SOFIA/FORCAST Observations of Jupiter:
The South Equatorial Belt Fade/Revival Cycle

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The SEB Cycle

Jupiter's South Equatorial Belt (SEB) has a highly variable appearance. It typically has a dark coloration and numerous convective storms, often to the west of the Great Red Spot. Infrared signatures of ammonia ice are spatially uncommon on Jupiter (Baines et al. 2002, Wong et al. 2004), but the SEB is one area where convective activity produces clouds with ammonia ice signatures.

In 2010, the SEB had an atypical white, zone-like appearance. Based on past cycles (Rogers 1995), observers anticipated the outbreak of large convective storms, whose activity would "revive" the SEB and restore its color. Indeed outbreaks started the revival in late 2010, and the SEB has by now returned to its normal state.

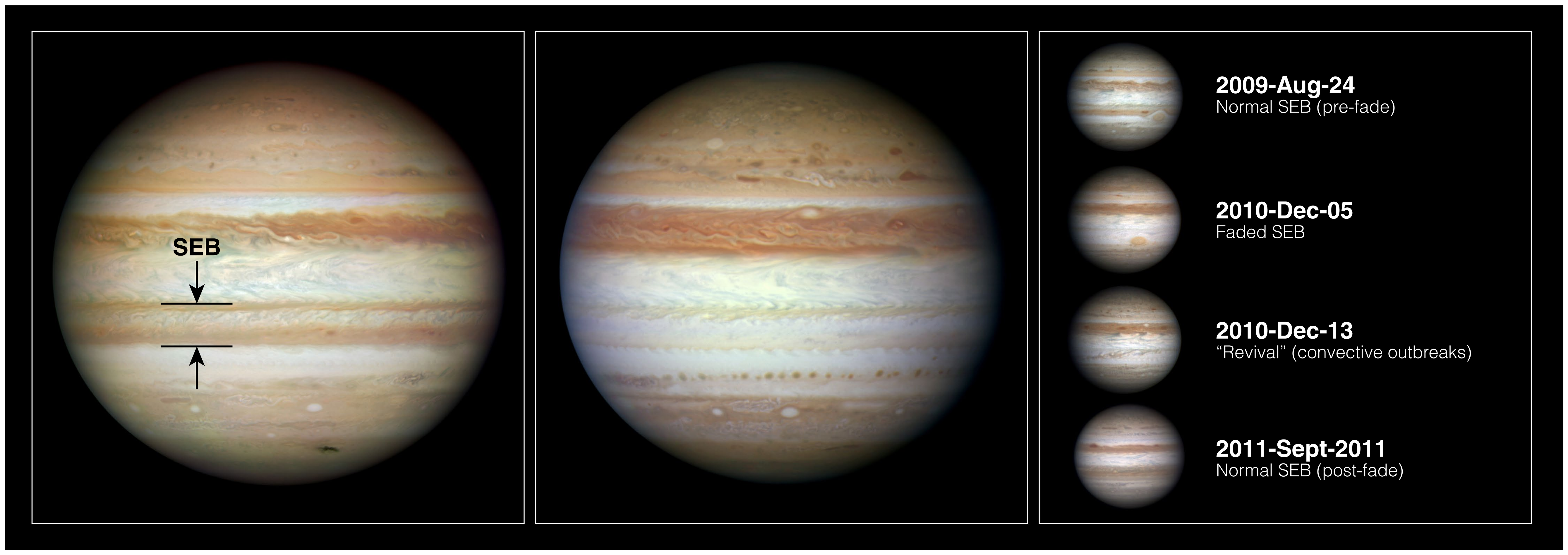
SEB fade/revival cycles occur at irregular intervals, and the underlying causes of the cycle are unknown. The 2009-2011 cycle is the first to be extensively observed in the thermal infrared. In this wavelength regime, unlike in the visible region of the spectrum, atmospheric conditions can be retrieved to determine physical and chemical changes associated with the SEB cycle. We need this quantitative measure of atmospheric properties during the cycle in order to determine what drives this dramatic Jovian climate phenomenon. Dynamical simulations of giant planet convection include an episodic convective pattern, with a thickening stratiform upper cloud deck prior to the outbreak of deep convection (Sugiyama et al. 2011).

Mid-infrared imaging with VLT/VISIR has already revealed intriguing details of the fade portion of the cycle (Fletcher et al. 2011). In particular, widespread deep cloud opacity increased before the visible whitening of the SEB fade took place. The faded SEB itself was a result of increased thickness of the upper tropospheric cloud, but not a significant increase in the elevation of the cloud layer. Tropospheric temperatures at altitudes above the upper cloud deck did not show any variation associated with the SEB fade.

2009-July-23 HST/WFC3
Initial "normal" SEB state

2010-June-07 HST/WFC3
Faded SEB state

2009-2011 Ground-based observations
Full SEB fade/revival cycle (images by Chris Go)



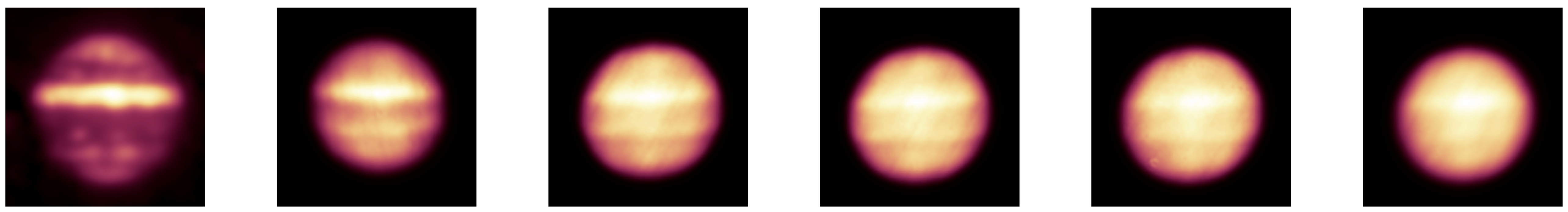
Visible-light images of Jupiter during the SEB fade/revival cycle. **LEFT:** The first on-orbit science observation taken with the Wide Field Camera 3 on Hubble show the SEB in its normal orange/dark state. A southern-hemisphere impact debris field is also visible. **CENTER:** This WFC3 image was taken during the faded state of the SEB in 2010. There are no more recent Hubble images of Jupiter. **RIGHT:** Amateur observations of Jupiter capture data at a much more rapid cadence. These images from Chris Go (Cebu, Philippines) show the complete cycle of fade and revival of the SEB.

SOFIA/FORCAST data

SOFIA/FORCAST data, taken in late 2010 near the end of the SEB fade event, will be useful to constrain the changes associated with the revival of the SEB. Here we present a very preliminary report on the data, emphasizing its value in characterizing the SEB cycle.

Filtered images were obtained at wavelengths from 5.36–37.14 µm. In most filters, observations were carried out over a five-hour period that allowed more than one full hemisphere of the planet to be mapped. Central meridian longitudes (CMLs) are listed for each filter at the right.

Below, a FORCAST zonal average at 5 µm during the SEB's faded state is compared with IRTF images from 2005, during the SEB's normal state. The thicker clouds in the SEB fade suppressed deeper thermal emission, transforming the SEB from one of the brightest (at 5-µm) regions of the planet to one of the darkest regions.



5.36 µm
2010-Dec-08
2:10 to 6:50 UT
CML 133°–302°

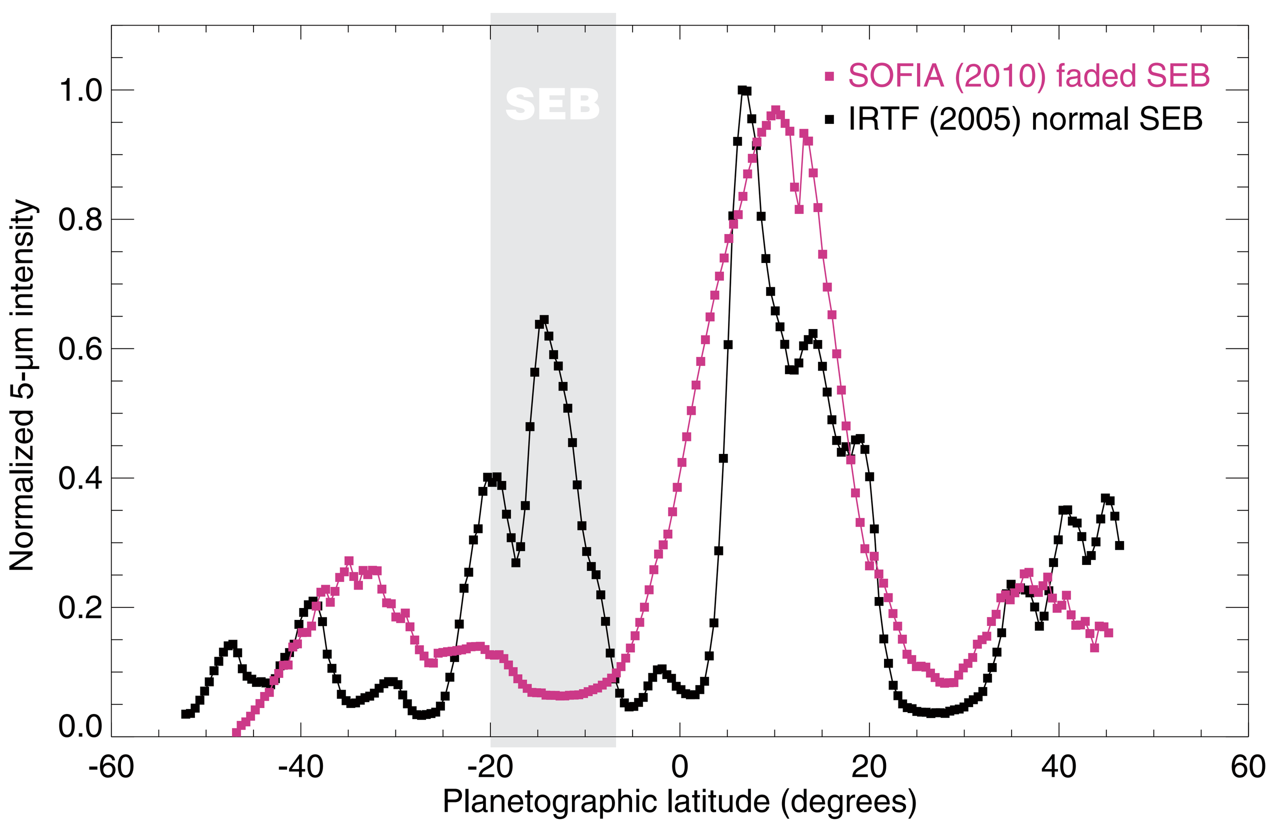
11.09 µm
2010-Dec-08
2:12 to 6:51 UT
CML 134°–303°

19.71 µm
2010-Dec-08
2:06 to 6:47 UT
CML 130°–300°

24.24 µm
2010-Dec-08
2:08 to 6:49 UT
CML 132°–302°

31.46 µm
2010-Dec-08
2:08 to 4:05 UT
CML 132°–202°

37.14 µm
2010-Dec-08
2:06 to 4:08 UT
CML 130°–204°



Normalized zonal-average 5-µm radiances from single images taken with SPEX on the IRTF and FORCAST on SOFIA. The increased cloud density present during the faded state of the SEB prevents the escape of thermal radiation from deeper levels. Brightest regions contain thermal emission from as deep as 8 bar (Roos-Serote et al. 2004).

Future work

SOFIA data will play a valuable role in characterizing the intriguing SEB fade/revival cycle. The current cycle is unique in that extensive thermal infrared observations from SOFIA and ground-based telescopes enable us to retrieve temperature, composition, and aerosol properties at different stages of the cycle.

Specifically, our next steps will include:

- Improve the calibration of the FORCAST data (geometric distortion, flat-fielding, absolute calibration)
- Navigation of the Jupiter images to calculate latitude, longitude, and emission angles for all pixels (Lii et al. 2010)
- Radiative transfer retrieval of atmospheric properties using the NEMESIS optimal estimation retrieval algorithm (Irwin et al. 2008)
- Correlative analysis with ground-based infrared measurements as well as Hubble imaging data

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