Seamus Clarke | Curriculum Vitae

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Education

Cardiff University — **Cardiff**
Doctor of Philosophy (Physics & Astronomy) — *2013–2016*

Oxford University — **Oxford**
Master of Physics, 2:1 — *2009–2013*

Doctoral thesis

Title: Numerical simulations of filamentary clouds

Supervisors: Prof. Anthony Whitworth & Dr. Nicolas Peretto

Description: Filamentary structures have been shown to be common on many different scales and are strongly linked to star formation. This thesis presents the results of a range of smoothed particle hydrodynamic (SPH) simulations which investigate the stability, collapse and fragmentation of filaments. The global longitudinal collapse timescale for filaments is found to be considerably longer than for equally dense spheres, allowing sufficient time for local collapse to occur, and to solely occur via the distinctive end-dominated mode. The fragmentation of accreting filaments is found to be more complicated than that of equilibrium filaments, since gravo-acoustic oscillations form along the longitudinal axis of the filament resulting in the fastest growing perturbation mode being independent of filament width. Our model of this phenomenon allows observers to estimate the age of a fragmenting filament and the mass accretion rate. We apply our models of global collapse and fragmentation to reproducing the properties of observed filaments. In addition, time-dependent chemistry allows us to present synthetic observations of our simulations, aiding observers in their interpretation of the kinematics inside filaments.

Master thesis

Title: Constraining the progenitors of Gamma-Ray Bursts from their host galaxies

Supervisors: Prof. Philipp Podsiadlowski

Description: Graham and Fruchter (2012) find that long duration gamma-ray bursts (LGRB) occur preferentially in low metallicity galaxies. We use a metallicity dependent initial mass function (IMF), the fundamental metallicity relation (Mannucci et al. 2011) and the Baldry et al. 2004 galactic mass distribution to produce a theoretical LGRB rate distribution. We find that a metallicity dependent IMF produces a distribution similar to the observed distribution; however, we also find that the standard Kroupa IMF (Kroupa et al. 2003) accurately reproduces the observed distribution. Thus these results lend support to the idea that the observed metallicity bias in LGRB host galaxies is as expected based solely on their position on the fundamental metallicity plane.

Publications

- **Clarke S. D.**, Whitworth A. P., Hubber D. A., 2016, MNRAS, 458, 319; *Perturbation growth in accreting filaments*
- **Clarke S. D.**, Whitworth A. P., 2015, MNRAS, 449, 1819; *Investigating the global collapse of filaments using smoothed particle hydrodynamics.*

Oral & poster presentations

- Perturbation growth in accreting filaments. Star Formation 2016, Exeter, 2016 **[Oral presentation]**
- The kinematics of filament fragmentation. Comparing Apples with Apples, Leiden, 2016 **[Oral presentation]**
- Perturbation growth in accreting filaments. The Early Phase of Star Formation, Ringberg, 2016 **[Oral and poster presentation]**
- Investigating the global collapse of filaments using SPH. Computational Astrophysics with GANDALF workshop, Freising, 2015 **[Oral presentation]**
- Perturbation growth in accreting filaments. The 6th Zermatt ISM Symposium, Zermatt, 2015 **[Poster presentation]**
- Simulations of globally collapsing filaments. Postgraduate Conference, Cardiff, 2014 **[Oral presentation]**
- Simulations of fragmenting filaments, The Bristol, Exeter and Cardiff Student seminars, Bristol, 2014 **[Oral presentation]**
- Simulations of fragmenting filaments, The Olympian Symposium on Star Formation, Paralia Katerini, 2014 **[Poster presentation]**

Workshops & schools

- Comparing Apples with Apples: Concordance Between Simulations and Observations of Star Formation, Leiden, 2016.
- Computational Astrophysics with GANDALF workshop, Freising, 2015.
- STFC Introductory Summer School: Atomic processes and spectral modelling in astrophysics, Belfast, 2015.

Computer skills

- Highly proficient at coding in C/C++ and Python. Moderately proficient in Fortran.
- Comfortable writing object-oriented codes.
- Comfortable writing parallelised code in C++ using OPENMP and MPI.
- Experience using the SPH codes: GANDALF, GADGET2, SEREN.
- Experience writing wrappers to allow C++/Fortran communication.
- I have made significant modifications to the SPH code GANDALF, in particular integrating Simon Glover's chemistry module.
- Experience using supercomputers: ARCCA's RAVEN.
- Experience using word processing and publishing software such as: Microsoft Word, Powerpoint and LaTex.

Awards

- Early Career Researcher Poster Competition 2013-14, First prize - Astronomy, Cardiff.

Teaching experience

2014–2016: Marking preliminary undergraduate mathematics assignments, Cardiff University.

2013–2016: Demonstrating 3rd and 4th year undergraduate python practicals, Cardiff University.

2013–2016: Marking 1st and 2nd year undergraduate astrophysics assignments, Cardiff University.

2006-2009: Science teaching assistant at the Thomas Wolsey special needs school, Ipswich.

Administrative experience

2014-2015: Seminar chair for the Cardiff star formation meetings

References

- Prof. Anthony Whitworth, Professor of Theoretical Astrophysics, Cardiff University
  - Primary PhD supervisor, 2013 - present.
  - email: anthony.whitworth@astro.cf.ac.uk
- Dr. Nicolas Peretto, Lecturer, Cardiff University
  - Secondary PhD supervisor, 2013 - present.
  - email: nicolas.peretto@astro.cf.ac.uk
- Dr Paul Clark, Lecturer, Cardiff University
  - email: paul.clark@astro.cf.ac.uk

Research statement

Large scale mapping of local molecular clouds and the galactic plane by telescopes such as Herschel has shown that filaments are ubiquitous over a large range of scales. Moreover, they are intrinsically linked to the formation of stars, as shown by the Herschel Gould Belt survey (HGBS) with more than 70% of prestellar cores being located within filaments. With such a wealth of observational data to study it has become imperative for theoreticians to better understand how a filamentary geometry allows the formation and regulates the evolution of these embedded cores. My recent research has used smoothed particle hydrodynamic (SPH) simulations to help answer some of the many questions such observations have raised, mainly focusing on the internal dynamics of filamentary structures.

My early research focused on considering the global longitudinal collapse of filaments, testing analytic predictions with numerical methods. Using SPH simulations to explore a wide parameter space I was able to study the global collapse timescale for filaments and derive a new filamentary free-fall equation, as well as constructing a semi-analytic model from first principles to describe the dynamics of the collapse. I found that the global collapse timescale for a filament is much longer than for an equally dense sphere. This results in filaments being ideal structures for fragmentation, unlike spheres. Moreover the global collapse of a filament proceeds solely via the end-dominated mode; due to "gravitational focusing", the gas at the ends of a filament experiences a much greater acceleration than the gas in the interior. This results in large dense clumps forming at either end of the filament and moving inwards. Meanwhile, the interior gas is relatively unaffected by the collapse until an end-clump reaches it. This form of collapse results in preferential star formation sites at the ends of a filament, as suggested by recent observations of isolated filamentary IRDCs (e.g. IRDC18223 observed by Beuther et al. 2015, the Musca filament observed by Kainulanien et al. 2015, and the main filament in NGC6334 observed by Zernickel, Schilke & Smith 2013). In collaboration with Sarah Ragan of Leeds University, I am currently applying my model of global collapse dynamics to high resolution $N_2 H^+$ data of IRDC18223.

Due to my early results showing that local collapse is favoured in filaments my current research focuses on how a filamentary geometry influences fragmentation. Many authors have studied the fragmentation properties of filaments; however, most previous work has been confined to equilibrium filaments. I have investigated how the addition of radial accretion onto the filament affects fragmentation. An accreting flow provides a mass-flux onto the filament as well as a variable confining ram pressure, resulting in a filament which is far from equilibrium. This leads to a more complicated dispersion relation, and the fastest growing perturbation length scale becomes independent of the filament's width. Using recent observational data to inform my simulations, I also find that the fastest growing mode remains dominant in a realistically perturbed filament. From this work I have developed a model for fragmentation that allows observers to estimate a minimum age for a filament which is breaking up into regularly spaced fragments, as well as an average mass accretion rate, by using the core separation distance. Applying this model to such fragmenting sub-filaments in Taurus, we find a mass accretion rate remarkably close to that inferred observationally by Palmeirin et al. (2013). I have recently added turbulent velocities to the material accreting onto a filament to better approximate realistic accretion flows, and am now exploring the consequences. I am also integrating Simon Glover's time-dependent chemistry into the SPH code GANDALF. The addition of time-dependent chemistry means that post-processing radiative transfer codes can be used to investigate how the signatures of fragmentation would appear to observers. This is being done in collaboration with Ana Duarte-Cabral of Exeter University and Nicolas Peretto of Cardiff University.

In the future I intend to continue investigating the link between large scale structures and dynamics, and the resulting star formation. Previously I have used small-scale simulations of relatively ideal initial conditions to gain a better understanding of the dominant dynamics and to construct useful models for observers; the next step is to perform larger scale simulations so that important physical processes are captured self-consistently, e.g. driven turbulence due to supernovae feedback. In these types of simulations large scale filamentary and other non-spherical structures form due to the interplay of turbulence and gravity. It would be interesting to see how the fragmentation and collapse of such structures are affected by their dynamic environment and feedback. Furthermore, magnetic fields have been shown to influence the stability and fragmentation of large scale structures, possibly changing the relationship between global and local collapse. Running magneto-hydrodynamic (MHD) simulations could therefore result in different processes becoming dominant and changing the resulting star formation. With recent observations we can constrain such simulations; polarisation mapping of the Milky Way by the Planck satellite and the numerous large scale CO maps in our own galaxy and nearby galaxies provide a wealth of data for comparison.

The large scale MHD simulations being performed at the University of Cologne provide an excellent platform for me to answer these questions. My experience in analysing the results from numerical simulations of non-spherical dynamics, constructing semi-analytic models describing the dominant physics, and implementing time-dependent chemistry will be useful in linking the local regions of star formation and the large scale evolution of the interstellar medium in such large scale MHD simulations. Furthermore, my focus on filamentary geometry would compliment the recent work in this area by Daniel Seifried; in collaboration we could develop new techniques to numerically investigate the dynamics of such structures.