in larger-scale observations by the James-Clerk-Maxwell Telescope (JCMT). We estimate an average magnetic field strength 9.4 mG and a total magnetic energy of 2×10^45 erg, which is three orders of magnitude less than the energy in the explosive CO outflow. We conclude that the field has been overwhelmed by the outflow and that a shock is propagating from the center of the nebula, where the shock front is seen in the magnetic field lines at a distance of ~5000 au from the explosion center.

Jin-Ah Kim (University of Minnesota)

Title: The Magnetic Field Geometry in the Halo of NGC891

Abstract: Measurements of the magnetic field geometry in galactic halos using interstellar polarization are sparse compared to observations within galactic disks due to observational constraints. The magnetic field well away from the disk has essential information on how the magnetic field in halos evolves and how the mixing of disk and halo materials affects the magnetic field configuration. While an X-shaped magnetic field structure or more complex vertical magnetic field geometries in halos have been studied using radio observations, far-IR polarimetry observations of interstellar polarization in halos have only recently become feasible. Far-IR observations of polarized dust emission, which is dependent on the presence of warm dust and is not influenced by Faraday effects, provides a unique and complementary tool for the study of the magnetic field geometry in galactic halos. Using SOFIA HAWC+ in polarimetry mode at 154μm, we found possible evidence for vertical magnetic fields in the well-known edge-on galaxy NGC891. The vertical fields seen in NGC891 could be extensions of the mean field formed by dynamo action in the disk and moderate galactic winds. Or, the fields could be correlated with super bubbles or loop structures, perhaps triggered by local enhanced star formation. To investigate vertical magnetic field in the halo of NGC891, we have been awarded further observations with SOFIA HAWC+ and we will use these observations to determine whether the vertical magnetic fields are clearly present in the dust halo and whether the vertical fields are correlated with local features such as super bubbles.

Yik Ki (Jackie) Ma (Australian National University)

Title: A GASKAP View of HI Filaments in the SMC: The Relationship with Magnetic Fields

Abstract: Neutral hydrogen (HI) in the interstellar medium often exhibits as a vast network of filamentary structures. The anisotropy of these HI filaments can be induced by supernova explosions, tidal forces, or magnetic fields. In the Milky Way, nearby HI filaments have been found to be oriented along the ambient magnetic fields traced by polarised starlight, suggesting an important role of magnetic fields in the formation of these neutral structures. We investigate if the same relation holds in the Small Magellanic Cloud (SMC), which harbours vastly different astrophysical conditions compared to the Milky Way. This study has been made possible by the new data from the Galactic ASKAP (GASKAP) survey, which provides an unprecedented combination of angular resolution, velocity resolution, and sensitivity of HI in the SMC. We identified ~100 pc scale HI filaments automatically using the Rolling Hough Transform machine vision algorithm, and carefully compared their orientations with the polarisation angles from a recent starlight polarisation catalogue of the SMC. In this talk, I will present the preliminary results from this work.

Fuda Nguyen (Vietnam National University)

Title: Modeling of CO Emission in Shocks of W 28 and IC 443

Abstract: Shocks into the interstellar medium is an incredibly effective laboratory for tracing the interplay of energies exchange in the interstellar medium. Carbon monoxide (CO) is amongst the most abundant gas in the ISM, second only to diatomic hydrogen (H_2). In the cooling phase of the shock, pure-rotational transitions of the $^{16}C^{12}O$ (Δ J=1) molecule, covering ranges of frequencies, are very accessible to observations. In this work, we made use of the Large Velocity Gradient (LVG) approximation to make the first radiative transfer model of CO emissions directly from the MHD Paris-Durham 1D shock code. Our model predicts well the CO emission observed with SOFIA from C-type, magnetic-dominated, multi-components shocks, which are strongly present in the bright molecular regions of W 28 and IC 443. The model provided constraints for pre-shock density of $n < 1E4\ cm^{-3}$ and ISM magnetic field of B < 350 uG, and also served as an effective guideline for identifying portion in the evolution of the shock which likely contributed to the final molecular emission.

Gina Panopoulou (Caltech)

Title: The North Polar Spur Puzzle: Feedback Near versus Feedback Far

Abstract: Filamentary structure is prevalent in the magnetized ISM. The relation between filament morphology and magnetic field geometry can shed light on the different formation mechanisms for such structures. I will discuss one of the prototypical examples of the link between the magnetic field and filament morphology in the diffuse ISM: the North Polar Spur. Existing determinations of the distance to the NPS are contradictory, fueling the ongoing debate on the origin of this object. Observations of stellar extinction and polarization strongly suggest that the NPS is a reheated SNR, with a diameter of ~200 pc. However, recent X-ray observations find that the NPS is a kpc-size structure created by activity near the Galactic center. I will review the evidence for/against each model and present new constraints on the distance to the structure from a combination of three magnetic field tracers: polarized dust emission, radio synchrotron and stellar polarizations.

Dylan Michelson Paré (University of Iowa)

Title: Characterizing Mechanisms Producing the Unusual Magnetic Field of the Galactic Center Radio Arc

Abstract: The Galactic Center (GC) is an unusual region of the Galaxy that contains a unique population of structures known as the non-thermal filaments (NTFs). The NTFs are highly polarized with polarized intensity distributions which trace the total intensity of the NTFs. In addition, their intrinsic magnetic fields are found to be parallel to the extent of the NTFs. By contrast, the most prominent NTF, the Radio Arc, exhibits polarized intensity structures which extend into regions of low total intensity. In addition, the intrinsic magnetic field of the Radio Arc alternates between being parallel and rotated with respect to the total intensity. The origin of these unusual features for the Radio Arc remains unclear. We obtained an Australia Telescope Compact Array (ATCA) data set of the Radio Arc covering a 4 – 11 GHz frequency range to probe the mechanisms responsible for the unique features seen for the Radio Arc. Using the 4 MHz spectral resolution of our ATCA data, we fit models of several Faraday rotation mechanisms to the spectral polarization data. This model fitting of the data allows us to analyze the number and nature of rotating media located along the line of sight to determine whether an additional intervening medium is responsible for the unusual polarized intensity and magnetic field properties observed for the Radio Arc. This work expands our understanding of the environment local to the Radio Arc, shedding light on the complex region it is embedded within.

Amit Seta (Australian National University)

Title: Magnetic Filaments in the ISM due to the Small-Scale Dynamo

Abstract: Magnetic fields in the interstellar medium (ISM) of galaxies is amplified and maintained by a dynamo action, whereby a part of kinetic energy gets converted to magnetic energy. A dynamo that produces magnetic structures at scales smaller than the driving scale of turbulence is known as the small-scale dynamo. We explore magnetic structures in the amplifying and statistically steady state of the small-scale dynamo in driven turbulence simulations. Using the Minkowski functionals, we quantify the shape of the magnetic structures produced by the dynamo as magnetic filaments and derive the scalings of the typical length, width, and thickness of these filaments with the magnetic dissipation. We show that all three of these magnetic length scales increases as the magnetic field amplifies. The study would help compare the theory of small-scale dynamo and magnetic filaments seen in various ISM simulations with direct and indirect observations of magnetic filaments in the ISM.

Fatemeh Tabatabaei (IPM/MPIA/MPIfR)

Title: Cloud-scale Radio Survey of Star Formation and Feedback in Triangulum Galaxy (CRASSFIT)

Abstract: CRASSFIT is a full polarization survey of M33 at C band (5-7 GHz) and L band (1-2 GHz) with the Karl G. Jansky Very Large Array (JVLA) to study star formation and feedback at spatial scales down to 40 pc. These scales are important to investigate the thermal and non-thermal processes controlling giant molecular clouds and regulating the formation of star clusters. The sensitive JVLA polarization observations show tangled magnetic field in star forming regions traced in synchrotron. These regions had been beam-depolarized in previous studies. We also find alignments of the B-vectors with gaseous filaments in the some parts of the main spiral arm in this galaxy. These regions are found to have a lower star formation activity compared to other regions. Similar to the clouds in the center of NGC1097, an anti-correlation is found between the magnetic field strength and the star formation efficiency in these clouds in M33. The aligned magnetic field, that is likely generated by shear gas motions, can support the gas against gravity decelerating the formation of cores of star clusters.

James Wurster (University of St Andrews)

Title: Magnetic Fields in the ISM and their Effect on Filaments, Stars & Discs

Abstract: Magnetic fields affect the evolution of the ISM in star forming regions on a variety of scales. They modify its large scale structure (e.g. its filamentary structure), which affects the magnetic field structure in star forming cores, which ultimately affects the magnetic field structure of any protostellar discs that form. Since the ISM is only weakly ionised, non-ideal MHD is a more realistic description of magnetic fields.

In this talk, I will present the results of numerical simulations that model star forming clusters. I will discuss the large- and small-scale effects of the magnetic field, the importance of ideal and non-ideal MHD and of the initial magnetic field strength. I will discuss the resulting gas structure of the ISM, the stellar populations, and the magnetic field in the discs that form.

Yapeng Zhang (Department of Astronomy, Beijing Normal University)

Title: Anchoring Magnetic Fields in Turbulent Molecular Clouds. II. From 0.1 to 0.01 pc

Abstract: We compared the magnetic field directions inferred from polarimetry data obtained from 100 pc scale inter-cloud media (ICM) and from sub-parsec scale molecular cloud cores. The highly correlated result led us to conclude that cloud turbulence must be sub-Alfvénic. Here we extend the study with 0.01 pc cores observed by interferometers. The inferred field directions at this scale significantly deviate from that of the surrounding ICM. An obvious question to ask is whether this high-resolution result contradicts the sub-Alfvénic picture concluded earlier. We performed MHD simulations of a slightly super-critical clouds with Alfvénic Mach number MA=0.63 which can reproduce the Paper I result, and observed the development toward smaller scales. Interestingly, all subregions hosting cores with n(H2)>10^5/cc (the typical density observed by interferometers) possess MA=2~3. Not too surprisingly, these slightly super-Alfvénic cores result in B-field orientation offsets comparable to the interferometer observations. The result suggests that gravity can concentrate (and maybe also contribute to, which requires further study to confirm) turbulent energy and create slightly super-Alfvénic cores out of sub-Alfvénic clouds. The results of our simulations also agree with the observed velocity-scale, mass-scale, and field-density relations.

Wednesday, June 23

Daisei Abe (Nagoya University)

Title: Classification of Filament Formation Mechanisms in Magnetized Molecular Clouds

Abstract: Recent observations of molecular clouds show that dense filaments are the sites of present-day star formation. Thus, it is necessary to understand the filament formation process because these filaments provide the initial condition for star formation. Theoretical research suggests that shock waves in molecular clouds trigger filament formation. Since several different mechanisms have been proposed for filament formation, the formation mechanism of the observed star-forming filaments requires clarification. In the present study, we perform a series of isothermal magnetohydrodynamics simulations of filament formation. We focus on the influences of shock velocity and turbulence on the formation mechanism and identified three different mechanisms for filament formation. The results indicate that when the shock is fast, at shock velocity v_sh = 7 km/s, the gas flows driven by the curved shock wave create filaments irrespective of the presence of turbulence and self-gravity. However, at a slow shock velocity v_sh = 2.5 km/s, the compressive flow component involved in the initial turbulence induces filament formation. When both the shock velocities and turbulence are low, the self-gravity in the shock-compressed sheet becomes important for filament formation. Moreover, we analyzed the line-mass distribution of the filaments and showed that strong shock waves can naturally create high-line-mass filaments such as those observed in the massive star-forming regions in a short time. We conclude that the dominant filament formation mode changes with the velocity of the shock wave triggering the filament formation.

Dana Alina (Nazarbayev University)

Title: The Monoceros OB1 East Filamentary Cloud and its Large-scale Magnetic Field

Abstract: Monoceros OB1 East molecular cloud is a large complex that has a filamentary shape in its Northern part and that contains a stellar cluster in its Southern part. It has a rich star formation history and an on-going an active star formation process. We study the large-scale magnetic field structure of the cloud using the Planck satellite data and the velocity gradients technique applied to the TRAO 14m telescope. This allows us to reveal the following dynamical characteristics of the cloud. First, we confirm a shock region between the Northern filaments, in which the magnetic field is elongated along the filament's long axes. Second, possible inflows of gas along magnetic field lines towards the densest part of the cloud, that contain the NGC2264 cluster, are detected. We conclude that the large-scale magnetic field has a dynamically important role in Monoceros OB1 East: in the Northern filaments it might be providing support against gravity while in the Southern part it might be guiding gas inflow.

Akanksha Bij (Queen's University)

Title: Magnetic Field Morphology in High-Mass Star Forming Filaments

Abstract: We implement a multi-scale and multi-tracer analysis of the orientation between magnetic field morphology and elongated gas structures in the densest filament of the young giant molecular cloud Vela C. This region is of particular interest as it is within 1 pc of a young ~1Myr old cluster that is powering the bipolar HII region RCW 36, allowing us to probe the impact of feedback on magnetic field geometry. To trace the magnetic field on filament scales (~0.03-0.1 pc), we use public observations from SOFIA/HAWC+ 79 microns (Band C) and 214 microns (Band E). To trace the dense filament and PDR, we use column density and temperature maps derived from Herschel and integrated line intensity maps such as 12CO(J=3-2) and 13CO(J=3-2) from APEX/LAsMA and CII from SOFIA/FEEDBACK. We also trace the core and sub-filament scales with ~4500 AU resolution using ALMA band 6 (1.1-1.4 mm) continuum maps. Previous studies using BLASTpol toward this region have found that the high column density filamentary structure has a strong statistical preference to align perpendicular to the cloud-scale magnetic field. Using the higher resolution magnetic field data, we also find that the column density structures preferentially align perpendicular to the magnetic field. However, for several of the line tracers (e.g 12CO, 13CO) the lower intensity structures are more likely to align perpendicular to the magnetic field whereas the higher intensity structures show non-preferential or parallel alignment. This could be caused by feedback from the nearby massive star cluster or gravitational collapse altering the magnetic field geometry.

Lars Bonne (SOFIA/USRA)

Title: The Role of the Magnetic Field in the Formation of the Musca Filament

Abstract: The Musca filament in the Southern Hemisphere is a low-mass filament at the stage just before fragmentation into prestellar cores, and thus an ideal target to study the initial conditions of low-mass star formation. Analyzing several CO transitions, continuous mass accretion on the filament was established. Further analyzing large CO(1-0) and HI maps indicates that the bending of the magnetic field, as described in e.g. Inoue et al. 2018, probably drives the mass accretion on the filament. This bending of the magnetic field appears to be the result of a 50 pc scale HI colliding flow in the Chameleon-Musca complex (Bonne et al. 2020a,b). Cycle 6 HAWC+ observations show that inside the Musca

filament, the magnetic field remains roughly perpendicular to the orientation of the filament, as was found on large scales around the filament with Planck and optical polarization data. Comparing the HAWC+ magnetic field orientation with the C18O(2-1) velocity field in the filament shows that they are closely aligned which confirms that the magnetic field and mass inflow to the filament are closely related. Combining the HAWC+ data with the optical polarization observations (Pereyra & Magalhaes 2004) confirms some reorientation of the magnetic field directly around the filament that was found with Planck at lower spatial resolution. This reorientation can have several potential interpretations such as bending of the magnetic field, an increasing role of gravity or shocks.

Shashwata Ganguly (University of Cologne)

Title: SILCC-Zoom: the Effect of Magnetic Fields on the Morphology, Dynamics and Fragmentation of Molecular Clouds

Abstract: To what extent magnetic fields affect how molecular clouds (MC) fragment and create dense structures is an open question. We present a numerical study of cloud fragmentation using the SILCC-Zoom simulations (Seifried+2017). These simulations follow the self-consistent formation of MCs in a few hundred pc sized region of a stratified galactic disc; and include magnetic fields, self-gravity, supernova driven turbulence, as well as a non-equilibrium chemical network. To discern the role of magnetic fields in the time evolution of MCs, we study seven simulated clouds, five with magnetic fields and two without, for 1.5 Myr with a maximum resolution of 0.1 pc. Using a dendrogram we identify hierarchical structures which form within the clouds. We find that five out of seven clouds are sheet-like on the largest scales with filamentary structures embedded within, consistent with the bubble driven MC formation mechanism proposed by Inutsuka+2015. Hydrodynamic simulations tend to produce more sheet-like structures, while MHD simulations seem equally likely to produce filaments or sheets. Moreover, magnetic fields lead to shallower density gradients such that dense structures are embedded in a more extended diffuse medium compared to hydrodynamic clouds. Analysing cloud energetics, we find that magnetic fields are dynamically important for less dense atomic structures, while the denser, potentially star forming structures, are energetically dominated by self-gravity and turbulence.

Jihye Hwang (Korea Astronomy and Space Science Institute/University of Science and Technology)

Title: The Distribution of Magnetic Field Strengths in the OMC-1 Region

Abstract: Estimate of magnetic field strengths in a molecular cloud is necessary to determine whether magnetic field can support the molecular cloud against gravitational collapse. We suggest a new application of the Davis-Chandrasekhar-Fermi (DCF) method to estimate magnetic field strengths in the OMC-1 region. We use dust polarization emission at 450 and 850 μm and C18O (3-2) spectral line data obtained with the JCMT as a part of the JCMT BISTRO survey. We estimate the volume density, the velocity dispersion and the polarization angle dispersion in a box, 40"×40" (5×5 pixels), which moves over the OMC-1 region. We estimate the distribution of magnetic field strengths in each box using the DCF method. The magnetic field strengths range from 0.8 to 26.4 mG and their mean value is about 6 mG. We also get maps of the mass-to-flux ratio in units of a critical value and the Alfvén Mach number. The central parts of two clumps (BN-KL and S) in the OMC-1 region are magnetically supercritical, but the outer parts of the region are magnetically subcritical. The Alfvén Mach numbers are smaller than 0.6 over the OMC-1 region, which implies that the magnetic field pressure exceeds the turbulent pressure in the OMC-1 region.

Janik Karoly (University of Central Lancashire)

Title: Multi-wavelength Analysis of the Magnetic Field in Ophiuchus A using SOFIA/HAWC+ and JCMT/POL-2

Abstract: We use previously published linear polarization observations of the Ophiuchus-A core carried out by SOFIA/HAWC+ at 89 and 154μm and from the BISTRO survey using JCMT/POL-2 at 850μm to determine the magnetic field in, and surrounding, the main core. Using N(H2) column density maps at each wavelength, we suggest that each wavelength traces a different component of the magnetic field, both spatially and depth wise. The 89μm magnetic field lies spatially to the east of the main Oph-A core and lies in the more diffuse layer, at column densities on the order of 10^19 cm^-2. The 154μm and 850μm are spatially coincident but trace the magnetic field at different depths in the main core, with the column density at 154μm on the order of 10^20-10^21 cm^-2 and at 850μm on the order of 10^22 cm^-2. The magnetic fields observed at 154 and 850μm are largely in agreement but do differ in certain regions. We suggest this supports previous findings that there is good grain alignment in the Oph-A core.

Dennis Lee (Northwestern University)

Title: HAWC+/SOFIA Polarimetry in L1688: Relative Orientation of Magnetic Field and Elongated Cloud Structure

Abstract: We present a study of the relative orientation between the magnetic field and elongated cloud structures for the Rho Oph A and Rho Oph E regions in L1688. Combining inferred magnetic field orientation from HAWC+ 154 μm observations of polarized thermal emission with column density maps created using Herschel submillimeter observations, we find consistent perpendicular relative alignment at scales of 0.02 pc (33.6" at d ~ 137 pc) using the histogram of relative orientations (HRO) technique. This supports the conclusions of Planck Intermediate Results XXXV for nearby clouds and extends the results to higher column densities. Combining this HAWC+ HRO analysis with a Planck HRO analysis of L1688, the transition from parallel to perpendicular alignment in L1688 is observed to occur at a molecular hydrogen column density of approximately 10^(21.7) cm^-2. This value for the alignment transition column density agrees well with values from Planck Intermediate Results XXXV. Using existing turbulent, MHD simulations of molecular clouds formed by colliding flows (from Chen et al. 2016; Vol 829, pg 84) as a model for L1688, we conclude that the molecular hydrogen volume density associated with this transition is approximately ~10^4 cm^-3. We discuss the limitations of our analysis, including incomplete sampling of the dense regions in L1688 by HAWC+.

Pak Shing Li (Astronomy Depart, University of California at Berkeley)

Title: Mapping the Magnetic Field in the Taurus/B211 Filamentary Cloud with SOFIA HAWC+ and Comparing with Simulation

Abstract: Molecular cloud L1495 in the Taurus region is a typical long, filamentary molecular cloud. Early optical and infrared polarization mapping and recent Planck observations of the cloud show that the large-scale field is approximately perpendicular to the long axis of the cloud. Numerical simulation of filamentary cloud formation shows that filamentary substructures inside filamentary clouds can strongly perturb the magnetic field inside the cloud. We use the HAWC+ polarimeter on SOFIA to probe the complex magnetic field in the B211 region of the cloud and reveal a dispersion of polarization angles of 36.1 degree, about five times that measured on a larger scale by Planck. It is extraordinary that in the small 0.82 pc mapped region, two distinctly different sub-regions are found with magnetic field strengths estimated by the Davis-Chandrasekhar-Fermi (DCF) method that differ by more than a factor 3, with velocity information obtained from IRAM 30m C18O(1-0) observation. The more quiet sub-region is subcritical and sub-Alfvénic; the field is comparable to the average field measured in molecular clumps based on Zeeman observations. The more chaotic super-Alfvénic sub-region shows at least 3 velocity components, indicating interaction among multiple substructures. Its field is much less than the average Zeeman field, suggesting that the DCF value of the field there may be an underestimate. We also show that the standard DCF method is valid even if the turbulence is not due to Alfven waves, and we present an alternate derivation of the structure function version of the DCF method.

Felix Priestley (Cardiff University)

Title: The Characteristic Widths of Magnetised Filaments

Abstract: Observations of the filamentary structures in molecular clouds find that they have a characteristic width of ~0.1 pc, and that they tend to be oriented perpendicularly to the local magnetic field, at least at high column densities. I show that the first property can be explained if filaments are formed via converging supersonic flows; for the gas properties and turbulent velocities typical of molecular clouds, an accretion shock forms at ~0.1 pc from the point of convergence, which effectively sets the boundary of the filament and thus its full-width half-maximum. The observed distribution of filament widths can be reproduced with a realistic distribution of the inflow Mach number. A perpendicularly-aligned magnetic field results in the observed width depending on viewing angle, and a broader filament width distribution compared to the non-magnetised case. I investigate whether this scenario is consistent with the observations, and to what extent filament widths can constrain the dynamical importance of magnetic fields.

Niko Zielinski (CAU Kiel, Institut für Theoretische Physik und Astrophysik)

Title: Magnetic Field Structure of OMC-3 in the Far-infrared Unveiled by SOFIA/HAWC+

Abstract: We report SOFIA/HAWC+ band D (154 μm) and E (214 μm) polarimetric observations of the filamentary structure OMC-3, part of the Orion molecular cloud. The polarization pattern is uniform for both bands and parallel to the filament structure. The polarization degree decreases towards regions with high intensity for both bands, revealing a so called “polarization hole”. We identify an optical depth effect in which polarized emission and extinction act as counteracting mechanisms as a potential contributor to this phenomenon. Assuming that the detected polarization is caused by the emission of magnetically aligned non-spherical dust grains, the inferred magnetic field is uniform and oriented perpendicular to the filament. The magnetic field strength derived from the polarization patterns at 154 μm and 214 μm amounts to 201 μG and 261 μG, respectively. The derived magnetic field direction is consistent with that derived from previous polarimetric observations in the far-infrared and sub-mm wavelength range. Investigating the far-infrared polarization spectrum derived from the SOFIA/HAWC+ observations we do not find a clear correlation between the polarization spectrum and cloud properties, i.e., column density and temperature.

Thursday, June 24

Mike Chen (Queen's University)

Title: Relative Orientations between Velocity Gradients and Magnetic Fields in Perseus NGC 1333 Filaments

Abstract: Motions of star-forming gas are guided by magnetic field lines when magnetic field energy dominates over its gas kinematic counterpart, driven either by turbulence, gravity, or both. The relative orientations between a magnetic field and the gas velocity gradients can thus place important constraints on the role of magnetic fields in assembling star-forming gas. Here we present the relative orientation analysis of Perseus NGC 1333 filaments between magnetic fields and velocity gradient fields measured by JCMT POL-2 and VLA ammonia observations, respectively, both on a 0.02 pc scale. The ammonia data, in particular, are fitted with two spectral components to decouple velocity structures along the lines of sight and ensure accurate measurements of velocity centroid and dispersion. While we find no strong correlation between column densities and relative orientations in NGC 1333, localized filaments and cores often display preferential parallel or perpendicular alignments over regions that are about 0.05pc - 0.15pc in sizes. This result suggests that while magnetic fields alone do not solely regulate the dense gas flow on the 0.02 pc scale, magnetic fields can still strongly influence the gas kinematics in filaments under certain conditions.

Eun Jung Chung (Chungnam National University)

Title: The Role of the Magnetic Field in the Evolution of the Hub-Filament Structures in IC5146

Abstract: Hub-filament structures (HFSs) are usually associated with stellar clusters and thus provide good laboratories for the star formation study. We have carried out polarimetric observations with the SCUBA2/POL-2 instrument on the James Clerk Maxwell Telescope (JCMT) toward the western hub (W-Hub) of IC5146 and investigated the roles of the magnetic field, turbulence, and gravity in forming cores. Using the molecular lines data obtained from TRAO 14m antenna, we estimated the magnetic field strengths, mass-to-flux ratios, and the Alfvénic Mach numbers of the cores in the W-Hub. In the presentation, we will show the result of the JCMT/Pol2 observation and make a comparison to the eastern hub of IC5146. We will discuss the roles of gravity, turbulence, and magnetic field in the formation of dense cores in the W-Hub of IC5146.

Woojin Kwon (Seoul National University)

Title: BISTRO: Magnetic Fields in Serpens Main

Abstract: We have studied the magnetic fields in the Serpens Main molecular cloud on about 6000 au scales, as a part of the B-fields In STar-forming Region Observations (BISTRO) survey using the JCMT and POL-2. Serpens Main consists of two subclusters and has six filamentary structures with various physical properties including star formation activities. Utilizing the histogram of relative orientations technique, we found that magnetic fields are parallel to the less dense filaments while being perpendicular to dense ones. In addition, the magnetic field orientations with respect to the structures change again in denser regions. We also estimated magnetic field strengths by the Davis-Chandrasekhar-Fermi method and found that magnetic field pressure is comparable to or larger than that of the turbulence in all filaments.

Diep Pham Ngoc (Vietnam National Space Center)

Title: BISTRO Survey: Dust Grain Properties from the Observation of Magnetic Fields Surrounding LkHa 101

Abstract: Using the polarimeter POL2 of the James Clerk Maxwell Telescope, the BISTRO Collaboration conducted the highest spatial resolution measurements of the magnetic fields surrounding the densest region of the Auriga-California molecular cloud (LkHa 101). The magnetic field morphology, the possible causes of the observed polarization hole, and the implications on the properties of the dust grains in the region will be discussed.

Cornelia Pabst (Leiden Observatory)

Title: How Do Magnetic Fields Regulate Star Formation? The Case of 30 Doradus

Abstract: The interaction of massive stars with their environment is crucial to the lifecycle of the interstellar medium as this feedback regulates the star formation potential of galaxies. Previously, we have studied the interaction of the Trapezium star cluster with the Orion Molecular Cloud. Here we report a similar study of the 30 Doradus region in the Large Magellanic Cloud. As the nearest starburst region 30 Doradus serves as a template to study star formation and stellar feedback in extreme environments. With SOFIA/upGREAT we have obtained velocity-resolved observations of the [CII] 158μm line of the entire nebula. The [CII] line is an excellent tracer of large-scale dynamics and expansion of the neutral gas. Together with archival SOFIA/HAWC+ observations of the dust polarization these data allow to investigate the role magnetic fields play in stellar feedback processes. I will show some preliminary results.

Shomanov Adai (Nazarbayev University)

Title: Filaments Segmentation: Mask RCNN Approach

Abstract: The interstellar filaments are believed to play a major role in star formation. Filament detection algorithms were developed to find a location

and extent of the filaments in the sky. Two of the commonly used methods for this task are the RHT (Rolling Hough Transform) and the DisPerse algorithms. Different by their nature, these algorithms depend on a large number of parameters and hence finding filaments in the images usually require a time-consuming process of finding the optimal set of these parameters. To facilitate this process and make it easier and more efficient we propose a deep neural network solution for the process of the filament segmentation. Our work depends on a particular architecture called Mask R-CNN, which is a variant of convolutional neural network that provides as an output the masked images, in which corresponding filaments can be found. In our work we have demonstrated a high mean average precision (mAP) of 90 percent for the filament segmentation task. In our approach we used datasets with different levels of complexity, both simulated and observational. We applied transfer learning for each consecutive step. The neural network was trained on a GeForce 2080 RTX GPU with a keras library and tensorflow backend used as software.

Derek Ward-Thompson (UCLAN)

Title: Some Insights from the JCMT BISTRO Surveys

Abstract: In this talk I will present some of the highlights of the JCMT BISTRO Surveys so far. I will not give a comprehensive review of the surveys but rather will share some insights into things we have learnt in general about magnetic fields in filamentary environments in the ISM. These will include the relationship between fields and outflows, a possible 'critical scale length' for magnetic fields, and interactions between fields and 'bubbles'. I will compare the BISTRO data with data at other wavelengths and different resolutions from other instruments and telescopes, such as Planck, ALMA and SOFIA HAWC+.

Friday, June 25

Jordan Guerra (Villanova University)

Title: Constructing Maps of Plane-of-Sky Magnetic Field Strength using FIR Polarimetric Data

Abstract: Far Infrared (FIR) dust polarimetry enables the study of the magnetic field in astrophysical objects such as molecular clouds. On one hand, polarization orientation provide information about the plane-of-sky (POS) direction of the magnetic field. On the other hand, the patterns observed in the polarization orientation can be used to estimate the POS magnetic field strength via the Davis-Chandrasekhar-Fermi (DCF) method. The advent of high angular-resolution polarimetric data from facilities such as HAWC+/SOFIA provide an unprecedented opportunity to study the magnetic field in further detail. We present here the application of the DCF method in combination with a moving kernel approach. This combination allows the construction of maps of the magnetic field strength. We will present such maps for the Orion Molecular Cloud region 1 (OMC-1) and their implications in the magnetic field — gravity balance that is fundamental for star formation process. In addition, we will discuss the shortcomings of the DCF method and what can be done to mitigate them by using simulated data.

Thiem Hoang (KASI & UST)

Title: Rotational Disruption and Alignment of Astrophysical Dust

Abstract: The alignment of dust grains causes the polarization of starlight as well as the polarization of thermal radiation from themselves. Efficient grain alignment, as required to reproduce observed dust polarization, is only achieved when grains can rotate suprathermally. The grain suprathermal rotation (e.g., by radiative torques) induces centrifugal stress within the grain that can exceed the binding energy of the grain material, resulting in the disruption of the grain into small fragments. The rotational disruption changes the grain size distribution, which affects all observable properties of dust (extinction, emission, polarization) and surface chemistry. In this talk, I will discuss the fundamental link between grain alignment, rotational disruption, and present our recent results in numerical modeling and observational evidence for the grain rotational disruption by radiative torques.

Raphael Skalidis (University of Crete and Institute of Astrophysics, FORTH)

Title: Precession Galactic Magnetometry through Dust Polarization

Abstract: Dust polarization is used to probe the magnetic field properties in the interstellar medium (ISM), but it does not provide a direct measurement of its strength. Various methods have been developed employing dust polarization and spectroscopic data in order to infer the magnetic field strength. All of these methods rely on the assumption that the observed linewidths of the emission spectra and the spread in the distribution of the polarization angle is due to the propagation of Alfvén waves. Observations, however, indicate that non-Alfvénic (compressible) waves may be important in the ISM kinematics. With simple Energetics arguments, we developed a new method which takes into account the compressible modes. We created synthetic observations from 3D MHD turbulent simulations in order to assess the accuracy of our method. For comparison, we applied two of the most widely accepted past methods developed by Davis 1951, Chandrasekhar & Fermi 1953 and Hildebrand et al. 2009 and Houde et al. 2009, which are solely based on Alfvénic modes. The omission of compressible modes highly affects these methods, which in some cases produced estimates which deviated more than a factor of two from the true magnetic field strength. In contrast to them, the proposed method produced estimates with a mean relative deviation from the true value equal to 17%. Our method achieved a uniformly low error in the estimation of the magnetic field strength independently of the turbulent properties of the medium.

Jean-Mathieu Teissier (Technische Universität Berlin)

Title: Magnetic Helicity Inverse Transfer in Supersonic Isothermal MHD Turbulence

Abstract: Magnetic helicity is an ideal invariant of the magnetohydrodynamic (MHD) equations which exhibits an inverse transfer in spectral space. Up to the present day, its transport has been studied in direct numerical simulations only in incompressible or in subsonic or transonic flows. Inspired by typical values of the turbulent root mean square (RMS) Mach number in the interstellar medium, this work presents some aspects of the magnetic helicity inverse transfer in high Mach number isothermal compressible turbulence, with RMS Mach number up to the order of ten:

1) a clear Mach-number dependence of the spectral magnetic helicity scaling but an invariant scaling exponent of the co-spectrum of the Alfvén velocity and its curl,

2) the approximate validity of a dynamical balance relation found by incompressible turbulence closure theory,

3) a characteristic structuring of helically-decomposed nonlinear shell-to-shell fluxes that can be disentangled into different spectrally local and non-local transfer processes.

Le Ngoc Tram (Max-Planck Institute for RadioAstronomy)

Title: Understanding Polarized Dust Emission from Rho Ophiuchi A in Light of Grain Alignment and Disruption by Radiative Torques

Abstract: The alignment of dust grains with the ambient magnetic field produces polarization of starlight and thermal dust emission. Using the SOFIA/HAWC+ polarimetric data observed toward the Rho Ophiuchus (Oph) A cloud hosted by a B star at 89 and 154 μm, we find that the fractional polarization of thermal dust emission first increases with the grain temperature and then decreases once the grain temperature exceeds ≃ 25-32 K. The latter trend differs from the popular RAdiative Torques (RATs) alignment theory prediction, which implies a monotonic increase of the polarization fraction with the grain temperature. We perform numerical modeling of polarized dust emission for the Rho Oph-A cloud and calculate the fraction of dust polarization by simultaneously considering the dust grain alignment and rotational disruption by RATs. Our modeling results could successfully reproduce both the rising and declining trends of the observational data, which suggest grains in the Rho Oph-A cloud have a composite structure, and the grain size distribution has a steeper slope than the standard size distribution for the interstellar medium. This study revealed the importance of the rotational disruption mechanism that needs to be considered together with RAT alignment to interpret SOFIA/HAWC+ observations of the polarized thermal dust emission toward an intense radiation source.

Siyao Xu (Institute for Advanced Study)

Title: Turbulence Anisotropy: a New Method for Measuring Magnetic Fields in Cold Interstellar Phases

Abstract: The interstellar turbulence is magnetized and thus anisotropic. The anisotropy of turbulent magnetic fields and velocities is imprinted in the related observables, including filamentary density structures. As theoretically expected and numerically tested, density filaments aligned with the local magnetic fields are naturally generated in sub-Alfvénic MHD turbulence, and their morphology is shaped by the turbulence anisotropy. Based on this knowledge, we found the difference between the turbulent fluctuations measured in different directions is closely correlated with the magnetic field strength. Their relation has been quantitatively confirmed by our synthetic observations of 12CO emission. The turbulence anisotropy provides a new method for measuring the plane-of-sky magnetic fields in cold interstellar phases.

Ka Ho Yuen (University of Wisconsin Madison)

Title: Velocity Caustics as the Tracer of Magnetic Field and Turbulence Statistics in Interstellar Media

Abstract: The success of the velocity gradient technique allows us to retrieve the magnetic field structures in both interstellar media and molecular clouds with relatively high accuracy. Yet, the fundamental reason why the gradient technique works rely on the fact that the velocity channels in the position-position-velocity cube are filamentary in nature and dominant by velocity fluctuations. The latter is hard to attain when there are other ongoing physical processes like shocks or outflows, strong absorptions, or underlying thermal broadening. The recent development of the Velocity Decomposition Algorithm allows observers to obtain velocity caustics from observations, which is suggested by the MHD turbulence theory to be the best magnetic field trader available in observations. In the talk, I will illustrate how to obtain velocity caustics from different molecular clouds, show the respective magnetic field structures outlined by the filamentary features from caustics, and reveal the underlying MHD turbulence statistics stored in the statistics of velocity caustics. The availability of velocity caustics for every PPV cube in molecular clouds will open a new avenue in studying magnetic fields or, more generally, studying turbulence in observations.