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# Exploring the Formation and Evolution of Planetary Systems

*Edited by*

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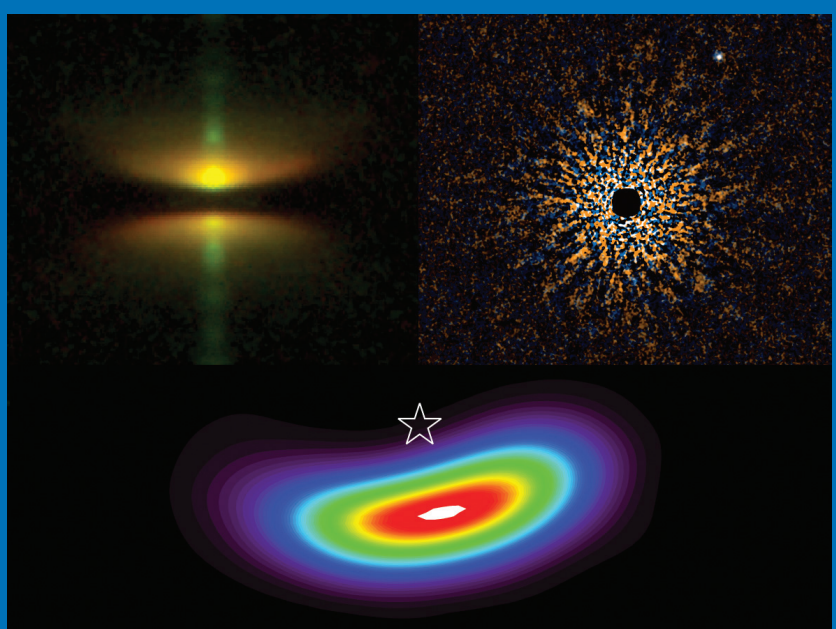
Brenda C. Matthews
James R. Graham



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EXPLORING THE FORMATION AND EVOLUTION
OF PLANETARY SYSTEMS

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*COVER ILLUSTRATION:* FROM DISKS TO PLANETS

Top left: HST imaging of the protoplanetary disk SSTtau J042021+281349, remarkable for its lateral symmetry and spectacular bipolar jet, highlighted by the F606W filter of HST (Duchêne *et al.*, this work).

Bottom: ALMA image of dust trapped in a ring around the Herbig Ae star Oph IRS 48. The dust and gas cavities of this protoplanetary disk are completely resolved in this 0.2″ resolution image (van der Marel *et al.*, this work).

Top right: Subaru direct imaging of the planetary companion GJ 504b which orbits a sun-like star 18 pc from the Earth. The projected distance of the planet from the star is 44 AU (Kuzuhara, M *et al.* 2013, ApJ, 774, 11).

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*Chief Editor*

THIERRY MONTMERLE, IAU General Secretary
*Institut d'Astrophysique de Paris,*
*98bis, Bd Arago, 75014 Paris, France*
*montmerle@iap.fr*

*Editor*

PIERO BENVENUTI, IAU Assistant General Secretary
*University of Padua, Dept of Physics and Astronomy,*
*Vicolo dell'Osservatorio, 3, 35122 Padova, Italy*
*piero.benvenuti@unipd.it*

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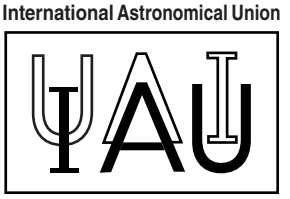


# EXPLORING THE FORMATION AND EVOLUTION OF PLANETARY SYSTEMS

## PROCEEDINGS OF THE 299th SYMPOSIUM OF THE INTERNATIONAL ASTRONOMICAL UNION HELD IN VICTORIA, CANADA JUNE 2 – 7, 2013

Edited by

**MARK BOOTH**
*Instituto de Astrofísica, Pontificia Universidad Católica de Chile, Vicuña Mackenna 4860, 7820436 Macul, Santiago, Chile*
*University of Victoria, BC, Canada*
*National Research Council of Canada Herzberg Astronomy & Astrophysics*

**BRENDA C. MATTHEWS**
*National Research Council of Canada, Herzberg Astronomy & Astrophysics*
*University of Victoria, BC, Canada*

and

**JAMES R. GRAHAM**
*University of California, Berkeley, CA, U.S.A.*

CAMBRIDGE UNIVERSITY PRESS
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## Session 2. Peering into Circumstellar Disks: Transformative Interferometry & High Resolution Imaging

*Chair: Meredith Hughes*

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**Session 6. Debris Disks as Signposts of Planetary Systems**
*Chair: David Wilner*



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# Preface

"Exploring the Formation and Evolution of Planetary Systems" is focussed on the evolution of proto-planetary disks and the formation and evolution of the planets themselves. This meeting, which is coincident with the end of observations by the Kepler space observatory, highlights a maturing view of planets detected by the transit and Doppler techniques, results from the first high-resolution imaging with ALMA, and sets the stage for the initial operations for a new generation of high contrast planet imaging instruments.

Circumstellar disks provide a unique window into the process of planet formation around young stars. Characterizing disk structure yields clues to disk evolution by determining the spatial distribution of gas and dust, probing the physical conditions in the disk, and providing snapshots of systems in the process of clearing natal material. The observational characterization of these planet-forming disks by, for example, Herschel, ALMA, and EVLA, is in an era of substantial progress. Together with ever-increasing theoretical attention and computational power, this confluence of developments promises an unusual period of rapid progress in understanding the domain of cool gas and dust in disks.

The timing of this meeting also coincides with advances in high-resolution imaging of planetary systems by interferometers on optical/IR 8-m class telescopes (LBTI and PRIMA) and direct imaging of exoplanets with dedicated high contrast adaptive optics coronagraphs (e.g., P1640, SCExAO, SPHERE, GPI). It is therefore a critical time to bring together the communities working on the earliest phases of planet formation with those studying mature planetary systems and associated debris disks.

While there is strong representation of observational work at this meeting, we solicited review talks that discuss the impact of the observations on models of planet formation and evolution in the broadest terms. No five-day meeting can address the full breadth of each field, but we hope that the legacy of the meeting is the enhanced interaction between those who study the formation of planets and those who study evolved systems.

It is especially fitting that an exoplanet meeting be held in British Columbia. Over thirty years ago, University of British Columbia astronomers Gordon Walker and Bruce Campbell pioneered gas absorption cell spectroscopy with the objective of using precision Doppler measurements to detect exoplanets. Hydrogen fluoride was selected on the advice of the Nobel prize-winning German-Canadian physical chemist Gerhard Herzberg, whose name has long been honored in the name of one of our organizers: the Herzberg Institute of Astrophysics (now NRC Herzberg Astronomy & Astrophysics Programs). By 1988 Campbell and Walker, together with UBC astronomer Stephenson Yang, had achieved a precision of 13 m/s, developed methods to remove differences in the velocity zero point between observing runs, and seen the Doppler signature of $\gamma$ Cephei b. A quarter of a century later, and with Doppler measurement of orbits for 500 exoplanets in hand, their vision has been realized. The current proceedings reveal a diversity of planetary systems and an array of detection and characterization methods unimaginable twenty five years ago.

*James R. Graham, chair SOC*
*Berkeley, CA, USA, 9 September 2013*

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# THE ORGANIZING COMMITTEE

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# Participants


| | |
|---|---|
| Brett **Addison**, Australia | b.addison@student.unsw.edu.au |
| Yukako **Aimi**, Japan | aimi@iral.ess.sci.osaka-u.ac.jp |
| Richard **Alexander**, United Kingdom | richard.alexander@leicester.ac.uk |
| France **Allard**, France | fallard@ens-lyon.fr |
| David **Anderson**, United Kingdom | d.r.anderson@keele.ac.uk |
| Sean **Andrews**, USA | sandrews@cfa.harvard.edu |
| Fabien **Anthonioz**, France | Fabien.Anthonioz@obs.ujf-grenoble.fr |
| David **Armstrong**, United Kingdom | d.j.armstrong@warwick.ac.uk |
| Jean-Charles **Augereau**, France | augereau@obs.ujf-grenoble.fr |
| Vanessa **Bailey**, USA | vbailey@as.arizona.edu |
| Kévin **Baillie**, France | kevin.baillie@univ-paris-diderot.fr |
| Gaspar **Bakos**, USA | gbakos@astro.princeton.edu |
| Nick **Ballering**, USA | ballerin@email.arizona.edu |
| Michele **Bannister**, Canada | michele.t.bannister@gmail.com |
| Sara **Barber**, USA | sara.d.barber@me.com |
| Jason W. **Barnes**, USA | jwbarnes@uidaho.edu |
| Mary **Barsony**, USA | mbarsony@seti.org |
| Jean-Loup **Baudino**, France | jean-loup.baudino@obspm.fr |
| Daniel **Bayliss**, Australia | daniel@mso.anu.edu.au |
| Thomas **Beatty**, USA | tbeatty@astronomy.ohio-state.edu |
| Will **Best**, USA | wbest@ifa.hawaii.edu |
| Beth **Biller**, Germany | biller@mpia.de |
| Anthony **Boccaletti**, France | anthony.boccaletti@obspm.fr |
| David **Bohlender**, Canada | david.bohlender@nrc-cnrc.gc.ca |
| Emeline **Bolmont**, France | Emeline.Bolmont@obs.u-bordeaux1.fr |
| Mariangela **Bonavita**, Italy | mariangela.bonavita@oapd.inaf.it |
| Mickaël **Bonnefoy**, Germany | bonnefoy@mpia.de |
| Amy **Bonsor**, France | amy.bonsor@gmail.com |
| Mark **Booth**, Canada | mark.booth@nrc.ca |
| Kim **Bott**, Australia | k.bott@unsw.edu.au |
| Brendan **Bowler**, USA | bpbowler@ifa.hawaii.edu |
| Tim **Brandt**, USA | tbrandt@astro.princeton.edu |
| Hannah **Broekhoven-Fiene**, Canada | broekhov@uvic.ca |
| Joanna **Brown**, USA | joannabrown@cfa.harvard.edu |
| Ludmila **Carone**, Belgium | ludmila.carone@wis.kuleuven.be |
| John **Carpenter**, USA | jmc@astro.caltech.edu |
| Sebastien **Charnoz**, France | charnoz@cea.fr |
| Eugene **Chiang**, USA | echiang@astro.berkeley.edu |
| Elodie **Choquet**, USA | choquet@stsci.edu |
| Duncan **Christie**, USA | dac5zm@astro.virginia.edu |
| Christian **Clanton**, USA | clanton@astronomy.ohio-state.edu |
| Laird **Close**, USA | lclose@as.arizona.edu |
| Christophe **Cossou**, France | Christophe.Cossou@u-bordeaux1.fr |
| Nicolas **Cuello**, France | nicolas.cuello@univ-lyon1.fr |
| Thayne **Currie**, Canada | currie@astro.utoronto.ca |
| Claire **Davies**, United Kingdom | cd54@st-andrews.ac.uk |
| Rebekah **Dawson**, USA | rdawson@cfa.harvard.edu |
| Maria **de Juan Ovelar**, Netherlands | mjovelar@strw.leidenuniv.nl |
| Ramiro **de la Reza**, Brazil | delareza@on.br |
| Robert **De Rosa**, USA | rjderosa@asu.edu |
| Denis **Defrère**, USA | ddefrere@email.arizona.edu |
| James **Di Francesco**, Canada | james.difrancesco@nrc-cnrc.gc.ca |
| Jack **Dobinson**, United Kingdom | jack.dobinson@bristol.ac.uk |
| Sally **Dodson-Robinson**, USA | sdr@astro.as.utexas.edu |
| Ruobing **Dong**, USA | rdong@astro.princeton.edu |
| René **Doyon**, Canada | doyon@astro.umontreal.ca |
| Zachary H **Draper**, Canada | zhd@uvic.ca |
| Gaspard **Duchene**, USA | gduchene@berkeley.edu |
| Rudolf **Dvorak**, Austria | dvorak@astro.univie.ac.at |
| Jo **Barstow**, United Kingdom | j.barstow1@physics.ox.ac.uk |
| Keigo **Enya**, Japan | enya@ir.isas.jaxa.jp |
| Steve **Ertel**, France | steve.ertel@obs.ujf-grenoble.fr |
| Catherine **Espaillat**, USA | cespaillat@cfa.harvard.edu |
| Neal **Evans**, USA | nje@astro.as.utexas.edu |
| Francesca **Faedi**, United Kingdom | F.Faedi@warwick.ac.uk |
| Jackie **Faherty**, Chile | jfaherty17@gmail.com |
| Virginie **Faramaz**, France | Virginie.Faramaz@obs.ujf-grenoble.fr |
| Jay **Farihi**, United Kingdom | jfarihi@ast.cam.ac.uk |
| Julien **Faure**, France | julien.y.faure@gmail.com |
| Stephen **Fendyke**, United Kingdom | s.m.fendyke@qmul.ac.uk |
| Debra **Fischer**, USA | debra.fischer@yale.edu |
| Mike **Fitzgerald**, USA | mpfitz@ucla.edu |
| Kate **Follette**, USA | kfollette@as.arizona.edu |
| Jonathan **Fortney**, USA | jfortney@ucolick.org |
| Wes **Fraser**, Canada | wesley.fraser@nrc.ca |
| Jeffrey **Fung**, Canada | fung@astro.utoronto.ca |
| Boris **Gaensicke**, United Kingdom | boris.gaensicke@warwick.ac.uk |
| Eric **Gaidos**, USA | gaidos@hawaii.edu |
| Raphael **Galicher**, France | raphael.galicher@obspm.fr |
| Antonio **Garufi**, Switzerland | antonio.garufi@phys.ethz.ch |
| Scott **Gaudi**, USA | gaudi@astronomy.ohio-state.edu |
| Yilen **Gómez Maqueo Chew**, United Kingdom | y.gomez@warwick.ac.uk |
| Jean-Franois **Gonzalez**, France | Jean-Francois.Gonzalez@ens-lyon.fr |
| James **Graham**, Canada/USA | jrg@berkeley.edu |
| Phil **Gregory**, Canada | gregory@phas.ubc.ca |
| Pin-Gao **Gu**, Taiwan | gu@asiaa.sinica.edu.tw |
| Janis **Hagelberg**, Switzerland | janis.hagelberg@unige.ch |
| Antonio **Hales**, Chile | ahales@alma.cl |
| Stephan **Hartmann**, Germany | hartmann@astro.uni-tuebingen.de |


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| | |
|---|---|
| Paul M. **Harvey**, USA | pmh@astro.as.utexas.edu |
| Yasuhiro **Hasegawa**, Taiwan | yasu@asiaa.sinica.edu.tw |
| Korey **Haynes**, USA | korey.n.haynes@nasa.gov |
| Raphaëlle **Haywood**, United Kingdom | rdh4@st-andrews.ac.uk |
| Sasha **Hinkle**, USA | shinkley@astro.caltech.edu |
| Tobias C. **Hinse**, South Korea | tchinse@gmail.com |
| John **Hodgson II**, USA | John.Hodgson.71@my.csun.edu |
| Wayne **Holland**, United Kingdom | wayne.holland@stfc.ac.uk |
| Derek **Homeier**, France | derek.homeier@ens-lyon.fr |
| Jonti **Horner**, Australia | j.a.horner@unsw.edu.au |
| Xu (Chelsea) **Huang**, USA | xuhuang@princeton.edu |
| Elsa **Huby**, France | elsa.huby@obspm.fr |
| Meredith **Hughes**, USA | amhughes@wesleyan.edu |
| Jason **Hwang**, USA | jasonhwang2014@u.northwestern.edu |
| Mike **Ireland**, Australia | michael.ireland@mq.edu.au |
| Alan **Jackson**, United Kingdom | ajackson@ast.cam.ac.uk |
| Marshall **Johnson**, USA | mjohnson@astro.as.utexas.edu |
| Daniel **Jontof-Hutter**, USA | daniel.s.jontof-hutter@nasa.gov |
| Marc **Joos**, France | marc.joos@cea.fr |
| Andres **Jordan**, Chile | ajordan@astro.puc.cl |
| Paul **Kalas**, USA | kalas@berkeley.edu |
| JJ **Kavelaars**, Canada | JJ.Kavelaars@nrc-cnrc.gc.ca |
| Grant **Kennedy**, United Kingdom | gkennedy@ast.cam.ac.uk |
| Matthew **Kenworthy**, Netherlands | kenworthy@strw.leidenuniv.nl |
| Jacques **Kluska**, France | jacques.kluska@obs.ujf-grenoble.fr |
| Mihoko **Konishi**, Japan | konishi@iral.ess.sci.osaka-u.ac.jp |
| Quinn **Konopacky**, Canada | konopacky@di.utoronto.ca |
| Taisiya **Kopytova**, Germany | kopytova@mpia.de |
| Quentin **Kral**, France | quentin.kral@obspm.fr |
| Adam L. **Kraus**, USA | akraus@cfa.harvard.edu |
| Alexander **Krivov**, Germany | krivov@astro.uni-jena.de |
| Sylvestre **Lacour**, France | sylvestre.lacour@obspm.fr |
| Anne-Marie **Lagrange**, France | lagrange@obs.ujf-grenoble.fr |
| Michiel **Lambrechts**, Sweden | michiel@astro.lu.se |
| Samantha **Lawler**, Canada | lawler@astro.ubc.ca |
| Zoë **Leinhardt**, United Kingdom | Zoe.Leinhardt@bristol.ac.uk |
| Min-Kai **Lin**, Canada | mklin924@cita.utoronto.ca |
| Douglas **Lin**, USA | lin@ucolick.org |
| Yoram **Lithwick**, USA | y-lithwick@northwestern.edu |
| Michael **Liu**, USA | mliu@ifa.hawaii.edu |
| Joe **Llama**, United Kingdom | joe.llama@st-andrews.ac.uk |
| Torsten **Löhne**, Germany | tloehne@astro.uni-jena.de |
| Meredith **MacGregor**, USA | mmacgreg@cfa.harvard.edu |
| Bruce **Macintosh**, USA | macintosh1@llnl.gov |
| Sarah **Maddison**, Australia | smaddison@swin.edu.au |
| Thomas I. **Maindl**, Austria | thomas.maindl@univie.ac.at |
| Anne-Lise **Maire**, France | Anne-Lise.Maire@obspm.fr |
| Jerome **Maire**, Canada | maire@di.utoronto.ca |
| Jared **Males** , USA | jrmales@email.arizona.edu |
| Carlo Felice **Manara**, Germany | cmanara@eso.org |
| Rosemary **Mardling**, Australia | rosemary.mardling@monash.edu |
| Naibi **Marias**, USA | marinas@astro.ufl.edu |
| Christian **Marois**, Canada | christian.marois@nrc-cnrc.gc.ca |
| Jonathan P. **Marshall**, Spain | jonathan.marshall@uam.es |
| David **Martin**, Switzerland | david.martin@unige.ch |
| Rebecca **Martin**, USA | rebecca.martin@jila.colorado.edu |
| Brenda **Matthews**, Canada | brenda.matthews@nrc-cnrc.gc.ca |
| Dimitri P. **Mawet**, Chile | dmawet@eso.org |
| Kyle **Mede**, Japan | kylemede@astron.s.u-tokyo.ac.jp |
| Heloise **Meheut**, France | heloise.meheut@cea.fr |
| Jonathan **Menu**, Belgium | jonathan.menu@ster.kuleuven.be |
| Farzana **Meru**, Switzerland | farzana@phys.ethz.ch |
| Dino **Mesa** , Italy | dino.mesa@oapd.inaf.it |
| Tiffany **Meshkat**, Netherlands | meshkat@strw.leidenuniv.nl |
| Stanimir **Metchev**, USA | stanimir.metchev@stonybrook.edu |
| Brian **Metzger**, USA | bmetzger@phys.columbia.edu |
| Cezary **Migaszewski**, Poland | migaszewski@astri.umk.pl |
| Max **Millar-Blanchaer**, Canada | maxmb@astro.utoronto.ca |
| Julien **Milli**, France | julien.milli@obs.ujf-grenoble.fr |
| Caroline **Morley**, USA | cmorley@ucolick.org |
| Katie **Morzinski**, USA | ktmorz@arizona.edu |
| Fatemeh **Motalebi**, Switzerland | fatemeh.motalebi@unige.ch |
| Matthias **Müller**, Germany | mmueller@aip.de |
| Ruth **Murray-Clay**, USA | rmurray-clay@cfa.harvard.edu |
| Erick **Nagel**, Mexico | erick@astro.ugto.mx |
| Valerio **Nascimbeni**, Italy | valerio.nascimbeni@unipd.it |
| Henry **Ngo**, USA | hngo@caltech.edu |
| Eric **Nielsen**, USA | enielsen@ifa.hawaii.edu |
| ke **Nordlund**, Denmark | aake@nbi.dk |
| Jack **O'Malley-James**, United Kingdom | jto5@st-andrews.ac.uk |
| Chris **Ormel**, USA | ormel@astro.berkeley.edu |
| Mayra **Osorio**, Spain | osorio@iaa.es |
| Rahul **Patel**, USA | rahul.patel.1@stonybrook.edu |
| Jenny **Patience**, USA | jennifer.patience@asu.edu |
| Matthew **Penny**, USA | penny@astronomy.ohio-state.edu |
| Marshall **Perrin**, USA | mperrin@stsci.edu |
| Cristobal **Petrovich**, USA | cpetrovi@princeton.edu |
| Neil **Phillips**, Chile | nphillip@alma.cl |
| Rafael **Pinotti**, Brazil | rpinotti@astro.ufrj.br |
| Giampaolo **Piotto**, Italy | giampaolo.piotto@unipd.it |
| Ana-Maria **Piso**, USA | apiso@cfa.harvard.edu |
| Ralph **Pudritz**, Canada | pudritz@mcmaster.ca |


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| | |
|---|---|
| Chunhua **Qi**, USA | cqi@cfa.harvard.edu |
| Andreas **Quirrenbach**, Germany | A.Quirrenbach@lsw.uni-heidelberg.de |
| Roman **Rafikov**, USA | rrr@astro.princeton.edu |
| Abhi **Rajan**, USA | arajan6@asu.edu |
| Julien **Rameau**, France | julien.rameau@obs.ujf-grenoble.fr |
| Emily **Rauscher**, USA | rauscher@astro.princeton.edu |
| Francoise **Remus**, France | francoise.remus@obspm.fr |
| Elisabetta **Rigliaco**, USA | rigliaco@lpl.arizona.edu |
| Paul B. **Rimmer**, United Kingdom | pr33@st-andrews.ac.uk |
| Adam **Ritchey**, USA | aritchey@astro.washington.edu |
| Timothy J. **Rodigas**, USA | rodigas@as.arizona.edu |
| Leslie **Rogers**, USA | larogers@caltech.edu |
| Katrin **Ros**, Sweden | katrin.ros@astro.lu.se |
| Katherine **Rosenfeld**, USA | krosenfeld@cfa.harvard.edu |
| John **Rostron**, United Kingdom | J.W.Rostron@warwick.ac.uk |
| Raquel **Salmeron**, Austalia | raquel@mso.anu.edu.au |
| Graeme **Salter**, Australia | g.salter@unsw.edu.au |
| Dmitry **Savransky**, USA | savransky1@llnl.gov |
| Gerald H. M. **Schieven**, Canada | gerald.schieven@nrc-cnrc.gc.ca |
| Hilke **Schlichting**, USA | hilke@ucla.edu |
| Cory **Shankman**, Canada | cshankm@uvic.ca |
| Andrew **Shannon**, United Kingdom | shannon@ast.cam.ac.uk |
| Evgenya **Shkolnik**, USA | shkolnik@lowell.edu |
| Mar **Sierra**, Spain | Mar.Sierra@sciops.esa.int |
| Jacob **Simon**, USA | jbsimon@jila.colorado.edu |
| Niki **Sipos**, Switzerland | siposn@phys.ethz.ch |
| Andy **Skemer**, USA | askemer@gmail.com |
| Ian **Skillen**, Spain | ian.skillen@gmail.com |
| Alexis **Smith**, Poland | amss@camk.edu.pl |
| Craig **Stark**, United Kingdom | crs21@st-andrews.ac.uk |
| Christopher **Stark**, USA | cstark@dtm.ciw.edu |
| Elad **Steinberg**, Israel | elad.steinberg@mail.huji.ac.il |
| Kate **Su**, USA | tinnin@as.arizona.edu |
| Motohide **Tamura**, Japan | motohide.tamura@nao.ac.jp |
| Stuart F. **Taylor**, Hong Kong | astrostuart@gmail.com |
| Susan **Terebey**, USA | sterebe@calstatela.edu |
| Johanna **Teske**, USA | jteske@as.arizona.edu |
| Philippe **Thebault**, France | philippe.thebault@obspm.fr |
| Feng **Tian**, China | tianfengco@gmail.com |
| Chris **Tinney** , Australia | c.tinney@unsw.edu.au |
| Amaury **Triaud**, Switzerland | amaury.triaud@unige.ch |
| Trifon **Trifonov**, Germany | ttrifono@lsw.uni-heidelberg.de |
| Anjali **Tripathi**, USA | atripath@cfa.harvard.edu |
| Ana **Uribe**, USA | auribe@oddjob.uchicago.edu |
| Nienke **van der Marel**, Netherlands | nmarel@strw.leidenuniv.nl |
| Matthijs **van der Wiel**, Canada | matthijs.vanderwiel@uleth.ca |
| Arthur **Vigan**, France | arthur.vigan@oamp.fr |
| Simon **Walker**, United Kingdom | simon.walker@warwick.ac.uk |
| Kimberly **Ward-Duong**, USA | kwardduo@asu.edu |
| Alycia **Weinberger**, USA | weinberger@dtm.ciw.edu |
| Peter **Wheatley**, United Kingdom | P.J.Wheatley@warwick.ac.uk |
| Sloane **Wiktorowicz**, USA | sloanew@ucolick.org |
| David **Wilner**, USA | dwilner@cfa.harvard.edu |
| Rob **Wittenmyer**, Australia | rob@phys.unsw.edu.au |
| Schuyler **Wolff**, USA | swolff@pha.jhu.edu |
| Yanqin **Wu**, Canada | wu@astro.utoronto.ca |
| Mark **Wyatt**, United Kingdom | wyatt@ast.cam.ac.uk |
| Ji-Wei **Xie**, Canada | jwxie@astro.utoronto.ca |
| Chao-Chin **Yang**, Sweden | ccyang@astro.lu.se |
| Xiaojia **Zhang**, China | xiaojia.f.zhang@gmail.com |
| Xiaochen **Zheng**, China | x.c.zheng1989@gmail.com |
| Alice **Zurlo**, France | alice.zurlo@oamp.fr |


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# Address from the Local & Science Organizing Committee Chairs

Dear colleagues,

When we began to plan this meeting, we anticipated approximately 200 attendees might come to Victoria, British Columbia to enjoy a joint meeting of "planet hunters" with those who study the processes that form planets in disks. We clearly underestimated the appeal such a meeting, of Victoria, or both. We had to raise the cap on the total number of registrants – twice – finally reaching 250, with interest in joining a wait list persisting until just weeks before the meeting.

The result of all our preparations was a spendid meeting with 54 science talks and 168 poster presentations. Though the delegates enjoyed a week of glorious sun in Victoria, the sessions were well attended to the very end.

This meeting would not have been the success it was without the dedicated efforts of the Science and Local Organizing Committees. The Science Organizing Committee selected invited speakers and ranked over 180 abstracts submitted for contributed talks to select 46 for the oral program. In all, 219 scientists presented reviews or their latest results at the meeting. The completed program provided a healthy balance of speakers based on science, gender, geography and professional status; 60% of the contributed talks were given by students or postdoctoral fellows. The Science Organizing Committee, along with the Local Organizing Committee, also read and provided comments to the proceedings' contributors, which helped ensure clarity of content and consistency of format for all the articles.

The Local Organizing Committee was distributed, with major organizational effort provided in Victoria by members at NRC and in Toronto, by members at the Dunlap Institute for Astronomy & Astrophysics. Particular acknowledgement is owed to Brenda Parrish (NRC), Alice Chow (DI) and Mark Booth (U. Vic/NRC), all of whom were able to rise to the call whenever their assistance was needed. Marlene Olsen and Jason Shrivell (NRC) also provided on-site support during the meeting. Acknowledement is also due for the efforts of Chris Sasaki (DI) who designed and maintained the webpage, registration and abstract forms and Gary Berry (NRC) who managed all the computing support during the meeting. Special thanks to Christian Marois, who recorded all the talks and made them available online, James Di Francesco who coordinated press during the meeting, and Gerald Schieven who assembled the program. JJ Kavelaars (NRC) helped organize the public talk and has created a permanent DOI for the meeting presentations and videos (10.11570/13.0003) to which we refer anyone interested in these records from the meeting.

The public talk was given by Prof. Debra Fischer (Yale U.), and presented jointly by the meeting organizers and the Royal Astronomical Society of Canada's Victoria chapter. We gratefully acknowledge the RASC's efforts in providing financial support and advertizing for Debra's excellent talk, entitled "HABITABLE WORLDS: The Search Continues".

The delegates selected their top three student talks and posters at the end of the meeting. The competition was strong, given the high quality of oral and poster presentations. The

awardees were Joe Llama (St Andrews) and Julien Faure (CEA/Saclay) for Best Student Talk and Best Student Poster, respectively.

We also wish to thank all the organizations that provided generous financial support to the meeting: the International Astronomical Union, the Dunlap Institute for Astronomy & Astrophysics, the National Research Council of Canada, the University of Victoria, Gemini Observatory and the Royal Astronomical Society of Canada's Victoria chapter.

*Brenda C. Matthews (LOC Chair) & James R. Graham (SOC Chair)*
*Victoria, BC, Canada & Berkeley, CA, USA, 9 September 2013*