

CURRICULUM VITAE

NORMAN MURRAY

17 June 2015

A. Biographical Information

1. Personal

Full Name: Norman Murray
Office Address: Canadian Institute of Theoretical Astrophysics (CITA)
University of Toronto,
60 St. George Street, Toronto, ON, M5S 3H8
Office Phone: 416 978-1778

2. Degrees

B.Sc. 1979 California Institute of Technology
Ph.D. 1986 University of California Berkeley
Thesis:
Diffusion in Hamiltonian Systems with Applications
to Twist Maps and the Two Beam Accelerator.
Supervisor: Michael Lieberman

3. Employment

Director	CITA, University of Toronto	July 2006-present
Miller Professor	University of California Berkeley	2003
Professor	CITA, University of Toronto	2003-present
Canada Research Chair in Astrophysics		2001-present
Associate Director	CITA, University of Toronto	1999-2006
Acting Director	CITA, University of Toronto	2002-2003
Associate Professor	CITA, University of Toronto	1998-2003
Assistant Professor	CITA, University of Toronto	1993-1998
Senior Research Fellow	Caltech	1991-1993
Postdoctoral Fellow	Caltech	1989-1991
Postdoctoral Fellow	Queen Mary College	1986-1989
Research Assistant	University of California, Berkeley	1982-1986
Teaching Assistant	University of California, Berkeley	1979-1982

4. Honours

Observatories of the Carnegie Institute of Washington Distinguished Visitor (2013)

Spitzer Distinguished Visiting Scientist, Spitzer Science Center, Caltech (2009)

Fellow, American Physical Society (2007)

Miller Visiting Professor, University of California, Berkeley (2003)

Canada Research Chair (2001)

Invited Speaker, US National Academy of Sciences 12th Annual Frontiers of Science Symposium (2000).

Premier's Research Excellence Award, Province of Ontario (2000).

American Association for the Advancement of Science Newcomb Cleveland award, for the "Best Paper in Science Magazine", for 1999; N. Murray and M. Holman, *Science*, **283** 1877 (1999).

5. Professional Affiliations And Activities

Member, American Astronomical Society	1989-
Member, Canadian Astronomical Society	1993-
Member, American Association for Advancement of Science	1998-
Member, American Physical Society	2005-

B. Academic History

6a. Research Endeavours and Key Contributions

1. **Nonlinear Dynamics:** Plasma Physics, Accelerator Physics. I calculated transport rates in chaotic systems.
2. **Helioseismology:** Astronomy, Stellar Physics. I developed theories of the excitation and damping of solar oscillations, and for the interaction between magnetic fields and sound waves.
3. **Solar Physics:** Astronomy, Magnetohydrodynamics. Combined observations with numerical and analytical models to study the origin and evolution of the solar magnetic field.

4. **Planetary Science:** Dynamics. I have carried out research on the origin and evolution of the solar system and various satellite systems. I have focused on the source of the chaotic motion seen in numerical simulations of the solar system. A paper resulting from this work was chosen as the best paper in the broadest journal in science, Science Magazine, in 1999.
5. **Active Galactic Nuclei:** Astronomy. I proposed a novel theory for emission line formation in quasars and other active galactic nuclei, and for broad absorption lines in quasars. This is now the standard theory of both emission and absorption lines in these, the most luminous objects in the universe.
6. **Cataclysmic Variables:** Astronomy. I have studied the accretion process in these binary stars, and proposed various line formation mechanisms.
7. **Extra Solar Planets:** Planet Formation. I have proposed that massive planetesimal disks around young stars are responsible for some of the short orbital periods of Jupiter-mass planets orbiting other stars. I have also suggested that such short period planets may arise due to the influence of a more distant object (a second planet or star) on a highly inclined orbit. One prediction of the latter theory is that the short period planet will orbit its host star on a highly inclined orbit; between a third and half the planets for which this inclination angle have been measured are indeed highly inclined, so this paper has received a great deal of attention (well over two hundred citations).
8. **Transit Time Variations:** Planet Formation. On a third front, in 2005, together with Matt Holman, I suggested that transiting planets in multiple planet systems would show transit-time variations (TTVs), or changes in the length of their year. TTVs can be used to infer the presence of non-transiting planets orbiting the same star, or to measure the mass and hence the density multiple transiting planets. Such TTVs have now been detected, and used to do both. The paper has over 300 citations.
9. **Earth & Neptune Mass Kepler Planets:** Planet Formation. The Kepler space telescope has found several thousand planet candidates; a substantial fraction of these candidates have been verified as true planets using the TTVs, as described above. The TTV method allows observers to obtain the mass of the planets, unavailable otherwise. Many of the Kepler system have multiple Earth to Neptune mass planets

(up to six in a single system) on very small orbits, smaller than that of Mercury in our Solar system. Brad Hansen and I have proposed that these planets formed in situ. We have performed simulations that show that the masses, spacings, eccentricities and inclinations observed in the Kepler systems can be reproduced by such a model. A clear prediction of the model is that the planets have high density cores; since a number of the Kepler planets have low bulk densities, we argue that they must have low mass but extended hydrogen atmospheres. I had earlier worked out the mass loss rates from Jupiter mass planets with Murray-Clay and Chiang. This idea has now been tested observationally; as we predicted, planets orbiting close to their host star do tend to have higher densities than more distant planets.

10. **Galaxy Formation:** Astronomy. In 2005, together with Todd Thompson and Eliot Quataert, I suggested that radiation pressure on dust is the primary feedback mechanism in starburst systems. This extra pressure support leads to a mechanism for avoiding disk fragmentation at parsec scales, allowing for the feeding of massive black holes.
11. **Galactic Winds:** Astronomy. In 2011 and 2012, in a series of papers with Phil Hopkins and Eliot Quataert, we used numerical simulations employing radiation feedback to show, for the first time that the rate of star formation in galaxies (the Kennicutt-Schmidt law) can be explained (MNRAS **417** **950**, number 73 in my publication list). The same simulations showed that, in rapidly star forming galaxies, the radiation pressure, combined with supernovae, will drive high velocity (500 kilometers per second) galaxy scale winds, also the first time this has been done (MNRAS **421**, 3488, no. 79).
12. **Star Formation:** Astronomy. In a second paper in 2005 with Thompson and Quataert, we proposed that radiative feedback slowed the rate of star formation in gas rich galaxies. I have since come to realize that the same feedback operates in our own Galaxy, the Milky Way. With then Toronto undergraduate Eve Lee and graduate student Mubdi Rahman, I used data from the WMAP cosmology satellite, the Spitzer Space telescope, and other instruments, to find about a dozen young star clusters ranking among the top 15 or so most massive clusters in the Galaxy (nos. 66, 68, 72, and 83). We showed that the radiative feedback from these clusters is disrupting the host gas clouds, halting further star formation. I have

also shown, in a 2015 ApJ paper, that the star formation in GMCs is very rapid. I have shown this both analytically, using three dimensional magnetohydrodynamic simulations, and using observational data; the star formation rate is not a constant, as is often asserted, but instead increases as the square of the time. The realization that star formation on small scales was rapid, and that therefore an early form of feedback must be important, is a major new result that has already had a large impact on our understanding of star and galaxy formation.

13. **Galaxy Formation:** Astronomy. I am part of a collaboration (the FIRE collaboration) doing numerical simulations of star and galaxy formation. We start with initial conditions a few million years after the big bang (dark matter densities, gas densities and temperatures) inferred from observations of the cosmic microwave background, and integrating forward to the present day. Using simplified prescriptions for the feedback from stars and supernovae described above, we find that, at every epoch we cover, the relation between the dark matter mass and stellar mass in our simulated galaxies closely matches that seen in observations. The first paper describing the simulations and the results, which appeared in 2014, already has more than 100 citations.
14. **Star Formation:** In two recent papers (Lee, Chang, & Murray, and Murray & Chang) I and my coauthors have worked out the dynamics of gravitational collapse in turbulent gas. We find that the turbulence is enhanced by the infall, so that the acceleration due to the turbulent pressure gradient is always comparable to the acceleration of gravity; star formation occurs in gas that is never in hydrostatic equilibrium, but neither is the gas ever in free fall. The theory explains heretofore unexplained deviations from Larson's law seen for twenty years in massive star forming regions. It also shows that the star formation rate increases rapidly with time.

Goldreich, P., Murray, N., & Kumar, P. Excitation of solar p-modes 1994, *The Astrophysical Journal*, **424**, 466-479

Murray, N., Chiang, J., Grossman, S. A., & Voit, G. M. Accretion Disk Winds from Active Galactic Nuclei 1995, *The Astrophysical Journal*, **451**, 498-

Murray, N., & Chiang, J. Active Galactic Nuclei Disk Winds, Absorption Lines, and Warm Absorbers 1995, *The Astrophysical*

- Journal, **454**, L105-
- Murray, N., Hansen, B., Holman, M., & Tremaine, S. Migrating Planets 1998, *Science*, **279**, 69-
- Wu, Y., & Murray, N. Planet Migration and Binary Companions: The Case of HD 80606b 2003, *The Astrophysical Journal*, **589**, 605-614
- Holman, M. J., & Murray, N. W. The Use of Transit Timing to Detect Terrestrial-Mass Extrasolar Planets 2005, *Science*, **307**, 1288-1291
- Murray-Clay, R. A., Chiang, E. I., & Murray, N. Atmospheric Escape From Hot Jupiters 2009, *The Astrophysical Journal*, **693**, 23-42
- Murray, N., Quataert, E., & Thompson, T. A. The Disruption of Giant Molecular Clouds by Radiation Pressure & the Efficiency of Star Formation in Galaxies 2010, *The Astrophysical Journal*, **709**, 191-209
- Hopkins, P. F., Quataert, E., & Murray, N. Self-regulated star formation in galaxies via momentum input from massive stars 2011, *Monthly Notices of the Royal Astronomical Society*, **417**, 950-973
- Croll, B., Albert, L., Jayawardhana, R., Miller-Ricci Kempton, E., Fortney, J. J., Murray, N., & Neilson, H. Broadband Transmission Spectroscopy of the Super-Earth GJ 1214b Suggests a Low Mean Molecular Weight Atmosphere 2011, *The Astrophysical Journal*, **736**, 78-
- Murray, N., Quataert, E., & Thompson, T. A. On the Maximum Luminosity of Galaxies and Their Central Black Holes: Feedback from Momentum-driven Winds 2005, *The Astrophysical Journal*, **618**, 569-585
- Thompson, T. A., Quataert, E., & Murray, N. Radiation Pressure-supported Starburst Disks and Active Galactic Nucleus Fueling 2005, *The Astrophysical Journal*, **630**, 167-185
- Murray, N., Ménard, B., & Thompson, T. A. Radiation Pressure from Massive Star Clusters as a Launching Mechanism for Supergalactic Winds 2011, *The Astrophysical Journal*, **735**, 66-
- Hopkins, P. F., Quataert, E., & Murray, N. Stellar feedback in galaxies and the origin of galaxy-scale winds 2012, *Monthly Notices of the Royal Astronomical Society*, **421**, 3522-3537
- Murray, N. Star Formation Efficiencies and Lifetimes of Giant Molecular Clouds in the Milky Way 2011, *The Astrophysical Journal*, **729**, 133-

Lee, E. J., Chang, P., & Murray, N. *Time-varying Dynamical Star Formation Rate*, The Astrophysical Journal, **800**, 49 (2015)

Murray, N., & Chang, P. *Star Formation in Self-gravitating Turbulent Fluids*, The Astrophysical Journal, **804**, 44 (2015)

6b. Research Awards (last 5 years)

2012-2015 NASA:ATP (Co-I) \$414,000US

2011-2016 NSERC Discovery \$240,000

2012-2015 NSERC MRS \$3,300,000

2007-2011 NSERC MRS \$5,500,000

C. Scholarly and Professional Work

7. Papers in Refereed Journals

7a. Career Totals of Publications

111 Refereed papers; 8552 citations, h-index = 51 (from Google Scholar)

Murray, N. W., Lieberman, M. A., & Lichtenberg, A. J. *Corrections to quasilinear diffusion in area-preserving maps*, Physical Review A, **32**, 2413-2424, (1985)

Murray, N. W. *Diffusion in Hamiltonian Systems with Applications to Twist Maps and the Two Beam Accelerator.*, Ph.D. Thesis, (1986)

Lichtenberg, A. J., Lieberman, M. A., & Murray, N. W. *The effect of quasi-accelerator modes on diffusion*, Physica D Nonlinear Phenomena, **28**, 371-381, (1987)

Dana, I., Murray, N. W., & Percival, I. C. *Resonances and diffusion in periodic Hamiltonian maps*, Physical Review Letters, **62**, 233-236, (1989)

Goldreich, P., Murray, N., Longaretti, P. Y., & Banfield, D. *Neptune's story*, Science, **245**, 500-504, (1989)

Chen, Q., Dana, I., Meiss, J. D., Murray, N. W., & Percival, I. C. *Resonances and transport in the sawtooth map*, Physica D Nonlinear Phenomena, **46**, 217-240, (1990)

Goldreich, P., Murray, N., Willette, G., & Kumar, P. *Implications of solar p-mode frequency shifts*, The Astrophysical Journal, **370**, 752-762, (1991)

- Woodard, M. F., Libbrecht, K. G., Kuhn, J. R., & Murray, N. *Short-term changes in solar oscillation frequencies and solar activity*, The Astrophysical Journal, **373**, L81-L84, (1991)
- Murray, N. W. *Critical function for the standard map*, Physica D Nonlinear Phenomena, **52**, 220-245, (1991)
- 10 Murray, N. *High latitude solar magnetic fields*, Solar Physics, **138**, 419-422, (1992)
- Banfield, D., & Murray, N. *A dynamical history of the inner Neptunian satellites*, Icarus, **99**, 390-401, (1992)
- Murray, N. *On the inclination of photospheric solar magnetic fields*, The Astrophysical Journal, **401**, 386-397, (1992)
- Murray, N., & Wilson, P. R. *The reversal of the solar polar magnetic fields. IV - The polar fields near sunspot maximum*, Solar Physics, **142**, 221-232, (1992)
- Goldreich, P., Murray, N., & Kumar, P. *Excitation of solar p-modes*, The Astrophysical Journal, **424**, 466-479, (1994)
- Goldreich, P., & Murray, N. *The effects of scattering on solar oscillations*, The Astrophysical Journal, **424**, 480-490, (1994)
- Murray, N., Grossman, S., & Chiang, J. *Accretion disk winds from active galactic nuclei.*, Journal of the Royal Astronomical Society of Canada, **88**, 253-254, (1994)
- Murray, N., Chiang, J., Grossman, S. A., & Voit, G. M. *Accretion Disk Winds from Active Galactic Nuclei*, The Astrophysical Journal, **451**, 498 (1995)
- Murray, N., & Chiang, J. *Active Galactic Nuclei Disk Winds, Absorption Lines, and Warm Absorbers*, The Astrophysical Journal, **454**, L105 (1995)
- Chiang, J., & Murray, N. *Reverberation Mapping and the Disk-Wind Model of the Broad-Line Region*, The Astrophysical Journal, **466**, 704 (1996)
- 20 Murray, N., & Chiang, J. *Wind-dominated optical line emission from accretion disks around luminous cataclysmic variable stars*, Nature, **382**, 789-791, (1996)
- Holman, M. J., & Murray, N. W. *Chaos in High-Order Mean Resonances in the Outer Asteroid Belt*, The Astronomical Journal, **112**, 1278 (1996)
- Murray, N., & Chiang, J. *Disk Winds and Disk Emission Lines*, The Astrophysical Journal, **474**, 91-103, (1997)
- Murray, N., & Holman, M. *Diffusive chaos in the outer asteroid belt.*, The Astronomical Journal, **114**, 1246-1259, (1997)

- Murray, N., Hansen, B., Holman, M., & Tremaine, S. *Migrating Planets*, Science, **279**, 69 (1998)
- Murray, N., & Chiang, J. *Photoionization of Disk Winds*, The Astrophysical Journal, **494**, 125-138, (1998)
- Murray, N., Holman, M., & Potter, M. *On the Origin of Chaos in the Asteroid Belt*, The Astronomical Journal, **116**, 2583-2589, (1998)
- Murray, N., Hansen, B., & Holman, M. *Migrating planets.*, Journal of the Royal Astronomical Society of Canada, **92**, 310 (1998)
- Murray, N., & Holman, M. *The Origin of Chaos in the Outer Solar System*, Science, **283**, 1877 (1999)
- Chiang, J., Reynolds, C. S., Blaes, O. M., Nowak, M. A., Murray, N., Madejski, G., Marshall, H. L., & Magdziarz, P. *Simultaneous EUVE/ASCA/RXTE Observations of NGC 5548*, The Astrophysical Journal, **528**, 292-305, (2000)
- 30 Lecar, M., Franklin, F. A., Holman, M. J., & Murray, N. J. *Chaos in the Solar System*, Annual Review of Astronomy and Astrophysics, **39**, 581-631, (2001)
- Murray, N., & Holman, M. *The role of chaotic resonances in the Solar System*, Nature, **410**, 773-779, (2001)
- Murray, N., Chaboyer, B., Arras, P., Hansen, B., & Noyes, R. W. *Stellar Pollution in the Solar Neighborhood*, The Astrophysical Journal, **555**, 801-815, (2001)
- Thompson, C., & Murray, N. *Transport of Magnetic Fields in Convective, Accreting Supernova Cores*, The Astrophysical Journal, **560**, 339-357, (2001)
- Arav, N., et al. *HST STIS Observations of PG 0946+301: The Highest Quality UV Spectrum of a BALQSO*, The Astrophysical Journal, **561**, 118-130, (2001)
- Chiang, J., Reynolds, C., Blaes, O., Nowak, M., Murray, N., Madejski, G., Marshall, H., & Magdziarz, P. *EUVE/ASCA/RXTE observations of NGC 5548*, X-ray Astronomy: Stellar Endpoints, AGN, and the Diffuse X-ray Background, **599**, 578-581, (2001)
- Murray, N., Paskowitz, M., & Holman, M. *Eccentricity Evolution of Migrating Planets*, The Astrophysical Journal, **565**, 608-620, (2002)
- Murray, N., & Chaboyer, B. *Are Stars with Planets Polluted?*, The Astrophysical Journal, **566**, 442-451, (2002)
- Chiang, E. I., & Murray, N. *Eccentricity Excitation and Apsidal Resonance Capture in the Planetary System ν Andromedae*, The Astrophysical Journal, **576**, 473-477, (2002)

- Weingartner, J. C., & Murray, N. *X-Ray versus Optical Observations of Active Galactic Nuclei: Evidence for Large Grains?*, The Astrophysical Journal, **580**, 88-95, (2002)
- 40 Medvedev, M. V., & Murray, N. *Hot Settling Accretion Flow onto a Spinning Black Hole*, The Astrophysical Journal, **581**, 431-437, (2002)
- Matsuyama, I., Johnstone, D., & Murray, N. *Halting Planet Migration by Photoevaporation from the Central Source*, The Astrophysical Journal, **585**, L143-L146, (2003)
- Wu, Y., & Murray, N. *Planet Migration and Binary Companions: The Case of HD 80606b*, The Astrophysical Journal, **589**, 605-614, (2003)
- Ballantyne, D. R., Weingartner, J. C., & Murray, N. *On the location and composition of the dust in the MCG-6-30-15 warm absorber*, Astronomy and Astrophysics, **409**, 503-509, (2003)
- Murray, N., Weingartner, J. C., & Capobianco, C. *On the Flux of Extrasolar Dust in Earth's Atmosphere*, The Astrophysical Journal, **600**, 804-827, (2004)
- Mandell, A. M., Ge, J., & Murray, N. *A Search for $i\text{SUP}_{\dot{6}i}/\text{SUP}_{\dot{6}Li}$ in Lithium-Poor Stars with Planets*, The Astronomical Journal, **127**, 1147-1157, (2004)
- Murray, N., Quataert, E., & Thompson, T. A. *On the Maximum Luminosity of Galaxies and Their Central Black Holes: Feedback from Momentum-driven Winds*, The Astrophysical Journal, **618**, 569-585, (2005)
- Holman, M. J., & Murray, N. W. *The Use of Transit Timing to Detect Terrestrial-Mass Extrasolar Planets*, Science, **307**, 1288-1291, (2005)
- Kley, W., Lee, M. H., Murray, N., & Peale, S. J. *Modeling the resonant planetary system GJ 876*, Astronomy and Astrophysics, **437**, 727-742, (2005)
- Thompson, T. A., Quataert, E., & Murray, N. *Radiation Pressure-supported Starburst Disks and Active Galactic Nucleus Fueling*, The Astrophysical Journal, **630**, 167-185, (2005)
- 50 Schuler, S. C., King, J. R., Terndrup, D. M., Pinsonneault, M. H., Murray, N., & Hobbs, L. M. *Oxygen from the $\lambda 7774$ High-Excitation Triplet in Open Cluster Dwarfs: Hyades*, The Astrophysical Journal, **636**, 432-444, (2006)
- Ballantyne, D. R., Everett, J. E., & Murray, N. *Connecting Galaxy Evolution, Star Formation, and the Cosmic X-Ray Background*, The Astrophysical Journal, **639**, 740-752, (2006)

- Thommes, E. W., & Murray, N. *Giant Planet Accretion and Migration: Surviving the Type I Regime*, *The Astrophysical Journal*, **644**, 1214-1222, (2006)
- Thompson, T. A., Quataert, E., Waxman, E., Murray, N., & Martin, C. L. *Magnetic Fields in Starburst Galaxies and the Origin of the FIR-Radio Correlation*, *The Astrophysical Journal*, **645**, 186-198, (2006)
- Everett, J. E., & Murray, N. *Large-Scale Parker Winds in Active Galactic Nuclei*, *The Astrophysical Journal*, **656**, 93-104, (2007)
- Thommes, E. W., Nilsson, L., & Murray, N. *Overcoming Migration during Giant Planet Formation*, *The Astrophysical Journal*, **656**, L25-L28, (2007)
- Murray, N., Martin, C. L., Quataert, E., & Thompson, T. A. *The Ionization State of Sodium in Galactic Winds*, *The Astrophysical Journal*, **660**, 211-220, (2007)
- Chang, P., Quataert, E., & Murray, N. *From Thin to Thick: The Impact of X-Ray Irradiation on Accretion Disks in Active Galactic Nuclei*, *The Astrophysical Journal*, **662**, 94-101, (2007)
- Wu, Y., Murray, N. W., & Ramsahai, J. M. *Hot Jupiters in Binary Star Systems*, *The Astrophysical Journal*, **670**, 820-825, (2007)
- Mudryk, L. R., & Murray, N. W. *RAPID: A fast, high resolution, flux-conservative algorithm designed for planet disk interactions*, *New Astronomy*, **14**, 71-87, (2009)
- 60 Murray, N. *The Sizes and Luminosities of Massive Star Clusters*, *The Astrophysical Journal*, **691**, 946-962, (2009)
- Murray-Clay, R. A., Chiang, E. I., & Murray, N. *Atmospheric Escape From Hot Jupiters*, *The Astrophysical Journal*, **693**, 23-42, (2009)
- Harper-Clark, E., & Murray, N. *One-Dimensional Dynamical Models of the Carina Nebula Bubble*, *The Astrophysical Journal*, **693**, 1696-1712, (2009)
- Thompson, T. A., Quataert, E., & Murray, N. *Radio emission from supernova remnants: implications for post-shock magnetic field amplification & the magnetic fields of galaxies*, *Monthly Notices of the Royal Astronomical Society*, **397**, 1410-1419, (2009)
- Hopkins, P. F., Murray, N., & Thompson, T. A. *The small scatter in BH-host correlations and the case for self-regulated BH growth*, *Monthly Notices of the Royal Astronomical Society*, **398**, 303-311, (2009)
- Hopkins, P. F., Bundy, K., Murray, N., Quataert, E., Lauer, T. R., & Ma, C.-P. *Compact high-redshift galaxies are the cores of the*

- most massive present-day spheroids*, Monthly Notices of the Royal Astronomical Society, **398**, 898-910, (2009)
- Murray, N., Quataert, E., & Thompson, T. A. *The Disruption of Giant Molecular Clouds by Radiation Pressure & the Efficiency of Star Formation in Galaxies*, The Astrophysical Journal, **709**, 191-209, (2010)
- Murray, N., & Rahman, M. *Star Formation in Massive Clusters Via the Wilkinson Microwave Anisotropy Probe and the Spitzer Glimpse Survey*, The Astrophysical Journal, **709**, 424-435, (2010)
- Hopkins, P. F., Murray, N., Quataert, E., & Thompson, T. A. *A maximum stellar surface density in dense stellar systems*, Monthly Notices of the Royal Astronomical Society, **401**, L19-L23, (2010)
- Rahman, M., & Murray, N. *A New Sample of Very Massive Star Forming Complexes in the Spitzer Glimpse Survey*, The Astrophysical Journal, **719**, 1104-1122, (2010)
- 70 Bundy, K., et al. *The Rise and Fall of Passive Disk Galaxies: Morphological Evolution Along the Red Sequence Revealed by COSMOS*, The Astrophysical Journal, **719**, 1969-1983, (2010)
- Croll, B., Lafreniere, D., Albert, L., Jayawardhana, R., Fortney, J. J., & Murray, N. *Near-infrared Thermal Emission from WASP-12b: Detections of the Secondary Eclipse in Ks, H, and J*, The Astronomical Journal, **141**, 30 (2011)
- Rubin, K. H. R., Prochaska, J. X., Ménard, B., Murray, N., Kasen, D., Koo, D. C., & Phillips, A. C. *Low-ionization Line Emission from a Starburst Galaxy: A New Probe of a Galactic-scale Outflow*, The Astrophysical Journal, **728**, 55 (2011)
- Murray, N. *Star Formation Efficiencies and Lifetimes of Giant Molecular Clouds in the Milky Way*, The Astrophysical Journal, **729**, 133 (2011)
- Harper-Clark, E., & Murray, N. *Simulations of Massive Star Cluster Formation and Feedback in Turbulent Giant Molecular Clouds*, Computational Star Formation, **270**, 235-238, (2011)
- Murray, N., Ménard, B., & Thompson, T. A. *Radiation Pressure from Massive Star Clusters as a Launching Mechanism for Supergalactic Winds*, The Astrophysical Journal, **735**, 66 (2011)
- Croll, B., Albert, L., Jayawardhana, R., Miller-Ricci Kempton, E., Fortney, J. J., Murray, N., & Neilson, H. *Broadband Transmission Spectroscopy of the Super-Earth GJ 1214b Suggests a Low Mean Molecular Weight Atmosphere*, The Astrophysical Journal, **736**, 78 (2011)

- Hopkins, P. F., Quataert, E., & Murray, N. *Self-regulated star formation in galaxies via momentum input from massive stars*, Monthly Notices of the Royal Astronomical Society, **417**, 950-973, (2011)
- Murray, N., & Chang, P. *Star Formation in Massive Clusters via Bondi Accretion*, The Astrophysical Journal, **746**, 75 (2012)
- Faucher-Giguère, C.-A., Quataert, E., & Murray, N. *A physical model of FeLoBALs: implications for quasar feedback*, Monthly Notices of the Royal Astronomical Society, **420**, 1347-1354, (2012)
- 80 Prodan, S., & Murray, N. *On the Dynamics and Tidal Dissipation Rate of the White Dwarf in 4U 1820-30*, The Astrophysical Journal, **747**, 4 (2012)
- Hopkins, P. F., Quataert, E., & Murray, N. *The structure of the interstellar medium of star-forming galaxies*, Monthly Notices of the Royal Astronomical Society, **421**, 3488-3521, (2012)
- Hopkins, P. F., Quataert, E., & Murray, N. *Stellar feedback in galaxies and the origin of galaxy-scale winds*, Monthly Notices of the Royal Astronomical Society, **421**, 3522-3537, (2012)
- Hansen, B. M. S., & Murray, N. *Migration Then Assembly: Formation of Neptune-mass Planets inside 1 AU*, The Astrophysical Journal, **751**, 158 (2012)
- Lee, E. J., Murray, N., & Rahman, M. *Milky Way Star-forming Complexes and the Turbulent Motion of the Galaxy's Molecular Gas*, The Astrophysical Journal, **752**, 146 (2012)
- Murray, N. W. *Evidence of Things Not Seen*, Science, **336**, 1121 (2012)
- O'Sullivan, E., et al. *A Giant Metrewave Radio Telescope/Chandra view of IRAS 09104+4109: a type 2 QSO in a cooling flow*, Monthly Notices of the Royal Astronomical Society, **424**, 2971-2993, (2012)
- Hopkins, P. F., Kereš, D., Murray, N., Quataert, E., & Hernquist, L. *Stellar feedback and bulge formation in clumpy discs*, Monthly Notices of the Royal Astronomical Society, **427**, 968-978, (2012)
- Longmore, S. N., et al. *Variations in the Galactic star formation rate and density thresholds for star formation*, Monthly Notices of the Royal Astronomical Society, **429**, 987-1000, (2013)
- Hezaveh, Y., Dalal, N., Holder, G., Kuhlen, M., Marrone, D., Murray, N., & Vieira, J. *Dark Matter Substructure Detection Using Spatially Resolved Spectroscopy of Lensed Dusty Galaxies*, The Astrophysical Journal, **767**, 9 (2013)
- 90 Hopkins, P. F., Cox, T. J., Hernquist, L., Narayanan, D., Hayward, C. C., & Murray, N. *Star formation in galaxy mergers with realistic*

- models of stellar feedback and the interstellar medium*, Monthly Notices of the Royal Astronomical Society, **430**, 1901-1927, (2013)
- Martin, C. L., Shapley, A. E., Coil, A. L., Kornei, K. A., Murray, N., & Pancoast, A. *Scattered Emission from $z \sim 1$ Galactic Outflows*, The Astrophysical Journal, **770**, 41 (2013)
- Hopkins, P. F., Kereš, D., & Murray, N. *Accretion does not drive the turbulence in galactic discs*, Monthly Notices of the Royal Astronomical Society, **432**, 2639-2646, (2013)
- Hopkins, P. F., Narayanan, D., & Murray, N. *The meaning and consequences of star formation criteria in galaxy models with resolved stellar feedback*, Monthly Notices of the Royal Astronomical Society, **432**, 2647-2653, (2013)
- Hopkins, P. F., Narayanan, D., Murray, N., & Quataert, E. *Dense molecular gas: a sensitive probe of stellar feedback models*, Monthly Notices of the Royal Astronomical Society, **433**, 69-77, (2013)
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- Davis, S. W., Jiang, Y.-F., Stone, J. M., & Murray, N. *Radiation Feedback in ULIRGs: Are Photons Movers and Shakers?*, The Astrophysical Journal, **796**, 107 (2014)
- Prodan, S., & Murray, N. *On the Dynamics of Ultra Compact X-Ray Binaries: 4U 1850-087, 4U 0513-40, and M15 X-2*, The Astrophysical Journal, **798**, 117 (2015)
- Lee, E. J., Chang, P., & Murray, N. *Time-varying Dynamical Star Formation Rate*, The Astrophysical Journal, **800**, 49 (2015)
- Lecante, J., Wu, H., Menou, K., & Murray, N. *Asynchronous rotation of Earth-mass planets in the habitable zone of lower-mass stars*, Science, **347**, 632-635, (2015)
- Hansen, B. M. S., & Murray, N. *Secular effects of tidal damping in compact planetary systems*, Monthly Notices of the Royal Astronomical Society, **448**, 1044-1059, (2015)
- Thompson, T. A., Fabian, A. C., Quataert, E., & Murray, N. *Dynamics of dusty radiation-pressure-driven shells and clouds: fast outflows from galaxies, star clusters, massive stars, and AGN*, Monthly Notices of the Royal Astronomical Society, **449**, 147-161, (2015)
- 110 Faucher-Giguère, C.-A., Hopkins, P. F., Kereš, D., Muratov, A. L., Quataert, E., & Murray, N. *Neutral hydrogen in galaxy haloes at the peak of the cosmic star formation history*, Monthly Notices of the Royal Astronomical Society, **449**, 987-1003, (2015)
- Murray, N., & Chang, P. *Star Formation in Self-gravitating Turbulent Fluids*, The Astrophysical Journal, **804**, 44 (2015)

8. Non-Refereed Publications, Book Reviews and Invited Reviews

N. Murray, in *The Physics of Cataclysmic Variables and Related Objects*, eds. B.T. Gansicke, K. Beuermann, K. Reinsch, ASP Conf. Ser. **261** p 308, (2002), (San Francisco: Astronomical Society of the Pacific), Disk outflows; radiation or hydromagnetic driving? (text of invited talk)

N. Murray and J. Chiang, in *Mass Ejection from AGN*, eds. N. Arav,

- I. Shlosman, and R. Weymann, ASP Conf. Ser. **128** 246 (1997), (San Francisco: Astronomical Society of the Pacific), Photoionized Disk Winds (text of invited talk)
- J. Chiang, and N. Murray, in *Mass Ejection from AGN*, eds. N. Arav, I. Shlosman, and R. Weymann, ASP Conf. Ser. **128** 253 (1997) (San Francisco: Astronomical Society of the Pacific), Outflows; Line Driven or Magnetically Driven? (text of invited talk)
- N. Murray and J. Chiang, in *Emission Lines in Active Galaxies: New Methods and Techniques*, eds. B.M. Peterson, F. Z. Cheng, and A.S. Wilson, IAU Colloq. 159 (ASP Conf. Ser. **113**, p220 (1997) (San Francisco: Astronomical Society of the Pacific), Disk Emission Lines (text of invited talk)
- N. Murray, in *GONG 1992: Seismic Investigation of the Sun and Stars*, T. Brown ed., ASP Conf. Ser. **42**, 3 (1993), The Excitation of Solar p-modes (text of invited talk)
- N. W. Murray and M. A. Lieberman, in *Advanced Accelerator Concepts*, F.E. Mills, ed., AIP Conference Proceedings #156 p345 (1986), Stochasticity and Resonances in the Two Beam Accelerator
11. Invited Lectures (last five years)
- | | | |
|--------------------------|--------|-------------------------------------|
| Perimeter Institute | Mar 15 | Looking for non-dark matter |
| KwaZulu-Natal | Jan 15 | Cosmology & Galaxy Formation |
| Aspen Center for Physics | Aug 14 | Line driven winds |
| Colorado | Jul 14 | Cosmology & Galaxy Formation |
| CASCA | May 14 | Rapid Star Formation |
| KITP | May 14 | Galaxy Formation |
| KITP | Apr 14 | Star formation in turbulent fluids |
| Simons Symposium | Mar 14 | Galaxy Formation |
| Atlantic Physics Conf. | Feb 14 | Galaxy Formation |
| Obs. Carnegie Inst. | Jan 14 | Emergence in Astronomy |
| Harvard | Oct 13 | Dynamical Star Formation |
| Cambridge | Jul 13 | Star Formation in Mergers |
| Aspen | Jun 13 | Driving Winds in Dense Environments |
| Munich | Jun 13 | Driving Winds in Dense Environments |
| CASCA | May 13 | Rapid Star Formation |

McGill	Apr 13	The Cerro Chajnantor Atacam Telescope
Carnegie	Mar 13	Rapid Star Formation
Univ. of Arizona	Jan 13	Galaxy Formation
Univ. of Victoria	Nov 12	Galaxy Formation
HIA	Nov 12	Rapid Star formation
Johns Hopkins	Nov 12	Rapid Star formation
Northwestern	Nov 12	Feedback and Galaxy Formation
Hebrew Univ.	Oct 12	Rapid Feedback
New York University	Sep 12	Feedback and Star Formation
IAU 292 Beijing	Aug 12	Feedback and Galaxy Formation
Sesto, Italy	Jul 12	Winds and Galaxy Formation
The Baryon Cycle, UC Irvine	Jun 12	Winds and Galaxy Formation
Technion, Israel	May 12	Quasar Broad Absorption Lines
UCLA	May 12	Feedback and Galaxy Formation
Space Telescope	May 12	Physics of Out flows
CIFAR	Mar 12	Feedback in Galaxy Formation
UBC	Mar 12	Feedback in Galaxy Formation
ALMA/NRAO	Mar 12	Galaxy Scale Winds
Chicago	Oct 11	Star Formation in the Milky Way
Illinois	Oct 11	Star Formation in the Milky Way
UC Santa Cruz	Aug 11	Galaxy Formation
Harvard	Jul 11	Star Formation
Ringberg/DLAs	Jul 11	Stellar Feedback
Ringberg/Max Planck	Jul 11	Star formation and Feedback
Gas in Galaxies	Jul 11	Radiation Pressure
Ohio State	Jan 11	Star Formation in the Milky Way
UCSB	Oct 10	Radiation Pressure Launches Cluster Winds
5th Zermatt ISM Symposium	Sep 10	Radiative Feedback
Physics of the ICM	Aug 10	Stellar Feedback and Galaxy Formation
COSPAR	Jul 10	Starburst and AGN Fueling
Central Massive Objects (ESO)	Jun 10	AGN fueling
Galaxies in Absorption	May 10	Physics of Galactic Out flows
Galaxies in the Distant Univ.	May 10	Galactic Feedback
From Stars to Galaxies	Apr 10	Rapid Star Formation in the Milky Way
Berkeley	Mar 10	Rapid Star Formation in the Milky Way
Harvard	Feb 10	Stellar Feedback and Galaxy Formation
Harvard	Feb 10	Dynamics of LMXBs in triple systems

E. Administrative Positions

13a. Outside University

Aspen Center for Physics General Member 2013-2018
Long Range Plan Implementation Committee, CASCA 2013-present
Canadian Atacama Telescope Consortium Board of Directors, Vice-Chair, 2012-present
CCAT Board of Directors, Vice-Chair 2014-present
CCAT Board of Directors 2011-present
Guelph-Waterloo Phys. Dept. Review 2013
UC Berkeley Astronomy Dept. Review 2008
NSF Midterm Review 2005
Ohio State Astronomy Dept. External Review, 2005

Reviewer for:

NSERC Canada Grant Selection Committee 17
Astrophysical Journal
Astronomical Journal
Nature
Science