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Characterization of Jupiter's Atmosphere by Juno and a Network of Earth-Based Observations

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Abstract

A key part of the Juno mission from the very beginning has been the involvement and coordination of supporting Earth-based observations, both from the professional and amateur communities. These have supplemented Juno's science return and even guided spacecraft operations and planning. In parallel to these efforts, quasi-continuous observations of Jupiter by a network of amateur astronomers and their analysis of JunoCam observations in the sub-micron range have greatly aided their interpretation. An overview of these results will be presented.

1. Introduction

The Juno mission is coordinating an active program of Earth-based support from both professional and amateur observers and space scientists. The additional observations provided by Earth-based stations include Earth-proximal, Earth-orbiting platforms, as well as ground-based telescopes operated by professional astronomers and citizen scientists. The supporting observations (1) provide additional spatial context that expands the area covered by often narrow spatial coverage of Juno's instruments, (2) document the evolution of features that Juno only observes in a single "snapshot", and (3) cover spectral regions not in the range of Juno's set of instruments. Observations by amateur astronomers provide key contributions to the first two categories, expanding the spatial and temporal context of Juno's observations. Furthermore, work by citizen scientists has been a key to understanding details of Juno and supporting observations, particularly in the visible range.

2. Space-based and large ground-based observatory results

Observations of Jupiter in support of the Juno mission from the professional community cover the spectrum from the X-ray to the radio. Over sixty observing groups are involved in this observing campaign, with a coordination of the results between contributors made through emails and posting on an interactive web site that can be accessed by the investigators and is mirrored on a web site available to the public: https://www.missionjuno.swri.edu/planned-observations.

Among the earliest of these were observation of Jovian auroral phenomena at X-ray, ultraviolet and infrared wavelengths and measurements of Jovian synchrotron radiation from the Earth simultaneously with the measurement of properties of the upstream solar wind. Other observations of significance to the magnetosphere measured the mass loading from Io by tracking its observed volcanic activity and the opacity of its torus. Observations of Jupiter's neutral atmosphere included observations of reflected sunlight from the near-ultraviolet through the near-infrared and thermal emission from 5 microns through the radio region. The point of these latter measurements is to relate properties of the deep atmosphere that are the focus of Juno's mission to the state of the "weather layer" at much higher atmospheric levels. We will summarize the results of measurements during the approach phase, as well as observations made by Juno and the supporting campaign during Juno's perijoves 1 through 14.

3. Small ground-based observatory results

Besides a global network of professional astronomers, the Juno mission also benefits from the enlistment of a network of dedicated amateur astronomers, "citizen scientists" who provide a quasi-continuous picture of the evolution of features observed by Juno's instruments. This complements the broad spectral network provided by professional astronomers at a much lower observational cadence. The quasi-continuous observing record is extremely important to understand the time evolution of atmospheric features that Juno observes, as well as characterizing the spatial context of features observed that have not been covered by the professional community because of observing restrictions, such as solar-avoidance requirements.

4. Public involvement with Juno data.

These observations are reported on the Mission Juno web site as a part of an outreach program [1]. The original goals of the outreach program involved allowing the public: to choose where to point the JunoCam visible camera and to process the data we get. To achieve this, four steps were envisioned: planning, discussing, voting and processing. The planning step is the one that involves observing Jupiter to characterize the state of Jupiter's cloud structure and dynamics. The images uploaded are then subject to discussion - commenting on the background and merits of cloud features as objects to be imaged by JunoCam. Voting involves selection of features of highest priority to be observed. JunoCam images are made available on our web site within 2-3 days of their reception from the spacecraft. The public is then free to download the images, processing them in various ways, and uploading them. The processed images have ranged from fanciful to seriously quantitative. The results of all these steps are posted on the JunoCam sites that is linked from the general Mission Juno site, although voting is no longer a part of the process: https://www.missionjuno.swri.edu/junocam/. Because of the restricted geometry of the orbits of the mission through early 2021 – covering up to perijove 33 (Table 1), the selection of regions to observe is extremely limited. As a result, the voting process has been suspended. However, it has been replaced.

5. Analysis: the "Think Tank"

A new addition to the JunoCam page has been activated, which involves the quantitative analysis of JunoCam data, with the title "Think Tank". There, threads of very early to very mature areas of JunoCam results are shown, such as "Mesoscale Waves" and "Hazes", as well as the results of specific orbits. In this way, the way in which scientific research proceeds is made available to the public. Examples will be discussed.

Table 1. Properties of Juno mission perijoves through perijove 33 (PJ33) of the continuation mission.

PJ	Date	Solar Elong.		PJ	Date	Solar Elong.
1	2016/8/27	23ºE		18	2019/2/12	63ºW
2	2016/10/19	17ºW		19	2019/4/6	112ºW
3	2016/12/11	61ºW		20	2019/5/29	166ºW
4	2017/2/2	110ºW		21	2019/7/21	137ºE
5	2017/3/27	167ºW		22	2019/9/12	88ºE
6	2017/5/19	136ºE		23	2019/11/3	43ºE
7	2017/7/11	86ºE		24	2019/12/26	1ºW
8	2017/9/1	43ºE		25	2020/2/17	41ºW
9	2017/10/24	2ºE		26	2020/4/10	85ºW
10	2017/12/16	40ºW		27	2020/6/2	135ºW
11	2018/2/7	86ºW		28	2020/7/26	159ºW
12	2018/4/1	139ºW		29	2020/9/16	113ºE
13	2018/5/24	164ºE		30	2020/11/8	66ºE
14	2018/7/16	139ºE		31	2020/12/30	25ºE
15	2018/9/7	64ºE		32	2021/2/21	18ºW
16	2018/10/29	22ºE		33	2021/4/15	105ºW
17	2018/12/21	20ºW				

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