University of Victoria | Graduate Studies

# PROGRAMME

The Final Oral Examination for the Degree of

DOCTOR OF PHILOSOPHY
(Department of Physics and Astronomy)

## Shadi Chitsazzadeh

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| 2009 | University of Western Ontario | MSc (Astronomy) |
| 2005 | Shahid Beheshti University | BSc (Physics) |

"Internal Physical and Chemical Characteristics of Starless Cores on the Brink of Gravitational Collapse"

Friday, August 8, 2014
1:00 p.m.
Elliot Building, room 105

Supervisory Committee:
Dr. James Di Francesco, Department of Physics and Astronomy, UVic (Co-Supervisor)
Dr. Sara Ellison, Department of Physics and Astronomy, UVic (Co-Supervisor)
Dr. Chris Pritchet, Department of Physics and Astronomy, UVic (Member)
Dr. Roberta Hamme, School of Earth and Ocean Sciences, UVic (Outside Member)

External Examiner:
Dr. Erik Rosolowsky, Department of Physics, University of Alberta

Chair of Oral Examination:
Dr. Michael McGuire, Department of Electrical and Computer Engineering, UVic

## Abstract

Using various molecular line and continuum emission selection criteria, we examine six isolated, dense concentrations of molecular gas, i.e., “cores”, which are either starless (L694-2, L429, L1517B, and L1689-SMM16) or contain a very low luminosity protostellar object and are currently experiencing gravitational collapse (L1014 and L1521F). Studying the molecular emission from dense gas tracers toward this sample of cores will probe the internal physical conditions of dense cores on the brink of gravitational collapse.

Line widths of $NH_3$ (1,1) and $N_2H^+$ (1−0) toward L1689-SMM16 show the presence of transonic turbulence across the core. Jeans and virial analyses made using updated measurements of core mass and size confirm that L1689-SMM16 is prestellar, i.e., gravitationally bound. It also has accumulated more mass compared to its corresponding Jeans mass in the absence of magnetic fields and therefore is a “super-Jeans” core. The high levels of X ($NH_3$)/X($N_2H^+$) and deuterium fractionation reinforce the idea that this core has not yet formed a protostar. Comparing its physical parameters with those of a Bonnor-Ebert sphere reveals the advanced evolutionary stage of L1689-SMM16 and shows that it might be unstable to collapse. We do not detect any evidence of infall motions toward the core, however. Instead, red asymmetry in the line profiles of HCN (1−0) and HNC (1−0) indicates expansion of the core’s outer layers at $\sim$0.2−0.3 km $s^{-1}$. For a gravitationally bound core, such expansion might indicate that L1689-SMM16 is experiencing oscillations.

L429 shows the most complicated structure among the cores in our sample. Also, the maxima of molecular line integrated intensities and dust continuum emission toward L429 show a significant offset. The rest of the cores in our sample are roughly round-shaped and the morphologies of line-integrated intensities follow closely that of the corresponding continuum emission. Cores in our sample have gas kinetic temperatures $\sim$9 − 10 K and therefore show comparable thermal velocity dispersions. L429 and L1517B are, respectively, the most turbulent and most quiescent cores in our sample. Finally, L1521F is the most centrally concentrated core of our sample.

We used the radiative transfer code MOLLIE to simulate the $NH_3$ emission toward L694-2 and L1521F at low and high spatial resolutions. We find that the less evolved core, L694-2, is best described by relatively constant radial profiles of temperature and fractional NH3 abundance. On the other hand, L1521F, which contains a very low luminosity protostellar object, is best described by a radial abundance profile that is enhanced toward the core center and a radial temperature profile that decreases toward the core center. Comparisons of our results with those of L1544, a previously well-studied starless core, imply that as dense cores evolve and progress toward the onset of collapse, they become more centrally concentrated. As a result, gas temperatures at their centers decrease, leading increases in CO depletion and $NH_3$ fractional abundance toward the centers.

## Awards, Scholarships, Fellowships

2012 - R. M. Petrie Memorial Fellowship
2009 - University of Victoria Fellowship
2008 - Western Graduate Research Scholarship
2007 - Western Graduate Research Scholarship

## Presentations

1. Chitsazzadeh S. "Molecular Emission Observations of Dense Core L1689-SMM16", New Trends in Radio Astronomy in the ALMA Era, Hakone, Japan, December, 2012 (Poster)

2. Chitsazzadeh S. "Ammonia Observations of Starless Cores on the Brink", The Milky Way in the Herschel Era, Rome, Italy, September, 2011 (Poster)

3. Chitsazzadeh S. "Characterization of Turbulence from Submillimeter Dust Emission", From Stars to Galaxies, Gainesville, Florida, April, 2012 (Poster)

4. Chitsazzadeh S. "Maser Science with a Space Based Interferometer", FIR Astronomy Discipline Working Group, University of Waterloo, February, 2009 (Oral)

5. Chitsazzadeh S. “Hunting for Methanol Masers”, Astronomical Polarimetry Conference, La Malbaie, QC, July, 2008 (Poster)

## Publications

1. Chitsazzadeh S.; Di Francesco J., et al.; “Physical and Chemical Characteristics of L1689-SMM16, an Oscillating Prestellar Core in Ophiuchus”, Astrophysical Journal, 2014, 790, 129
2. Chitsazzadeh S.; Houde M., et al.; “Characterization of Turbulence from Submillimeter Dust Emission”, Astrophysical Journal, 2012, 749, 45
3. Sadavoy S. I., Di Francesco J., Andre Ph., Pezzuto S., Bernard J.-P., Bontemps S., Bressert E., Chitsazzadeh, S., et al.; “Herschel Observations of a Potential Core-Forming Clump: Perseus B1E”, Astronomy & Astrophysics, 2012, 540, 13
4. Houde M., Vaillancourt J. E., Hildebrand R. H., Chitsazzadeh S.**,** Kirby L., “Dispersion of Magnetic Fields in Molecular Clouds. II”, Astrophysical Journal, 2009, 706, 1504