The Breathing Plasmasphere

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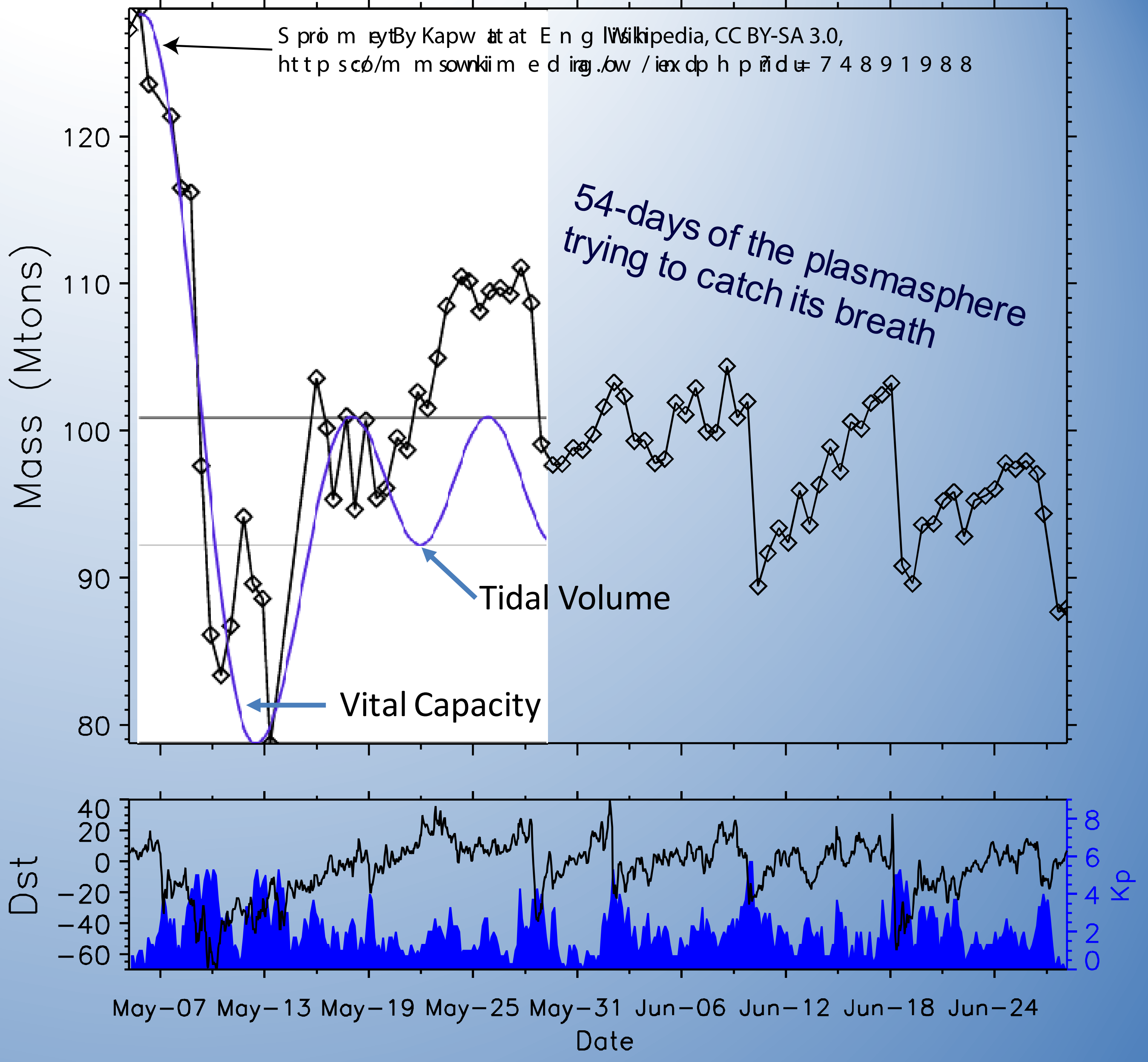
https://doi.org/10.1029/2020/jA028727

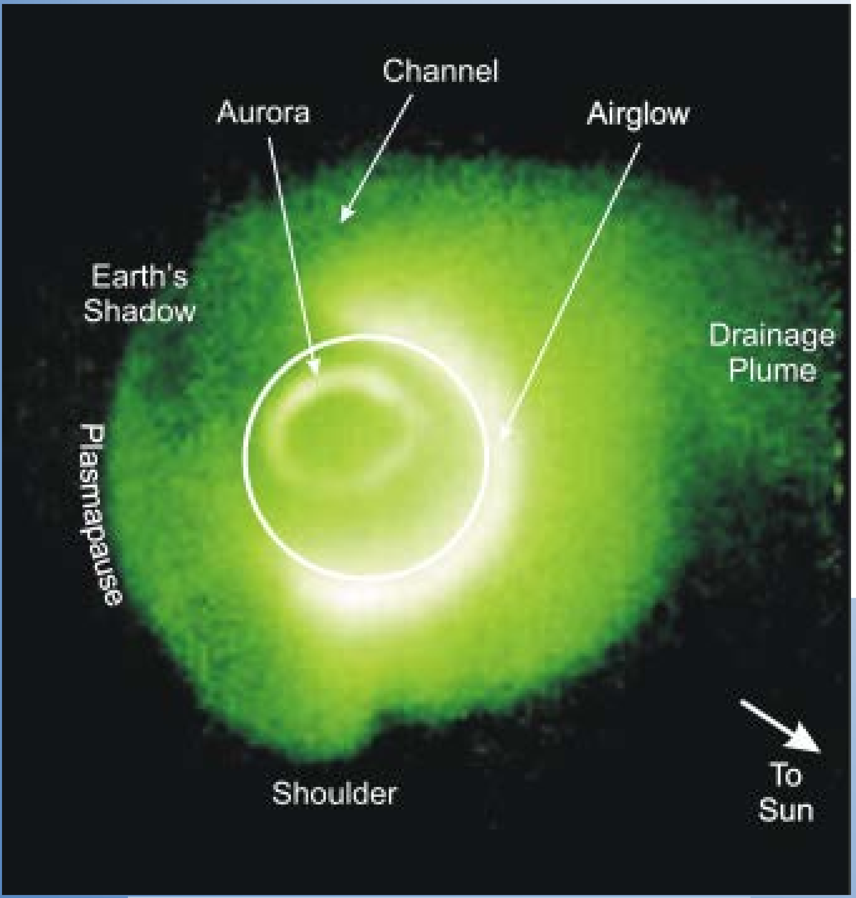
The Breathing Plasmasphere

- **Study emphasizes a change in perspective from a local-view to a system-level view, that offers extensive quantitative information as well as a more encompassing perspective of the plasmasphere.**
- A view of the plasmasphere's breath is a view of the system.
- An in situ measurement of density, temperature, or particle flux cannot realistically be knitted together to give the whole at any given time.
- However, both are critical for understanding the system behavior and the micro-processes that create that behavior.
- **Technique enables detailed study of L-shell dependent corotation, inter-regional mass transport versus field-aligned flow, and can directly incorporate oxygen imaging.**

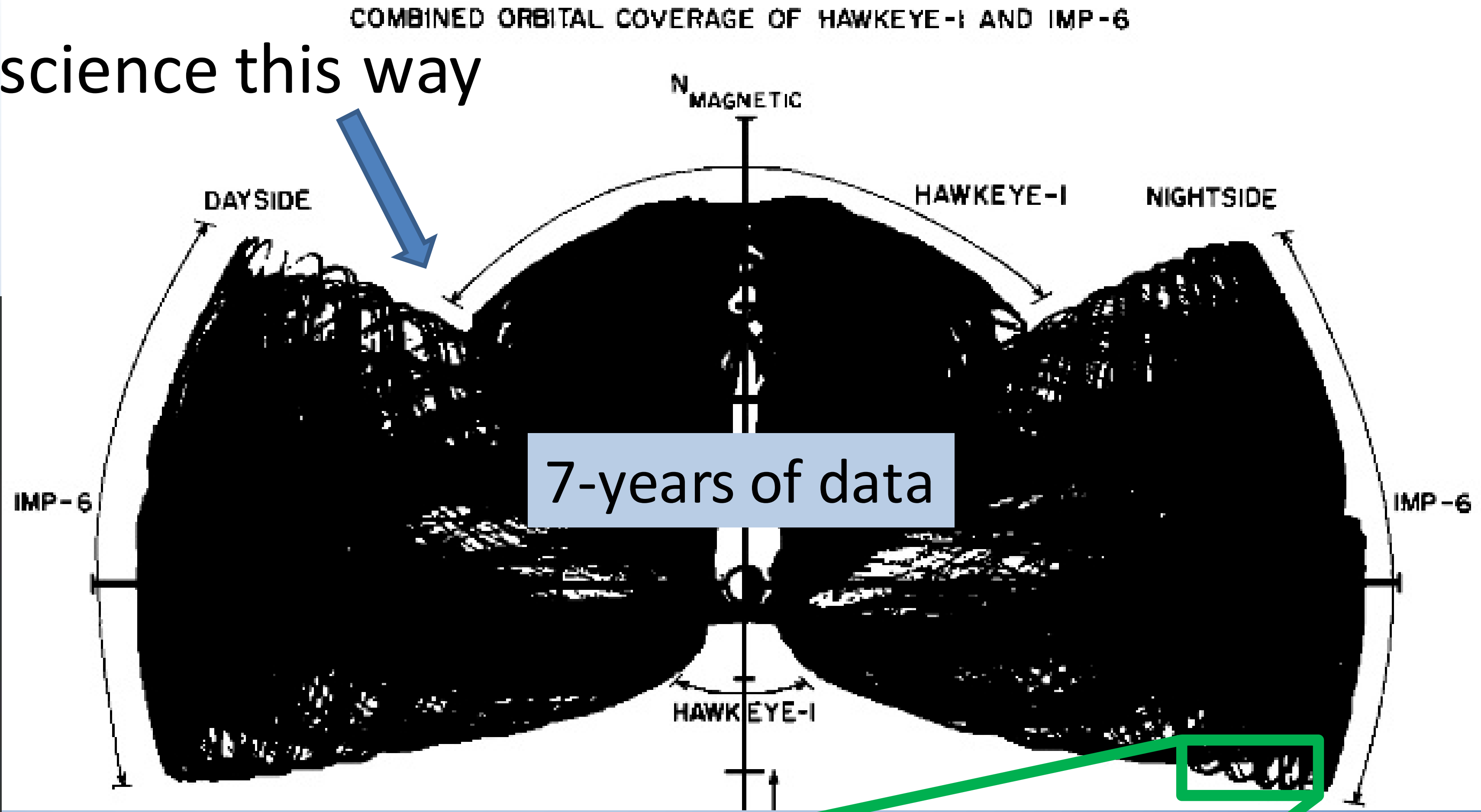


60+ years of science this way

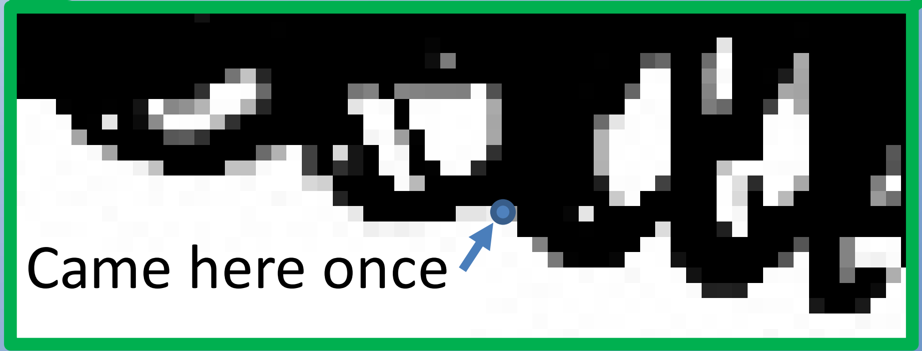
Just a pretty face?



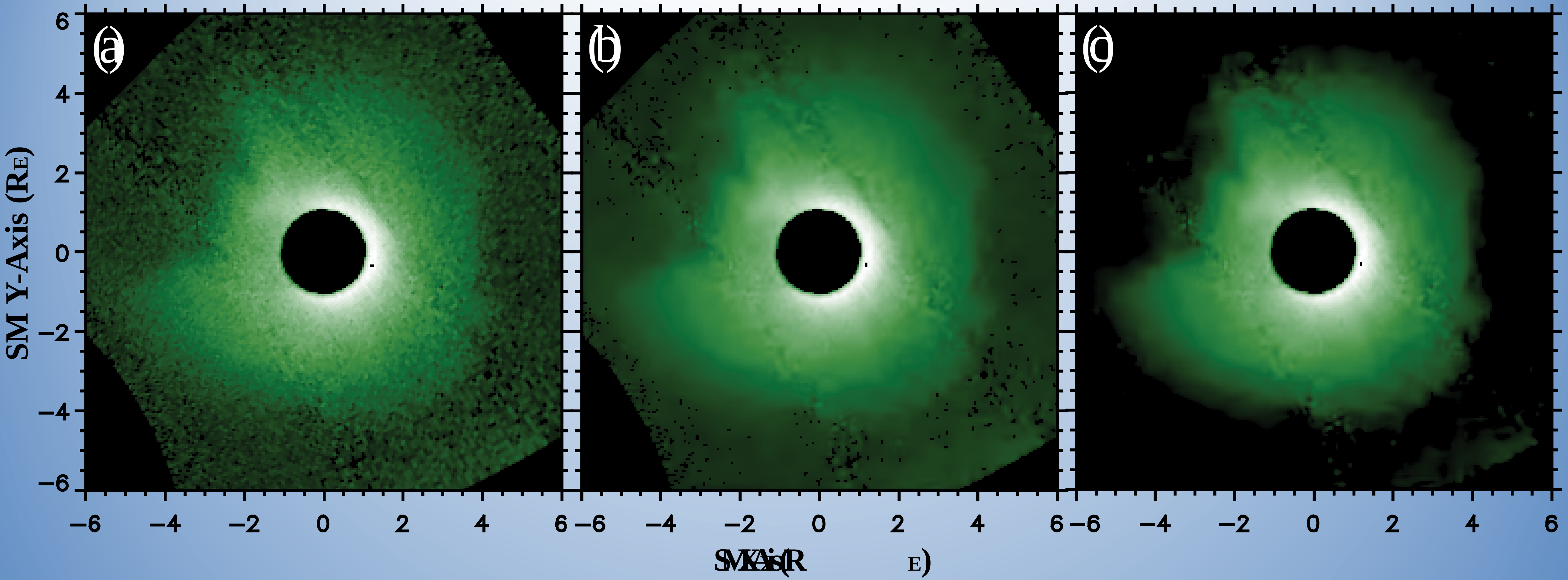
10-Minutes of data



7-years of data



4,800 EUV images – 2,800 “keepers”, nearly 60%



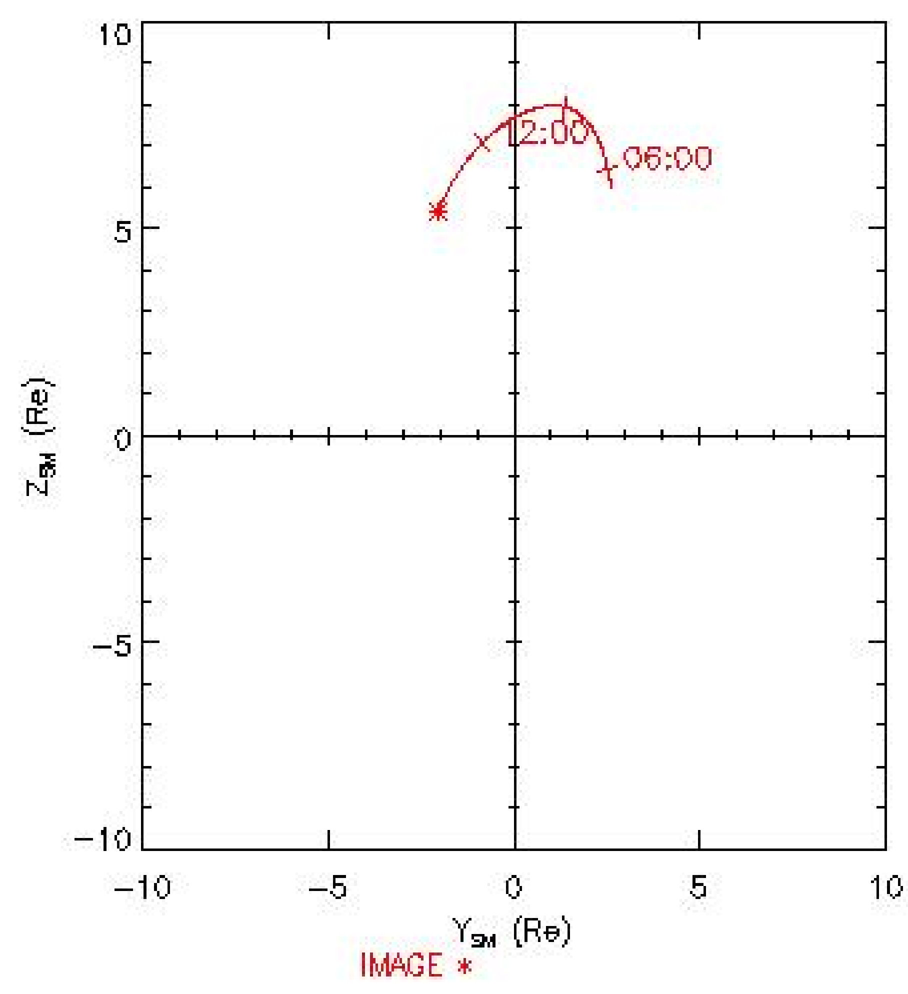
Original Equatorial Mapped EUV Observation

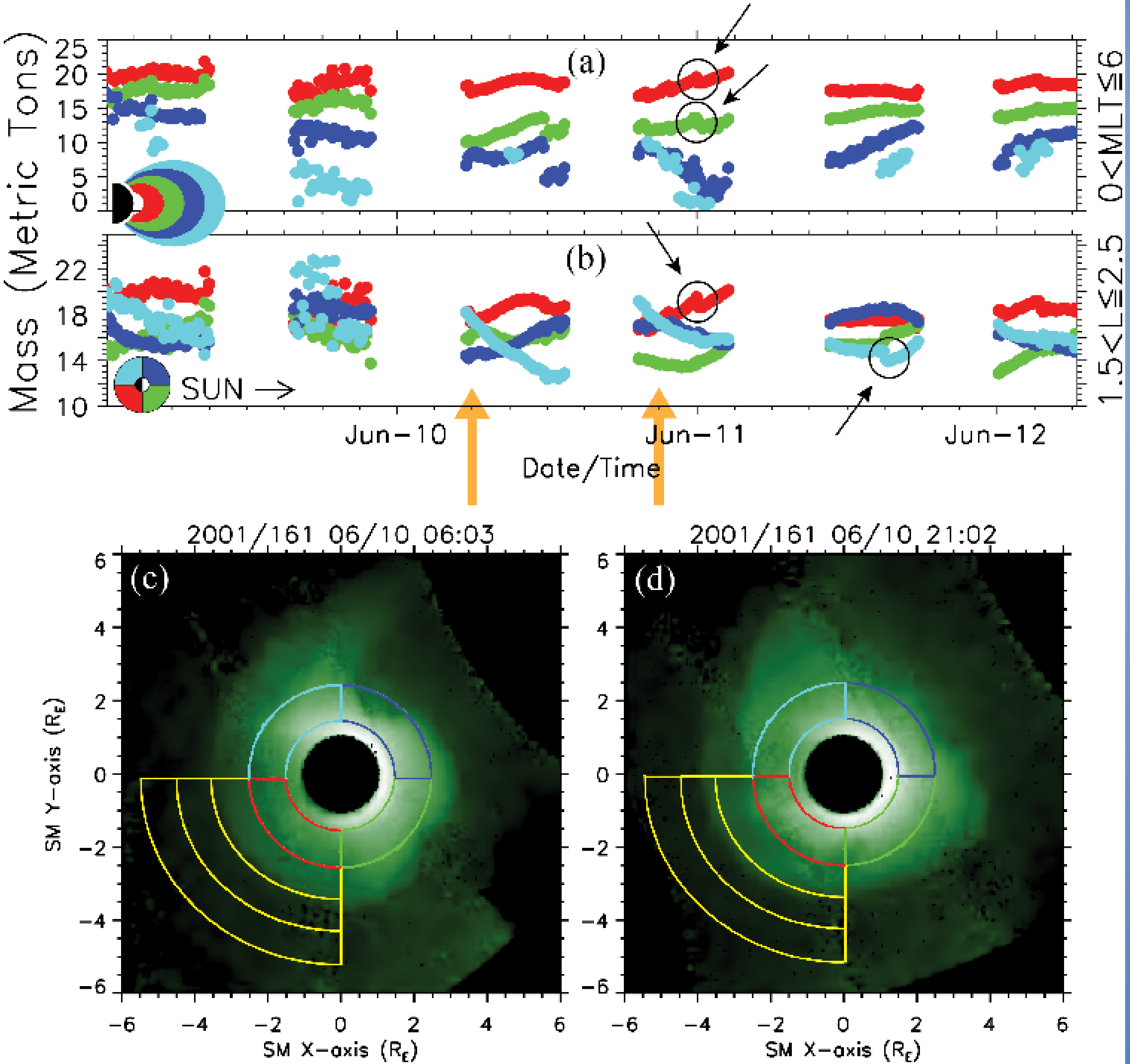
Poisson noise reduction, SHINE Routine

Background noise removed

A first step in a follow-the-mass concept.

IMAGE Orbit 2001 Jun 10 0530-1330UT





- It's behaved
- **Inner L-shells fill slower than outer**
- Values are there to examine erosion and refilling

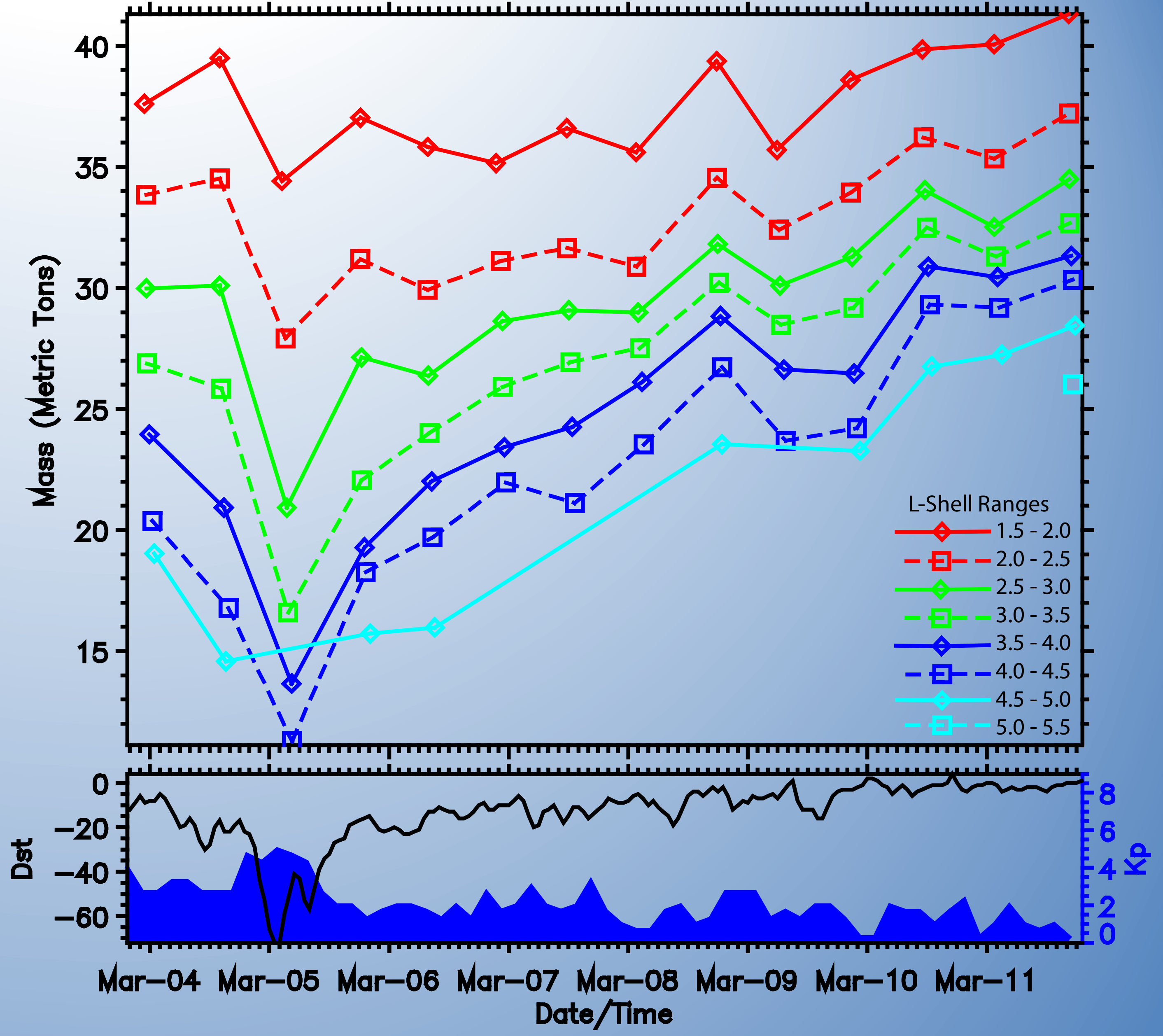
$$log_{10}\left({}^{n_{He+}}/_{n_{H+}}\right) = b_0 + b_1 \cdot r + b_2 \cdot P + b_3 \cdot P^2$$

Craven et al. 1997

$$P = \left(F_{10.7} + \langle F_{10.7}\rangle_{81^d}\right)/2 \qquad {}^{n_{O+}}/_{n_{H+}} = 0.01$$

$$M = \int_{-\lambda_o}^{\lambda_o} \rho L^2 cos^7(\lambda) d\lambda d\phi dL$$

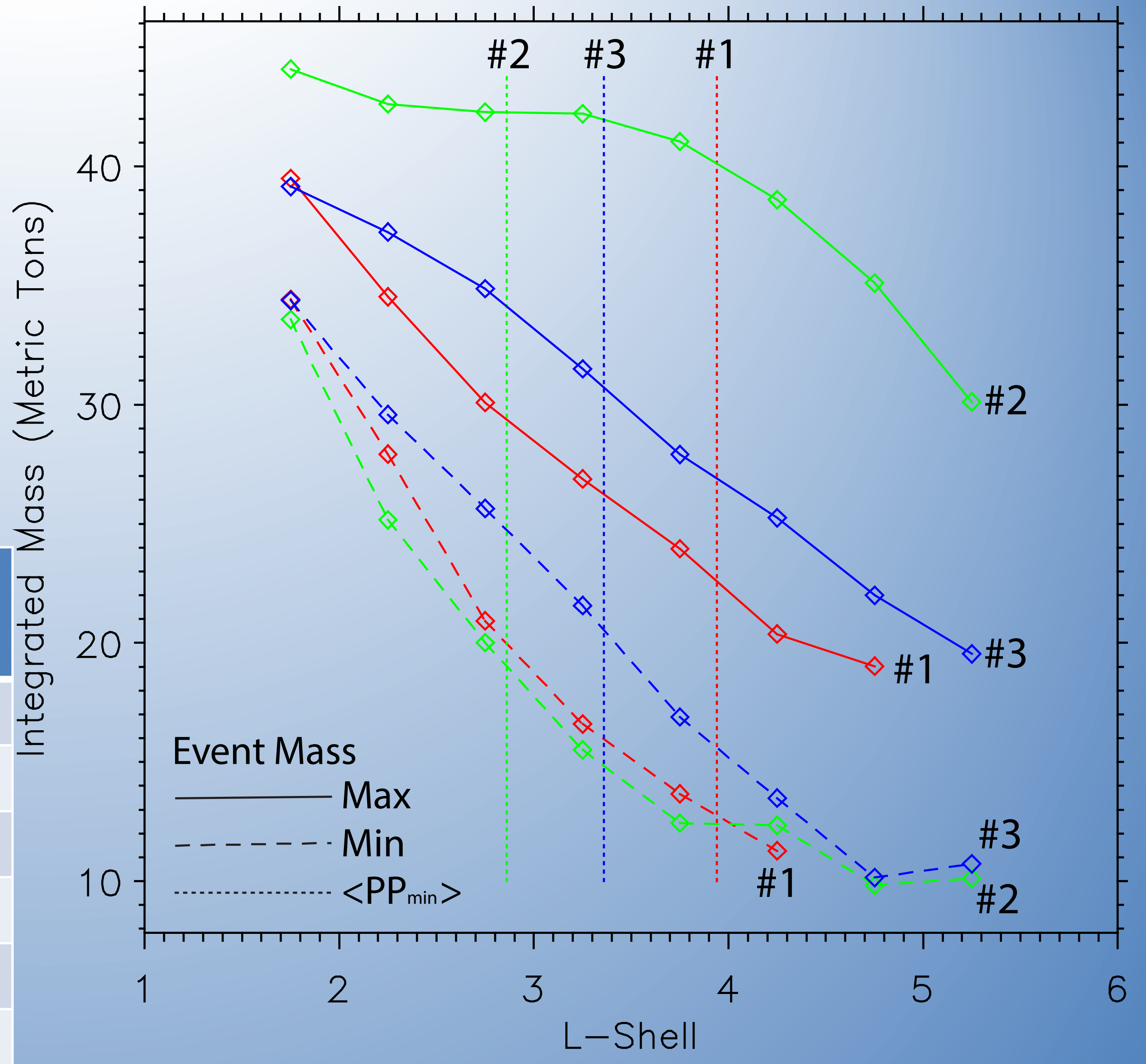
Event #	Start Time	End Time	Refilling Time (days)	Max Kp	Min Dst
1	03-Mar-2001 1926 UT	11-Mar-2001 1909 UT	6.5	5	-72
2	05-May-2001 0228 UT	23-May-2001 0142 UT	12	5+	-70
3	17-Jun-2001 0851 UT	26-Jun-2001 0716 UT	7	5+	-57
4	19-Sep-2005 1106 UT	25-Sep-2005 0946 UT	5.75	3-	-44
5	03-Oct-2005 1610 UT	07-Oct-2005 1745 UT	3.5	2	-23
6	11-Oct-2005 0824 UT	16-Oct-2005 0539 UT	4.75	2	-20
7	14-Nov-2005 1710 UT	19-Nov-2005 1230 UT	5	2+	-23



- Mass-vs-L before and after erosion
- Quantitative measures throughout the inner magnetosphere
- Vertical lines give the average plasmapause L-value derived separately by Katus et al. 2015 corresponding to maximum erosion
- **The eroded plasmapause is not a barrier to erosion**

Mass loss inside/outside the full Katus15 PP versus MLT Determined at time of maximum erosion.

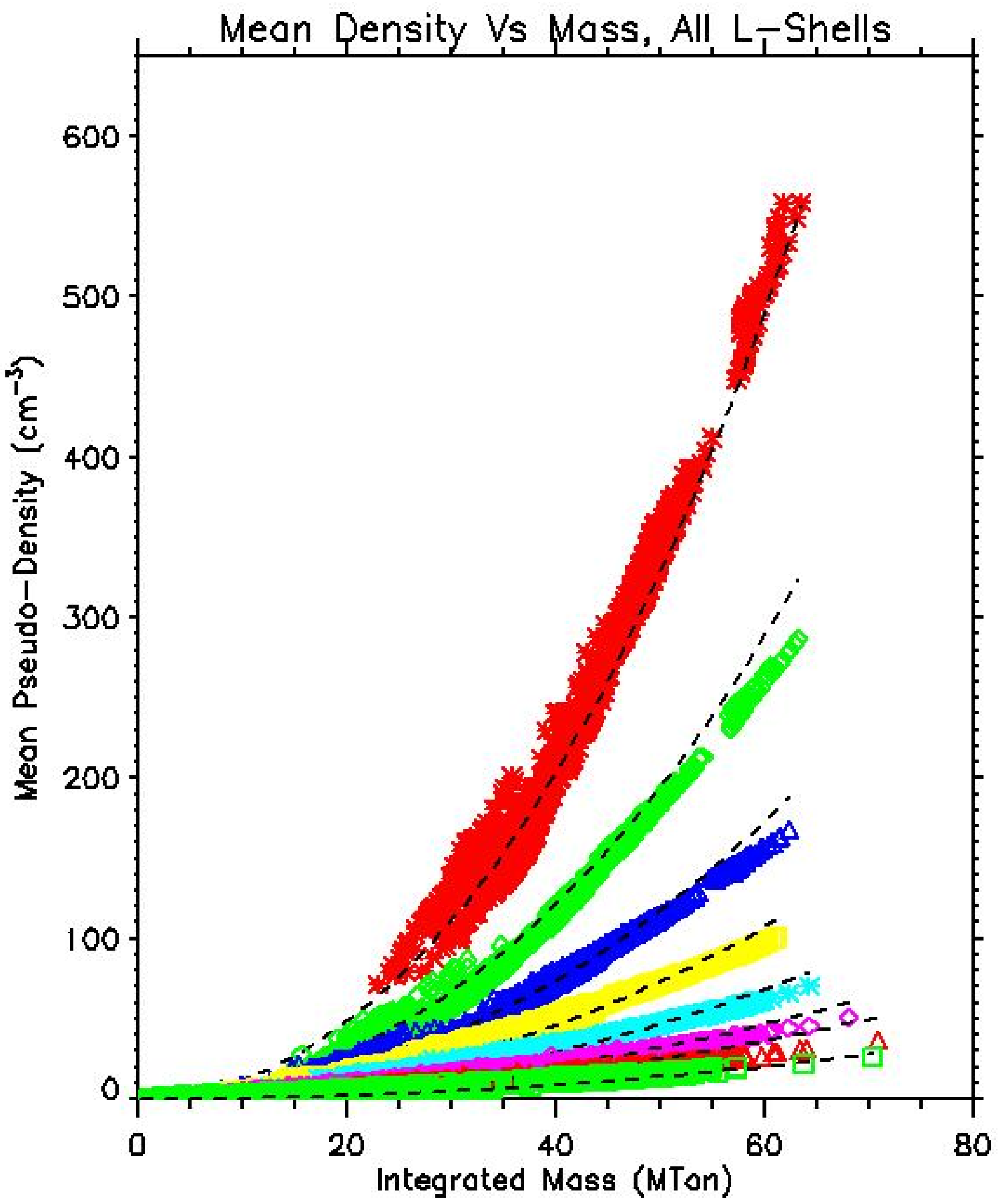
Event #	Times Pre/Post Erosion	Inside Mass Pre/Post (MT)	% Loss Inside	$L_{<KPP>}$ ref only	% Lost Outside	Outside Mass Pre/Post (MT)
1	04-Mar-2001 14:00 UT	141	26%	3.9	35%	120
	05-Mar-2001 02:28 UT	104				78
2	05-May-2001 19:44 UT	121	42%	2.9	72%	257
	13-May-2001 08:11 UT	70				72
3	18-Jun-2001 02:14 UT	132	22%	3.4	46%	147
	19-Jun-2001 07:01 UT	103				79



Most previous studies derive relative change in the magnetic equatorial density. To validate the results by mass and using remote EUV images it is necessary to compare to previous results.

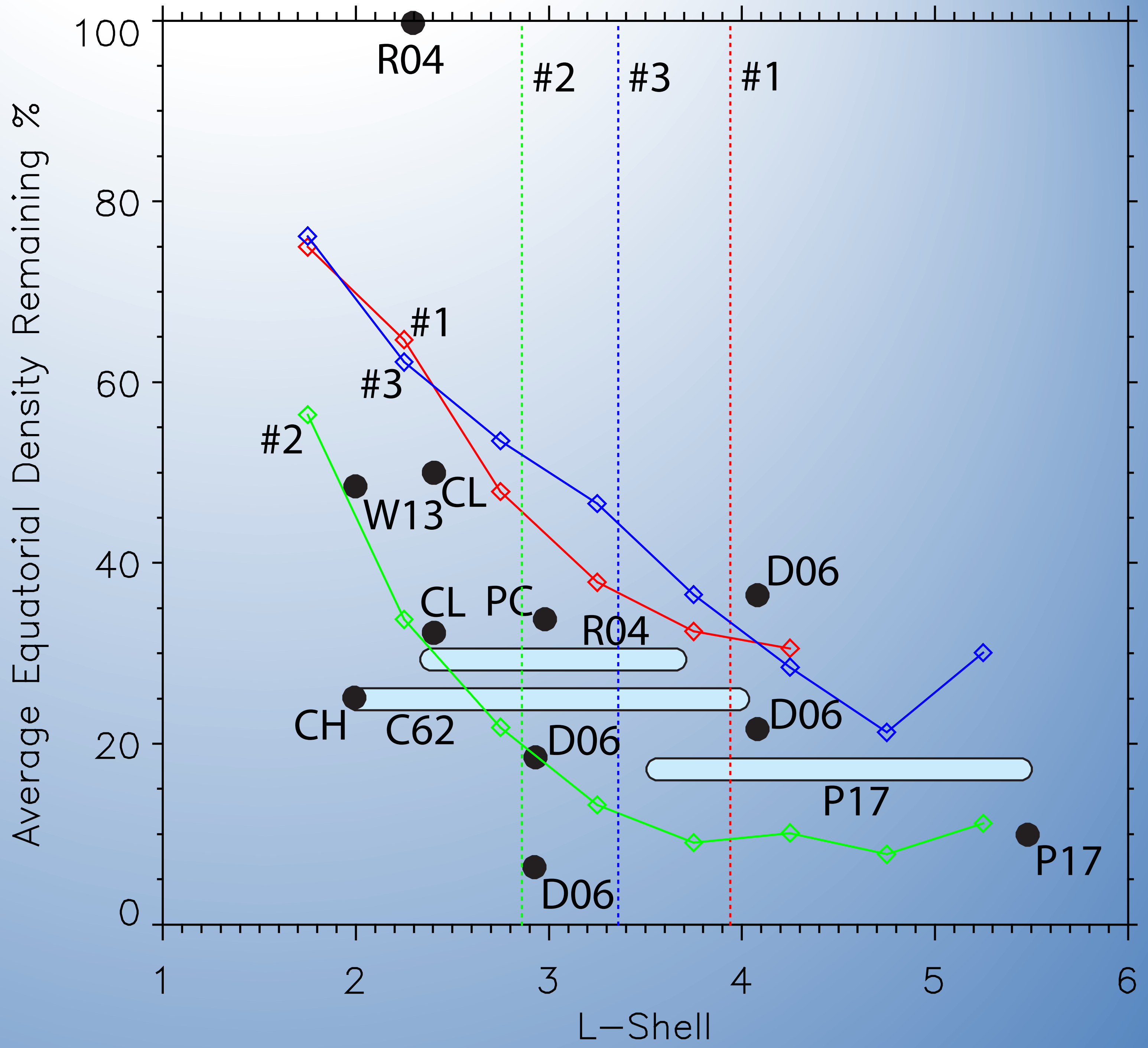
To do that mass is correlated with the corresponding average equatorial mass in the integration volume and then fit with the function below. The mass-density value pairs as a function of the center L-value in the integration volume are separately fit and the fit parameters then fit versus L-value.

$$Pseudodensity = a_0 \cdot cosh(a_1 \cdot Mass)$$
$$a_0 = (853 \pm 64) + (-133 \pm 16) \cdot L$$
$$a_1 = (0.27 \pm 0.002) + (-0.004 \pm 0.001) \cdot L$$

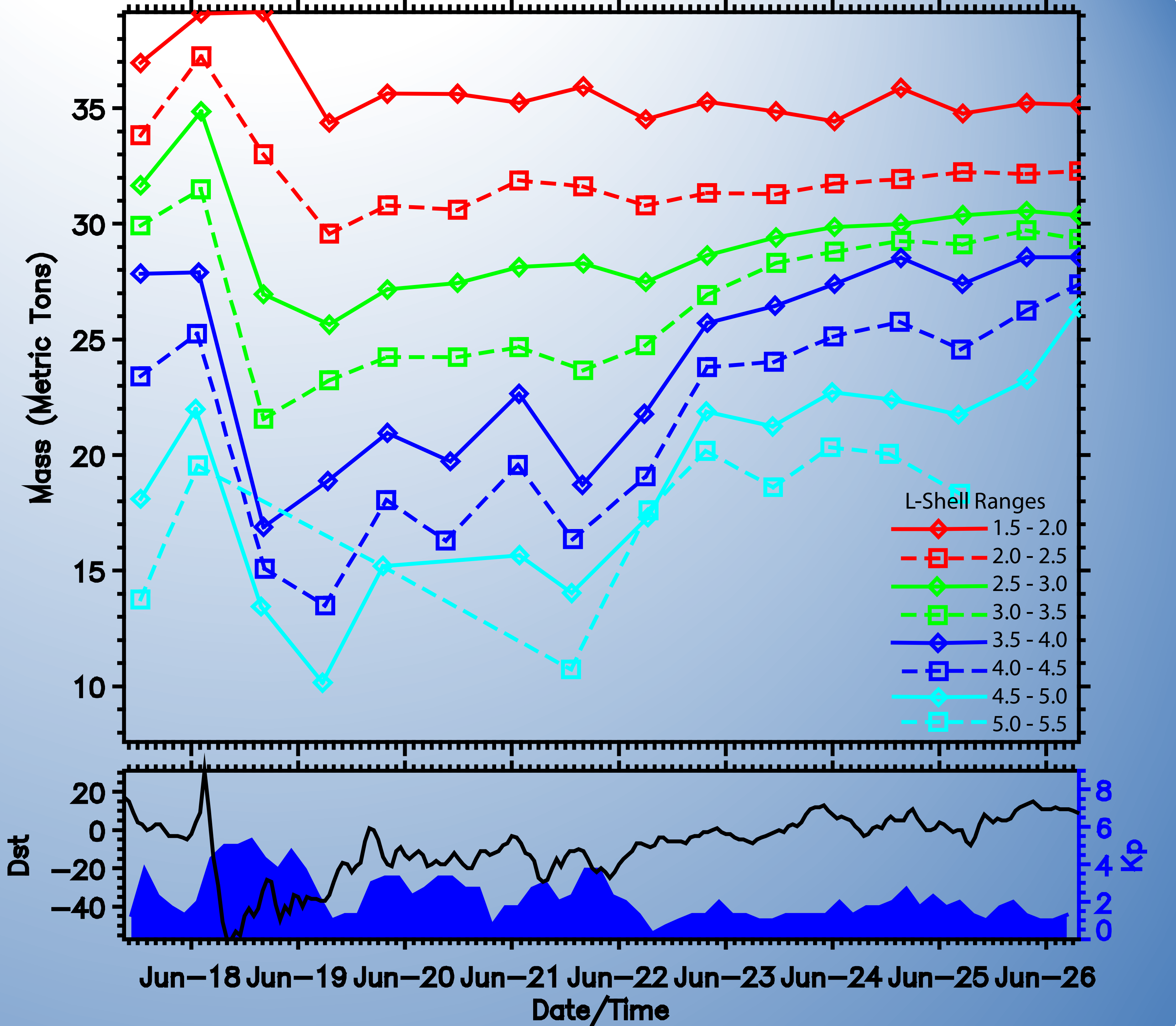


- The average equatorial density remaining in each integration volume versus L-value and compared to previous results.
- These new results are comparable.
- Note that previous results are mostly limited to one location in parameter space.
- **These results provide a more system-level result, yet are limited to only 3-events.**

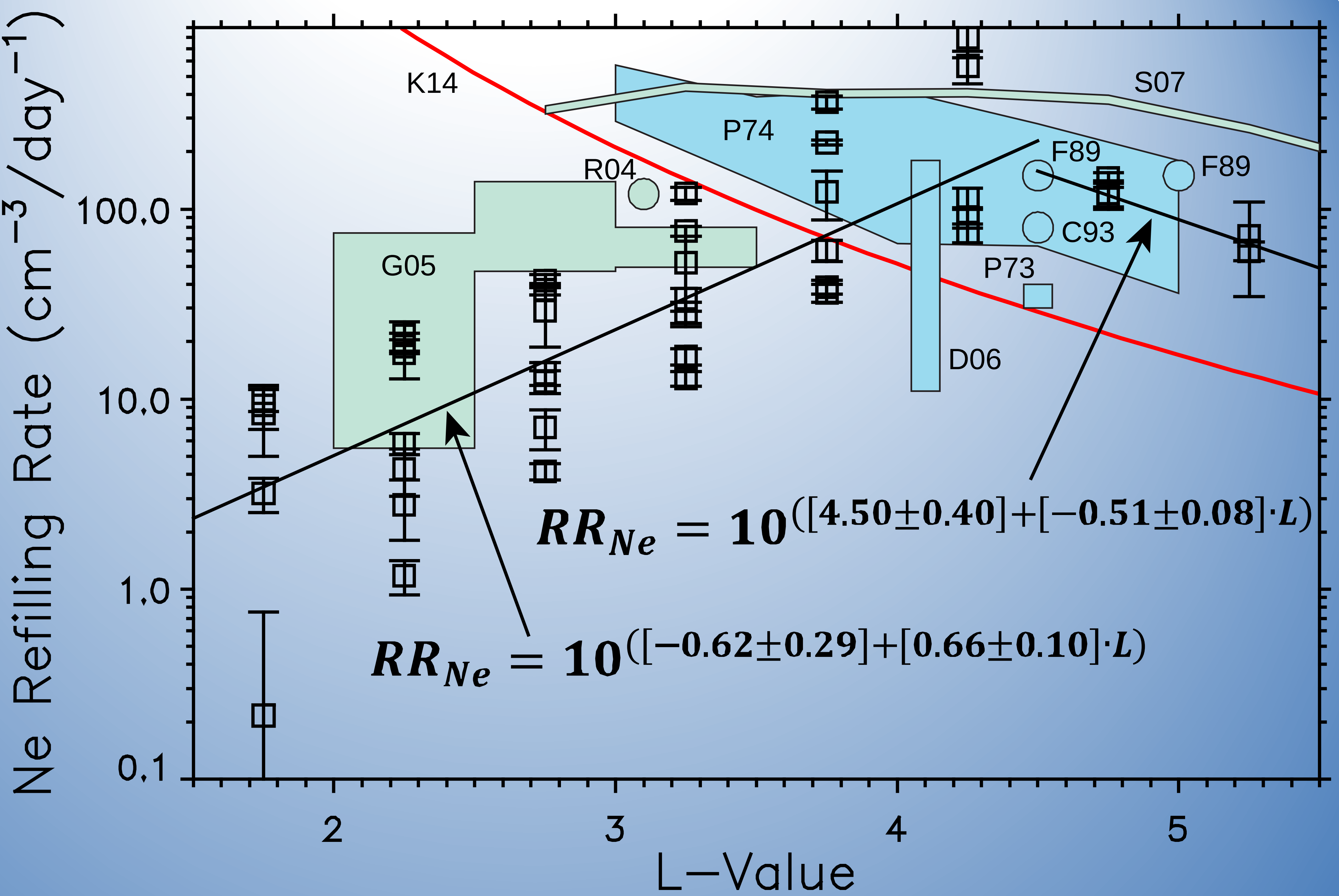
PC: Park-73/Carpenter-95	C62: Carpenter-62
CL: Clilverd-00	CH: Chi et al-01
W13: Wang et al-13	D06: Dent et al-06
R04: Reinisch et al-04	P17: Piersanti et al-17



- The 18 June 2001 event includes two extra minor erosion intervals
- Refilling starts, then there is erosion, then refilling, then erosion, followed by more extended refilling.
- The higher L-shell volumes are most responsive to changing conditions.
- **The innermost L-shells show much reduce, but still present response to these minor increases in erosion.**
- The physical mechanism must differ for plasma loss outside the penetrating convection seperatrix than inside, which might depend on change in the ionosphere that rebalance the pressure along inner magnetic field lines or plasmaspheric wind.



- Refilling followed for 3.5 to 12 days.
- **They fall for low L-shells and fall at higher L-shells**
- Even modest expansion of studied events may contribute much.
- **Even a few events offer system-level measurements.**



Previous Studies Cited as Providing Plasmasphere Refilling Rates

Source	L	Refilling Rate ($cm^{-3}d^{-1}$)	Filling Phase
Gallagher et al. 2005	2-2.5	5.5-75	Early to late
	2.5-3	46.8-139	
	3-3.5	49.4-80	
Reinisch et al. 2004	3.1	~120	Early to late
Sandel & Denton 2007	2.75	334	Early to late
	3.25	439	
	3.75	407	
	4.25	411	
	4.75	377	
	5.25	265	
	5.75	157	
	6.25	78	
	6.75	58	
Park 1974	3	290-570	Late
	3.5	140-390	
	4	66-420	
	4.5	64-280	
	5	36-180	

Source	L	Refilling Rate ($cm^{-3}d^{-1}$)	Filling Phase
Dent et al. 2006	4.12	~11-180	Late
Park 1973	4.5	30-40	Late
Carpenter et al. 1993	4.5	~80	Late
Farrugia et al. 1989	4.5 & 5	150	Late
Sojka & Wrenn 1985	6.6	30-50	Early to late
Décréau 1983, Décréau et al. 1986	6.6	8	Early
Song & Caudal 1987	6.6	4.9-13.0	Late
Song et al. 1988	6.6	7-25	Late
Gallagher et al. 1998	6.6	13.4	Early
Lawrence et al. 1999	6.6	~0.6-12	Early
		10-50	Late

Mass in 1,000kg/day refilling rate as a function of L and average daily sum of Kp

$$RR_{mass}[Mt \cdot day^{-1}] = a_0 + \ a_1 \cdot L + \ a_2 \cdot \langle \sum_{daily} K_P \rangle \qquad (3)$$

$$a_0 = 0.37$$

$$a_1 = (1.00 \pm 0.16) \cdot L$$

$$a_2 = (-0.15 \pm 0.3) \cdot \langle \sum_{daily} K_P \rangle$$

The multiple-linear correlation coefficient for Equations 3 is 0.77.

Average equatorial density refilling rate as a function of L and average daily sum of Kp

$$log_{10}(RR_{Ne}\text{-}[cm^{-3} \cdot day^{-1}]) = b_0 + \ b_1 \cdot L + \ b_2 \cdot \langle \sum_{daily} K_P \rangle \qquad (5)$$

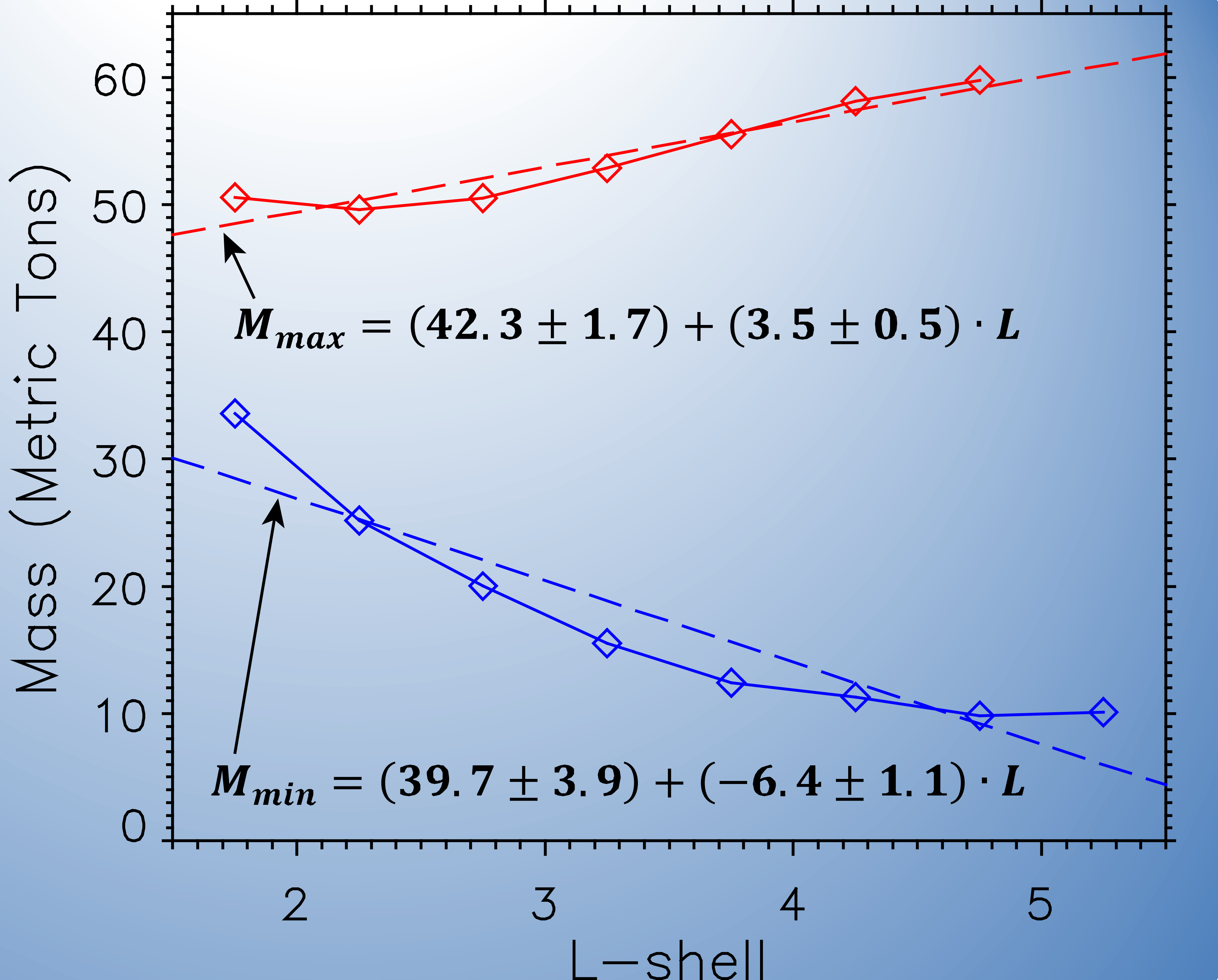
$$b_0 = -0.02$$

$$b_1 = (0.79 \pm 0.05) \cdot L$$

$$b_2 = (-0.09 \pm 0.01) \cdot \langle \sum_{daily} K_P \rangle$$

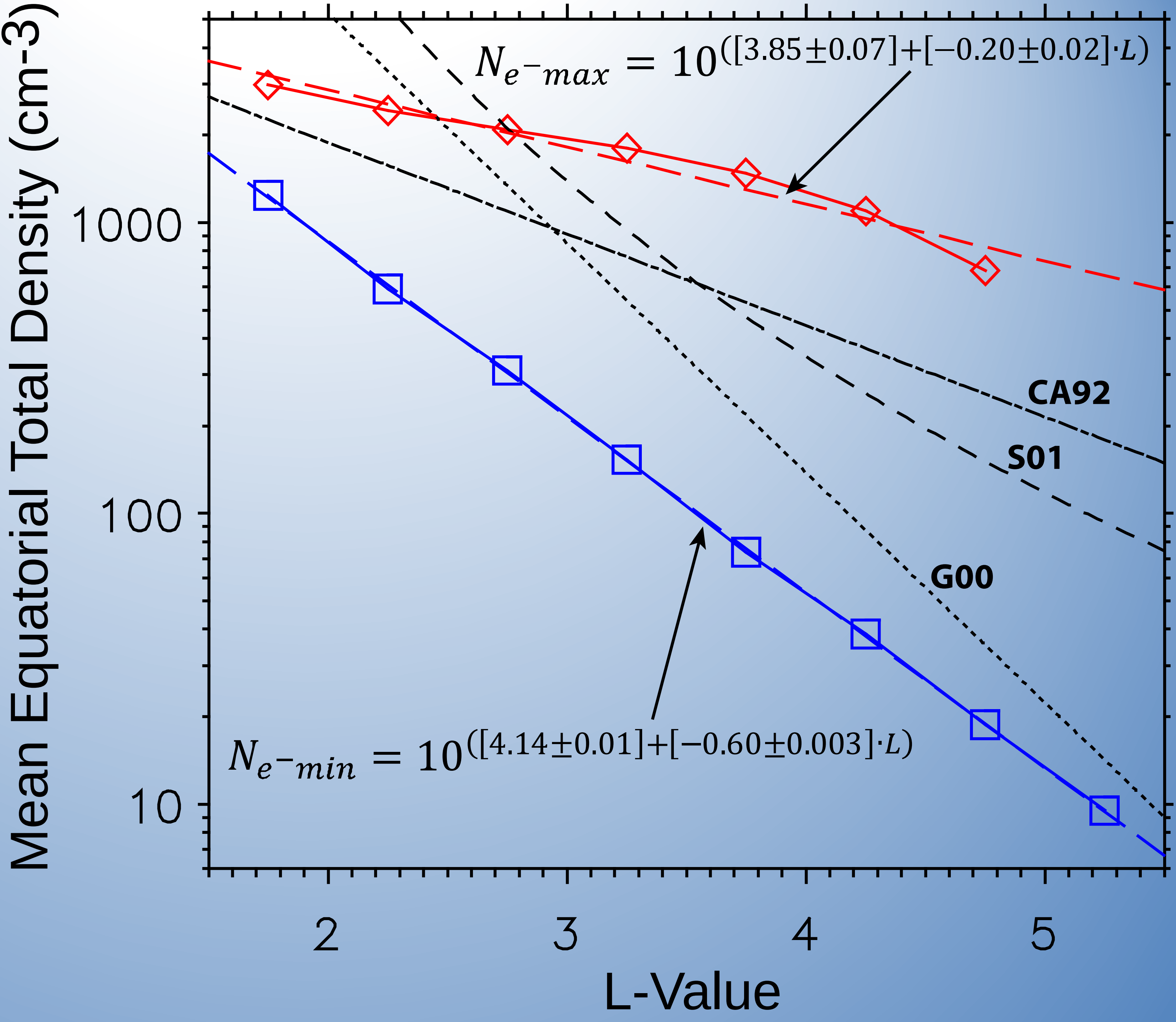
The multiple-linear correlation coefficient for Equations 5 is 0.95.

Minimum and Maximum Mass versus L-shell for 7-Events



Minimum and Maximum Densities versus L-shell for 7-Events

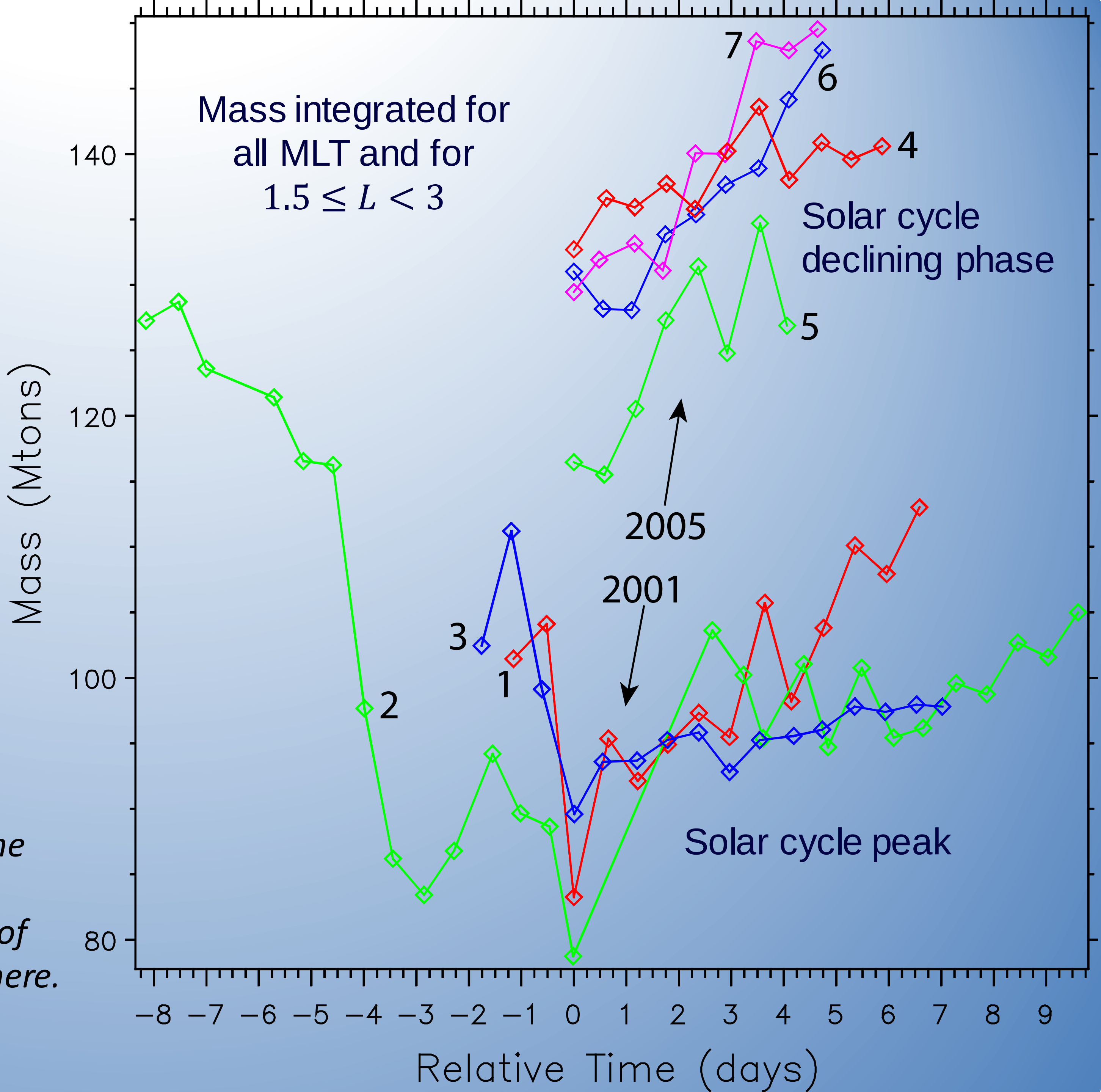
CA92: Carpenter/Anderson-1992
G00: Gallagher et al-2000
S01: Sheeley et al-2001



Summary of Results

- The use of images is capable of providing system-level quantitative measures of plasmasphere dynamics.
- The eroded plasmapause location is confirmed not to be a boundary for plasma loss or yet shown to suggest a boundary in the effectiveness of loss processes.
- The study of integrated plasma content, such as mass, is a new method of analysis that offers previously difficult or impossible to obtain measures of plasma transport through the magnetospheric system.

While the solar wind and its coupling into the magnetosphere drive space weather impacts, it is the spatial and temporal dynamics of plasma mass in geospace that guides the magnetospheric conduits of energy and plasma transport in the inner magnetosphere.



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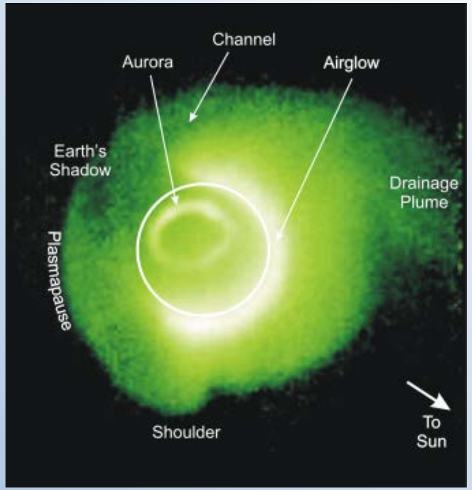

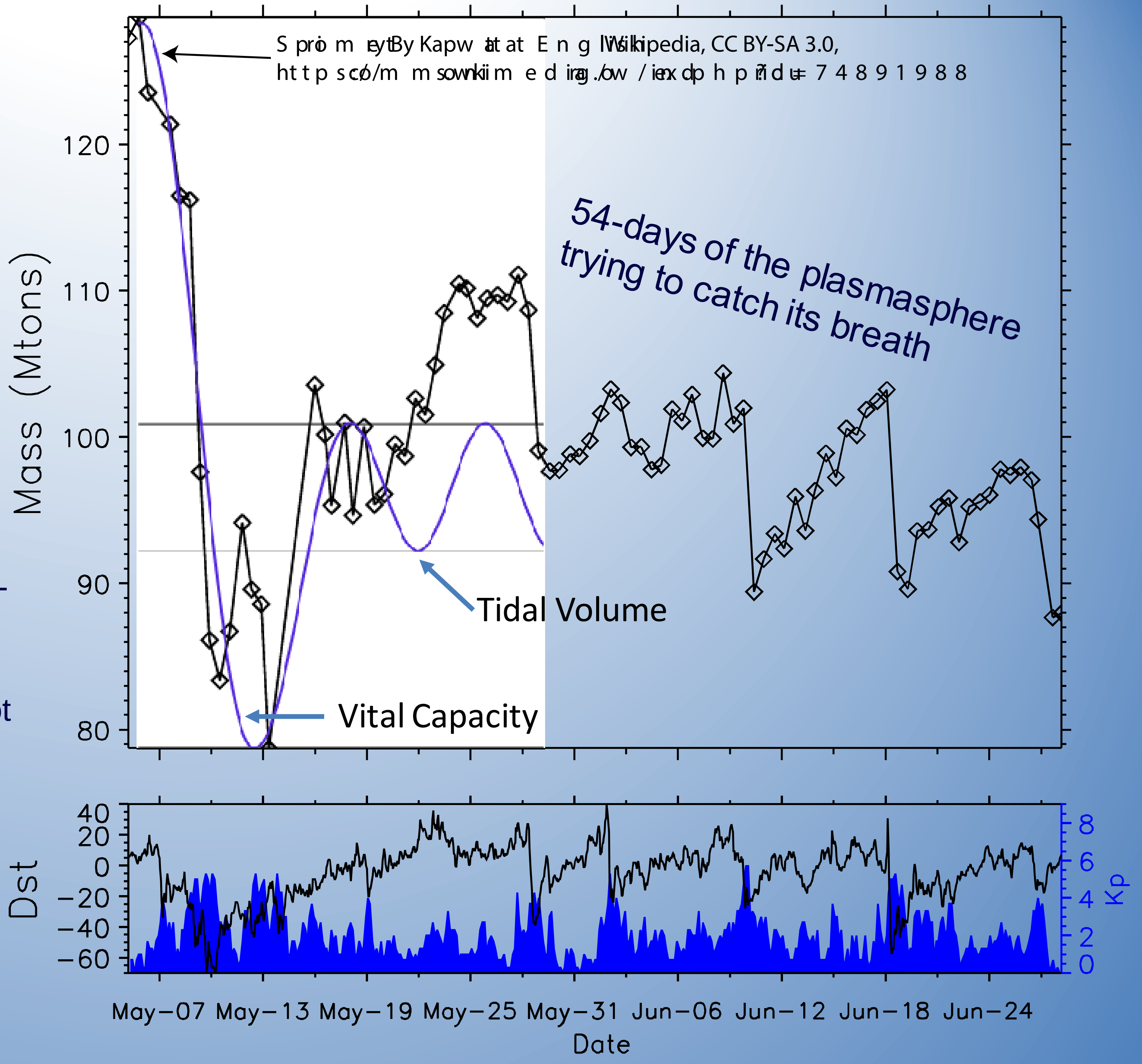

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A Next Focus on Erosion