Ana-Maria A. Piso

Contact Information

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Education

Harvard University, Cambridge, MA

Ph.D., Astronomy & Astrophysics, May 2016 (expected)
Advisor: Dr. Karin Öberg
Thesis Topic: "Dynamics and Chemistry in Protoplanetary Disks"

Harvard University, Cambridge, MA

A.M., Astronomy & Astrophysics, May 2013
Advisor: Dr. Ruth Murray-Clay
Research Exam Project: "On the Minimum Core Mass for Giant Planet Formation"

Massachusetts Institute of Technology, Cambridge, MA

S.B., Physics, June 2010 — Major GPA: 4.6/5.0
S.B., Mathematics, June 2010 — Major GPA: 4.8/5.0

Research Experience & Employment

Research assistant — **August 2010 - July 2011**
MIT, EAPS Department — *Cambridge, MA*
Project: The Magnetic Field Signature of Super Earths
Advisor: Prof. Sara Seager

Undergraduate researcher — **June 2008 - June 2010**
MIT, Kavli Institute or Astrophysics — *Cambridge, MA*
Project: The Solar Wind (2008) & Structure of Accretion Disks (2009 - 2010)
Advisors: Dr. Paola Rebusco & Prof. Edmund Bertschinger

Research assistant — **June 2009 - August 2009**
Vienna University of Technology (TU Wien) — *Vienna, Austria*
Project: Exact relativistic viscous fluid solutions in near horizon extremal Kerr background
Advisor: Dr. Daniel Grumiller

Undergraduate researcher — **January 2007 - August 2007**
MIT, Laboratory of Nuclear Science — *Cambridge, MA*
Project: Dark Matter Direct Detection
Advisors: Prof. Gabriela Sciolla & Dr. Denis Dujmic

Assistant manager — **November 2005 - June 2006**
Neuron Group S.R.L. Software Company — *Bucharest, Romania*
Digital map designer and database manager for the '112 Emergency Call Center' national project

Teaching & Outreach

WISTEM Program Mentor — **September 2013 - present**
Mentor for a Harvard College undergraduate — *Cambridge, MA*

MIT Educational Counselor — **December 2011 - present**
Interviewer for prospective undergraduate students — *Cambridge, MA*

Science Club For Girls Mentor Scientist **September 2014 - May 2015**
Taught second grade girls at the Amigos School the class "Sound & Light" *Cambridge, MA*

CfA Summer Mentor **June 2014 - August 2014**
Co-mentored an REU summer student *Cambridge, MA*

Co-Organizer of Harvard Graduate Student Prospective Visits **March 2013**
Organized and coordinated meetings and activities for two groups of 10 prospective graduate students each *Cambridge, MA*

Teaching Fellow **February 2012 - May 2012**
Harvard College class SPU 30: Life as a Planetary Phenomenon *Cambridge, MA*
Course Head: Prof. Dimitar Sasselov
Held two weekly two-hour sections

Refereed Publications

Piso, A.-M. A., Öberg, K. I., Birnstiel, T., & Murray-Clay, R. A. *C/O and Snowline Locations in Protoplanetary Disks: The Effect of Radial Drift and Viscous Gas Accretion.* ApJ, 2015, 815, 109

Piso, A.-M. A., Youdin, A. N., & Murray-Clay, R. A. *Minimum Core Masses for Giant Planet Formation with Realistic Equations of State and Opacities.* ApJ, 2015, 800, 82

Piso, A.-M. A. & Youdin, A. N. *On the Minimum Core Mass for Giant Planet Formation at Wide Separations.* ApJ, 2014, 786, 21

Publications in Preparation

Piso, A.-M. A., Öberg, K.I., & Pegues, J. *The Role of Ice Compositions and Morphology For Snowlines and the C/N/O Ratios in Active Disks*

Online Publications & Educational Material

The Solar Wind
(Mathematica Demonstration Project: http://demonstrations.wolfram.com/TheSolarWind/)
Author: Ana-Maria Piso

The Interplanetary Magnetic Field (Parker Spiral)
(Mathematica Demonstration Project:
http://demonstrations.wolfram.com/TheInterplanetaryMagneticFieldParkerSpiral/
Author: Ana-Maria Piso

Conferences and Seminars

C/O and Snowline Locations in Protoplanetary Disks: The Effect of Radial Drift and Viscous Gas Accretion
Extreme Solar Systems III, Waikoloa Village, HI, December 2015
Poster

Giant Planet Formation and Snowlines in Protoplanetary Disks
University of Michigan Astronomy Lunch Talk, Ann Arbor, MI, November 2015
Seminar speaker

Giant Planet Formation and Snowlines in Protoplanetary Disks
University of Chicago Exoplanet Journal Club, Chicago, IL, November 2015
Seminar speaker

Giant Planet Formation and Snowlines in Protoplanetary Disks
MIT Exoplanet Tea, Cambridge, MA, October 2015
Seminar speaker

Giant Planet Formation and Snowlines in Protoplanetary Disks
Center for Integrative Planetary Science Planet and Star Formation Seminar, Berkeley, CA, September 2015
Invited talk

Minimum Core Masses for Giant Planet Formation
CfA Exoplanet Pizza Lunch, Cambridge, MA, May 2015
Internal department talk

Minimum Core Masses for Giant Planet Formation
Star and Planet Formation in the Southwest, Oracle, AZ, March 2015
Contributed talk

On the Minimum Core Mass for Giant Planet Formation
CfA Exoplanet Pizza Lunch, Cambridge, MA, November 2013
Internal department talk

On the Minimum Core Mass for Giant Planet Formation
Protostars and Planets VI, Heidelberg, Germany, July 2013
Poster

On the Minimum Core Mass for Giant Planet Formation
IAUS 299: Exploring the Formation and Evolution of Planetary Systems, Victoria, BC, June 2013
Contributed talk

The Structure and Stability of Atmospheres Accreting around Protoplanetary Cores
Exoplanets in Multi-body Systems in the Kepler Era, Aspen, CO, February 2013
Poster

Magnetic field signature of Super Earths
AAS 217^{th} Meeting, Washington, Seattle, January 2011
Poster

Exact relativistic viscous fluid solutions in NHEK background
APS April Meeting, Washington, DC, February 2010
Poster

The Solar Wind
Vienna Theory Lunch Club, TU Wien, Vienna, Austria, June 2009
Invited talk

Professional Activities & Service

American Physical Society member
American Astronomical Society member

Skills

Languages: Fluent in Romanian, English and Spanish, Conversant in German, Basics in French
Computer: Python, Mathematica, Matlab, LaTeX, C++, ROOT, Mac OS, Windows 2000/XP/Vista, Microsoft Office, Corel, Database Desktop

Ana-Maria Piso: List of Publications

Refereed Publications

Ana-Maria A. Piso, Karin I. Öberg, Tilman Birnstiel, and Ruth A. Murray-Clay, *C/O and Snowline Locations in Protoplanetary Disks: The Effect of Radial Drift and Viscous Gas Accretion*. Astrophysical Journal, 2015, 815, 109

Ana-Maria A. Piso, Andrew N. Youdin, A, and Ruth A. Murray-Clay, *Minimum Core Masses for Giant Planet Formation with Realistic Equations of State and Opacities*. Astrophysical Journal, 2015, 800, 82

Ana-Maria A. Piso and Andrew N. Youdin, *On the Minimum Core Mass for Giant Planet Formation at Wide Separations.* Astrophysical Journal, 2014, 786, 21

Publications in Preparation

Ana-Maria A. Piso, Karin I. Öberg, and Jamila Pegues, *The Role of Ice Compositions and Morphology For Snowlines and the C/N/O Ratios in Active Disks* (to be submitted to the Astrophysical Journal January 2016)

Online Publications and Educational Material

Ana-Maria A. Piso, *The Interplanetary Magnetic Field***.** February 2009. Mathematica Demonstrations Project

Ana-Maria A. Piso, *The Solar Wind*. August 2008. Mathematica Demonstrations Project

Postdoctoral Position Research Proposal: The Role of Disk Volatile Chemistry and Dynamics in Shaping the Compositions of Nascent Planets

Ana-Maria Piso

Within the last two decades, more than one thousand extrasolar planets (exoplanets) have been discovered [1]. Their diversity in terms of mass, radius, location and composition [2] provides an exciting field of research, with the eventual goal of finding planets that are similar to our own Earth and may sustain life. For this purpose, it is thus crucial to explore and understand how planets obtain their compositions. Observations of Earth-like planets that can provide useful insight about their composition are challenging — the solid interior structure of terrestrial planets cannot be detected, and their gaseous envelopes are small by comparison (both in mass and radius), which makes it difficult to obtain atmospheric spectra and find out what chemical compounds they are made of. We therefore turn to giant planets, which have provided a rich and intriguing research area for decades. Gas giants contain most of their mass in their atmosphere, hence their chemical composition is determined by that of their envelopes. The last few years have seen a substantial increase in the number of giant planets with observed atmospheric spectra (e.g., [3], [4]), which has enhanced our understanding of these planets' chemical structure, and has provided us with quantitative information about the abundances of various compounds in their envelopes besides hydrogen and helium. Finally, gas giants shape the architecture of planetary systems and affect the delivery of volatile compunds to terrestrial planets, which has direct consequences for the habitability of worlds similar to our own. Thus testing theories of planet formation against gas giant compositions will help constrain planet formation theories more generally.

Both terrestrial and giant planets are born in protoplanetary disks, which implies that their **compositions are determined by and tightly linked to the structure and composition of the disk**. The chemical and dynamical evolution of disks, as well the formation of giant planets have both been previously investigated in isolation. However, the coupled chemo-dynamical disk evolution, planet compositions, and most importantly the disk-planet connection have not yet been considered in detail. As shown in my work on the minimum core mass of gas giants ([5], [6]), planet formation depends sensitively on disk physics and chemistry. **I propose to develop a holistic chemo-dynamical framework to explore how disk dynamics and chemistry, as well as the dynamics of nascent planets and planetesimals, regulate the compositions of mature giant planets.** Such a model will enhance our understanding of planetary structures by enabling us to predict what kind of planet compositions result from planet formation in different parts of the disk. Furthermore, this work provides essential context for characterizing the gas giants that instruments such as the James Webb Space Telescope (JWST) and the Transiting Exoplanet Survey Satellite (TESS) will one day discover.

1. Coupled Chemical and Dynamical Disk Evolution

Chemical and dynamical processes in a protoplanetary disk affect the disk structure and composition, and thus the composition of nascent planets. As shown in Figure 1, the timescales for various disk chemical and dynamical processes may be comparable at least in some parts of the disk. It follows that these two effects cannot be decoupled, and that the chemo-dynamical evolution of the disk has to be studied simultaneously and self-consistently. Through **analytical and numerical calculations**, I will first explore a

range of dynamical processes that may affect the distribution of volatiles in disks, expanding and generalizing the framework I developed during my dissertation research [7]. Such effects include particle growth and fragmentation, as well as accretion rate and stellar luminosity evolution.

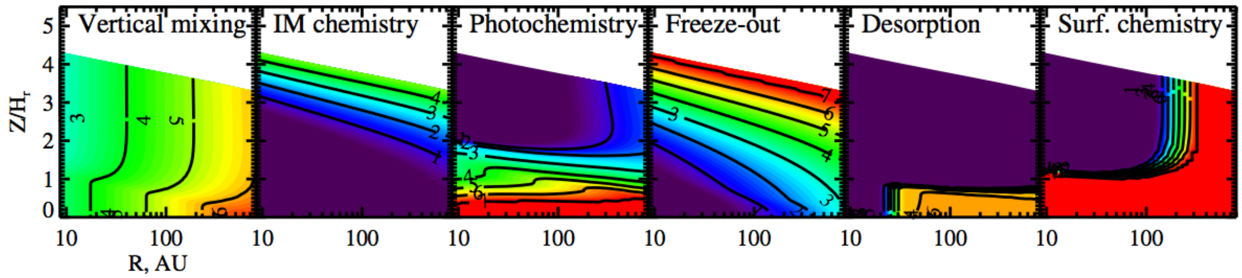

Figure 1: The distribution of characteristic chemical and dynamical timescales τ in disks as a function of semi-major axis and height. The numbered curves are $\log_{10}(\tau)$ in million years (from [11]).

From the chemistry perspective, molecular abundances vary significantly across a typical disk, due to steep gradients in temperature, density and radiation. The complexity of disk chemistry means that coupling it with dynamical processes, while necessary, is non-trivial. I will couple the dynamical framework outlined above with **time-dependent chemical models of increasing complexity**, informed by results from state-of-the-art disk chemistry models (that can only be run on static disks). This will show how the snowline locations of volatiles, as well as the chemical composition of the disk gas and dust evolve, which has **direct implications on the compositions of young planets**. Moreover, since I am primarily interested in processes that affect the disk mid-plane where planets form, my results could be simplified by the fact that certain chemical processes may not be important in this disk parameter space.

2. Planet and Planetesimal Migration

The complex processes outlined in part 1 will directly impact the composition and dynamics of forming gas giants, as the latter are born and evolve simultaneously with the disk. The chemical evolution of the gas disk molecular abundances, as well as disk dynamics, determine how a young planet's atmospheric composition changes in time and with the planet's location, and therefore the final chemical structure of mature planets. **It is thus clear that disks and planets are deeply connected, and that this relation needs to be explored**.

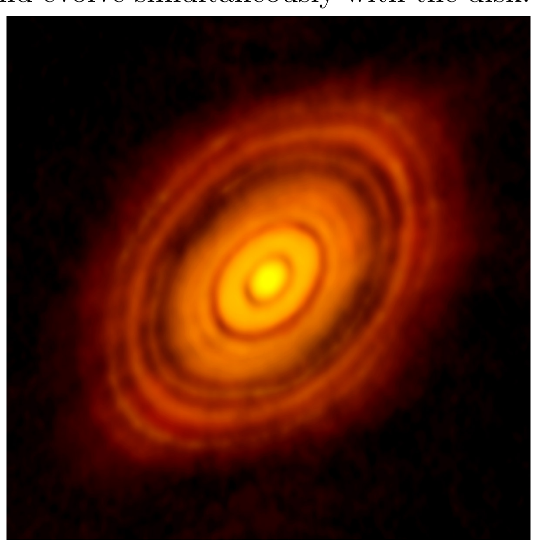

Figure 2: ALMA continuum image of the disk around HL Tau, which shows evidence of a gas gap in the disk, most likely created due to planetary migration (from [8]).

Giant planets can migrate through the disk while still accumulating gas. Figure 2 shows an exciting ALMA observation of a planetary gap in the disk around HL Tau [8]. This will change a planet's atmospheric composition since the disk chemical abundances are different at different disk locations. Additionally, giant planets may still accumulate planetesimals while accreting nebular gas [9]. The final composition of a planet's atmosphere will thus depend on how much gas and solids are accreted in this stage. **I will add planet dynamical effects such as migration and planetesimal accretion in the chemical and dynamical model developed in part 1, and quantify how these processes affect the chemical composition of gas giant envelopes**.

3. Model Planet Populations

The results from parts 1 and 2 will feed into a **large planet synthesis model**, in which I will use a grid of different **initial disk and planetary embryo conditions**. I will develop my own numerical program instead of using already existing codes of planet population synthesis (e.g., [10] and references therein), since the latter involve many complex physical processes, some of which might not be necessary or relevant for my own calculations. To minimize computational expenses, I will build a program from bottom-up that includes select physical and chemical processes based on the local simulations from steps 1 and 2. This will allow me to predict the **range of planet compositions that can form under reasonable disk conditions**, as well as **constrain a planet's formation location based on its chemical composition**. Comparing my results with current observations of atmospheric spectra (e.g., Figure 3 from [4]), and more importantly future JWST observations, will lead to great scientific strides in understanding the complex connection between protoplanetary disks and the formation, evolution and composition of exoplanets.

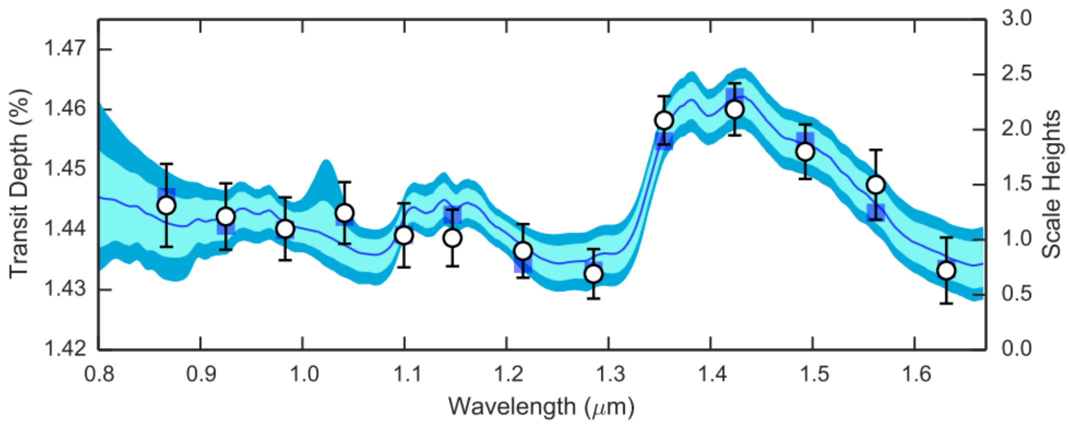

Figure 3: The transmission spectrum of exoplanet WASP-12b measured with the Hubble Space Telescope/Wide Field Camera 3. The white dots are the measured transit depths, the blue squares and dark blue line are the best fit model, while the shaded regions represent 1- and 2 σ intervals in the retrieved spectrum. The increase in transit depth around $\sim$1.4 μm is evidence for a water feature in the atmosphere (from [4]).

MIT is the ideal place for me to pursue my postdoctoral work. Its research facilities and academic excellence are unparalleled. I would love the opportunity to work with **Prof. Hilke Schlichting**, an expert in planet formation theory and dynamics — such a collaboration would be instrumental in achieving my research goals during my postdoctoral tenure and afterwards. I would also like to collaborate with **Prof. Sara Seager**, a co-investigator of the TESS mission and a leading theorist in atmospheric chemistry, as well as with members of her group, who specialize in a broad range of exoplanet theory and computational topics. **Dr. Margaret Pan**, an excellent theorist in planetary dynamics and protoplanetary disks, will join the MIT EAPS department in early 2016 — it would be a pleasure to work with her as well. Additionally, the MIT Physics department hosts leaders in detecting and characterizing worlds outside the Solar system, such as **Prof. Joshua Winn**, which presents great prospects in connecting my theoretical research work with observations.

[1] Batalha, N. M. 2014, Proceedings of the National Academy of Science, 111, 12647
[2] Lissauer J. J., Dawson R. I., Tremaine S., 2014, Nature, 513, 336
[3] Debes, J. H., Jang-Condell, H., Weinberger, A. J., Roberge, A., & Schneider, G. 2013, ApJ, 771, 45
[4] Kreidberg, L., Line, M. R., Bean, J. L., et al. 2015, ApJ, 814, 66
[5] Piso, A.-M. A., & Youdin, A. N. 2014, ApJ, 786, 21
[6] Piso, A.-M. A., Youdin, A. N., & Murray-Clay, R. A. 2015, ApJ, 800, 82
[7] Piso, A.-M. A., Öberg, K. I. , Birnstiel, T., & Murray-Clay, R. A. 2015, ApJ, 815, 109
[8] ALMA Partnership et al., 2015, ApJ, 808, L3
[9] Öberg, K. I., Murray-Clay, R., & Bergin, E. A. 2011, ApJ, 743, L16
[10] Ida, S., Lin, D. N. C., & Nagasawa, M. 2013, ApJ, 775, 42
[11] Semenov, D., & Wiebe, D. 2011, ApJS, 196, 25