第43回木星会議
われわれは何を観測するのか

月惑星研究会
会長:田部一志

月惑星研究会（1959年設立） 初代会長：平林　勇さん、関西支部長：安達　誠さん、
副会長：堀川邦昭さん（OAA木土星課長）

木星会議（1974年より） 47年目 （だけど43回！）（木星の対衝（シーズン）に１回、13年に12回（サボっていない！）
各回主催地の人々が世話役、今回は月惑星研究会（関西支部）
過去には、九州、米子、姫路、和歌山、京都、富山、滋賀、神戸、大阪、名古屋、静岡、横浜、川崎、三鷹、科博、
オリ青センター、品川、お茶の水、仙台、宇都宮、山形、旭川など

観測対象　惑星（表面の大気現象）～なんでも

観測方法　スケッチ、CMT（木星）、写真（銀塩）、ビデオ（webcam)、合成画像（さまざまな技術開発）

観測波長　可視（RGB)、IR、UV、メタン（890nm)

活動：観測結果のHP上への公表 （世界的に高い評価）とアーカイブ、大気現象の解析（世界的に高い評価）
観測技術の開発
（もしかしたら今が全盛期なのかも知れない）

資金：個人の活動の集合体ゆえ公にはほとんど0

同業者（ライバル）　ALPO（米）、BAA（イギリス）、スペイン、JPL、その他

存続：会員の高齢化により危ぶまれている。　長所・欠点：一騎当千、会員が一匹狼的？？

観測の楽しみ

１　よく見えた

２　珍しい物が見えた

３　スケッチできた

４　良く写った

５　珍しい現象が写った

６　動きが分かった

７　変化が分かった

８　変化が解明できた

９　未知の現象が分かった

解析の楽しみ

１　変化が分かった

２　変化が解明できた

３　過去の事例と類似した例を見つけた

４　未知の現象が起こった

解析手法

１　並べてみる

２　展開図

３　ドリフト（移動）チャート

４　自転周期、風速への換算

５　長期間の変化

６　色の変化

木星観測の歴史

1600年台から	天体望遠鏡による眼視観測（ガリレオ、マリウス）
1800年代末	アマチュアが活躍
1900年代	アマチュアが大活躍（～1970年台）
1960年代から	+写真（写りは悪い！）
1973-74年	初めての探査機（パイオニア10,11号） フライバイ
1979年	ボイジャー1、２号（フライバイ） （風速の精密測定）
1994年	Hubble Space Telescope(HST) （SL-9）
1995年	ガリレオ（オービター）、プローブ
2000年	カッシーニ（フライバイ）
2002年	Web-Camera+Registax（革命的だった）
2010年	微小天体の衝突現象
2016年	ジュノー（オービター）

大気現象

- 色（濃さ）の変化
- 風の変化
- 渦の発生、消滅
- 突発現象（撹乱等）
- （電波）

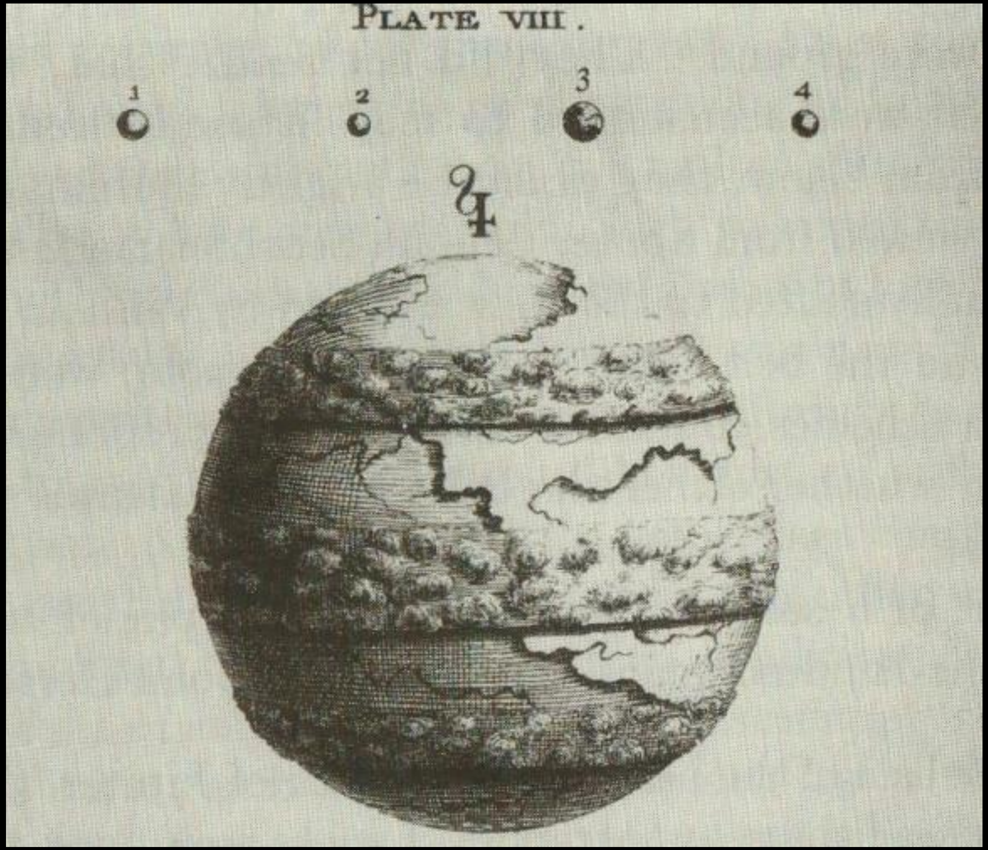
外的要因

- 天体衝突

成因

衛星

組成

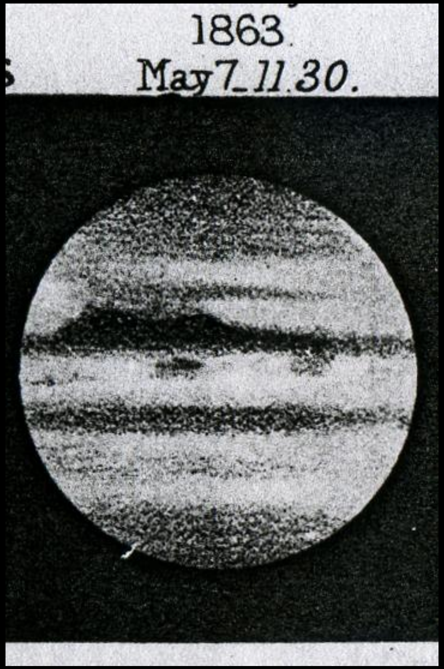


Thomas Wright 1711

地球のような惑星に帯状の雲

木星は見た目より軽い！

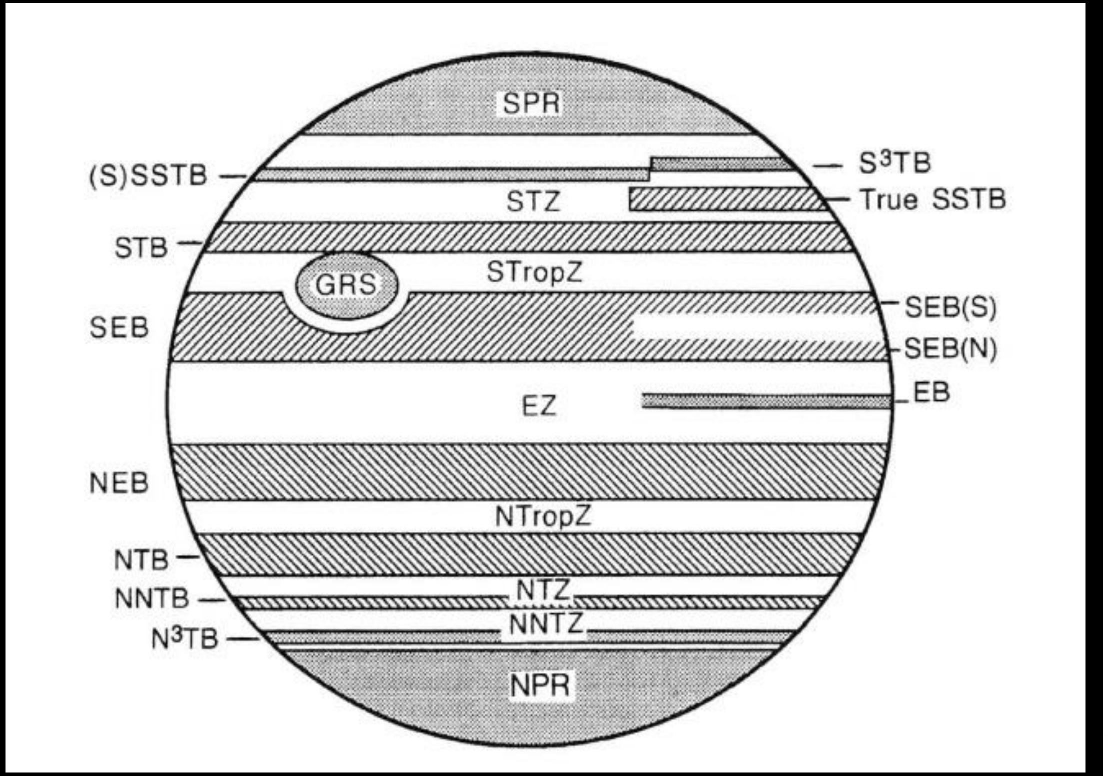
ガス惑星
ハーシェル、シュレーター、
ベアとメドレル。。。

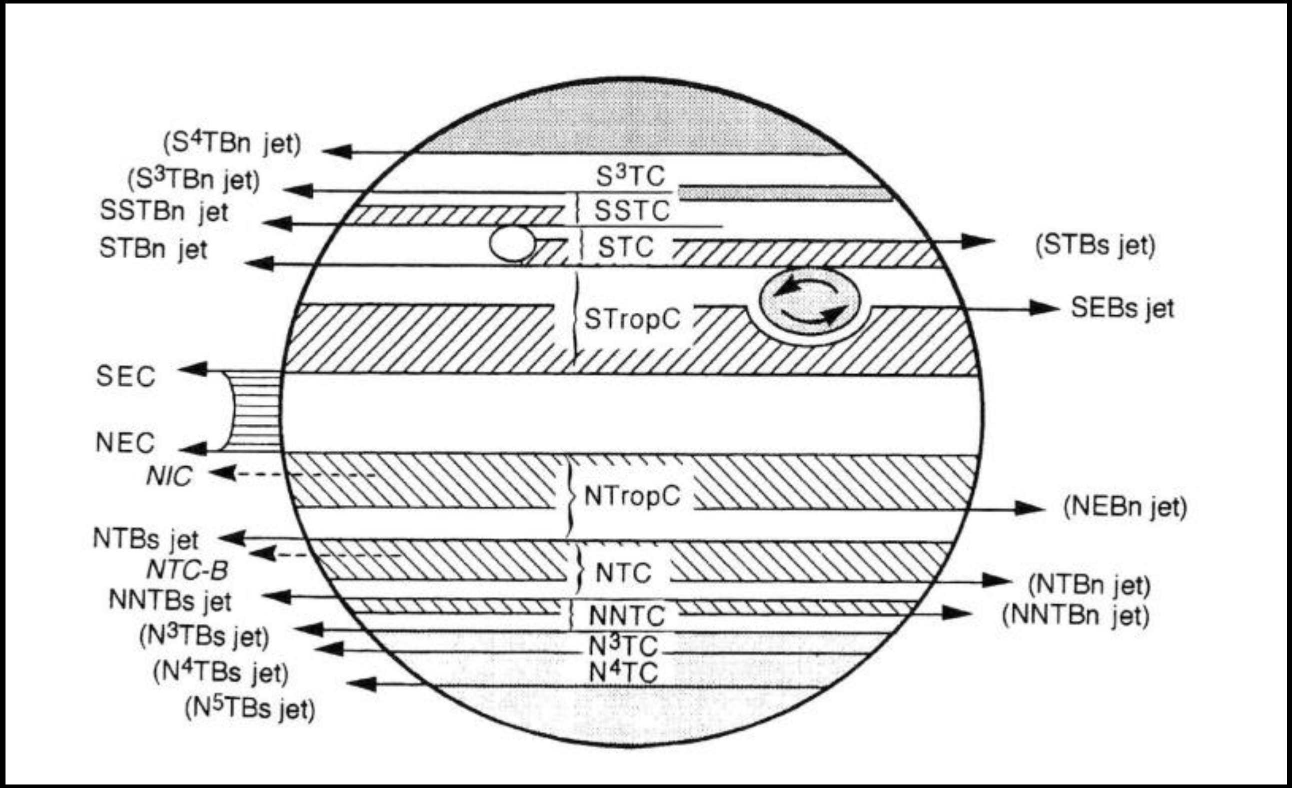


Nathaniel Greenのスケッチ

暗いところ＝ベルト（縞）
明るいところ＝ゾーン（帯）

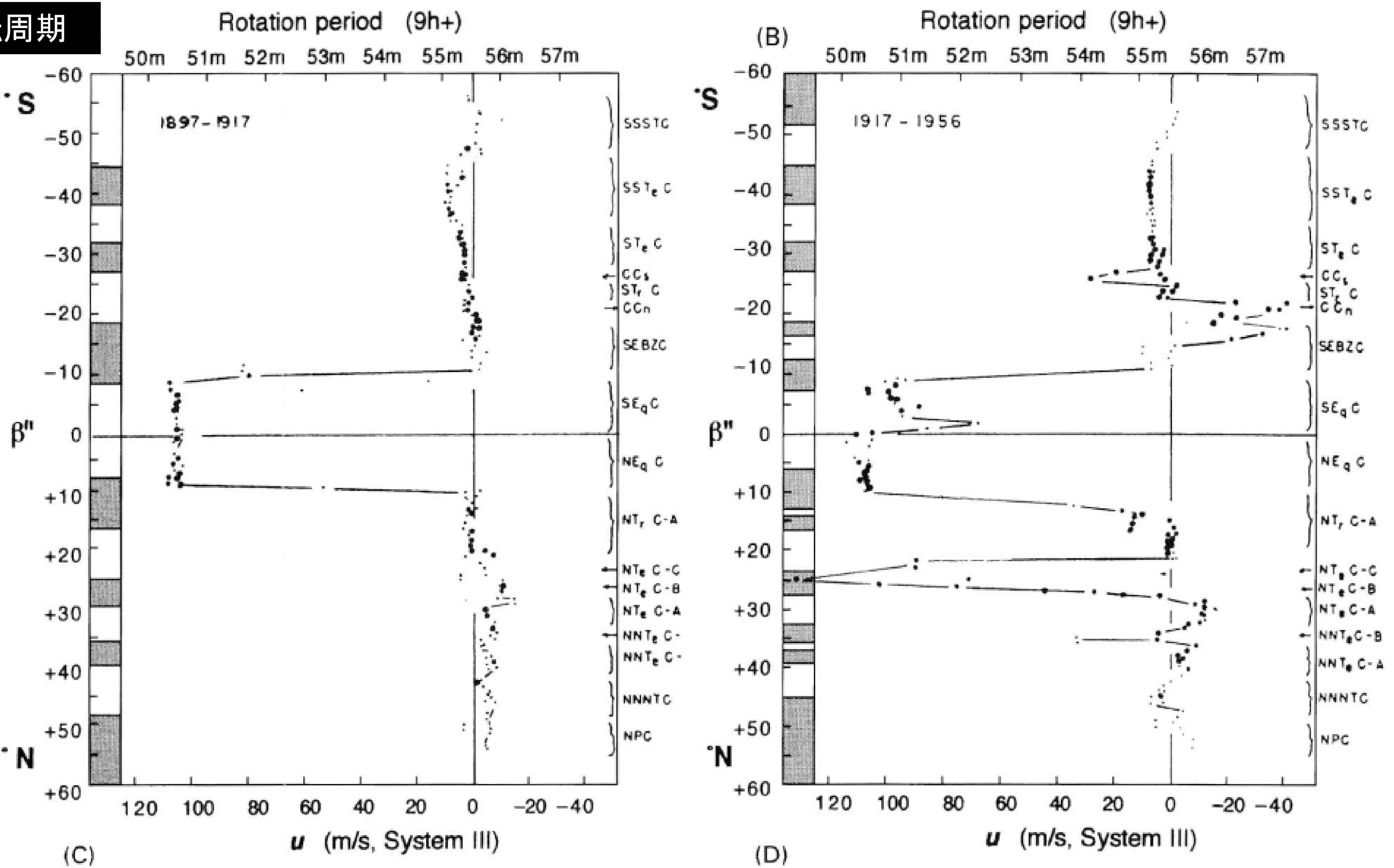
木星の経度と自転周期と風速





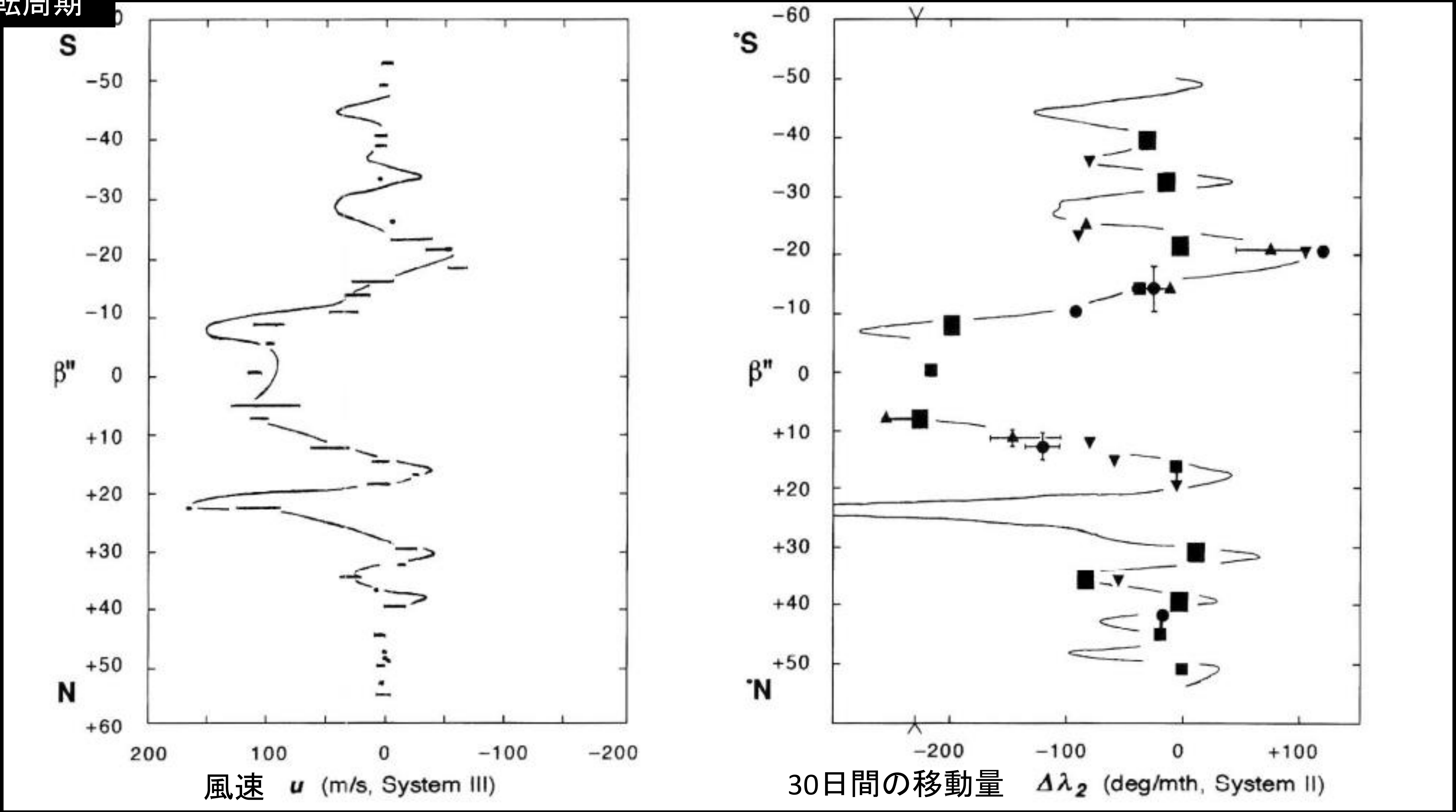
Rogers 1995 The Giant Planet Jupiter
BAA流の命名、他の流儀を駆逐

風速と自転周期



Rotation period (9h+)
50m 51m 52m 53m 54m 55m 56m 57m
1897-1917
1917 - 1956
(B)
°S
°N
β"
SSSTC
SST_e C
ST_e C
CC_s
ST_r C
CC_n
SEBZC
SE_q C
NE_q C
NT_r C-A
NT_e C-C
NT_e C-B
NT_e C-A
NNT_e C-B
NNT_e C-A
NNNTC
NPC
u (m/s, System III)
(C)
(D)

風速と自転周期



New Mexco State University 1964-1978

Voyager 1979 とBAAの比較


Planetary Astronomy
ROGERS
THE GIANT PLANET JUPITER
CAMBRIDGE
JUPITER
JUPITER
WILLIAM SHEEHAN AND THOMAS HOCKEY
GALILEO'S PLANET
THOMAS HOCKEY
GEHRELS
JUPITER
Arizona
The Planet Jupiter
Bertrand M. Peek
FABER
惑星ガイドブック 2

1　力学（風速）の系統

1950年頃
縞-帯の最初の気象力学的アプローチ

1952年　The Planet Jupiter ,Peek(1958) 口絵

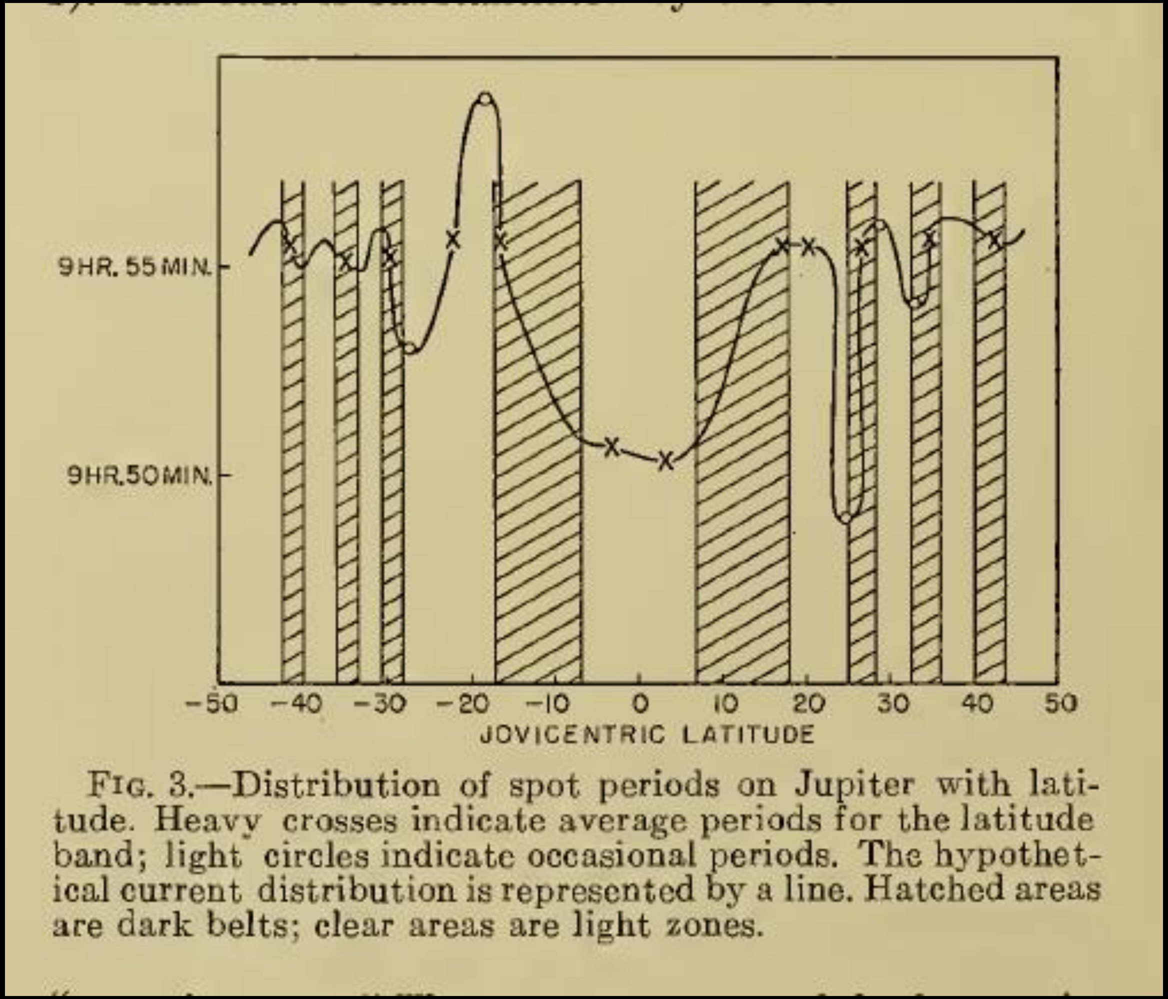


Fig. 3.—Distribution of spot periods on Jupiter with latitude. Heavy crosses indicate average periods for the latitude band; light circles indicate occasional periods. The hypothetical current distribution is represented by a line. Hatched areas are dark belts; clear areas are light zones.

Hess,S.

Hess and Panofsky (1951)　より

Ephemeris for Physical Observations of Jupiter, 1891. By A. Marth.

Greenwich Noon	Angle of Position of ♃'s Axis. P	L − O.	Diff.	B	Corr. of log. Δ.	Light-time.	A − O.	β	Longitude of ♃'s Central Meridian. (877°·90) I.	(870°·27) II.	Corr. for Phase.	Apparent Diameter. Equat.	Phase.	Polar.
1891.	°	°		°		m	°	°	°	°	°	"	"	"
April 17	335·765	203·513	391	+1·005	–									
19	·714	203·904	386	1·026										
21	·665	204·290	380	1·046										
23	·618	204·670	374	1·067										
25	·572	205·044	368	1·087										
27	335·528	205·412	361	+1·108	–									
29	·486	205·773	354	1·128										
May 1	·445	206·127	348	1·148										
3	·406	206·475	340	1·168										
5	·369	206·815	332	1·188										
7	335·333	207·147	325	+1·207	–									
9	·299	207·472	318	1·227										
11	·266	207·790	309	1·246										
13	·235	208·099	301	1·265										
15	·206	208·400	292	1·284										
17	335·178	208·692	283	+1·303	–									
19	·151	208·975	275	1·322										

β	Longitude of ♃'s Central Meridian. (877°·90) I.	(870°·27) II.	Corr. for Phase.
·7930	216°·99	32°·64	+0°·32
·8022	172·52	332·91	·34
·8115	128·06	273·19	·36
·8207	83·61	213·47	·37

木星の経度

体系	24時間あたりの自転率	自転周期
第１系 （System I)	877.90 (deg/day)	9h50m30.003s
第２系 （SystemII)	870.27 (deg/day)	9h55m40.632s
第３系 （SystemIII 1965)	870.536 (deg/day)	9h55m29.711s

１系は主に赤道地方、２系は主に中緯度以上地方に適合（例外：NTCurrent-C ）
場合によっては、任意の自転率の特殊経度を使うこともある （極端に速く移動する模様の場合）

補正項
木星が地球に対してどっちの方向にあるのか？　光行差　欠けた部分　時計の狂い（DT-UT=70秒？）
（全面 full disk, 輝面 illuminated disk ） 測定の時には重要！

木星面の風速 第3系に対する風速 （m/sec)

個々の模様　大赤斑（1831-　　　）

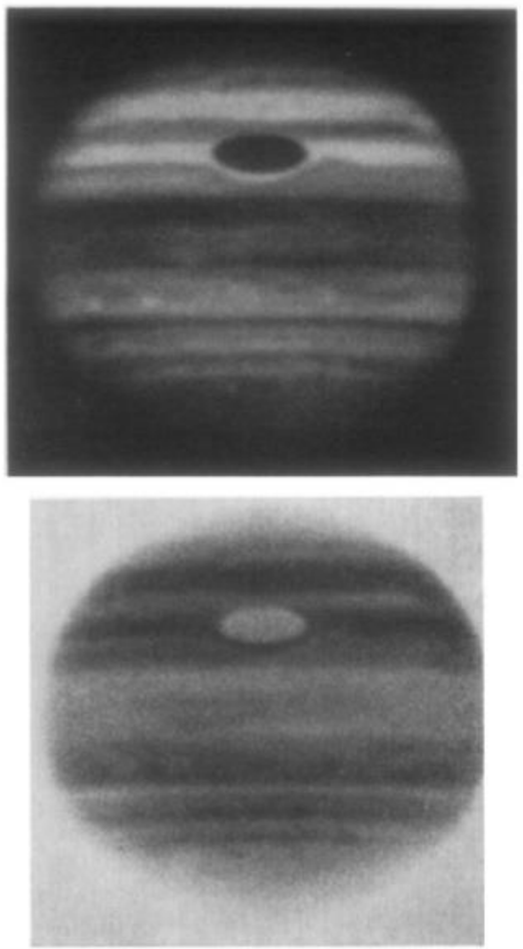
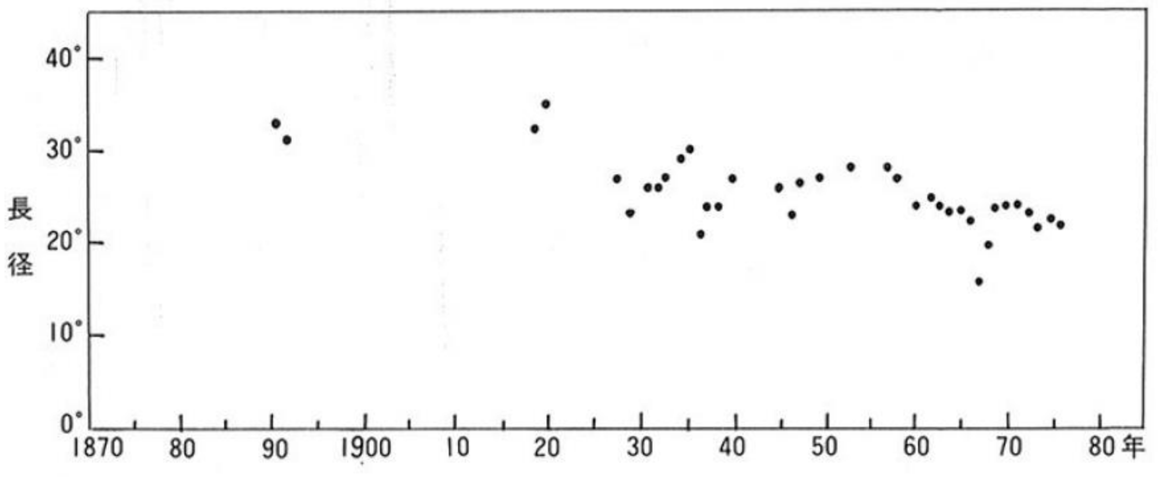


FIG. 3. Positive and negative prints of Jupiter in blue light, 23 October 1964, 0901 U. T., $\omega_2 = 19°$. The positive print is a composite of three images. The negative print was made from a single image. In preparing the negative prints for this and the following figure, an attempt was made to reproduce the photographic image much as it appears on the original plate.

Reese 1964



【図1】 大赤斑の長径の変化

2018年
1980年代の半分くらいの大きさ

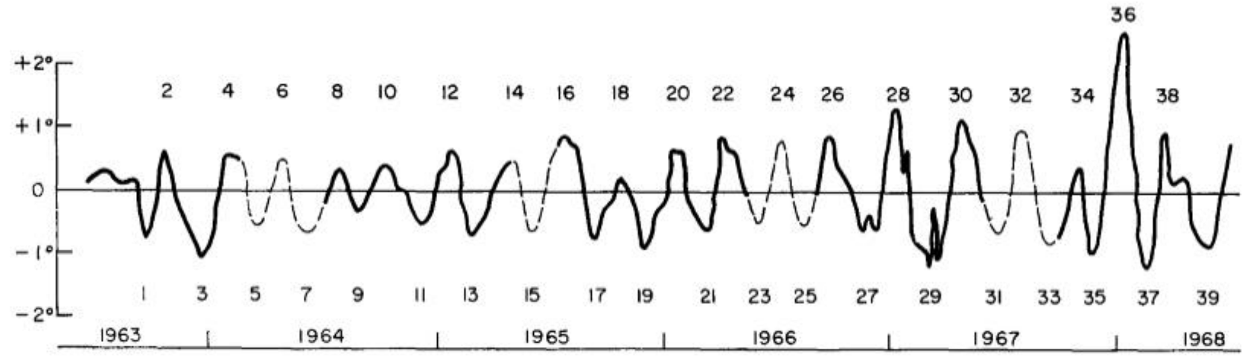
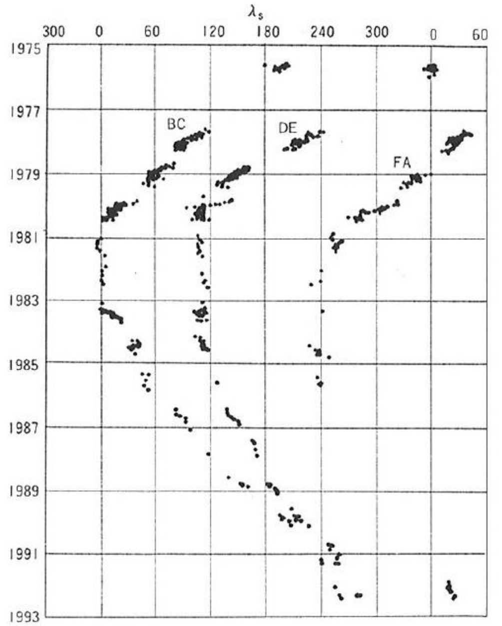


FIG. 3. SECULAR CHANGES IN THE RED SPOT'S LONGITUDE HAVE BEEN REMOVED BY CALCULATING THE LEAST SQUARES DRIFT OF THE RED SPOT CENTER FOR EACH OF THE FIVE APPARITIONS.
Longitudes are plotted as deviations from the least-square solutions. The heavy line represents the observed oscillation, while the dashed line is the interpolated curve.

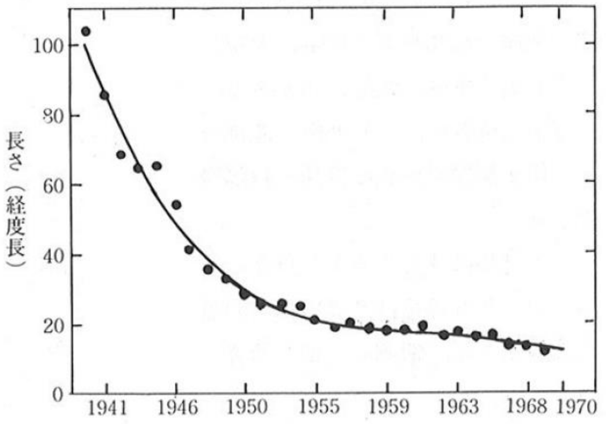
Solberg 1969　90日周期の経度方向の振動

個々の模様　永続白斑

1952年10月24日　Palomar



【図1】 永続白斑の18年間の経度変化



【第2図】 永続白斑の長径の変化

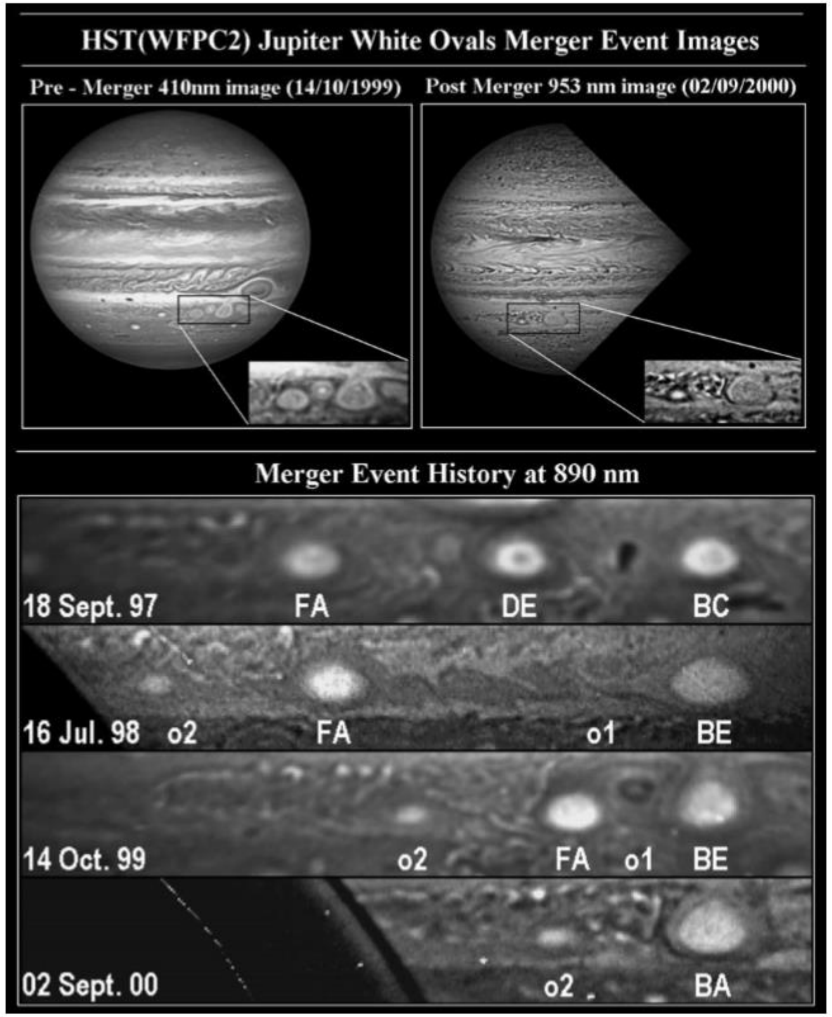
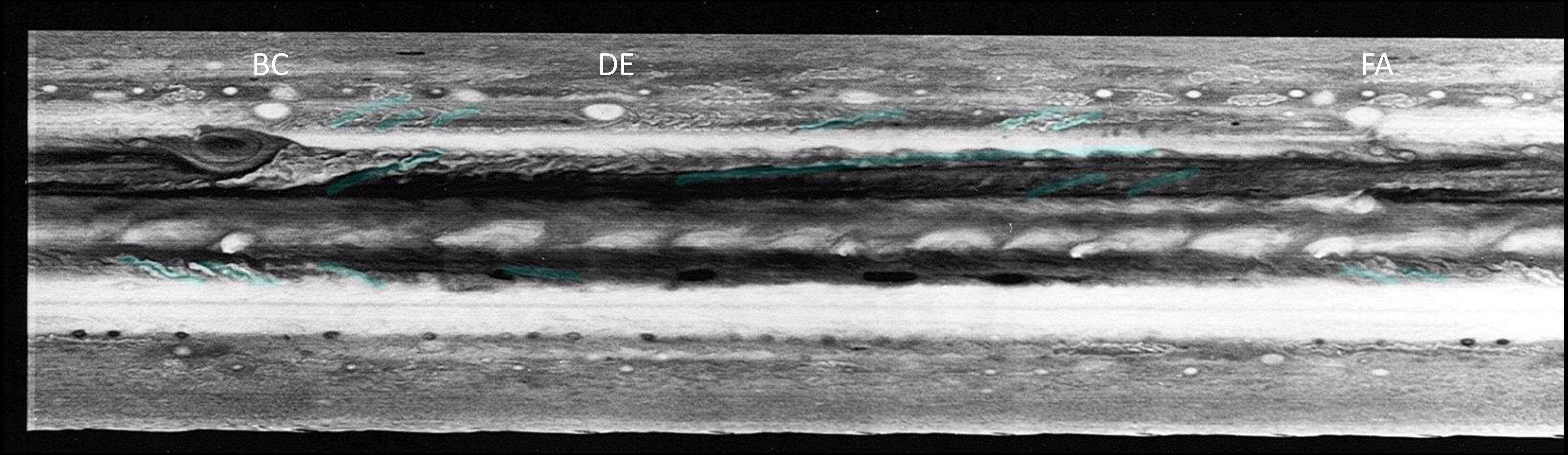
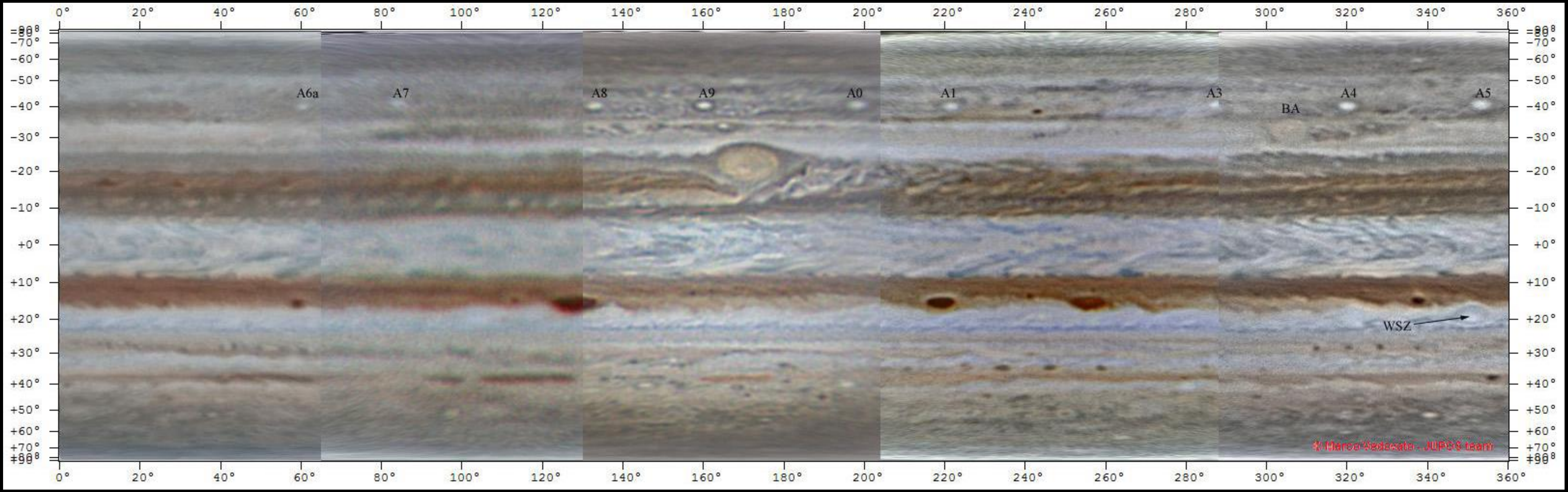


Fig. 1. Hubble Space Telescope images of Jupiter's White Oval anticyclones. Upper left: blue-filter image (419-nm) showing the ovals FA, the cyclone cell and BE (from left to right in the inset). Upper right: red-filter image (953-nm) showing the final oval BA in the inset. The lower image shows the progressive evolution from three ovals (FA, DE, BC, upper shot), to two (FA, BE, two middle shots) and finally to one single oval (BA, lower shot). This series was taken with a 890 nm methane band filter.

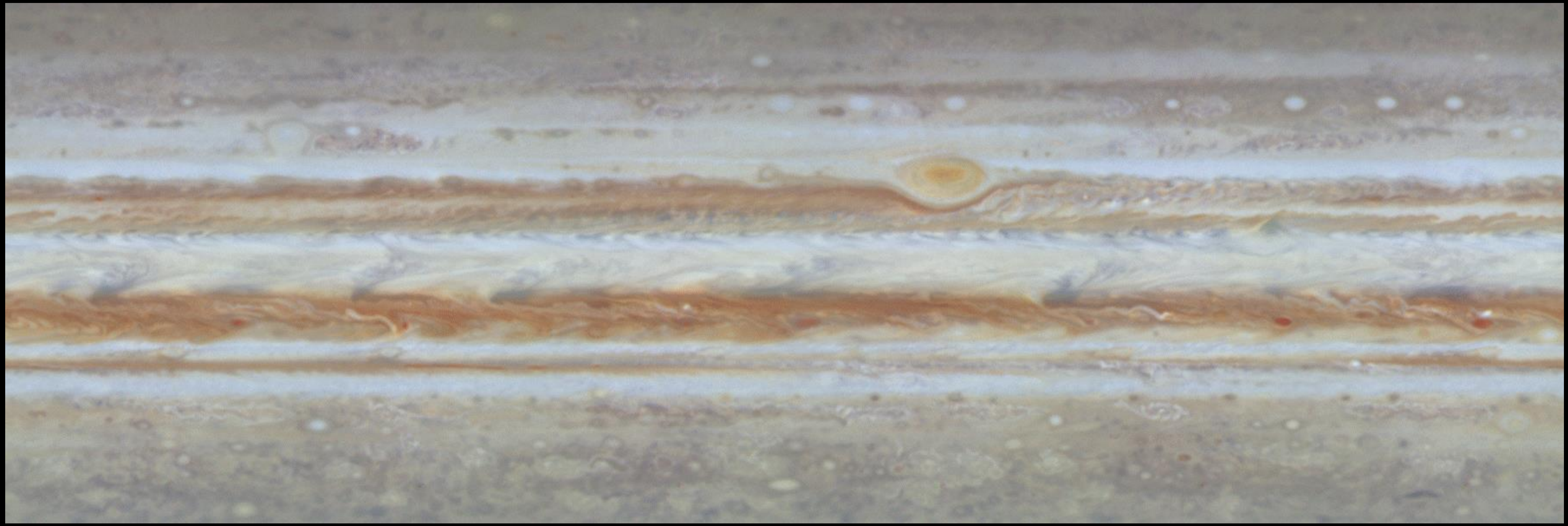
1979 V1

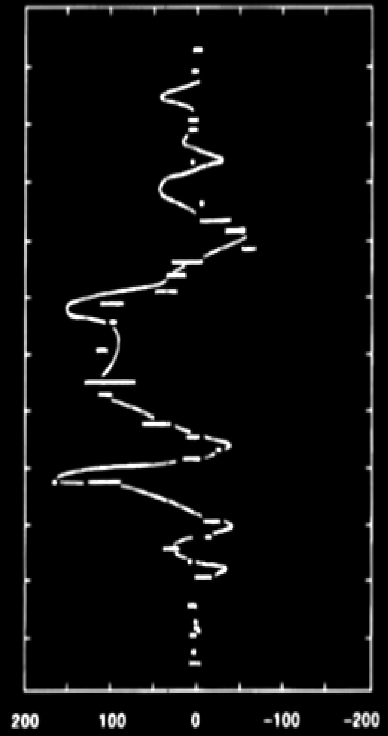


2011
Vedvato



2000年　土星へ向かうCassiniが撮影





SEPTEMBER 1969 ANDREW P. INGERSOLL AND JEFFREY N. CUZZI 983

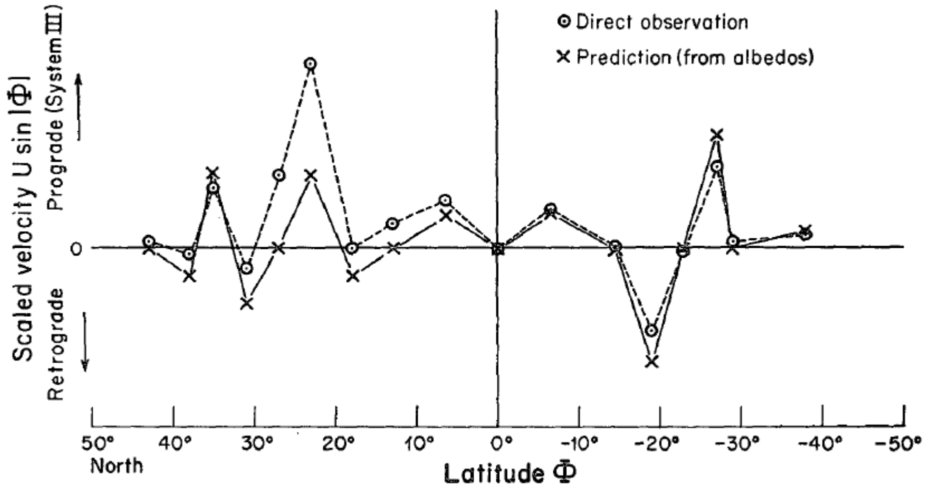


FIG. 1. Comparison of observed zonal velocity and that predicted from the visual albedo gradient. The observational data are from Peek (1958). Velocity is measured relative to System III, in arbitrary units. The factor sin|Φ|, which suppresses data at the equator, arises naturally from the geostrophic approximation. The sense of the correlation indicates that zones are hotter than belts.

Ingersoll and Cuzzi (1969)

左：Peek(1958)による風速

下：東西方向の風速のy（南北）による2階微分とβの比

$f=f_0+\beta y$ f:コリオリパラメータ

風速の測定が大雑把すぎて何も分からない！

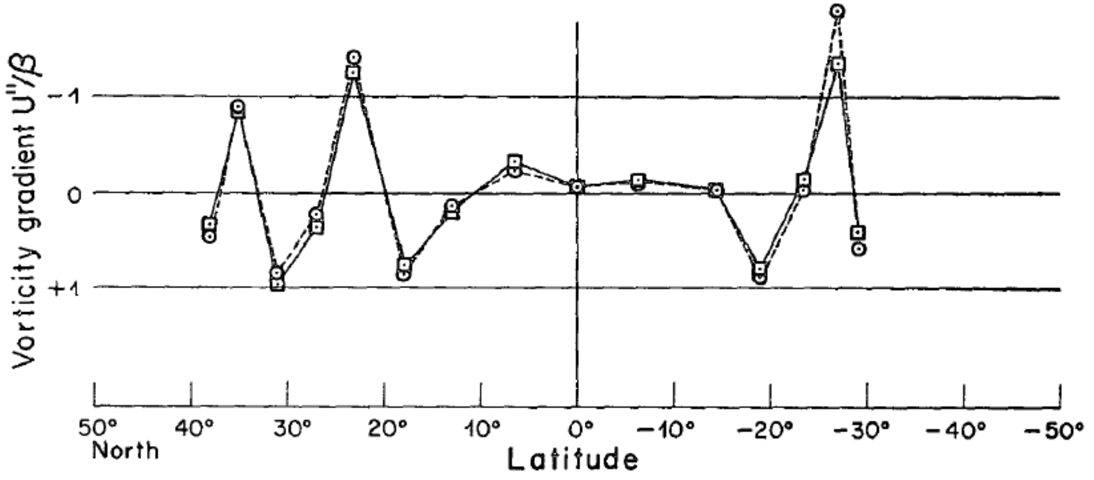
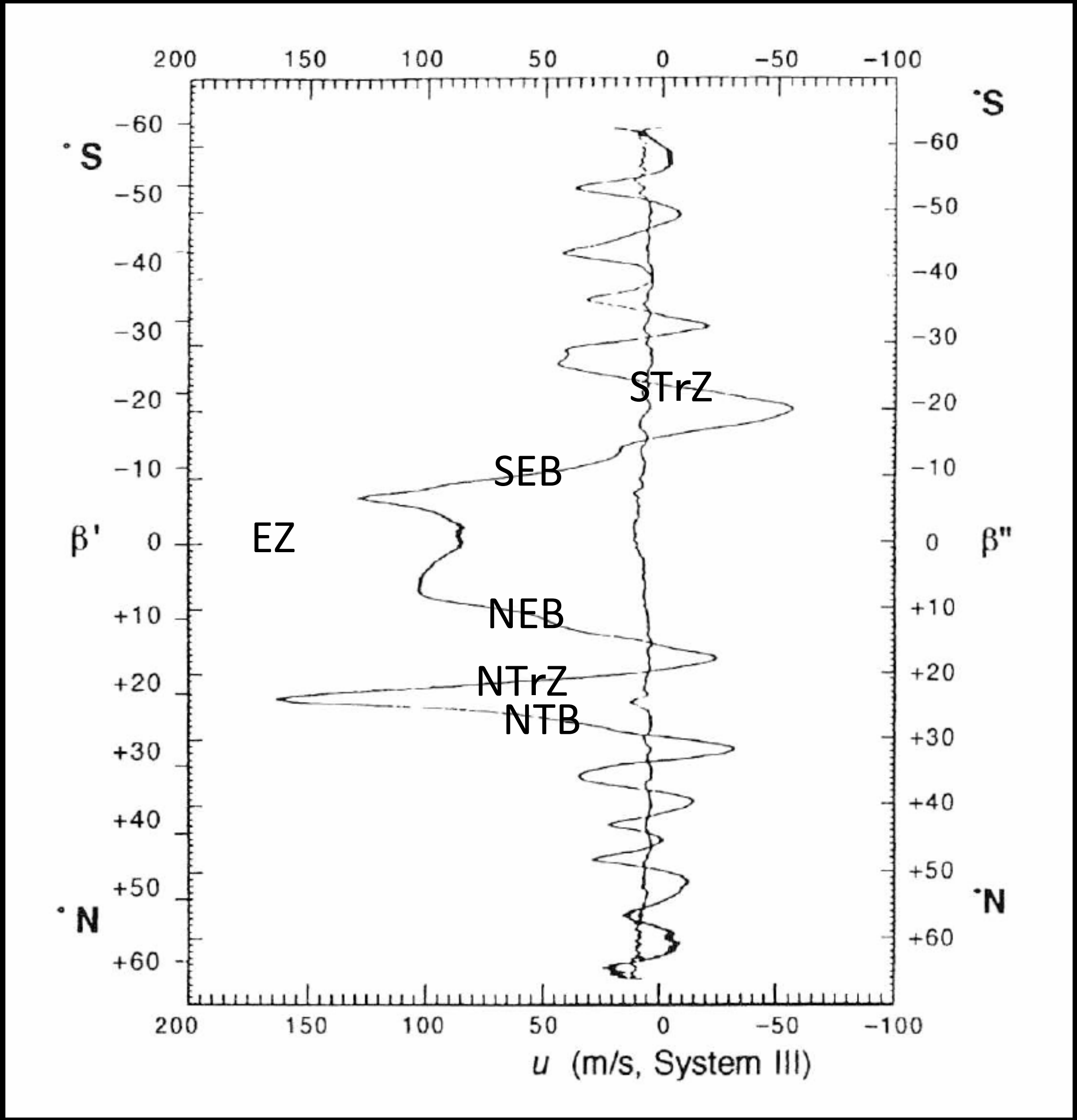


FIG. 2. Comparison of the relative vorticity gradient, $-U''$, and the planetary vorticity gradient, $\beta=(2\Omega_0/a)\cos\Phi$. The second derivative U'' was estimated by a three-point finite difference method, using Peek's (1958) data. Squares: Peek's data treated as a point-by-point sampling of the actual flow; circles: Peek's data treated as a set of averages, band by band, of the actual flow. The barotropic stability criterion states that $U''/\beta>1$ is necessary for instability.



Rogers 1994
木星の風速
1979年のV1,2の観測は地上観測者にとって挫折感を与えるものであった。

座標（局所直交）
東西　x　u
南北　y　v
上下　z　w

Ingersoll and Polard (1982)

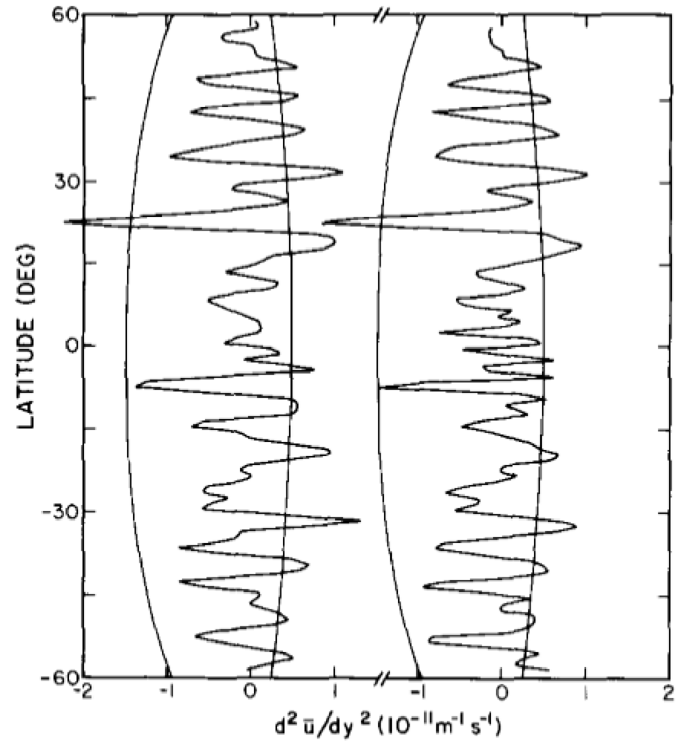
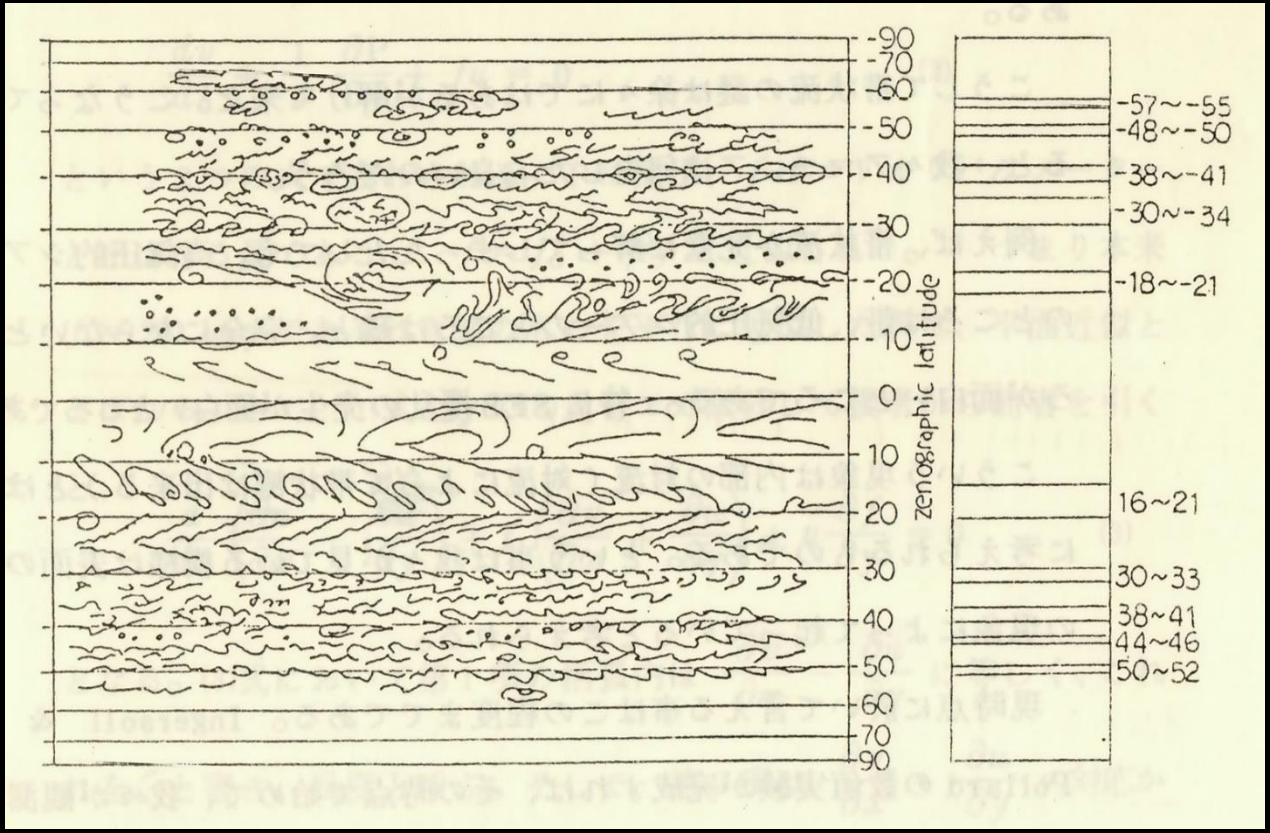
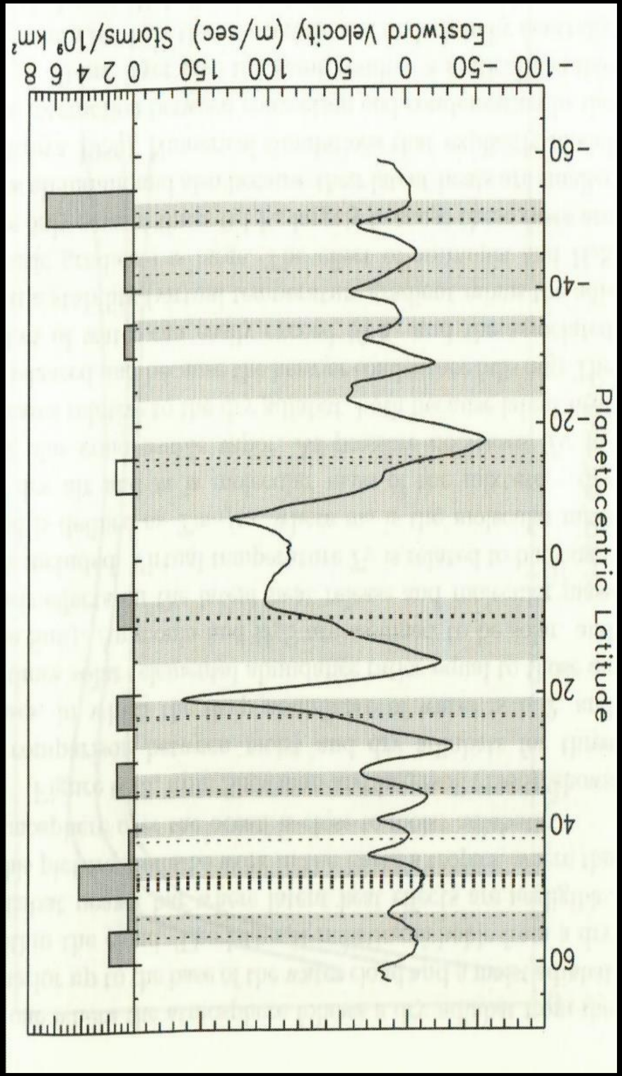


FIG. 4. Curvature or second derivative of Jupiter's zonal velocity profile for the solid curves of Fig. 3. Voyager 1 is on the left and Voyager 2 is on the right. The smooth curve on the right of each profile is β, the planetary vorticity gradient for thin spherical shells. The smooth curve to the left of each profile is $B \sin^2\lambda$, derived in the text for deep fluid spheres. The $B \sin^2\lambda$ curve is relevant up to a latitude of about 40 to 45°, where effects of the metallic core become important. The limiting curve (not shown) for deep flow at higher latitudes is infinite at the critical latitude and lies to the right of each profile. Notice that the observed profiles rarely cross the left curve, but often cross the right curve, suggesting that a deep interior flow with the observed curvature might be marginally stable.



Tabe (1983)　Voyager1の流線に順圧不安定臨界を重ねたもの



Ingersoll et al, 2004
中緯度における雷の発生頻度

2 雲物理の系統

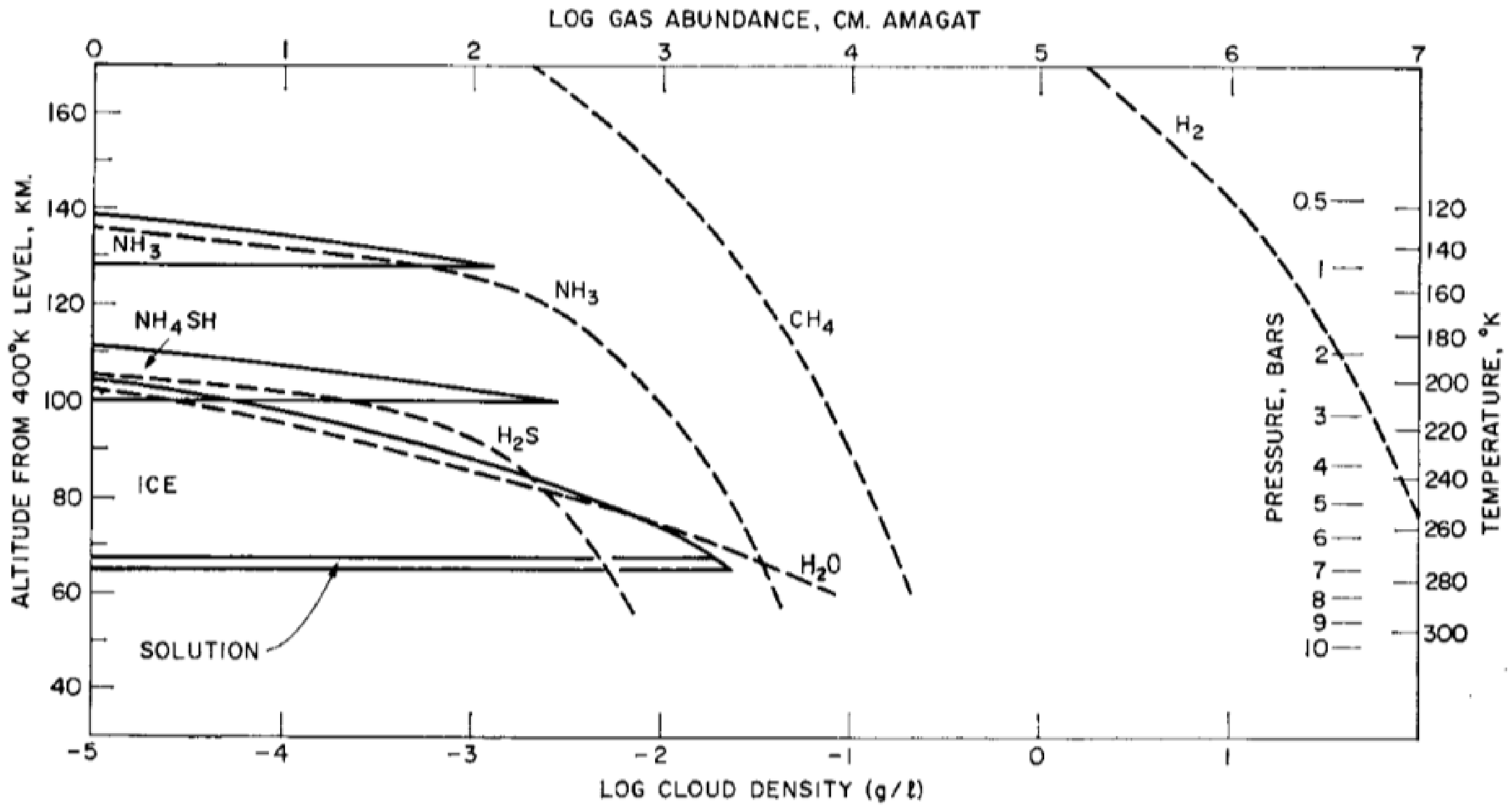
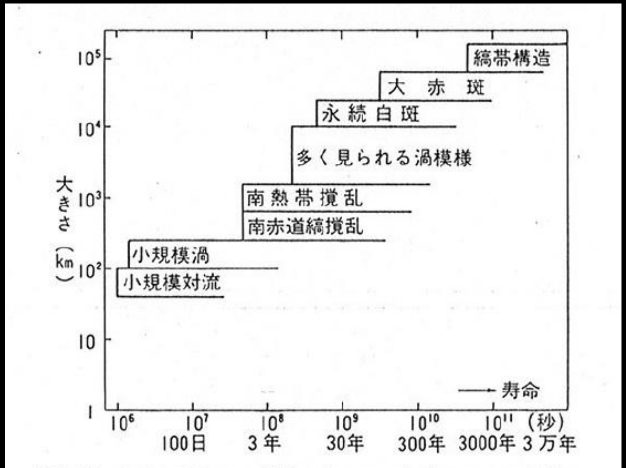


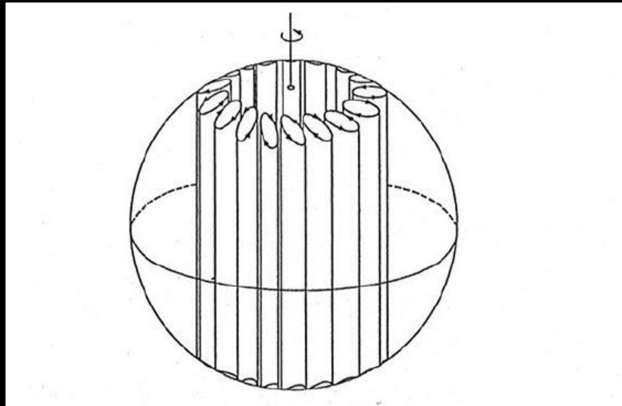
FIG. 3. Nominal atmospheric profile for solar-composition Jupiter. Solid lines show computed cloud densities; dashed lines are integrated amounts of spectroscopically active compounds in the gas phase present in a vertical column above any altitude, in cm amagat. The zero of altitude is at the 400°K level. Most of the H_2O forms ice clouds; aqueous NH_3 solution is present only marginally if supercooling is not assumed.

Weidenschilling and Lewis (1973)

木星の内部の構造とBelt-Zone構造の関係（風の起源



【図1】 木星に見られる模様を大きさと寿命について分類したもの


【図2】 F.H. ビュッセにより考えられた木星内部の対流の構造

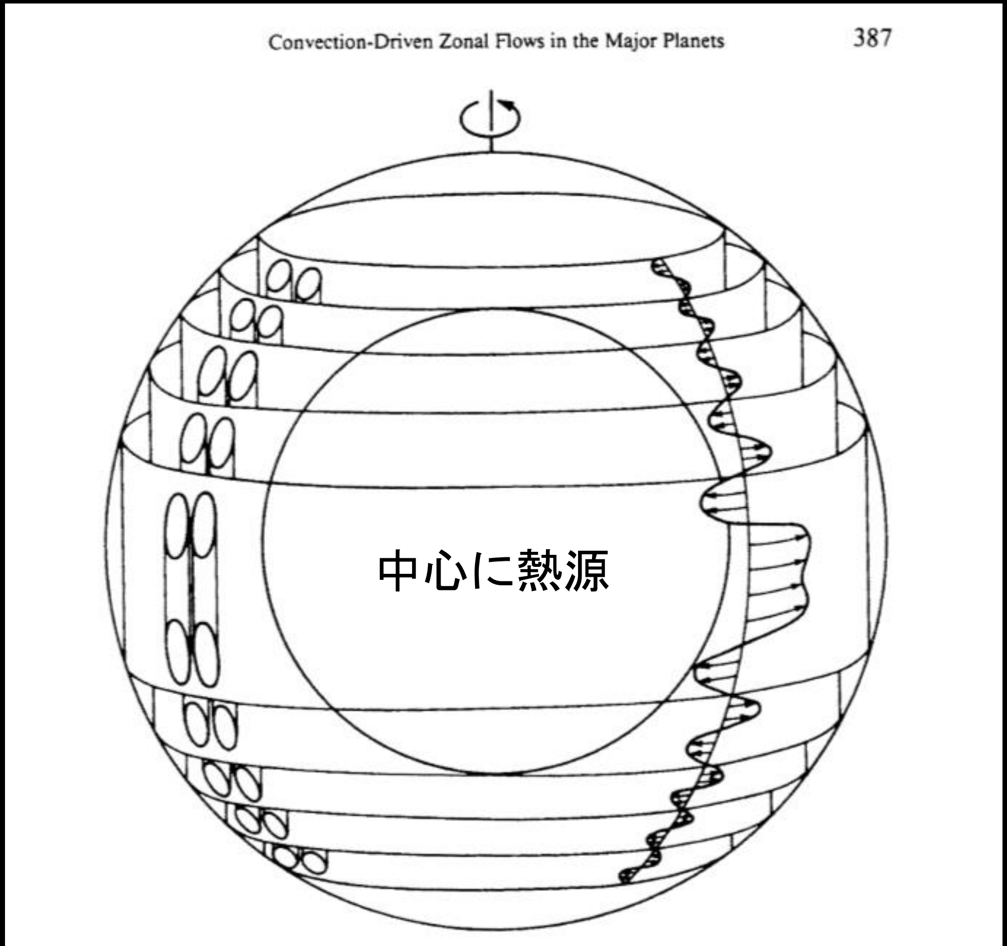
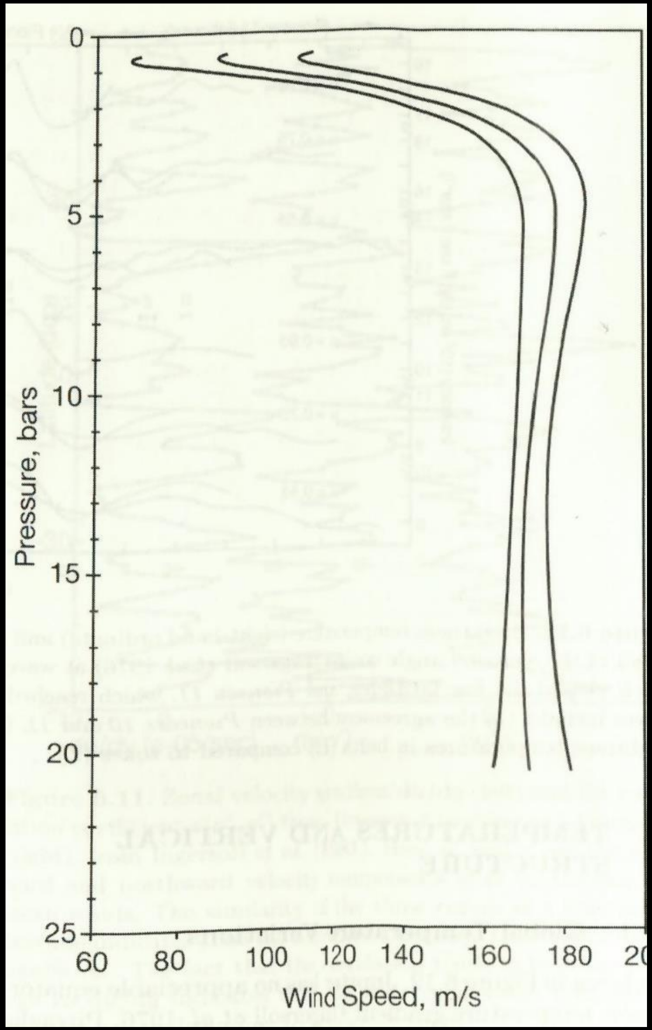


Figure 3. Model of annular convection layers for the description of Jovian dynamics, after BUSSE (1983).



Poincare1910, Roberts1961, Busse1970, SkyLabにおける水槽実験

Seiff 1996 Galileo Probeの観測
東西流は20b付近までは安定して続いている。

３　では、Belt-Zone（縞-帯）の概念

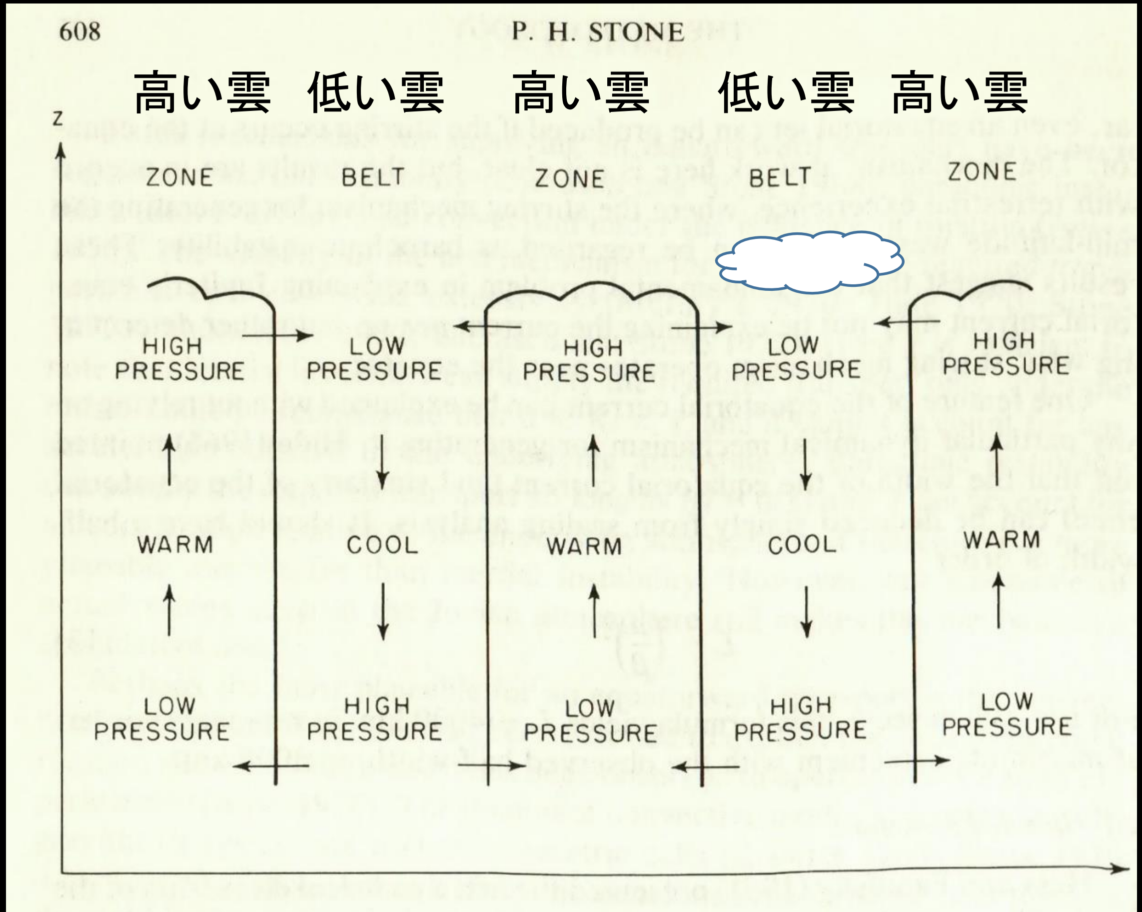


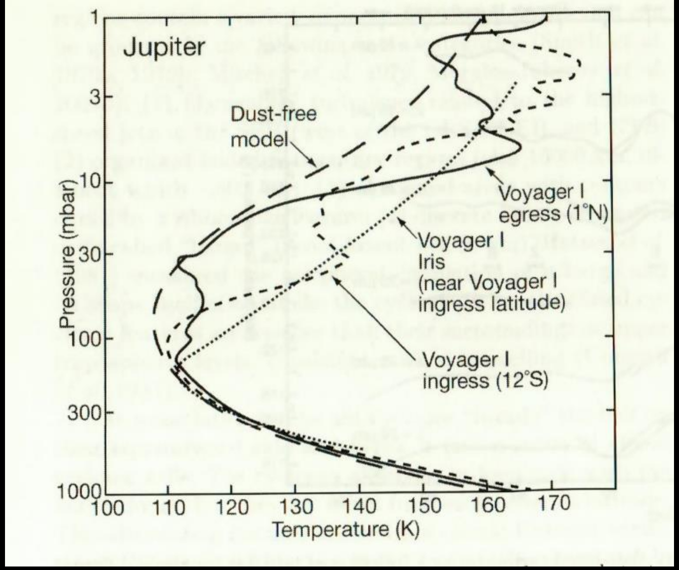
Fig. 4.　Schematic diagram of Jupiter's meridional circulations.

Stone 1976　この図は多くの教科書に引用されたが。。。

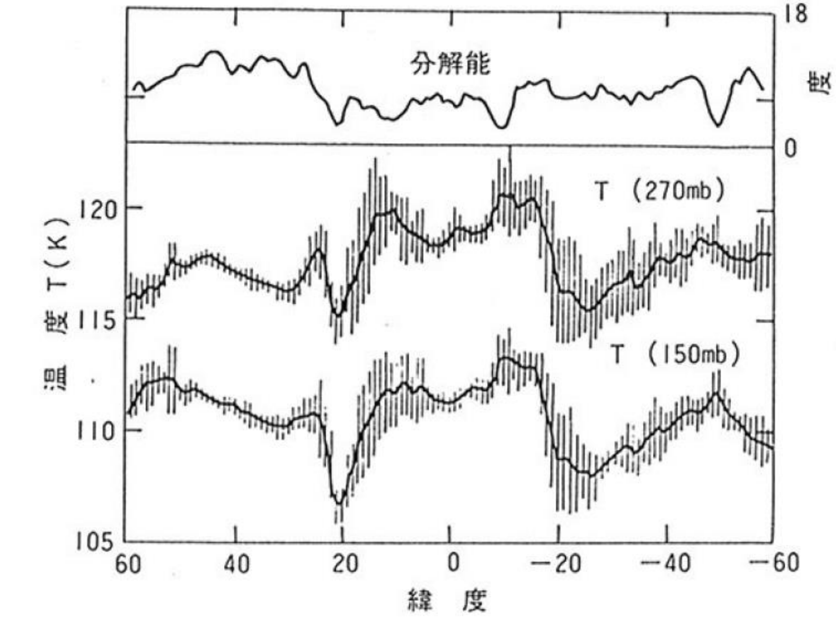
高い雲＝NH3の氷晶
低い雲＝H2Oの雲？　着色物質？

2010年8月9日　阿久津富夫氏撮影
縞が1本帯になった！？

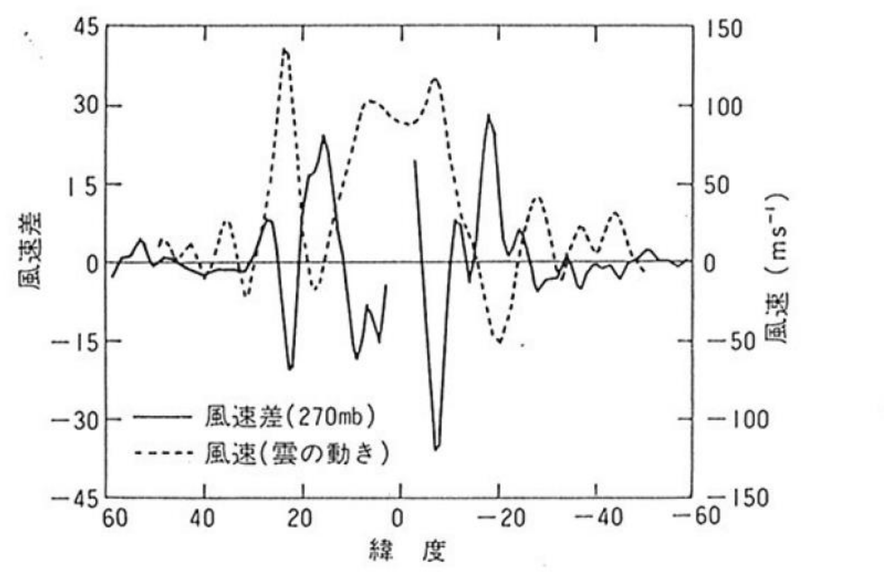
流れのパターンが変わった？？？



Ingersoll et al, 2004



【図１】 270 mb と150 mb の温度分布



【図２】 温度場から得られた風速差と雲の運動から求めた風速の比較

Gierasch 1986

木星の温度構造：表層は対流圏、下層に放射層があるだろう
温度の変化はあまりない（内部でよくかきまぜられている）
太陽から受けるのと同じくらいの内部発熱

メタンバンドによる観測
West (1979,1980)

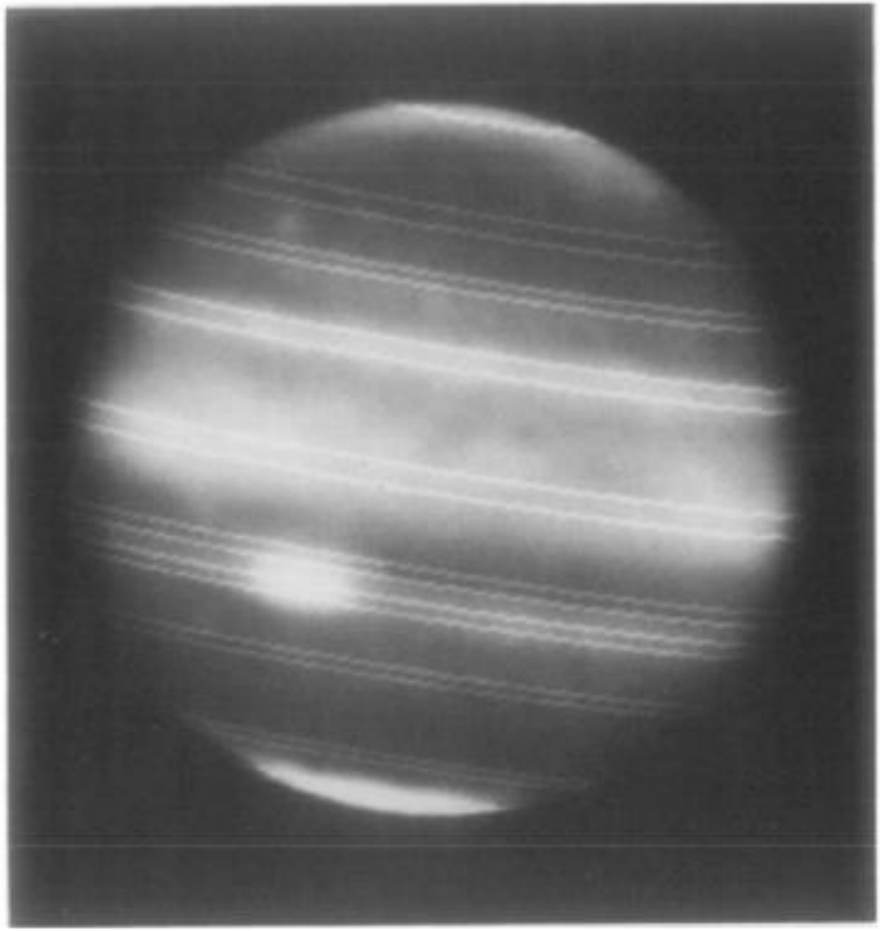


Fig. 4. Latitude boundaries for all regions in Table IV except the GRS. Th
(left) and 9500-Å image (right). The images have been contrast enhanced a

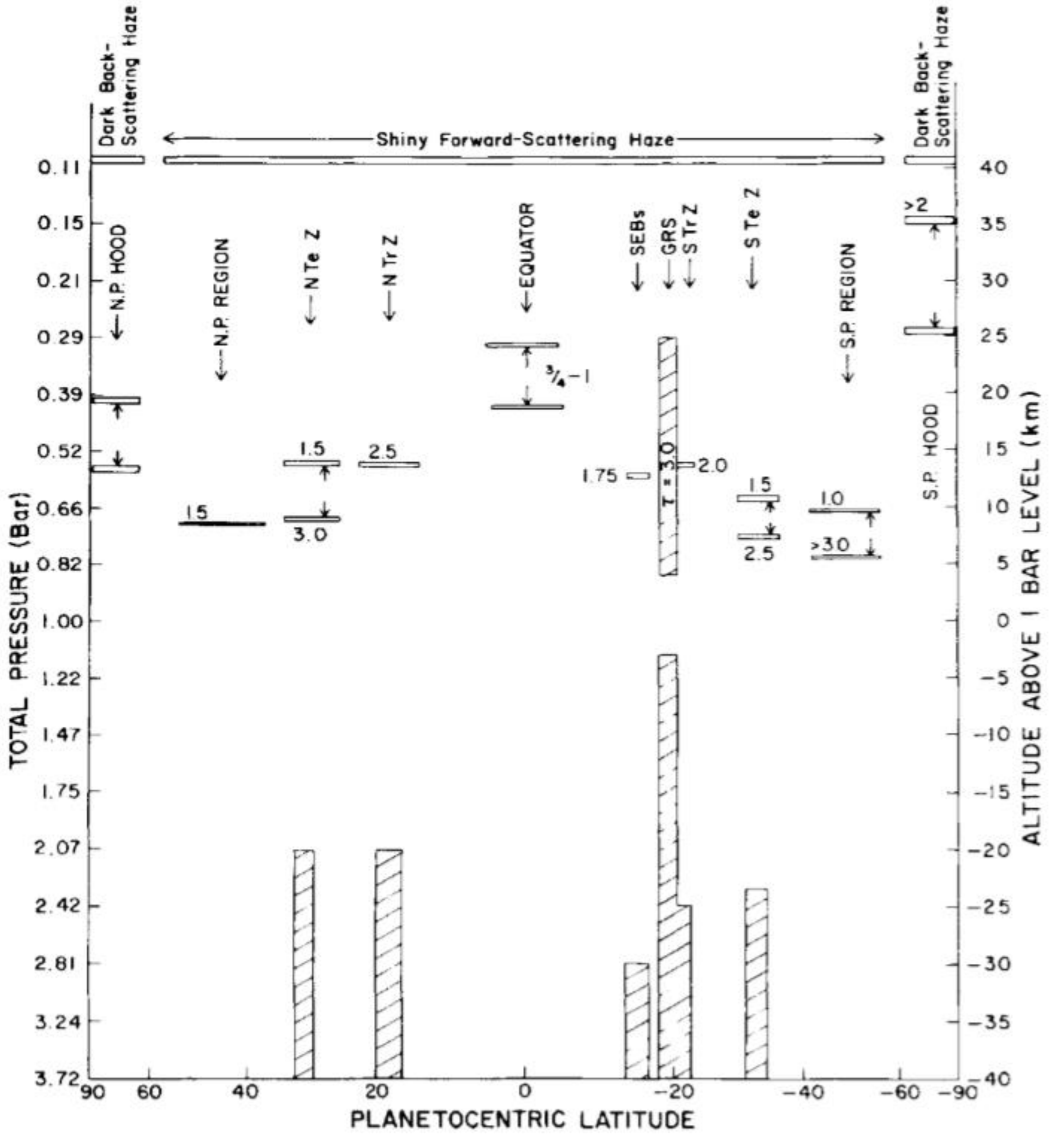
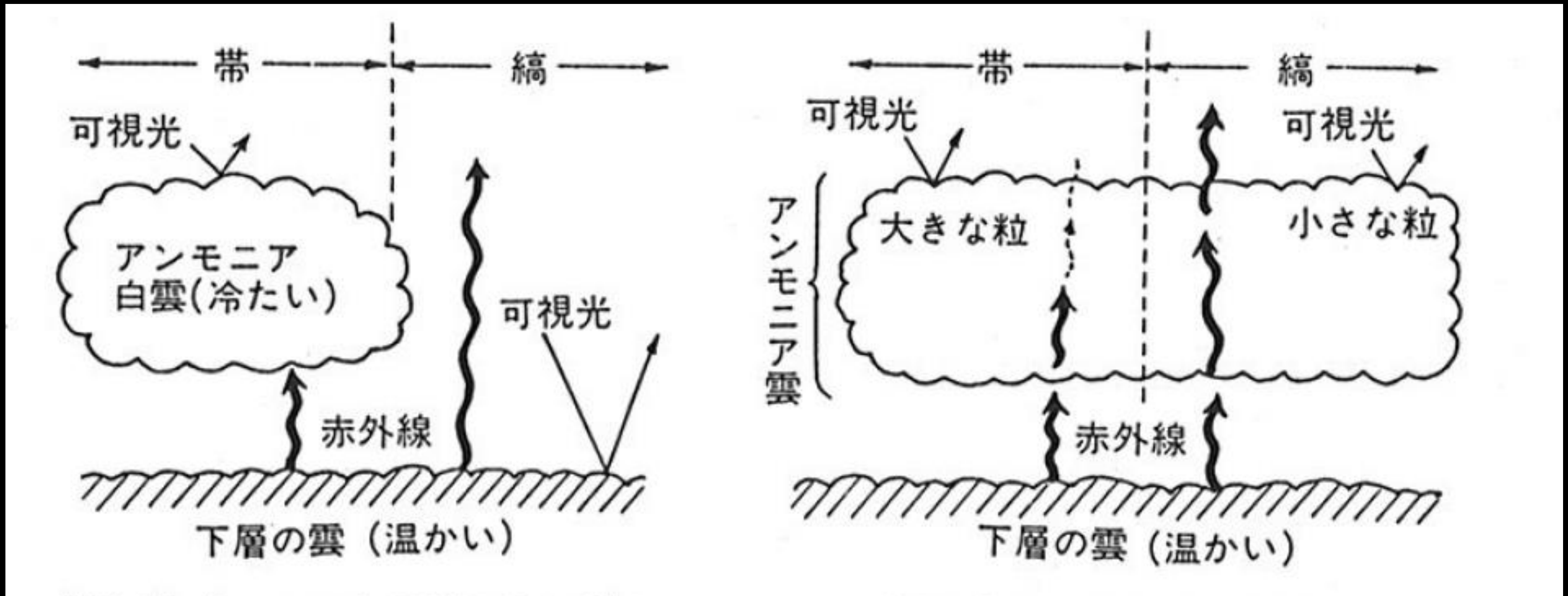


Fig. 7. Schematic representation of the global variation of cloud structure. Cloud altitudes (above the 1-bar pressure level) and optical depths are indicated. The areas are depicted wider in latitude than the bins used in this study.

解釈



【図1】オーエンとテリルのモデル　【図2】ウェストらのモデル

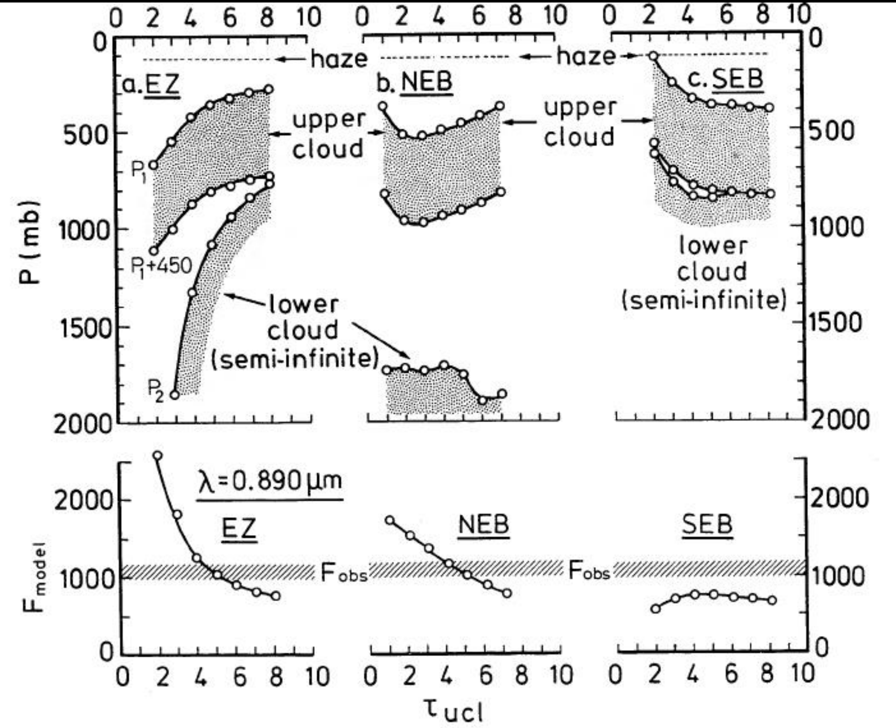


FIG. 4.—Locus of the value for the theoretical solar flux F_{model} in arbitrary units and the ranges of the cloud locations, obtained through the present analysis of the methane band data with the TCM. In the case of the EZ and the NEB, the values for F_{model} show good agreements with F_{obs} provided that the models have a cloud optical thickness of approximately 5. For the SEB, on the other hand, none of the F_{model} values based on parameter values capable of reproducing the observed CTLV agrees with that for F_{obs}. The improper theoretical brightness of the SEB model is likely to originate from the lack of gaseous absorption within the LCL.

Satoh and Kawabata 1994

NTBs outbreak

NTCurrent-C
NTCurrent-D

Reese 1971 , NMSUOの観測
9h47m台の自転周期の白斑

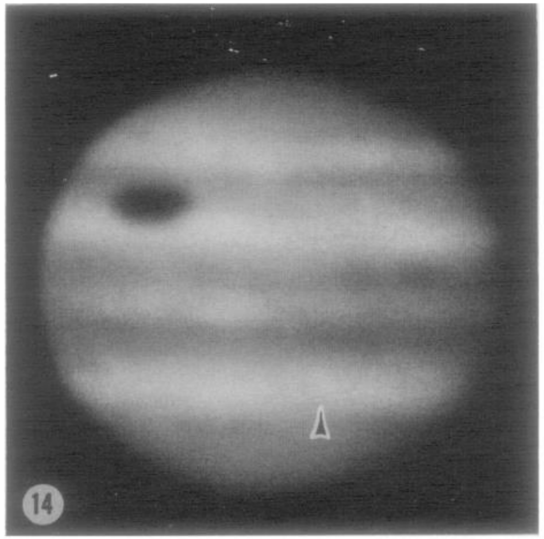


FIG. 14. Jupiter in blue light, 21 August 1970, 0203 UT, ω_1 323°, ω_2 55°, showing the pr
end of the south tropical disturbance approaching the Red Spot. The arrow points to a brig
at latitude 23°8 N which had the shortest rotation period ever recorded on Jupiter.

TABLE IV

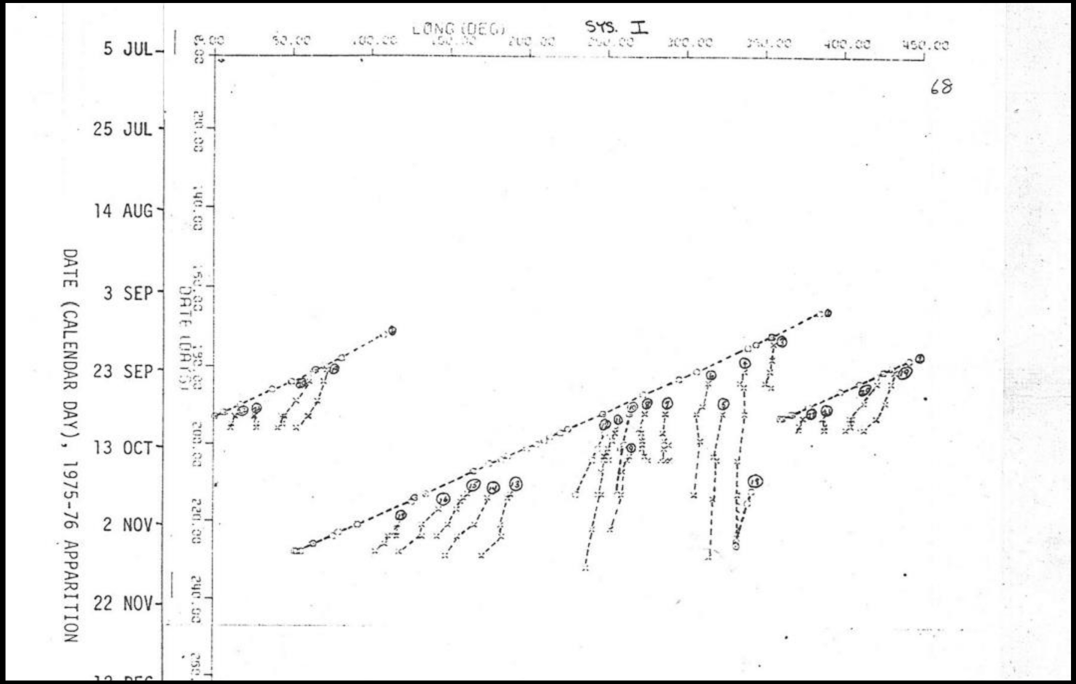
LATITUDE AND LONGITUDE MEASUREMENTS OF A RAPIDLY MOVING WHITE SPOT ON SOUTH EDGE OF NORTH TEMPERATE BELT

1970 Date	Longitude (System I)	Std. dev.	Number of measurements	Deviation from linear least squares position	Zenographic latitude
Aug 12.13	377°1	±0°3	6	−1°7	
19.08	344.5	±0.2	5	+1.5	+23°5
21.09	333.5	±0.2	7	+0.8	+24.1
28.09	295.8	±0.8	4	−0.7	
30.07	286.4	±0.3	4	+0.1	
Sep 8.06	239.8	±0.4	4	−0.0	
12.10	220.1	±0.2	5	+1.1	
21.07	171.6	±0.5	4	−1.1	

Least squares drift in System I = −5.162 deg/day
Least squares drift in System II = −12.792 deg/day or −170.65 ± 0.45 m/sec
Rotation period = $9^h47^m2^s.9 \pm 1^s.4$
Mean zenographic latitude = +23°8
Mean width = 5°6 = 6300 km (4 measurements)
Mean length = 6°5 = 7500 km (39 measurements)

NTBs outbreak in 1975-76 apparition

New Mexico State University Observatoryの観測結果
２つのリーディングスポット（白斑）(white spot)
多くの暗斑（dark spot)



P N.TEMP.CURRENT - C

1975-76

OBJECT	DESCRIPTION	LAT.	LENGTH	WIDTH	LIMITING DATES		DUR.	LIMITING LONGITUDES		N	SYS I DRIFT(D/D)	PERIOD 9HR+ MIN SEC	STD. DEV.	III(65) M/SEC	III(65) D/D
P 1	WC2 SPOT	23.2	6.6	4.0	75 9 9	75111C	62	386.5	53.7	55	-5.3755	46 54.4	0.2	170.61	-12.7385
P 2	WC2 SPOT	23.6	6.4	4.1	75 915	7510 6	21	110.0	1.9	16	-5.1820	47 2.1	2.0	167.64	-12.5450
MEAN	2 SPOTS	23.4					41				-5.2788	46 58.2		169.12	-12.6417
	(RECORD RAPID RATE FOR NTEC-C)														
P 14	DC2 BAR	24.3	9.0	4.0	751027	751111	15	175.1	147.6	4	-1.8596	49 15.1	9.4	122.67	-9.2226
P 15	DC2 BAR	24.1	9.2	4.5	751026	7511 6	11	161.0	142.8	6	-1.6524	49 23.4	3.8	120.05	-9.0154
P 16	DC2 BAR	23.9	8.5	4.5	75103C	751110	11	143.2	119.4	4	-2.1494	49 3.5	9.9	126.67	-9.5124
P 17	DC2 BAR	24.0	8.8	4.4	7511 3	75111C	7	118.5	104.0	6	-2.0914	49 5.8	9.9	125.98	-9.4544
P 20	DC2 BAR	23.9	8.8	4.8	75 927	751C 9	12	60.3	40.6	6	-1.6580	49 23.2	5.3	120.26	-9.0210
MEAN	5 SPOTS	24.0					11				-1.8822	49 14.2		123.17	-9.2452
MEAN	3 SML DARK	23.9	8.7	4.6			10							124.27	-9.3293

45.8.

IAUC 3478 (21 May 1980)

JUPITER
New Mexico State University Observatory is tracking a very bright spot in the jet in Jupiter's North Temperate Current C at 23o latitude. The spot was first seen on plates taken on May 11 and was measured at longitude 118o.5 (system II) on a plate taken on May 15d03h05m UT. Calculations from measurements on three dates yield a velocity of -13o.55 per day relative to system II. Plates taken in red light show a series of dark spots trailing the fast-moving bright spot.

360/(870.27-13.55)*24h = 9h46m32s

Rogers 1995 The Giant Planet Jupiter

Average (1891–1944)			49m 9.0s (±7.7s)	–60.4 (*N*=7)	53m 16.7s (+24.3s)	+123.4 (*N*=6)		
1964/65			49m 18.5s	–53 (1)			+24.2	NMSUO
1970	47m 3s	–155 (1)					+23.8	NMSUO
1975:								
Main:	46m 57s	–159 (3)						BAA
Main:	47m 18s	–144						SAF
Main:	46m 50s	–164 (1)	49m 35s	–41 (4)	52m 19s	+81 (2)	+23	SL&Q†
Second:	[48m 47s	–77]*						SAF
Second:	[48m 19s	–98]*(5)					+23	SL&Q†
1980	46m 33s	–178 (1)						NMSUO
1990	46m 50s	–165 (2)	49m 57s	–25 (9)			+23.8	BAA
Average (1964–1990)	46m 51.9s (±13.9s)	–163.4 (*N*=4)	49m 36.8s (±19.3s)	–39.6 (*N*=3)			+23.6 (±0.5°)	
Average (overall)	46m 51.9s (±13.9s)	–163.4 (*N*=4) (±10.7)	49m 17.4s (±17.4s)	–54.2 (*N*=10) (±12.6)	53m 8.4s (+31.1s)	+117.2 (*N*=7) (+22.5)	+23.6 (±0.5°)	
Voyager	47m 15s	–146 (global)					+23.8	Limaye (*1986*)
Voyager	46m 19s	–188 (global)					+23.7	Maxworthy (*1984*)

For each apparition, the Table gives the observed speed in two forms: *P* (rotation period, 9 hrs+), $\Delta\lambda_1$ (speed in System I in degrees per 30 days). (*N* is the number of spots with drifts recorded; see text for total number of spots in outbreak). 1892 values are approximate and not included in averages.

* Intermediate drift rates not included in averages.

†Sanchez-Lavega & Quesada (*1988*). Their speeds were approximate, ≈±30°/mth. Their latitude was for D and C current spots; B current spots were at 26.5°N. See text for descriptions of features.

2007(SEB攪乱直前）, 2012（シーズン末）, 2016（合直後）, 2020

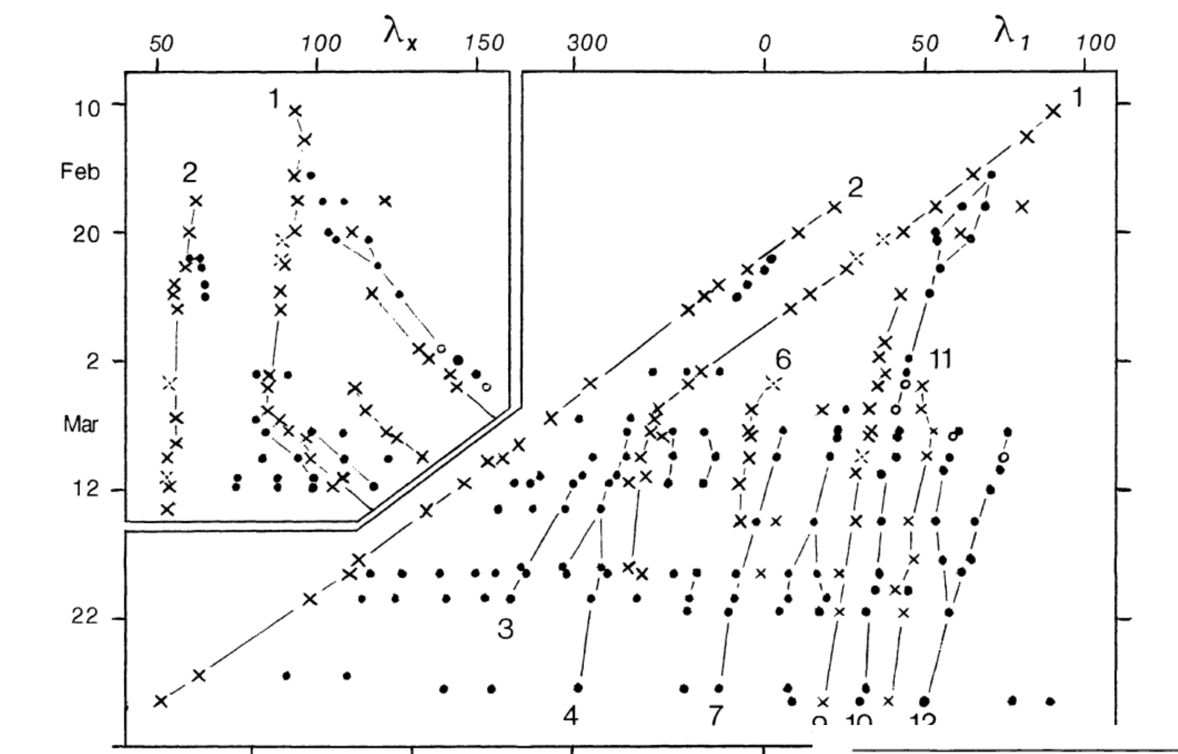


Figure 24. Chart of the NTBs jetstream outbreak, plotted in System I longitude. x, white oval; ●,
longitude system moving at −5.0°/day relative to System I.

1989-90 Apprition
Rogers (1992)

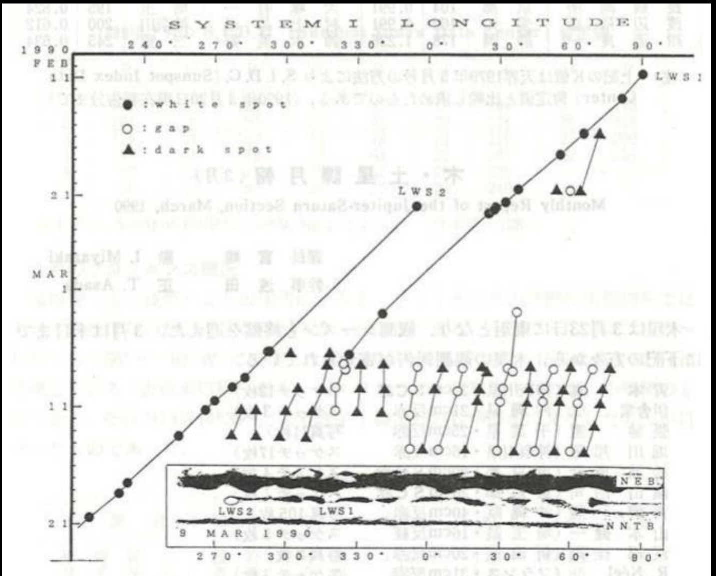


図1　NTBs の高速前進斑点のドリフトチャート
Longitude chart of rapidly moving NTBs spots.
図中の枠内は，3月9日の NEBn～NNTB の概略を示す。

宮崎　1990
天界　780

NTBs jetstream (Current D)			λ_1*(Feb 20)*			
1	Bright w. oval (also see no.5)	23.7	41	-169	Feb 10—Mar 4	6,5(12)
2	Bright w. oval (p. end of disturbance)	23.7	10	-160	Feb 17—Mar 20 (Apr 6)	11,4(21)
NTBs jetstream (Current C)			λ_1*(Mar 12)*			
3	D.s.	24.0	300	(-68)	Mar 9—Mar 20	7.0(11)
4	D.s.	24.0	310	-26	Mar 6—Mar 27	10,0(10)
5	Bright w. oval (=no.2)	23.5	322	(-21)	Mar 5—Mar 18	7,2(9)
6	Bright w. oval	(23.5)	353	-12	Mar 5—Mar 14	4,2(6)
7	D.s.	24.0	360	-36	Mar 5—Mar 21 (27)	7.0(8)
8	D.s.	24.0	17	-38	Mar 5—Mar 21	6,2(8)
9	Bright w. oval	(23.5)	30	-22	Feb 24—Mar 28	6,6(16)
10	D.s.	24.0	38	-27	Feb 20—Mar 10	4.6(13)
				-12	Mar 10—Mar 28	6.1(7)
11	W. bay NTBs	–	48	-12	Mar 4—Mar 28	2,8(11)
12	D.s. (f. end of disturbance)	24.2	71	-39	Mar 7—Mar 28	8,0(9)

Notes: *For NTropC features in 1988/89, which did not appear until after opposition, longitudes are for 1989 Feb 25, and the quoted drift between apparitions is calculated on the assumption that these longitudes were 2° too high due to phase effect.
For NTBs jetstream features, latitudes were measured by Miyazaki from his own photographs.

IAUC 4991, 1990 April
Tabe, Goto Optical, Tokyo, telexes that observations of the bright spot at latitude +24 deg (cf. IAUC 4967) by I. Miyazaki, K. Horikawa, T. Akutsu, M. Sato, and K. Yamamoto during Feb. 10-22 indicate a very short rotation period of 9h46m55s +/- 2s, corresponding to a wind speed of -150 m/s relative to System III. On Mar. 4.565 UT, T. Sata, Science University of Tokyo, using the 1.88-m reflector of Okayama Astrophysical Observatory (+ CCD camera at 890 nm, the methane absorption band), found this to be the brightest spot on the planet's disk, indicating a high altitude.

堀川　OAA木土星課　木星面　クロニクルより

1990年以来17年ぶりとなる。最初の観測はブラジルのCalvalho氏によるもので、27日に淡化したNTB上に2個の明るい白斑を捉えており、29日のPujic氏の画像では、白斑の後方に暗斑とやや北寄りに小白斑が出現している。白斑の位置は、前方(LS1)がI:37.7°(29日、Pujic氏)、後方(LS2)がI:97.5°(30日、Olivetti氏)で、LS1の初期のドリフトは-4.1°/day(自転周期換算で9h47m45s)と、北温帯流-CのLeading spotとして典型的な値を示している。NTBは2002年末以降、4年以上に渡り淡化状態にあった。今後はLeading spotの後方に少し遅い9h48m～49m台の自転周期で前進する暗斑群が出現し、NTBを数ヶ月足らずで濃化復活させると予想される。

北半球では、3月末に始まった北温帯流-Cの活動により、濃く太いNTBが復活しつつある。最初に発生した先行白斑(LS1)は木星面をほぼ半周して、I:227.7°(29日、Go氏)へと進んでおり、この間の前進速度は体系Iに対して-5.5°/dayに達する。これは自転周期に換算すると9h46m50.8s(体系IIIに対する風速では+168.8m/s)で、北温帯流-Cの先行白斑として典型的な値である。後方ではNTBが復活し、灰色の不規則な暗部や小白斑が連なって乱れており、高解像度の画像では隣接するゾーンにも微細な模様が広がっている。活動開始直後にはもうひとつの白斑(LS2)が観測されたが、4月中頃までに消失してしまったようである。4月末の時点では、LS1からI:70°付近まででNTBが濃く太く復活しており、その後方でもI:110°付近まで青灰色の暗斑が連なっている。一方、LS1前方のNTBはまだ淡く細いままであるが、高解像度の画像では小白斑やフィラメント状の暗部が見られる。

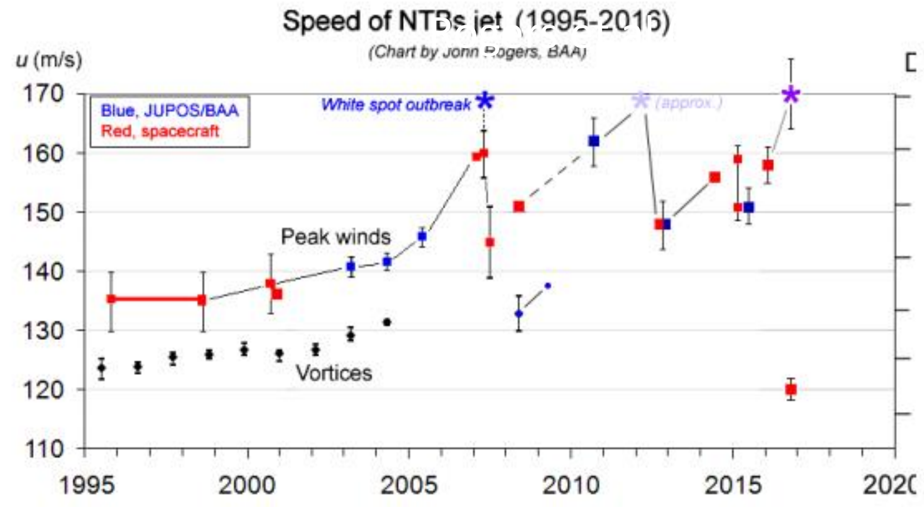


Figure 1. Chart of NTBs jet peak speed over recent decades.

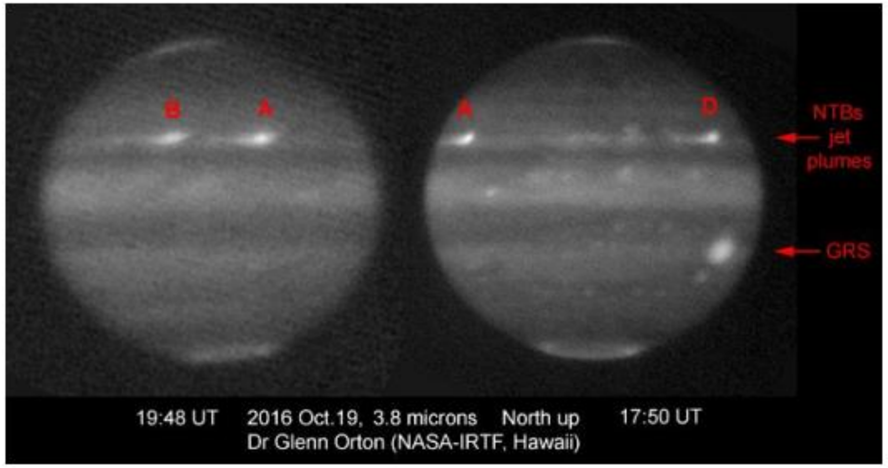
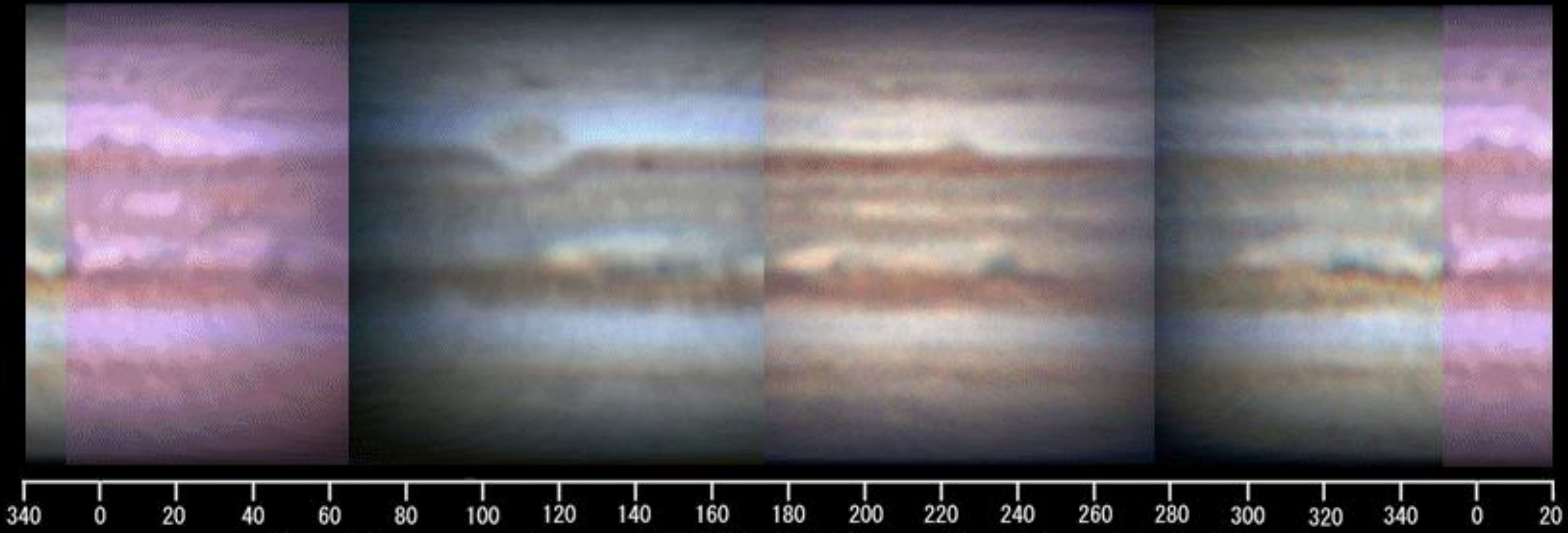


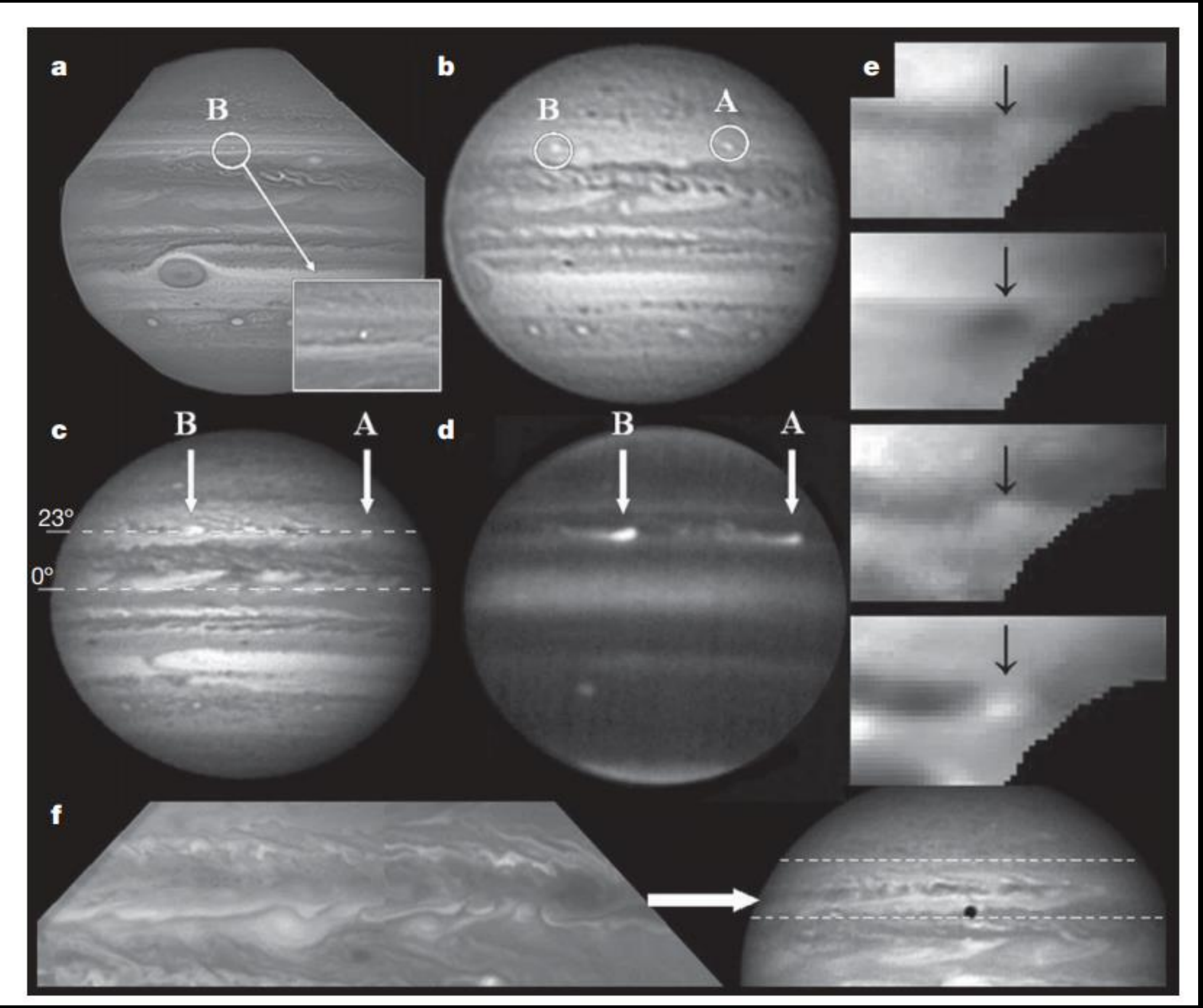
Figure 2. Discovery images of the NTB plumes, 2016 Oct.19 (from SpeX on the IRTF at 3.8 μm, sensitive to gas absorption).

2007年2月～4月　伊賀祐一さん作成



Cylindrical map on January 10/11/12, 2007 (Imaged by F.Carvalho, A.Wesley)

Sanchez-Lavega 2008 Nature 451、437



a 2007 25 March HST

b 2007 27 March IOPW

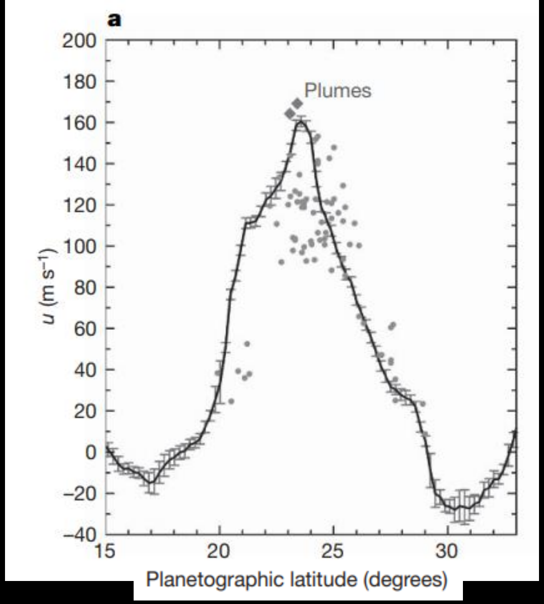
c 2007 5 April IOPW

d 2007 5 April IRTF

f 2007 1 May HST

plume A 23.4 ±04 169.2 ± 0.5m/s

plume B 23.1 ±0.1 164.3 ± 1.7 m/s



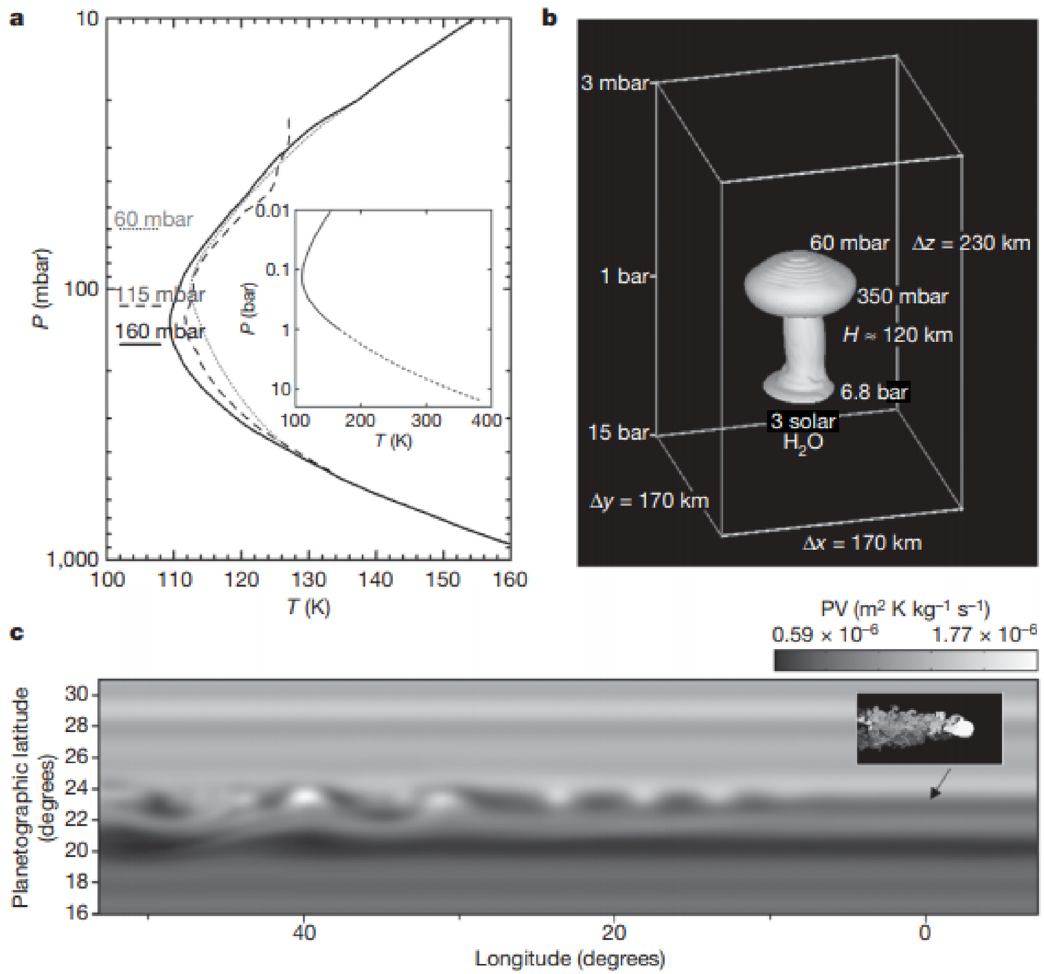


Figure 3 | Models of the plume onset and disturbance development. **a**, **b**, Wet convective three-dimensional model of the plumes. **a**, Thermal profiles used to run the simulations and the cloud top level reached by the convective cell assuming a deep water content of 3 times solar abundance and 95% of relative humidity above the condensation level. *P*, pressure; *T*, temperature. The continuous line corresponds to the Cassini CIRS thermal profile at the NTB location[19], the dashed line to the Voyager IRIS thermal profile[18] and the dotted line to a synthetic profile with less static stability from 500 to 200 mbar required for the storms to reach the 60 mbar level. The inset shows the wet adiabat extension deep in the atmosphere. **b**, Convective cell resulting from the model able to fit the observed cloud tops of the plumes and the domain of simulation. **c**, The plume brightness distribution (inset) results from a two-dimensional model of a round cloud placed in the peak of the jet and evolving as it interacts with the meridional shear of the zonal wind[17] with a spatial resolution of 5 km over a 10,000 × 5,000 km area. The map (main panel) shows the distribution of Ertel's potential vorticity (PV; greyscale) at 650 mbar after 30 days for a simulation where the jet extends vertically downwards with constant value from the upper cloud layer at altitude ~0.6 bar down to at least 5–7 bar (the location of the water clouds and the plume source). Inset and map are at the same scale.

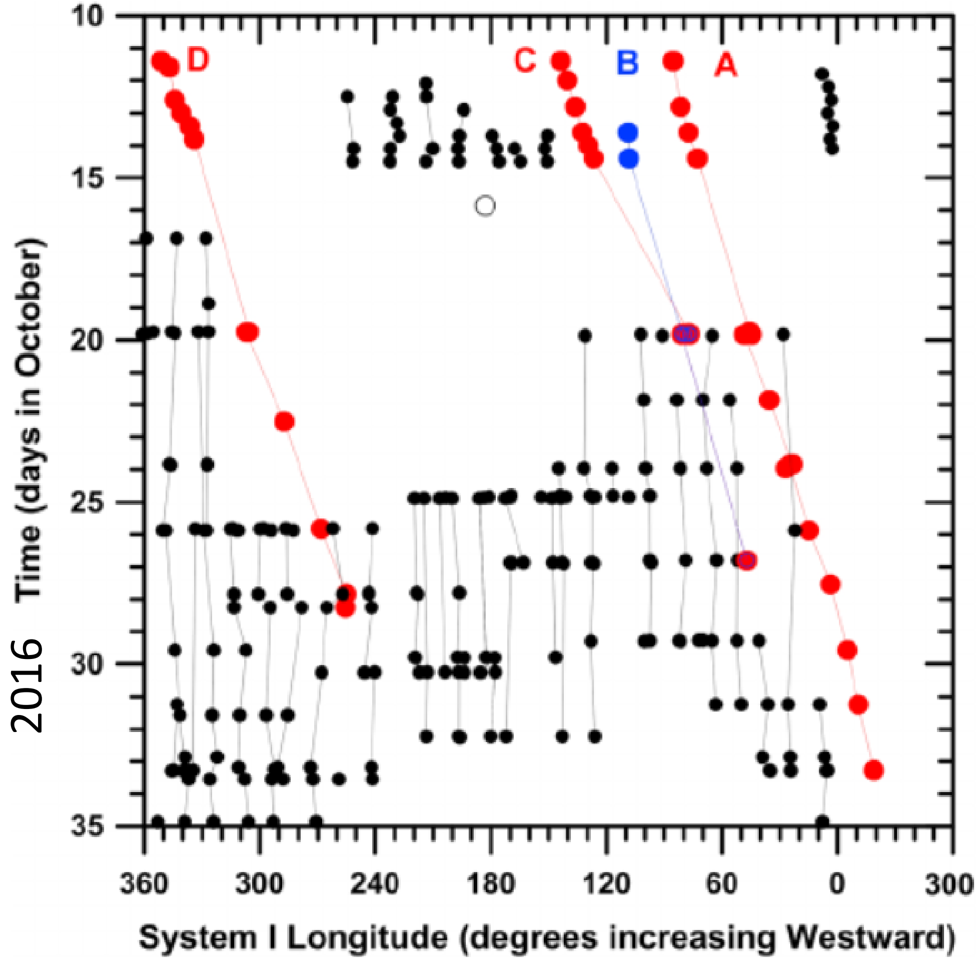


Figure 2. Drift rate in System I longitude of the features pertaining to the NTBD, tracked between 10 October and 4 November 2016. The plumes A, C, and D are identified by red dots. Plume B is the blue dot: it disappeared or merged with plume C. The dark dots indicate features forming the NTBD westward of the plumes. The lines identify the tracking of the features. Data from JunoCam images are for 11–14 October.

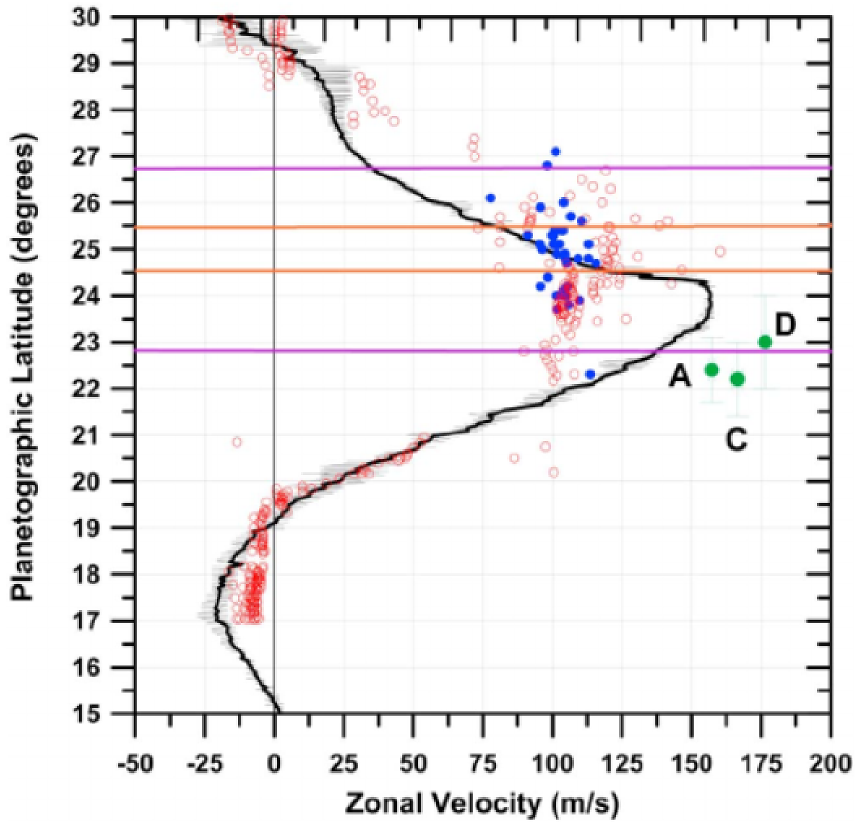


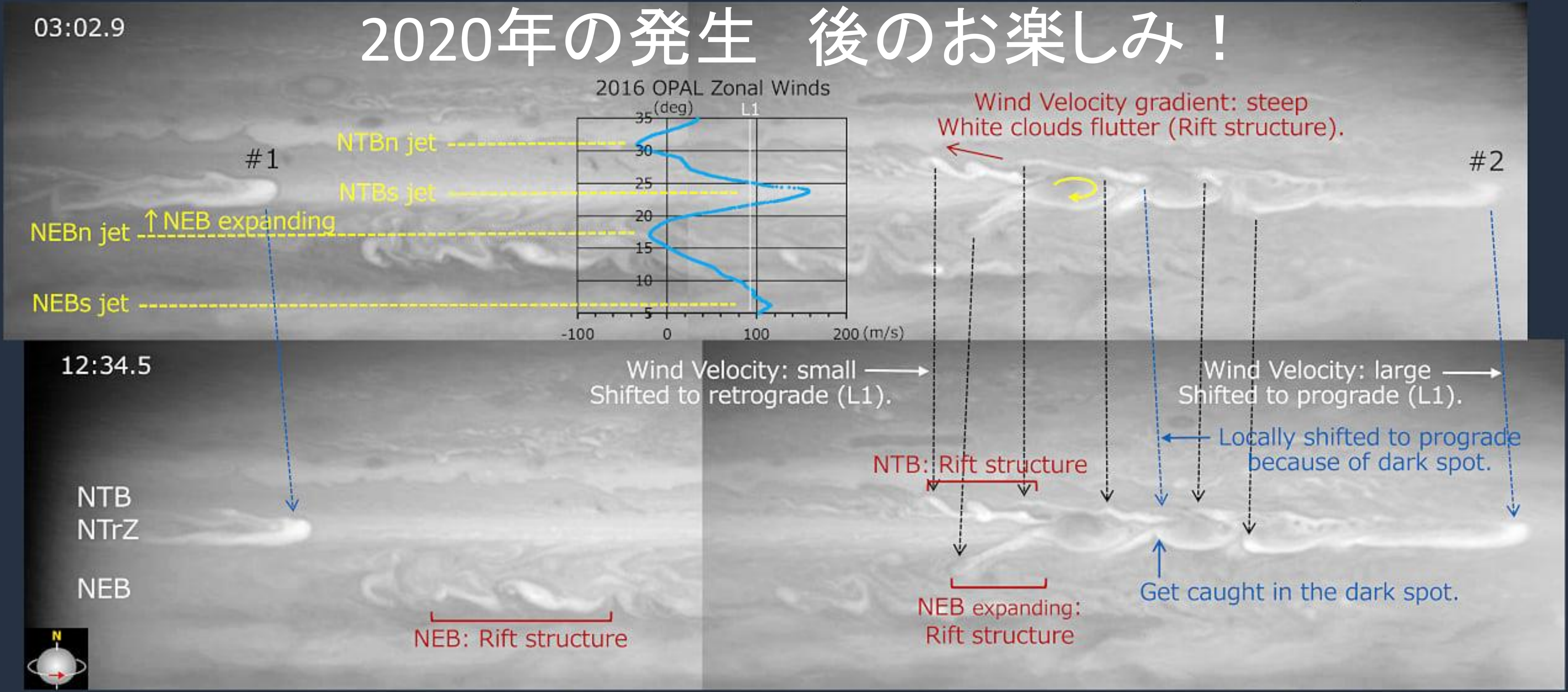
Figure 4. Meridional profile of the NTBs jet stream as measured using HST images on 9–10 February 2016 about 7–8 months before the outbreak (black curve with wind error measurement indicated [*Hueso et al.*, 2017b]). The velocity and location of the NTBD disturbance features are shown as dots: green for the plumes (A, C, and D), blue dots for long-term tracked features (dark and white spots, tracking for 5–10 days), and circles for all kind of features (tracking on Pic-du-Midi images for about 50 h using two methods). The NTBD data correspond to the period 11 October to 11 November 2016. The horizontal orange lines mark the limits of the pre-outbreak band that was bright in UV but dark in methane absorption at 890 nm (Figure S1). The horizontal purple lines mark the limits of the reddish band that formed when the NTBD activity ceased (Figure S5).

Sanchez-Lavega (2017) GRL

Winds around NTBs jet-stream Outbreak

2020 Sep. 20 HST, UV (F343N) – Maps (L1)

credit: ESA Science Archive / S. Mizumoto

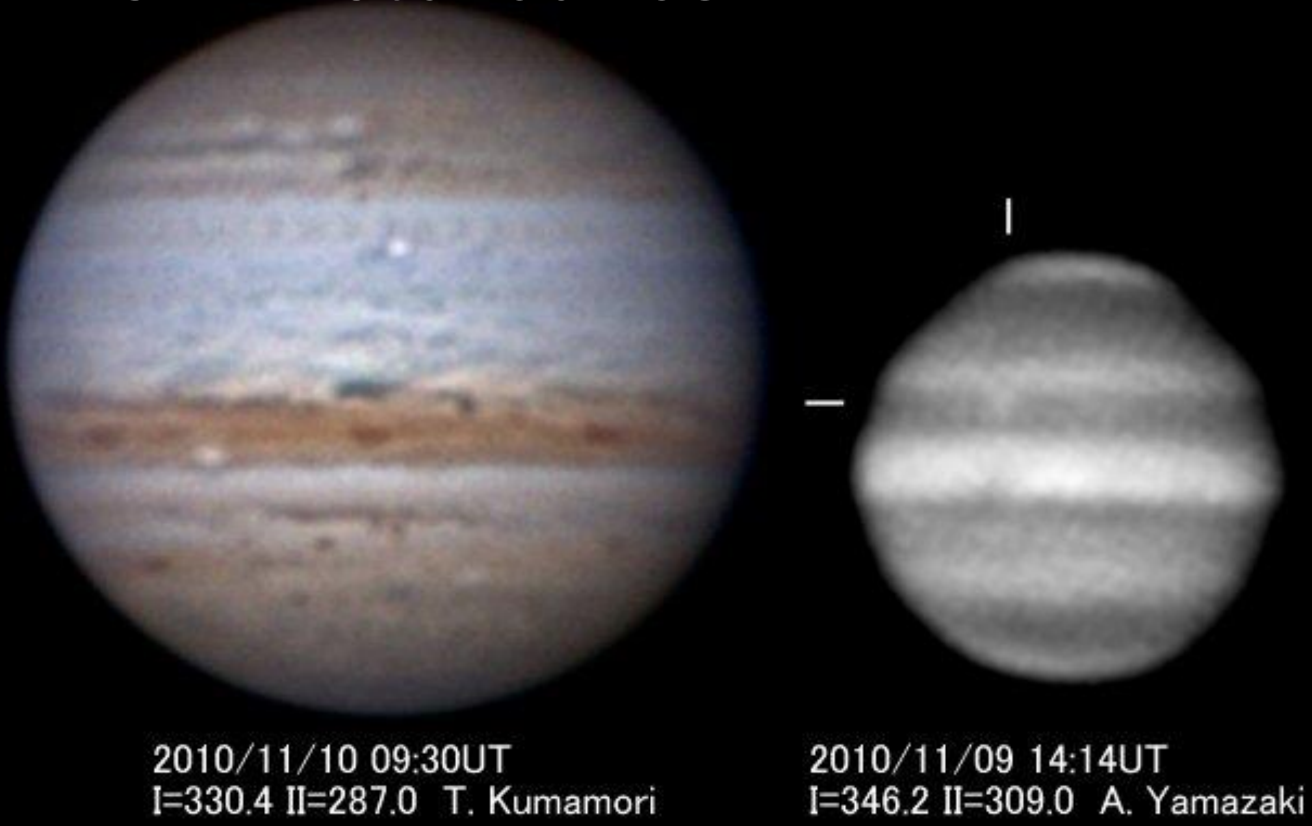


- NTBs white clouds and NTrZs white clouds appear to be fluttering and stretched by steep wind velocity gradients.
  → Rift structure

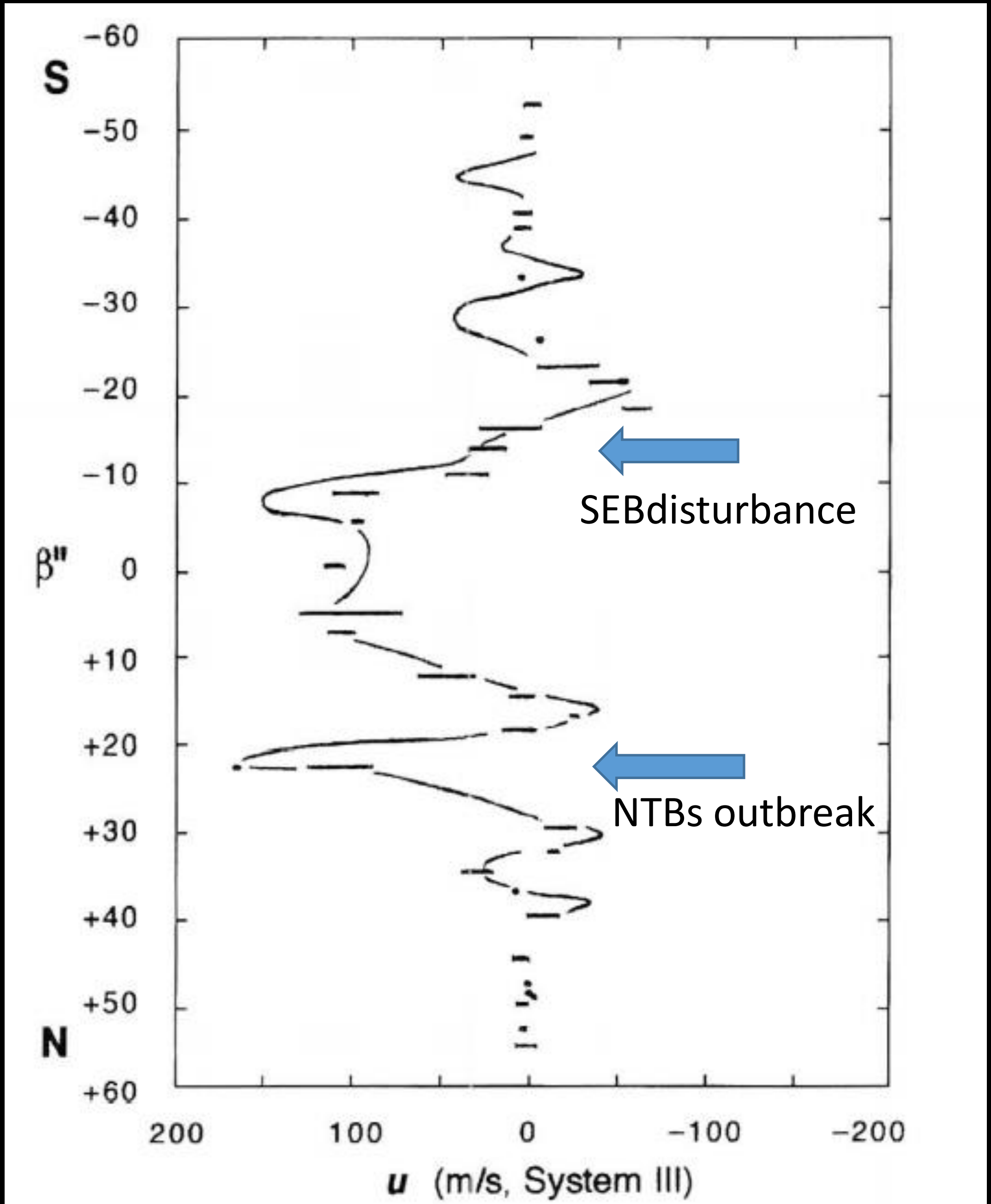
Lead Spot	最初の観測	木心緯度	風速（m/s）	自転周期	出典
1970A	1970/8/12.13	+23.8	170.65	9h47m2.9s ± 1.4	Reese 1971
1975A	1975/9/9	+23.2	170.61	9h46m54.4s ± 0.2	NMSUO 1977
1975B	1975/9/19	+23.6	167.64	9h47m2.1s ± 2.0	NMSUO 1977
1980A	1980/5/15	+23	(-13.55deg/day II)	9h46m32.68s	IAUC3478
1990A	1990/2/10	+23.7	169		Rogers 1992
1990B	1990/2/17	+23.7	160		Rogers 1992
2007A	2007/3/25	+23.4	169.2 ± 0.5		Sanchez-Lavega 2008
2007B	2007/3/27	+23.1	164.3 ± 1.7		Sanchez-Lavega 2008
2016A	2016/10/11	+22.4 ± 0.7	157.3 ± 1.1		Sanchez-Lavega 2017
2016B+C	2016/10/11	+22.2 ± 0.8	198.6 ± 2.0		Sanchez-Lavega 2017
2016D	2016/10/11	+23.0 ± 1.0	176.4 ± 1.3		Sanchez-Lavega 2017
2020A		+23.1 ± 0.3			
2020B					

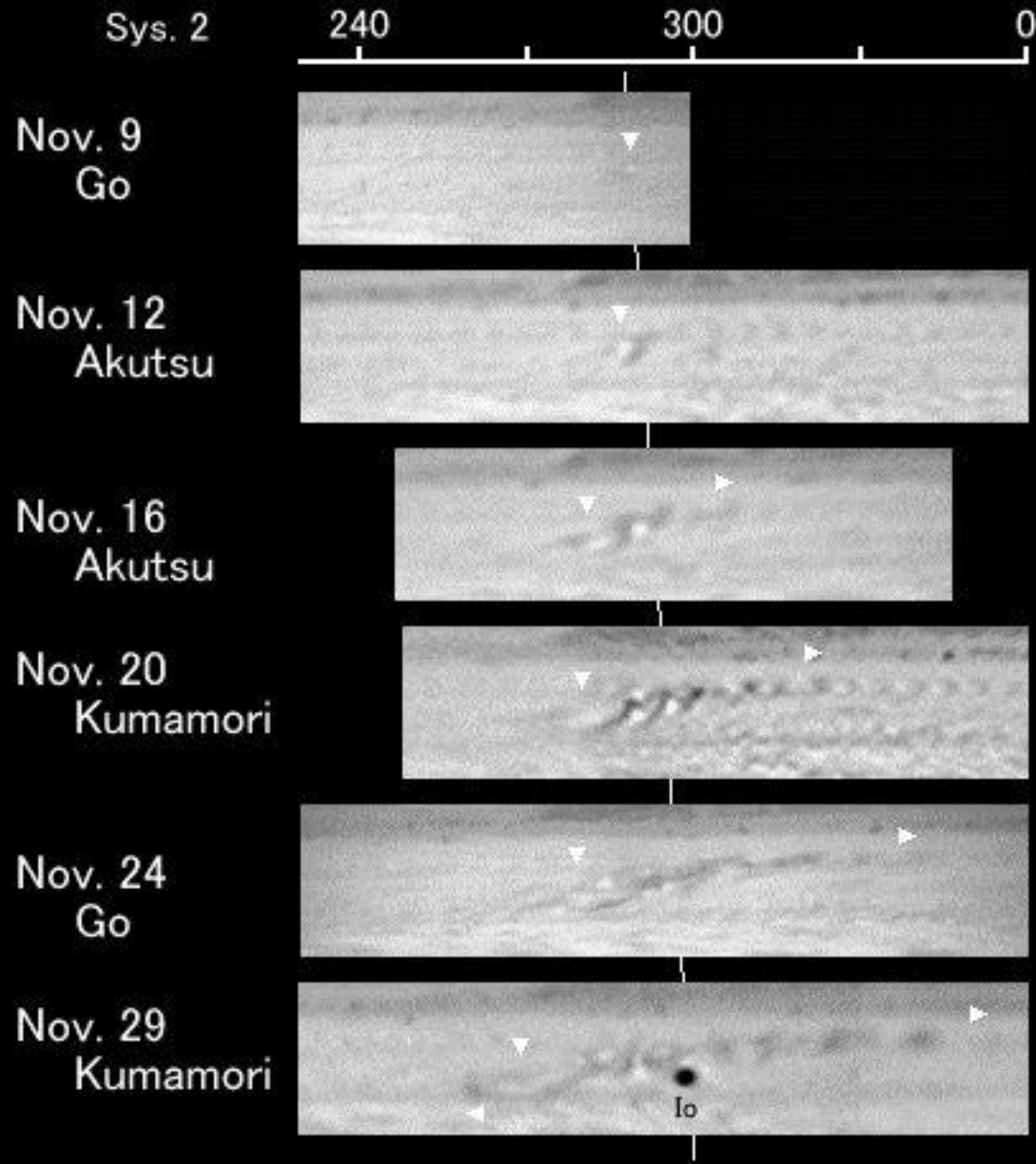
類似の現象

類似の現象
SEBDisturbance



2010年のSEB攪乱の初期の状態：OAA木土星課





SEB攪乱の発達

堀川　OAA　木土星課
木星面クロニクルより

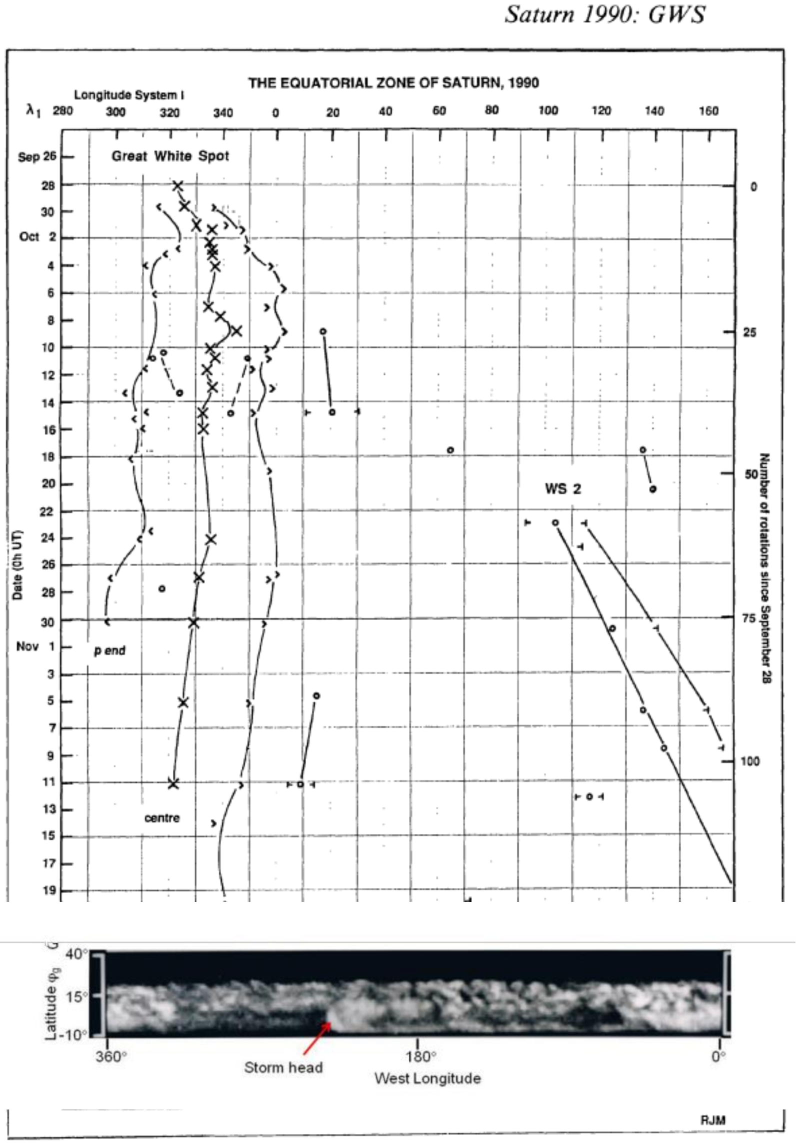


Figure 1. The motion of the GWS and other EZ features in System I longitude. Rotational averages of the GWS centre are marked by crosses, whilst open circles denote either bright patches within the GWs or white ovals at other longitudes.

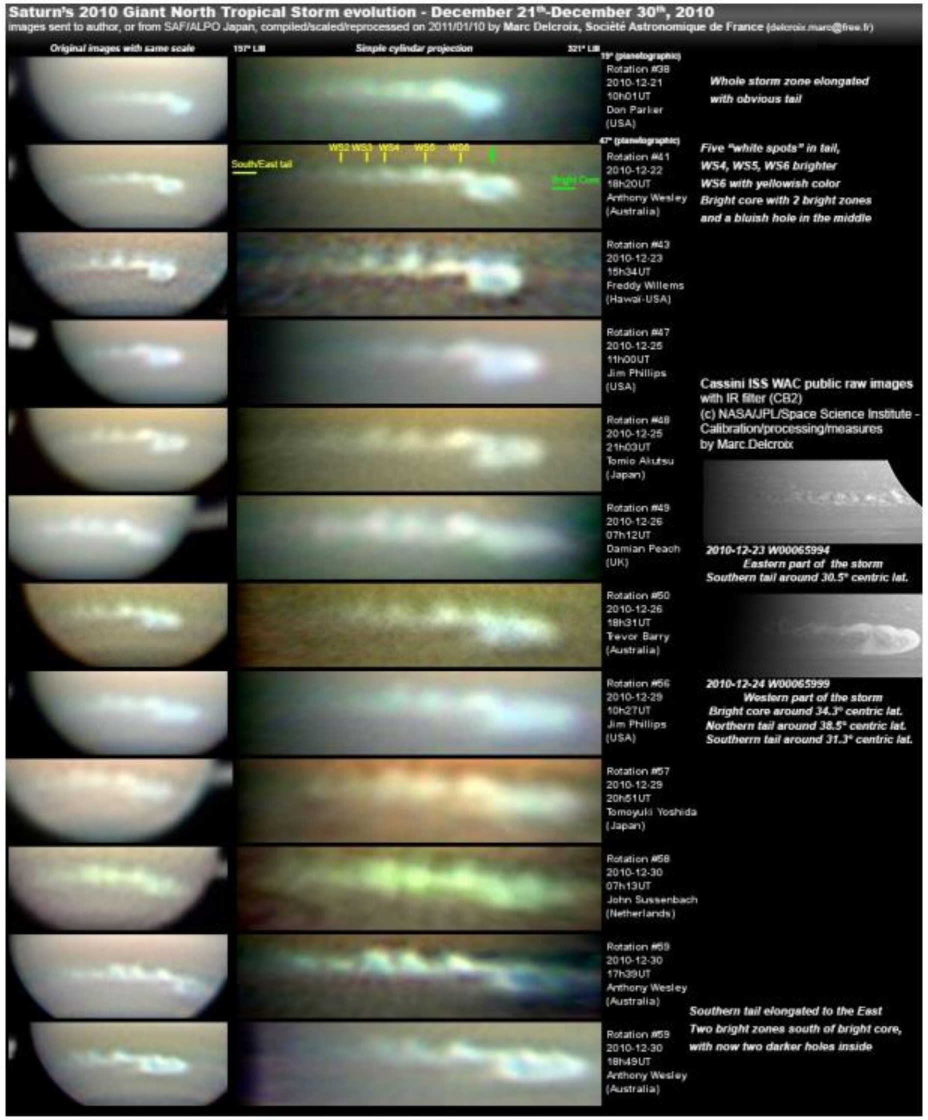
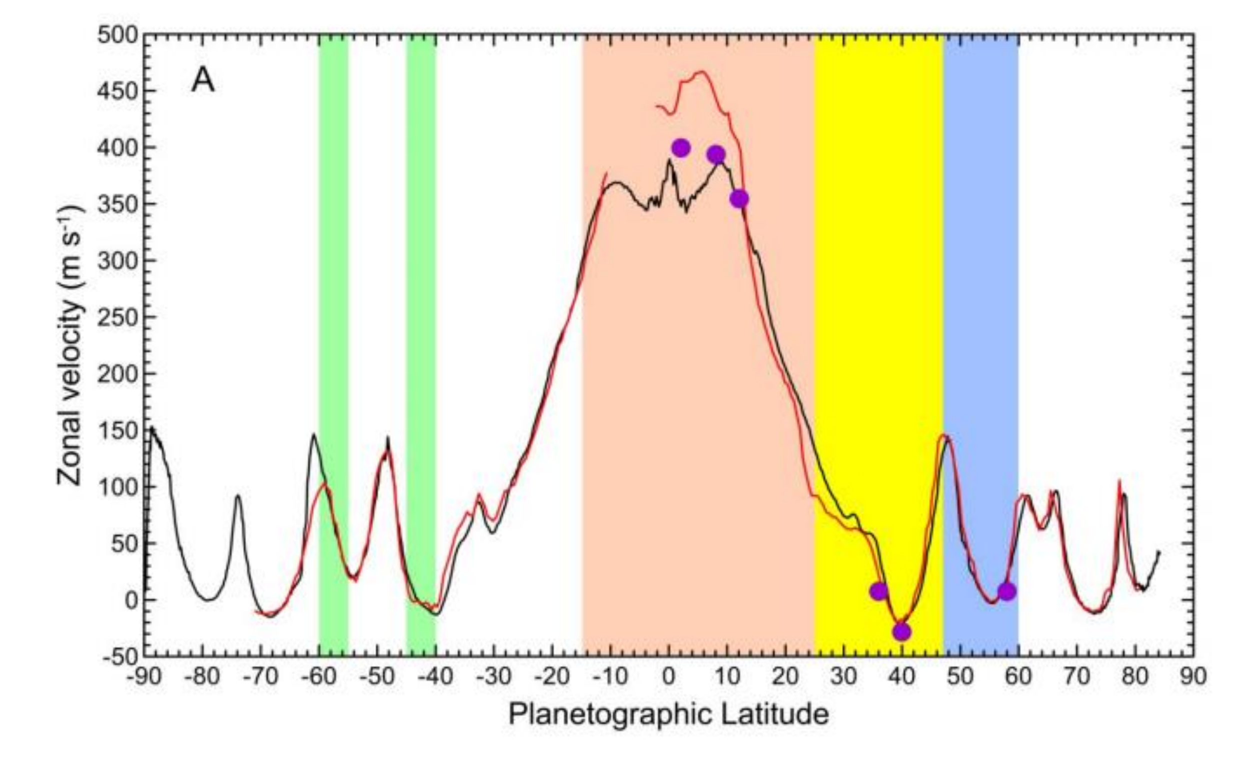


Figure 10.a: Evolution of Saturn's growing Great White Spot in 2010-11 from amateur images in scale (left), maps made from the amateur images (center) and images by Cassini spacecraft (right).

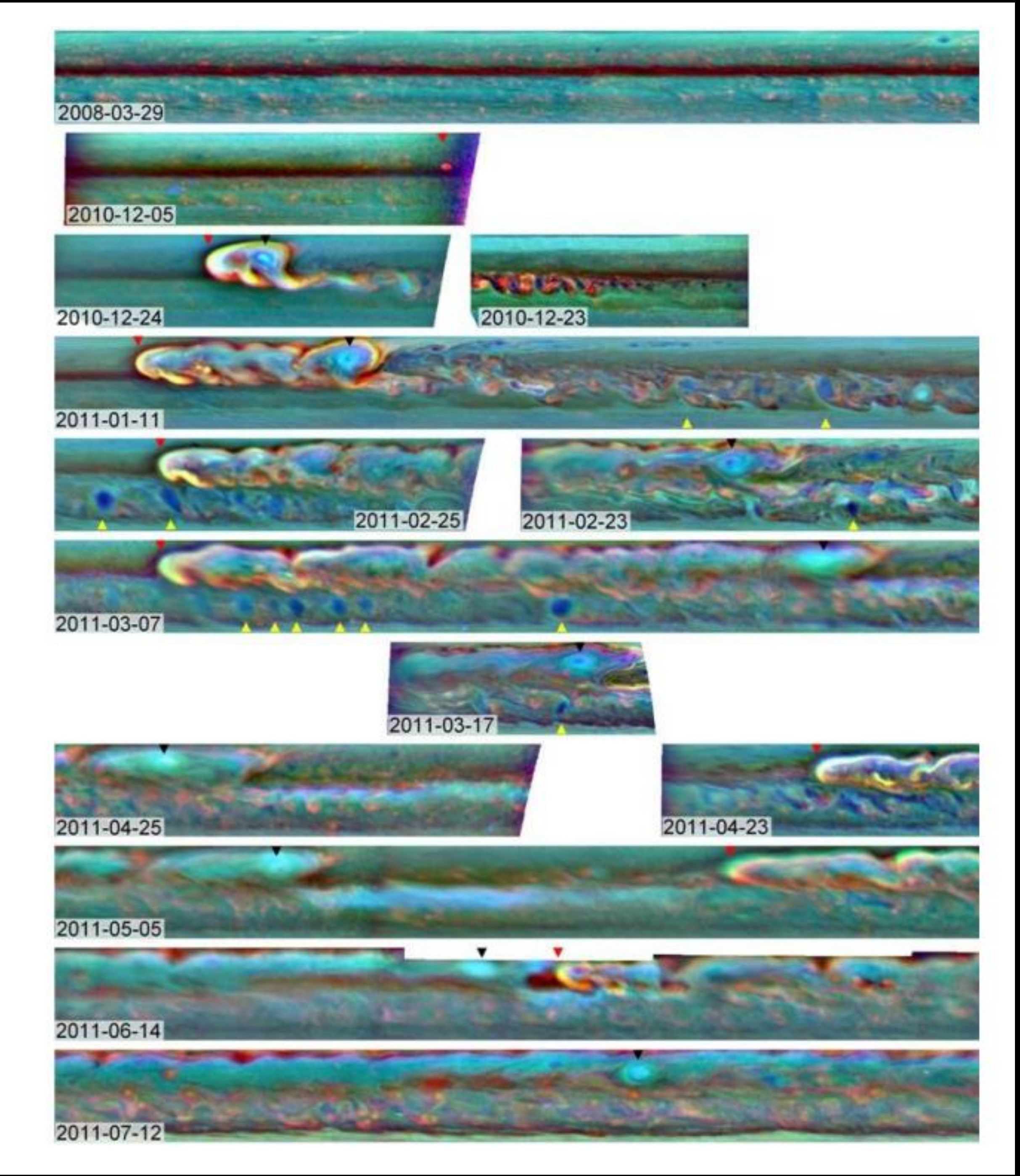
1990年のEZの白斑　Heath and McKim (1992)

Karadasis 2014



Event	First detection	Orbital longitude	Latitude Planetographic (Planetocentric)	Velocity (ms^{-1})	Affected latitude band	Ambient vorticity (s^{-1})	Planetary vorticity (s^{-1})
GWS 1876	1876.9	170°	8°±3°N (6.5°)	396	~ 0° – 20ºN	-4x10^{-6}	4.6x10^{-5}
GWS 1903	1903.5	130°	36°±2°N (30.6°)	19	~ 30° – 45ºN	-7x10^{-6}	1.8x10^{-4}
GWS 1933	1933.7	134°	2°±3°N (1.6°	400	~ -5° – 20ºN	2.0x10^{-5}	1.1x10^{-5}
GWS 1960	1960.25	106°	58ºN ± 1º (52.5°)	4	48ºN – 60ºN [78ºN]*	10^{-5}	2.8x10^{-4}
GWS 1990	1990.9	121°	12ºN ± 1º (9.8°) [5ºN ±2º]† (4.1°)	365.0 [402.0]†	15ºS – 25ºN	-4x10^{-5} [2.0x10^{-6}]†	6x10^{-5}
GWS 2010	2010.93	16°	38ºN (32.4°) [41ºN ± 1º]& (35.2°)	-27.8	25ºN – 48ºN	3x10^{-6}	1.9x10^{-4}

Sanchez-Lavega 2017



NTBs outbreak
SEB 攪乱、midSEB outbreak
土星に起こる白斑

Bright Spotが内部から上ってくる （**何故か固い棒！**）

上って来る場所は帯状流とは関係ない
（ただし、その場所の風に乗っている。これが風速に影響を与えることはない？）

ジェットのピーク付近に上ってくると、NTBs outbreak のような振る舞いになる

ジェットの中腹に上ってくると、SEB攪乱のような振る舞いになる