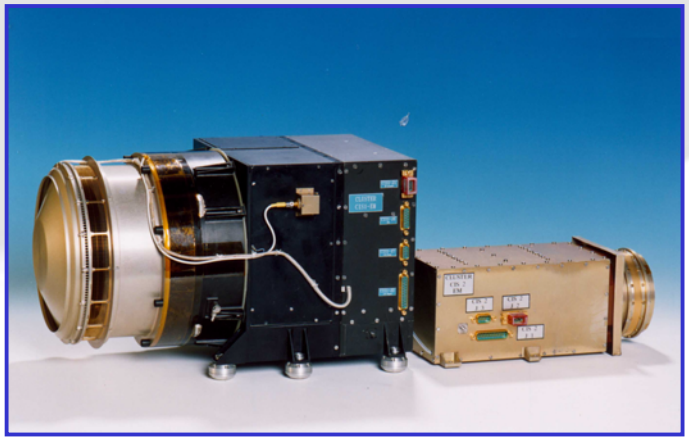


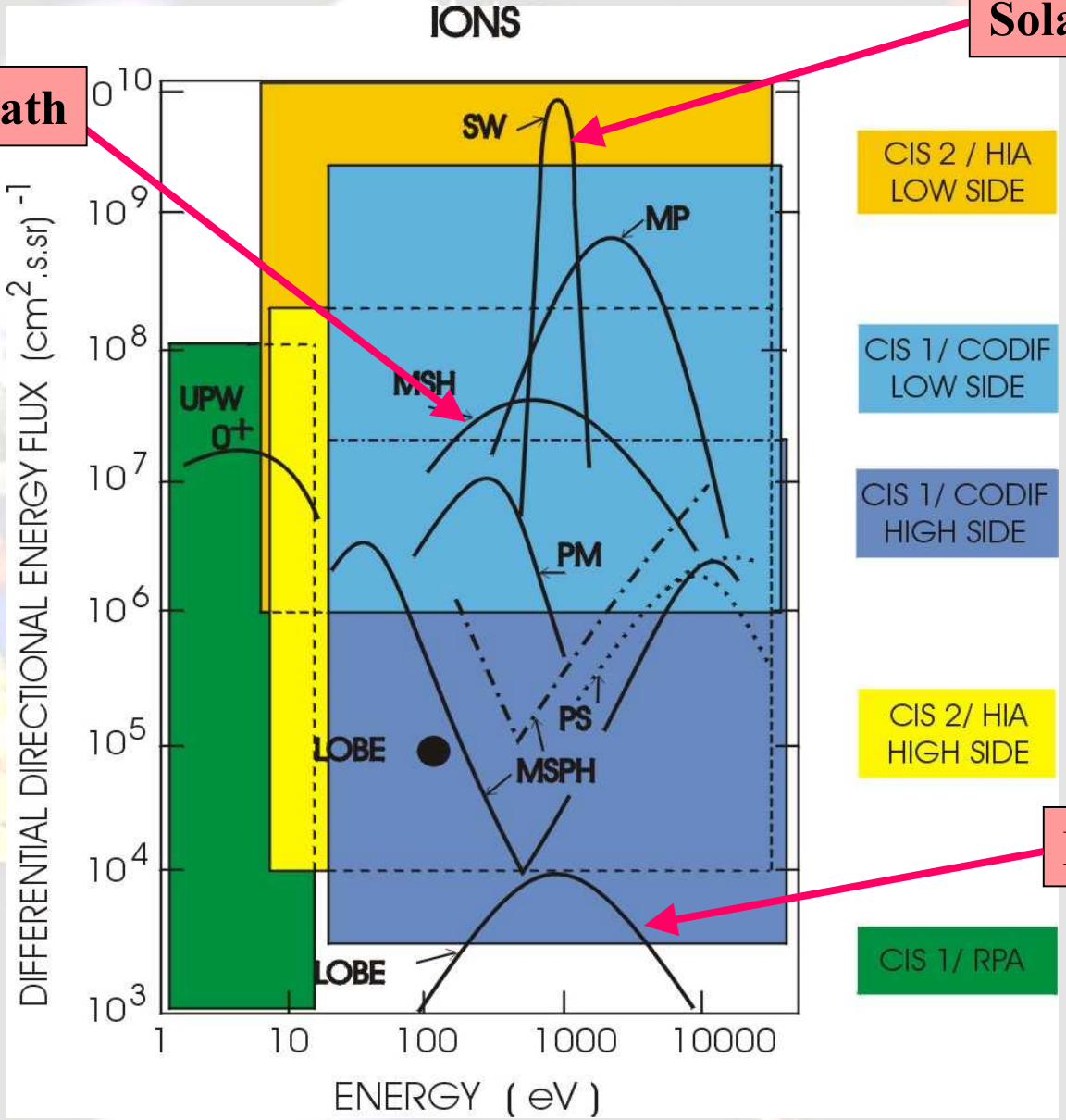
Cluster Ion Spectrometry:

Instrument Description, Modes and Operations

Iannis Dandouras

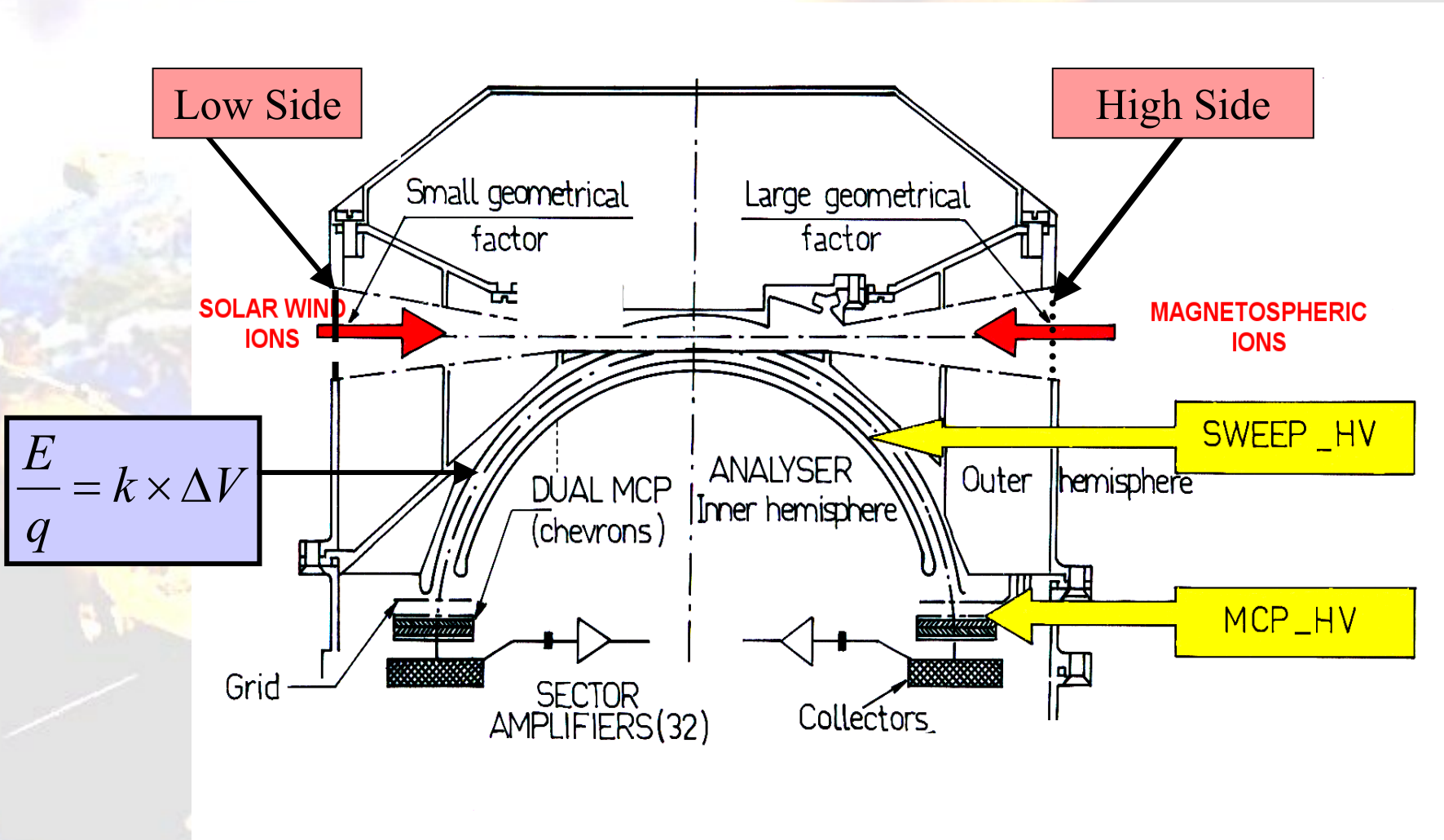
and the CIS Team

CIS Dynamic Range

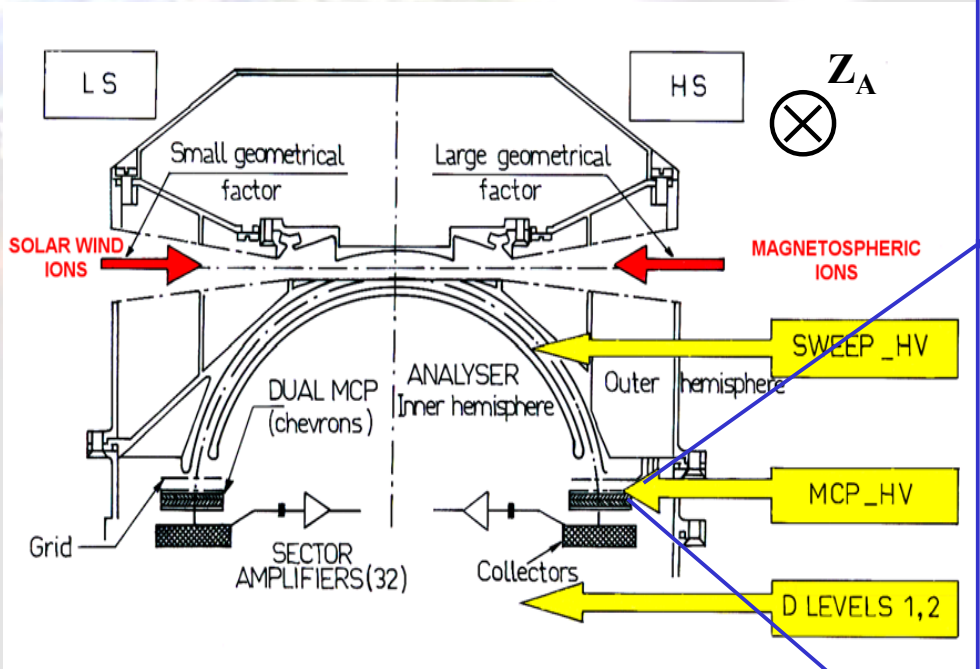


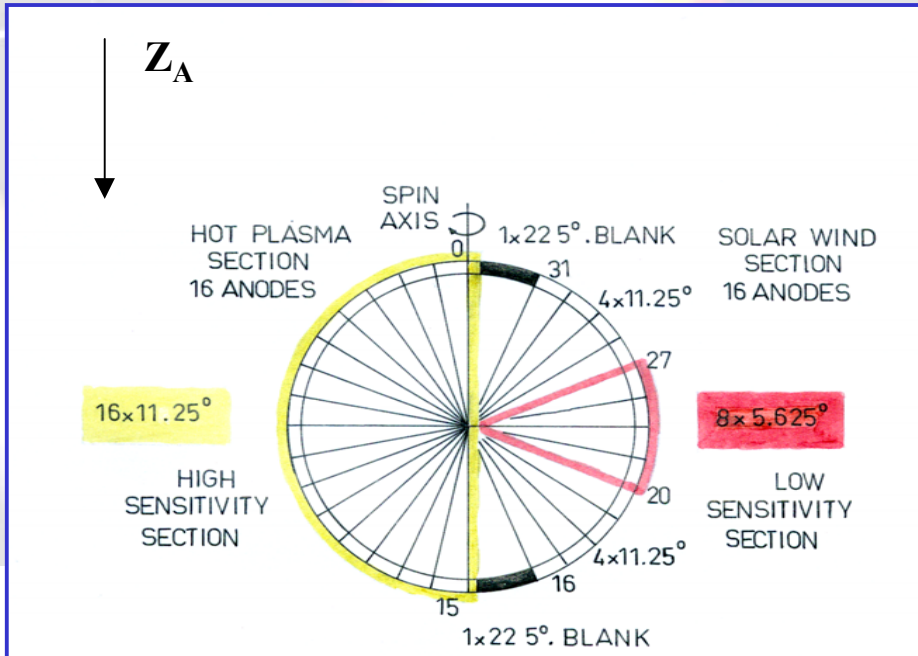
Cluster Ion Spectrometry:

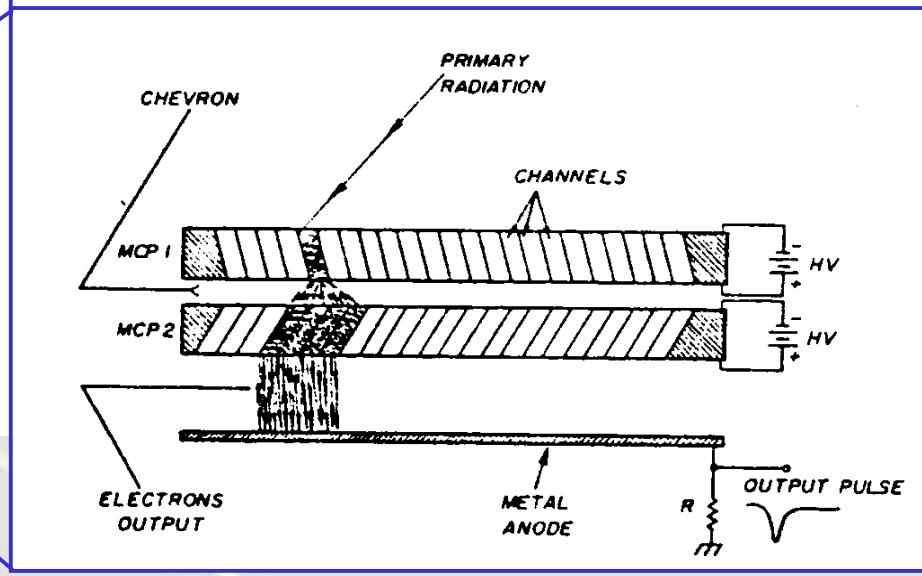
HIA: Hot Ion Analyser



Detectors:
Micro-Channel Plate



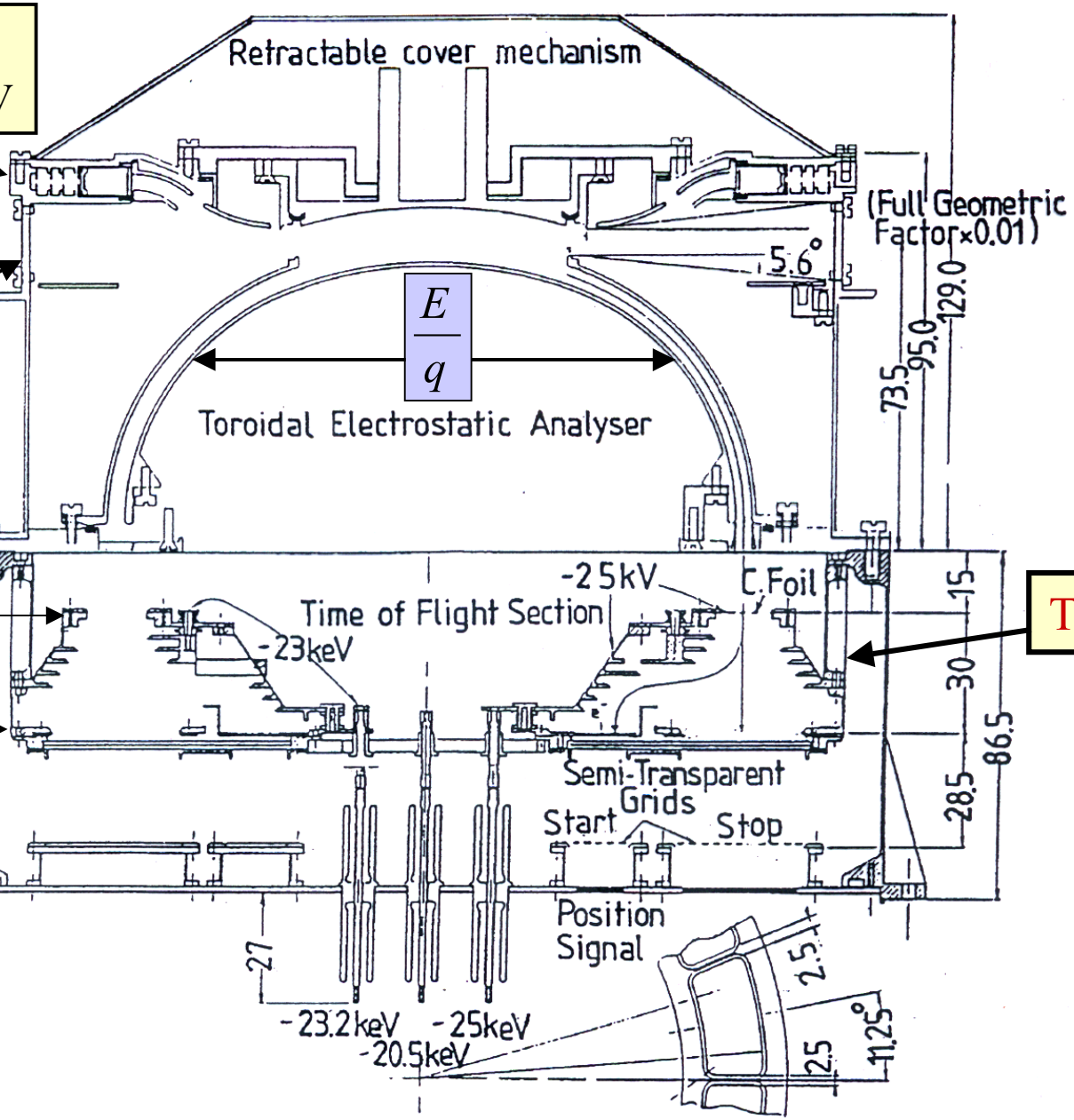




CODIF: Ion Composition and Distribution Function Analyser

RPA entrance :
$\approx 0\ eV \leq E_{RPA} \leq 25\ eV$

Main entrance



L

TOF system

$$\frac{m}{q} = \frac{2 \times \left(\frac{E}{q}\right)}{\left(\frac{L}{TOF}\right)^2}$$

Main features and measured parameters of the CIS experiment

- Full 3D ion distribution functions
- Flux as a function of time, mass and pitch angle
- Moments of the distribution functions : density, bulk velocity, pressure tensor, heat flux vector
- Beams

Analysers	Energy Range	Energy Distribution (FWHM)	Time Resolution		Mass Resolution M/ΔM	Angular Resolution	Geometrical Factor (Total) $cm^2.sr.keV/keV$	Dynamics $(cm^2\ sec\ sr)^{-1}$
			2D ms	3D s				
Hot Ion Analyser HIA	~ 5 eV/e – 32 keV/e	18%	62.5	4	-	~ 5.6° x 5.6°	1.9×10^{-4} for one half $4.9.10^{-3}$ for the other half	$10^4 - 2 \times 10^{10}$
Ion Composition and Distribution Function Analyser CODIF	~ 0 - 38 keV/e Mass range 1 – 32 amu	16%	125	4	~ 4 - 7	~11.2° x 22.5°	1.9×10^{-2} for one half 2.1×10^{-4} for the other half 3.0×10^{-2} cm^2 sr for the RPA	$3.10^3 - 3.10^9$

Analysers	Full Instantaneous Field of View	Mass	Power (Nominal Operations)
Hot Ion Analyser HIA	8° x 360°	2.45 kg	2.82 watts
Ion Composition and Distribution Function Analyser CODIF	8° x 360°	8.39 kg	6.96 watts

CIS total raw CIS Total Weight : 10.84 kg without harness

Average power : 9.78 watts

CIS Telemetry : ~ 5.5 kbit/s

Expected total bit number (for the 4 spacecraft) : 10^{12} bits

CIS Instrument Status

S/C 1		S/C 2		S/C 3		S/C 4	
HIA	CODIF	HIA	CODIF	HIA	CODIF	HIA	CODIF
HS LS	HS (LS)	Not Operational		HS LS	HS (LS)	Switched OFF	HS LS

CIS Mode Combinations

16 CIS Modes × 4 (+ 2 + 1) Spacecraft TM Modes

Mode	BPS	Bytes/Blk	Blks /Frame	Bytes/ Frame
HKP	83,85	54	1	54
> NM1	5 527,71	356	10	3 560
NM2	6 521,46	420	10	4 200
NM3	4 502,91	290	10	2 900
> BM1	26 762,82	278	62	17 236
BM2	6 546,3	68	62	4 216
BM3	29 458,36	306	62	18 972

CIS Modes

Data Compression Modes

>	= 0	solar wind — mode 1
>	= 1	solar wind/upstreaming ions — mode 2
>	= 2	solar wind — mode 3
>	= 3	solar wind/upstreaming ions — mode 4
	= 4	solar wind - data compression — mode 1
>	= 5	solar wind/upstreaming ions — data compression — mode 2
>	= 6	RPA mode
	= 7	PROM operation
>	= 8	magnetosphere — mode 1
>	= 9	magnetosphere — mode 2
>	= 10	magnetosphere — mode 3
>	= 11	magnetosheath/magnetotail — mode 1
>	= 12	magnetosheath/magnetotail — mode 2
>	= 13	magnetosphere — data compression — mode 1
>	= 14	magnetosheath/magnetotail — data compression — mode 2
	= 15	calibration/test mode

Solar Wind Modes

Magnetospheric Modes

CODIF Telemetry Products : Example

(Time resolution in number of spins)

Moments H^+, He^{++}, He^+, O^+ | 3-D 64 ions | 3-D H^+ | 3-D He^{++} | 3-D He^+, O^+ | Rates | Selected Events

NM1	P3	P5	P6	P7	P9	P11	P12 (P39)	P13 (P40)	P14 (P41)	P15 (P42)	P16 (P43)	P17 (P44)	P18	P23	P24	P25	P27	P28	P29	P32 (P46)	P33 (P47)
Mode 0 - SW1					1			4			4	8					1	1			
Mode 1 - SW2					1			4			4	8					1	1			
Mode 2 - SW3				1				4			8	16					1	1			
Mode 3 - SW4				1				4			8	16					1	1			
Mode 4 - SWC1					1			(2)			(8)	(8)		4			1	1			
Mode 5 - SWC2				1				(3)			(4)	(8)		4			1	1			
Mode 6 - RPA																	1	1	4		
Mode 8 - MAG1				1		8	4			4							1			4	4
Mode 9 - MAG2				1			4			8							1	1		8	4
Mode 10 - MAG3				1			8			16							1	1		8	8
Mode 11 - MAG4				1		8	3			4							1			16	4
Mode 12 - MAG5				1			4			4							1	1		8	8
Mode 13 - MAGC1				1				(2)		(4)				8			1	1		(4)	(2)
Mode 14 - MAGC2				1			(2)			(2)				4			1	1		(4)	(2)
Mode 15 - CAL	2		2	1			4										1				

BM1	P3	P5	P6	P7	P9	P11	P12 (P39)	P13 (P40)	P14 (P41)	P15 (P42)	P16 (P43)	P17 (P44)	P18	P23	P24	P25	P27	P28	P29	P32 (P46)	P33 (P47)	P34 (P48)	P35 (P49)
Mode 0 - SW1			2		1			1			1						1					2	2
Mode 1 - SW2			2		1			1			1						1					2	2
Mode 2 - SW3			2	1				1			1						1	1				2	2
Mode 3 - SW4			2	1				4			1						1	1				4	2
Mode 4 - SWC1				1				4			2		2										
Mode 5 - SWC2				1				4			2		2										
Mode 6 - RPA																	1	1	2				
Mode 8 - MAG1				1				1		1				2			1	1		2			1
Mode 9 - MAG2				1		4	1			1							1			1	1		
Mode 10 - MAG3				1		4	1			1							1			1	1		
Mode 11 - MAG4				1		2	1			1					2		1			1	1		
Mode 12 - MAG5				1		4	1			1							1			1	1		
Mode 13 - MAGC1				1		2	1			1				2						1	1		
Mode 14 - MAGC2				1		2	1			1				2						1	1		
Mode 15 - CAL	1		1	1				1									1						

HIA
Telemetry Products
(Time resolution in number of spins)

MAGNETOSPHERIC MODES						HIGH G SECTION							
TELEMETRY MODE				HIA Bit rate (bit/s)		M	1D	2D			3D		
OPERATION MODE						P2	P9	P10	P11	P12	P6	P15	P17
NM1	NM2/BM2	NM3	BM1	Alloc.	HIA	Mom.	62E	2Dϕ AZ	2Dθ POL	2DαPAD	31Ex88Ω	16Ex88Ω	62Ex88Ω
5527	6521/6546	4503	26762			117.5	125	998	996	1996/1008	5480	2828	10948
MODES 8-11				1272	**1238**							**3 sp**	
MODES 6-9-12 (&10 NM3)				2135	**2070**						**3 sp**		
MODE 7				2135	**2112**								
10				3124	**3071**							**1 sp**	
	MODE 10			4148	**4079**					**1 sl.**			
			6-7-8-11	7000	**6731**					**1 sl.**			
			9-10-12	13162	**13062**					**2 sl.**			

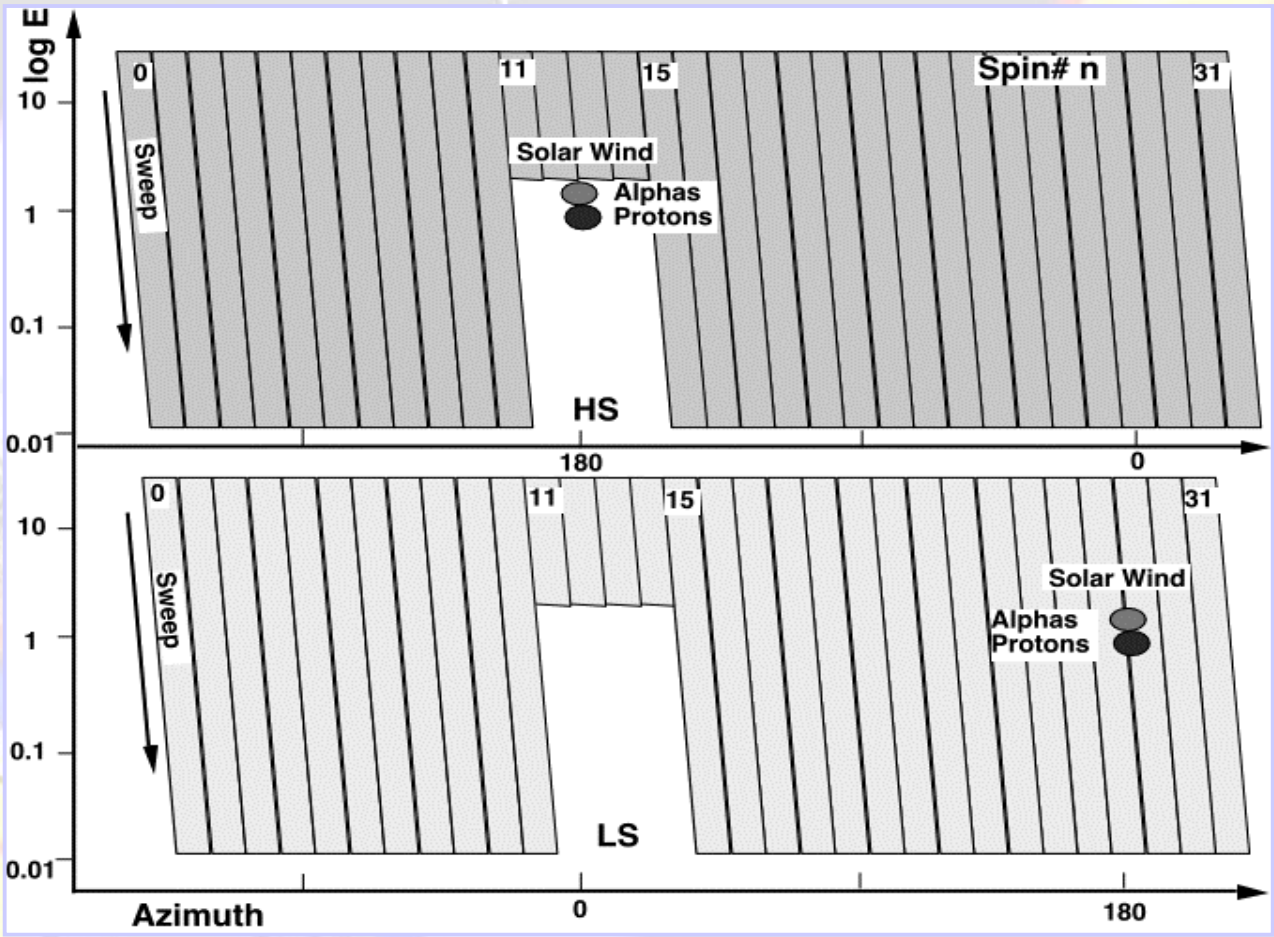
SOLAR WIND MODES						HIGH G SECTION					Low g SECTION			
TELEMETRY MODE				HIA Bit rate (bit/s)		1D	2D		3D		M	2D		3D
OPERATION MODE						P18	P10	P20	P6	P15	P4	P13	P14	P8
NM1	NM2/BM2	NM3	BM1	Alloc.	HIA	31E	2DϕAZ	2DθPOL	31Ex88Ω	16Ex88Ω	M	2Dθ POL	2Dϕ AZ	31Ex8θx8ϕ
5527	6521/6546	4503	26762			63	998	2976	5480	2828	82.5	498	498	3976
MODE 0				1272	**1275**		**5 sp**							**/4 sp**
MODE 2				2135	**2141**									**/2 sp**
			MOD 0-6	7000	**6869**				**2 sp**					
			MODE 2	13162	**12531**									
MODE 1				1272	**1088**					**3 sp**				**/18 sp**
MODE 3				2135	**2074**				**3 sp**			**/2 sp**		**/18 sp**
			MODE 1	7000	**6307**									**/5 sp**
			MODE 3	13162	**6464**									**/15 sp**

COMPRESSION MAGNETOSPHERE						HIGH G SECTION		
TELEMETRY MODE				HIA Bit rate (bit/s)		M	1D	3D
OPERATION MODE						P2	P9	P23
NM1	NM2/BM2	NM3	BM1	Alloc.	HIA	Moments	1D62 E	31Ex8θx16ϕ
5527	6521/6546	4503	26762			117.5	124.5	3206 [COMP=2.5]
MODES 13-14				1272	**~1270**			**~ 3 sp**
			13 -14	7000				

COMPRESSION SOLAR WIND						HIGH G SECTION		Low g SECTION			
TELEMETRY MODES Operation Modes (see Table)				HIA Bit rate (bps)		3D		M	2D		3D
						P6	P23	P4	P13	P14	P24
NM1	NM2 BM2	NM3	BM1	Alloc.	HIA	31E x88Ω	31Ex8θx16ϕ	M	2Dθ POL	2Dϕ AZ	31Ex8θx8ϕ
5527	6521 6546	4503	26762			5480	3206 [COMP=2.5]	78.5	498	498	1992 [COMP=2]
PRIORITY: SOLAR WIND											
MODE 4				2 165	**~1732**						
			MODE 4	13162	**~4844**						
PRIORITY: UPSTREAMING IONS											
MODE 5				2 165	**2076**		**2 sp.**				**/16 sp.**
			MODE 5	13162							**/5 spins**

3 sp.: integrated over 3 spins **/3 sp.**: once every 3 spins **1,2 sl.**: 1 or 2 slices

CODIF Solar Wind Modes



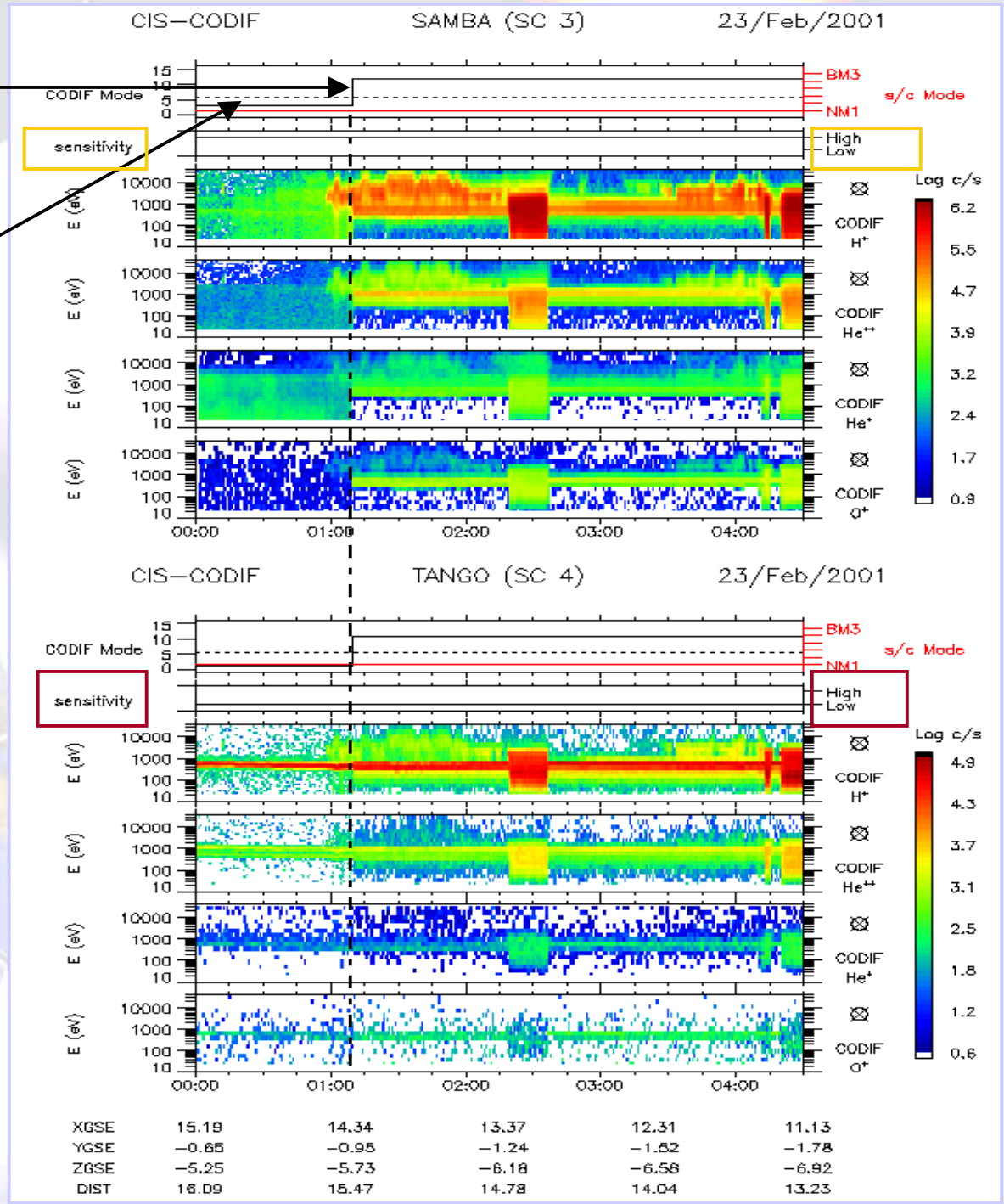
- **Reduced Energy-Sweep when High-Sensitivity side facing the Solar Wind (45° in azimuth over 360°)**
- **Either side is selectable by command, the two sides are mutually exclusive**

⇒ check from which side of the instrument the data are coming from

Magnetospheric Mode

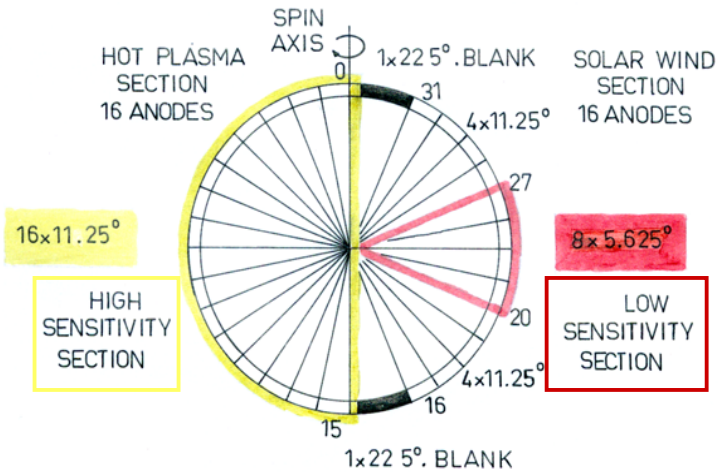
Solar Wind Mode

CODIF
High / Low Sensitivity
SW / MAG Modes
Example

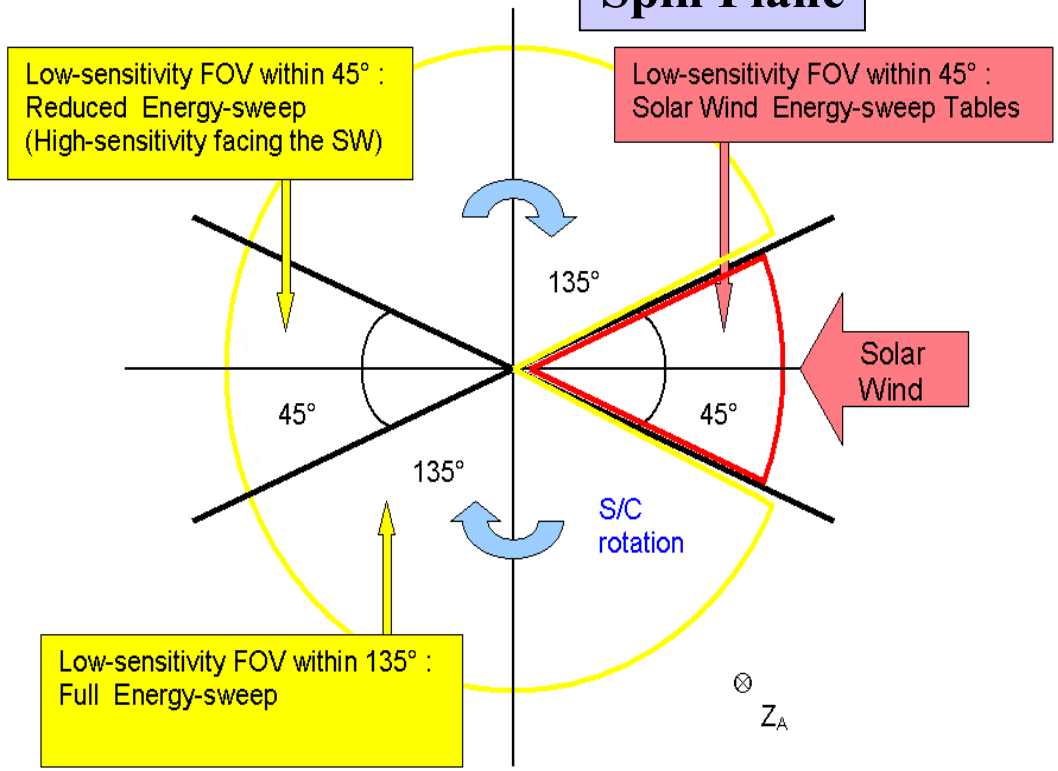


HIA Solar Wind Modes

Detector Plane



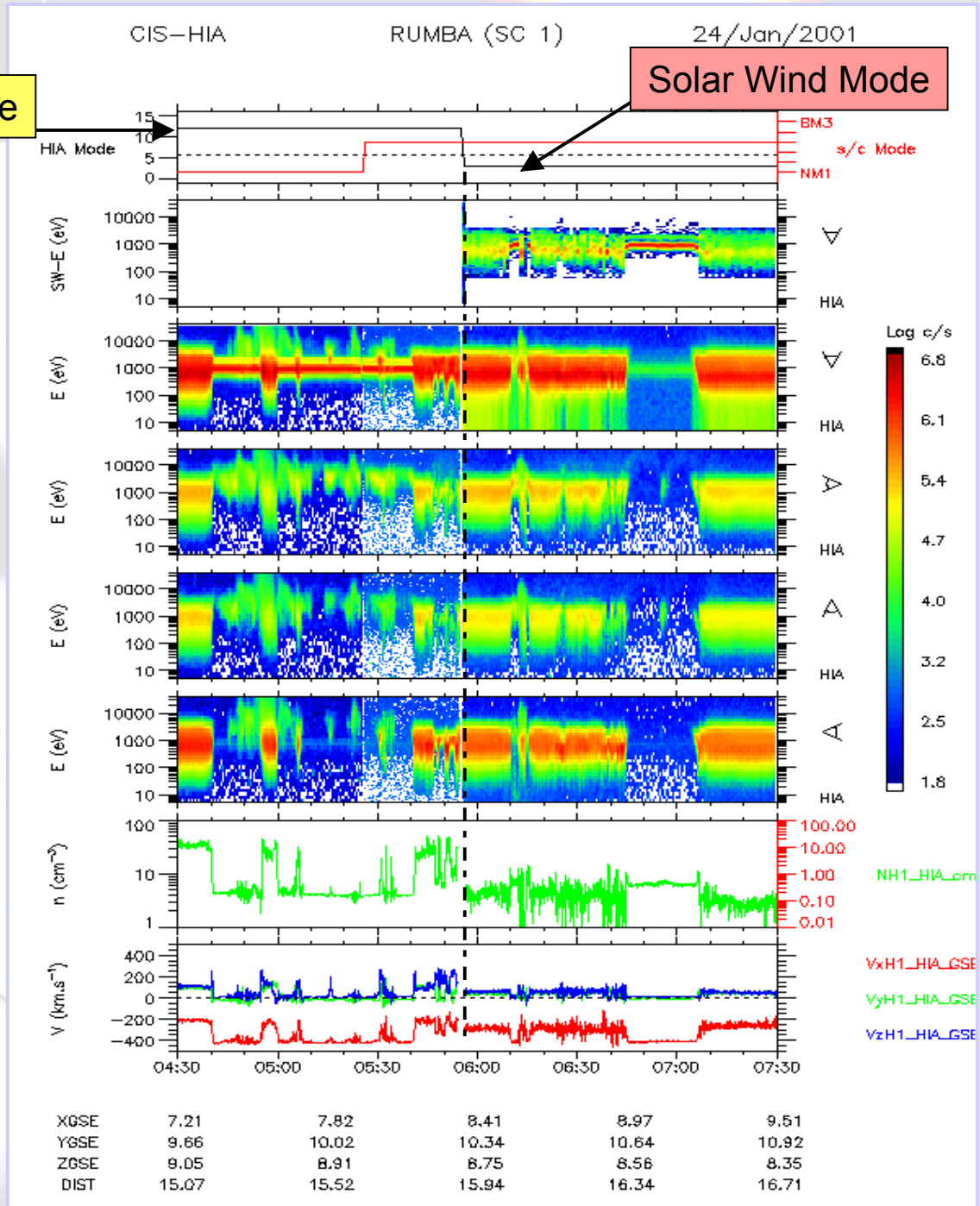
Spin Plane



- Both sensitivity sides can supply data simultaneously
- Solar Wind Energy-sweep Tables (1 out of 9 possible) when low-sensitivity side facing the Solar Wind (45° in azimuth over 360°)
- Full Energy-sweep when looking away of the Solar Wind (2 × 135° in azimuth over 360°)
- Reduced Energy-Sweep when High-Sensitivity side facing the Solar Wind (45° in azimuth)
- Moments come from the 45° × 45° centred in the Solar Wind direction, low-sensitivity side

⇒ Under-sampled distributions in the Magnetosheath when in a Solar Wind Mode

HIA
High / Low Sensitivity
SW / MAG Modes
Example



CIS Mode Selection Rules

- **14 JAN → 21 FEB 2001 (orbits 86 to 101) :** No Data Compression

Region	s/c 1	s/c 2	s/c 3	s/c 4
Magnetosphere	9 (MAG2)	OFF	9 (MAG2)	8 (MAG1)
Magnetosheath	12 (MAG5)	OFF	12 (MAG5)	11 (MAG4)
Solar Wind	3 (SW4)	OFF	3 (SW4)	1 (SW2)

- **21 FEB → 26 APR 2001 (orbits 102 to 128) :** Data Compression on SC 1 only

Region	s/c 1	s/c 2	s/c 3	s/c 4
Magnetosphere	13 (MAGC1)	OFF	9 (MAG2)	8 (MAG1)
Magnetosheath	14 (MAGC2)	OFF	12 (MAG5)	11 (MAG4)
Solar Wind	5 (SWC2)	OFF	3 (SW4)	1 (SW2)

- **Since 26 APR 2001 (since orbit 129) :** Data Compression on all SC

Region	s/c 1	s/c 2	s/c 3	s/c 4
Magnetosphere	13 (MAGC1)	OFF	13 (MAGC1)	13 (MAGC1
Magnetosheath	14 (MAGC2)	OFF	14 (MAGC2)	14 (MAGC2)
Solar Wind	5 (SWC2)	OFF	5 (SWC2)	5 (SWC2)

CIS Mode Switch Logic

- **Switch to Magnetosheath Modes :**
  - Model MP -2 hours (outbound)
- **Switch to Solar Wind Modes :**
  - Model BS +2 hours (outbound)
- **CODIF HS/LS Selection Logic** *(since 23 JAN 2001)* **:**
  - s/c 1 and 3 : continuously in HS
  - s/c 4 : HS in the magnetosphere, LS in the sheath and in the solar wind
- **RPA Mode :**
  - Has been used on all s/c, but priority for s/c 3 (ASPOC and HIA operational)
  - On an “orbit case by orbit case” basis