

This substorm onset matrix shows relevance of various observations/modellings to various substorm-onset physical models. Comments and suggestions are very welcome.	merit	near-earth reconnection	flow braking	current distruption	ballooning/ interchange	convection reduction	Nishimura/ Lyons model	Alfven wave model	M-I coupling model	excuse, other explanations, criticism, comments
Pre-onset characteristics										
satellite signatures										
Thinning and stretching of the magnetotail current sheet: Increase in the cross-tail current density (Sanny et al., 1994, Pulkkinen et al., ...; Petrukovich et al., 2007); Decrease in Bz (Petrukovich et al., 2007)		TCS formation								
Configurational changes: Minimum Bz formation (was it observed?)					Tailward Bz gradient (Pritchett and Coronity, 2010)					
ground signatures										
Onset Signatures										
satellite signatures										
earthward bursty bulk flow (BBF) Angelopoulos et al. (JGR, 1994; 1996)		result from reconnection Nagai et al. (???) Miyashita et a.. (???)	N/A (either from reconnection or rarefaction)	rarefaction wave after current disruption	rarefaction wave after ballooning onset	rarefaction wave after onset				
dipolarization in the plasma sheet										
dispersionless injection at geosynchronous orbit										
plasmoid/TCR signatures		result of reconnection								
two-step onset of AKR									Two-altitude onsets may give some constraints on M-I coupling process at onset.	
ground signatures										
auroral initial brightening Akasofu (PSS, 1964)		result from earthward flow braking and flow shear	driven by inertia current and flow shear (voltage) associated with flow braking	connected to the current disruption	connected to the ballooning region	connected to the convection mismatch and Harang discontinuity				
100-km scale wave forms of onset aurora Donovan et al. (ICS6, 2006) Liang et al. (???)					evidence of ballooning mode					K-H vortex
10-km scale wave forms and cascade signature of onset aurora Sakaguchi et al. (AnnGeo, 2009; GRL 2009)				evidence of current disruption	evidence of ballooning mode?			evidence of Alfven wave resonance between ionosphere and middle altitude		K-H vortex
negative H decrease at high latitudes										
PI2 in the auroral zone										
PIB in the auroral zone										
PI2 at middle latitudes										
positive H bay / D variations at midlatitudes										
PBI->equatorward-moving arc->onset at equatorward arc (84% of all events) Nishimura et al. (AGU, 2009) Kepko et al. (???)		evidence of reconnection->flow braking	evidence of reconnection->flow braking				evidence of BBF from distant NL --> near-Earth instability --> substorm onset			The onset aurora is already very bright. Not quiet-time onset