The Oldest Planetary Astrochemical Mystery, Jupiter’s Great (but Shrinking) Red Spot

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Some Recognizable Objects in our Solar System

Rings of Saturn
Lunar Craters
Martian Polar Caps

Jupiter’s Great Red Spot (GRS)

Galileo (1610)
Hooke (1664)
Cassini (1665)

19th-century observers
Hubble (HST)
Pioneer 10 & 11
Voyager 1 & 2
Galileo
Cassini
New Horizons

The Incredible Shrinking Spot

1890 Simulated
1890
Simulated

2015 Actual

15° \times (1 \text{ year} / 0.5°) = 30 \text{ years}!

Some Background

Not as red as sometimes depicted

Some Proposed Explanations

Tables of R. West et al., 1986 and 2004

1986 → 2016 ??
Proposed Explanations

Carl Sagan (1934-1996)
Bishun Khare (1933-2013)
Harold Urey (1893-1981)
Francis O. Rice (1890-1989)
Rupert Wildt (1905-1976)

Energy – radiation & UV

Some Atmospheric Suspects

$\text{H}_2$, $\text{He}$, $\text{H}_2\text{O}$, $\text{NH}_3$, $\text{NH}_4\text{SH}$

Coloring agents?

Ammonium Hydrosulfide $\text{NH}_4\text{SH}$

... What's Known?

$\text{NH}_3(g) + \text{H}_2\text{S}(g) \rightarrow \text{NH}_4\text{SH}(s)$

crystal structure, density, color, vapor pressure, spectra, reaction products

$\text{NH}_4\text{SH}$

tetragonal, $Z = 2$, $d = 1.18$ g/cm$^3$

Zeit. für Kristall., 1934, 88(2), 97

Who is C. D. West?

1903 born in Glenn Falls, NY

Attended Glenn Falls High School

1924 – Wesleyan Univ., bachelor’s
1929 – Harvard, master’s
1934 – Harvard, Ph.D. (chemistry)

1934 – hired by Edwin Land (Mr. Polaroid)
1941 – World War II

Cutler DeLong West’s war service with Polaroid

Crystal growth … $\text{NaNO}_3$

Life, June 18, 1945
Polaroid PR, ca. 1945
Popular Science, Dec., 1945
"Cutler was always a pleasure"
"kind and very quiet"
“He was said to have more money than Rockefeller, but rode a women’s 3 speed bike.”
"a genius"
“Edward Land’s right hand man.”
(Scott R Chamberlain, Boston Raleigh Users Group)
"rode his beat-up bike to Polaroid every day"
“ate all his meals in the company cafeteria”
"exuded the Polaroid legend of mad scientist”
(Edna Dorfman, artist & photographer)

Cutler DeLong West
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1941 – World War II
1993 – died on March 3 (Boston Globe)

Ammonium Hydrosulfide NH₃SH
... What’s Known?

\[ \text{NH}_3(g) + \text{H}_2\text{S}(g) \rightarrow \text{NH}_4\text{SH(s)} \]

- crystal structure
- density
- color
- vapor pressure
- spectra
- reaction products

Three Tests for the GRS and NH₄SH Reactions

1. Infrared spectra
   - Can identify reaction products?
2. Colors
   - Looks like GRS?
3. UV-vis spectrum
   - Matches Hubble telescope data?

Radiation Products of NH₄SH – Thermal Stability

The Great Green Spot ?!?!
Color changes in NH$_4$SH on irradiation at 120 K ...

![GRS Voyager 2 Image](image)

The GRS and Hubble Space Telescope Results

![Graph](image)

**New Observations of Jupiter Coming**

**Hubble Space Telescope**

Hubble Telescope result from 2015

Polysulfide work to be continued.

JWST to launch in October 2018.

Fuming Liquor of Boyle

Robert Boyle (1627 - 1691)

ammonium polysulfide (NH$_4$)$_2$S$_x$

For More Information ...

The Astrochemistry Subdivision of the American Chemical Society

Frontiers of Solar System Chemistry: Planets to Comets and Beyond

ACS National Meeting – Philadelphia, August 2016

Organizers – Reggie Hudson & Stefanie Milam

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**NASA $$ Programs**

Planetary Atmospheres

Planetary Astronomy

**On the Web**

http://science.gsfc.nasa.gov/691/cosmicice/