A pro-am workshop in London, 2018 May 10–11:

'New Views of Jupiter': Pro-Am collaborations during and beyond the NASA *Juno* mission

This workshop was hosted by the Royal Astronomical Society in Burlington House, London, and on the second day in the equally handsome and historic rooms of the Linnean Society next door. It was organised by Dr John Rogers (BAA) and Dr Leigh Fletcher (University of Leicester), as a follow-up to the workshop in Nice two years earlier [BAA *Journal* vol.126 p.199, 2016]. The workshop was principally funded by EuroPlanet with funding from the European Union, with a contribution from the European Research Council, and the RAS provided the venue and staff free of charge.

The workshop was designed to promote collaboration between amateur astronomers and professional space scientists in studies of the atmosphere of Jupiter, in support of the ongoing NASA *Juno* mission and future ground-based studies. It brought together 33 amateurs (some who take images, some who analyse and interpret them, and some who develop software tools), and 17 professionals. Participants were principally from Europe including the UK, but included four leading amateurs from outside Europe, and three senior *Juno* team members from the USA.

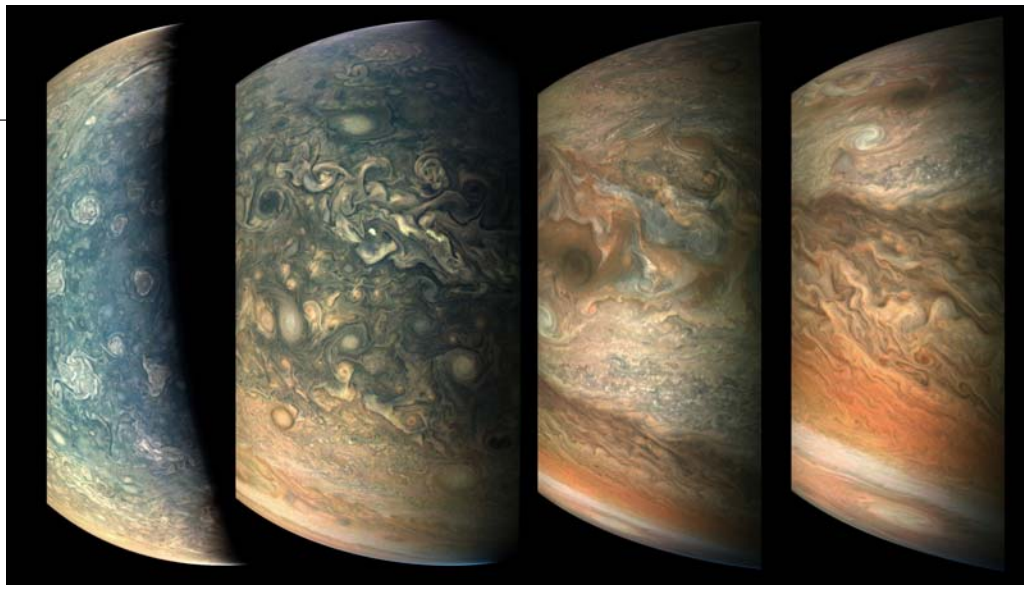
This summary cannot mention all the talks, but the workshop Web page contains virtually all of them in full, as well as a summary of the scientific content and the discussions, and videos and photos of the event: **https://www2.le.ac.uk/departments/physics/people/leighfletcher/ras-juno-europlanet-meeting-2018**

The first morning was devoted to reviews of the results so far from *Juno*, given by leading *Juno* scientists and their collaborators. Dr Scott Bolton, Principal Investigator of the project, summarised the mission and its conclusions so far. He included results from *Juno*'s Microwave Radiometer, which is revealing unexpectedly complex circulation patterns below the visible clouds.

Among *Juno*'s main goals are the mapping of Jupiter's gravitational and magnetic fields. Dr Tristan Guillot (Obs. de Nice, France) explained the gravitational results, which have answered a long-standing question: the major jetstreams that we see at Jupiter's cloud tops extend deep down, to a depth of about 3000km, but no further. The fluid planet at deeper lev-

1.Jean-Luc Dauvergne 2.Glenn Orton 3.Peter Rosen 4.Manos Kardasis 5.Clyde Foster 6.Silvia Kowollik 7.Leigh Fletcher 8.Ricardo Hueso 9.Simon Kidd 10.Tirs Abril 11.Christopher Go 12.Joaquin Camarena 13. Agustin Sanchez-Lavega 14.Josep Soldevilla 15.Paulo Casquinha 16.John Rogers 17.Peter Edwards 18.John Sussenbach 19.Martin Lewis 20.Patrick Irwin 21.Candy Hansen 22.Ashwin Braude 23.Constantin Sprianu 24.Kuniaki Horikawa 25.Michel Jacquesson 26.Anthony Wesley 27.Sean Doran 28.Padma Yanamandra-Fisher 29.Peter Lawrence 30.Emil Kraaikamp 31.Matt Brealey 32.Gerald Eichstaedt 33.Marc Delcroix 34.Arrate Antuñano 35.Padraig Donnelly 36.Alexei Pace 37.Johan Warell 38.Christophe Pellier 39.Mike Foulkes 40.Manuel Scherf 41.Marco Vedovato 42.Miguel Araújo 43.Scott Bolton

The workshop participants in the courtyard at Burlington House. ***Image by Manos Kardasis.***



A series of images from JunoCam at perijove 8 (2017 Sep 1), ranging from one directly over the north pole (*left*) to one directly over the south pole (*far right*). *NASA/SwRI/MSSS/Gerald Eichstädt/John Rogers.*

els appears to be rotating as a rigid body, denser toward the centre but without a discrete boundary between the core and overlying envelope. Dr Chris Jones (Univ. of Leeds, UK) described how the magnetic field arises from much slower convection in the deep conducting fluid, and its complex structure being mapped by *Juno*. Dr Alessandro Mura (JIRAM team, Italy) showed results from the Jupiter Infrared Auroral Mapper, including spectacularly detailed maps and animations of Jupiter's aurorae and circumpolar cyclones.

JunoCam's beautiful images and discoveries were described by the team leader, Dr Candy Hansen (Planetary Science Institute, Arizona, USA). She includes the amateur astronomical community in the 'JunoCam virtual imaging team'. Drs Bolton, Hansen and Orton all emphasised the important role that the amateur community has played in assisting the *Juno* project in these discoveries, with Dr Bolton declaring 'It's truly a collaboration; you are definitely part of the *Juno* team.'

Lunch in the handsome premises of the Linnean Society. *Photo: John Rogers.*

In the afternoon, Gerald Eichstädt (Germany), who (as an amateur) has taken on the work of full-quality processing and mapping the JunoCam images, showed how he can now produce animated displays of wind fields from images taken only minutes apart.

Three talks then considered recent studies of visible atmospheric features, including comparison of ground-based with JunoCam images, by Dr Agustin Sanchez–Lavega and Dr Ricardo Hueso (Universidad del Pais Vasco, Bilbao, Spain) and Dr John Rogers (BAA, UK). The first day ended with Christopher Go (Philippines) explaining his techniques for getting the best ground-based images – a valuable set of tips for imagers, worth viewing in the online version of this talk.

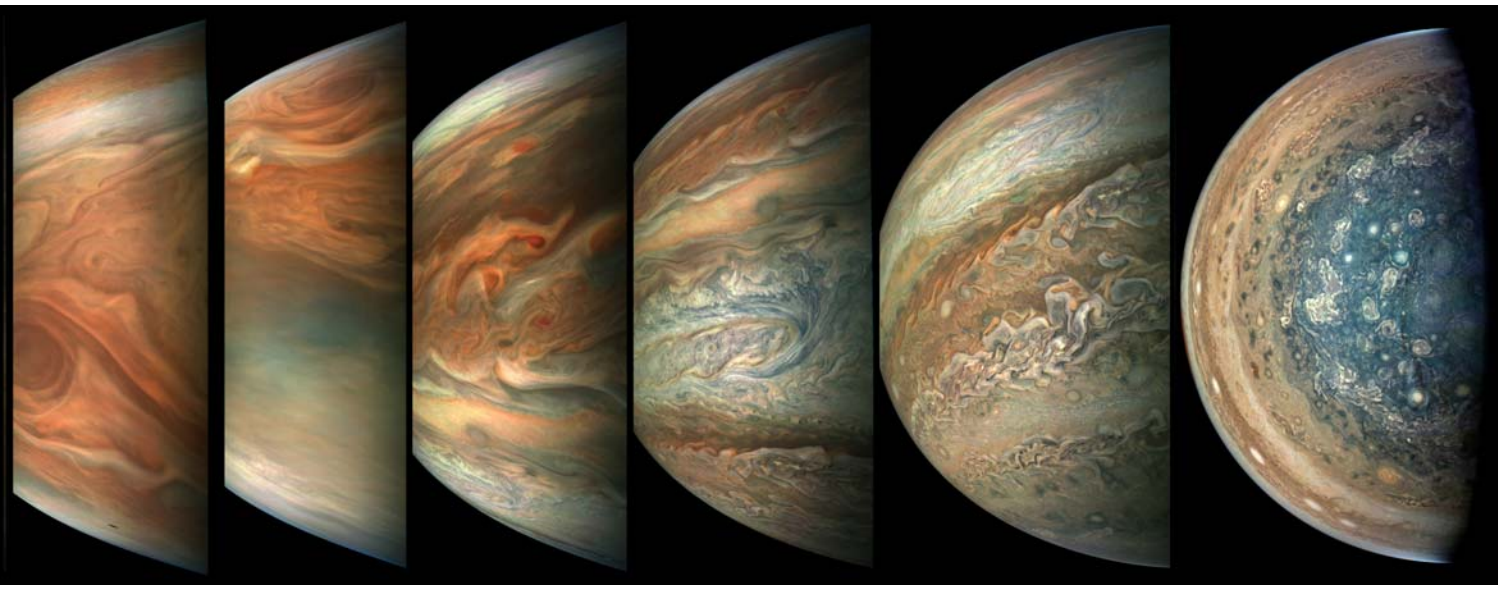
Participants also viewed historic drawings and notebooks of Jupiter by famous observers of the 19th and early 20th century, from the archives of the RAS and the BAA, displayed in the RAS Library. Many participants were also able to take a guided tour of the Royal Society premises nearby, with views of further precious archives.

The second morning was devoted to nine amateur speakers explaining some of their latest techniques in imaging and image analysis, including Anthony Wesley (Australia) and Clyde Foster (South Africa). Jean–Luc Dauvergne (France) described a promising new Adaptive Optics system being developed on the 1-metre telescope at the Pic du Midi. Kuniaki Horikawa (Japan) reported the first visible correlate of the 90-day oscillation of the Great Red Spot, from archival amateur images. Emil Kraaikamp (Netherlands) discussed innovations that he is developing in his *AutoStakkert!* software.

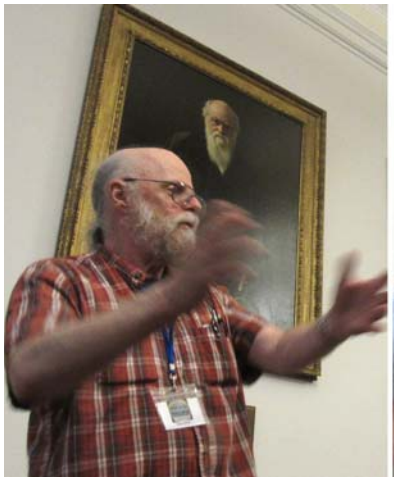
The session concluded with a discussion about optimising procedures for amateur imaging and for pro-am collaboration, and imagers are advised to look at this in the review of the meeting online [URL above]. It is recommended that images should be submitted with north up, and with standard PVOL filenames.

The final afternoon session considered other collaborations and future directions. Dr Glenn Orton (NASA-JPL, USA) is the coordinator of *Juno*-supporting projects by professional astronomers as well as the amateur community, and gave a resumé of these projects. In orbit, they range from the Chandra X-ray Observatory to the Hubble Space Telescope; on the ground, they range from imaging with giant telescopes, to radio-wave observations from the VLA and ALMA. Drs Orton and Hansen also revealed the *Juno* team's new plans for the remainder of *Juno*'s 34 orbits, now approved by NASA, culminating in a fatal plunge into Jupiter's atmosphere at the end of the 35th orbit on 2021 July 30. Dr Leigh Fletcher (University of Leicester, UK) showed the remarkable potential of ground-based infrared observations, and of two forthcoming space missions: NASA's

Left:* Dr Scott Bolton (Juno PI) giving a toast to us all: 'One team'. *Paulo Casquinha
Centre:* Dr Candy Hansen (JunoCam PI) studying 130-year old drawings. *John Rogers
Right:* Michel Jacquesson and Marco Vedovato of the *JUPOS* team. *John Rogers



John Rogers & Leigh Fletcher: a pair of contented organisers. *Peter Rosen*



Dr Glenn Orton channelling Charles Darwin. *John Rogers*

Martin Lewis, Simon Kidd & Peter Edwards, plus Alfred Russell Wallace (with beard). *John Rogers*

James Webb Space Telescope, and ESA's Jupiter Ice Moons Explorer (JUICE). Lessons learned from the successful pro-am collaboration for *Juno* will be applied in these future projects.

Finally, some short talks showed how people familiar with advanced image processing systems outside the astronomical community can make great contributions. The concluding presentation was from Seán Doran (UK), who showed a 7-minute video (with music) of *Juno*'s flights over Jupiter, compiled from his animations of Gerald Eichstädt's JunoCam images (some of which can be found on *YouTube*). It left participants on an emotional high at seeing the sheer splendour of Jupiter's cloudscapes, as revealed by JunoCam and by pro-am collaboration in processing the images.

Amateur imagers Christopher Go (left) and Anthony Wesley with Dr Candy Hansen. *John Rogers*

The workshop left us with a clear feeling that we – including the many amateur imagers who were not at the workshop – are all participants in an exciting research collaboration. *Juno*'s instruments are continuing to work well, so the collaboration involving JunoCam is expected to continue for the remaining three years of the mission. It was also evident that the mission has incentivised other professional ground-based and space-based research on Jupiter which will also benefit from collaboration with amateurs as discussed at the workshop.

John Rogers & Leigh Fletcher