Curriculum Vitae

Michelle Anne Borkin

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Education

B.A. Harvard College, Astronomy and Astrophysics & Physics with Honors, 2006.
Ph.D. Candidate, School of Engineering and Applied Sciences, Harvard University, Applied Physics.

Experience

- **Researcher, School of Engineering and Applied Sciences, Harvard University, September 2008-present**

As a graduate student at Harvard's School of Engineering and Applied Sciences (SEAS), I am currently working as a researcher for the "Multiscale Hemodynamics" Project (an Initiative in Innovative Computing sponsored project). This interdisciplinary project is bringing together cardiologists, radiologists, physicists, and computational scientists to compare and integrate patient medical imaging data with fluid dynamics simulation data in order to better study and diagnose heart disease. For more information about the project, go to: http://www.seas.harvard.edu/ekaxiras/research/research.html#A2

- **Data Visualization & Analysis**
  I work with all the project participants on optimizing the data visualization and analysis, and fully integrating the simulation and imaging data. This analysis includes visualizing and measuring such variables as blood flow velocity, angular momentum, and endothelial shear stress (ESS) as surface, vector field, tensor, and streamline representations in order to determine their relevance and effect on heart disease. This simulation output is then compared to other patient data (e.g. angiogram, IVUS, etc.) in order to determine the model's accuracy. The visualization and data analysis is conducted with a variety of tools emphasizing 3D and originating in multiple disciplines including medicine and theoretical physics (e.g. Paraview).

- **HemoVis**
  HemoVis, an interactive visualization tool, was developed to aid in the analysis of data from the Multiscale Hemodynamics project. Having effective visualizations of the simulation's multidimensional output are vital for the quick and thorough evaluation by a cardiologist. HemoVis was developed to aid in the visualization and analysis of the endothelial shear stress (ESS) in a patient's coronary arteries. By identifying the areas of low ESS, cardiologists are able to determine the likely sites of atherosclerotic lesion formation and can take action to prevent further

progression. I built HemoVis in Processing and it can be viewed online at: http://people.seas.harvard.edu/~borkin/HemoVis/

- **Hemodynamics User Study**
  As part of the motivation to develop visualizations specifically targeted at the medical audience interpreting the Hemodynamics simulation output, I conducted a user study to evaluate the effectiveness of various display techniques and to determine the best methods for interacting with the data. The user study participants included the various end users of the simulation output: both clinical doctors who will use the simulation output for specific patient diagnoses, and research doctors investigating the fundamental causes of heart disease. The study gave insight into the optimal color palettes, vector representations, 2D topological mappings and projections to be used with the data. The study's results were incorporated into the design of the HemoVis application (see above).

- **Research Assistant in Computational Scientific Visualization, Astronomical Medicine Project, Initiative in Innovative Computing (IIC) at Harvard, August 2006-August 2008**

The Astronomical Medicine Project is the first project of the Initiative in Innovative (IIC) Computing at Harvard University. The project exemplifies the interdisciplinary innovative computing goals of the IIC by endeavoring to extend the state of the art of complex data understanding in the fields of astronomy and medical imaging by using a broad-based approach to data exploration and analysis. For more information about the project, go to: http://am.iic.harvard.edu

- **3D Slicer Development**
  Development of the 3D Slicer visualization software in order to make it useable not only for medical imaging, but also for astronomy imaging (the first step in making it a more general scientific application). This includes adding astronomical coordinate support, expanded file support (including FITS), and better volume rendering capabilities. 3D Slicer, an open source application, was originally developed as a brain imaging package by the Surgical Planning Laboratory at Brigham and Women's hospital and the MIT Artificial Intelligence Laboratory. For more information, go to: http://www.slicer.org

- **Velocity Structure of Star Forming Regions**
  Study of star forming regions using 3D visualization and analysis techniques to better understand the velocity and spatial structure of the gas. This work is in collaboration with Héctor Arce (American Museum of Natural History) and the COMPLETE team at the Harvard-Smithsonian Center for Astrophysics (CfA). The work has focused on surveying molecular line maps of Perseus in RA-DEC-Velocity space and then identifying extreme velocity excursions (traditionally something very tedious and impossible for large surveys, now made easy because of the 3D visualization). The implications of this work on outflowing gas has given insight into where high velocity gas comes from, and the distribution of gas and density in star forming regions. This research in the Perseus region has

resulted in the identification of many new expanding shells and over doubling the number of known outflows.

- **Segmentation**
  Working both with astronomy and medical experts, segmentation algorithms for feature extraction and the hierarchical descriptions have been applied to molecular clouds. This work is in collaboration with Erik Rosolowsky and the COMPLETE team, and with Kilian Pohl (Brigham & Women's Hospital). This has resulted in new algorithms and visualization programs to view the segmented data that are applicable to both astronomy and medical data sets. The work with COMPLETE resulted in a Nature publication for which I created 3D graphics. This is the first time a major scientific journal has used interactive graphics in an article.

- **Stereo Imaging**
  As part of the Astronomical Medicine project, I collaborate with Nick Holliman (Durham University, UK) on the 3D (stereographic) imaging and display of scientific data in order to advance scientific research and collaboration. This imaging has included single images and 3D animations in order to view and understand the multidimensional data in a more intuitive way. We are currently working on a 3D movie discussing star formation in Perseus for outreach purposes in order to explain the astronomy, to show the value and utility of viewing scientific data in 3D, and to advance stereographic movie making techniques along the way.

- **Interactive Media for Scientific Collaboration**
  As part of the Scientists' Discovery Room project at the IIC in collaboration with the Mitsubishi Electric Research Laboratories (MERL), I have contributed to the development of interactive digital environments for scientific collaboration. This has included the development of software to compare visual data and documents from various sources, and seamlessly display the original and overlaid data across multiple media including laptops, visualization walls, and touch tables.

- **Ammonia Survey of Perseus**
  In order to better understand the gas temperatures and dynamics of the Perseus star forming regions, I worked with the COMPLETE team to conduct a survey of ammonia observations of dense cores. We collected point data of 193 cores at the Green Bank Radio Telescope (GBT) in Green Bank, West Virginia. For each core, the local velocities, kinetic temperatures, and column densities were calculated.

- **3D Corneal Imaging**
  In collaboration with Dr. Taha Ahmed and his group at the Tennent Institute of Ophthalmology (Glasgow, UK) I have worked to develop 3D visualization techniques of confocal microscopy data to assist doctors in their diagnosis of certain corneal diseases. Conventional medical data visualization and segmentation techniques do not work well for these data sets, however their

inhomogeneous and "nebulous" appearance makes the data work well with astronomical techniques.

- **Cambridge Science Festival 2008**
  As part of the Harvard-Smithsonian Center for Astrophysics' "Cambridge Explores the Universe" event at the 2008 Cambridge Science Festival, a city wide festival highlighting science from Harvard to MIT, I organized a series of booths highlighting astronomy research at the IIC. As part of this, I personally ran a booth dedicated to the Astronomical Medicine project, explaining and demonstrating the research to school children and their families.

- **Astronomical Medicine Project Movie**
  For the IIC's inaugural symposium, I produced a mini-documentary entitled "The Astronomical Medicine Project: Mapping New Frontiers in Astronomy and Medicine" discussing the background, people, and science of the project. I managed a team of editors and film crew, and wrote the narration script. It can be viewed online through the project's movie webpage at: http://am.iic.harvard.edu/movies

- **Undergraduate Senior Thesis, 2005-2006**

For my Senior thesis, a detailed survey of the velocity features in COMPLETE's ^{12}CO and ^{13}CO data of the Perseus star forming region was conducted using three dimensional visualization techniques with medical imaging software (3D Slicer). While my Junior thesis proved the utility of the visualization software, the Senior thesis went on to gather actual scientific results unattainable with conventional methods. This visualization allowed for a rapid review of a large area (over 8 square degrees) and a total of 217 high velocity points were marked in 3D Slicer for all of Perseus. Three regions (B5, IC 348, and L1448) were investigated in which all known outflows were detected, 20 points were identified as possibly being associated with a undocumented outflows, and 9 points were identified as possibly being associated with expanding shells. Analysis of the B5 region showed high velocity gas detected from outflowing gas in the B5 region accounts for about 10% of all the high velocity gas in the region thus implying that most of the high velocity gas is from undetected outflows, from outflowing gas where the source has stopped producing new outflowing gas, or from some other unexplained turbulent process.

- **Research Assistant, Application of Medical Imaging Software to Astronomy Data, Harvard-Smithsonian Center for Astrophysics, Summer 2005**

In collaboration with Michael Halle of Brigham and Women's Hospital's Surgical Planning Lab, as the pilot project of Harvard's Initiative in Innovative Computing (IIC), I worked on applying medical imaging programs (3D Slicer and OsiriX) to better visualize astronomical data in three dimensions. In displaying spectral line data cubes (RA-DEC-Velocity) as three-dimensional models, both dense cores and velocity features like shells and young stellar outflows are easily identified. This work was carried through for regions of Perseus including B5 and NGC 1333. Other medical imaging tools, such as ITK, were tested as a segmentation and visualization tool on Perseus.

- **Undergraduate Junior Thesis, 2005**

  For my Junior thesis, a detailed study of IC 348 using medical imaging software showed the hierarchical structure of clumping in the cloud, and the association of a young cluster of stars with one portion of the cloud moving at a different velocity from the rest of the complex. This work served as a "proof of concept" that visualization techniques from one discipline could be applied to another, and became the basis for the Astronomical Medicine Project, the pilot project of the Initiative in Innovative Computing (IIC) at Harvard.

- **Research Assistant, COMPLETE Survey of Star Forming Regions, Harvard-Smithsonian Center for Astrophysics, Summers 2001-2004**

  The COMPLETE (CoOrdinated Molecular Probe Line Extinction Thermal Emission) Survey of Star Forming Regions has conducted multiwavelength observations of three star forming regions (Perseus, Ophiuchus, and Serpens). The goal is to gain a better understanding of the physics of star formation by "completely" observing different regions to compare and analyze them in an unbiased fashion. More information can be found on the projects website: http://www.cfa.harvard.edu/COMPLETE/

  - **Survey of Dense Cores in Perseus**
    CLUMPFIND, a segmentation algorithm in IDL, was used in order to identify "clumps" in star forming regions in Perseus. Both the 2D and 3D versions of CLUMPFIND were tested for validity, and then applied to IC 348 and NGC 1333 using ^{13}CO data from COMPLETE. 91 dense clumps were identified in IC 348 and 44 dense clumps were identified in NGC 1333.

  - **Spectral Correlation Function (SCF)**
    Updated the Spectral Correlation Function (SCF) in IDL and applied it to spectral line data cubes in order demonstrate that it can identify outflows from young stars. Using the SCF on ^{12}CO data of Perseus, known outflows and 4 new outflows and 11 suspect outflows were identified.

  - **COMPLETE Reference Database**
    Created an informational database for the COMPLETE Survey of papers and online data relating to the regions and observational methods to be used in the survey. The database is online at:
    http://www.cfa.harvard.edu/COMPLETE/complete_reference_db.html

  - **Webmaster and Website Designer for Prof. Alyssa A. Goodman**
    During the summers of 2001 and 2002, I created and updated the professional homepage for Prof. Alyssa Goodman.

- **High School/Undergraduate Volunteer, CfA Redshift Survey, Harvard-Smithsonian Center for Astrophysics, Summers 2001-2003**

Classified over 3,000 galaxies and did data management and organization for the CfA Redshift Survey Catalog (http://cfa-www.harvard.edu/~huchra/zcat). Also made plots (RA vs. redshift for certain DEC thicknesses) using Fortran and Super Mongo of the galaxies for different regions and morphologies to examine the structure and distribution of galaxies. I also assisted Prof. Huchra in July 2001 at the Fred Lawrence Whipple Observatory on Mt. Hopkins, Arizona to make observations of galaxies's redshifts and to observe globular clusters in the Andromeda galaxy using the 6.5-meter MMT (Multiple Mirror Telescope).

- **High School Volunteer, Whitin Observatory, Wellesley College, September 2000 – May 2001**

  Assisted Prof. Wendy Hagen-Bauer in the preparation of Bauer, W. H., Bennett, P. D., & Brown, A. 2000, "Systematic Line Profile Variation in VV Cephei During Total Eclipse" AAS Meeting 197, #44.19. I used IDL to plot the spectra obtained with IUE and Hubble telescopes in order to determine the stellar atmosphere's composition, and to study the red and blue shifted properties of the emitted wind. I also made solar observations with the 6" Alvan Clark Refractor in order to track the movement of sunspots. These observations were used for Prof. Wendy Hagen-Bauer's courses.

Awards and Outreach

- **TEDGlobal 2009 Fellow**

  The TED Fellowship is awarded to young individuals who have "demonstrated remarkable achievement in their field of endeavor" by TED ("Technology Entertainment Design", http://ted.com). At TEDGlobal 2009, I was invited to give two short talks: one on the TED mainstage, "Visualizing The Substance Of Things Not Seen", and one on the TED Fellows stage, "Serendipity: How I Discovered Astronomy."

  I am also a contributor to the TED Fellows Blog, available online at: http://tedfellows.posterous.com/

- **Invited Speaker at Science Chicago's "Science Works!"**

  I was an invited speaker in May 2009 at the Museum of Science and Industry in Chicago for "Science Works!". The event hosted by Science Chicago, a science education outreach organization in Chicago, was aimed at children (13 years old and up) in order to inspire them to pursue scientific careers. In addition to giving a short invited talk, I hosted an exhibit booth through-out the day demoing my research and answering the attendees' questions. My talk is available online at: http://bit.ly/mborkin_scichicago

- **SEED Magazine "Revolutionary Mind"**

  As part of SEED Magazine's "Revolutionary Minds" series, I was profiled as one of five "Re-envisionaries" conducting innovative research across traditional disciplines. The article with accompanying media is available online at: http://revminds.seedmagazine.com/revminds/member/michelle_borkin/

  As a follow-up to the article, I was asked by SEED to be a contributing writer on their "Revolutionary Minds Think Tank" blog. The blog is available at: http://scienceblogs.com/revminds/

Memberships

- Member of the American Astronomical Society (AAS)
- Member of the American Physical Society (APS)
- Member of the Association for Comupting Machinery (ACM)
- Member of the Alumni Board and Board of Visitors, Brimmer and May School
- Member of MENSA

Publications & Conference Proceedings

Arce, H., **Borkin, M.**, Pineda, J., Goodman, A. & Halle, M., 2009, "A COMPLETE Survey of Velocity Features in Perseus." *(in prep, to be submitted to the Astrophysical Journal)*

Kauffmann, J., Rosolowsky, E., Pineda, J., Foster, J., **Borkin, M.**, Goodman, A., Halle, M., & Alan, D., 2009, "The Complete Structure of L1448: Where (and Why) Dense Cores Do Form." *(in prep, to be submitted to the Astrophysical Journal)*

Borkin, M., Melchionna, S., Feldman, C., Kaxiras, E., & Pfister, H., 2009, "Multidimensional Visualization of Hemodynamic Data", *Proceedings of IEEE Visualization Conference 2009*, Held October 11-16 2009 in Atlantic City, NJ, USA. (*accepted*)

Foster, J. B., Rosolowsky, E. W., Kauffmann, J., Pineda, J. E., **Borkin, M. A.**, Caselli, P., Myers, P. C., & Goodman, A. A. 2009, "Dense Cores in Perseus: The Influence of Stellar Content and Cluster Environment", *Astrophysical Journal*, 696, 298.

Wigdor, D., Jiang, H., **Borkin, M.**, Forlines, C., & Shen, C., 2009, "The WeSpace: The Design, Development, and Deployment of a Walk-Up and Share Multi-Surface Visual Collaboration System", *Conference Proceedings of CHI 2009*, Boston, USA, April 4-9, 2009.

Rybicki, F., Melchionna, S., Mitsouras, D., Coskun, A., Whitmore, A., Steigner, M., Nallamshetty, L., Welt, F., Bernaschi, M., **Borkin, M.**, Sircar, J., Kaxiras, E., Succi, S., Stone, P., & Feldman, C. 2009, "Prediction of coronary artery plaque progression and potential rupture from 320-detector row prospectively ECG-gated single heart beat CT angiography: Lattice Boltzmann evaluation of endothelial shear stress", *International Journal of Cardiovascular Imaging*, Published online: January 15, 2009.

Kauffmann, J., Rosolowsky, E., Pineda, J., Foster, J., **Borkin, M.**, Goodman, A., Halle, M., & Alan, D. 2009, "The L1448 Molecular Cloud: Where (and why) do Stars form?", *Bulletin of the American Astronomical Society*, AAS Meeting 213, #347.04.

Goodman, A. A., Rosolowsky, E., **Borkin, M.**, Foster, J., Halle, M. , Kauffman, J. & Pineda, J. 2009, "A role for self-gravity at multiple length scales in the process of star formation", *Nature*, 457, 63.

Melchionna, S., Rybicki, F., Mitsouras, D., Coskun, A., Succi, S., Bernaschi, M., **Borkin, M.**,

Sircar, J., Kaxiras, E., Stone, P., & Feldman, C. 2008, "Non-invasive Prediction of Localization and Progression of Coronary Disease in Man Using Shear Stress Profiles Derived from 320-Row Detector Computed Tomography: Implications for Widespread Screening", *Proceedings of the American Heart Association (AHA) Scientific Sessions 2008*, Held 9-11 November 2008 in New Orleans, LA, USA.

Jiang, H., Wigdor, D., Forlines, C., **Borkin, M.**, Kauffman, J., & Shen, C., 2008, "LivOlay: Interactive Ad-Hoc Registered Overlapping of Applications for Collaborative Visual Exploration", *Conference Proceedings of CHI 2008*, Florence, Italy, April 5-10, 2008.

Rosolowsky, E. W., Pineda, J. E., Foster, J. B., **Borkin, M. A.**, Kauffmann, J., Caselli, P., Myers, P. C., & Goodman, A. A. 2008, "An Ammonia Spectral Atlas of Dense Cores in Perseus", *Astrophysical Journal Supplement Series*, 175, 509.

Borkin, M. A., Arce, H. G., & Goodman, A. A. 2008, "A COMPLETE Survey of Outflows in Perseus", *Bulletin of the American Astronomical Society*, AAS Meeting 211, #154.01.

Kauffmann, J., Rosolowsky, E., Pineda, J., Foster, J., **Borkin, M.**, & Goodman, A. 2008, "The COMPLETE Context of Structure in L1448", *Bulletin of the American Astronomical Society*, AAS Meeting 211, #153.03.

Shetty, R., Goodman, A. A., Schnee, S., Pineda, J., Foster, J., **Borkin, M.**, Rosolowsky, E., Kauffmann, J., Arce, H., & Caselli, P. 2008, "Updated Offerings From The COMPLETE Survey Of Star-forming Regions", *Bulletin of the American Astronomical Society*, AAS Meeting 211, #132.06.

Borkin, M. A., Goodman, A. A., Alan, D., Kauffmann, J., & Halle, M. 2007, "Application of Medical Imaging to the 3D Visualization of Astronomy Data", *Proceedings of IEEE Visualization Conference (Vis 2007)*, Held 28 October - 1 November 2007 in Sacramento, CA, USA.

Borkin, M., Arce, H., Goodman, A., & Halle, M. 2007, "3D Visualization and Detection of Outflows From Young Stars", *Astronomical Data Analysis Software and Systems XVII ASP Conference Series*, Proceedings of the Conference Held 23-26 September 2007 in London, England, UK.

Borkin, M. A., Goodman, A. A., Halle, M., Alan, D., & Kauffmann, J. 2007, "Application of Medical Imaging Software to the 3D Visualization of Astronomical Data", *Bulletin of the American Astronomical Society*, AAS Meeting 209, #57.06.

Borkin, M., Goodman, A., Halle, M., & Alan, D. 2006, "Application of Medical Imaging Software to 3D Visualization of Astronomical Data", *Astronomical Data Analysis Software and Systems XVI ASP Conference Series*, Proceedings of the Conference Held 15-18 October 2006 in Tucson, Arizona, USA.

Borkin, M. A., "A COMPLETE Survey of Velocity Features in Perseus", 5/2006, Harvard University Undergraduate Senior Thesis.

Pineda, J. E., Goodman, A. A., Ridge, N. A., **Borkin, M. A.**, & Schnee, S. L. 2006, "Clumpfind

in Perseus Molecular Cloud", XI IAU Regional Latin American Meeting of Astronomy, *Revista Mexicana de Astronomía y Astrofísica (Serie de Conferencias)* Vol. 26, p. 164

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Pineda, J.E., Goodman, A., Ridge, N.A., **Borkin, M.**, & Schnee, S. 2005, "Clumpfinding in the Perseus Molecular Cloud", *Bulletin of the American Astronomical Society*, AAS Meeting 207, #184.10.

Borkin, M. A., Ridge, N. A., Goodman, A. A., & Halle, M. 2005, "Demonstration of the Applicability of 3D Slicer to Astronomical Data Using 13CO and C18O Observations of IC 348" 6/2005, Harvard University Undergraduate Junior Thesis, (astro-ph/0506604).

Borkin, M., Ridge, N., Schnee, S., Goodman, A., & Pineda, J. 2004, "A COMPLETE Survey for Dense Clumps in Perseus", *Bulletin of the American Astronomical Society*, AAS Meeting 205, #140.13.

Ridge, N. A., Schnee, S. L., Goodman, A. A., & **Borkin, M. A.** 2004, "New Structures Revealed Through 12CO and 13CO Mapping of the Perseus Molecular Cloud Complex", *Bulletin of the American Astronomical Society*, AAS Meeting 205, #74.05.

Fallscheer, C., **Borkin, M.**, Ridge, N., Schnee, S., & Goodman, A. 2003, "A COMPLETE Search for Molecular Outflows in Perseus", *Bulletin of the American Astronomical Society*, AAS Meeting 203, #77.02.