

MICHAEL C. LIU

Institute for Astronomy
2680 Woodlawn Drive
University of Hawai'i
Honolulu, HI 96822

Phone: (808) 956-6666
Fax: (808) 956-9580
Email: mliu@ifa.hawaii.edu
<http://www.ifa.hawaii.edu/~mliu>

Personal Information

Citizenship: United States

Education

University of California, Berkeley Ph.D. Physics, 2000 (advisor: James R. Graham)
University of California, Berkeley M.A. Physics, 1993
Cornell University B.A. Physics, *summa cum laude*, 1992

Research Interests

Star and planet formation
Extrasolar planets
Brown dwarfs
Adaptive optics
Infrared astronomy and instrumentation

Employment History

Associate Astronomer (w/tenure), Institute for Astronomy, University of Hawai'i, 2007 –
Assistant Astronomer (tenure-track), Institute for Astronomy, University of Hawai'i, 2003 – 2007
Hubble Postdoctoral Fellow, Institute for Astronomy, University of Hawai'i, 2003
Beatrice Watson Parrent Fellow, Institute for Astronomy, University of Hawai'i, 2000 – 2003
Research Assistant, Department of Astronomy, UC Berkeley, 1993 – 2000

Honors and Awards

Regents' Medal for Excellence in Research, University of Hawaii, 2007
Gemini-South NICI Planet-Finding Campaign, PI, 2006–present
Alfred P. Sloan Research Fellow, 2005–2007
Invited plenary lecture, American Astronomical Society, 2004
 ("Formation and Early Evolution of Substellar Objects")
Hubble Postdoctoral Fellowship, 2003
Beatrice Watson Parrent Fellow, Institute for Astronomy, Univ. of Hawai'i, 2000–2003
Uhl Prize for Excellence in Dissertation Research, Dept of Astronomy, UC Berkeley, 1999
National Science Foundation Graduate Fellowship, 1992–1995
Kieval Prize (top graduating physics undergraduate), Cornell University, 1992
Dr. Robert H. Goddard Scholarship, National Space Club, 1992
Merrill Presidential Scholar, Cornell University Class of 1992
Phi Beta Kappa

Research Grants

- 2009 – "Ultracool Astrophysics with Brown Dwarf Binaries", NSF (PI)
 2009 – "A Galex Search for the Missing Young Low-Mass Stars Within 100 pc", Galex Cycle 5 (PI)
 2008 – "Debris Disks around Young M Dwarfs," Spitzer Cycle 5 (PI)
 2007 – 2008 "Identifying the Missing Young Low-Mass Stars," Galex Cycle 3 (co-I)
 2007 – "The Pan-STARRS Brown Dwarf Factory," NSF (co-I)
 2007 – "The Gemini NICI Planet-Finding Campaign," NSF (PI)
 2007 – "Resolving Ultracool Astrophysics with Brown Dwarf Binaries," HST Cycle 16 (PI)
 2007 – 2010 "A Wide-Field, Low-Mass Census of the Nearest Star-Forming Region," Spitzer Cycle 4 (PI)
 2007 – 2008 "SGER: Starting the NICI Planet-Finding Campaign," NSF (PI)
 2006 – 2008 "Debris Disks Around Young M Dwarfs," HST Cycle 15 (PI)
 2005 – 2007 Alfred P. Sloan Research Fellowship
 2005 – 2010 "Formation and Physical Properties of Substellar Objects," NSF (PI)
 2005 – 2008 "A Search for Debris Disks in the Beta Pictoris Moving Group," HST Cycle 14 (co-I)
 2004 – 2009 "New Windows Into the Substellar Mass Function," NSF (PI)
 2003 – 2005 "NICMOS Confirmation of a Young Planetary-Mass Companion," HST Cycle 12 (PI)
 2002 – 2003 "A Search for Young Jovian-Mass Planets," Hubble Postdoctoral Fellowship
 2002 – 2003 "Chandra Observations of a Protocluster at $z = 1.31$," Chandra Cycle 4 (PI)
 1999 – 2001 "WFPC2 Imaging of a Galaxy at $z=5.34$ and Its Field," HST Cycle 8 (co-I)
 1998 – 1999 "Weighing the Stellar Halo of NGC 5907 With NICMOS," HST Cycle 7, (co-I)
 1998 – 1999 "IR Luminous Stars & Stellar Populations in Nearby Giant Ellipticals," HST Cycle 7 (co-I)
 1998 – 2000 "IR Surface Brightness Fluctuations of Fornax Cluster Galaxies," HST Cycle 7 (co-I)
 1997 – 2000 "Extragalactic Distances Using IR Surface Brightness Fluctuations," NSF (co-I)

Professional Service

University of Hawaii, Institute for Astronomy Director Search Advisory Committee, 2010
 Thirty-Meter Telescope, IRIS (InfraRed Imaging Spectrograph), science team, 2010 – present
 IfA/UH Telescope Time Allocation Committee, chair, 2008 – present
Hubble Space Telescope, Cycle 16 review panel, 2007
 Gemini Observatory, US Science Advisory Committee, 2006 – present
 Gemini Observatory, Gemini Science Committee, 2006
 ASIAA, optical/IR review panel, Taiwan, 2006
 Keck Observatory, Science Steering Committee, 2006 – present
 Keck Observatory, Next-Generation Adaptive Optics Science Case, Co-Chair, 2006
 NASA Keck Time Allocation Committee, 2006 – 2007
 AURA Giant Segmented Mirror Telescope, Science Working Group, 2005 – present
 Keck Observatory, Adaptive Optics Working Group, 2002 – 2005; Co-Chair 2005 – present
 Thirty-Meter Telescope Mid-IR Echelle Spectrograph (MIREs), IfA/NOAO Science Team, 2005
 Gemini Observatory Precision Radial Velocity Spectrograph, IfA/UK ATC Science Team, 2005 – 2008
 Keck OSIRIS (OH-Suppressing Infra-Red Imaging Spectrograph) pre-ship review panel, 2004
Spitzer Space Telescope Cycle 1 science review panel, 2004
 NASA Origins/TPF Detection of Extrasolar Planets panel, 2003
 External reviewer for NSF, NASA, and PPARC
 Referee for *Nature*, *Science*, *Astrophysical Journal*, and *Astronomy & Astrophysics*

Observing Expertise

Optical and infrared imaging and spectroscopy (numerous telescopes)
Infrared adaptive optics (Keck, Subaru, Gemini, Lick, and CFHT Telescopes)

Advising Experience

Postdoc advisor, IfA/Hawaii:

Katelyn Allers (2006–2009; now Asst Prof at Bucknell University)
Zahed Wahhaj (2006–present)
Evgenya Shkolnik (NRC Fellow, 2006–2008; now Carnegie Fellow at DTM/CIW)
Beth Biller (Hubble Fellow, 2007–2010; now postdoc at Max Planck Institute for Astronomy)
John Johnson (NSF Fellow, 2007–2009; now Asst Prof at Caltech)
Lucas Cieza (Spitzer Fellow, 2007–2010; now Sagan Fellow at IfA/Hawaii)
Adam Kraus (Hubble Fellow, 2009–present)
Niall Deacon (2009–present)

PhD thesis advisor, IfA/Hawaii:

Trent Dupuy (2005–2010; now Hubble Fellow at Harvard/CfA)
Brendan Bowler (2008–present)

Supervised graduate (Master's) research, IfA/Hawaii:

Mark Willman (2003–2004)
Mark Pitts (2004–2005)
Dagny Looper (2005–2006)
Geoff Mathews (2007–2008)
Kimberly Aller (2010–present)

Supervised post-graduate research, IfA/Hawaii:

Jonathan Leong (Caltech; 2001–2002)
Brandon Swift (UC Berkeley; 2005–2006)
William Best (Haverford College/Punahou School, 2010)

Research mentor for IfA/Hawai'i NSF REU program:

Meghan McGarry (UC Berkeley; 2001)
James Wray (Princeton; 2005)

Supervised undergraduate research at UC Berkeley, 1999–2000:

Melissa Enoch (UC Berkeley)
Kevin Bundy (UC Berkeley)
Genevieve Graves (Harvard)

A. Refereed Publications

- A75. "Near-Infrared Spectroscopy of the Extrasolar Planet HR 8799 b." Bowler, B., Liu, M., Dupuy, T., & Cushing, M. 2010, *Astrophysical Journal*, in press (accepted Aug 2010)
- A74. "The Gemini NICI Planet-Finding Campaign: Discovery of a Close Substellar Companion to the Nearby Young Solar Analog PZ Tel." Biller, B., Liu, M., Wahhaj, Z., Nielsen, E., Close, L., Dupuy, T., Hayward, T., Burrows, A., et al. (27 total authors), *Astrophysical Journal Letters*, 720, 82
- A73. "A Spitzer Search for Planetary-Mass Brown Dwarfs with Circumstellar Disks: Candidate Selection." Harvey, P. M., Jaffe, D. T., Allers, K., Liu, M. 2010, *Astrophysical Journal*, 720, 1374
- A72. "On the Distribution of Orbital Eccentricities for Very Low-Mass Binaries." Dupuy, T. & Liu, M. 2010, *Astrophysical Journal*, revised July 2010
- A71. "Studying the Physical Diversity of Late-M Dwarfs with Dynamical Masses." Dupuy, T., Liu, M., Bowler, B., Cushing, M., Helling, C., Witte, S., & Hauschildt, P. 2010, *Astrophysical Journal*, in press (accepted July 2010)
- A70. "Hawaii Quasar and T-Dwarf (HQT) Survey I. Method and Discovery of Faint Field Ultracool Dwarfs." Kakazu, Y., Hu, E., Liu, M. C., Wang, W.-H., Wainscoat, R. J., & Capak, P. L. 2010 *Astrophysical Journal*, in press (accepted March 2010)
- A69. "SDSS J141624.08+134826.7: A Nearby Blue L Dwarf From the Sloan Digital Sky Survey." Bowler, B. P., Liu, M. C., & Dupuy, T. J. 2010, *Astrophysical Journal*, 710, 45
- A68. "Discovery of a Highly Unequal-Mass Binary T Dwarf with Keck Laser Guide Star Adaptive Optics: A Coevolution Test of Substellar Theoretical Models and Effective Temperatures." Liu, M. C., Leggett, S. K. & Dupuy, T. J. 2010, *Astrophysical Journal*, 722, 311
- A67. "Retired A Stars and Their Companions. III. Comparing the Mass-Period Distributions of Planets Around A-Type Stars and Sun-Like Stars." Bowler, B. P., Johnson, J. A., Marcy, G. W., Henry, G. W. et al. (11 total authors) 2010, *Astrophysical Journal*, 709, 396
- A66. "Thirty New Low-Mass Spectroscopic Binaries." E. Shkolnik, L. Hebb, M. C. Liu, I. N. Reid, & A. C. C. Cameron, *Astrophysical Journal*, 716, 1522
- A65. "Discovery of a Young L-Dwarf Binary, SDSS J2249+0044AB." Allers, K. N, Liu, M. C., Dupuy, T. J. & Cushing, M. C. 2010, *Astrophysical Journal*, 715, 561
- A64. "The Benchmark Ultracool Subdwarf HD 114762B: A Test of Low-metallicity Atmospheric and Evolutionary Models." Bowler, B., Liu, M. & Cushing, M. 2009, *Astrophysical Journal*, 706, 1114

- A63. “Dynamical Mass of the M8+M8 Binary 2MASS J2206–2047AB.”
Dupuy, T. J., Liu, M. C. & Bowler, B. P. 2009, *Astrophysical Journal*, 706, 328
- A62. “Detectability of Transiting Jupiters and Low-Mass Eclipsing Binaries in Multi-Epoch All-Sky Surveys.” Dupuy, T. J. & Liu, M. C. 2009, *Astrophysical Journal*, 704, 1519
- A61. “Keck Laser Guide Star Adaptive Optics Monitoring of the M8+L7 Binary LHS 2397aAB: First Dynamical Mass Benchmark at the L/T Transition.” Dupuy, T. J., Liu, M. C., & Ireland, M. J. 2009, *Astrophysical Journal*, 699, 168
- A60. “2MASS 2234+4041AB: A Wide, Accreting, Low-Mass Binary in the LkH α 233 Group.” Allers, K. N., Liu, M. C., et al. (9 total authors), *Astrophysical Journal*, 697, 824
- A59. “The Discovery of an M4+T8.5 binary system.”
Burningham, B., Pinfield, D. J., Leggett, S. K., Tinney, C. G., Liu, M. C. et al. (21 total authors) 2009, *MNRAS*, 395, 1237
- A58. “Identifying the Young Low-Mass Stars Within 25 pc.”
Shkolnik, E., Liu, M. C., & Reid, I. N. 2009, *Astrophysical Journal*, 699, 649
- A57. “The Dynamical Mass of the Substellar Benchmark Binary HD 130948BC.”
Dupuy, T. J., Liu, M. C., & Ireland, M. J. 2009, *Astrophysical Journal*, 692, 729
- A56. “The Circumstellar Environment of Young Low-Mass Object IRAS 04158+2805.”
Andrews, S. M., Liu, M. C., Williams, J. P. & Allers, K. N. 2008, *Astrophysical Journal*, 685, 1039
- A55. “Subtle Signatures of Multiplicity in Late-type Dwarf Spectra: The Unresolved M8.5 + T5 Binary 2MASS J03202839–0446358.” Burgasser, A. J, Liu, M. C., Ireland, M. J., Cruz, K. L. & Dupuy, T. J. 2008, *Astrophysical Journal*, 681, 579
- A54. “HN Peg B: A Test of Models of the L to T Dwarf Transition.”
Leggett, S. K. et al. (10 authors) 2008, *Astrophysical Journal*, 682, 1256
- A53. “CFBDS J005910.90–011401.3: Reaching the T-Y Brown Dwarf Transition?”
Delorme, P. et al. (12 authors) 2008, *A&A*, 482, 961
- A52 “Keck Laser Guide Star Adaptive Optics Monitoring of 2MASS J1534–2952AB: First Dynamical Mass Determination of a Binary T Dwarf.” Liu, M. C., Dupuy, T. J., & Ireland, M. J. et al. 2008, *Astrophysical Journal*, 689, 436
- A51. “BD –22° 5866: A Low-mass Quadruple-lined Spectroscopic *and* Eclipsing Binary,”
Shkolnik, E., Liu, M. C., Reid, I. N., Hebb, L., Cameron, A. C., Torres, C. A., and Wilson, D. N. 2008, *Astrophysical Journal*, 682, 1248
- A50. “Four T Dwarfs from the UKIRT Infrared Deep Sky Survey (UKIDSS) Southern Stripe.”
Chiu, K, Liu, M. et al. (11 authors) 2008, *MNRAS*, 385, 53
- A49. “L Dwarf Binaries in the 20-Parsec Sample.”
Reid, I. N., Cruz, K. L., Burgasser, A. J., & Liu, M. C. 2008, *Astronomical Journal*, 135, 580

- A48. “A Very Cool Brown Dwarfs in UKIDSS Data Release 1.”
Warren, S. et al. (18 authors) 2007, *MNRAS*, 381, 1400
- A47. “Physical and Spectral Characteristics of the T8 and Later-Type Dwarfs.”
Leggett, S., Marley, M., Freedman, R., Saumon, D., Liu, M., Geballe, T., Golimowski, D., & Stephens, D. 2007, *Astrophysical Journal*, 667, 537
- A46. “Eight New Late-T Dwarfs Discovered by the UKIDSS Large Area Survey Data Release 1.” Lodieu, N. et al. (36 authors) 2007, *MNRAS*, 379, 1423
- A45. “The Late T-Dwarf Companion to the Exoplanet Host Star HD 3651: A New Benchmark for Gravity and Metallicity Effects in Ultracool Spectra.” Liu, M., Leggett, S. & Chiu, K. 2007, *Astrophysical Journal*, 660, 1507
- A44. “Near-IR Spectroscopy of Young Brown Dwarfs with Disks.”
Allers, K., Jaffe, D., Luhman, K., Liu, M., et al. (10 authors) 2007, *Astrophysical Journal*, 657, 511
- A43. “Discovery of the High Proper Motion L Dwarf Binary 2MASS 15200224–4422419AB.”
Burgasser, A.,Looper, D. L., Kirkpatrick, J. D., & Liu, M. 2007, *Astronomical Journal*, 658, 557
- A42. “S-COSMOS: The Spitzer Legacy Survey of the HST-ACS 2-Square Degree COSMOS Field. I: Survey Design and Scientific Goals.” Sanders, D. B. et al. 2007, *Astrophysical Journal Supplement Series*, 172, 86
- A41. “A Re-Appraisal of the Habitability of Planets Around M Dwarf Stars.”
Tarter, J. et al. (35 authors) 2007, *Astrobiology*, 7, 30
- A40. “CLOUDS Search for Variability in Brown Dwarf Atmospheres. I. Infrared Spectroscopic Time Series of L/T Transition Brown Dwarfs.” Goldman, B. and the CLOUDS collaboration 2008, *Astronomy & Astrophysics*, 487, 272
- A39. “SDSS 1534+1615AB: A Novel T Dwarf Binary Found with Laser Guide Star Adaptive Optics and the Potential Role of Binarity in the L/T Transition.” Liu, M., Leggett, S., Golimowski, D., Chiu, K., Fan, X., Geballe, T., Schneider, D., & Brinkmann, J. 2006, *Astrophysical Journal*, 647, 1393
- A38. “Kelu-1 is a Binary L Dwarf: First Brown Dwarf Science from Laser Guide Star Adaptive Optics.” Liu, M. & Leggett, S. 2005, *Astrophysical Journal*, 634, 616
- A37. “New Near-Infrared Surface Brightness Fluctuation Models.”
Mouhcine, M., Gonzalez, R. A., & Liu, M. 2005, *MNRAS*, 362, 1208
- A36. “Morphologies in a Cluster of Extremely Red Galaxies with Old Stellar Populations at $z=1.34$.” Fu, H., Stockton, A., & Liu, M. 2005, *Astrophysical Journal*, 632, 831
- A35. “Near-IR Surface Brightness Fluctuations and Optical Colours of Magellanic Star Clusters.” Gonzalez, R. A., Albarran, M. Y., Mouhcine, M., Liu, M. C., Bruzual, G., & Batz, B. 2005, *MNRAS*, 363, 1279

- A34. "Substructure in the Circumstellar Disk around the Young Star AU Mic (GJ 803)."
Liu, M. C. 2004, *Science*, 305, 1442
- A33. "A Sub-Millimeter Survey of Nearby Young Stars for Cold Dust: Discovery of Debris Disks Around Two Low-Mass Stars." Liu, M. C., Matthews, B. C., Williams, J. P. & Kalas, P. G. 2004 *Astrophysical Journal*, 608, 526
- A32. "IR Surface Brightness Fluctuations of Magellanic Globular Clusters."
González, R. A., Liu, M. C., & Bruzual, G. 2004, *Astrophysical Journal*, 611, 270
- A31. "Discovery of a Large Dust Disk Around AU Microscopium."
Kalas, P., Liu, M. C., & Matthews, B. C. 2004, *Science*, 303, 1990
- A30. "23 High Redshift Supernovae from the IfA Deep Survey: Doubling the SN Sample at $z > 0.7$." Barris, B. J. et al. (31 authors) 2004, *Astrophysical Journal*, 602, 571
- A29. "Detection of Cool Dust around the G2V Star HD 107146."
Williams, J. P., Najita, J., Liu, M. C., Bottinelli, S., Carpenter, J. M., Hillenbrand, L. A., & Meyer, M. 2004, *Astrophysical Journal*, 585, 372
- A28. "A Giant Outburst at Millimeter Wavelengths in the Orion Nebula."
Bower, G. C., Plambeck, R. L., Bolatto, A., McCrady, N., Graham, J. R., de Pater, I., Liu, M. C., & Baganoff, F. K. 2003, *Astrophysical Journal*, 598, 1140
- A27. "Optical and Near-Infrared Spectroscopy of a High-Redshift Hard X-ray Emitting Spiral Galaxy." S. Dawson, N. McCrady, D. Stern, M. Eckart, H. Spinrad, M. C. Liu & J. R. Graham 2003, *Astrophysical Journal*, 125, 1236
- A26. "A Survey for Circumstellar Disks around Young Substellar Objects."
Liu, M. C., Najita, J., & Tokunaga, A. T. 2003, *Astrophysical Journal*, 585, 372
- A25. "Measuring Distances and Probing Unresolved Stellar Populations of Galaxies Using IR Surface Brightness Fluctuations." Jensen, J. B., Tonry, J. T., Barris, B. J., Thompson, R. I., Liu, M. C., Rieke, M. J., Ajhar, E. A., & Blakeslee, J. P. 2003, *Astrophysical Journal*, 583, 712
- A24. "Discovery of a Methane Dwarf from the IfA-Deep Survey."
Liu, M. C., Wainscoat, R., Martín, E., Barris, B., & Tonry, J. 2002, *Astrophysical Journal Letters*, 568, L107
- A23. "Crossing the Brown Dwarf Desert Using Adaptive Optics: A Very Close L-Dwarf Companion to the Nearby Solar Analog HR 7672." Liu, M. C., Fischer, D., Graham, J. R., Lloyd, J. P., Marcy, G. W., & Butler, P. et al. 2002, *Astrophysical Journal*, 571, 519
- A22. "A Search for Stellar Companions to Stars with Planets."
Patience, J., McCabe, C., White, R., Ghez, A. M., Lloyd, J. P., Liu, M. C., Graham, J. R., et al. 2002, *Astrophysical Journal*, 581, 654

- A21. "Infrared Surface Brightness Fluctuations of the Coma Elliptical NGC 4874 and the Value of the Hubble Constant." Liu, M. C., & Graham, J. R. 2001, *Astrophysical Journal Letters*, 557, L31
- A20. "Surface Brightness Fluctuations of Fornax Cluster Galaxies: Calibration of Infrared SBFs and Evidence for Recent Star Formation." Liu, M. C., Graham, J. R., & Charlot, S. 2002, *Astrophysical Journal*, 564, 216
- A19. "Two Substellar Companions Orbiting HD 168443." Marcy, G. W., Butler, B. P., Vogt, S. S., Liu, M. C., Laughlin, G., Apps, K., Graham, J. R., Lloyd, J. P., Luhman, K. L., & Jayawardhana, R. 2001 *Astrophysical Journal*, 555, 418
- A18. "The Infrared Surface Brightness Fluctuation Hubble Constant." Jensen, J. B., Tonry, J. L., Thompson, R. I., Ajhar, E. A., Lauer, T. R., Rieke, M. J., Postman, M., & Liu, M. C. 2001, *Astrophysical Journal*, 550, 503
- A17. "A Candidate Submillimeter-Selected Proto-Cluster." Ivison, R. J., Dunlop, J. S., Smail, I., Dey, A., Liu, M. C. & Graham J. R. 2000, *Astrophysical Journal*, 542, 27
- A16. "Three High-Redshift Millimeter Sources and Their Radio and Near-IR Identifications." Bertoldi, F., Carilli, C., Menten, K., Owen, F., Dey, A., Graham, J. R., Gueth, F., Kreysa, E., Liu, M. C., Motte, F., Schilke, P. & Zylka, R. 2000, *Astronomy & Astrophysics*, 360, 92
- A15. "Theoretical Predictions for Surface Brightness Fluctuations and Implications for Stellar Populations of Elliptical Galaxies." Liu, M. C., Charlot, S., & Graham, J. R. 2000, *Astrophysical Journal*, 543, 644
- A14. "The Nature of the Halo Population of NGC 5128 Resolved with NICMOS on the Hubble Space Telescope." Marleau, F. R., Graham, J. R., Liu, M. C., & Charlot, S. 2000, *Astronomical Journal*, 120, 1779
- A13. "Extremely Red Objects in the Field of QSO 1213–0017: A Galaxy Concentration at $z=1.31$." Liu, M. C, Dey, A., Graham, J. R., Bundy, K. A., Steidel, C. C., Adelberger, K. L., & Dickinson, M. E. 2000, *Astronomical Journal*, 119, 2556
- A12. "Tests of the Accelerating Universe with Near-Infrared Observations of a High-Redshift Type Ia Supernova." Riess, A. G., Filippenko, A. V., Liu, M. C., Challis, P., Clocchiatti, A., Diercks, A. et al. (28 authors) 2000, *Astrophysical Journal*, 536, 62
- A11. "The Stellar Content of the Halo of NGC 5907 from Deep NICMOS Imaging." Zepf, S., Liu, M. C., Marleau, F. R., Sackett, P. & Graham, J. R. 2000, *Astronomical Journal*, 119, 1701
- A10. "The New Complex Gravitational Lens System HE 0230–2130." Wisotzki, L., Christlieb, N., Liu, M. C., Maza, J., Morgan, N. D., & Schechter, P. L. 1999, *Astronomy & Astrophysics*, 348, 41

- A9. "Observations of a $z = 1.44$ Dusty, Ultraluminous Galaxy and Implications for Deep Sub-mm Surveys." Dey, A., Graham, J. R., Ivison, R. J., Smail, I., Wright, G. S., & Liu, M. 1999, *Astrophysical Journal*, 519, 610
- A8. "Two New Planets in Eccentric Orbits." Marcy, G. W., Butler, R. P., Vogt, S. S., Fischer, D. & Liu, M. C. 1999, *Astrophysical Journal*, 520, 239
- A7. "Keck Infrared Observations of Jupiter's Ring System Near Earth's 1997 Ring Plane Crossing." de Pater, I., Showalter, M. R., Burns, J. A., Nicholson, P. D., Liu, M. C., Hamilton, D. P. & Graham, J. R. 1999, *Icarus*, 138, 214
- A6. "Image Improvement from a Sodium-Layer Laser Guide Star Adaptive Optics System." Max, C. E. et al. (16 authors) 1997, *Science*, 277, 1649
- A5. "Investigation of Crater 'Saturation' Using Spatial Statistics." Squyres, S., Howell, C., Liu, M. C., & Lissauer, J. J. 1997, *Icarus*, 125, 67
- A4. "IRAS FSC 15307+3252: Gravitationally-Lensed Seyfert or Cannibal Elliptical at $z = 0.93$?" Liu, M. C., Graham, J. R., & Wright, G. S. 1996, *Astrophysical Journal*, 470, 771
- A3. "Mid-Infrared Imaging of Young Stellar Objects." Liu, M. C., Graham, J. R., Ghez, A. M., Meixner, M., Skinner, C. J., Keto, E., Ball, R., Arens, J. F., & Jernigan, J. G. 1996, *Astrophysical Journal*, 461, 334
- A2. "High Resolution Near-Infrared Imaging of FSC 10214+4724: Evidence for Gravitational Lensing." Graham, J. R. & Liu, M. C. 1995, *Astrophysical Journal*, 449, L29
- A1. "W.M. Keck Telescope Observations of the Comet Shoemaker-Levy Fragment R Impact with Jupiter." Graham, J. R., de Pater, I., Jernigan, J. G., Liu, M. C., & Brown, M. E. 1995, *Science*, 267, 1320

B. Conference Proceedings and White Papers

- B37. "The Gemini NICI Planet-Finding Campaign." M. Liu et al. (24 authors) 2010, *Proceedings of the SPIE: Advances in Adaptive Optics* (San Diego, CA), in press
- B36. "Testing Substellar Models with Dynamical Mass Measurements." Dupuy, T., Liu, M. & Ireland, M. 2009, *Proceedings of "New Technologies for Probing the Diversity of Brown Dwarfs and Exoplanets"*, in press
- B35. "The Pan-STARRS 3II Survey and the Brown Dwarf Factory." Magnier, E. A., Liu, M. C., Goldman, B., Monet, D. G., Chambers, K. C., & Kaiser, N., in *The Galactic Plane in Depth and Across the Spectrum*", XXVIth IAU General Assembly Conf Proc (Aug 2009), in press
- B34. "Testing Models with Brown Dwarf Binaries." Dupuy, T. & Liu, M., *Proceedings of IAU 2009 Session S7: "Young Stars, Brown Dwarfs, and Protoplanetary Disks"* (Aug 2009), in press

- B33. "Direct Detection and Spectroscopic Characterization of Extrasolar Planets." Macintosh, B. et al. (10 authors) 2009, white paper submitted to the Astro2010 Decadal Survey
- B32. "The Formation and Architecture of Young Planetary Systems." Kraus, A. et al. (8 authors) 2009, white paper submitted to the Astro2010 Decadal Survey
- B31. "Confronting Substellar Theoretical Models with Stellar Ages." Dupuy, T., Liu, M., & Ireland, M. 2009, *Proceedings of IAU Symposium 258: The Ages of Stars* (ed. E. Mamajek, D. Soderbolm, & R. Wyse), ASP Conf Series, 258, 337
- B30. "Observing Strategies for the NICI Campaign to Directly Image Extrasolar Planets." Biller, B. et al. (10 authors) 2009, *Proceedings of the 15th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun* (ed. E. Stempels), AIP Conference Series, 1094, 425
- B29. "Precision radial velocity spectrograph." Jones, H. et al. (14 authors) 2008, *Proceedings of the SPIE: Ground-based and Airborne Instrumentation for Astronomy* (ed. I. McLean & M. Casali), 7014, 31
- B28. "The Gemini NICI Planet-Finding Campaign." Liu, M. et al. (12 authors) 2008, *Proceedings of the 15th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun* (ed. E. Stempels), AIP Conference Series, 1094, 461
- B27. "Fundamental Properties of Low-Mass Stars and Brown Dwarfs." Liu, M. et al. (10 authors) 2008, *Proceedings of the 15th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun* (ed. E. Stempels), AIP Conference Series, 1094, 258
- B26. "LGS AO Science Impact: Present and Future Prospects." Liu, M. 2008, *Proceedings of the SPIE* (Marseilles), 7015, 3
- B25. "Performance of the Near-Infrared Coronagraphic Imager on Gemini-South." Chun, M. et al. (10 authors) 2008, *Proceedings of the SPIE* (Marseilles), 7015, 49
- B24. "Suppressing Speckle Noise and Retrieving Faint Companions: Data Analysis Techniques for the Near-Infrared Coronagraphic Imager." Biller, B. et al. (10 authors) 2008, *Proceedings of the SPIE* (Marseilles), 7015, 184
- B23. "NICI: Combining ADI, SDI, and Coronagraphy." Artigau, E. et al. (12 authors) 2008, *Proceedings of the SPIE* (Marseilles), 7014, 66
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- B13. "Disks Around Young Brown Dwarfs." Liu, M. C. 2002, in *Proceedings of IAU 211: Brown Dwarfs*, ed. E. Martín, in press
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- B10. "Subaru IR Spectroscopy of Candidate Young Brown Dwarfs and Planetary-Mass Objects in IC 348." Liu, M. C. 2001, in *The Future of Cool-Star Astrophysics: 12th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun*, eds. A. Brown, G. M. Harper & T. Ayers, 12, 141
- B9. "Discovery of a New Multiple Gravitationally Lensed QSO." Wisotzki, L., Christlieb, N., Liu, M. C., Maza, J., Morgan, N. D., & Schechter, P. L. 2001, in *Gravitational Lensing: Recent Progress and Future Goals*, eds. T. G. Brainerd & C. S. Kochanek (ASP Conf. Series), 237, 63
- B8. "Ages of Early-Type Galaxies from Infrared Surface Brightness Fluctuations." Jensen, J. B., Tonry, J. L., Barris, B. J., & Liu, M. C. 2001 in *Astrophysical Ages and Timescales*, eds. T. von Hippel, N. Manset & C. Simpson (ASP Conf. Series), in press

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- B6. “IRCAL — The Near-Infrared Camera for Adaptive Optics at Lick Observatory.”
Lloyd, J. P., Liu, M. C., Macintosh, B. A., Sevenson, S. A., Deich, W. T. S., & Graham, J. R. 2000, in *Astronomical Telescopes and Instrumentation 2000* (Proc. SPIE), 4008, 814
- B5. “Calibration of Near-IR Surface Brightness Fluctuations for Cosmological Distance Measurements.” Liu, M. C., Graham, J. R., & Charlot, S. 1999, in *Cosmic Flows: Towards an Understanding of Large-Scale Structure*, eds. S. Courteau, M. Strauss, & J. Willick (ASP Conf. Series, Vol. 201), 142
- B4. “Extremely Red Galaxies in the Field of QSO 1213–0017: A Galaxy Concentration at $z = 1.31$.” Liu, M. C., Dey, A., Graham, J. R., Steidel, C. C., & Adelberger, K. 1999, in *The Hy-Redshift Universe: Galaxy Formation and Evolution at High-Redshift*, eds. A. J. Bunker & W. J. M. van Breugel (ASP Conf. Series, Vol. 193), 344 (astro-ph/9910434)
- B3. “The Nature of the Red Giant Branch Population of NGC 5128 with NICMOS on the Hubble Space Telescope.” Marleau, F. R., Graham, J. R., Charlot, S. & Liu, M. 1999, in *Galaxy Dynamics: From the Early Universe to the Present*, eds. F. Combes, G. A. Mamon, & V. Charmandaris (ASP Conf. Series, Vol. 197), 265
- B2. “Stellar Populations of Elliptical Galaxies from Surface Brightness Fluctuations.”
Liu, M. C., Charlot, S., & Graham, J. R. 1999, in *Spectrophotometric Dating of Stars and Galaxies*, eds. I. Hubeny, S. Heap, & R. Cornett (ASP Conf. Series, Vol. 192), 311 (astro-ph/9905190)
- B1. “Weighing the Stellar Content of NGC 5907’s Dark Matter Halo.”
Liu, M. C., Marleau, F. R., Graham, J. R., Charlot, S., Sackett, P., & Zepf, S. 1999, in *Proceedings of the 19th Texas Symposium on Relativistic Astrophysics*, eds. J. Paul, T. Montmerle, & E. Aubourg (Paris, Dec 1998)

C. Invited Scientific Talks and Colloquia

- C40. Cool Stars 16, Ultracool Dwarf Sciences from Wide-field Multi-Epoch Surveys (Seattle, WA), Sept 2010
- C39. AAS Meeting, Science with Adaptive Optics, May 2009
- C38. Subaru Observatory Conference, Exoplanets and Disks: Their Formation and Diversity (Kona, HI), March 2009
- C37. SPIE Meeting, Advances in Adaptive Optics (Marseilles), June 2008
- C36. AAS Meeting, Cool Brown Dwarfs and Hot Exoplanets, May 2007
- C35. AAS Meeting, Science from Wide-Field Surveys, May 2007

- C34. Harvard-Smithsonian Center for Astrophysics, April 2007
- C33. Caltech, April 2007
- C32. Cool Stars 14, Disks around Brown Dwarfs and Cool Stars, Nov 2006
- C31. American Museum of Natural History (New York, NY), July 2006
- C30. University of Florida, May 2006
- C29. National Central University (Taoyuan, Taiwan), August 2005
- C28. Academia Sinica Institute of Astronomy and Astrophysics (Taipei, Taiwan), August 2005
- C27. National Astronomical Observatory of Japan (Tokyo, Japan) August 2005
- C26. Institute of Space and Astronomical Science (Sagamihara, Japan), August 2005
- C25. University of Colorado, Boulder, February 2005
- C24. Space Telescope Science Institute (Baltimore, MD), October 2004
- C23. Carnegie Institution, Dept of Terrestrial Magnetism (Washington, DC), October 2004
- C22. University of California, Los Angeles, March 2004
- C21. American Astronomical Society Meeting (Atlanta, GA), January 2004
- C20. *Facing the Future: Formation and Evolution of Planets* (Austin, TX), October 2003
- C19. European Southern Observatory Headquarters (Garching, Germany), October 2003
- C18. *Stellar Populations 2003* (Garching, Germany), October 2003
- C17. University of California, Santa Cruz, May 2003
- C16. Cornell University (Ithaca, NY), April 2003
- C15. Lawrence Livermore National Lab (Livermore, CA), April 2003
- C14. University of California, Berkeley, April 2003
- C13. Hubble Fellows Symposium (Baltimore, MD), March 2003
- C12. Carnegie Institution, Dept of Terrestrial Magnetism (Washington, DC), March 2003
- C11. University of California, Santa Barbara, February 2003
- C10. Universidad de Chile (Santiago, Chile), January 2003
- C9. Infrared Processing and Analysis Center (IPAC; Pasadena, CA), November 2002
- C8. Cerro Tololo Interamerican Observatory (La Serena, Chile), July 2002
- C7. Academia Sinica Institute of Astronomy and Astrophysics (Taipei, Taiwan), March 2002

- C6. Joint Astronomy Centre (Hilo, HI), October 2001
- C5. Yale University (New Haven, CT) May 2001
- C4. Infrared Processing and Analysis Center (IPAC; Pasadena, CA), December 2000
- C3. European Southern Observatory (Garching, Germany), January 2000
- C2. Observatories of the Carnegie Institution of Washington (Pasadena, CA), January 2000
- C1. Academia Sinica Institute of Astronomy and Astrophysics (Taipei, Taiwan), March 1996

D. Public Talks and Presentations

- D13. "Seeing the Invisible"
Evenings with Astronomers, Keck Observatory fund-raising lecture series, Kona, HI, Jan 2010
- D12. "The Universe: Birth and Death of a Star"
The History Channel, August 2007
- D11. "Where Do Planets Come From?"
Keck Observatory Headquarters, July 2007
- D10. "Hitchhiker's Guide to the End of the Universe"
University of Hawaii, Manoa, Oct 2005 (and Hilo and Maui)
- D9. "Worlds Around Other Stars" Keck Observatory Headquarters, Dec 2003
- D8. "Extrasolar Planets"
The Manoa Forum, University of Hawaii, Sept 2003
- D7. "Extrasolar Planets"
National Public Radio, Science Friday, Sept 2002
- D6. "Searching for Brown Dwarfs and Young Planets Using Adaptive Optics"
TOPS (Toward Other Planetary Systems) presentation, University of Hawai'i, June 2002
- D5. "Extrasolar Planets and Brown Dwarfs"
AstroDay 2K2, Hilo, Hawai'i, April 2002
- D4. "Worlds Around Other Stars: New Sharp Views from Mauna Kea"
Inaugural Frontiers of Astronomy community lecture, University of Hawai'i, Feb 2002
- D3. "A Brown Dwarf Companion Around a Sun-Like Star"
Friends of Hawai'i Astronomy, University of Hawaii, Feb 2002
- D2. "New Telescopes and Telescope Technology"
National Public Radio, Science Friday, Jan 2002
- D1. "With a Clear Sky, You Can See Forever: Adaptive Optics in Astronomy"
Morrison Planetarium, San Francisco Amateur Astronomers, July 1998

E. Books Reviewed

- E1. *Magnificent Universe*.
K. Croswell 1999, Simon & Schuster (New York).

F. Abstracts, Posters, and Circulars

- E48. "A Novel Method for Finding Young Brown Dwarfs: New Discoveries in Ophiuchus and Perseus." Allers, K. and Liu, M., 2010, *Bulletin of the American Astronomical Society*, 41, 335
- E47. "Comparing the Mass-Period Distributions of Planets Around A-Type Stars and Sun-Like Stars." Bowler, B. et al. (11 authors) 2010, *Bulletin of the American Astronomical Society*, 41, 329
- E46. "Preliminary Infrared Parallaxes for Ultracool Binaries."
Dupuy, T. J. & Liu, M. C., 2009, *Bulletin of the American Astronomical Society*, 41, 201
- E45. "The Gemini NICI Planet-Finding Campaign: A Direct Imaging Search for Planets around Beta Pictoris and TW Hydra." Wahhaj, Z. et al. (12 authors), *Bulletin of the American Astronomical Society*, 41, 457
- E44. "The Gemini NICI Planet-Finding Campaign." Liu, M. et al. (12 authors), *Bulletin of the American Astronomical Society*, 41, 457
- E43. "Preliminary Infrared Parallaxes for Ultracool Binaries."
Dupuy, T. & Liu, M. 2009, *Bulletin of the American Astronomical Society*, 214, 411.23
- E42. "The Gemini NICI Planet-Finding Campaign."
Liu, M. 2009, *Bulletin of the American Astronomical Society*, 214, 230.01
- E41. "Keck LGS AO Orbital Monitoring of Brown Dwarf Binaries."
Dupuy, T., Liu, M. & Ireland, M. 2009, *Bulletin of the American Astronomical Society*, 214, 211.04
- E40. "The Hawaii Keck LGSAO Survey of Young Field Dwarfs."
Allers, K., Liu, M. et al. (7 authors) 2009, *Bulletin of the American Astronomical Society*, 41, 199
- E39. "Dynamical Mass of the Young Benchmark Substellar Binary HD 130948BC."
Dupuy, T. J., Liu, M. C., & Ireland, M. J. 2008, *Bulletin of the American Astronomical Society*, 40, 204
- E38. "Keck Laser Guide Star Adaptive Optics Monitoring of 2MASS J1534-2952AB: First Dynamical Mass Determination for a Binary T Dwarf." Liu, M. C., Dupuy, T. J., & Ireland, M. J. 2008. *Bulletin of the American Astronomical Society*, 40, 204
- E37. "Estimating The Orbital Period Of Ultracool Visual Binaries Using Only Two Observations." Dupuy, T. J., Liu, M. C. 2007, *Bulletin of the American Astronomical Society*, 38, 924

- E36. "First Results: A Custom Near-IR Filter For Finding Young Brown Dwarfs."
Allers, K. N., Liu, M. C. 2007, *Bulletin of the American Astronomical Society*, 38, 921
- E35. "Pan-STARRS-1 Key Project: The Extended Solar Neighborhood and Star-Forming Regions." Liu, M. C. et al. (18 authors) 2007, *Bulletin of the American Astronomical Society*, 38, 806
- E34. "BD-22°5866: A Rare Low-mass Quadruple-lined Spectroscopic Binary."
Shkolnik, E., Liu, M. C., Reid, I. N. 2007, *Bulletin of the American Astronomical Society*, 38, 771
- E33. "Direct Imaging of Extrasolar Planets."
Liu, M. 2007, *Bulletin of the American Astronomical Society*, 38, 228
- E32. "Brown Dwarf Science from Pan-STARRS."
Liu, M., Magnier, E., Dupuy, T. 2007, *Bulletin of the American Astronomical Society*, 38, 166
- E31. "Identifying the Missing Population of Nearby Young M Dwarfs."
Shkolnik, E., Liu, M., & Reid, I. N. 2006, *Bulletin of the Amer. Astr. Soc.*
- E30. "One Year of Brown Dwarf Binaries from Keck Laser Guide Star Adaptive Optics."
Liu, M. et al. 2006, *Making the Most of the Great Observatories* (Pasadena, CA)
- E29. "New Debris Disks around Low-Mass Stars."
Wray, J. J., Liu, M. C., Reid, I. N. 2005, *Bulletin of the Amer. Astr. Soc.*, 207, 10.07
- E28. "Substellar Astrophysics from Brown Dwarf Binaries."
Liu, M. C. et al. 2005, *Bulletin of the Amer. Astr. Soc.*, 207, 98.05
- E27. "Morphologies in a Cluster of Extremely Red Galaxies with Old Stellar Populations at $z=1.34$." Fu, H., Stockton, A., & Liu, M. C. 2005, *Bulletin of the Amer. Astr. Soc.*, 207, 190.08
- E26. "Novel Brown Dwarf Binaries from Laser Guide Star Adaptive Optics."
Liu, M. C. 2005, *PPV Brown Dwarf Workshop: Late-L, T, and T Dwarfs — New Results* (Kona, HI), online proceedings
- E25. "AU Microscopii and Debris Disks around Low-Mass Stars."
Liu, M. C. 2005, *Proceedings of Mini-workshop on Nearby Resolved Debris Disks* (STScI, Baltimore, MD)
- E24. "HST Morphology of a Galaxy at $z=5.34$."
te Velde, V., Stern, D., Zirm, A., & Liu, M. C. 2003, *Bulletin of the Amer. Astr. Soc.*, 203, 90.02
- E23. "Formation and Early Evolution of Substellar Objects."
Liu, M. C. 2003, *Bulletin of the Amer. Astr. Soc.*, 203, 74.01 (major invited talk)
- E22. "Searching for Young Planets with Adaptive Optics: The View from Hawaii."
Liu, M. C., *IAU 211: Star Formation at High Angular Resolution* (Sydney, Australia)

- E21. "Circumstellar Disks around Young Brown Dwarfs".
Liu, M., Najita, J., & Tokunaga, A. 2003, *Bulletin of the Amer. Astr. Soc.*, 201, 25.03
- E20. "Supernovae 2001jy, 2001jz, 2001ka, 2001kb, 2001kc, 2001kd."
Barris, B., Chambers, K., & Liu, M. 2001, *IAU Circ.*, 7849
- E19. "An Adaptive-Optics Search for Young Jovian-Mass Planets."
Liu, M. C. 2002, *Bulletin of the Amer. Astr. Soc.*, 199, 03.06
- E18. "Lick Adaptive Optics Companion Search around Nearby Solar-Type Stars."
Lloyd, J. P., Liu, M. C., Fischer, D., Graham, J. R., Marcy, G. W. 2002, *Bulletin of the Amer. Astr. Soc.*, 199, 03.05
- E17. "Adaptive Optics Observations of Radial Velocity Planetary Systems."
Lloyd, J. P., Liu, M. C., Graham, J. R., Fischer, D., & Marcy, G. W. 2001, *Bulletin of the Amer. Astr. Soc.*, 197, 93.03
- E16. "Distances and Stellar Populations of Ellipticals from Surface Brightness Fluctuations."
Liu, M. C. 2001, *Bulletin of the Amer. Astr. Soc.*, 197, 58.05 (thesis talk)
- E15. "First Light of the World's First Silicon Grisms."
Ge, J., Ciarlo, D., Kuzmenko, P., Macintosh, B., Alcock, C., Cook, K., Gavel, D., Max, C., Lloyd, J., Graham, J., Liu, M., & Sevenson, S. 2000, *Bulletin of the Amer. Astr. Soc.*, 195, #87.15
- E14. "A High-Resolution Search for Stellar Companions to Stars with Planets."
Patience, J., Ghez, A. M., White, R. J., McCabe, C., Macintosh, B., Liu, M. C., Graham, J. R., Max, C. E., Gavel, D., Olivier, S., Rudy, R., Puetter, R., Matthews, K., & Weinberger, A. J. 1999, *Bulletin of the Amer. Astr. Soc.*, 193, #97.08
- E13. "IR Surface Brightness Fluctuations of Fornax and Coma Cluster Ellipticals."
Charlot, S., Liu, M. C., & Graham, J. R. 1999,
Bulletin of the Amer. Astr. Soc., 193, #9.06
- E12. "Weighing the Stellar Content of NGC 5907's Dark Matter Halo."
Liu, M. C., Marleau, F. R., Graham, J. R., Charlot, S., Sackett, P., & Zepf, S. 1999,
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- E11. "IR Surface Brightness Fluctuations of Fornax and Coma Cluster Ellipticals."
Liu, M. C., Graham, J. R., & Charlot, S. 1998, poster presented at the
19th Texas Symposium on Relativistic Astrophysics, Paris, Dec 1998
- E10. "Keck Infrared Observations of Jupiter's Ring System."
de Pater, I., Graham, J. R., Liu, M. C., Showalter, M. R., Burns, J. A., Nicholson, P. D., &
Hamilton, D. P. 1998, DPS Meeting (Oct 1998, Madison, WI)
- E9. "IR Surface Brightness Fluctuations: From the Local Group to the Coma Cluster."
Liu, M. C. & Graham, J. R. 1996,
Bulletin of the Amer. Astr. Soc., 188, #12.15

- E8. "Observations of Comet P/Shoemaker-Levy 9 Impact on Jupiter from Lick Observatory Using a High Resolution Speckle Imaging Camera." Max, C., Gavel, D., Johansson, E., Sherwood, B., Liu, M. & Bradford, B. 1996, Technical report, Lawrence Livermore National Laboratory
- E7. "A Near-Infrared Camera for the Lick Observatory/Livermore National Lab Adaptive Optics System." Liu, M. C., Graham, J. R., Macintosh, B. A., & Max, C. E. 1995, poster presented at the VII Canary Winter School in Astrophysics, *Instrumentation for Large Telescopes*, Dec 1995, Tenerife, Spain
- E6. "W.M. Keck Telescope High Resolution Near-Infrared Imaging of FSC 10214+4724: Evidence for Gravitational Lensing." Liu, M. C. & Graham, J. R. 1995, *Bulletin of the Amer. Astr. Soc.*, 186, #52.01 (oral presentation)
- E5. "The R-Impact: Flashes and Fireballs." de Pater, I. et al. 1995, poster presented at the IAU Colloquium 156, "The Collision of Comet P/Shoemaker-Levy 9 and Jupiter," May 1995, Baltimore, Maryland
- E4. "Observations of Comet P/Shoemaker-Levy 9 Impact on Jupiter from Lick Observatory Using a High Resolution Speckle Imaging Camera." Gavel, D., Max, C., Johansson, E. Sherwood, B, Liu, M. & W. Bradford 1995, Proc. IAU Symp. no. 156, in press
- E3. "Keck Telescope Observations of the Comet SL-9 Fragment R Jupiter Collision." Graham, J. R., de Pater, I., Jernigan, J. G., Liu, M. C., & Brown, M. E. 1994, poster presented at the American Geophysical Union meeting, December 1994, San Francisco
- E2. "Investigation of Crater Saturation Using Spatial Statistical Techniques." Squyres, S., Howell, C., Lissauer, J., & Liu, M. C. 1993, *Bulletin of the Amer. Astr. Soc.*, 25, 1113
- E1. "Distribution of Strain in the Floor of the Olympus Mons Caldera." Watters, T. R., Chadwick, D. J., & Liu, M. C. 1990, *Abstracts of the Lunar and Planetary Science Conference*, 21, 1310