Time variation of optical thickness of haze over South Equatorial Belt in 2009-14 apparition of Jupiter

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Abstract

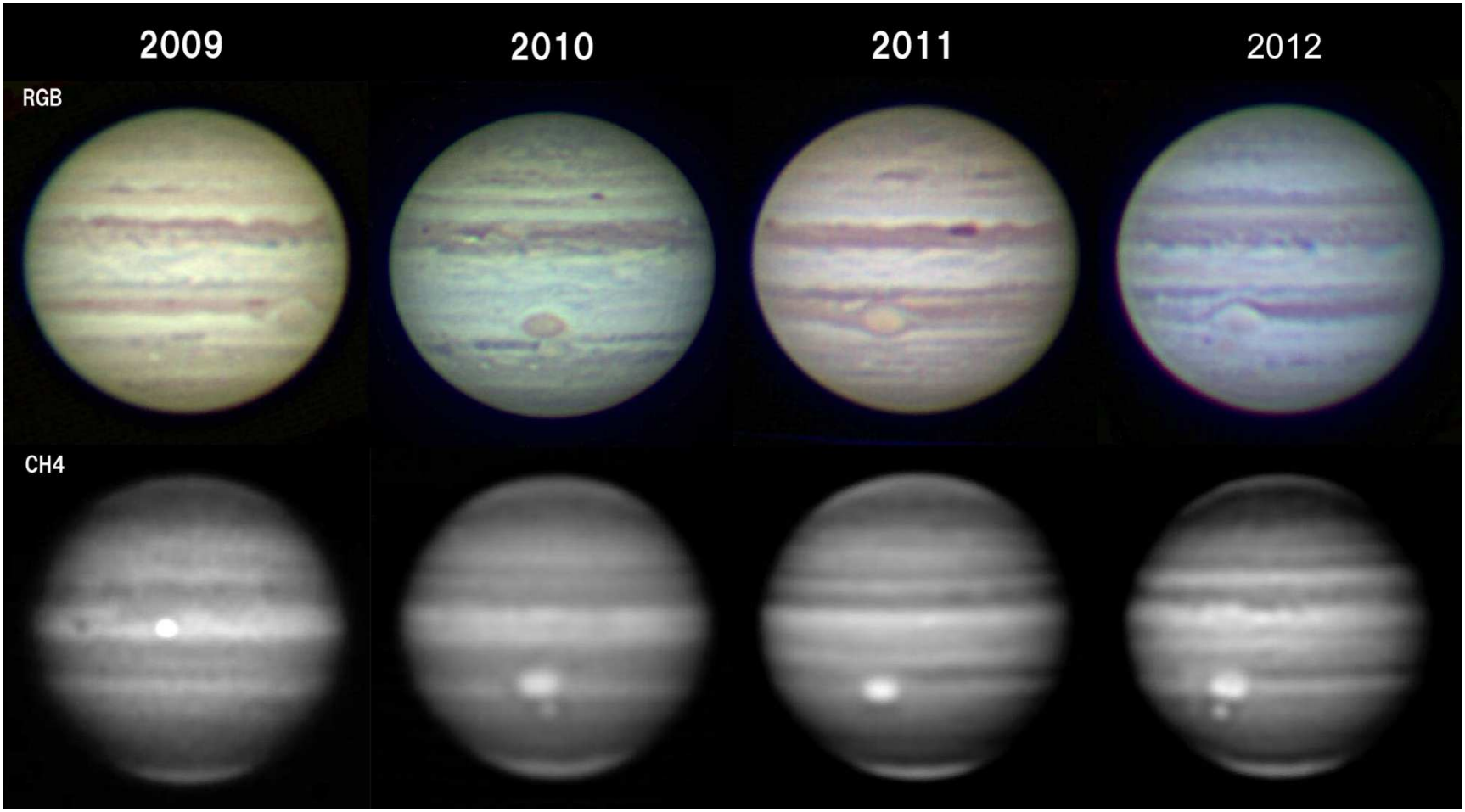
Imaging of Jupiter with 6 filters (RGB, IR continuum, weak and strong Methane band) were carried out using 65cm Zeiss refractor at the Hida Observatory from 2009 to 2014. In this period, the South Equatorial Disturbance occurred in November 2010.

From the center-to-limb profile along the South Equatorial Belt (SEB) in IR continuum, we could detect the variation of the optical depth of haze(τ_h). τ_h was increasing from 2009 to 2010, decreased in 2011 and was increasing from 2011 to 2014.

Comparing the ratio of brightness near central meridian to Io in strong Methane band with that in IR continuum, we could estimate the optical depth of Methane band(τ_{ch4}). The tendency was the same as τ_h. τ_{ch4} shows the thickness of Jovian atmosphere, or the altitude of cloud top.

Our results was expected to provide the clue for the moist convection in SEB including the South Equatorial Disturbance.

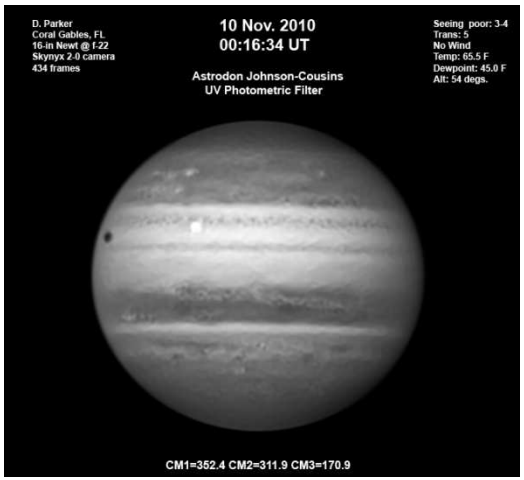
Jupiter in 2009-12

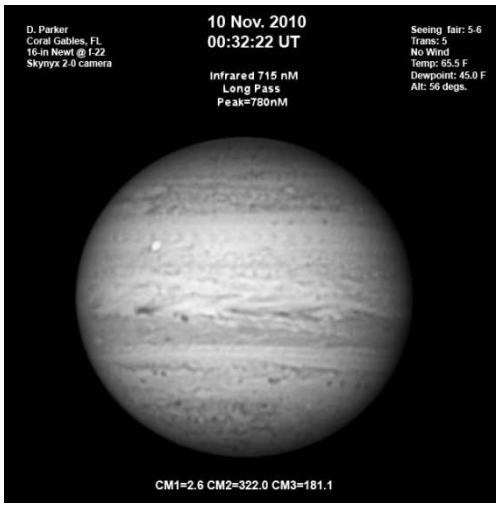


South Equatorial Belt(SEB)

- 2009-14
  - Dark in 2009
  - Bright in RGB but dark in CH4 (2010 September)
    - Disturbance in November
      - Very Bright Spot
      - Revival of dark SEB
  - Dark in 2011-14
- 1990-91
  - Satoh & Kawabata(1994,JGR)
  - Bright in RGB but dark in CH4(1990)
  - Dark in 1991

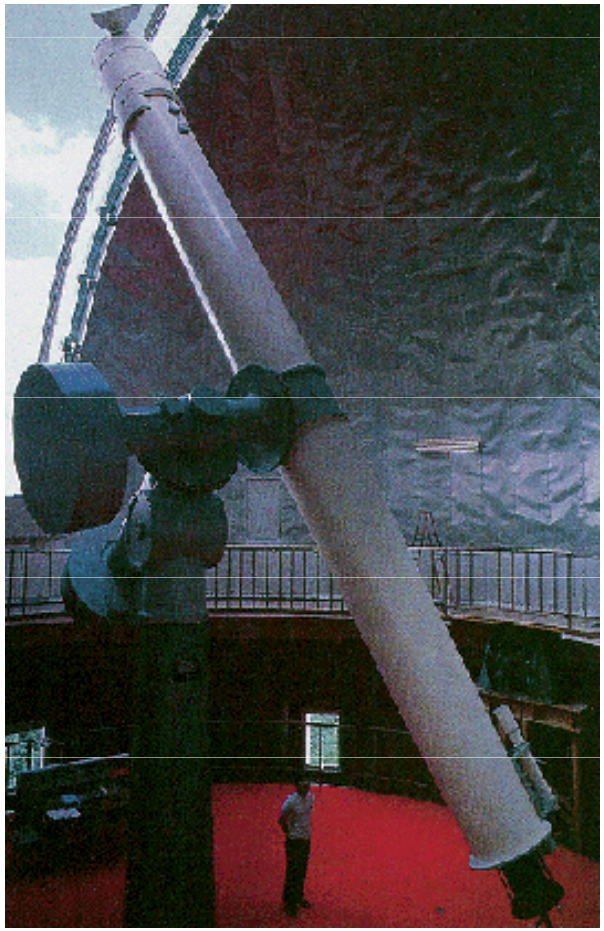
Nov. 10, 2010(South is top) by D. Parker





Telescope

- Main
  - Zeiss 65cm refractor at Hida Observatory
- Sub
  - Meade 30cm Schmidt-Cassegrain



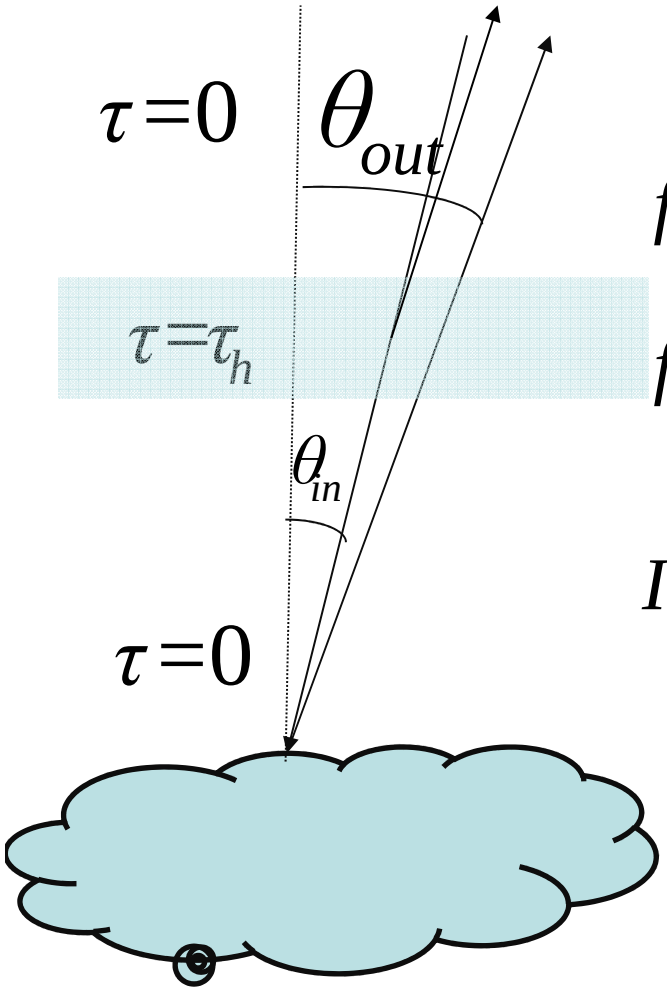
Web Camera

- Lumenera Lu075M
  - Sony ICX424(CCD)
  - 640 × 480 Pixels
- Point Grey Blackfly BFLY-PGE-05S2M-CS
  - Sony ICX693(CCD)
  - 808 × 608 Pixels

Images

- Filters
  - RGB
  - 727nm(weak methane band)
  - 750nm(continuum)
  - 893nm(strong methane band)
- Processing
  - Stacking
  - (Wavelet transformation)
  - (Maximum Entropy Method)

Center-Limb Variation in IR Continuum



$$from\ haze: I_{haze}$$

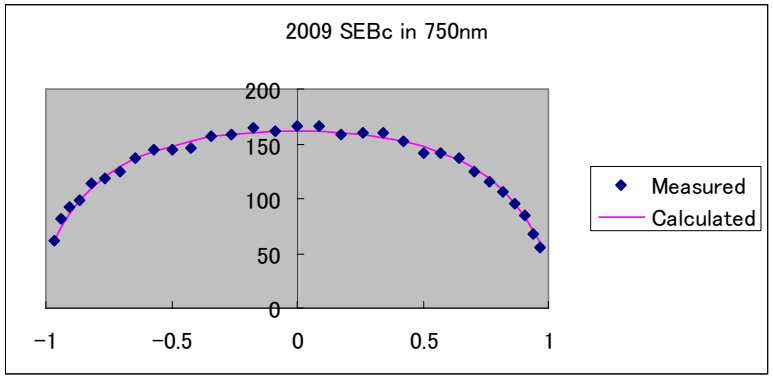
$$from\ cloud: I_{cloud}\exp\left(-\frac{\tau_h}{\cos\theta_{in}}-\frac{\tau_h}{\cos\theta_{out}}\right)$$

$$I_{obs}=I_{haze}+I_{cloud}\exp\left(-\frac{\tau_h}{\cos\theta_{in}}-\frac{\tau_h}{\cos\theta_{out}}\right)$$

Measurements

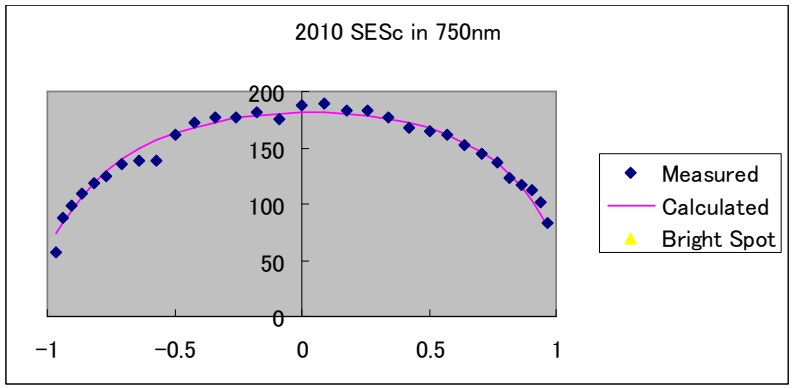
- IR Continuum(750nm)
  - East-west scan in SEB
    - Central meridian -75˚ ~+75˚ (each 5˚)
- Optical thickness of haze(τ_h):assume
  - Calculate Zenith angle of Sun(θ_{in}) and Earth(θ_{out}) at each point
  - Maximum coefficient of determination→ τ_h

Aug. 17, 2009

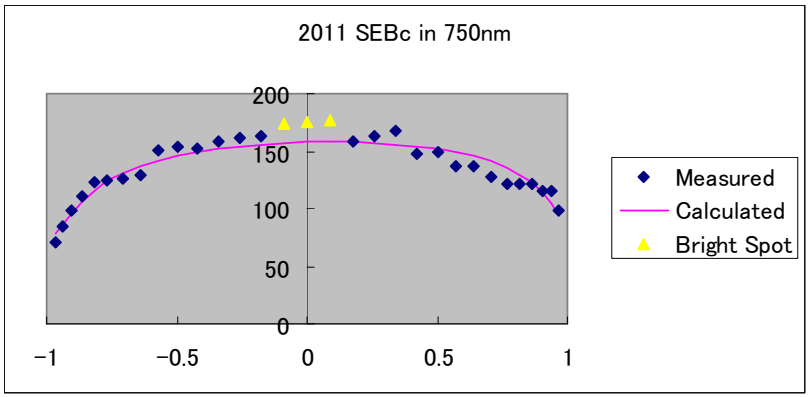


$$\tau_h = 0.44$$

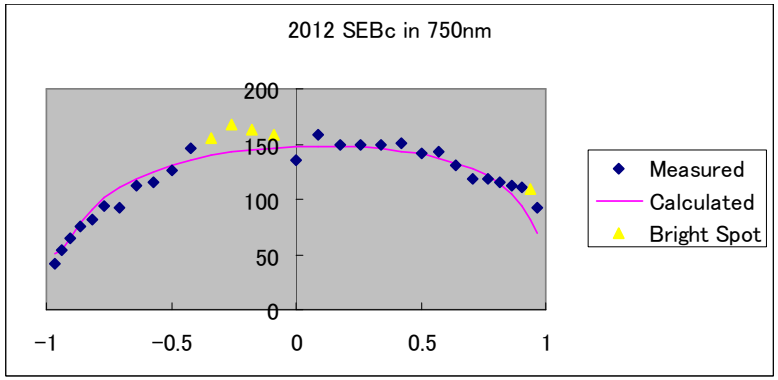
2010 - 2014



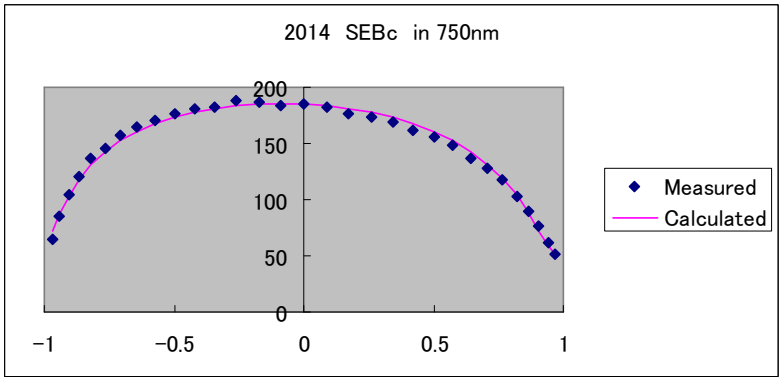
$\tau_h = 0.49$



$\tau_h = 0.35$



$\tau_h = 0.38$



$\tau_h = 0.43$

Brightness Near Central Meridian and Io in 893nm and 750nm

$$\frac{I_{SEB,893}}{I_{IO,893}} = \frac{I_{SEB,750}}{I_{IO,750}} \exp\left(-\frac{\tau_{CH4}}{\cos\theta_{in}} - \frac{\tau_{CH4}}{\cos\theta_{out}}\right)$$

$$I_{SEB,893}, I_{IO,893}, I_{SEB,750}, I_{IO,750} \rightarrow \tau_{\mathrm{CH4}}$$

Results

Date	τ_h	τ_{CH4}	Satoh & Kawabata τ_h	
Aug. 17, 2009	0.44	3.87		
Sep. 4, 2010	0.49	4.20	0.63	1990
Sep. 13, 2011	0.35	3.54	0.51	1991
Sep. 6, 2012	0.38	3.87		
May 2, 2014	0.43			

Summary

- Haze optical thickness(τ_h) was increasing in 2009(0.44) and 2010(0.49).
- τ_h decreased in 2011(0.35).
- τ_h was increasing gradually from 2011 to 2014.
- τ_{CH4} was 4.20 in 2010, 3.54 in 2011.
- In Satoh & Kawabata
  - if haze is thick, cloud top was low.
  - if haze is thin, cloud top is high.

Future work

- Continue imaging Jupiter with 6 filters
- Calculate cloud top height
  - P_2, P_4 in Satoh & Kawabata's Two Cloud Model
  - Time variation of Cloud structure → Clue for Convection in SEB