This substorm onset matrix contains all the presentations of GEM Substorm FG on June 24-25, 2010 and June 30, 2011, as well as some	merit	near-earth reconnection	flow braking	current disturption	ballooning/ interchange	convection reduction	Nishimura/ Lyons model	Alfven wave model	M-I coupling model	excuse, other explanations, critisism, 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) Angelopoulous 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 (voltex) 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 voltex
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 voltex
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
Below are from GEM Substorm FG presentations on June 24, 2010.										
Session 1 (Timing)										
Vassilis Angelopoulos - Toshi Nishimura: THEMIS reconnection occur 5 min after PBI		PBI may not be the near-earth reconnection					PBI corresponds to the distant neutral line?			* satellite may be missing the first signature of reconnection (in both X and Y direction) * propagation takes time of an order of minutes.
Jiang Liu (Vassilis Angelopoulos): timing of Jan.29, 2008 (Lui et al) and Feb.2 2008 (Mende et al.) : rotate the coordinate of P1/P2 to plasma sheet -> plasmoind signature appears + southward field at P2 -> onset signatures to be consistent with MHD propagation		supportive to the reconnection-first model								auroral brightening local time is 1-2 LT different from satellite location? (Mende) Which one should we take in the multiple aurora brightening? (Mende)
Jim LaBelle: onset signature on MF radio waves (few minutes at the onset) coming from poleward arc can be an indicator of PBI. Their spectra show patchy structure and group delay with a time scale of 0.1s, giving a F-region density profile. AKR observation on the ground and Geotail. -> usable for timing analysis	usable for onset timing analysis									

Christine Gabrielse: constructionof substorm timing database, Pi2, AE, Bz, Vx, flux, and Ey with error bar	usable for conclusive timing analysis									
Jian Liu: Magnetic flux transport increases prior to the Pi2 onset (more earlier at tailside) in the statistical study.		supportive to the reconnection-first model								Statistics show large variation of timings.
Mike Shay: In kinetic Alfven reconnection model, Hall strucutre propagate much faster than the outflow from the reconnection region (V=1000-5000 km/s).	*easy to monitor the reconnection signature by satellites									
Yan Song: momentum transfer through Alfvenic interaction from magnetopause into the magnetosphere in the growth phase, causes tailward force in the plasma sheet which balances with earthward JxB force. Sudden change of solar wind condition stops this tailward force and then earthward force excess occur to initiate substorm. Multiple onset corresponds to multiple localized Alfveninc interaction at the plasma sheet and breakdown of frozen-in condition.								observational support is needed.		ULF wave activity seems to be very weak during the substorm growth phase.
Jo Baker: SuperDARN (7s resolution) show Pi2 oscillation (4.5-6mHz, amplitude=~50m/s) at subauroral latitudes	Possible to calculate Pi2 Poynting flux									
Toshi Nishimura: typical time delay from PBI to auroral onset (start of rapid birghtening and poleward expansion) is 5.5 min. PBI occurs 0-2 MLT later local time than onset. About 95% of events show PBIs before auroral onset. Two events (Feb.2, 2008) of fairly-isolated substorm shows PBI->onset brightening.		near-earth reconnection (PBI) and flow braking (aurora onset)	near-earth reconnection (PBI) and flow braking (aurora onset)		near-earth or distant reconnection (PBI) initiate near-earth ballooning/interchange instability (auroral onset)	distant reconnection (PBI) initiate near-earth instability (auroral onset)	distant/near-earth reconnection (PBI) initiate near-earth instability (auroral onset)			PBI - auroral onset (5-degree latitude) magnetic flux should correspond some large area in the plasma sheet
Toshi Nishimura: reconnection at 0736UT, but PBI occur at 0730 UT and other PBIs well before that time (more than 10 min)		PBI may not be the near-earth reconnection					PBI corresponds to the distant neutral line?			* satellite may be missing the first signature of reconnection (in both X and Y direction) * propagation takes time of an order of minutes.
Session 2 (propagation)										
Andrei Runov: P2 (-17Re) tailward flow and 6-min later at P4 injection/dipolarization at -8 Re		near-Earth reconnection first					near-earth reconnection initiate instability at 10 Re.			
Andrei Runov: dipolarization front (Bz increase) propagate from P1, P2, P3, P4, to P5 from 20 Re to inside 10 Re. The dipolarization front structure is something like a magnetopause, showing clear boundary of density, temperature, $PV^{5/3}$. Ion energization at 5-300keV occurs 30s before the dipolarization front occurs with 30mV/m normal E-field at the dipolarization front.		dipolarization front can be an evidence of transient near-earth reconnection		BBF can make dipolarization front	BBF can make dipolarization front	BBF can make dipolarization front	BBF can make dipolarization front			
Stephen Mende: IMAGE WIC rarely shows PBI-related N-S aurora (diffucult to see in IMAGE due to spatial resulution, sensitivity, …)										
Stephen Mende:tailward-moving rarefaction wave always accompany earthward plasma motion.										
Stephen Mende: cross-tail current (THEMIS, 6A/km) is not enough.										
Ping Zhu: MHD modeling of PBI and N-S arc (Feb. 29, 2008 event). PBI and their equatorward and westward motion are reproduced. But it is well equatorward of the open-closed boundary. Local minimum of PV^{γ}) developed to cause interchange instability										
Mike Shay: Kinetic Alfven wave from the reconnection has suffficient energy to produce visible aurora. The Poynting flux S is 0.01-0.09 ergs/cm2/s at 20 Re and 1-10 erg/cm2/s in the ionosphere, sufficient to create visible aurora. Size: 190-750km in longitude		PBI can be caused by near-earth reconnection					PBI can be caused by distant neutral line			Waves can propagate across B-field and may be spread out. Attenuation may also occur but it is already considered as 90%.
Joachim Birn: t=61 finite resistivity , t=90s onset of reconnection, t=120 onset of fast reconnection, lobe reconnection, ballooning/interchange instability, entropy minimum, t=127 Jpara at x=0 (SCW), t=130 dipolarization near inner boundary (t=1 (Alfven time) corresponds to 6seconds)		consistent with the near-earth reconnection model	consistent with the near-earth reconnection -> flow braking model		consistent with the near-earth reconnection -> ballooning/interchange instability model					

Yasong Ge: BBF/dipolarization front (Feb.27, 2009) simulation (OpenGGCM), brightening aurora maps to X=-17 Re and caused by flow voltex associated with near-earth reconnection.		THEMIS observations of earthward flow and dipolarization front can be understood by MHD simulation of earthward BBF from near-earth reconnection								MHD simulation cannot reproduce near-earth plasma instabilities
Marck Lessard: PiB observed on the ground, GOES, and THEMIS corresponds well. Time delay from THC, THD, THE, GOES12, and South Pole is within 2 minutes, from THC first to South Pole last. Earthward fast flow caused compressionl PiB that is transferred field-aligned Alfven waves to cause Alfvenin aurora at the onset. (both reconnection and near-eath instability can make Alfven waves).										
Bob Lysak: modeling fast flows, wave generation and FAC, the cause of equatorward-moving aurora can be not only (1) earthward fast flow, but also (2) Alfven wave propagation, (3) total pressure fluctuations								Alfven wave can make equatorward-moving aurora		Can single equatorward-moving arc structure be made by Alfven wave?
Session 3 (mapping)										
Gang Lu: From AMIE E-field pattern (Feb.11, 2000 0433UT), auroral onset occurs poleward of the Harang discontinuity. E-W structure in the ionosphere can be mapped to the X-direction structure in the tail, using modified Tsyganenko model.						supportive for convection reduction model				
Toshi Nishimura: location of auroral onset is equatorward of the Harang discontinuity for 54% of events (=84/156events)		near-earth reconnection (PBI) and flow braking (aurora onset)	near-earth reconnection (PBI) and flow braking (aurora onset)		near-earth/distant reconnection (PBI) cause BBF (bubble) and then initiate ballooning/interchange instability at high-pressure region (~10 Re)	not supportive for convection reduction model, since convection reduction (initiation of rarefaction) should occur at Harang discontinuity	some instability occur at the location of high-pressure buildup and convection flow change their direction			
Xiaoyan Xing: THC observation of magnetotail counterpart (-18Re (-22Re at equatorial plane)) of pre-onset N-S arc (Feb.4, 2008 10:48UT) shows earthward flow and pressure reduction. So source region of PBI will be tailward of -22 Re.		PBI should map to near-earth reconnection					PBI should map to distant neutral line			
Kubyshkina (Angelopoulos): mapping the breakup region to the magnetosphere gives significant difference from T96 model in maximum 3-4 degrees in latitudes and 68deg point map 11Re (T96) to 22-26 Re (modified mapping)	showing the large ambiguity of mapping of 3-4 degree in latitude and more than 10 Re in x direction.									
Christine Gabriels: mapping diffuse aurora to the magnetosphere by comparing enegy spectra between THEMIS and DMSP	Toward a convincing mapping in future									
Emma Spanswick/Eric Donovan: Tried to make realistic proton aurora mapping to the tail. Proton aurora intensity estimated from THEMIS ion flux with full pitch-angle scattering assumption gives decrease of proton aurora intensity down less than 50 R outside 10 Re.	usable for proton aurora mapping									
Shin Ohtani: brightening arc is located equatorward boundary of upward region 1 field-aligned current. Auroral emission is a convolution of magnetospheric signature and M-I coupling (parallel E-field prevents ions to precipitate in the region 1 current region).	causion on the mapping of auroral structure to the plasma sheet									
Session 4 (transision region)										
Xiaoyan Xing: Azimuthal pressure gradient at the growth phase estimated by two THEMIS satellites shows sharp gradient development at a few min before onset corresponding to upward FAC.										
Ping Zhu: Plasma sheet become (interchange) unstable at highly-stretched transition region at pre-onset phase (Open CCGM for a black-aurora event).										

Uritsky (Eric Donovan): east-west wave-like structure on the multiple onset arc, showing different propagation at three neighboring arcs					distant reconnection (poleward arc) initiate ballooning instability (wave structure in the equatorward arc)					
Below are from GEM Substorm FG presentations on June 28, 2011.										
session 1 (10:00-11:30) pre-onset signatures										
Larry Lyons: enhanced flow burst across polar cap boundary prior to PBIs observed by RISR-N, RANK polarDARN radar, and THEMIS ASI.							tail reconnection is triggered by the enhanced localized flow across the polar-cap boundary			What makes the localized antisunward flow bursts? It may be related to the patchy dayside reconnection and/or polar-cap high-density plasma patches.
Ping Zhu: ky=0 mode (axial mode, no structure in y-direction) can cause initial loss of equilibrium on closed field line at onset in the near-Earth tail in resistive 2D (X-Z) MHD/OpenGGCM simulation, leading to subsequent tearing/reconnection.					speeding up the balooning instability?					
Larry Lyons for Toshi Nishimura: Pre-onset arc is located as a localized upward current in the region 2 downward current system for two cases.										breakup arc is located in the inner plasma sheet
Kazuo Shiokawa (Ryuho Kataoka): Pre-onset arc shows fine structures about 3-4 km (3-min before breakup) to more than 10 km scale (1-min before breakup)									possible role of the ionosphere for modulating the triggering process of the onset via the self-organization of the IAW turbulence associated with Kelvin-Helmholtz and pressure-driven instabilities of the thin current sheet of auroral arc.	
session 2 (11:30-12:00) relative timing										
Michael Shay: Super-Alfvenic flux transport by kinetic Alfven waves near the separatrix in the Hall MHD simulation. Vpara=1500-5500km/s in the magnetosphere, Poynting flux is 1-10 ergs/cm2/s at ionosphere enough to create visible aurora with a scale size of 6-70km in latitude and ~700km in longitudes. Confirmed by Cluster statistical study of Poynting flux distribution in V-B plane.	This process creates Alfvenic onset aurora	Alfvenix auora from reconnection					This reconnection Poynting flux may correspond to the pre-onset PBIs and/or expansion phase PBIs.			
Joachim Birn: 3D MHD simulation of mid tail reconnection. Onset of reconnection -> several min -> onset of fast reconnection and entropy loss -> ~2min -> onset of SCW and penetration of low entropy to near tail, braking and diversion of flow.		based on the NENL and flow braking senario	based on the NENL and flow braking senario							
session 2 (13:30-15:30) relative timing										
Jim LaBelle: The MF radio wave burst (1-4 MHz) at the onset of substorm are associated with poleward-most expanding aurora. The burst starts from a middle frequency, showing C-shape in dynamic spectra. This can be explained by the wave generation by electron beam and density profile at the topside ionosphere.	observation suggests Alfvenic low-energy precipitation at the poleward edge arc.									

Larry Lyons: Dipolarization fronts and associated flow bursts are associated with auroral streamers for 5 events in total 6 events. Azimuthal separation of spacecraft may create apparent time difference of timing.										
Russell Cosgrove: global correlation analysis among data of 24 magnetometers. The first disturbance has a broadband correlation signature, but later the pulsations coalesce to a few discrete frequencies. Correlation steeply increases and ceases, while power slowly grows, suggesting transition from linear to non-linear global instability as a whole magnetosphere-ionosphere system.										
session 3: flux, energy, and plasma transport										
Xiaoyang Xing: Observation of THEMIS ion spectra indicates that ion injection at the dipolarization front causes enhancement of azimuthal pressure gradient a few min before the onset, and causes enhanced upward FAC and intensification of thin onset arc. Ion parallel pressure increase is lager than the perpendicular pressure.										
Joo Hwang: particle energization associated with dipolarization front (DF)/BBFs. Fermi-acceleration makes bi-directional electrons. Then the electron beam cause whistler mode waves that energize particles at and around the DF. PIC simulation of DF and Cluster observation Ion energy inceases while electron energy decreases after DF/BBF.										
Jian Yang: visualising the substorm injection boundary and related bubbles using 3D simulation. Two step flux enhancement, 1) high PV5/3 plasma ahead of bubble, and then 2) inside the bubble.										
Yasong Ge: ion and electron features at the dipolarization front. One case ESA shows earthward flow, while SST do not. The other case, both ESA/SST shows earthward flow. Dipolarization front can energize and reflect plasma sheet ions in field-aligned direction and cause proton aurroa in the ionosphere,										field-line mapping (correspondence between THEMIS and ground proton aurora) is difficult
session 3: flux, energy, and plasma transport (16:00-18:00)										
Michael Shay for Penny Wu: How are the reconnection properties changes by lobe density. Dipolarization front amplitude and reconnetion rate increase linearly with increasing Nps/Nlobe. The reconnection occurs faster for lower lobe density.										
Feifei Jiang: preexisting arc observed by THEMIS, FAST, and ground ASI. The preexisting arc just before onset is located at the boundary between the dusk Region 1 and 2 current region. Preexisting arc is located at the poleward part of the energetic ion precipitation. preexisting arc corresponds to the inverted-V region.										pre-existing arc is located in the inner plasma sheet

James Weygant: Locating the Harang discontinuity from equivalent ionospheric current using magnetometer arrays. The onset arc is close to the Harang discontinuity. The onset arc is mostly at the boundary between region 1 and 2 current systems.	mgnetometer array and radars can show location of Harang discontinuity and region 1/2 current.										
Stefan Kiehas: A series of plasmoids observed by ARTEMIS at X=-56 Re and -70 Re. Two-satellite measurements give propagating velocity of the plasmoid. The plasmoid velocity increases for later times. B and V are highly correlated.											