50.07 Uranus at Equinox: Cloud morphology and dynamics

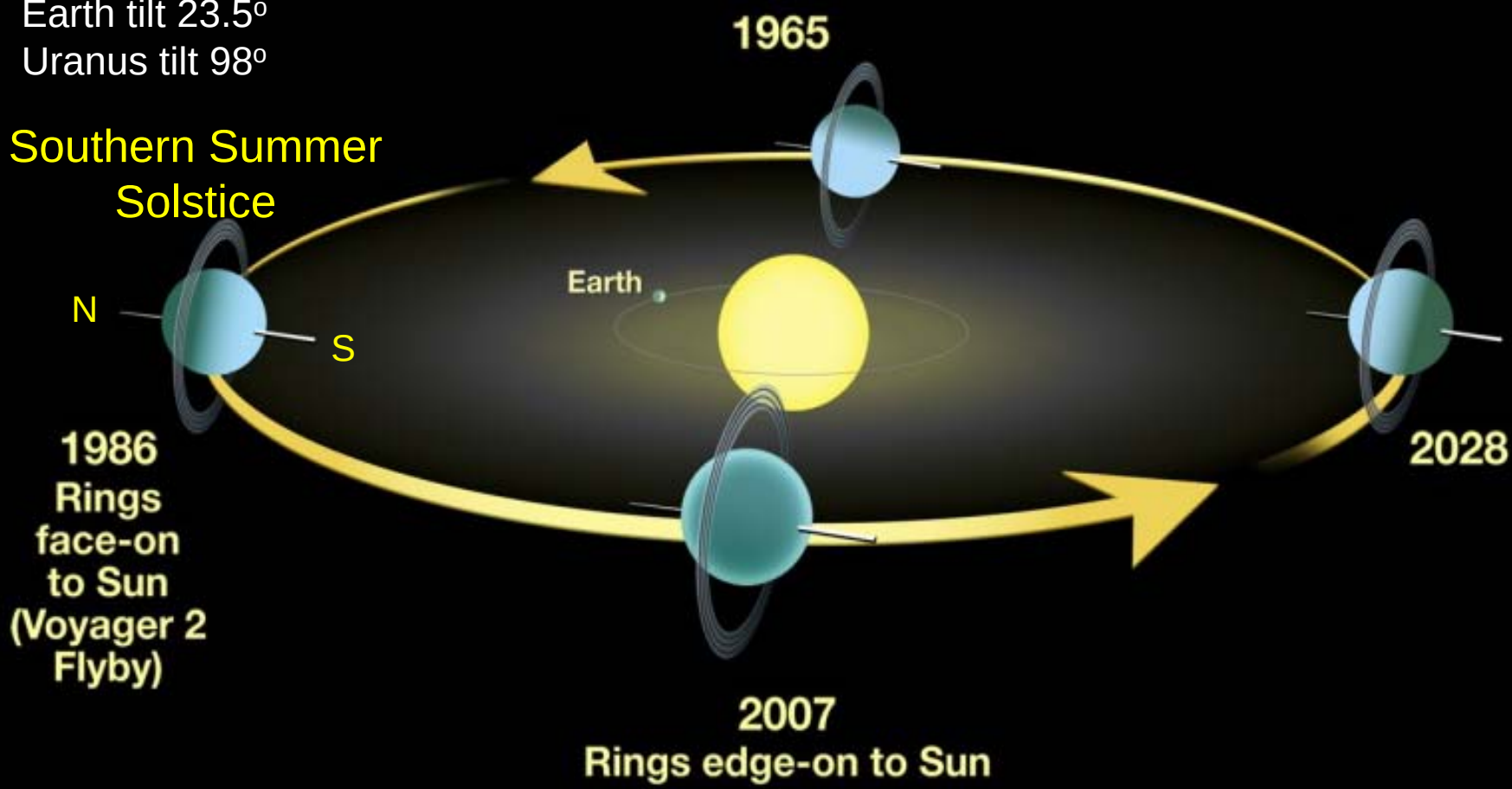
14 October 2008 DPS Meeting, Ithaca, NY

Lawrence A. Sromovsky[1], P. M. Fry[1], W. M. Ahue[1], H. B. Hammel[2], I. de Pater[3], K. A. Rages[4], M. R. Showalter[4], M. A. van Dam[5]

[1]Univ. of Wisconsin, Madison, [2]Space Science Institute, [3]University of California, Berkeley, [4]SETI Institute, [5]W. M. Keck Observatory.

Seasons of Uranus

84 year orbit
spin axis tilt forces seasons
Jupiter tilt 3°
Earth tilt 23.5°
Uranus tilt 98°



graphic from M. Showalter and M. Gordon, SETI Institute

Opportunities at Equinox

- Equal views of both hemispheres.
- First look at complete northern hemisphere with modern instruments.
- Ring plane crossing.
- Views of dark side of rings.

2007 Keck and HST observations used in collaborative analysis:

Keck II

Date	Temporal Coverage (h UT)	Sub Obs. Lat.(° PG)	Sub Sol. Lat. (° PG)	Uranus Diam. (as)	Phase Angle (°)	PI
7 June 2007	14:19-15:23	0.97	-2.03	3.504	2.893	van Dam
26 July 2007	10:44-15:11	0.66	-1.49	3.639	2.076	de Pater
27 July 2007	10:37-15:34	0.64	-1.48	3.641	2.041	Hammel
28 July 2007	12:07-15:12	0.61	-1.47	3.643	2.005	Hammel
30 July 2007	11:24-15:28	0.56	-1.45	3.648	1.932	Sromovsky
31 July 2007	10:34-15:22	0.53	-1.43	3.650	1.894	Sromovsky
8 August 2007	11:15-15:06	0.29	-1.35	3.665	1.574	de Pater
9 August 2007	10:53-15:20	0.25	-1.33	3.666	1.531	de Pater
19 August 2007	10:30-14:51	-0.10	-1.22	3.680	1.083	Sromovsky
20 August 2007	10:27-14:49	-0.14	-1.21	3.682	1.036	Sromovsky
7 September 2007	10:47-13:26	-0.86	-1.01	3.693	0.153	Hammel
9 September 2007	8:13-13:21	-0.94	-0.99	3.693	0.061	Showalter

HST

Date	Temporal Coverage (h UT)	Sub Obs. Lat. (° PG)	Sub Sol. Lat. (° PG)	Uranus Diam. (as)	Phase Angle	PI
28 July 2007	2:48-11:25	0.61	-1.47	3.643	2.005	Sromovsky
29 July 2007	2:47-11:23	0.59	-1.46	3.645	1.969	Sromovsky
17 August 2007	7:14-7:29	-0.03	-1.25	3.678	1.176	Rages
19 August 2007	23:16-23:31	-0.10	-1.22	3.680	1.083	Rages
27 August 2007	6:59-8:53	-0.41	-1.13	3.688	0.699	Rages

Objectives of atmospheric collaboration:

Extend wind observations to higher northern latitudes.
Increase wind speed accuracy with longer time base.
Characterize dynamics of major discrete features.
Characterize evolution of major cloud bands.

Questions to be answered:

Is the circulation profile symmetric?
Does it vary with the seasons?
Is the asymmetric band structure seasonal?
What changes in vertical structure are occurring?
How do major circulation features evolve?

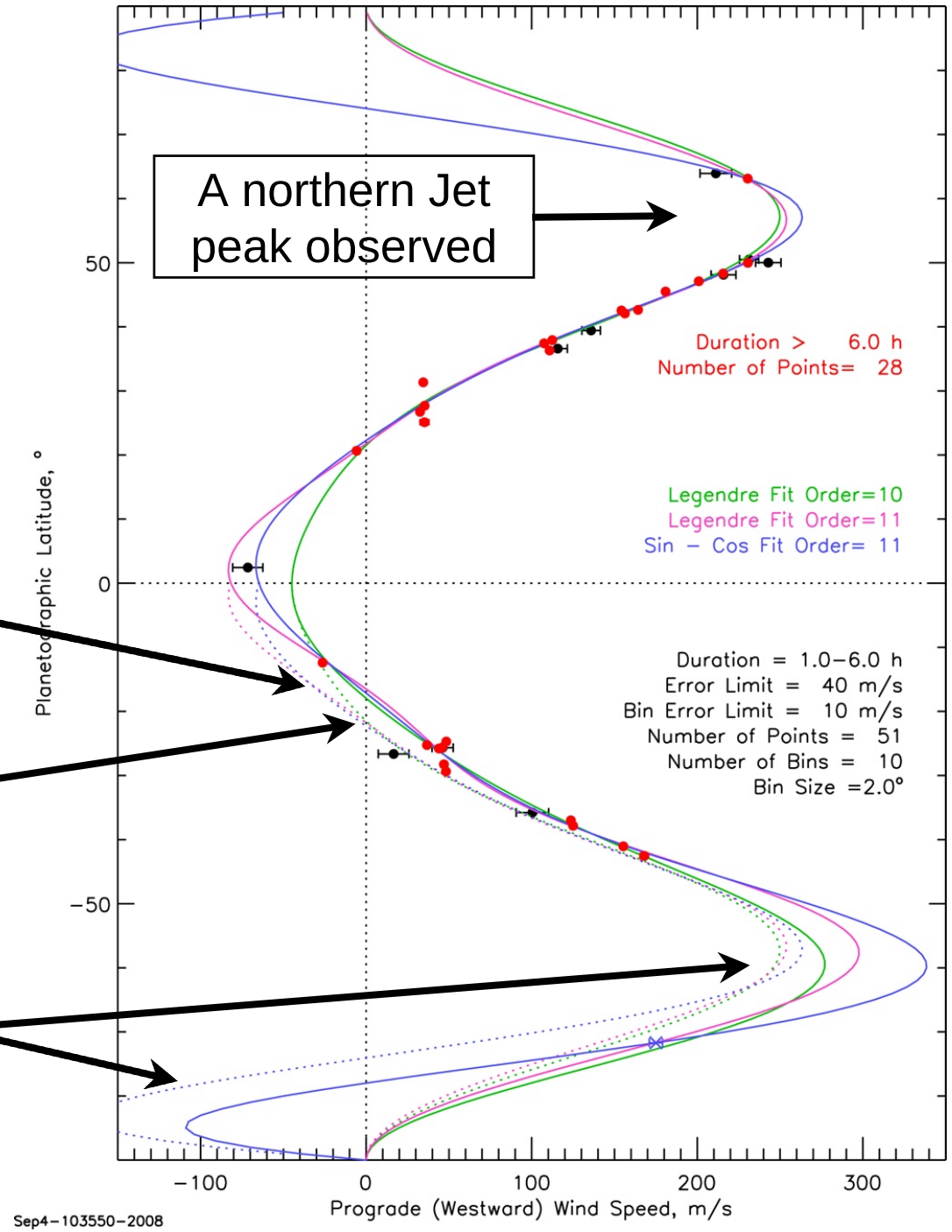
Fits to high-accuracy 2007 winds:

Fourier and Legendre fits illustrate lack of constraints at high latitudes and near the equator.

Dotted curves show northern fits reflected about equator.

At mid latitudes, northern reflection is 20 m/s slower than southern fit.

There might be asymmetries at other latitudes, but current observations can't define them.

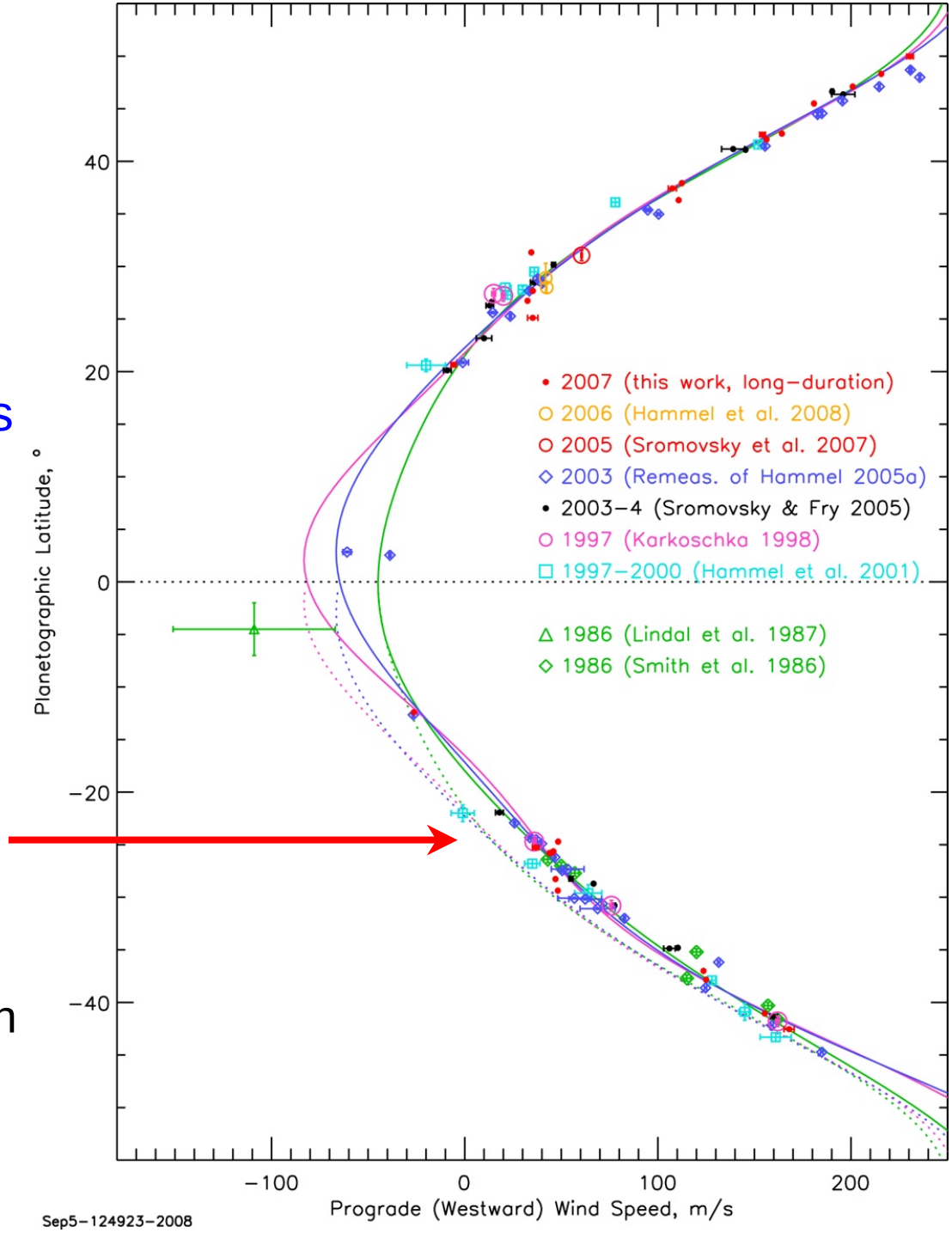


Comparison with prior observations.

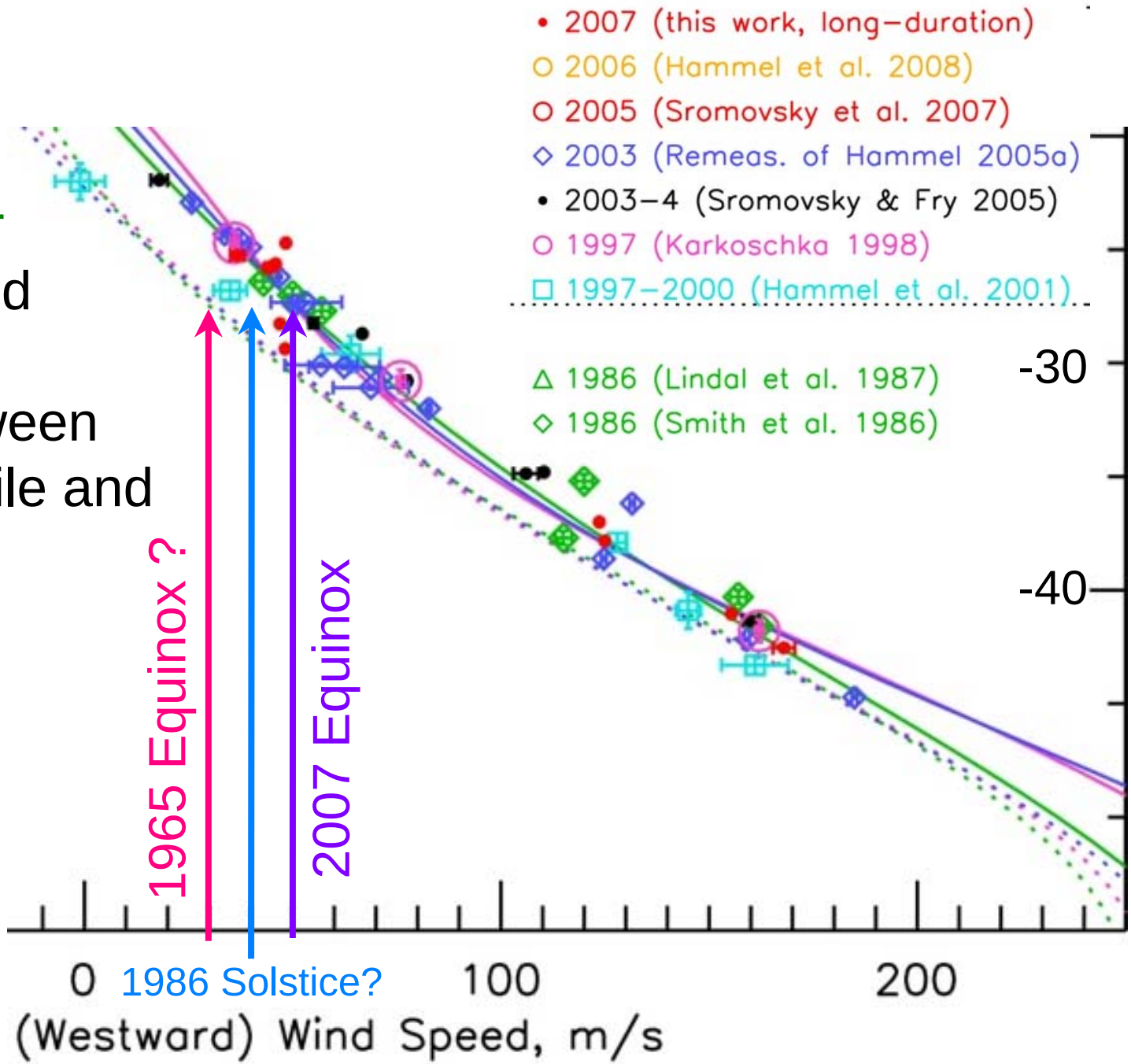
High accuracy HST, Voyager, and Keck results from 1986 to 2007 exhibit a high degree of consistency.

There is no clear evidence for reversal of the current asymmetry.

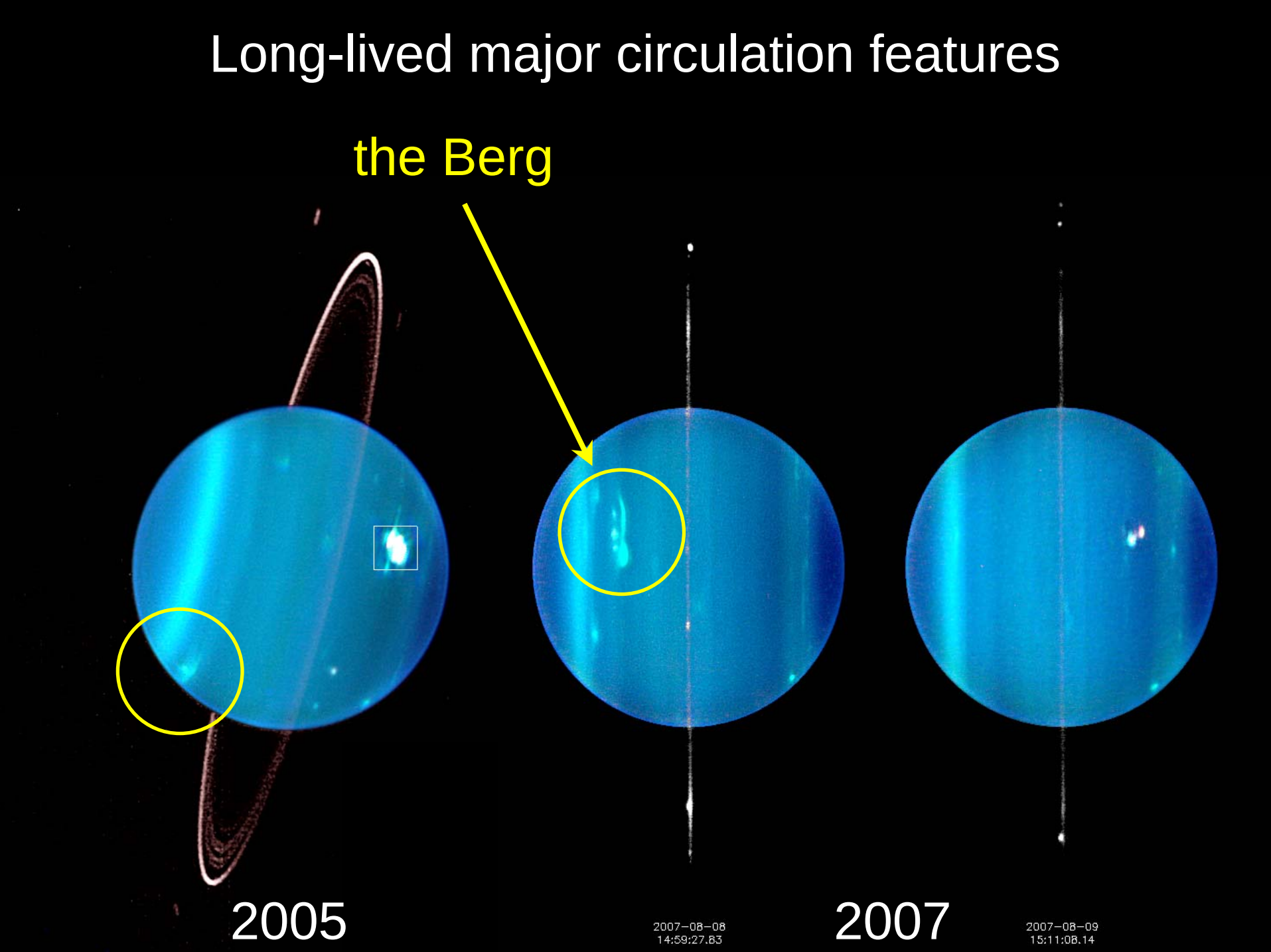
The Voyager southern wind profile is not midway between equinox profile and its inversion.



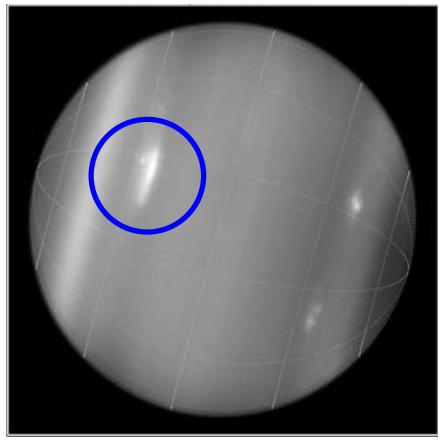
The Voyager southern wind profile is not midway between equinox profile and its inversion.



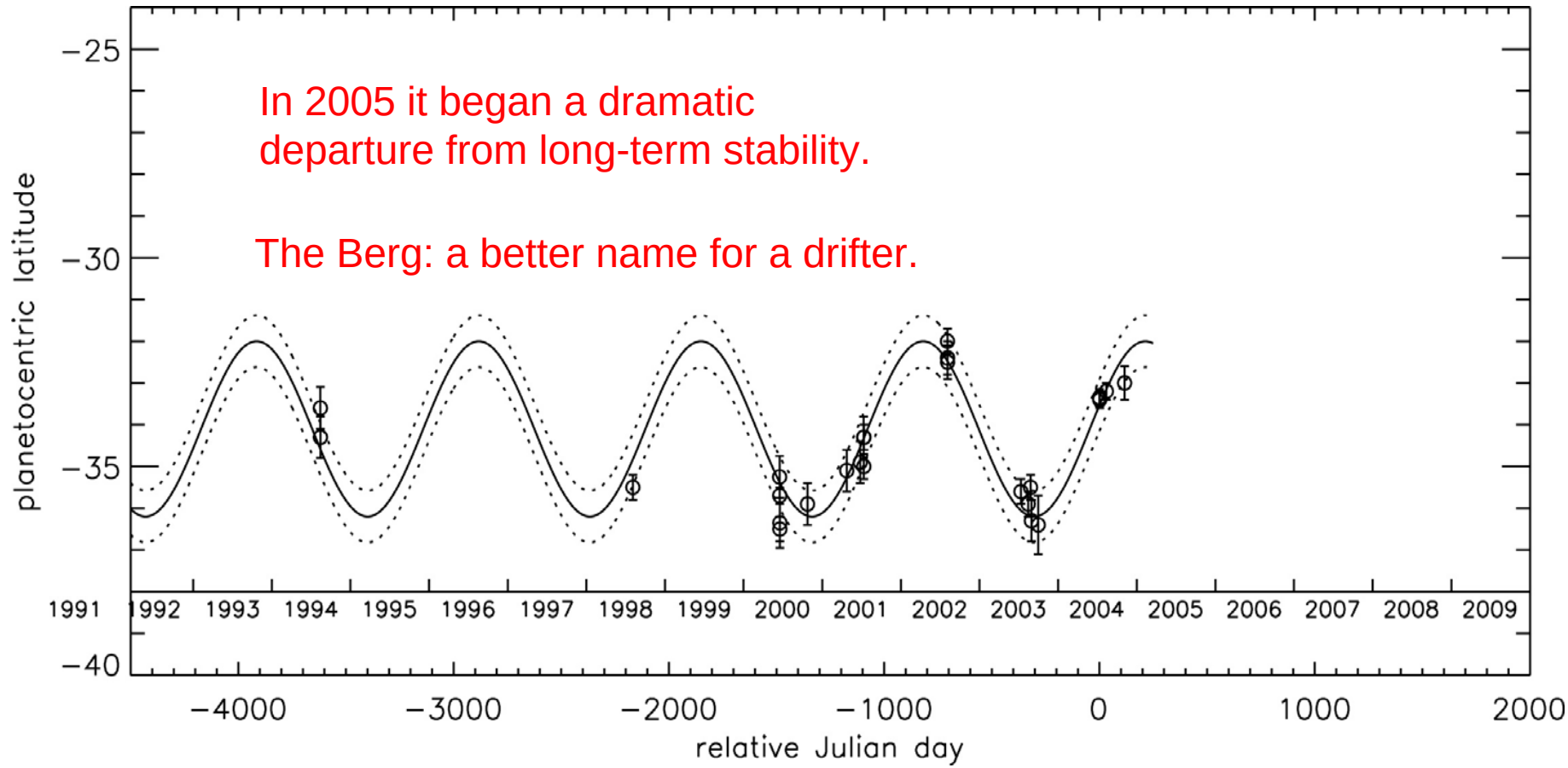
Long-lived major circulation features



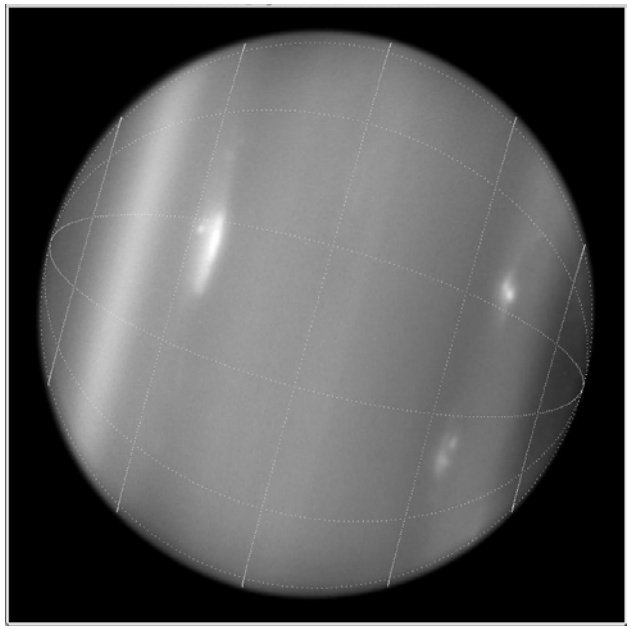
S34: the oldest cloud feature on Uranus, oscillated between 32 S and 36 S, possibly ever since the 1986 Voyager encounter.



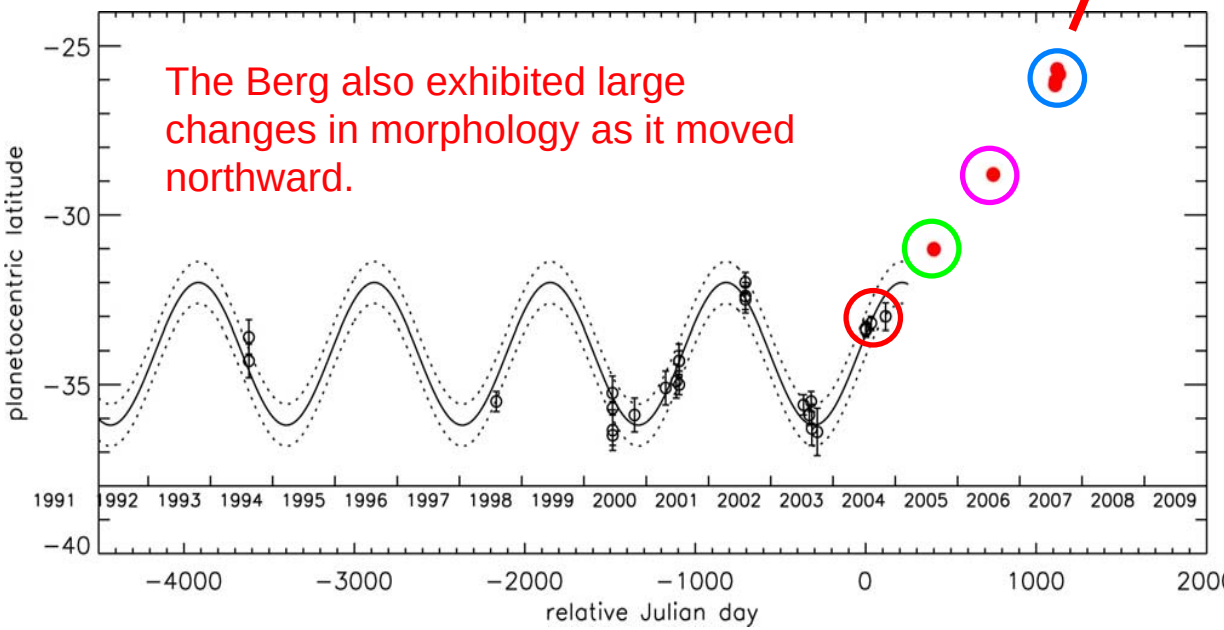
latest HST location

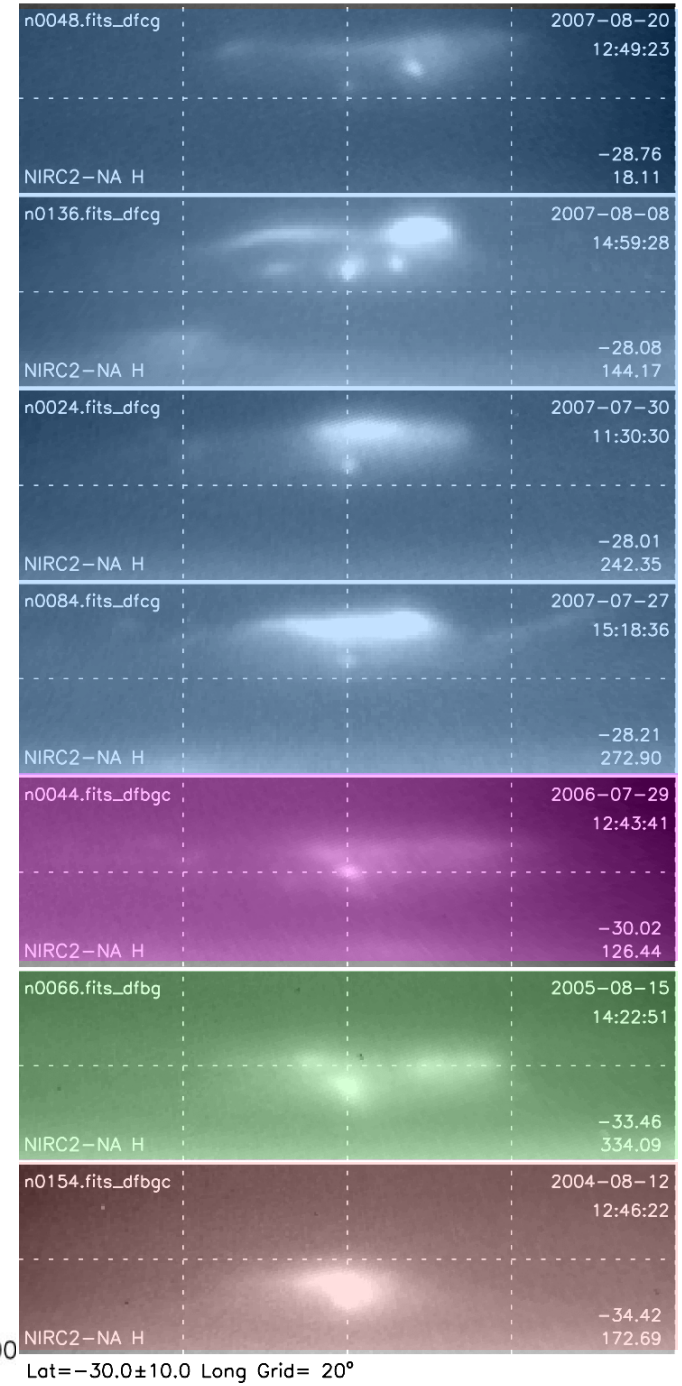


Keck H filter images



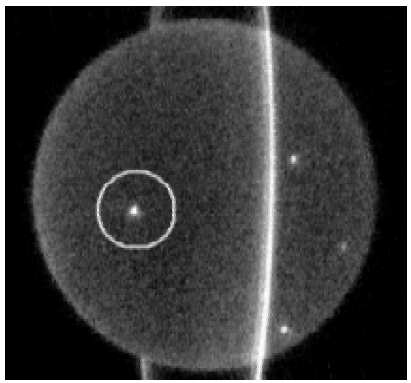
latest HST location

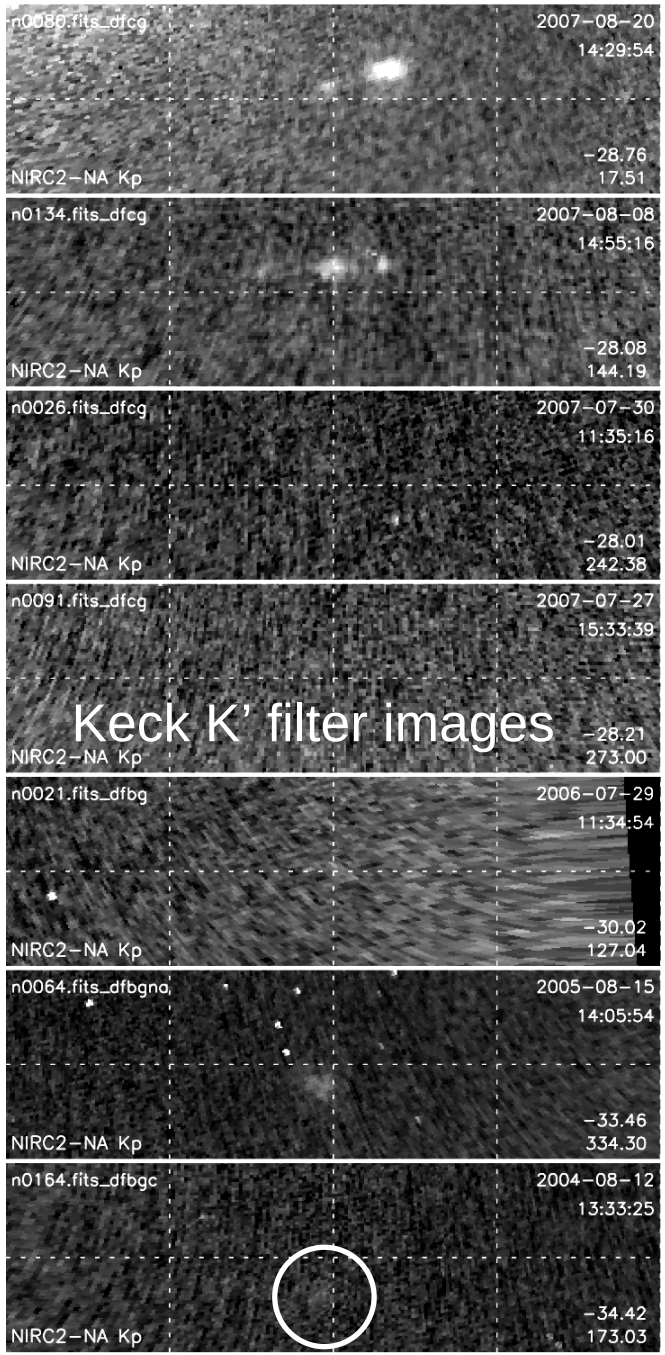


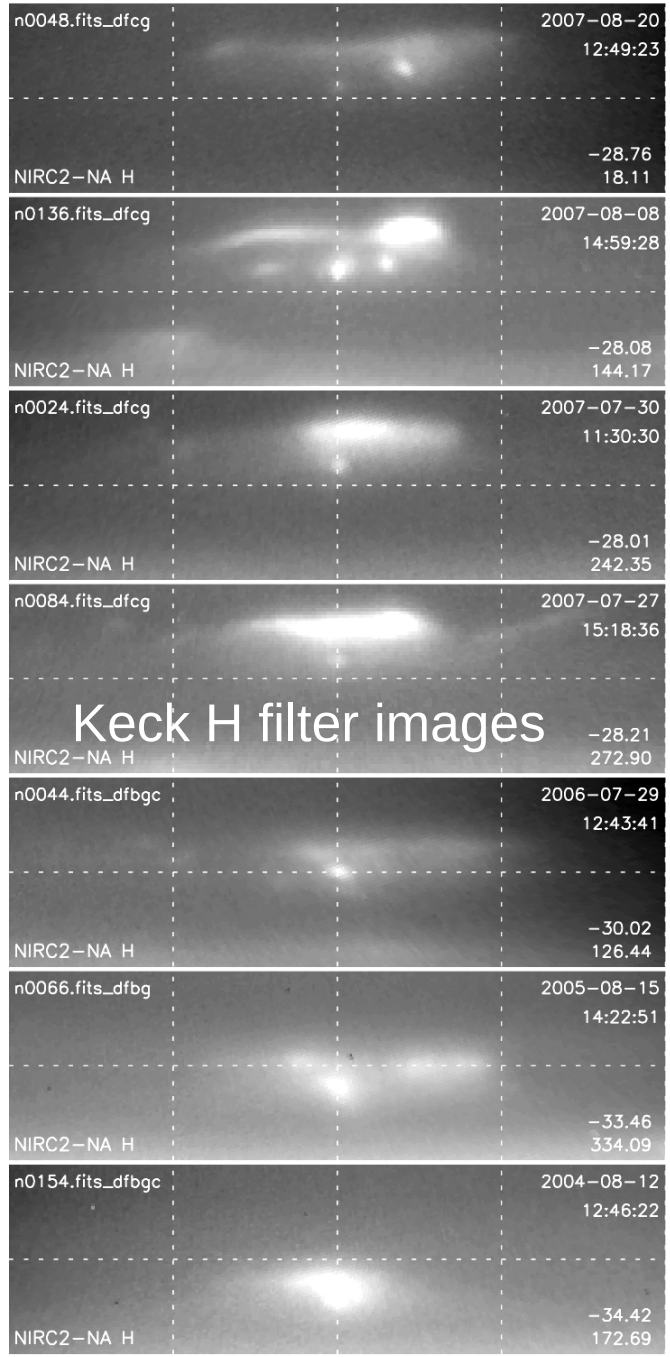


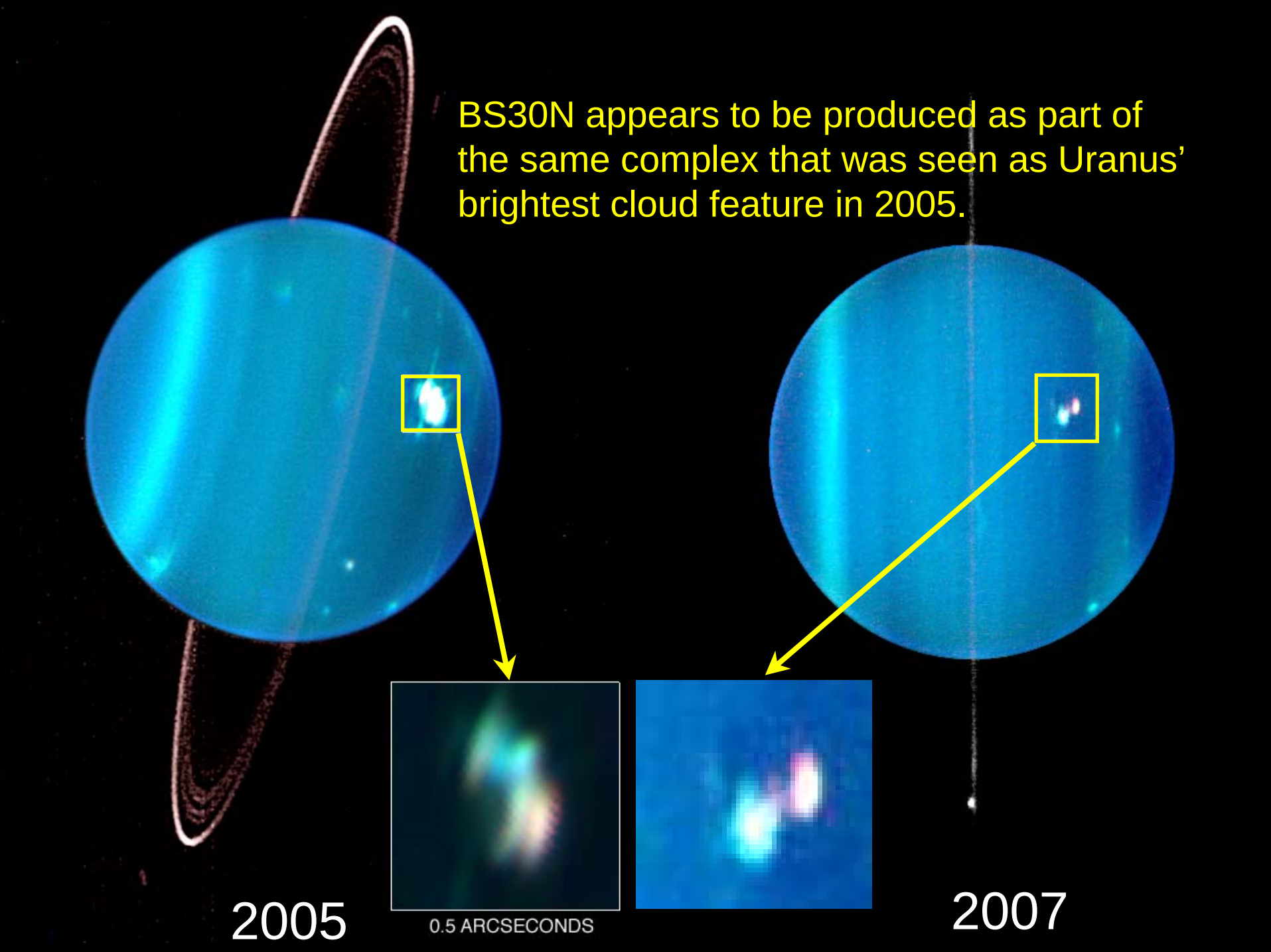
Berg appearance in K' images implies sporadic increases in cloud altitude (from bars to 100's of mb).

First detection of southern K' feature in 2004 images (Hammel et al. , Icarus 175, 2005) suggests a link to subsequent northward drift of the Berg.

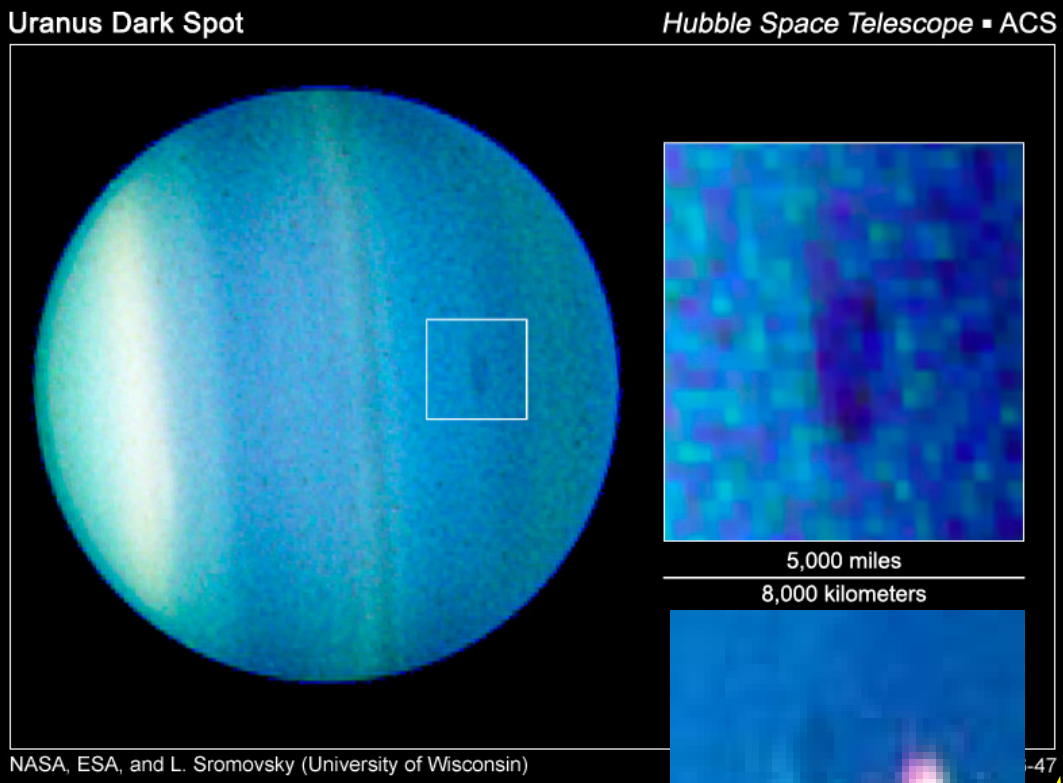


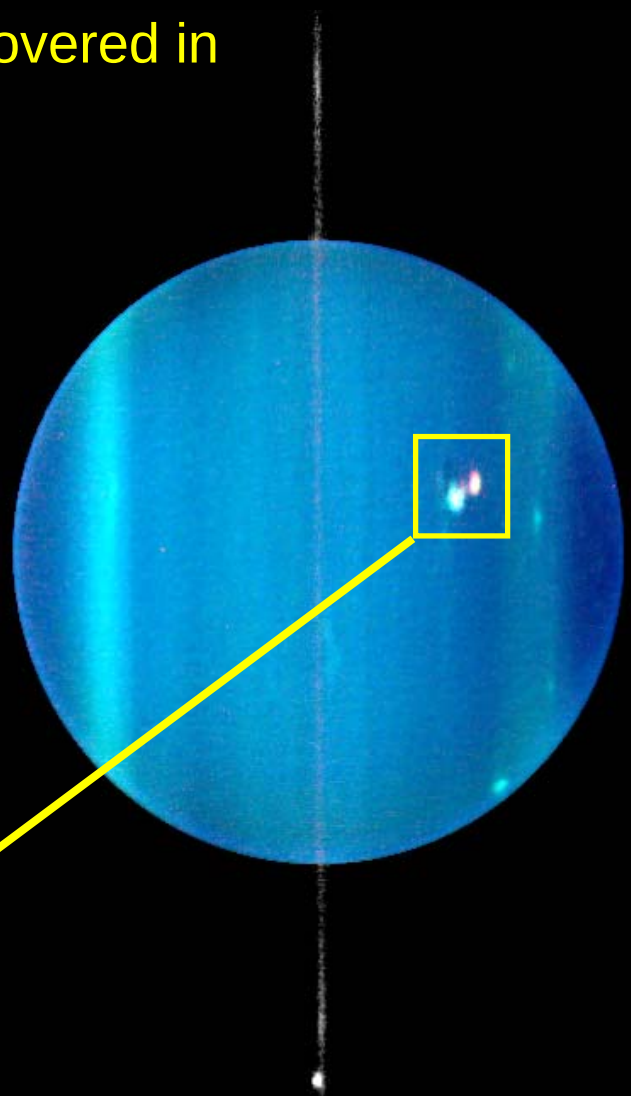





BS30N appears to be produced as part of the same complex that was seen as Uranus' brightest cloud feature in 2005.
2005
0.5 ARCSECONDS
2007

BS30N also appears to be a bright companion
to a Uranus Dark Spot (UDS) discovered in 2006 HST images.



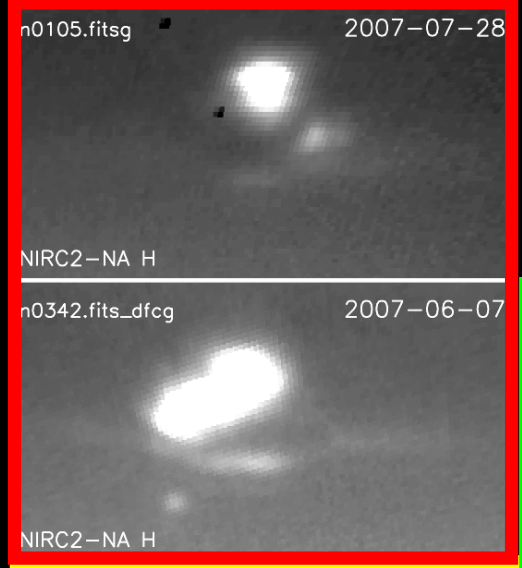


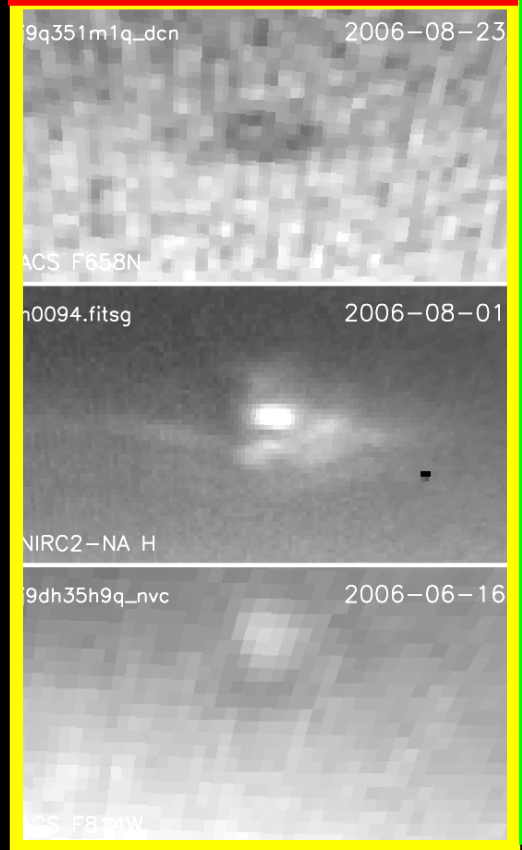
2006

2007

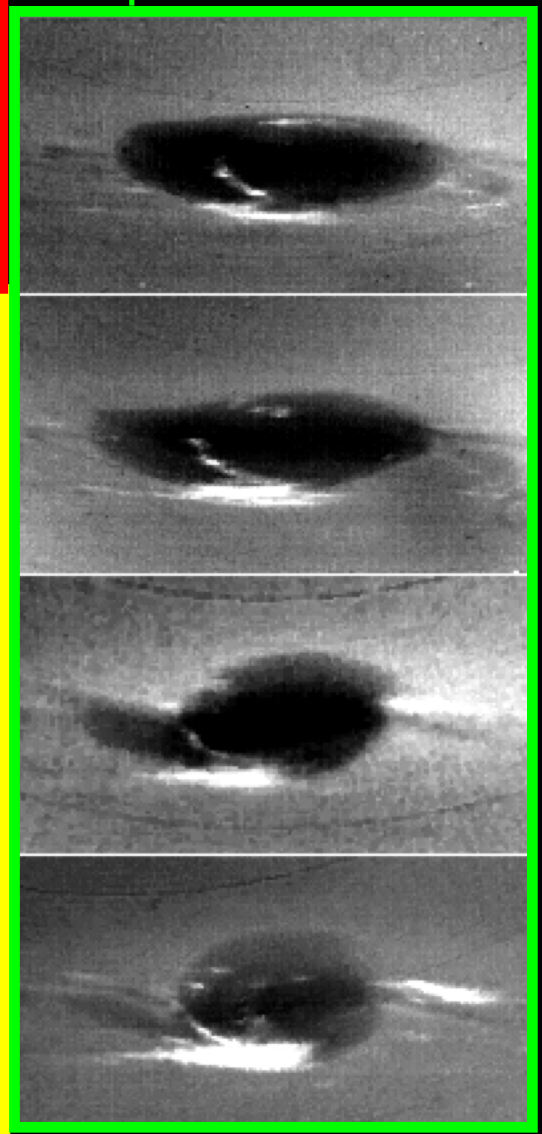
2007 Images show dark spot and highly variable companions

In 2006 images UDS showed dark spot with bright companions in both HST and Keck images (Hammel et al. Icarus, 2008).

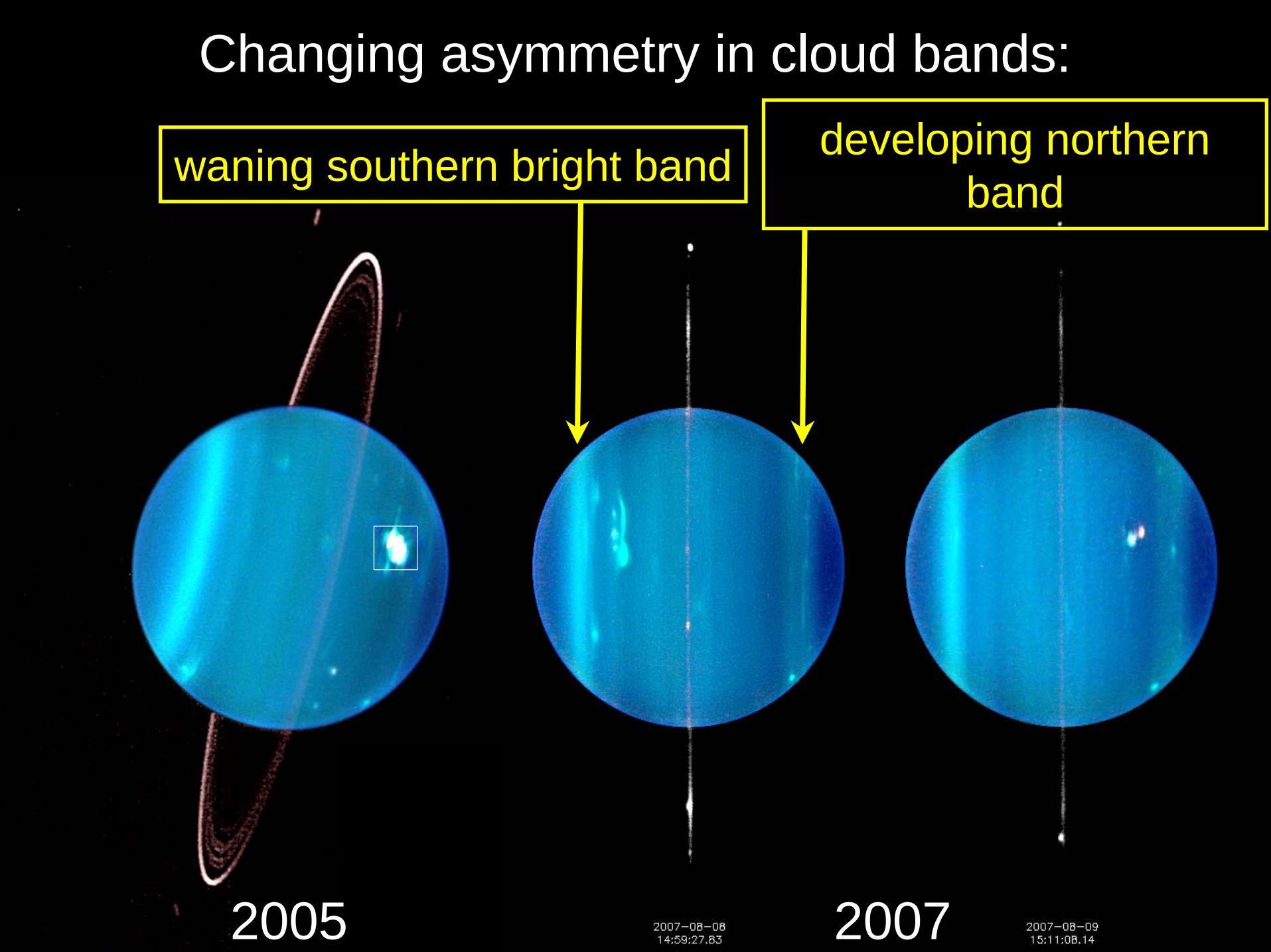


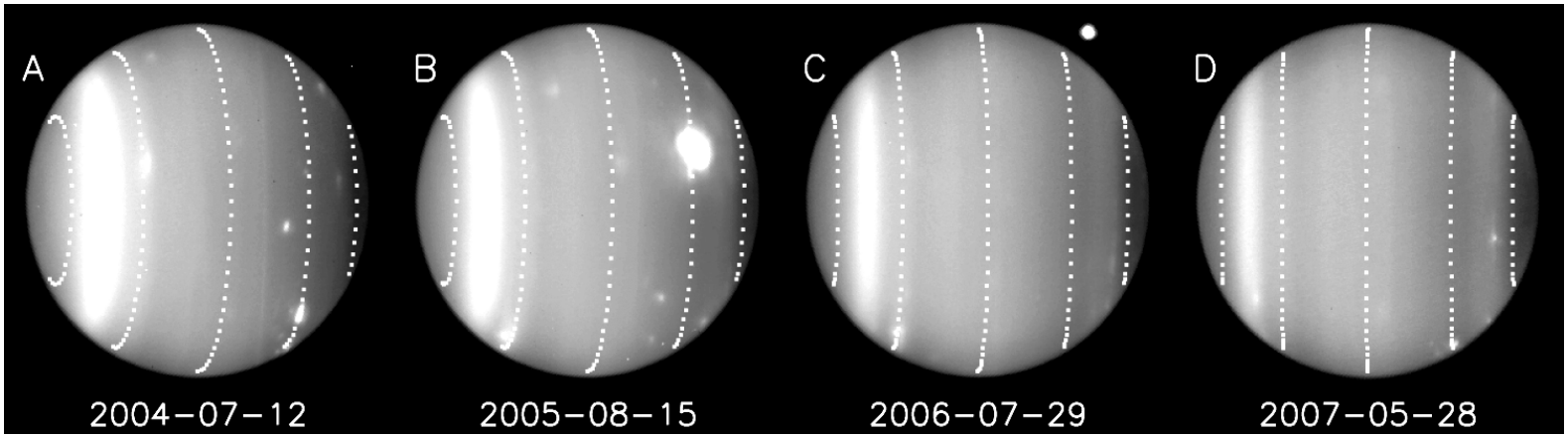


UDS is morphologically similar to Neptune's GDS



Changing asymmetry in cloud bands:

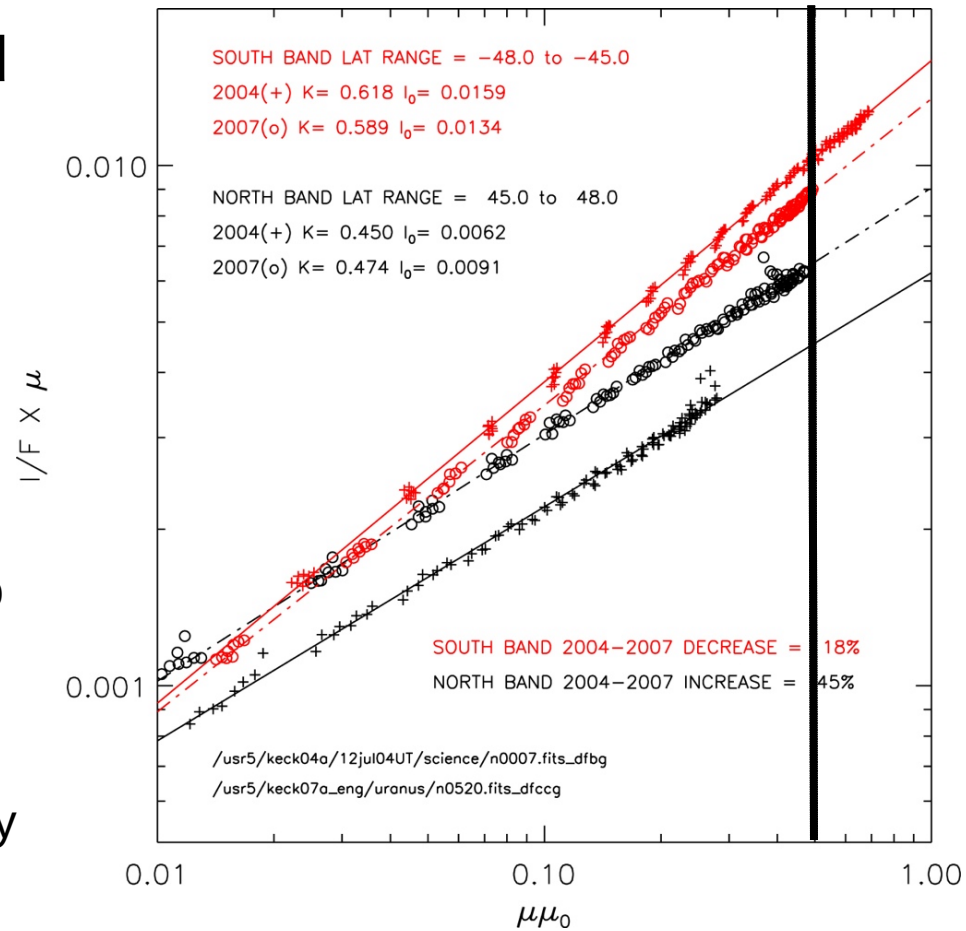


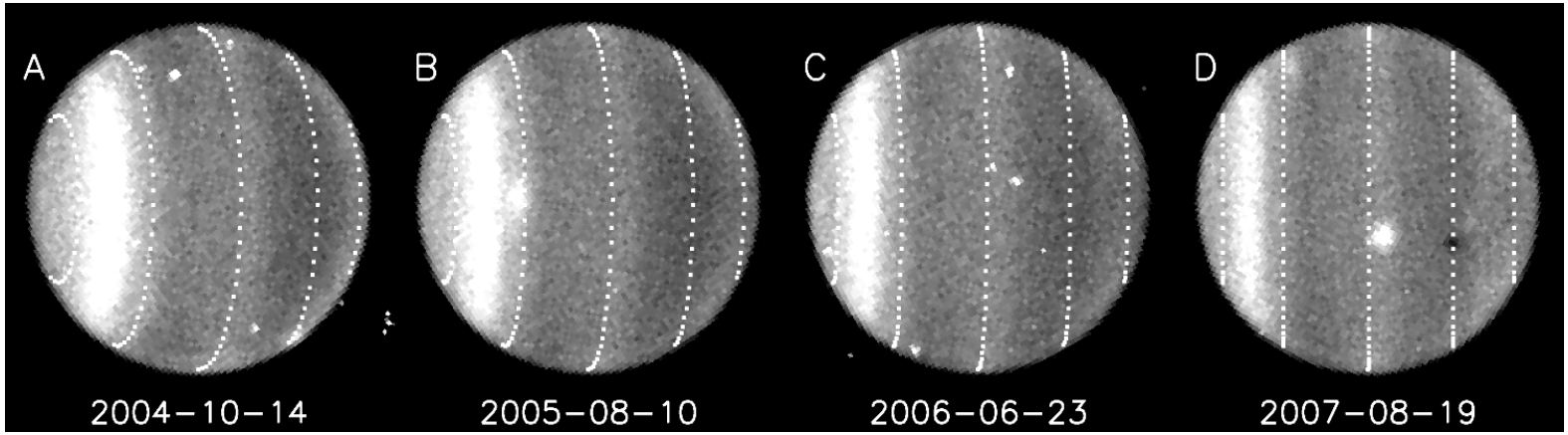


Minnaert function fits used to correct to 60º view and illumination angles.

From 2004 to 2007 in H filter:
south band declined 18%
north band increased 45%

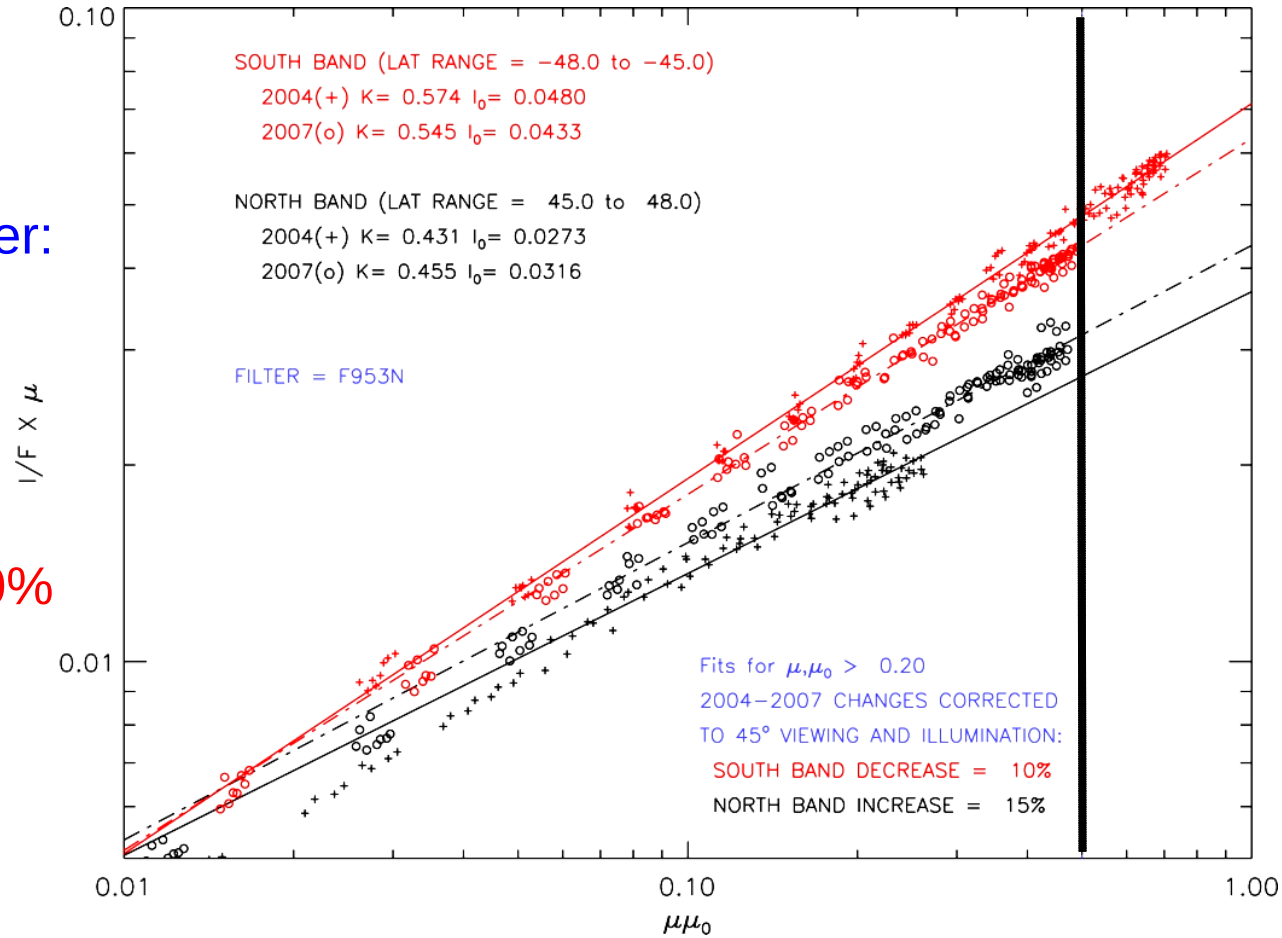
The southern bright band appears to decline significantly and a bright northern band appears to be intensifying (described at shorter wavelengths in a 2007 DPS paper by Kathy Rages et al.)





F953N HST/WFPC2 filter:

From 2004 to 2007:
south band declined 10%
north band increased 15%



Uranus Equinox Summary

- Wind measurements at equinox extended to higher northern latitudes, revealing a northern jet similar to Uranus' southern jet.
- The 2007 Uranus zonal wind profile is slightly asymmetric about the equator, by about 20 m/s at lower mid latitudes.
- The lack of measurable change in summer hemisphere winds since 1986 suggests that the asymmetry may be permanent.
- Two long lived discrete circulation features remain active:
  - After possibly decades long oscillation between 32 and 36 S, from 2005 to 2007 the "berg" drifted 5 degrees north, accelerated in 2008, and is possibly headed for dissipation.
  - The BS30N / Bright Complex / UDS is more clearly showing itself as a dark spot / vortex with bright companions of highly variable brightness.
- Bright band asymmetry reversal is further confirmed by near-IR and F953N view-angle corrected measurements.