

# Filaments 2014 Abstracts

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**Crystal Anderson** (New Mexico Institute of Mining and Technology)

David S Meier (New Mexico Institute of Mining and Technology)

Juergen Ott (National Radio Astronomy Observatory)

Annie Hughes (Max-Planck-Institut f ur Astronomie)

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Presentation requested: poster

**From Gas to Stars in Energetic Environments: Dense Gas Clumps in the 30 Doradus Region Within the Large Magellanic Cloud**

We present parsec scale interferometric maps of HCN(1-0) and HCO<sup>+</sup>(1-0) emission from dense gas in the star-forming region 30 Doradus, obtained using the Australia Telescope Compact Array. This extreme star-forming region, located in the Large Magellanic Cloud (LMC), is characterized by a very intense ultraviolet ionizing radiation field and sub-solar metallicity, both of which are expected to impact molecular cloud structure. We detect 13 bright, dense clumps within the 30 Doradus-10 giant molecular cloud. Some of the clumps are aligned along a filamentary structure with a characteristic spacing that is consistent with formation via the varicose fluid instability. Our analysis shows that the filament is gravitationally unstable and collapsing to form stars. There is a good correlation between HCO<sup>+</sup> emission in the filament and signatures of recent star formation activity including H<sub>2</sub>O masers and young stellar objects (YSOs). YSOs seem to continue along the same direction of the filament toward the massive compact star cluster R136 in the southwest. We present detailed comparisons of clump properties (masses, linewidths, sizes) in 30Dor-10 to those in other star forming regions of the LMC (N159, N113, N105, N44). Our analysis shows that the 30Dor-10 clumps have similar mass but wider linewidths and similar HCN/HCO<sup>+</sup> (1-0) line ratios as clumps detected in other LMC star-forming regions. Our results suggest that the dense molecular gas clumps in the interior of 30Dor-10 are well-shielded against the intense ionizing field that is present in the 30Doradus region.

**Philippe ANDR** (CEA Saclay)

Presentation requested: oral

## **Herschel Observations of Nearby Interstellar Filaments**

Herschel imaging surveys have given us key insight into the link between the large-scale filamentary structure of molecular clouds and the formation of prestellar cores. I will give an overview of the results obtained in this area as part of the Herschel Gould Belt survey, one of the largest key projects with Herschel. The Herschel images reveal a rich network of filaments in every interstellar cloud and suggest an intimate connection between the filamentary structure and the core formation process. A large fraction ( $\sim 50\%$  or more) of the dense molecular gas is found to be in the form of filaments and most ( $\sim 75\%$ ) of prestellar cores are located within dense, “supercritical” filaments. Remarkably, filaments are omnipresent even in unbound, non-star-forming complexes and seem to be characterized by a narrow distribution of widths around  $\sim 0.1$  pc. The origin of this characteristic width is not yet well understood but possible interpretations will be briefly discussed. Altogether, the Herschel results support a star formation scenario in which filaments play a central role: first, the dissipation of kinetic energy in large-scale MHD flows (turbulent or not) generates  $\sim 0.1$  pc-wide filaments in the cold ISM; second, the densest filaments grow and fragment into prestellar cores (and ultimately protostars) by gravitational instability above a critical threshold  $\sim 16 M_{\odot}/\text{pc}$  in mass per unit length or  $\sim 160 M_{\odot}/\text{pc}^2$  in gas surface density ( $A_V \sim 8$ ). This scenario provides new insight into the inefficiency of star formation and the origin of the initial mass function.

**Cara Battersby** (Harvard-Smithsonian Center for Astrophysics)

Phil Myers (Harvard-Smithsonian Center for Astrophysics)  
Yancy L Shirley (University of Arizona)  
Eric Keto (Harvard-Smithsonian Center for Astrophysics)  
Helen Kirk (McMaster University)

Presentation requested: oral

## **Radial Infall onto a Massive Star-Forming Filament**

Emerging research demonstrates the ubiquity of massive-star-forming filaments in the Milky Way, yet their role in the star formation process remains unclear. Whether most of the matter that forms a massive star cluster is present prior to the formation of stars or if it accretes onto the forming cluster over time, potentially guided by filamentary structures, remains an open question. We investigate the role of continuing accretion onto a forming massive star cluster by presenting global line asymmetries toward a massive molecular filament ( 80 pc long,  $10^5 M_{\odot}$ ). These line asymmetries are interpreted as a signature of large-scale radial collapse. Using line asymmetries observed with optically thick HCO+ (1-0) and optically thin H13CO+ (1-0) across a range of massive star forming regions in the filament, we estimate the global radial infall rate of the filament to range from a few 100 to a few 1000  $M_{\odot}/pc/Myr$ . At its current infall rate the densest portions of the cloud will more than double their current mass within a Myr. The discovery of such a reservoir of infalling gas has important ramifications on the course of star formation in the cloud and on our overall understanding of star cluster formation.

**John Bieging** (University of Arizona)

Presentation requested: poster

**Molecular cloud structure revealed in fully sampled degree-scale maps of CO and  $^{13}\text{CO}$  J=2-1 emission with the Heinrich Hertz Submm Telescope**

We present highlights from a mapping program utilizing mainly the J=2-1 transitions of CO and  $^{13}\text{CO}$  to examine a selection of: (1) giant molecular clouds, which typically lie at distances  $\geq 2$  kpc and are forming massive OB associations; (2) clouds which are intermediate in mass ( $\lesssim 10^4 M_{\odot}$ ) at distances of a few hundred pc and which are forming low mass stellar clusters; and (3) nearby low mass dark clouds or “Bok globules” which may be forming one or a few stars with masses  $\lesssim 1 M_{\odot}$ .

Our results illustrate the wide range of cloud structure through maps that cover degree-scale areas with full spatial sampling at an angular resolution of  $< 40 \text{ arcsec}$ , velocity resolution of  $\sim 0.3 \text{ km s}^{-1}$ , and sensitivity of 0.1 K RMS noise per pixel in one spectral channel. Papers in this series made such data available for the giant molecular clouds near W51 and W3 (Bieging et al. 2010; Bieging & Peters 2011); and for the intermediate mass clouds in Serpens (Burleigh et al. 2013) and Perseus/NGC 1333 (Bieging et al. 2014). Observations of Bok globules are shown in Stutz et al. (2009) and Lippok et al. (2013). We have also given summary results for GMCs associated with the H II regions Sh 254-258 (Bieging et al. 2009) and M17 (Povich et al. 2009).

This paper will illustrate the variety of structures (filamentary, flocculent, diffuse) found in clouds as well as evidence for dynamical processes (converging flows, cloud collisions, Alfvén waves) across a wide range of spatial scales. We will emphasize new and recently published results for GMCs associated with M17, Cep A, Sh 235, and intermediate mass clouds Serpens and NGC 1333.

**Lauren Cashman** (Boston University)

Lauren Cashman (Boston University)  
D P Clemens (Boston University)

Presentation requested: poster

**Testing for Helical Magnetic Fields in the Orion Molecular Cloud Integral-Shaped Filament**

The Orion Molecular Cloud (OMC) is one of the closest and most well-studied regions of ongoing star formation. Within the OMC, the Integral-Shaped Filament (ISF) is a long, filamentary structure of gas and dust that stretches over 7 pc and is itself comprised of many smaller filaments. Previous observations of the ISF indicate that these filamentary structures may be supported by helical magnetic fields. To test for the presence of helical fields, we have collected deep near-infrared (NIR) H-band ( $1.6 \mu\text{m}$ ) and K-band ( $2.2 \mu\text{m}$ ) linear polarimetry of background starlight for five overlapping  $10 \times 10$  arcmin fields of view that fully span the ISF. Preliminary analysis indicates that the NIR polarization position angles (which trace the plane of sky magnetic field direction) are predominantly perpendicular to the long axis of the ISF. The data were collected using the Mimir NIR instrument on the 1.8m Perkins Telescope located outside of Flagstaff, AZ.

**Nicholas Chapman** (Northwestern University)

Di Li (National Astronomical Observatories of China)  
Giles Novak (Northwestern University)  
Thagasamy Velusamy (Jet Propulsion Laboratory)

Presentation requested: oral

## The Magnetic Field in OMC3

We present  $350\mu\text{m}$  polarization measurements of the filament OMC3 and compare them with previous polarization measurements made at  $850\mu\text{m}$ . The magnetic field directions traced at the two wavelengths are consistent with one another along most of the length of the filament, the main exception being the region near MMS6, the brightest and most massive protostar in OMC3. The mean field direction is nearly perpendicular to the filament axis, suggesting the filament formed via gravitational collapse along the field lines. Smaller scale features, such as a kink in the filament, are not mirrored by a complementary kink in the field direction. The filament is not visible in polarized intensity at  $350\mu\text{m}$ , but it is very evident at  $850\mu\text{m}$ . Given that the  $850\mu\text{m}$  should trace bigger, cooler dust grains, we infer that the  $350\mu\text{m}$  data are tracing the magnetic field in the envelope, while the  $850\mu\text{m}$  data probe deeper inside. Lastly, the polarized intensities are slightly higher north of the filament at  $350\mu\text{m}$ , which may indicate better dust grain alignment with the magnetic field via Radiative Alignment Torques.

**Che-Yu Chen** (University of Maryland)

Eve Ostriker (Princeton University)

Presentation requested: oral

## **Self-gravitating Filament Formation from Shocked Flows**

Recently, the CARMA Large Area Star Formation Survey (CLASSy) observed five star-forming regions in the Perseus and Serpens Molecular Clouds to investigate the kinematics of dense gas. Several filaments identified in CLASSy data show prominent velocity gradient perpendicular to their major axes. Perpendicular velocity gradients of this kind are a common feature seen in our numerical simulations, in which filaments develop by the combined action of large-scale converging flows, smaller-scale turbulence, and self-gravity. In our simulations, large-scale converging flows (modeling the largest-scale turbulence in a cloud) creates a stagnant post-shock compressed layer. Within this dense layer, self-gravity pulls gas into filamentary structures (seeded by smaller-scale turbulence), with gas velocities mostly parallel to the plane of the layer. When the dense shocked layer is viewed from any angle other than face-on, the line-of-sight velocity around a filament has gradient perpendicular to its major axis, similar to those seen in CLASSy filaments. From this evidence, we propose an “in-plane accretion” model for filament formation, and provide both qualitative and quantitative comparisons between simulation results and observational data. In particular, we show that the ratio  $v^2/(GM/L)$ , where  $v$  is the observed perpendicular velocity difference across a filament, and  $M/L$  is the filament’s mass per unit length, can distinguish between filaments formed purely due to turbulence and those formed due to self-gravity. In addition to describing kinematic signatures of different filament formation mechanisms, I will also discuss more generally the properties of filaments formed in our MHD simulations. These include the mass per unit length and the radial density profiles at different stages of evolution, contrasting filaments formed purely by turbulence and those formed by a combination of turbulence and self-gravity.

**Sarah Church** (Stanford University)

Sarah Church ()

Presentation requested: oral

### **The capabilities of the Argus Instrument for the GBT**

The Argus receiver – a 16-element heterodyne array based on MMIC HEMT amplifiers – is being built by Stanford University in collaboration with Caltech, JPL, U. Maryland, U. Miami and NRAO. Argus will be deployed on the GBT in early 2015 and will be able to carry out spectroscopic studies from 75-115.3 GHz. Argus on the GBT will be well-suited to wide-field mapping of star forming regions. I will describe the capabilities of Argus and its expected modes of operation.

\*\* this is a companion talk to that proposed by Paul Goldsmith will will concentrate on the expected Argus science

**Susan Clark** (Columbia University)

Joshua E.G. Peek (Space Telescope Science Institute)  
Mary E. Putman (Columbia University)  
Lowell E. Schudel (Columbia University)

Presentation requested: poster

## **Quantifying Filamentary Structure with the Rolling Hough Transform**

We present the Rolling Hough Transform (RHT), a new machine vision code for parameterizing the coherent linearity of image structures. The RHT allows a quantitative analysis of morphology by encoding the probability that any given image pixel is part of a linear structure in any direction. Unlike DisPerSE the RHT does not rely on a definition of filament that is unique to self-gravitating structures. The RHT has been used to demonstrate the alignment of the interstellar magnetic field with diffuse HI. The Directional RHT (dRHT), an extension to the method, allows us to explore morphology questions in dense or collapsed regimes. We present RHT and dRHT analyses of simulations and observations of molecular clouds. The code is easy to use and publicly available on github.

**Yanett Contreras** (CSIRO Astronomy and Space Science)

Presentation requested: poster

## **Fragmentation of filamentary molecular clouds**

Recent surveys of dust continuum emission at sub-mm wavelengths have shown that filamentary molecular clouds are ubiquitous along the Galactic Plane. These structures are not homogeneous, presenting over densities associated with signspot of star formation suggesting that stars are forming within the filaments. To investigate the connection between filaments and star formation, we performed a multi-wavelength study of five filamentary molecular, containing several clumps in different evolutionary stages. We derive the physical properties of the clumps and analyse the fragmentation of the filaments. In this presentation I will show the results of this work.

**James Di Francesco (NRC)**

Presentation requested: oral

**The Relationships between Filaments and Protostars in Molecular Clouds**

Herschel has recently revealed the connection between dense filaments and star formation; namely, protostars form preferentially in dense filaments since presumably such environments allow mass buildup and fragmentation to occur, and thus prestellar cores to form efficiently. Moreover, cluster formation may occur preferentially in clumps formed at the intersections of filaments due to increased mass buildup and fragmentation at those locations. In this presentation, we will review the observational evidence for these statements, and discuss observational possibilities of expanding further our understanding of the relationship between filaments and star formation.

**William Dirienzo** (University of Wisconsin-Sheboygan)

Crystal Brogan (NRAO)

Remy Indebetouw (University of Virginia NRAO)

Claire J Chandler (NRAO)

Rachel K Friesen (Dunlap Institute for Astronomy and Astrophysics)

Kathryn E Devine (College of Idaho)

Presentation requested: poster

## **Physical Properties, Kinematics , and Substructure in the Molecular Gas of Infrared Dark Clouds**

Infrared Dark Clouds (IRDCs) harbor the earliest phases of massive star formation, and many of the compact cores in IRDCs, traced by millimeter continuum or by molecular emission in high critical density lines, host massive protostars. We used the Robert C. Byrd Green Bank Telescope (GBT) and the Very Large Array (VLA) to map NH<sub>3</sub> and CCS in nine IRDCs to reveal the temperature, density, and velocity structures and explore chemical evolution in the dense ( $> 10^{22}$  cm<sup>-2</sup>) gas. Ammonia is an ideal molecular tracer for these cold, dense environments. The internal structure and kinematics of the IRDCs include velocity gradients, filaments, and possibly colliding sub-clouds that elucidate the formation process of these structures and their protostars. We find a wide variety of substructure including filaments and globules at distinct velocities, sometimes overlapping at sites of ongoing star formation. It appears that these IRDCs are still being assembled from molecular gas clumps even as star formation has already begun, and at least three of them appear consistent with morphology of the “hub-filament structure” discussed in the literature. Furthermore, we find that these clumps are typically near equipartition between gravitational and kinetic energies, so these structures may survive for multiple free-fall times.

**Rachel Friesen** (University of Toronto)

Presentation requested: oral

### **Tracing the mass flow in clustered star forming regions**

Most stars in our galaxy do not form in isolation. Instead, stars are born in groups and clusters embedded within dense filaments and clumps in molecular clouds. Many clustered star-forming regions share similar morphologies, where the greatest star formation rates are found within a central 'hub' of dense molecular gas, that is connected to streams or filaments of additional material. To understand how stars form in clusters, we need to understand how these filaments accrete mass from the surrounding environment, funnel mass to star-forming 'hubs', and fragment to form dense star-forming cores. I will present observational evidence of ongoing accretion of material onto dense filaments in a nearby young cluster, with derived mass accretion rates that are sufficient to trigger additional fragmentation and gravitational collapse. In particular, I will show how combining observations of gas dynamics and chemistry in star forming regions can be used to answer these questions.

**Yasuo Fukui** (Nagoya University)

Presentation requested: oral

**Resolved filaments and star formation in N159 with ALMA Cycle1: Most active on-going star formation in the Local Group**

High-mass star forming regions are relatively few in the solar neighborhood. Much more active and extensive high-mass star formation is found outside the Milky Way. Our target here is the giant molecular cloud GMC in N159, an HII region located in the nearest external galaxy Large Magellanic Cloud having lower metalicity than the Milky Way. N159 is the most intense and concentrated molecular cloud as shown by the brightest CO  $J=3-2$  source in the LMC, and is thus ideal to study the most-massive current cluster formation in the Local Group. Nearby HII region 30Dor is not forming massive clusters anymore and is not suitable to witness cluster formation. In ALMA cycle1 operation we have observed five  $J=2-1$  and  $1-0$  transitions of 12CO and 13CO,  $J=2-1$  transition of CS and dust continuum in band 3 and 6. We present the first maps of pre-stellar cores and linking filaments at sub-pc resolution and discuss the formation process of massive clusters.

**Gary Fuller** (Jodrell Bank Centre for Astrophysics University of Manchester)

N Peretto (Cardiff University)  
C Lenfestey (University of Manchester)  
A Daute-Cabral (Exeter University)  
P Andre (CEA Saclay)  
D Arzoumanian (IAS Universit Paris-Sud)

Presentation requested: oral

### **Filamentary Infrared Dark Clouds**

Infrared dark clouds (IRDC) are cold, dense clouds seen in absorption against the Galactic diffuse infrared radiation field. These regions are ideal for studying the initial conditions for star formation as, by definition, they are not (yet) dominated by the feedback from star formation. In this presentation I will discuss three very different examples of filaments seen in IRDCs in the Spitzer Dark Cloud (SDC) catalogue. The first will focus on recent ALMA observations of the hub-filament structure associated with the most massive protostar known in the galaxy. The second will look at an example of collapse along filamentary clouds. Moving to much larger size scales, the final example will look at a catalogue of recently identified large scale filamentary structures comprised of multiple SDCs.

**Brandt Gaches** (University of Massachusetts)

Stella Offner (University of Massachusetts)

Erik Rosolowsky (University of Alberta)

Thomas Bisbas (University College London)

Presentation requested: oral

## **Structure Analysis Using the Spectral Correlation Function**

We investigate the spectral structure of different chemical tracers used to observe molecular clouds. We study a  $600 M_{\odot}$  molecular cloud modelled with the magnetohydrodynamic code ORION. We calculate chemical abundances using 3D-PDR, a three-dimensional astrochemistry code and perform radiative transfer post-processing using RADMC-3D. We use the Spectral Correlation Function (SCF) to quantify the structure of the model cloud in position-position-velocity space for 16 different tracers. The SCF measures the average rms velocity between spectra separated by a given length scale. The SCF can be fit by a power law over the length scales the species traces. We show that the power law exponent gives a robust measure of the structure that chemicals tracer. Species with small SCF exponents trace more diffuse structure, while species with larger SCF exponents trace denser environments. In particular, the pairs C and CO, C<sup>+</sup> and CN, HCN and CS and NH<sub>3</sub> and N<sub>2</sub>H<sup>+</sup> have very similar SCFs. The results of this study provide groups of homologous species that trace different densities and size scales. We find that the SCF exponent correlates with the fraction of filamentary structure, where tracers with steeper slopes, like HCN, exhibit more filamentary emission. The SCF slope provides a dimensionless parameter that can be used to compare models and observations.

**Steven Gibson** (Western Kentucky University)

Presentation requested: oral

## **Cold HI Filamentary Structure and Magnetic Fields near the Galactic Plane**

The cold neutral atomic gas from which molecular clouds form has abundant filamentary structure in HI 21cm line maps. This structure is more apparent at higher angular resolution and often displays a distinct affinity for magnetic field structure traced by interstellar optical starlight polarization. Clark et al. (2014) recently developed a method of automatically identifying and measuring HI "fibers" and used this to quantify HI - B-field alignments in high-latitude fields from Arecibo and Parkes and an ATCA Galactic-center field. Using a similar approach, we have mapped HI "fibers" in the Canadian Galactic Plane Survey (CGPS; GLON = 52:193, GLAT=-3:+5) and the Arecibo Inner-Galaxy ALFA survey (I-GALFA; GLON=32:77, GLAT=-20:+20). We find conspicuous HI alignments with both optical polarization and first-look Planck sub-mm polarimetry. These occur predominantly in local-velocity gas with minimal sight line confusion and track the global B-field geometric variation vs. Galactic longitude. Where measurable, typical aligned HI structures have line widths a few km/s, indicating that cold atomic gas, despite its low ionization fraction, either influences or is influenced by the magnetic field.

**Paul Goldsmith (JPL)**

Presentation requested: oral

## **Spectral Line Mapping with ARGUS on the GBT**

The discovery by Herschel and other facilities that filaments are a critical component of the internal structure of interstellar clouds has had a major impact on thinking about the evolution of these clouds, and of the star formation that takes place within them. Probing the structure of filaments requires high spectral resolution observations of key molecular tracers to study kinematics and determine physical conditions. These observations require high angular resolution as well to discern details, but these structures often have angular sizes measured in degrees. The GBT offers impressive angular resolution (6.7" at 115 GHz, corresponding to 0.005 pc at the 140 pc distance of Taurus) and very high brightness temperature sensitivity. But to carry out imaging projects on the angular scale of filaments in a reasonable time requires a focal plane array. ARGUS is a 16-pixel array covering 85-116 GHz, based on InP MMICs cooled to 15 K. It covers high density tracers such as HCN and HCO+ (and isotopologues) as well as all isotopologues of carbon monoxide. The receiver noise temperature for Argus pixels is expected to be below 60 K across its frequency range and should reach as low as 40 K at its best operating frequency, near 105 GHz. Each pixel in the 4x4 square array is coupled to the antenna by a scalar feedhorn. Additional details can be found in paper by Sieth et al. (Proc SPIE June 2014, vol. 9153, Coherent Detector Technology). Argus will be used with the NRAO VEGAS autocorrelation spectrometer system to allow observation of multiple spectral lines within a 1.5 GHz window that can be placed anywhere within the ARGUS bandpass. This will allow efficient on-the-fly mapping of both high- and low-density tracers to probe filaments in molecular clouds. The combination of the large instantaneous bandwidth and high sensitivity of ARGUS with the flexibility of the VEGAS system enables observations of other types as well.

**Alyssa Goodman** (Harvard-Smithsonian Center for Astrophysics)

Jaime Pineda (ETH-Zurich)

Hope Chen (Harvard-Smithsonian CfA)

Presentation requested: oral

**Do filaments cross core "boundaries"?**

Thanks to extensive observations of the Perseus star-forming region, and the Barnard 5 (B5) star-forming core within it, we can study filamentary structure at scales from 10's or pc down to hundredths of pc using a wide variety of gas and dust tracers. Recently, in compositing Herschel dust emission maps of Perseus with GBT and JVLA maps of NH<sub>3</sub> in B5, we noticed that the large scale (>1 pc) filaments that "lead to" the B5 core appear to \*continue\* across the "coherent core" boundary, right down into the sub 0.1 pc scales traced by NH<sub>3</sub>. We find this result very surprising, since it suggests that the "core" is not as distinct from its filamentary surroundings as we—and current conventional wisdom—would have predicted. Numerical simulations on 1-10 pc scales currently create "sink" particles on scales small enough to correspond to our JVLA measurements. The new B5 results presented here should inspire new simulations which offer enough dynamic range to trace the morphology of self-gravitating, non-isothermal turbulence continuously from 10 to 0.01 pc scales, in order to see how, why, and how long filamentary structure is maintained across these scales.

**Robert Gutermuth** (University of Massachusetts)

Riwal Pokhrel (University of Massachusetts)

The Herschel MonR2 Survey Team ()

Presentation requested: oral

**A taxonomy of gas substructures in the MonR2 giant molecular cloud.**

Are filaments universal, and/or ubiquitous, in star-forming molecular clouds? What role do they play in the star-forming process? The need to evaluate the preponderance of filamentary substructures over the alternatives in a relatively unbiased way is clear. The high spatial dynamic range maps of gas column density derived from Herschel dust emission maps of entire nearby molecular clouds offer the best-yet means of establishing a taxonomy of gas substructures. I will present a morphological taxonomy of the hierarchical, or nested, substructures extracted via the astrodendro python package from the Herschel/SPIRE survey of the entire MonR2 giant molecular cloud, and briefly examine star-formation activity by structure type based on our extant Spitzer survey, enhanced with new Herschel/PACS photometry.

**Andres Guzman** (Harvard-Smithsonian CfA)

Andres Guzman (Harvard-Smithsonian CfA)  
Howard Smith (Harvard-Smithsonian CfA)  
Philip Myers (Harvard-Smithsonian CfA)

Presentation requested: oral

### **Massive molecular filaments in the Galactic plane**

We present set of approximately a hundred molecular filaments located in the Galactic Plane between longitudes  $+20^\circ$  and  $-60^\circ$ , defined as coherent structures in column density and  $V_{\text{LSR}}$ . We obtain column density and temperature maps for the filaments using far-IR Herschel observations. These filamentary clouds harbor massive molecular clumps which are able to sustain high-mass star formation in different evolutionary states. The size of our sample allows us to establish some general characteristics about the massive molecular cloud population, where most of the star formation at a Galactic level occurs. We define and describe several geometric and physical parameters of these clouds, such as orientation, length, width, clump positions, branches, mass, temperature, and column density transverse profile shape. We explore the statistics of the population of filaments, and how the physical parameters relate with their star formation evolutionary state, and find a small preponderance of filaments aligned in the direction parallel to the Galactic plane.

**Alvaro Hacar** (Institut fuer Astrophysik Univ Vienna Austria)

Mario Tafalla (Observatorio Astronomico Nacional Spain)

Presentation requested: oral

## Bundles of fibers: the case of the B213-L1495 Taurus filament

Among all filamentary structures in nearby clouds, the B213-L1495 filament is the finest case. Early discovered by Barnard in 1907, with its  $\sim 10$  pc of length and a total mass of  $700 M_{\odot}$  it dominates the entire structure of the Taurus molecular cloud. Moreover, and with more than 40 YSOs and around 20 dense cores, it is also one of the most active regions within these cloud. These properties have made these filament the prototype of a star-forming filament being subject of all kind of studies from optical to radio wavelengths.

To investigate the formation mechanism of cores and stars inside these kind of objects, we have studied the internal gas kinematics of the B213-L1495 filament using FCRAO large scale observations of both  $C^{18}O$  (1–0) and  $N_2H^+$  (10) lines (Hacar et al 2013). Our analysis of the molecular emission inside these region shows the presence of a complex kinematic structure with multiple components in velocity superposed along the line-of-sight. A detailed study of these components demonstrate that, although apparently monolithic when observed at the continuum, the B213 filament is actually a collection of 35 velocity-coherent filaments (fibers) forming a bundle. Characterized by presenting a typical length of  $\sim 0.5$  pc, (tran-)sonic velocity dispersions, and masses per unit length close to the equilibrium, the distribution of these fibers explain the whole internal structure of the B213-L1495 region observer by Herschel. In addition to it, they also contain all the dense cores found inside these region indicating that these last objects inherit the kinematic properties of their parental fibers.

Our results suggest that the formation of dense cores and stars inside filaments like B213 occurs in a two-step process. First, and during the formation of these cloud, the gas is efficiently structured forming multiple of these 0.5 pc and quiescent fibers, most likely as a result of the turbulence dissipation after the collision of large scale flows. Second, and in a subsequent stage, only a small fraction of these fibers form cores via gravitational fragmentation. These results have been confirmed by both recent simulations (e.g. Moeckel & Burkert 2014) and new sets of observations in more complex filamentary regions (Hacar et al 2014, in prep). During my talk I will discuss the key role of the velocity-coherent fibers for our understanding of the star-formation process within molecular clouds.

**Fabian Heitsch** (UNC Chapel Hill)

Presentation requested: oral

**Does accretion control filament evolution?**

Recent observations have re-emphasized the prominence of "filamentary" molecular cloud structure. Filaments are the most beneficial geometry for local gravitational collapse to occur before global collapse. Theoretical studies have focused on hydrostatic cylinders with and without pressure confinement. Yet, self-gravitating molecular clouds rarely exist in complete isolation, and therefore are expected to accrete ambient material - as observed. I will discuss conceptual models of accreting filaments, highlighting possible observable effects.

**Sadia Hoq** (Boston University)

Dan Clemens (Boston University)

Presentation requested: poster

## The Role of Magnetic Fields in IRDCs

The role of the Galactic magnetic field in the formation of Infrared Dark Clouds (IRDCs) and their star formation is not well understood. We use a sample of 30 IRDCs in the first Galactic quadrant to study the relationships between magnetic fields and cloud properties. To trace the magnetic field in the vicinity of the clouds, we use near-infrared (NIR) H ( $1.6 \mu\text{m}$ ) polarimetric observations of background starlight from the Mimir instrument on the 1.8m Perkins telescope. For a subsample of 5 clouds, in addition to the H-band observations, we use deep K-band ( $2.2 \mu\text{m}$ ) polarimetric observations to trace the magnetic field to higher densities. The Herschel Hi-GAL Survey of dust continuum emission was used to estimate the IRDC column densities, and the Spitzer GLIMPSE & MIPS GAL Surveys were used to find their level of star formation activity. We test magnetic field models based on the direction of the magnetic field inferred from the NIR, and determine whether any correlations exist between magnetic field properties (direction and dispersion) and IRDC properties, such as density and level of star formation activity.

**Chat Hull** (NRAO Harvard-CfA)

M C H Wright (UC Berkeley)

T Pillai (MPIfR Bonn)

Jun-Hui Zhao (Harvard-CfA)

G ran Sandell (SOFIA-USRA NASA Ames)

Presentation requested: oral

### **CARMA observations of magnetic fields in star-forming filaments**

Here we present  $\lambda$  1.3 millimeter CARMA observations of polarization in both low- and high-mass star-forming filaments. In the high-mass category we have NGC 7538 IRS 1, where  $\sim 2.5''$  resolution images show a remarkable spiral pattern in the magnetic field (B-field), the dust emission, and the molecular outflow. These data dramatically illustrate the interplay between a high infall rate onto IRS 1 and a powerful outflow disrupting the dense, clumpy medium surrounding the star. And in the low-mass category we have a string of low-mass cores in Serpens, all of which lie along the same filament. The B-field toward the two brightest cores—Ser-emb 8 and 8(N)—looks like it may lie along the filament, and has no obvious relationship to the orientation of the cores' bipolar outflows. Studying both B-field morphology and dynamics in filaments across the many orders of spatial magnitude where these structures appear will be crucial for understanding the role B-fields play in the star- and filament- formation processes.

**Juan C Iba ez-Mejia** (AMNH)

Mordecai M Mac Low (AMNH)

Ralf Klessen (Uni Heidelberg)

Christian Baczynski (Uni Heidelberg)

Presentation requested: oral

## **Formation of Filamentary Structure in a Supernova-Driven Interstellar Medium**

Molecular filaments are ubiquitous in the interstellar medium (ISM) spanning a vast range of length scales, thickness, density contrasts, magnetic field strengths and shapes. Long dense filaments spanning tens of parsecs, observed as infrared dark clouds (IRDCs) appear to be the precursors of star clusters and massive star forming regions. We present three-dimensional simulations of a supernova-driven turbulent, magnetized, stratified, self-gravitating section of a galactic disk (neglecting shear) with dimensions of  $1 \times 1 \times 40$  kpc. The interaction between turbulence, supernovae, superbubbles, and self-gravity triggers the formation of IRDC-like structures with internal filamentary sub-structure down to star forming scales ( $\sim 0.1$  pc). We follow the dynamical evolution of these filaments developing within a realistic galactic environment, and measure their collapse, gas accretion, and fragmentation rates. Gravitationally bound structures with typical masses of the order of  $M \sim 10^5$   $M_\odot$  form, and show signatures of global gravitational collapse. They evolve on timescales of their free fall time  $\tau_{ff} \approx 1$  Myr, fragment into cores with typical separations of the Jeans length and accrete gas at rates of the order of  $\dot{M} \sim 10^{-2}$   $M_\odot$  yr $^{-1}$ . We also note that some morphologies are more common than others and may indicate different evolutionary histories: the more common “beads on a string” morphology occurs in relatively isolated regions, whereas converging filaments are a sign of core mergers.

**Erica Kaminski** (University of Rochester )

Adam Frank (University of Rochester)

Fabian Heitsch ( University of North Carolina Chapel Hill)

Presentation requested: poster

**Colliding Flow Models For Molecular Clouds. The Effect of Magnetic Fields**

Large scale colliding flows are a plausible model for molecular cloud formation. Previously, we have explored hydrodynamical simulations of colliding flows to study energy budgets and protocluster core formation within the collision zone using the adaptive mesh refinement fluid code, AstroBEAR (Carroll, Frank, and Heitsch 2013). We have now extended this set of simulations further by adding magnetic fields and shear. In addition to our previous analyses for the hydrodynamical colliding flows simulations, we are now identifying filaments formed in our flows as well as studying their geometry, radial profiles, and core formation distributions.

**Helen Kirk** (National Research Council of Canada)

Mikhail Klassen ( McMaster University)

Ralph Pudritz (McMaster University)

Presentation requested: oral

## **Evolution of Filaments in Numerical Simulations**

The role of filaments in star formation has become increasingly apparent over the last few years, but much remains to be learned about the filaments themselves, such as how they form and evolve. I present results from numerical simulations of a cluster-forming region which has properties similar to observations. Through the comparison of simulations with and without magnetic fields and with different initial densities, we can gain insight into the competing effects of magnetic fields, turbulence, and gravity on the formation and evolution of the filaments. Even the weak magnetic fields adopted in the simulation are enough to play a strong role in shaping the emergent filaments, leading to puffier, wider filaments than in the non-magnetic case. Furthermore, we find that not all of the filaments formed are stable, long-lived entities; some filaments form and disperse in just a few tenths of a Myr, including some which temporarily achieve a mass per unit length ratio well in excess of the critical value. I also compare some of the features of the simulated filaments with those found in the nearby Orion molecular cloud observed as part of the JCMT Gould Belt Survey.

**Helen Kirk** (National Research Council of Canada)

Presentation requested: oral  
**Filamentary Flows**

Observations over the last few years, especially those from the Herschel Space Telescope have shown that filaments are intimately connected with dense cores. Both theory and observations are starting to suggest that filaments may provide an important reservoir of material both in the accretion of relatively isolated dense cores found along filaments, as well cluster-forming cores, which tend to be found at the junction of multiple filaments. I will review some of the recent evidence of gas flows in filaments, highlighting results from the young Serpens South cluster-forming region. I will also touch on recent analysis of numerical simulations which suggests a similar behaviour.

## **Adam Kobelski (NRAO)**

Adam Kobelski (NRAO)

David Frayer (NRAO)

Ron Maddalena (NRAO)

Brian Mason (NRAO)

Karen O Neil (NRAO)

Presentation requested: poster

## **High Frequency Instruments for the GBT**

The Robert C. Byrd Green Bank Telescope (GBT) is the premiere single-dish radio telescope for cm and mm observations. VEGAS, our recently deployed, next-generation spectrometer and pulsar backend, provides new science opportunities for all receivers and up to eight times more efficient observing than that provided by the 20-year-old GBT Spectrometer. With a fleet of receivers covering the 0.1-115 GHz spectral range, it is an ideal instrument for high frequency observations, especially those that require sensitivity to weak, extended emissions. Mustang 1.5 is a 32 feedhorn dual polarization TES bolometer observing between 75 and 105 GHz, to be expanded to the 223 element array Mustang 2. Also to be commissioned in the coming months is the 16 element Argus which observes between 75 and 115.3 GHz. The W-band 4mm receiver operates in the 67-93.5 GHz bandpass, and the KFPA receiver is a 7 beam focal plane array observing between 18 and 26 GHz. These systems allow the GBT to be a highly capable instrument for high-frequency radio observing, both for single beam and multi-beam mapping studies.

**Shuo Kong** (University of Florida)

Jonathan C Tan (University of Florida)

Paola Caselli (Max-Planck-Institute for Extraterrestrial Physics)

Francesco Fontani (INAF - Osservatorio Astro sico di Arcetri)

Mike Butler (University of Zurich)

Valentine Wakelam (University of Bordeaux)

Presentation requested: oral

## **Massive Starless Cores in a Massive IRDC Filament**

Two potentially massive starless cores were found at one end of a filamentary Infrared Dark Cloud (IRDC) G28.34+0.06. The two cores have high deuteration level, which was revealed through ALMA Cycle 0 molecular line observations. Both extinction mapping and 1.3 mm continuum suggest they have a mass of about  $60 M_{\odot}$ . Multiple transitions of  $N_2H^+$  and  $N_2D^+$  lines were obtained with a variety of telescopes. The deuterium fractions of  $N_2H^+$ ,  $D_{\text{frac}}^{N_2H^+} (\equiv N(N_2D^+)/N(N_2H^+))$ , are very high compared to the interstellar medium. A comparison between this and chemical modeling indicates that the cores are old compared to their local free-fall times, consistent with our dynamical study that suggested the cores are virialized, as long as a strong magnetic field is present. To obtain a larger sample, we further mosaicked the entire IRDC with CARMA in multiple molecular lines. In particular, we detect multiple  $N_2H^+$  aggregations along the filamentary structures, which will be compared with our upcoming ALMA Cycle 2  $N_2D^+$  mosaic in this IRDC. In the meantime, I will present some preliminary results about the molecular observation from CARMA. The Global kinematics of the filament and its comparison with the cores will be discussed.

**Katherine Lee** (University of Maryland)

Manuel Fernandez-Lopez (Instituto Argentino de Radioastronomia)  
Shaye Storm (University of Maryland)  
Leslie Looney (University of Illinois)  
Lee Mundy (University of Maryland)  
Dominique Segura-Cox (University of Illinois)

Presentation requested: poster

### **Morphological and Kinematic Properties of Filaments in Serpens Main**

Recent molecular line observations of filaments in several star-forming regions have advanced our understanding toward kinematic structures of filaments. We present the morphological and kinematic properties of identified filaments in Serpens Main with CARMA Large Area Star Formation Survey (CLASSy) and Herschel data. Two types of filaments with opposite properties have been observed. One type has smaller velocity gradients, larger masses, and more critical mass-per-unit length ratios than the other type. Filaments in each type are spatially correlated, suggesting these filaments are originated from two large-scale structures. Also, we compare the properties of the filaments and the distribution of YSOs. The comparison suggests that YSOs are formed on gravitationally unstable filaments.

## **Adam Leroy (NRAO)**

Antonio Usero (Amanda Kepley)  
David Frayer (Fabian Walter)  
Frank Bigiel (Alberto Bolatto)

Presentation requested: oral

### **Dense Structures in Molecular Clouds Outside the Milky Way**

To understand the role of filamentary substructure in star formation, it will be essential to expand studies of how high density gas (the gas that preferentially resides in filaments in local clouds) relates to star formation beyond the Milky Way and its immediate neighbors. Even with ALMA, our best tools for statistical studies along these lines remain spectroscopic, as resolving cloud substructure at extragalactic distances will be extraordinarily challenging. Observations of high critical density transitions like HCN 1-0, HCO+ 1-0, and CS 2-1 in a multiwavelength context represent the current best tools to pursue the questions at the core of this workshop: where do high density substructures form? How do stars form out of dense gas? Do high density substructures represent a regulating step for star formation? I will present the state of the art in studies comparing high critical density tracers to the overall molecular reservoir and recent star formation, including a new survey of HCN in the disks of star forming galaxies, full galaxy maps of HCN in M82 and M51, and high resolution observations of the high density structures at the heart of the starburst in NGC 253. I will highlight how findings from these studies contrasts with the picture of star formation emerging from studies of solar neighborhood clouds and discuss how with its new high frequency capabilities, the GBT can play a forefront role in helping us understand the role of dense gas in star formation across the whole local universe. I will also call out key areas where extragalactic studies need to be informed by detailed studies of local clouds.

**Di Li** (National Astronomical Observatories of China)

Paul F Goldsmith (JPL)

Jens Kauffmann (MPIfR)

Nicholas Chapman (Northeastern U)

Zhiyuan Ren (NAOC)

Presentation requested: oral

## **Going Beyond Phenomenological Description of Filaments**

Filament is a common feature in cosmological structures of various scales, ranging from dark matter cosmic web, galaxy clusters, inter-galactic gas flows to ISM clouds. In some cases, even within cold dense molecular cores, filaments have been detected. Theories and simulations with (or without) different combination of physical principles, including gravity, thermal balance, turbulence, and magnetic field, can reproduce intriguing images of filaments. The ubiquity of filaments and the similarity in simulated ones make physical parameters, beyond dust column density, a necessity for understanding filament evolution.

I report three projects attempting to measure physical parameters of filaments. In Li & Goldsmith (2012), we derive the volume density of a dense Taurus filament based on several cyanoacetylene transitions observed by GBT and ART. In Li et al. (2013), we measure the gas temperature of the OMC 2-3 filament based on combined GBT+VLA ammonia images. Chapman et al. (2014) measured the sub-millimeter polarization vectors along OMC3. These filaments were found to be likely a cylinder-type structure, without dynamic heating, and likely accreting mass along the magnetic field lines.

**Wanggi Lim** (University of Florida)

Sean J Carey (IPAC)

Jonathan C Tan (University of Florida)

Presentation requested: oral

## **Dust Evolution in Dense Cores and Filaments**

Dense, cold molecular cores embedded in filamentary clouds are likely to be the initial conditions of massive star and star cluster formation. In such environments, dust grains are expected to grow by coagulation and formation of ice mantles, which affects the cooling efficiency and sub-mm emissivity of the clouds (and thus also derived column densities, e.g., from *Herschel* and ALMA observations of sub-mm dust continuum). Large dust grains may also be the seeds for planet formation in circumstellar disks fed from these cores. We present analysis of photometric (*Spitzer*-IRAC & MIPS; *Herschel*-PACS) and spectroscopic (*Spitzer*-IRS) MIR to FIR data of an IRDC, G028.37+0.07, which includes a massive molecular filament, to constrain the dust extinction law over these wavelengths. We search for extinction law variations with environment, i.e., mass surface density. From comparison with theoretical dust models, e.g., Ossenkopf & Henning (1994) and Ormel et al. (2011), we find evidence for grain and ice mantle growth in the highest mass surface density regions. We discuss the implications for mass estimates derived from sub-mm emission.

**Ronald J Maddalena** (NRAO)

Adam Kobelski (NRAO)  
David Frayer (NRAO)  
Anish Roshi (NRAO)  
Frank Ghigo (NRAO)  
Karen O Neil (NRAO)

Presentation requested: poster

### **High Frequency Performance of the GBT**

The Robert C. Byrd Green Bank Telescope (GBT) has been going under continuous improvements that have increased its scientific productivity especially for high frequency observing above 68 GHz. In particular, upgrades have ensured that the telescope's performance complements the existing and planned suite of receiver and spectrometers. We will present the current pointing and surface characteristics of the GBT as well as present some low cost plans for further improvements that use our Quadrant Detector. The weather in Green Bank is well suited for a telescope that is under high pressure from the scientific community for observing at our frequencies: low (300 to 1420 MHz), mid (22.2 GHZ) and high frequency (currently 96 GHZ but extending to 115 GHZ in the upcoming winter season). The telescope's Dynamical Scheduling System ensues observers will not observe under weather conditions that significantly compromise their scientific productivity. The  $\approx$ 100m collecting area, unblocked aperture, and fully movable structure allow unequalled sensitivity and coverage of the celestial sphere.

**Steve Mairs** (University of Victoria)

Doug Johnstone (UVIC NRC-CNRC JAC)  
Stella S R Offner (Yale University)  
Scott Schnee (NRAO)

Presentation requested: oral

**Synthetic Observations of the Evolution of Starless Cores in a Molecular Cloud Simulation: Comparisons with JCMT Data and Predictions for ALMA**

Interpreting the nature of starless cores has been a prominent goal in star formation for many years. In order to characterize the evolutionary stages of these objects, we perform synthetic observations of a numerical simulation of a turbulent molecular cloud. We find that nearly all cores that we detect are associated with filaments and eventually form protostars. The final masses of these protostars are not well represented by the initial masses of their parent cores, indicating the significance of mass flow on larger scales (filaments). We also find that simulated starless cores that appear Jeans unstable are only marginally larger than their respective Jeans masses (within a factor of three). We note that single dish observations such as those performed with the James Clerk Maxwell Telescope appear to miss significant core structure on small scales because of beam averaging. Finally, we predict that interferometric observations with the Atacama Large Millimeter Array (Cycle 1) will resolve the important small-scale structure, which has so far been missed by millimeter wavelength observations. This research has recently been published in The Astrophysical Journal: Mairs, S; Johnstone, D; Offner, S. S. R.; and Schnee, S. 2014, ApJ 783:60.

**Johanna Malinen** (Univ of Helsinki Florida State University)

Mika Juvela (University of Helsinki)  
Alana Rivera-Ingraham (CNRS IRAP Toulouse)  
Mark G Rawlings (NRAO Charlottesville)

Presentation requested: poster

## **Profiling filaments: dust emission, extinction, and scattering**

Interstellar filaments play an important part in the star formation process. They are often associated with prestellar and protostellar sources and the filament profiles are studied to understand their formation and evolution. This profiling is commonly done using submm observations, especially with *Herschel*. If these data are not available, it would be convenient if filament properties could be studied using groundbased near-infrared (NIR) observations. We present the main results of several recent studies using different observational methods (submm dust emission, NIR extinction, and NIR scattering) and simulations. In [1], we compare the filament profiles obtained by high- and low-resolution NIR extinction maps and submm observations to find out if reliable profiles can be derived using NIR data. We also present two new methods to estimate profiles from NIR data: Plummer profile fits to median Av of stars within certain offset or directly to the Av of individual stars. We compare these methods by simulations. In [2], we use scattered NIR light to derive the column density map at the scale of a complete filament. In [3], we examine the observational biases of filament profiles derived from submm dust emission observations using MHD simulations and radiative transfer calculations. In [4], we present the results of a comprehensive statistical analysis of the filaments observed in the *Herschel* programme Galactic Cold Cores, showing a range of different environments and star forming conditions.

### References

- [1] Malinen et al. 2012, A&A, 530, A101
- [2] Malinen et al. 2013, A&A, 544, A50
- [3] Juvela et al. 2012, A&A, 544, A141
- [4] Rivera-Ingraham et al. 2014, submitted

**Brian Mason (NRAO)**

B. Mason (NRAO)

S. Schnee (NRAO)

S. Dicker, J. Aguirre , J. Brevik , H. Cho , M. Devlin

J. Di Francesco , D. Egan , P. Ford , J. Ford , R. Friesen , J. Hubmayer

K. Irwin , D. Li , P. Marganian , J. McMahon , M. Mello , K. O'Neil1 , S. Sadavoy

S. Stanchfield , T. Stanke , C. Tucker , S. White , A. Young , P.A.R. Ade

Presentation requested: poster

**Current and Future High Frequency Continuum Capabilities of the GBT for Studying Star Formation in Molecular Clouds**

The Robert C. Byrd Green Bank Telescope (GBT) is a powerful and flexible instrument for mapping the context and physical conditions of star formation in our Galaxy and nearby galaxies. We present an overview of the GBT's current, planned, and potential millimeter-wave capabilities to support these studies, with a particular focus on continuum instrumentation (MUSTANG and MUSTANG-2). We also present a recent GBT 3.3mm result from MUSTANG showing likely grain growth in the star-forming filament OMC-2/3.

**Brian Mason** (NRAO)

B Mason (NRAO)

S Schnee S Dicker J Aguirre J Brevik H Ch ()

Presentation requested: oral

**Current and Future High Frequency Continuum Capabilities of the GBT for Studying Star Formation in Molecular Clouds**

The Robert C. Byrd Green Bank Telescope (GBT) is a powerful and flexible instrument for mapping the context and physical conditions of star formation in our Galaxy and nearby galaxies. We present an overview of the GBT's current, planned, and potential millimeter-wave capabilities to support these studies, with a particular focus on continuum instrumentation (MUSTANG and MUSTANG-2). We also present a recent GBT 3.3mm result from MUSTANG showing likely grain growth in the star-forming filament OMC-2/3.

**Anthony Minter (GBT)**

Presentation requested: oral

**GBT Observations of Atomic to Molecular Clouds to Star Formation**

Filaments exist in the ISM on large scales as well as on small scales in star forming regions. It is possible that the filaments are an indication of the turbulence that exists in both these regions. I will present GBT observations of HI, OH obtained towards molecular clouds with atomic gas halos. This data along with other observational transitions can illuminate how the turbulence and structure of the gas changes as clouds transform from the atomic to molecular state and then into the star forming regime.

**Phil Myers** (Harvard-Smithsonian Center for Astrophysics)

Presentation requested: oral

## **Cloud Probability Density Functions and Filamentary Structure**

Molecular cloud gas has probability density functions (pdfs) of density and of column density which resemble a lognormal function (LN) or a LN with a power law tail (LNPL), according to observations and simulations of turbulent fragmentation. These properties imply a characteristic density profile for single-peak condensations. The density decreases from infinite to negligible values over a finite spatial extent, with steeper density gradients than in standard self-gravitating models. For LN pdfs, the density follows an inverse complementary error function. For LNPL pdfs, the density follows a truncated power law, a composite of a power law and a partial inverse complementary error function. These density profiles have no preferred size scale, so their pdfs are also consistent with an ensemble of similar condensations having a fixed profile shape and a range of size scales. Density profiles are derived for condensations having planar, cylindrical, and spherical symmetry. The column density profile of a LNPL condensation with cylindrical symmetry (LNPL filament) closely fits the Plummer-like profile typical of filaments in nearby clouds, according to *Herschel* observations. For typical observed pdf parameters, the mass fraction of PL gas is too great to match observed dense cores alone, but it gives better match to that of filaments, or of filaments with embedded cores. LNPL filaments are probably not in radial equilibrium, but on large scales their density power law does not change much between static and free fall models.

**Atsushi Nishimura** (Nobeyama Radio Observatory)

Tomofumi Umemoto (Nobeyama Radio Observatory)  
Tetsuhiro Minamidani (Nobeyama Radio Observatory)  
Nario Kuno (Tsukuba University)  
Toshihiro Handa (Kagoshima University)  
Toshikazu Onish (Osaka Prefecture University)

Presentation requested: oral

**Nobeyama 45m CO Galactic Plane Survey: Seek the Smallest to Biggest Structures in Molecular Clouds**

The Nobeyama 45m CO Galactic Plane Survey is one of Legacy Projects which are three-year projects carried by the Nobeyama Radio Observatory. The project is designed to provide the highest angular resolution ( $\sim 15$  arcsec.) of  $^{12}\text{CO}(1-0)$ ,  $^{13}\text{CO}(1-0)$  and  $\text{C}^{18}\text{O}(1-0)$  dataset toward the inner part of the Galactic plane ( $l = 10^\circ - 50^\circ$ ,  $b = \pm 1$ ) and the outer part ( $l = 198^\circ - 236^\circ$ ,  $b = \pm 1$ ) by using the FOREST multi-beam receiver which is currently under the commissioning phase.

In the first observation season (March – May 2014), we were allocated 210 hours observation time, and have observed  $31 \text{ deg}^2$  areas in the inner Galaxy ( $24 \text{ deg}^2$ ) and the outer Galaxy ( $7 \text{ deg}^2$ ). The observations also served as a science verification of the FOREST receiver. We reduced the observed data carefully, especially the stability of the receiver and the calibration of the intensity were checked for all observations. After the reductions, we obtained the data which have the averaged rms noise level of  $0.4 \text{ K}$  (in  $T_A^*$  scale) at the velocity resolution of  $1.0 \text{ km sec}^{-1}$ . Most of diffuse components are detected only in the  $^{12}\text{CO}$  line, and a lot of filaments and cores are also detected. Most of  $^{13}\text{CO}$  emissions are detected from filaments and cores, and the  $\text{C}^{18}\text{O}$  emissions are not distributed as elongated large filaments. This remarkable characteristic is seen in the all observed regions, and this indicates that the phase transition of the molecular clouds (i.e. diffuse components, filaments and cores) is universal. These impressive features are never seen in the previous blurry CO surveys and the continuum infrared/sub-mm surveys which lack the velocity information. It is undoubtable that the data will separate the heavily overlapped molecular clouds in the Galactic plane, and then offer new insight about the filaments study into us.

**Giles Novak** (Northwestern University)

Giles Novak (Northwestern University)

Presentation requested: oral

**Observational Constraints on the Relationship between Filament Orientations and B-Field Directions**

Filamentary structure in molecular clouds was observed long ago, many decades before observers used ESA's Herschel telescope to definitely confirm the ubiquity of such structures and accurately measure their width distribution. Similarly, astronomers have been tracing magnetic field lines in molecular clouds for at least three decades, via the polarization induced by magnetically aligned dust grains, both in extinction and emission. Given this long history, it is perhaps surprising that we have been unable to establish any definitive general relationship between filament orientation and magnetic field direction. I will review the current observational situation as well as the prospects for major advances that will come soon from stratospheric and space-based polarimetry via HAWC+/SOFIA, BLAST-TNG, and Planck.

**Juergen Ott** (NRAO)

Presentation requested: poster

## **Filamentary Dense Gas Clump Structures in the Galactic Center**

The Galactic Center is a violent place where large amounts of gas and dust follow trajectories that lead to frequent cloud-cloud collisions. The gas is funneled from the disk along self-intersecting  $x_1$  orbits toward the inner, orthogonal  $x_2$  orbits. We present interferometric ATCA data which is sensitive to the cold, clumpy structure of the dense gas. The data are insensitive to the large-scale, extended, warmer gas envelopes that otherwise dominate Galactic Center gas maps. We use NH<sub>3</sub> as a gas tracer and we show that a large fraction of gas clump locations seem to be aligned. Some of the gas likely follows the 100pc dust ring, but other structures may be due to re-alignment due to the mechanical impact of massive star clusters. We also show the relation of large scale magnetic field structures to the dense gas clumps. In particular we find an anti-correlation of the thin thermal and non-thermal radio continuum filaments with the dense gas clumps which indicates that large scale magnetic fields only have limited influence on the formation and alignment of dense gas filaments.

**Frank Otto** (The Chinese University of Hong Kong)

Hua-bai LI (The Chinese University of Hong Kong)

Presentation requested: oral

## **Modeling the bimodal orientation of filamentary molecular clouds**

It has recently been observed [1] that filamentary molecular clouds are preferentially aligned either parallel or perpendicular to the magnetic field direction of the local intercloud media. This bimodal orientation of the filaments, together with other observations [2], hints at a formation scenario in which magnetic fields are dynamically important, being able to both guide gravitational contraction and channel sub-Alfvenic turbulence. Here we present magnetohydrodynamics (MHD) simulations of the filament formation process, including self-gravity as well as turbulence driven at large wavelengths. Our goal is to narrow down the parameter space of the initial conditions which are able to reproduce the observed bimodal distribution of filament orientations.

[1] H.-b. Li et al. MNRAS 436, 3707 (2013) [2] H.-b. Li et al. arXiv:1404.2024 (2014)

**Georgia Virginia Panopoulou** (University of Crete)

Tassis K (University of Crete)  
Goldsmith P F (JPL and Caltech)  
Heyer M H (UMASS)

Presentation requested: oral

### **13CO filaments in the Taurus molecular cloud**

We have carried out a search for filamentary structures in the Taurus molecular cloud using  $^{13}\text{CO}$  line emission data from the FCRAO survey of  $\sim 100 \text{ deg}^2$ . We have used the topological analysis tool, DisPerSe, and post-processed its results to include a more strict definition of filaments that requires an aspect ratio of at least 3:1 and cross section intensity profiles peaked on the spine of the filament. In the velocity-integrated intensity map only 10 of the hundreds of filamentary structures identified by DisPerSe comply with our criteria. Unlike Herschel analyses, which find a characteristic width for filaments of  $\sim 0.1 \text{ pc}$ , we find a much broader distribution of profile widths in our structures, with a peak at 0.4 pc. Furthermore, even if the identified filaments are cylindrical objects, their complicated velocity structure and velocity dispersions imply that they are probably gravitationally unbound. Analysis of velocity channel maps reveals the existence of hundreds of ‘velocity-coherent’ filaments. The distribution of their widths is peaked at lower values (0.2 pc) while the fluctuation of their peak intensities is indicative of stochastic origin. These filaments are suppressed in the integrated intensity map due to the blending of diffuse emission from different velocities. Conversely, integration over velocities can cause filamentary structures to appear. Such apparent filaments can also be traced, using the same methodology, in simple simulated maps consisting of randomly placed cores. They have profile shapes similar to observed filaments and contain most of the simulated cores.

**Joshua Peek (STScI)**

Susan Clark (Columbia University)  
Mary Putman (Columbia University)

Presentation requested: oral

## **Linear Features and the Neutral ISM**

We have known for many years that the ISM harbors both neutral and molecular gas, and that material flows through these phases to form stars. As telescope resolution has improved, we have discovered that both these phases contain gas in linear features, often referred to as filaments. In this contribution I will give an overview of state of the art and future observations of neutral gas and discuss the relevance of the neutral phases of the ISM to the formation of molecular clouds, especially in the context of filamentary features. We have recently made significant progress both in finding and characterizing linear features in neutral gas, showing a tight relationship with magnetic fields. I will discuss these results, and also give our views on the future of methods for linear feature detection and characterization in both phases.

**Adele Plunkett** (Yale University)

Hector Arce (Yale University)  
Michael Dunham (CfA-SAO)

Presentation requested: poster

**Protostellar outflows and turbulence amidst the filamentary structure of Serpens South**

Molecular outflows driven by protostellar cluster members likely impact their surroundings and contribute to turbulence, affecting subsequent star formation. A particularly high density of star formation and a dominant filamentary component comprise the very young Serpens South cluster, yielding a relevant case study for protostellar outflows and their impact on the filaments and the cluster environment. We combined CO J=1-0 observations using CARMA and IRAM, and the combined map allows us to probe CO outflows within the central, most active region at size scales of 0.01 pc to 0.6 pc. We measure the mass, momentum, and energy of molecular outflows in this region, and we characterize the continuum sources located at the hub of these outflows. The outflow mass loss rate, force, and luminosity, compared with diagnostics of turbulence and gravity, suggest that outflows drive enough energy to sustain turbulence, but not enough energy to substantially counter the gravitational potential energy and disrupt the clump. Further, we compare Serpens South with the slightly more evolved cluster NGC 1333, and we propose an empirical model for outflow-cluster interaction at different evolutionary stages such that this very young cluster will become reminiscent of the somewhat more evolved NGC 1333. The Serpens South case is important because the outflows are impacting the cluster and likely the filamentary structure at a very early evolutionary stage.

**Riwaj Pokhrel** (University of Massachusetts Amherst)

Robert Gutermuth (University of Massachusetts Amherst)

Babar Ali (IPAC)

Thomas Megeath (U of Toledo)

Judith Pipher (U of Rochester)

Philip Myers (CfA)

Presentation requested: poster

### **A Herschel-SPIRE Survey of the MonR2 Giant Molecular Cloud**

We present a new survey of the MonR2 giant molecular cloud with SPIRE on the Herschel Space Observatory. We cross-calibrated SPIRE data with Planck-HFI and accounted for its absolute offset and zero point correction. We fixed emissivity with the help of flux-error and flux ratio plots. As the best representation of cold dusty molecular clouds, we did greybody fits of the SEDs. We studied the nature of distribution of column densities above and below certain critical limit, followed by the mass and temperature distributions for different regions. We isolated the filaments and studied radial column density profile in this cloud.

**Ralph Pudritz** (McMaster University)

Presentation requested: oral

## **From Filaments to Stars: a Theoretical Perspective**

Filamentary structure is ubiquitous on multiple scales in molecular clouds and is closely connected with star formation. In this review I will highlight some of the significant advances that have occurred in theoretical and numerical simulations of the formation, structure, and evolution of filaments and how this affects star formation. I will first address some basic ideas of the structure and stability of equilibrium models of filaments including the role of gravity, turbulence, and magnetic fields. Simulations of turbulent clouds emphasize the highly dynamical aspects of filament formation including accretion flows onto and along filaments, the creation of cluster forming regions at filament nodes, and the combination of dynamical fragmentation and filamentary flow that leads to the formation of individual stars and disks. Finally I will touch on the question of how filamentary structure may affect how star formation is finally shut down as a consequence of stellar feedback from massive stars.

**Goran Sandell** (SOFIA-USRA)

Wright MELVYN (UC Berkeley)

Presentation requested: oral

**Star forming filaments in NGC 7538**

High mass stars form in extremely dense, massive, self gravitating cloud cores embedded in Giant Molecular Clouds. Such cores have sizes of  $< 1$  pc, masses  $> 1000 M_{\odot}$ , densities  $\gtrsim 10 \times \text{cm}^{-3}$ , and often show filamentary structures. These filaments are very prominent in sub-mm dust images but often more difficult to see in molecular maps of high density tracers like HCN and HCO<sup>+</sup> or their optically thin isotopomers. The interior of these cores and filaments is colder than the surrounding envelope and the molecules may be depleted due to freeze out on grains. However, deuterated molecules like NH<sub>2</sub>D appear to be better tracers than H<sup>13</sup>CN of the cold gas in these dense filaments and allow us to probe fragmentation and cold protostellar condensations in these filaments, which represent the earliest phases of star formation. In this presentation we discuss some results from both single dish and mm-interferometers (BIMA/CARMA) on NGC7538, a well known high-mass star forming region.

**Eugenio Schisano (IAPS INAF Italy )**

Sergio Molinari (IAPS INAF Italy)

Kazy Rygl (ESA ESTEC Netherlands)

Davide Elia (IAPS INAF Italy)

Gemma Busquet (Instituto de Astrofisica de Andalucia SPAIN)

Danae Polychroni (University of Athens Greece)

Presentation requested: oral

**Morphology, physical conditions and relation with star formation of filamentary structure. Initial results from the Hi-GAL survey of the Galactic plane.**

Observations indicate that everywhere in the Galaxy the dense interstellar material is arranged into a filamentary pattern. In particular, the molecular clouds, the birthplace of the stars, show filamentary shapes with various degree of complexity, from single long filaments to multiple sub-filaments nesting each other into hubs. The abundance of compact star-forming condensations along filaments indicates that the initial conditions for star formation may be set in the filaments. How much and why does the dense material aggregate in these structures ? How are gravity, turbulence and magnetic field contributing to shape the observed filamentary network? What is the role that filaments have in the process of star formation? To answer such a questions it is necessary to study representative samples of filaments from different environments. In this talk we discuss the morphological and physical properties of a large sample structures identified as filaments on the *Herschel* maps of the Galactic plane in the longitude range of  $l=216.5^\circ$  to  $l=225.5^\circ$  obtained by the Hi-GAL project. The correlation with the compact sources identified in the region show that most, but not all, the clumps lies on filaments. However, high surface density clumps, expected to eventually form massive stars, are only found on filaments suggesting that these structures help to channel the material into small regions. Furthermore, we discuss the stability of the filaments against gravitational collapse by comparing their linear densities,  $m_{lin}$ , to the theoretical critical limit,  $m_{lin}^{crit}$ , that a structure supported only by thermal pressure can have to maintain the equilibrium against its self-gravity. Finally we investigate the relationship between the structure stability and the star formation within its border.

**Youngmin Seo** (Steward Observatory University of Arizona)

Yancy L Shirly (Steward Observatory University of Arizona Tucson AZ USA)

Paul Goldsmith (Jet Propulsion Laboratory USA)

Derek Ward-Thompson (Jeremiah Horrocks Institute University of Central Lancashire Preston UK)

Jason M Kirk (Jeremiah Horrocks Institute University of Central Lancashire Preston UK)

Markus Schmalzl (Leiden Observatory Leiden University Netherlands)

Presentation requested: oral

**An Ammonia Spectral Map of The L1495-B218 Filaments in The Taurus Molecular Cloud : Physical Properties of Filaments and Dense cores**

We present deep NH<sub>3</sub> observations of the L1495-B218 filaments in the Taurus molecular using the K-band focal plane array on the 100m Green Bank Telescope. The L1495-B218 filaments are an interconnected, nearby low mass star forming complex extending over 8 pc (3 degree angular range). We observed NH<sub>3</sub> (1,1) and (2,2) with a spectral resolution of 0.038 km s<sup>-1</sup> and a spatial resolution of 31''. Most of NH<sub>3</sub> (1,1) intensity peaks agrees with intensity peaks of dust continuum maps at 350  $\mu$ m and 500  $\mu$ m. Physical properties of the filaments are deduced by fitting a spectrum model to NH<sub>3</sub> (1,1) and (2,2) lines. We find the kinetic temperatures of 8 – 15 K, narrow velocity dispersions of 0.05 – 0.25 km s<sup>-1</sup>, and NH<sub>3</sub> column densities of  $5 \times 10^{12}$  –  $1 \times 10^{14}$  cm<sup>-2</sup>. Total 55 NH<sub>3</sub> structures including 39 leaves and 16 branches are identified using the CSAR algorithm, which is a hybrid of seeded watershed and binary dendrogram algorithms. The masses of NH<sub>3</sub> leaves and branches range from 0.05 M<sub>⊕</sub> to 9.5 M<sub>⊕</sub>. The virial masses of NH<sub>3</sub> leaves estimated from internal and gravitational energies are usually larger than the corresponding observed masses, which suggests that most of NH<sub>3</sub> leaves are gravitationally unbound. Only 9 out of 39 NH<sub>3</sub> leaves are gravitationally bound and 7 out of 9 gravitationally bound leaves are associated with star formation activities. 12 out of 30 gravitationally unbound NH<sub>3</sub> leaves are pressure-confined (work done by external pressure > gravitational energy). Thus, a dense core in the L1495-B218 filaments may form as a pressure-confined structure, evolve to a gravitational bound core, and undergo collapse to form a protostar.

**Yancy Shirley** (Arizona MPIA)

Presentation requested: oral

**A Review of the Structure of Nearby Molecular Filaments as Traced by Different Molecular Tracers**

Filamentary structures provide the conduits along which the majority of dense cores in nearby molecular clouds are formed. I shall present an overview of recent observations of the structure of filaments in nearby molecular clouds. Due to the progression in effective excitation density of molecular tracers such as C<sup>18</sup>O 1–0, CCS 1<sub>2</sub>–2<sub>1</sub>, NH<sub>3</sub> (1, 1), HCN 1–0, and N<sub>2</sub>H<sup>+</sup> 1–0, different density components within filaments are traced. I shall also summarize observations of one of the best observed nearby filament complexes, the 3 degree wide L1495-B218 filament complex in the central region of the Taurus Molecular Cloud. Multi-pixel heterodyne receivers which will play an increasingly important role in the near future in shaping our understanding of the physical structure of filamentary complexes.

**Shaye Storm** (University of Maryland)

Lee Mundy (University of Maryland)  
Eve Ostriker (Princeton University)  
Leslie Looney (University of Illinois)  
Manuel Fernandez-Lopez (University of Illinois)  
Katherine Lee (University of Maryland)

Presentation requested: oral

**High resolution studies of filament structure and kinematics in Perseus and Serpens**

The CARMA Large Area Star Formation Survey (CLASSy) is a CARMA Key Project that spectrally imaged N2H+ J=1-0 across 800 square arcminutes of the Perseus and Serpens Molecular Clouds with 7 angular resolution and 0.16 km/s velocity resolution. This talk will focus on how the project is addressing two of the main issues outlined in the science program. First, CLASSy is uniquely able to address the kinematic characteristics of filaments and their local environment. We developed a framework to use the size-linewidth relations from the centroid velocity field and the velocity dispersion field to show that filaments form in a local environment that is flattened (sheet-like) at parsec scales. This result is supported by our detections of strong cross-filament velocity gradients within several filaments; this kinematic signature is seen in numerical simulations of converging, turbulent flows that produce self-gravitating filaments with planar post-shock layers. The detected cross-filament gradients are an order of magnitude larger than the detected axial gradients, suggesting that the dense gas will collapse locally within the filament. Second, CLASSy can address the universal nature of filamentary structure. We resolved the dense gas structure within several Herschel filaments, and found that the filaments exhibit a wide range of structure and kinematics. In our data, some lower-resolution dust filaments break up into two to three narrower sub-filaments with similar radial velocities, others break up into narrow filaments with distinct radial velocities, while some remain a single filament with significantly narrower width. This shows that there is a wide range of complexity in filaments that is missed when only using dust detections with single-dish facilities. CLASSy is a model for further observations that are needed to fully characterize the internal structure of molecular clouds. In the future, we want to expand this type of survey to lower-density molecular tracers, and even larger areas, to form a more complete picture of filament formation and evolution in nearby molecular clouds.

**Jonathan Tan** (University of Florida)

Presentation requested: oral

## **Filaments and High-Mass Star Formation**

I review our current understanding of high-mass star formation and the potential implications for theoretical models if the initial gas structures have a predominantly filamentary structure.

**Leonardo Testi** (ESO)

Anna McLeod (ESO)

Jim Dale (USM)

Veronica Roccagliata (USM)

Adam Ginsburg (ESO)

Suzie Ramsay (ESO)

Presentation requested: oral

### **Molecular clouds structure in observations and simulations**

Filamentary structures are ubiquitously observed in the ISM from large to small scales in molecular clouds. Similar structures are also seen in numerical simulations of turbulent clouds, prior and after the onset of star formation (i.e. with and without feedback). Going beyond a general morphological comparison and quantitatively analyse the outcome of numerical simulations with different physical prescriptions against real observations is a non trivial enterprise. In this talk I will describe the approach that our group is following to attempt this feat. I will show the initial results of our comparisons of numerical simulations with feedback against Herschel, single dish sub-mm, and optical/infrared VLT observations. An outlook on future developments and comparisons with ALMA observations will also be discussed.

**Tomofumi Umemoto** (Nobeyama Radio Observatory)

Tetsuhiro Minamidani (Nobeyama Radio Observatory)  
Atsushi Nishimura (Nobeyama Radio Observatory)  
Nario Kuno (Tsukuba University)  
Toshihiro Handa (Kagoshima University)  
Toshikazu Onish (Osaka Prefecture University)

Presentation requested: oral

### **Nobeyama 45m CO Galactic Plane Survey: Project Overview**

We are conducting a simultaneous survey of the  $^{12}\text{CO}$ ,  $^{13}\text{CO}$ , and  $\text{C}^{18}\text{O}$   $J=1-0$  line emissions in the Galactic Plane using the new multi-beam receiver FOREST installed on the Nobeyama 45m telescope, in order to obtain the distribution, kinematics, and physical properties of the molecular gas in the Galaxy at the highest angular resolution of  $sim15''$  to date. We plan to make maps of the inner Galaxy (galactic longitude:  $10circ < l < 50circ$ , galactic latitude:  $b < 1circ$ ) and the outer Galaxy ( $198circ < l < 236circ$ ,  $b < 1circ$ ) including spiral arms, bar structure, and molecular gas ring.

The survey will provide us with invaluable data set for investigating the physics of galactic ISM, particularly the evolution of neutral gas from galactic scale to small filament/clump/core scales, even inside GMCs. Main scientific purposes of our survey are (1) formation of molecular clouds through transition from atomic to molecular gas, (2) relation between PDF of gas density reflecting structure formation mechanism and the Galactic structures, e.g., arm and bar, (3) survey of dense clumps and variation of physical properties of clumps in GMCs in various environments, etc.. This project will link the ALMA era ISM study of nearby galaxies to the study of star formation in the Galaxy. We will present an overview of this project, observation plan, and results of the test observations in the last season.

**Enrique Vazquez-Semadeni** (CRyA UNAM)

Gilberto Gomez (CRyA UNAM)

Vianey Camacho (CRyA UNAM)

Presentation requested: oral

**Filament formation and evolution in gravitationally collapsing GMCs**

We report on the filaments that develop self-consistently in simulations of GMCs undergoing global gravitational contraction. The collapse of the cloud proceeds in a nearly pressureless manner because its mass is much larger than the Jeans mass, thus contracting first along the shortest dimensions of the clouds, naturally forming first sheets and then filaments. The filaments are not in equilibrium at any time, but instead are long-lived flow features, through which the gas flows from the cloud to the clumps. The filaments are long-lived because they accrete from their environment while simultaneously accreting onto the clumps within them. We discuss the evolution and physical properties of the filaments, such as density and velocity structure, and the hierarchical nesting they exhibit. Finally, we discuss the physical conditions of the cores embedded in the filaments.

**Jia-Wei Wang** (National Tsing Hua University Taiwan)

Chakali Eswaraiah (National Central University Taiwan)

Shih-Ping Lai (National Tsing Hua University Taiwan)

D P Clemens (Boston University U S A)

Wen-Ping Chen (National Central University Taiwan)

Anil K Pandey<sup>2</sup> (Aryabhatta Research Institute of Observational Sciences ARIES India)

Presentation requested: oral

### **Magnetic Field Structure of the Filamentary Cloud IC5146**

To understand the physical conditions for filament formation, the magnetic field measurements would provide crucial information. Here we present our optical and infrared polarization observations toward IC5146 taken with AIMPOL (India), TRIPOL (Taiwan) and Mimir (US). IC5146 is one of the filamentary clouds observed in Herschel Gould Belt Survey, and Arzoumanian et al. (2011) claimed that the complex network of filaments discovered within the cloud favors the scenario that the filaments network are generated by large scale MHD turbulence and fragment into prestellar cores by gravitational instability. Our results reveal that the large scale structure of magnetic field is well perpendicular to the main filament, but more or less parallel to the sub-filaments, which are structure extended out from the main filaments. We have also conducted CO observations which show that the material in the sub-filament is flowing to the main-filament along the magnetic field; this result suggests the gas is possibly confined by magnetic field. In addition, the magnetic field strength map derived from the Chandrasekhar-Fermi method indicates a significant magnetic enhancement even in these sub-filaments, which suggest the gas is compressed perpendicular to the magnetic field in early stage possibly by turbulence, shock or cloud-cloud collision. Furthermore, the correlation between magnetic strength and density reveals that there are possibly two evolutionary stages existing in IC5146, collapsing along magnetic field in magnetically sub-critical region and isotropic collapsing in magnetically super-critical regions. Our results suggest that magnetic fields are one of the key factor during the filament formation and fragmentation processes.

**Al Wootten** (NRAO)

Presentation requested: oral

## **Filamentary Structures Nearby: Observational Capabilities**

Long but narrow, with complex velocities and morphology, filaments challenge instrumental imaging capabilities. Fortunately facilities are available which can provide three dimensional views of their structures. Opportunities for future development will also be discussed.

**Benjamin Wu (UF)**

Sven Van Loo (Leeds)  
Simon Bruderer (MPIA)  
Jonathan Tan (UF)  
Fumitaka Nakamura (NAOJ)

Presentation requested: oral

## **Role of GMC Collisions in Dense Filament, Clump, and Star Formation**

We utilize magnetohydrodynamic (MHD) simulations with adaptive mesh refinement (AMR) to explore the process of GMC-GMC collisions as a potential trigger for dense filament, clump, and star formation. We implement new PDR-based density/temperature/extinction-dependent heating and cooling functions in Enzo that span the atomic to molecular transition and can return detailed diagnostic information. We initially perform a parameter space study via a suite of idealized 2D simulations for GMC-GMC collisions, which track the fate of an initially stable clump embedded within one of the clouds. We then extend these calculations to 3D, including introduction of initial turbulence into the clouds. Different turbulent spectra types, magnetic field strengths and orientations are considered, as is the role of cloud collisions. The density and kinematic structure of dense filaments are visualized and characterized, in addition to magnetic field configuration. We discuss potential diagnostic signatures of each case and compare to some proposed examples in the Galaxy.

**Ka Ho Yuen** (Research Graduate Student The Chinese University of Hong Kong)

Hua-bai Li (Assistant Professor The Chinese University of Hong Kong)

Frank Otto (Postdoctorial fellow The Chinese University of Hong Kong)

Po Kin Leung (Lecturer The Chinese University of Hong Kong)

T K Sridharan (Harvard-Smithsonian Center for Astrophysics)

Qizhou Zhang (Harvard-Smithsonian Center for Astrophysics)

Presentation requested: oral

## **Self-similar Fragmentation and Magnetic Field Configurations in a Massive Star Forming Filament**

Whether magnetic field plays an important role in star formation has been already debates for years. Here I, representing and referencing on a submitted paper, to present evidences on the presences of magnetic field channelled fragmentation in NGC6334.

Using the multiscale optical and submillimeter polarimetry data from 100 to 0.1 parsecs, it is observed that, with the consideration that it is not significantly affected by stellar feedback, the mean field direction on various scales are mostly aligned, which implies dynamically important B-fields as distinct from gravity and turbulence. The result is similar to those appearing in the more intensively-studied low-mass star forming regions.

Moreover, *hourglass – shaped* B-field morphologies are observed at multiple scales, and the column density peaks at the field line *pinches*. Assuming a balance between the forces of gravity, magnetic pressure and magnetic tension, the field strength is estimated to range from 0.1 to 10 mG proportional to  $n^{0.41 \pm 0.04}$ , where n is the gas density, which differs from the theoretical  $\frac{2}{3}$  value when assuming the magnetic field does not channel the process but close to the magnetic-involved counterpart of  $\frac{1}{2}$ . This suggested that the magnetic field plays an important role in the fragmentation process of NGC6334.

**Catherine Zucker** (University of Virginia CfA)

Cara Battersby (CfA)

Alyssa Goodman (CfA)

Presentation requested: oral

## **The Milky Way Skeleton**

Recently, Goodman et al. (2014) argued that a very long, very thin infrared dark cloud “Nessie” lies directly in the Galactic mid-plane and runs along the Scutum-Centaurus arm in position-position-velocity space as traced by low density CO and high density NH<sub>3</sub> gas. Nessie was presented as the first bone of the Milky Way, an extraordinarily long, thin, high contrast filament that can be used to map our galaxy’s “skeleton.” We present the first evidence of additional “bones” in the Milky Way galaxy, arguing that Nessie is not a curiosity but one of many filaments that could potentially trace Galactic structure. Our list of ten bone candidates are all long, filamentary, mid-infrared extinction features which lie parallel to, and no more than twenty parsecs from, the physical Galactic mid-plane. We use CO, N<sub>2</sub>H+, and NH<sub>3</sub> radial velocity data to establish the location of the candidates in position-velocity space. Of the ten filaments, three candidates have a projected aspect ratio of >50:1 and run along, or extremely close to, the Scutum-Centaurus arm in position-velocity space. Evidence suggests that these three candidates are Nessie-like features which mark the location of the spiral arms in both physical space and position-velocity space. Other candidates could be spurs, feathers, or interarm clouds associated with the Milky Way’s galactic structure. As molecular spectral-line and extinction maps cover more of the sky at increasing resolution and sensitivity, we hope to find more bones in future studies, to ultimately create a global-fit to our galaxy’s spiral arms by piecing together individual skeletal features. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution.