Paul Withers
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2002.11.10

To: Visiting Scientist Selection Committee
Program in Atmospheric and Oceanic Sciences
Princeton University

In response to your recent advertisement in Eos, I would like to be considered for a postdoctoral position.

I enclose:
3 page application form
2 page research proposal
5 page CV and publication list
4 reprints of published papers
1 manuscript currently under review by Icarus

I have arranged for my referees (Stephen Bougher, Greg Neumann, and John Wilson) to send letters directly to you.

Thank you,

Paul Withers

# Atmospheric Tides

My research aims are focused towards improving our understanding of atmospheric tides. Atmospheric tides transport energy and momentum vertically within an atmosphere. Due to their modification of the background thermal structure, they can be an important component of atmospheric circulation. At AOS/GFDL, the research areas of both the Weather and Atmospheric Dynamics and the Atmospheric Physics and Chemistry groups include processes related to atmospheric tides. I plan to collaborate closely with John Wilson.

**Broad Goals:**
(1) Studies of tides in the martian upper atmosphere [Keating *et al.,* 1998; Withers *et al.,* 2002].
(2) Studies of tides in the martian lower atmosphere, in conjunction with the upper atmospheric results of goal 1, to test theories of how it is dynamically coupled to the upper atmosphere [Banfield *et al.,* 2000; Hinson *et al.,* 2001].
(3) Compare tidal observations to John Wilson's General Circulation Model simulations to test theories of how atmospheric tides are generated [Wilson and Hamilton, 1996].

**Background:**
Atmospheric tides are departures from a mean, static behaviour with a harmonic relation to diurnal solar forcing. Solar heating is stronger in the atmosphere of Mars than Earth's, per unit mass, and this causes strong thermal tides [Zurek *et al.,* 1992]. Different tidal modes have specific zonal wavenumbers and periods which define their vertical and meridional structure. They originate at the planet's surface, and propagate upwards, affecting the transport of energy and momentum in the atmosphere. Tides should increase in amplitude as they propagate upwards, but are dissipated to varying degrees dependent on the lower atmospheric winds and their vertical wavelength [Forbes, 1995]. Mars Global Surveyor (MGS) accelerometer data have shown that tides are immensely important in the martian upper atmosphere, causing longitudinal variations in density of a factor of two or more [Keating *et al.* 1998; Withers *et al.,* 2002]. Since the tides are affected by the lower atmosphere as they propagate upwards to the upper atmosphere, observations of upper atmospheric tides contain information about the state of the lower atmosphere. For example, eastward winds in the lower atmosphere prevent the existence of stationary Rossby waves, a specific tidal mode, in the upper atmosphere [Joshi *et al.,* 2000].

**Specific Objectives in each Goal:**
(1) I plan to quantify the longitudinal structure, caused by thermal tides, in the martian upper atmosphere seen in neutral and electron density data from MGS and Mars Odyssey as a function of latitude, altitude, season, time of day, and phase in the 11 year solar cycle, and identify the dominant tidal modes [Keating *et al.,* 1998; Bougher *et al.,* 2001; Withers *et al.,* 2002].

(2) I will then study tidal signatures in the lower and middle atmosphere using measured temperature profiles from other instrument, identifying their vertical wavelengths,

meridional structure, and time of day dependence. The lower and upper atmospheric results will then be compared to test whether simple, classical theories of tidal propagation are adequate to explain the observations or whether more detailed theories are needed.

(3) By comparing lower and upper atmospheric measurement of tidal signatures to John Wilson's simulations from a general circulation model, we can test how completely current models reproduce all the processes affecting atmospheric tides. Of particular interest is how the tides are generated near the surface. Topography, rather than any other spatially non-uniform surface physical property such as thermal inertia, is likely to play the dominant role in modulating solar forcing to generate these non-migrating tides, but this process has not been completely studied yet [Wilson and Hamilton, 1996; Withers *et al.,* 2002]. Wilson and I will test whether topography is responsible for all the tidal modes in the upper atmosphere, how the dominant tidal modes change with seasonal changes in atmospheric circulation, and how well simulations can reproduce the observations. An important goal is to test whether observations of upper atmospheric tides, which have propagated upwards through the lower atmosphere, can also reveal useful information about the thermal structure and circulation in the lower atmosphere. Finally, insight into tidal processes from another planet can be applied to problems in terrestrial geophysical fluid dynamics.


- Banfield, D, BJ Conrath, JC Pearl, MD Smith, and P Christensen (2000) Thermal tides and stationary waves on Mars as revealed by Mars Global Surveyor thermal emission spectrometer, *J. Geophys. Res.,* **105,** 9521-9538.
- Bougher SW, S Engel, DP Hinson, and JM Forbes (2001) Mars Global Surveyor Radio Science electron density profiles: Neutral atmosphere implications, *Geophys. Res. Lett.,* **28,** 3091-3094.
- Forbes, JM (1995) Tidal and Planetary Waves, in *The Upper Mesosphere and Lower Thermosphere* (eds. Johnson and Killen) American Geophysical Union.
- Hinson, DP, GL Tyler, JL Hollingsworth, and RJ Wilson (2001) Radio occultation measurements of forced atmospheric waves on Mars, *J. Geophys. Res.,* **106,** 1463-1480.
- Joshi, MJ, JL Hollingsworth, RM Haberle, and AFC Bridger (2000) An interpretation of Martian thermospheric waves based on analysis of a general circulation model, *Geophys. Res. Lett.,* **27,** 613-616.
- Keating, GM, and 28 coauthors (1998) The Structure of the Upper Atmosphere of Mars: In Situ Accelerometer Measurements from Mars Global Surveyor, *Science,* **279,** 1672-1675.
- Wilson, RJ, and K Hamilton (1996) Comprehensive model simulation of thermal tides in the Martian atmosphere, *J. Atmos. Sci.,* **43,** 1290-1326.
- Withers, P, SW Bougher, and GM Keating (2002, submitted) The Effects of Topographically-controlled Thermal Tides in the Martian Upper Atmosphere as seen by the MGS Accelerometer, under review by *Icarus*.
- Zurek, RW, JR Barnes, RM Haberle, JB Pollack, JE Tillman, and CE Leovy (1992) Dynamics of the atmosphere of Mars, in *Mars* (eds. Keiffer, Jakoksy, Snyder, and Matthews) University of Arizona Press.

# Paul Withers

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## Education

- PhD, Planetary Science, University of Arizona 2003(planned)
  All requirements, except thesis, satisfied. Completion expected in late spring.
- MS, Physics, Cambridge University, Great Britain 1998
- BA, Physics, Cambridge University, Great Britain 1998

## Professional Experience

- Graduate research assistant Dr. Stephen Bougher (Univ. of Arizona) 1998 – present
  Studied weather in the martian upper atmosphere. Played an advisory role in mission operations for Mars Global Surveyor and Mars Odyssey aerobraking
- Research consultant Dr. John Zarnecki (Open University) 2001(summer)
  Worked in Great Britain, developed techniques to analyze accelerometer data from entry probes, concentrating on the British Beagle 2 Mars Lander.
- Research assistant Dr. Greg Neumann (NASA/Goddard) 2000(summer)
  Worked with MOLA team to investigate the geology of the northern plains of Mars, supported by the competitive Goddard Summer Student Program.
- Research assistant Dr. Andrew Melatos (Caltech) 1997(summer)
  Modeled pulsar outflows, supported by a competitive Caltech Summer Undergraduate Research Fellowship.
- Website designer Dr. Nicholas Walton (ING) 1996(summer)
  Worked at the Isaac Newton Group (ING) of Telescopes, La Palma, Spain.

## Fellowships, Honors, and Awards

- Kuiper Memorial Award from the University of Arizona for excellence in academic work and research in planetary science. 2002
- Nominated for the Meteoritical Society/Geological Society of America's Best Student Paper in Planetary Sciences Award. 2002
- Galileo Circle Graduate Scholarship from the University of Arizona. 2001
- Highly Commended in annual British Young Science Writer Contest. 2000
- Graduate Registration Fellowships from the University of Arizona. 1999 – 2002

## Research Interests

- Current research interests include the dynamics of upper atmospheres, accelerometer data analysis, historical astronomy, and martian tectonism. Future research directions will include the outer solar system, building on the results of Galileo and preparing for Cassini.

**Professional Activities**

- NASA 2003 Mars Rovers – Atmosphere Science Advisor for Landing. 2002(selected)
- Author of publicly available programs to analyze entry accelerometer data (http://www.lpl.arizona.edu/~withers/beagle2/). 2002
- Attended two-week Summer School on Planetary Geology in Italy. 2002
- Reviewer for *Icarus*, *Meteoritics and Planetary Science*, and *Science*. 2001 – present
- PI and Co-I on 2 proposals to NASA, neither funded. 2001
- Community discussion forum moderator and member of community panel on Education/Public Outreach for Solar System Exploration Decadal Survey. 2001
- "Oceans on Mars" – invited colloquium at Imperial College, Great Britain. 2001
- Participated in PDS review of MGS accelerometer dataset (MGSA_0002). 2000

**Teaching Experience**

- Participated in the University of Arizona's Scientist-Teacher Alliance, developed teaching plans and visited classrooms with middle school teachers. 2002
- Attended three national workshops on graduate student teaching. 2000 – 2002
- Teaching Assistant for Profs. John Lewis and Jonathan Lunine in introductory science classes for non-science majors, including lecturing on human evolution. 1999 – 2000

**Public Outreach**

- Presentation on "Shallow Ridges on the Northern Plains of Mars" at a University of Arizona Open House Evening. 2001
- Media interviews about my research on the martian northern plains and lunar crater Giordano Bruno, featured on CNN, print, and online media. 2001
- Presentations on "The Martian Upper Atmosphere" and "The Age of Lunar Crater Giordano Bruno" at the University of Arizona's Student Showcase, best presentation by a graduate student in the physical sciences in 1999. 1999 – 2000
- Named NASA's Deep Space 2 Mars Microprobes *Scott* and *Amundsen.* 1999

**Geological Field Experience**

- Organized short sections of the University of Arizona's planetary geology fieldtrip each semester, planning field stops and leading discussions. Went on 9 geological fieldtrips around the southwestern US and nearby Mexico. 1998 – 2002
- Participated in week-long Cambridge University geological fieldtrip to study the tectonics of Greece. 1997

**Language Skills**: Proficient in written French. Conversational level in French and Spanish.

**Professional Affiliations**: Member of the American Geophysical Union's Planetary Sciences Section, the American Astronomical Society's Division for Planetary Science, and the British Planetary Forum.

# Publications

## Peer Reviewed Publications

- **Withers**, Neumann, and Lorenz, "Comparison of Viking Lander descent data and MOLA topography reveals kilometer-scale error in Mars atmosphere profiles", (2002) *Icarus*, **159,** 259-261.

- Nockolds and **Withers**, "Comment and reply on "Meteor storm evidence against the recent formation of lunar crater Giordano Bruno" by Paul Withers" (2002) *Meteoritics and Planetary Science*, **37**, 465 – 466.

- **Withers** and Neumann, "Enigmatic northern plains of Mars" (2001) *Nature*, **410**, 651.

- **Withers**, "Meteor storm evidence against the recent formation of lunar crater Giordano Bruno" (2001) *Meteoritics and Planetary Science*, **36**, 525 – 529.

- Lorenz, Lunine, **Withers**, and McKay, "Titan, Mars and Earth: Entropy Production by Latitudinal Heat Transport" (2001) *Geophys. Res. Lett*., **28**, 415 – 418.

## Other Publications and Manuscripts under Review

- **Withers**, Bougher, and Keating, "The Effects of Topographically-controlled Thermal Tides in the Martian Upper Atmosphere as seen by the MGS Accelerometer" – under review by *Icarus.*

- **Withers**, Towner, Hathi, and Zarnecki, "Analysis of Entry Accelerometer Data: Preparations for Beagle 2" – under review by *Planetary and Space Science.*

- Grier, Atkinson, Barlow, Griffin, Hoffman, Kelly-Serrato, Keszthelyi, Klein, Klug, Kolvoord, Lanagan, Lebofsky, Lien, Lindstrom, Lopes, Lowes, Manifold, Mastrapa, Milazzo, Miner, Morris-Smith, Rivkin, Runyon, Sohus, Urquhart, Vasavada, Warasila, **Withers**, and Wood, "Setting Goals and Priorities for Education and Public Outreach" (2002) in *The Future of Solar System Exploration 2003-2013: Community Contributions to the NRC Solar System Exploration Decadal Survey* (*ed.* Mark Sykes) Volume 272 of the Astronomical Society of the Pacific's Conference Series.

- **Withers**, "Atmospheric Structure Reconstruction using the Beagle 2 Accelerometer" (2001) Technical Report to the Open University, Great Britain, available at http://www.lpl.arizona.edu/~withers/pppp/pdf/oureport.pdf

## Conference Presentations: Weather in the Martian Upper Atmosphere

- **Withers**, Bougher, and Keating, "Measurements of Winds in the Martian Upper Atmosphere from the MGS Accelerometer" (2002) *34th DPS Meeting*, Abstract #05.05.

- **Withers**, Bougher, and Keating, "MGS Accelerometer-derived profiles of Upper Atmospheric Pressures and Temperatures: Similarities, Differences, and Winds" (2002) *Spring AGU Meeting*, Abstract #P41A-10.

- Bougher, Keating, Forbes, Murphy, Hollingsworth, Wilson, and **Withers**, "The Upper Atmospheric Wave Structure of Mars as Determined by Mars Global Surveyor" (2001) *Fall AGU Meeting*, Abstract #P32E-12.

- **Withers**, Bougher, and Keating, "Unpredictable day-to-day variability in the martian upper atmosphere" (2001) *33rd DPS Meeting*, Abstract #19.29.

- **Withers**, Bougher, and Keating, "Harmonic Analysis of Zonal Density Structures in Martian upper atmosphere" (2001) *Spring AGU Meeting*, Abstract #P41A-05.

- **Withers** and Bougher "Understanding the martian upper atmosphere with the MGS Accelerometer" (2001) *4th LPL Internal Conference*, Tucson.

- Keating, Tolson, Wilson, Dwyer, Bougher, **Withers**, and Forbes, "Persistent planetary-scale wave-2 and wave-3 density variations observed in Mars upper atmosphere from MGS accelerometer experiment" (2001) *26th EGS General Assembly*, Session #PS2.02.

- Keating, Dwyer, Wilson, Tolson, Bougher, **Withers**, and Forbes,*et al.,* "Evidence of Large Global Diurnal Kelvin Wave in Mars Upper Atmosphere" (2000) *32nd DPS Meeting*, Abstract #50.02.

- Bougher, **Withers**, Murphy, Roble, and Keating, "Longitude Structure in the Mars Upper Atmosphere : Characterization and Model Simulations" (Solicited Key Note Paper) (2000) *33rd COSPAR Scientific Assembly*, Abstract #C3.2-0011.

- **Withers**, Bougher, and Keating, "New results from the Mars Global Surveyor Accelerometer" (2000) *31st LPSC Meeting*, Abstract #1268.

- **Withers**, Bougher, and Keating, "The martian upper atmosphere during phase 2 of Mars Global Surveyor aerobraking: comparison to predictions" (1999) *Fifth International Conference on Mars*, Abstract #6073.

- **Withers**, Bougher, and Keating, "The Martian Upper Atmosphere as Revealed by Mars Global Surveyor's Aerobraking (1999) *2nd LPL Internal Conference*, Tucson.

**Conference Presentations: Ridges in the Martian Northern Plains**

- **Withers** and Neumann, "Enigmatic northern plains of Mars" (2002) *Geoplanets Summer School*, Italy.

- **Withers** and Neumann, "A test of the martian northern ocean hypothesis" (2001) *4th LPL Internal Conference*, Tucson.

- **Withers** and Neumann, "Ridges in the Martian northern plains" (2001) *33rd Brown-Vernadsky Microsymposium*, Houston.

- **Withers** and Neumann, "Shallow Ridges in the Martian Northern Plains" (2000) *Fall AGU Meeting*, Abstract #P62B-02.

**Conference Presentations: Age of lunar crater Giordano Bruno**

- **Withers**, "Meteor storm evidence against the recent formation of lunar crater Giordano Bruno" (2001) *4th LPL Internal Conference*, Tucson.

- **Withers**, "Meteor storm evidence against the recent formation of lunar crater Giordano Bruno" (2001) *32nd LPSC Meeting*, Abstract #1007.

**Conference Presentations: Atmospheric Structure Profiles from Entry Accelerometers**

- **Withers**, Hathi, Towner, and Zarnecki, "Development of software for analysing entry accelerometer data in preparation for the Beagle 2 mission to Mars: Towards a Publicly Available Toolkit" (2002) *33rd LPSC Meeting*, Abstract #1203.

- **Withers**, Lorenz, and Neumann, "Errors in Viking Lander Atmospheric Profiles discovered using MOLA Topography" (2002) *33rd LPSC Meeting*, Abstract #1294.

**Conference Presentations: Simple Extremal Climate Models**

- **Withers** and Lorenz, "Simple Tests of Simple Climate Models" (2001) *Spring AGU Meeting*, Abstract #U32A-05.

- Lorenz, Lunine, **Withers**, and McKay, "Latitudinal Temperature Contrasts on Titan and the Principle of Maximum Entropy Production" (2000) *32nd DPS Meeting*, Abstract #17.07.

**Conference Presentations: Simple Asteroid Shape Models**

- **Withers**, "Angle of repose-limited shapes of asteroids" (2000) *3rd LPL Internal Conference*, Tucson.

- **Withers**, "Angle of repose-limited shapes of asteroids" (2000) *31st LPSC Meeting*, Abstract #1270.

**Conference Presentations: Education and Public Outreach**

- Grier, Atkinson, Barlow, Griffin, Hoffman, Kelly-Serrato, Keszthelyi, Klein, Klug, Kolvoord, Lanagan, Lebofsky, Lien, Lindstrom, Lopes, Lowes, Manifold, Mastrapa, Milazzo, Miner, Morris-Smith, Rivkin, Runyon, Sohus, Urquhart, Vasavada, Warasila, **Withers**, and Wood, "Defining Long Term Goals and Setting Priorities for Education and Outreach, 2003 to 2013 - Panel Report" (2001) *33rd DPS Meeting*, Abstract #19.29.