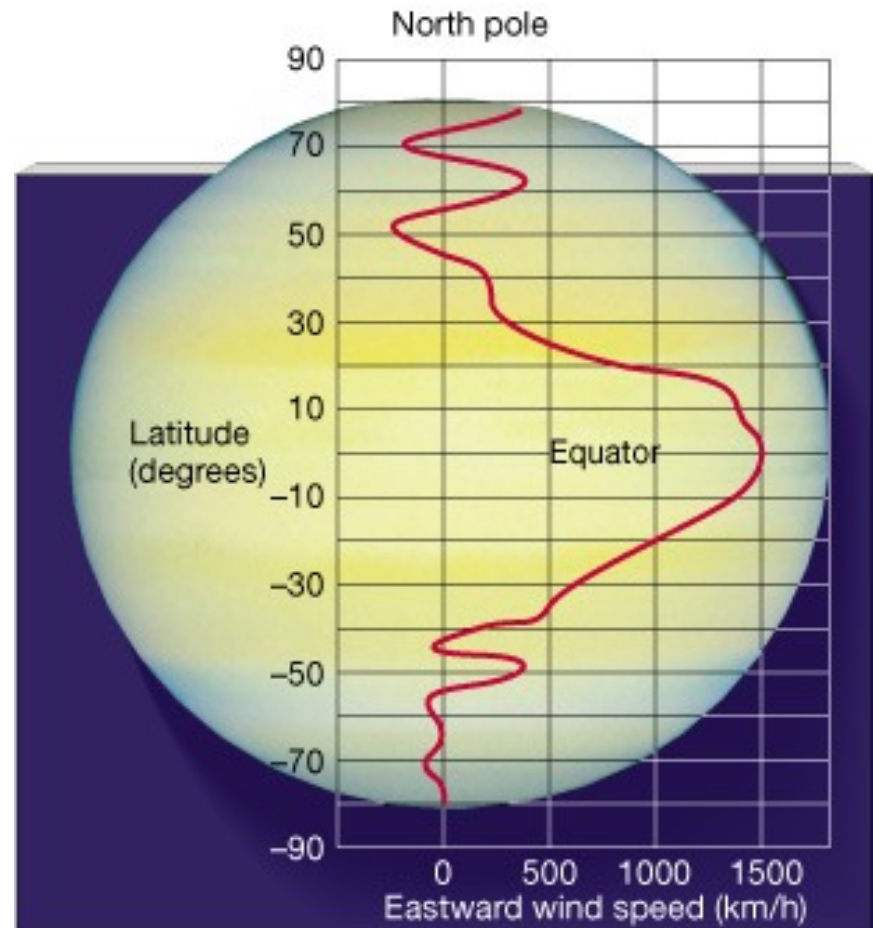
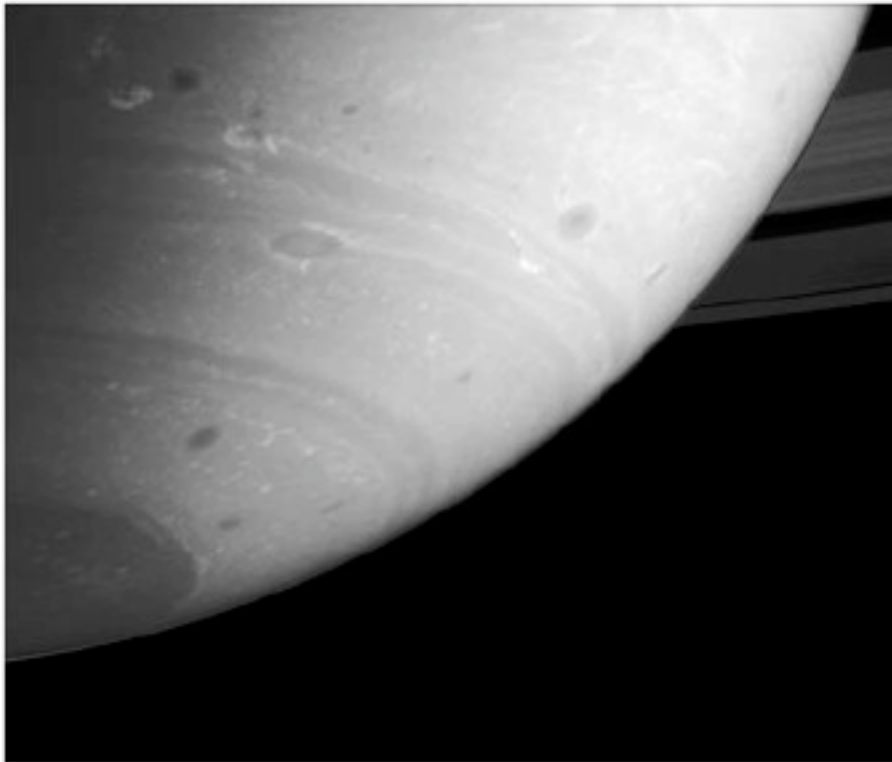


Un modèle pour la rotation radio variable de Saturne

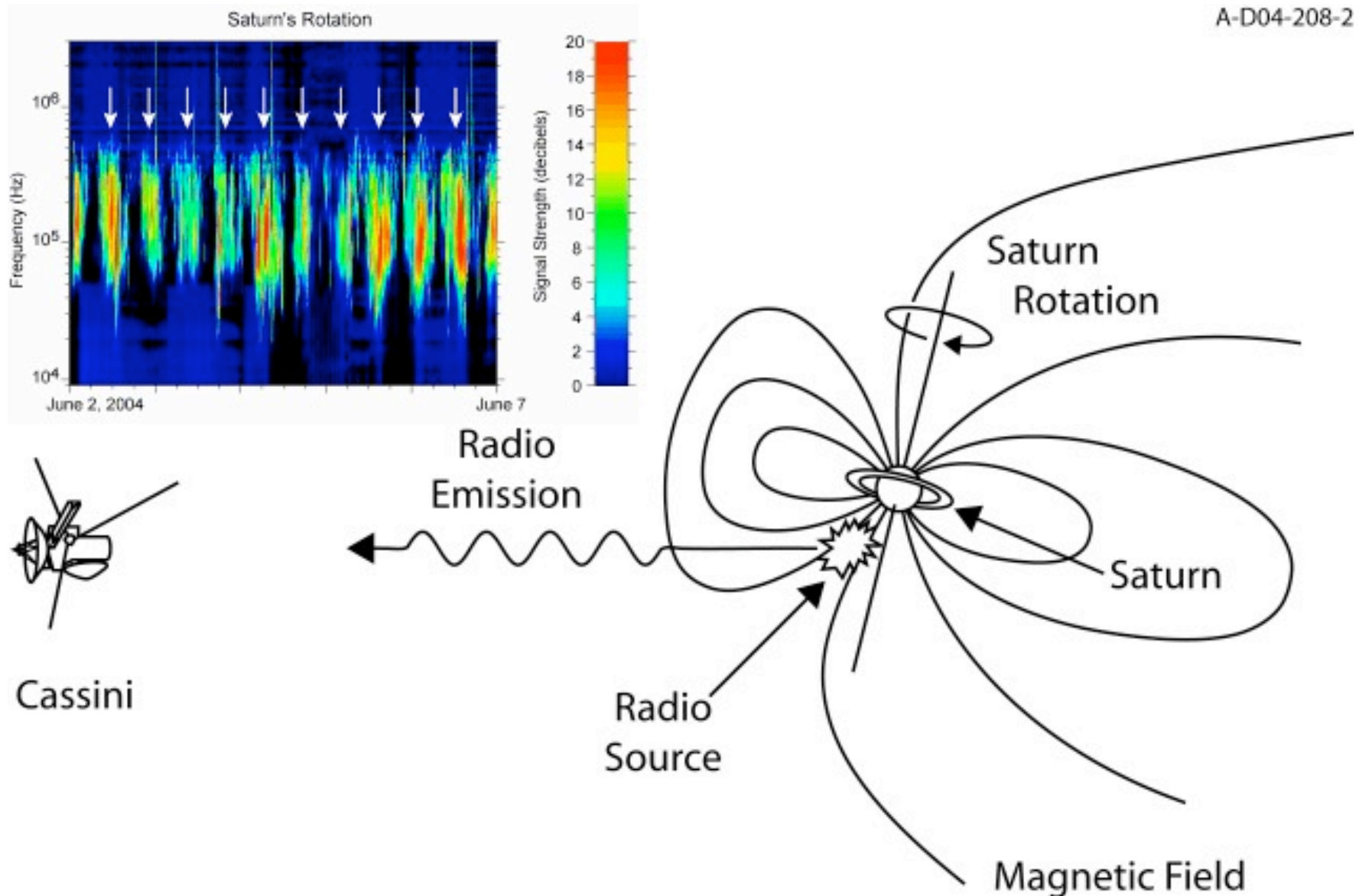
Philippe Zarka

B. Cecconi & P. Zarka, Model of a variable radio period for Saturn,
J. Geophys. Res., sous presse, 2005

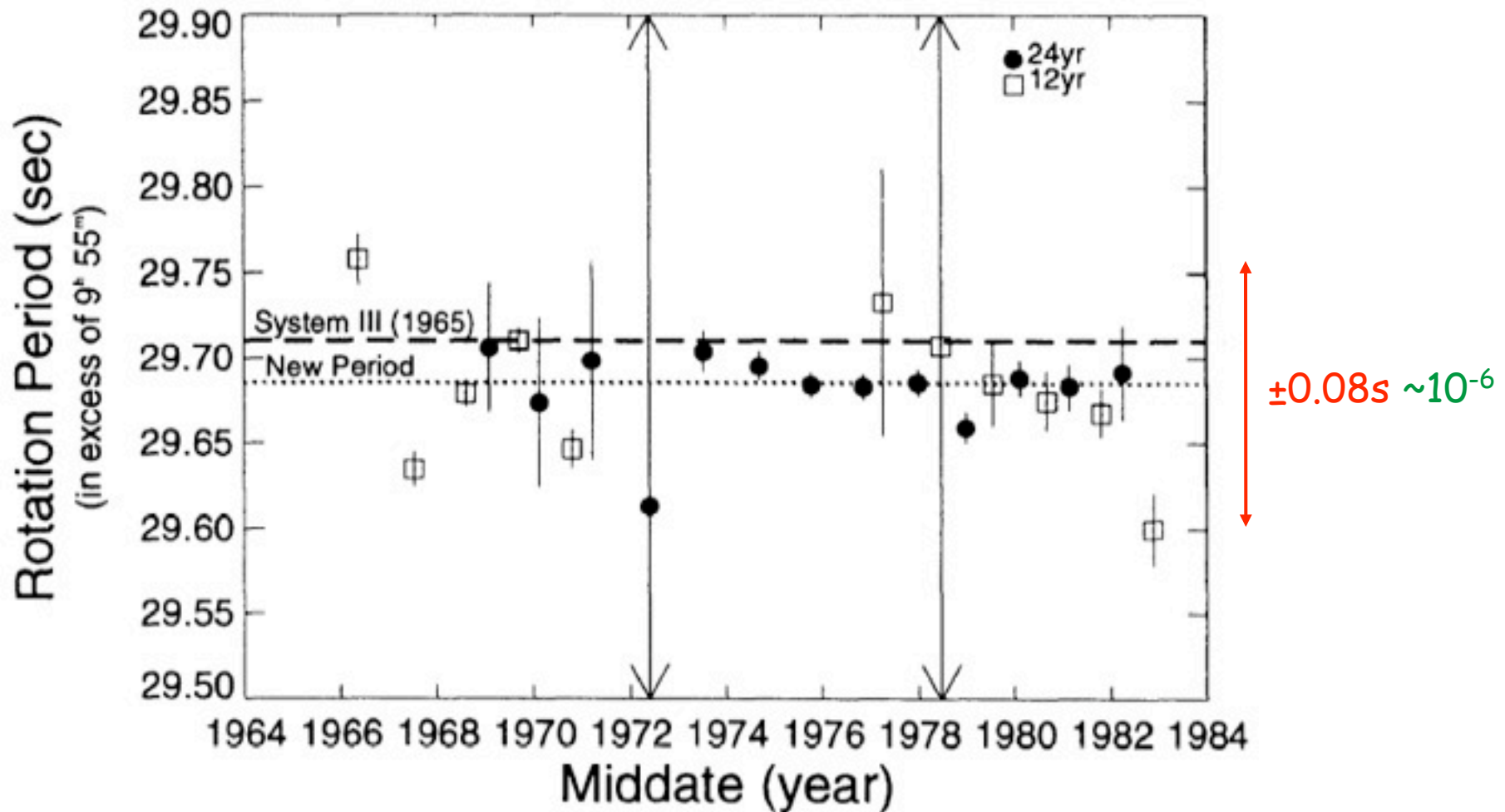
- Planetary rotation period cannot be accurately derived from « optical » measurements



- Usually derived from magnetospheric (auroral) radio emission periodicity

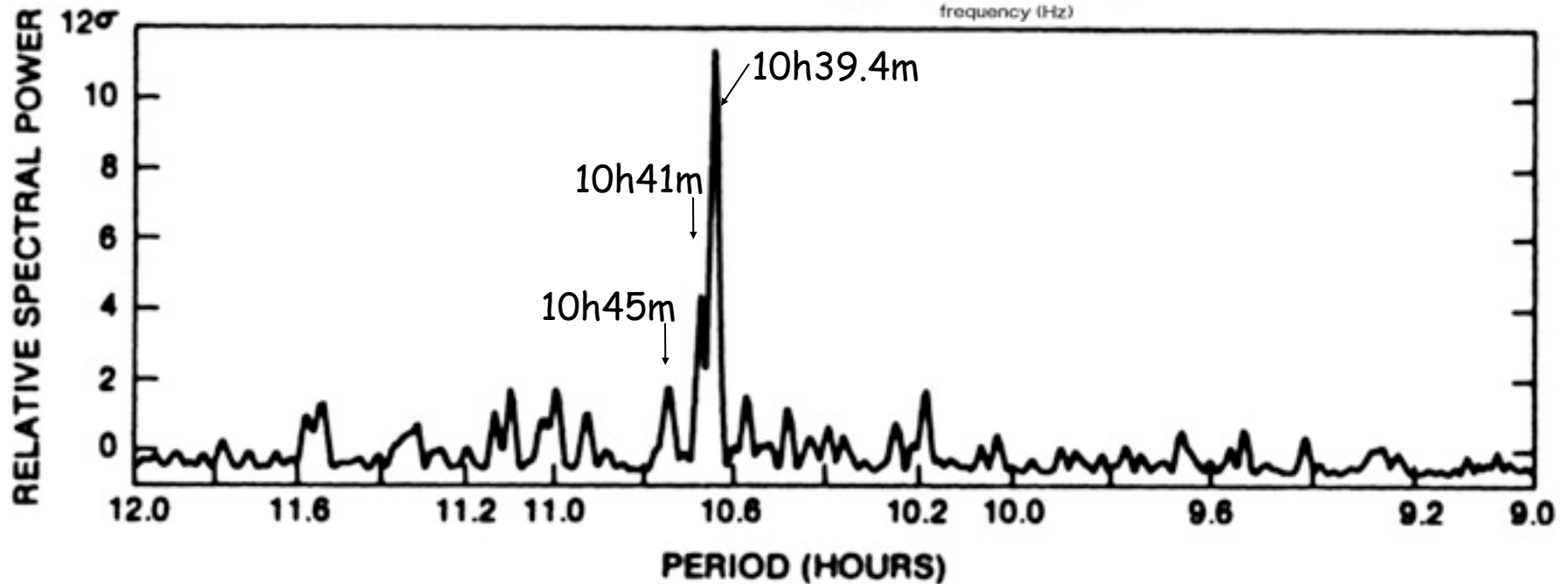
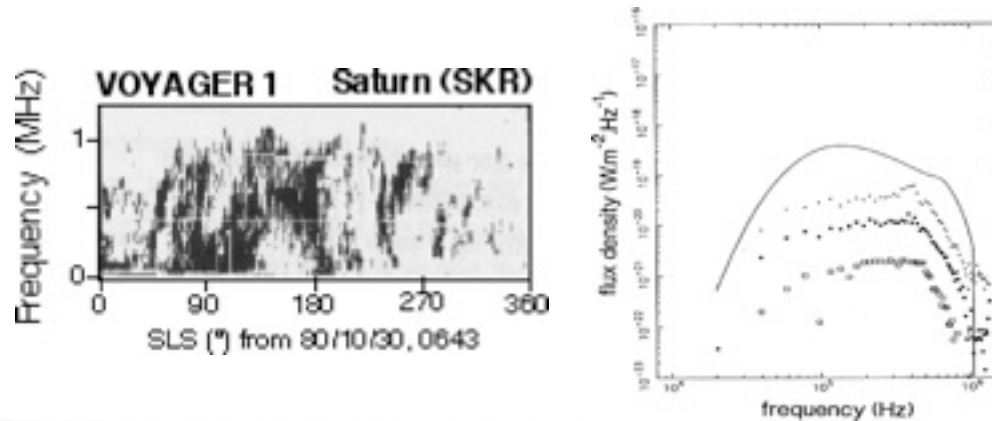


- At Jupiter, analysis of 24 years of « Io-DAM » ground-based observations
 $\Rightarrow P_{\text{Jup}} = 9\text{h } 55\text{m } 29.685\text{s} \pm 0.04\text{s}$



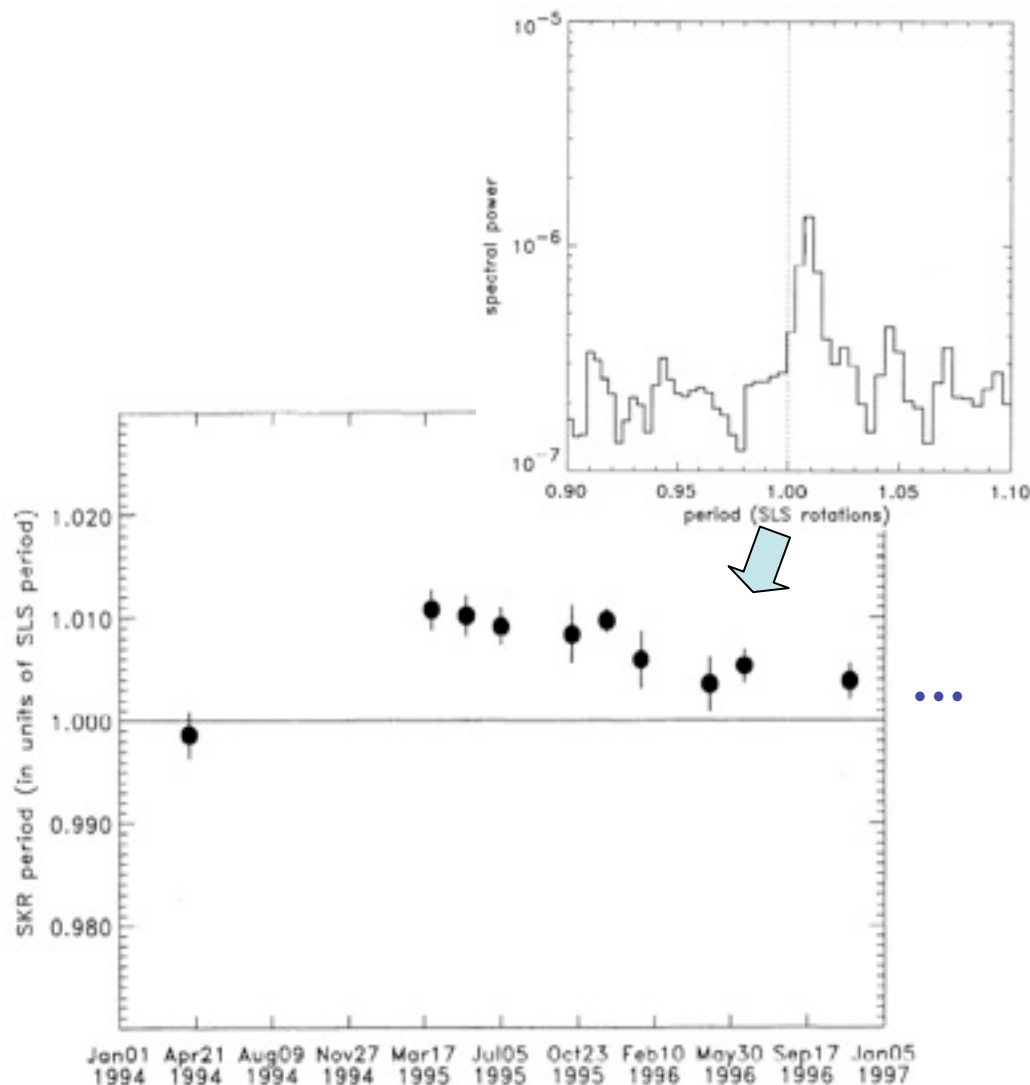
[Higgins, 1997]

- At Saturn, analysis of 267 days of SKR observations by Voyager 1
 $\Rightarrow P_{\text{Sat}} = 10\text{h } 39\text{m } 24\text{s} \pm 7\text{s}$ ($\sim 2 \times 10^{-4}$ accuracy)

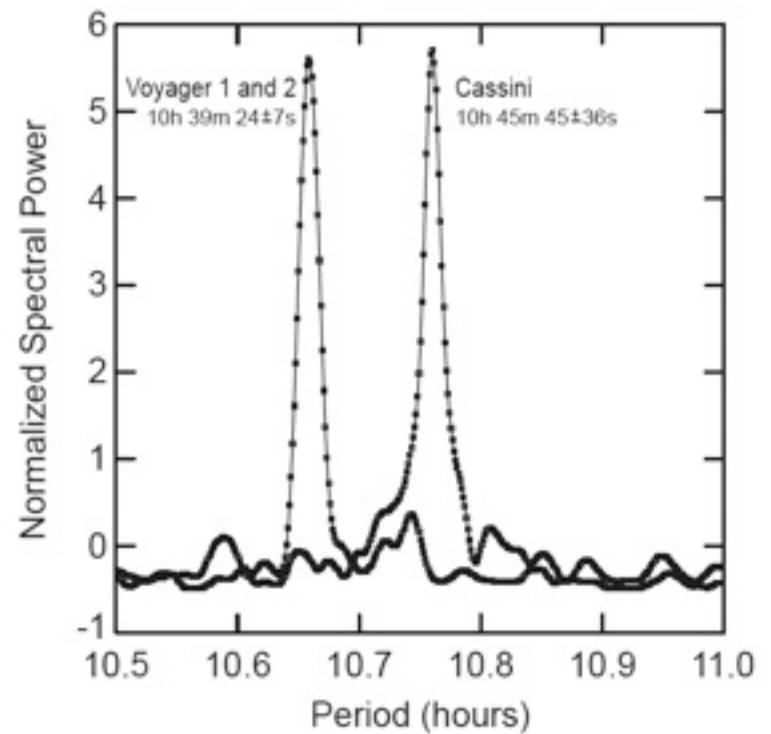


[Desch & Kaiser, 1981]

- Analysis of SKR observations by Ulysses & Cassini :
 ⇒ variable radio period P_{SKR} (+ 0.5-1% level)



[Galopeau & Lecacheux, 2000]



[Gurnett et al., 2005]

- Change of Saturn's true sidereal period excluded

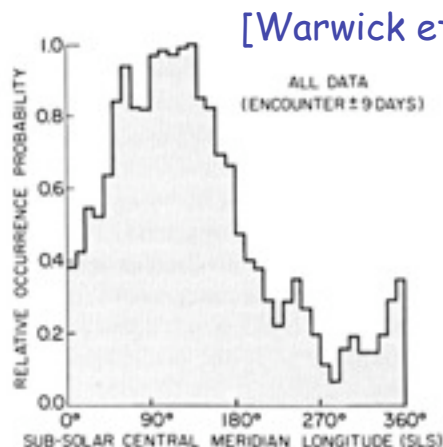
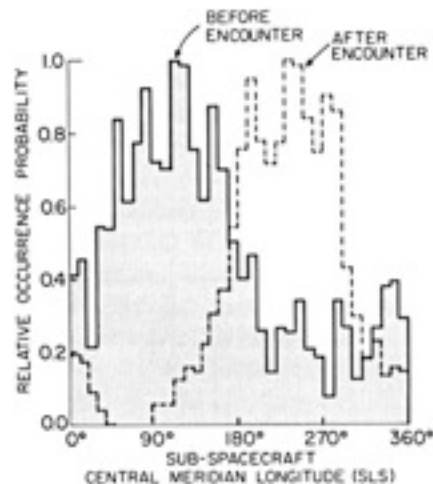
⇒ Origin of SKR period variability ?

⇒ What changed between Voyager and Cassini ?

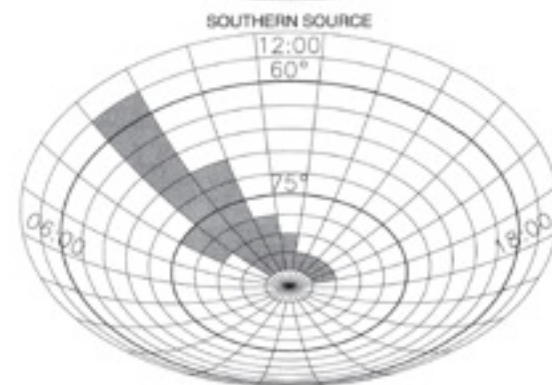
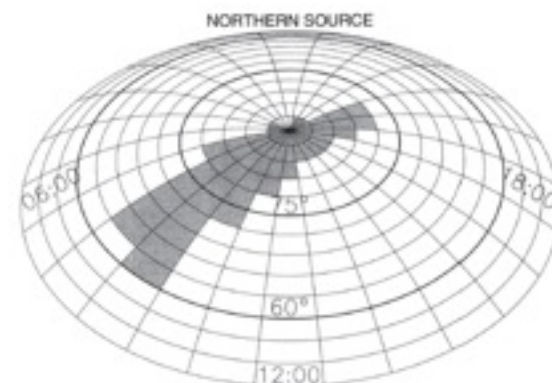
⇒ Expected accuracy on P_{Sat} from P_{SKR} ?

⇒ Implications ?

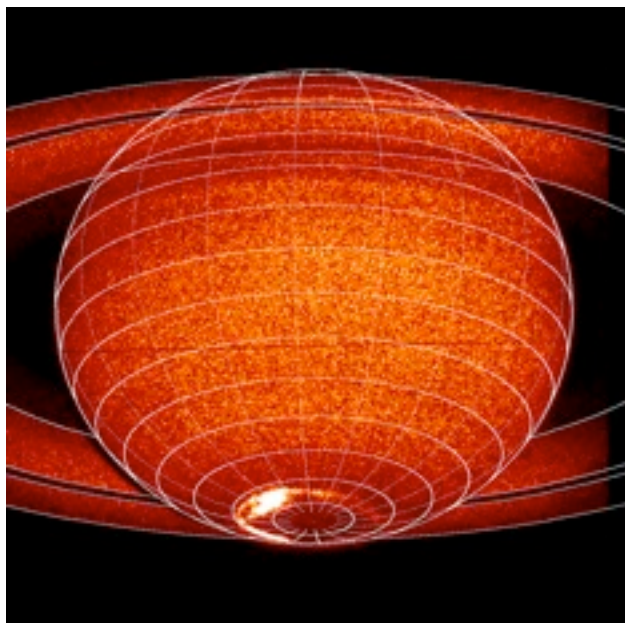
- SKR sources (N&S) **do not corotate** with the planet
 ⇒ restricted to/enhanced in a morning-noon LT sector, as UV aurora



[Warwick et al., 1981]

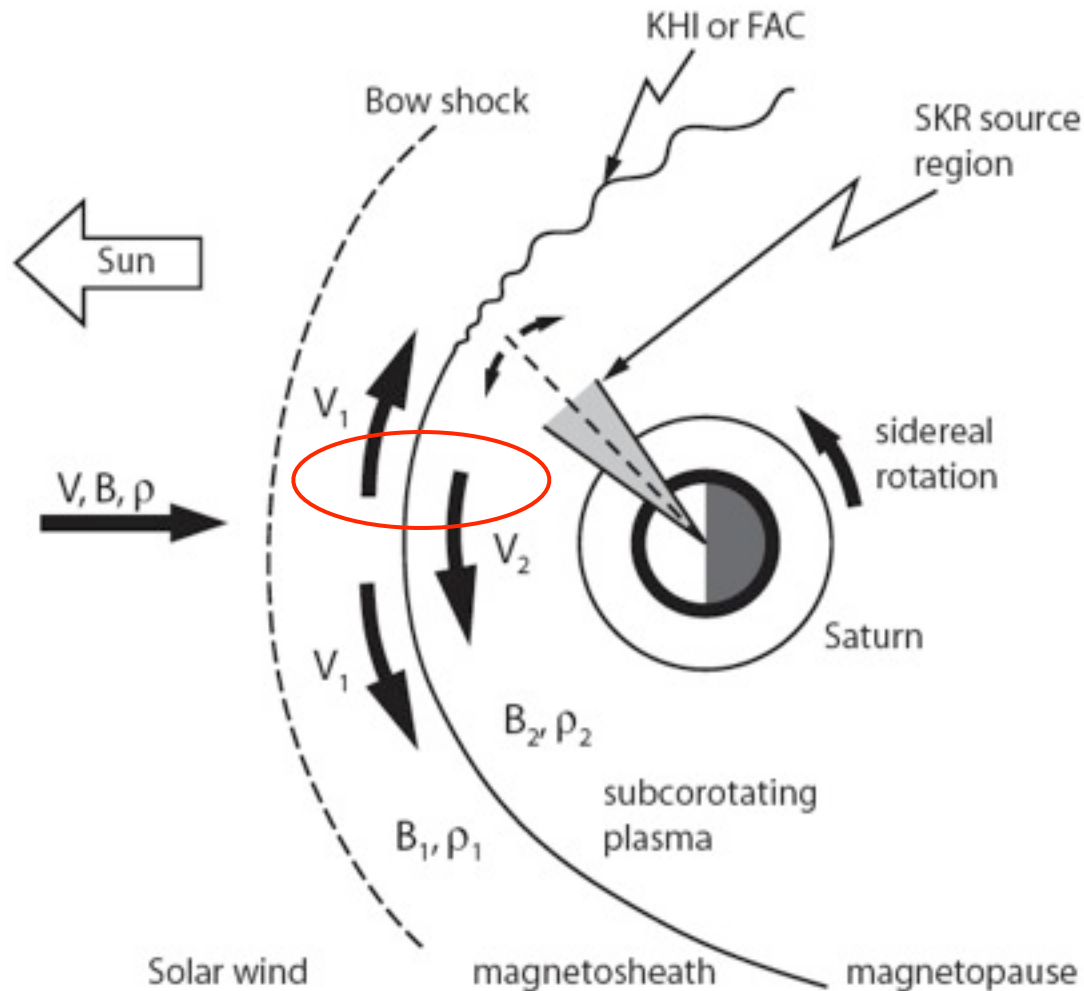


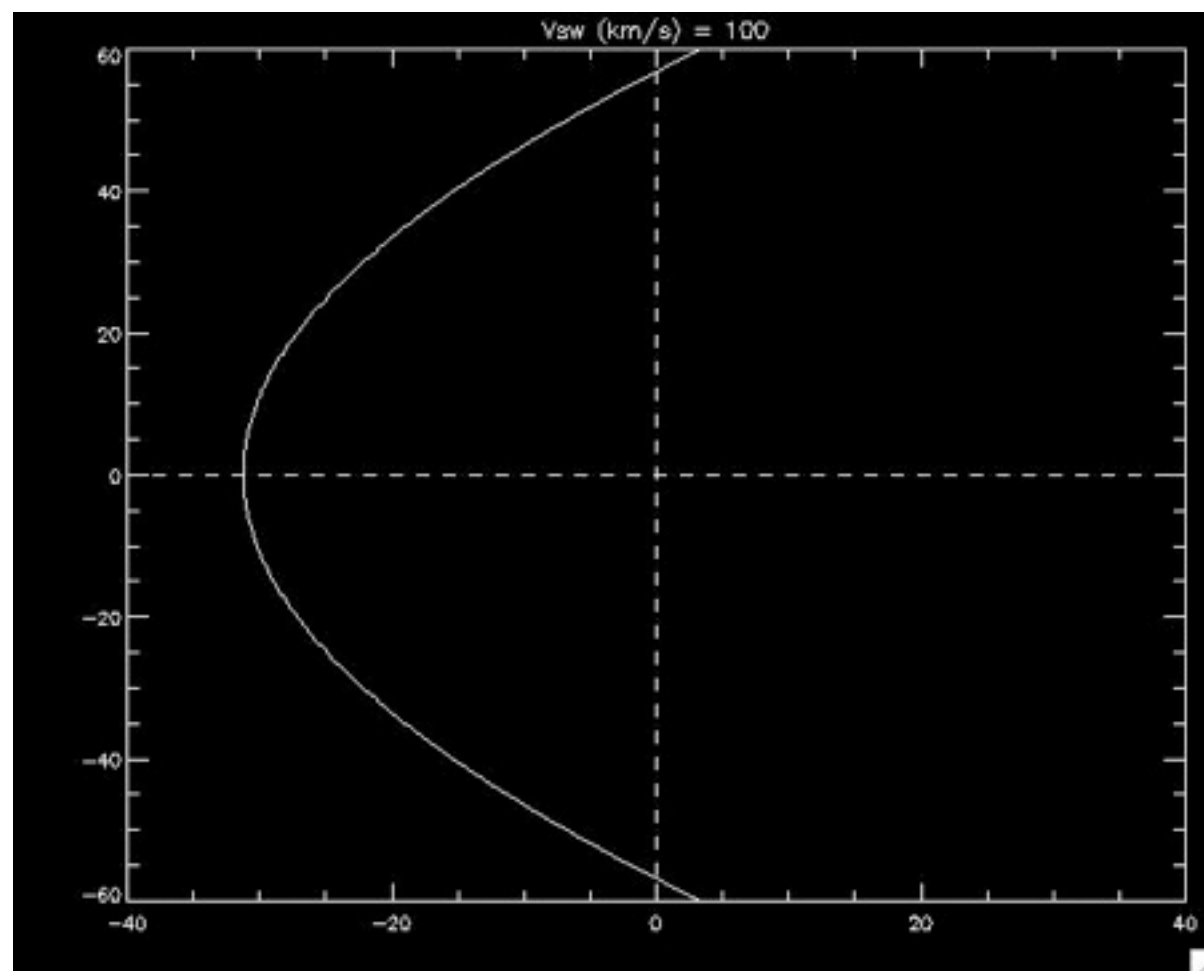
[Galopeau et al., 1995]



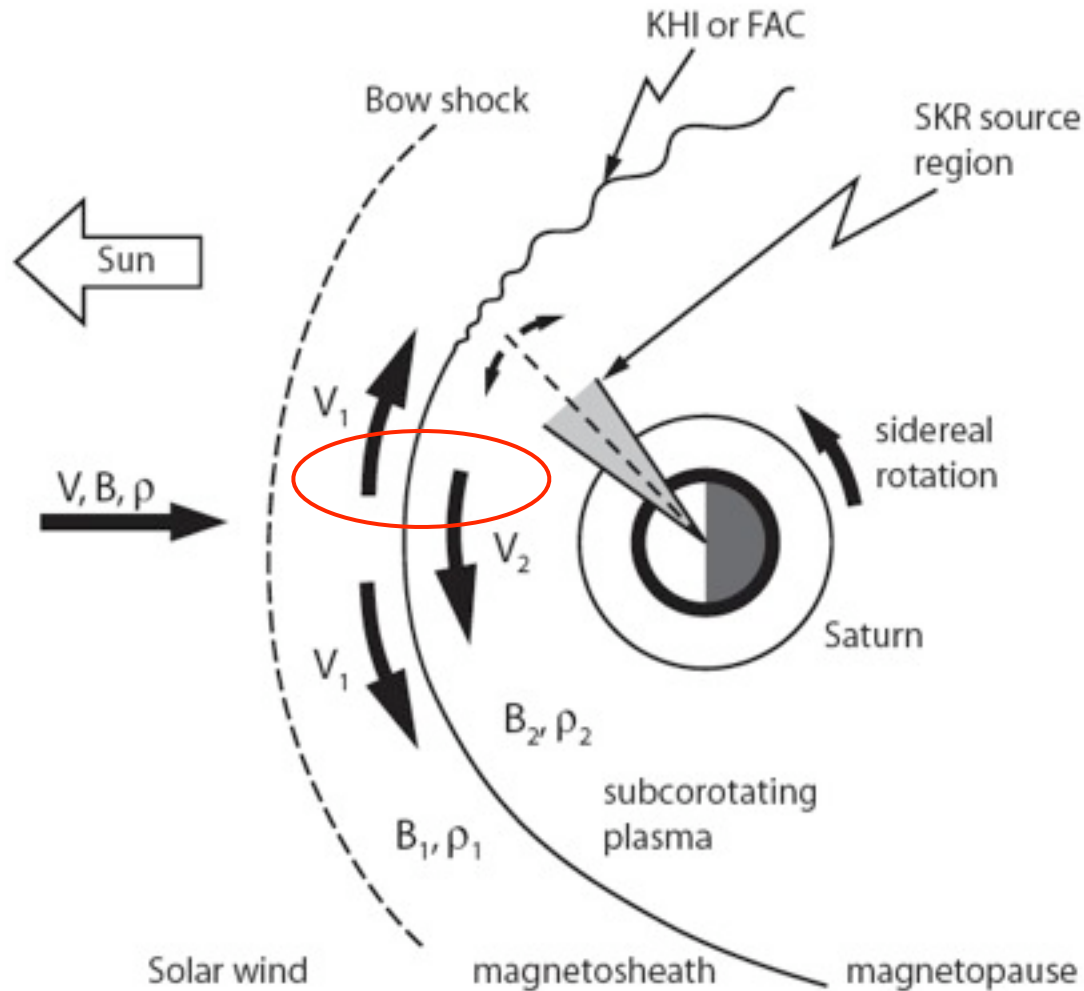
[Prangé et al., 2004]

- Conjugate high-latitude morning-noon sources $\Rightarrow$ electrons accelerated via Kelvin-Helmholtz instability at dayside magnetopause ? [Galopeau et al., 1995]
 (alternative : FAC at open/closed field lines boundary [Cowley et al., 2004])



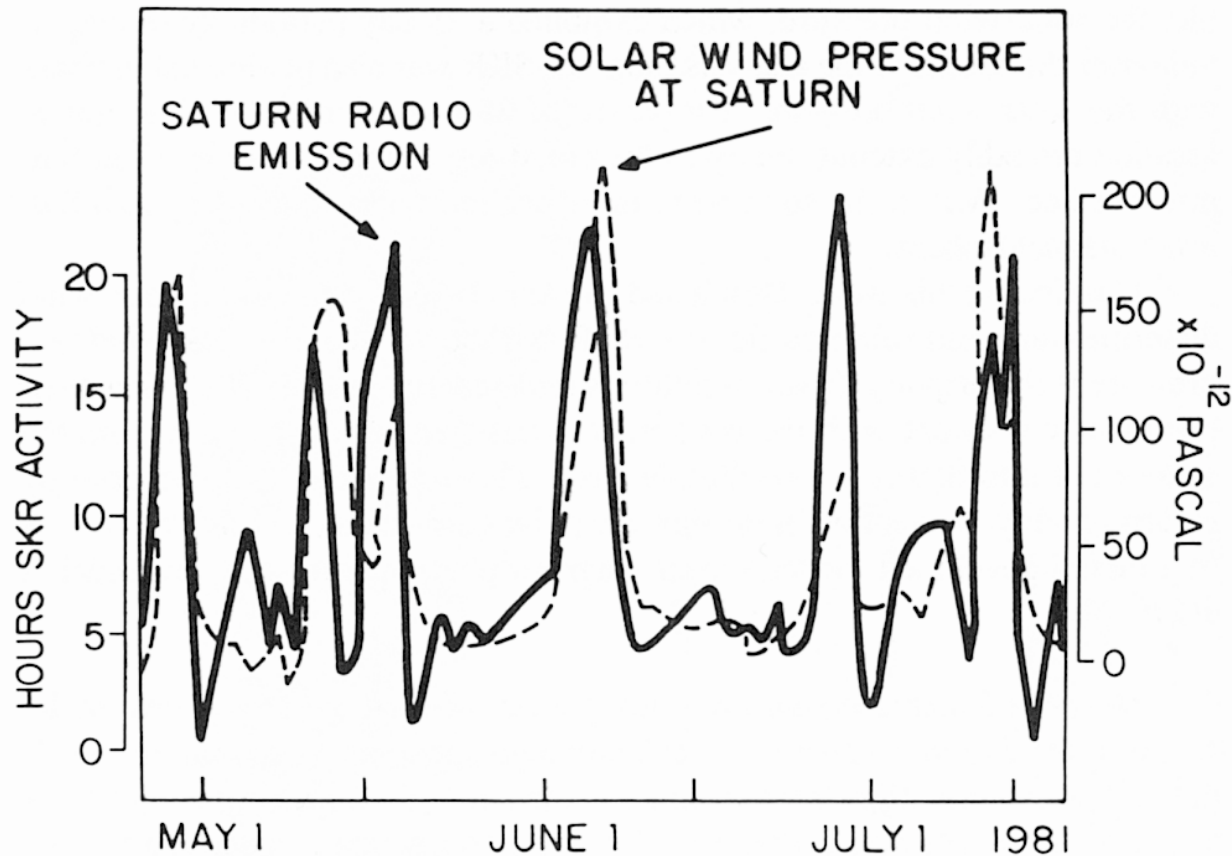


- Conjugate high-latitude morning-noon sources $\Rightarrow$ electrons accelerated via Kelvin-Helmholtz instability at dayside magnetopause ? [Galopeau et al., 1995]
(alternative : FAC at open/closed field lines boundary [Cowley et al., 2004])



$\Rightarrow$ role of V_{sw} on LT location of SKR sources ?

- Rotation-averaged **SKR intensity** correlated to Solar Wind variations (ρV^2 & ρV^3) $\Rightarrow$ **role of V_{sw}**



[Desch, 1982 ; Desch & Rucker, 1983]

- Solar Wind variations near Saturn

Voyager 1 - CA

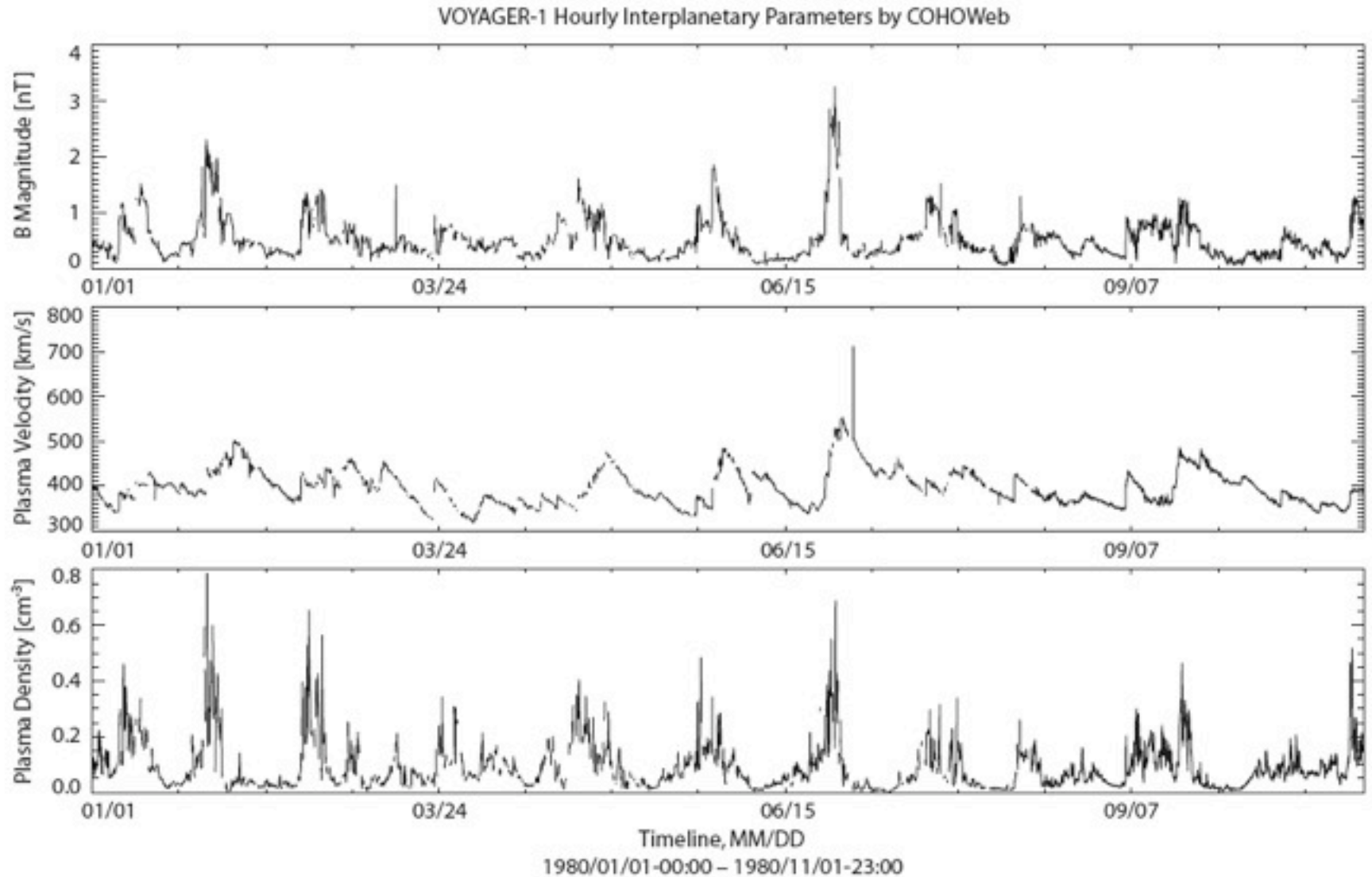
⇒ regular/organized variations of V_{sw}

B_{sw}

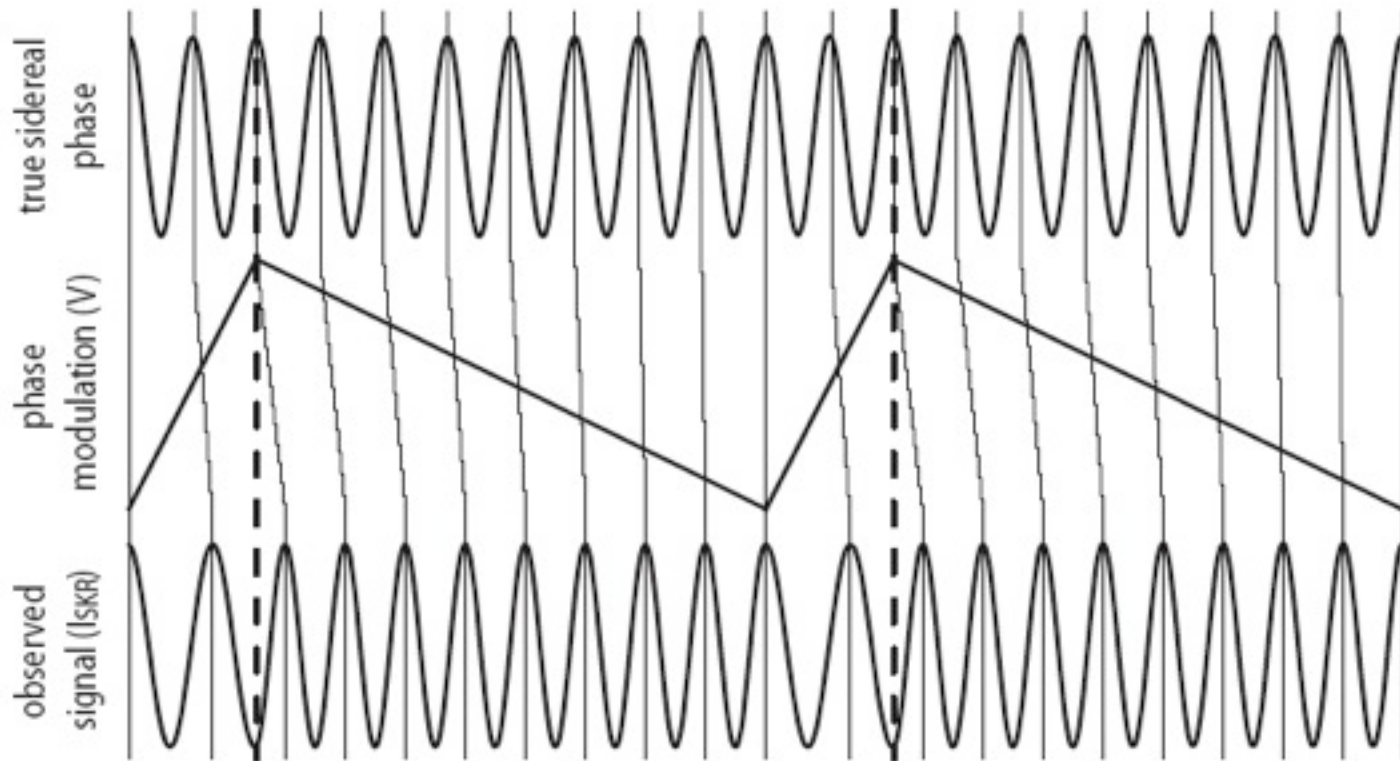
V_{sw}

ρ_{sw}

N_{sw}



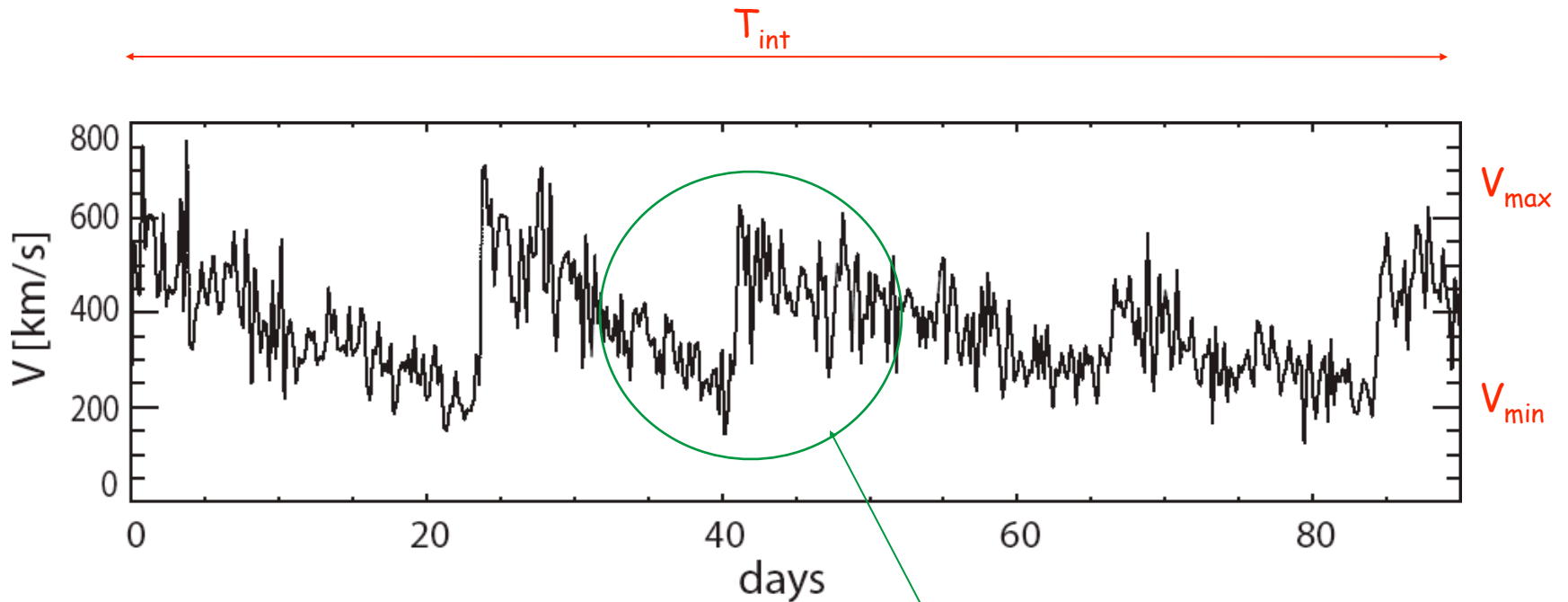
- Role of Solar Wind Velocity variations on SKR source location : Model



$$I_{SKR}(t) = I_0 \sin [2\pi (t/P_{Sat} - \alpha V(t)/360)]$$

- ⇒ Simulated series $I_{SKR}(t)$ using trigger at $P_{Sat} \otimes$ KHI sources
- ⇒ predicted P_{SKR}

- Solar Wind Velocity modelling : asymmetric sawtooth



R : randomization of V_{min} , V_{max} , T_{up} , T_{down}
 + short term fluctuations as $(1+rR)$ with
 r normal random variable [here $R=0.2$]

- Parametric study : $100 \times \text{TF}[I_{\text{SKR}}(t)]$ per parameter set $\Rightarrow P_{\text{SKR}}$

$T_{\text{int}} = 45 - 270$ days

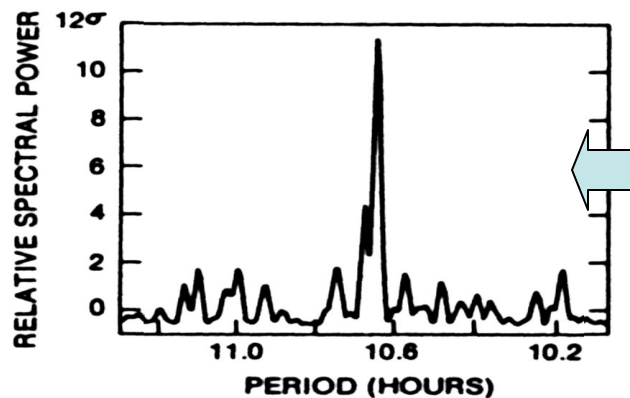
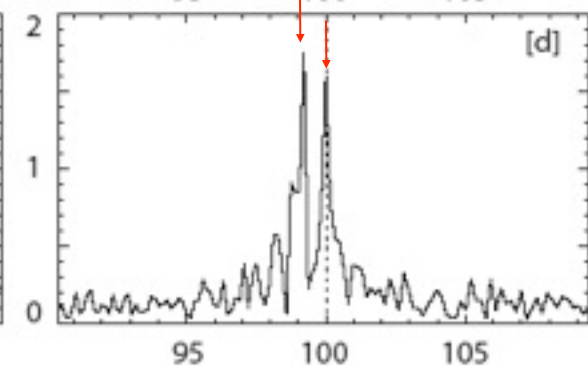
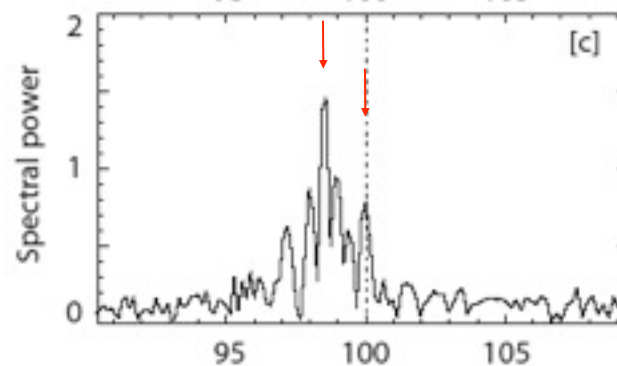
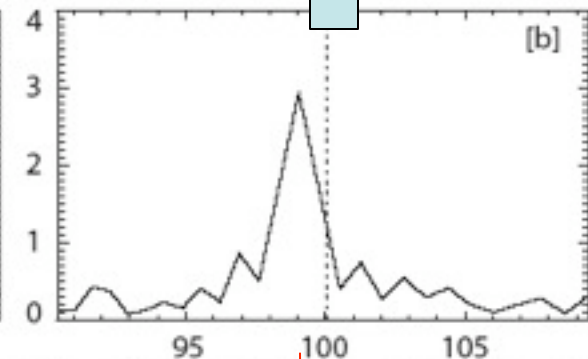
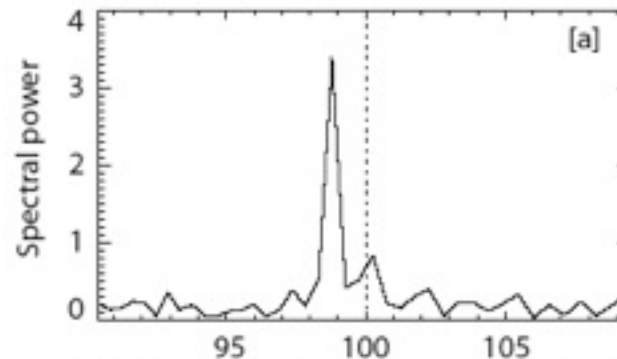
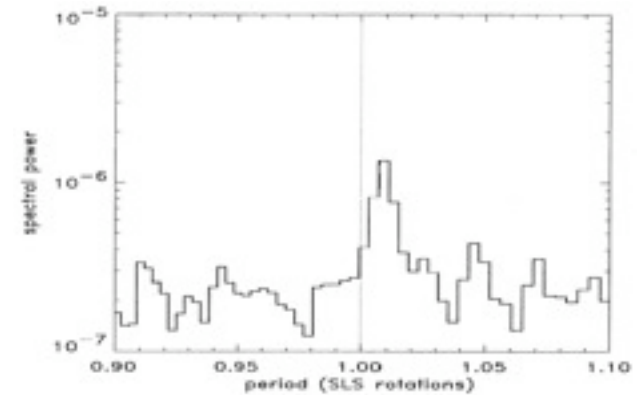
$T = 13 - 26$ days

$V_{\text{min}}, V_{\text{max}}$ fixed

$R = 0 - 0.2$

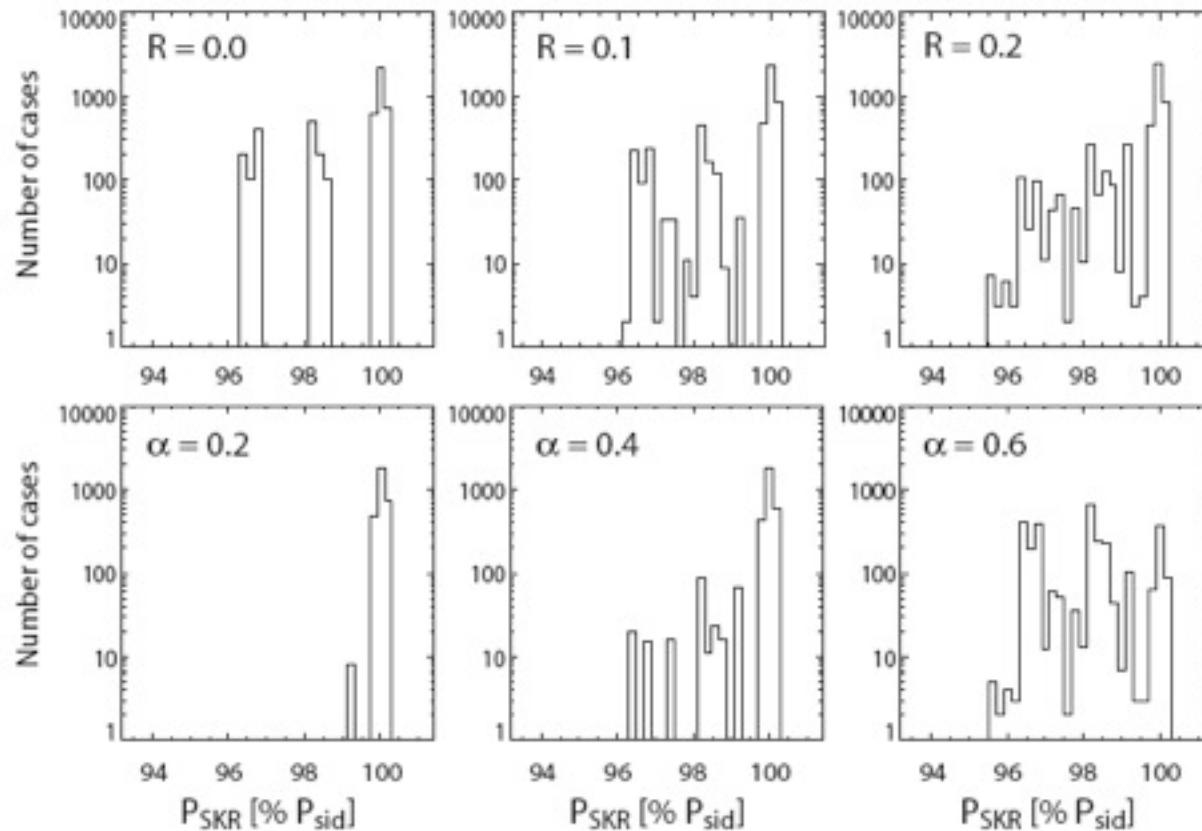
$\alpha = 0.1 - 0.6$ $^{\circ}/(\text{km/s})$

	T_{int}	T	α	R	$P_{\text{SKR}}/P_{\text{Sat}}$
[a]	90	26	0.5	0.2	0.987
[b]	60	26	0.4	0.2	0.993
[c]	270	26	0.6	0.2	0.985
[d]	270	26	0.6	0.2	0.991



$P_{\text{SKR}} [\% \text{ of } P_{\text{sid}}]$

$P_{\text{SKR}} [\% \text{ of } P_{\text{sid}}]$

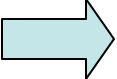


- $P_{SKR} \in [0.96-1.] \times P_{sat}$
for $R \geq 0.1$ $\alpha \geq 0.2$ °/(km/s) $T_{int} = 45 - 270$ days
- $P_{SKR} \leq P_{Sat}$ because $\alpha > 0$

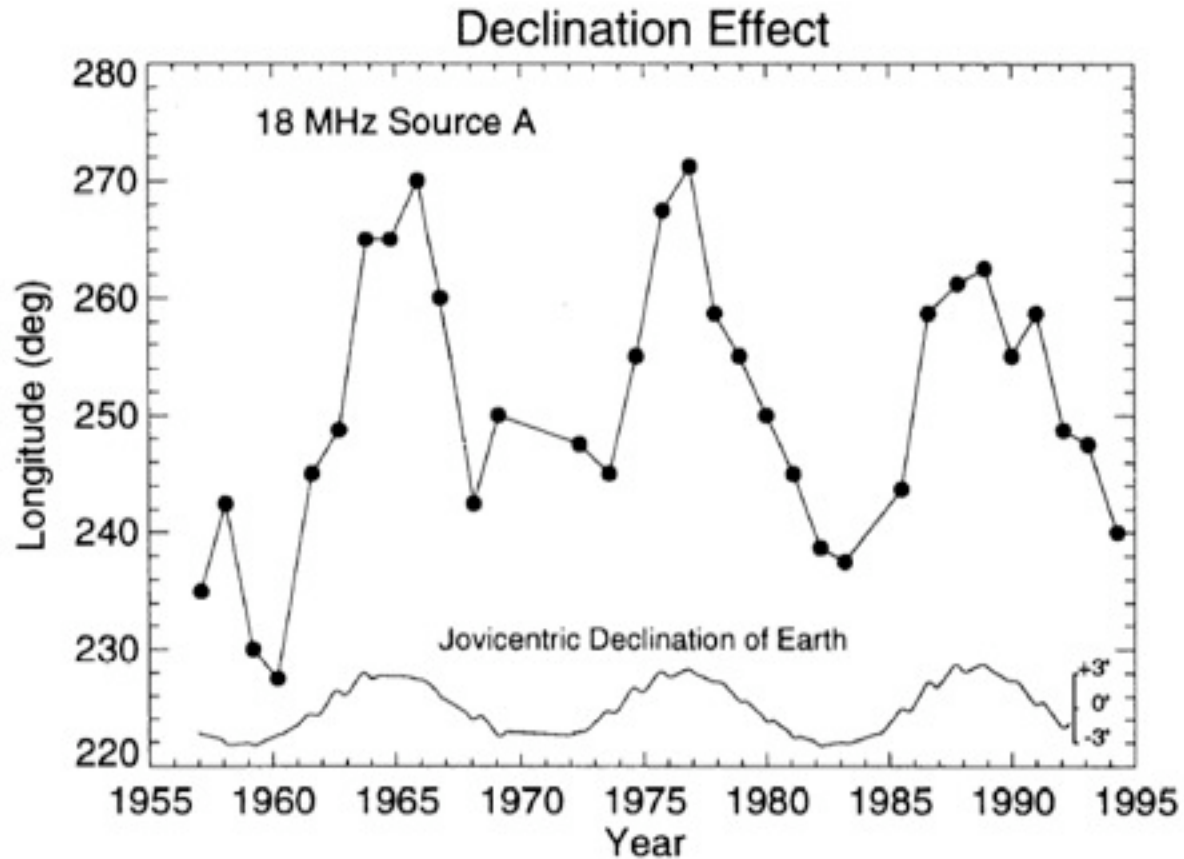
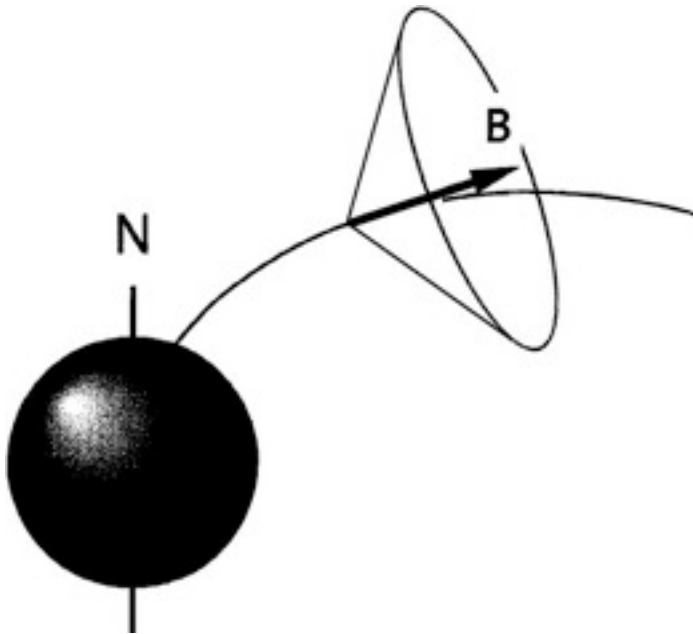
⇒ Model results compatible with measurements

Conclusions

⇒ Origin of SKR period variability ?

- Variable $P_{SKR} \sim 1\%$ explained by asymmetrical phase modulation of source LT (non-random SW velocity variations)
- Apparent source motion over $\geq 70^\circ$ in LT 

- Apparent source motion over $\geq 70^\circ$ in LT ?
⇒ beaming may turn small latitudinal variation of source position
in large LT/longitudinal variation



[Higgins, 1997]

Conclusions

⇒ Origin of SKR period variability ?

- Variable $P_{\text{SKR}} \sim 1\%$ explained by asymmetrical phase modulation of source LT (non-random SW velocity variations)
- Apparent source motion over $\geq 70^\circ$ in LT
- V shear at magnetopause important for e^- precipitations ?
- Voyager + Ulysses + Cassini $\Rightarrow P_{\text{sat}} \sim 10\text{h}45\text{m}$
($\sim 1.01 \times P_{\text{sat}}[\text{Voyager}]$)

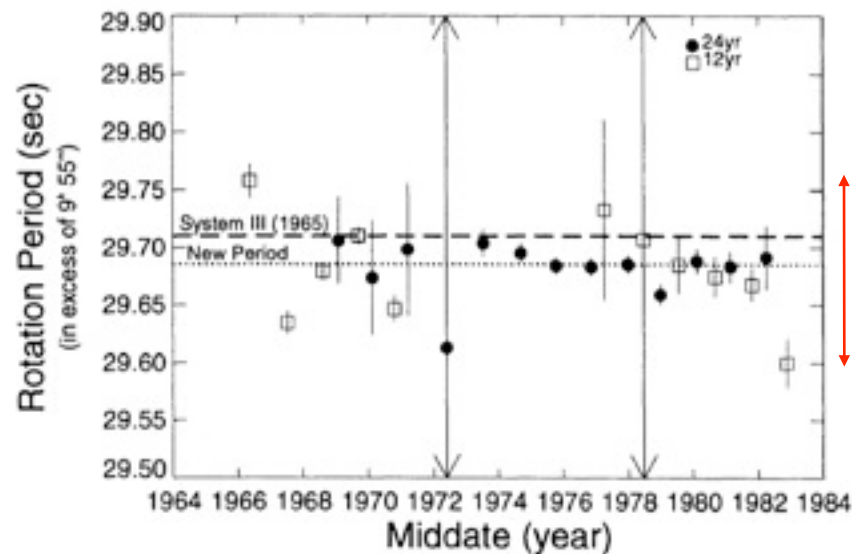
⇒ What changed between Voyager and Cassini ?

- Possibly nothing (long-term variations of SW fluctuations ?)

⇒ Expected accuracy on P_{Sat} from P_{SKR} ?

- 500 to 1000 days SKR obs. required for P_{Sat} at $<10^{-3}$
(analysis of overlapping 6-12 month-intervals)

- Back to Jupiter :

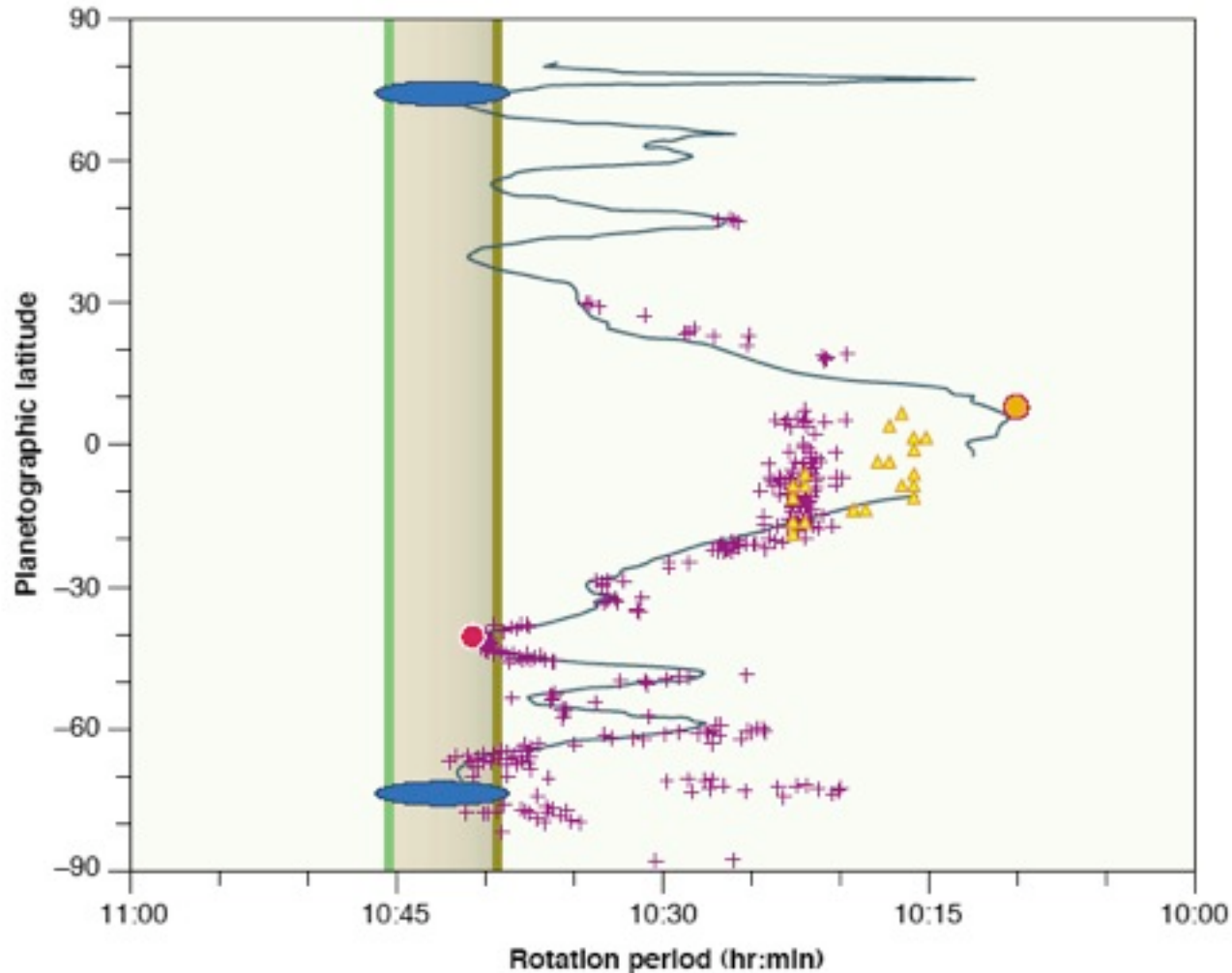


$\pm 0.08s \sim 10^{-6}$

- P_{Jup} from 24 years data set of « Io-DAM » (independent of SW)
- Torus density $\sim \times 2$ between Voyager (1979) and Galileo (1995-97)
 $\Rightarrow$ source longitude change $\theta_A = 2\pi t_A / P_{Jup} \sim 10^\circ - 20^\circ$
 $\Rightarrow$ error on $P_{Jup} = (\theta_A / 360^\circ) \times (P_{Jup} / 24 \text{ years}) \sim 10^{-6}$ as observed !

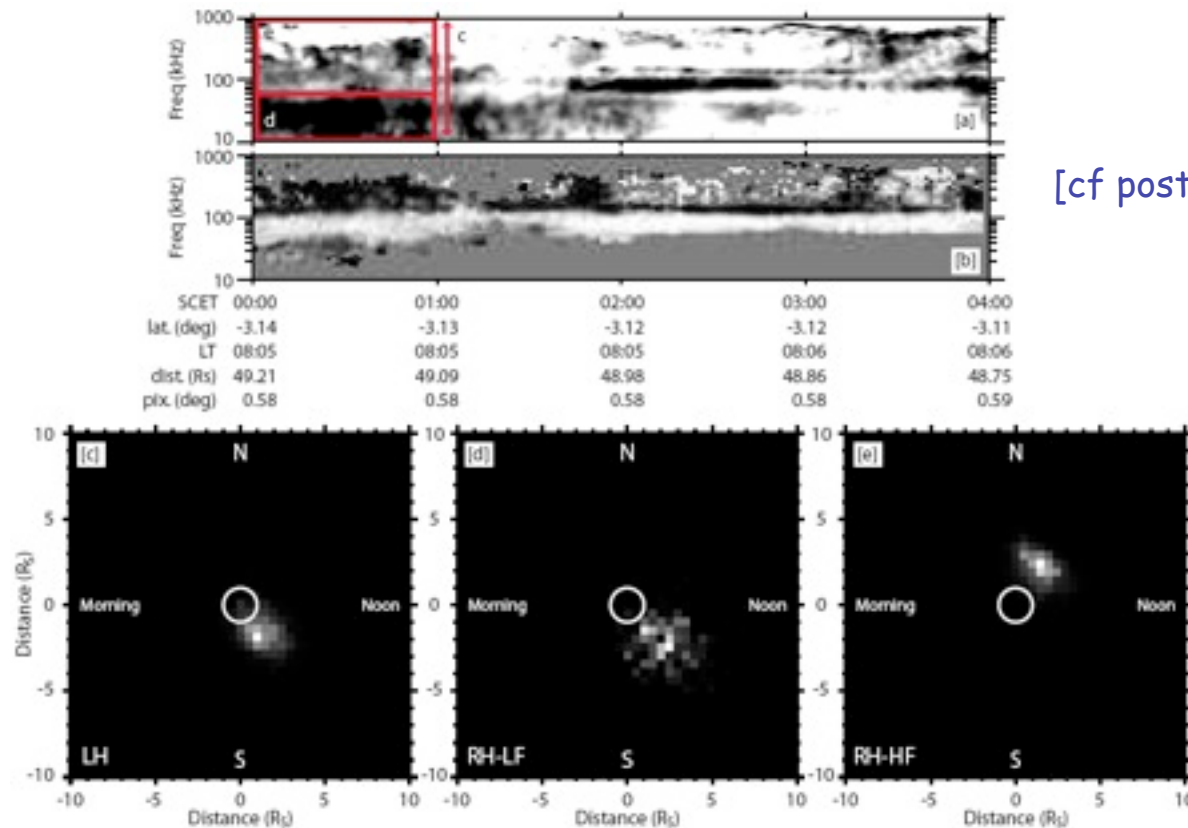
⇒ Implications ?

- Whole atmosphere in super-rotation (eastward) ?



Future Studies

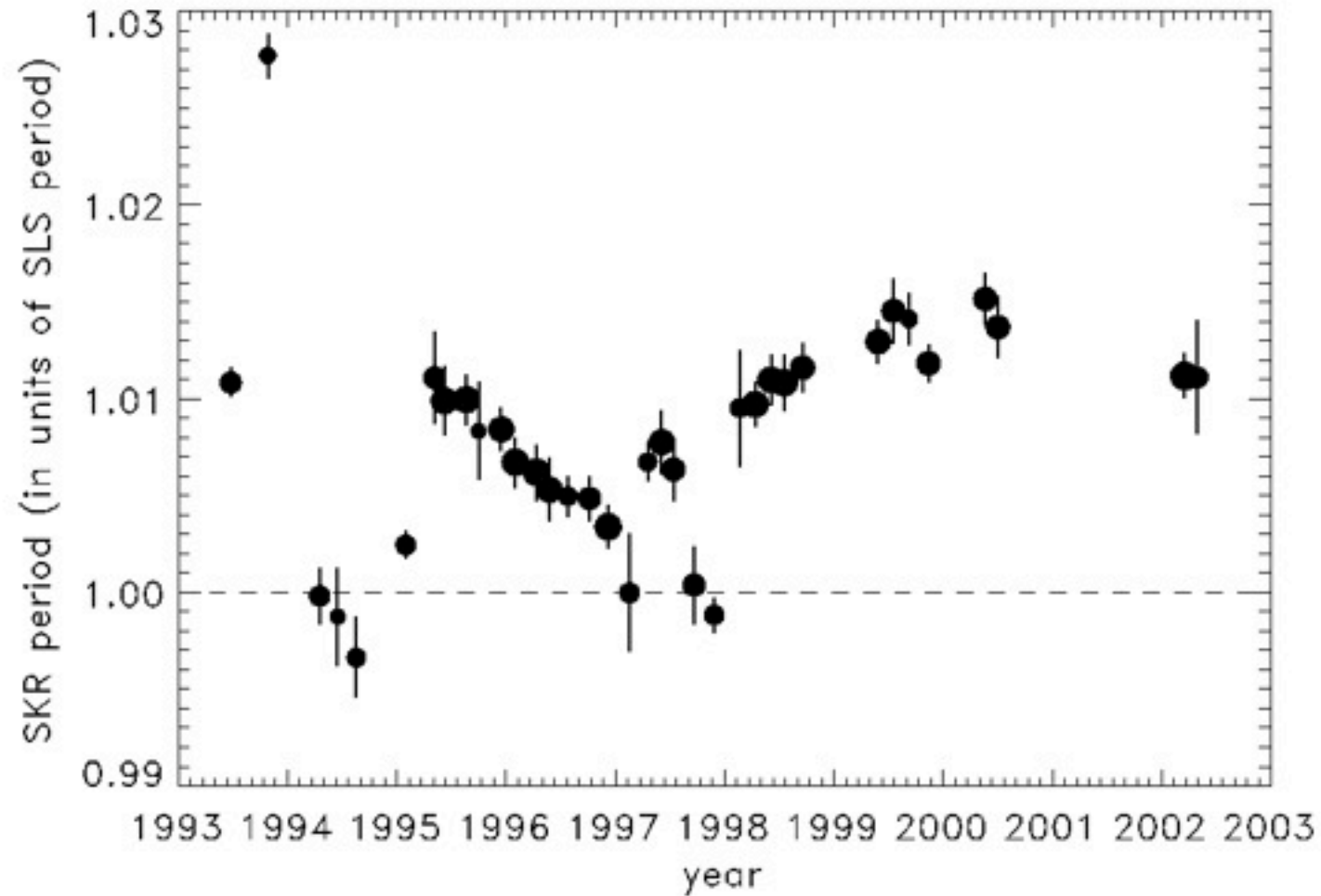
- Confirmation using Voyager SW & SKR data
- Confirmation using Cassini SW & SKR (direction-finding) data



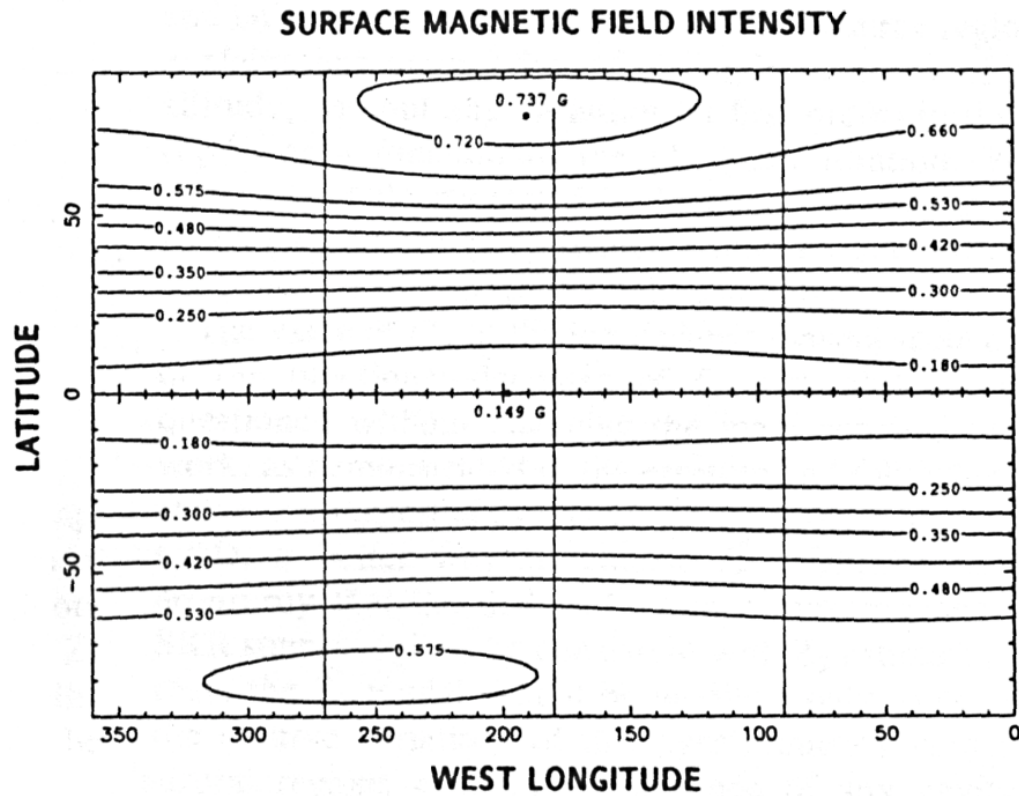
[cf poster Cecconi et al., 2005]

- Variable SKR period

[Galopeau & Lecacheux, 2000] + Ulysses update

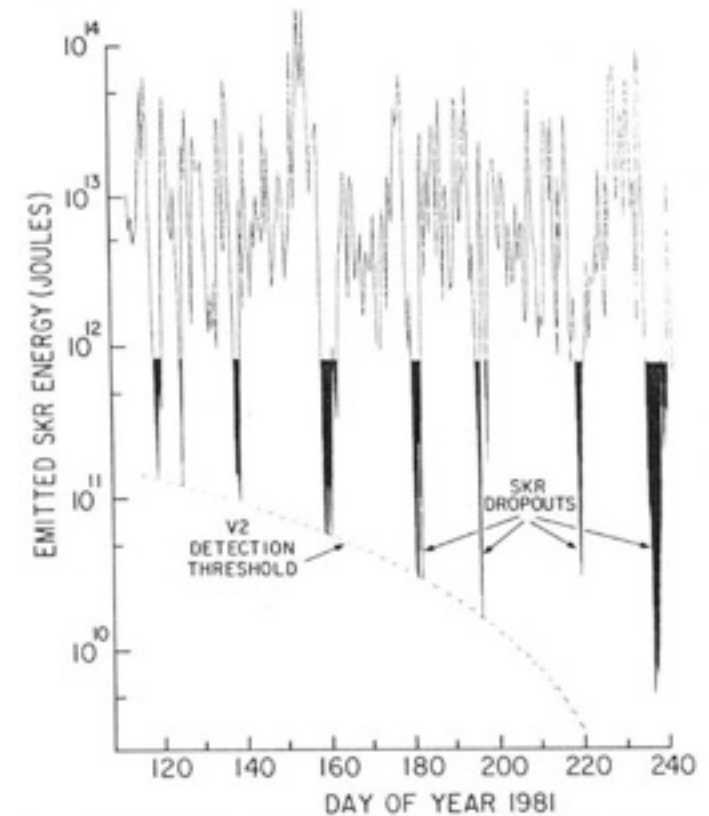
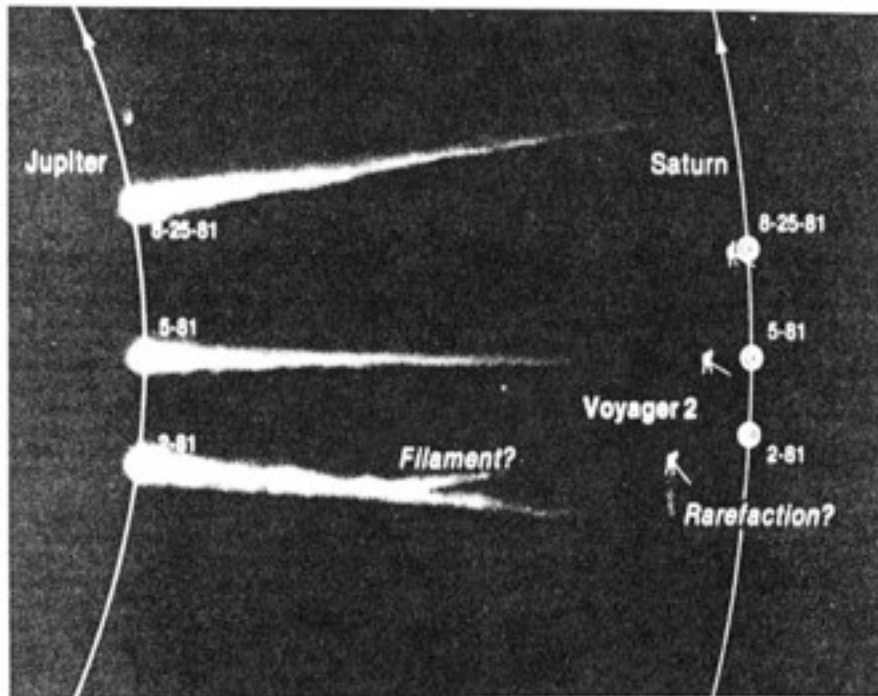


- Rotational modulation of SKR due to magnetic anomaly ?



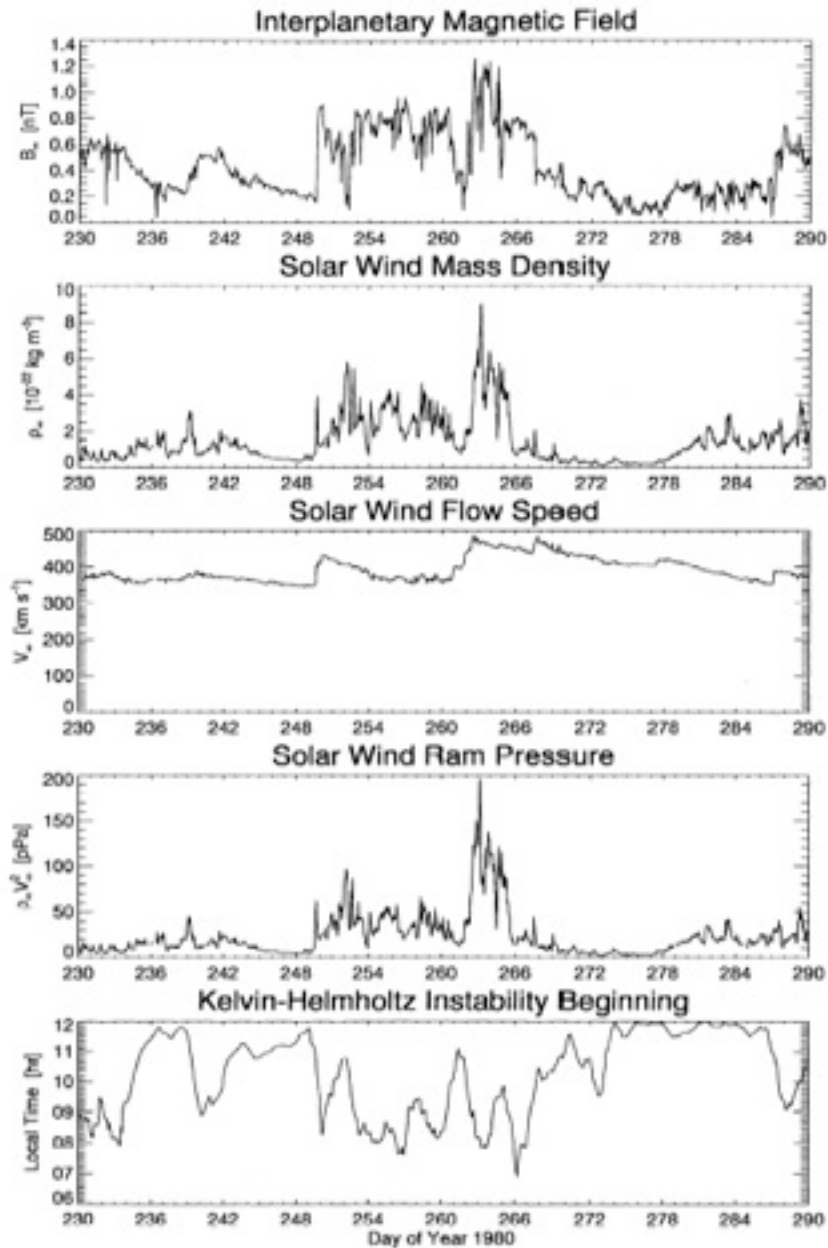
[Galopeau & Zarka, 1992]

- SKR extinctions when Saturn is immersed in Jupiter's magnetotail



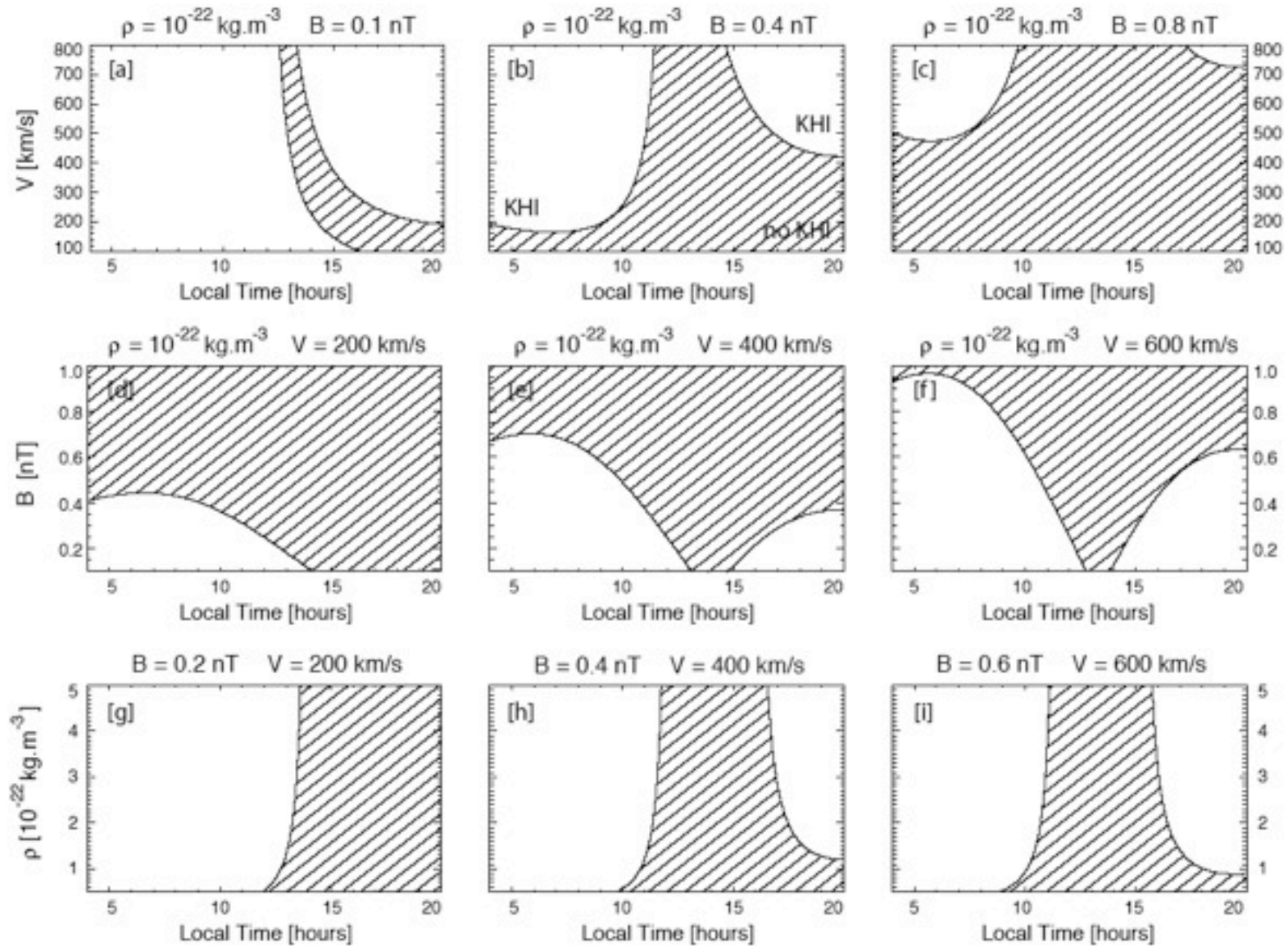
[Desch, 1983]

- Time variations of KHI threshold

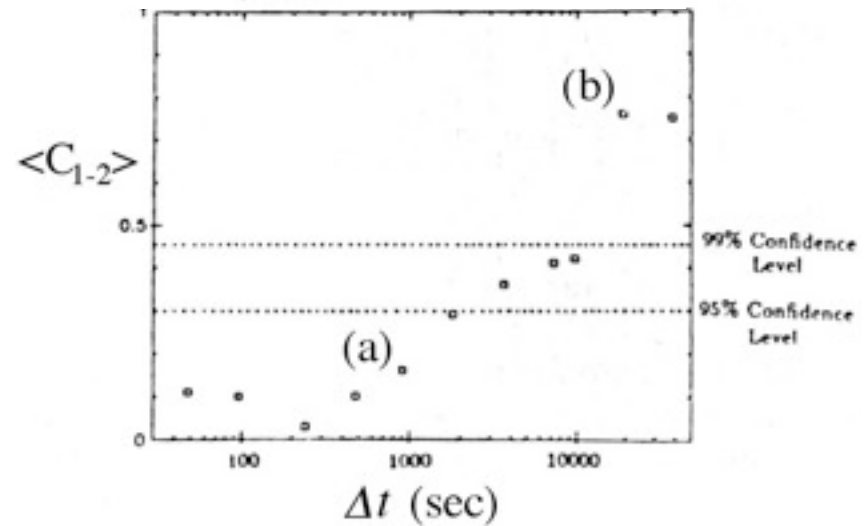
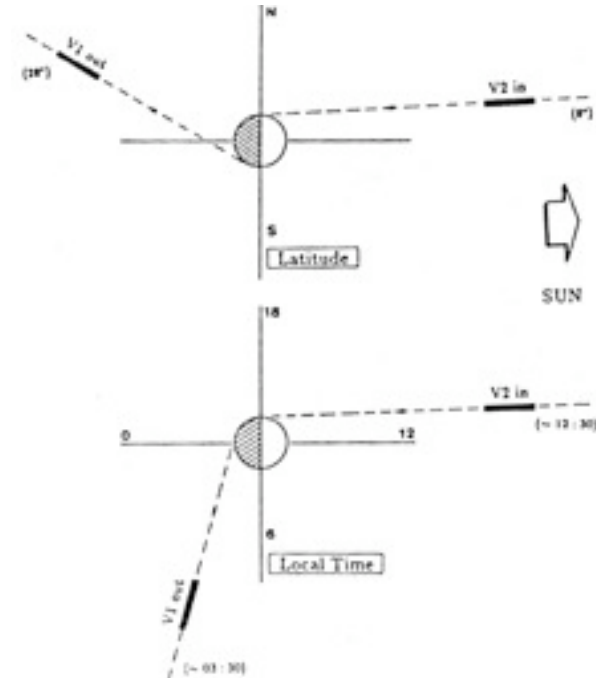
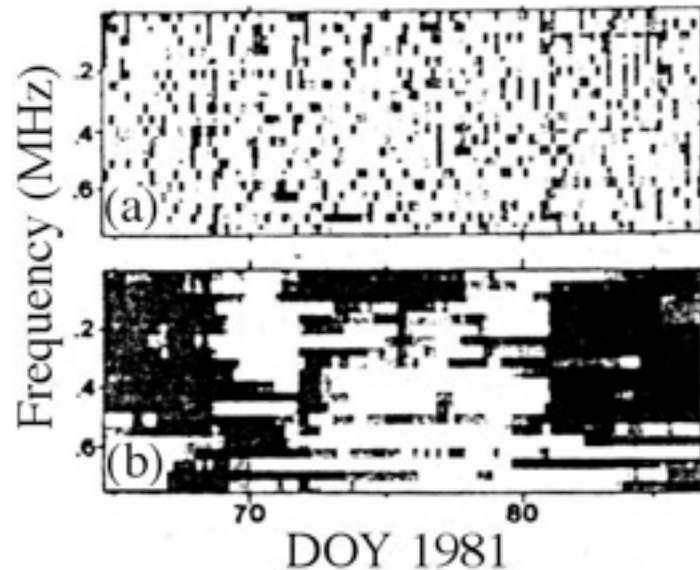
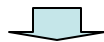
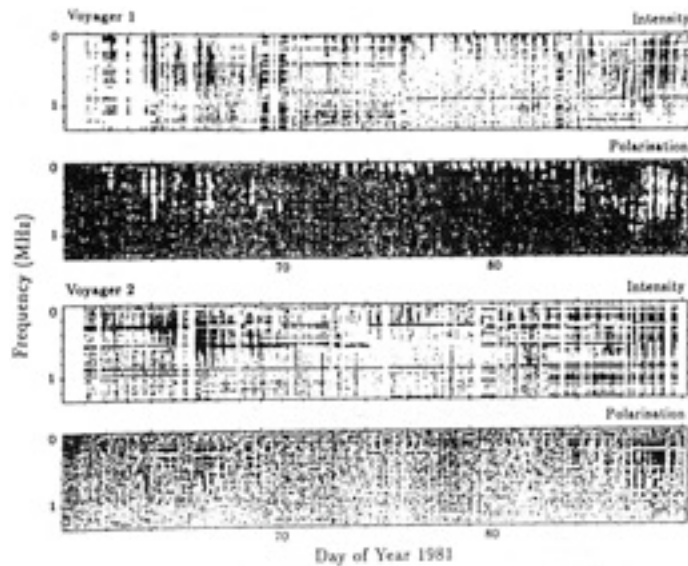


[Galopeau & Lecacheux, 2000]

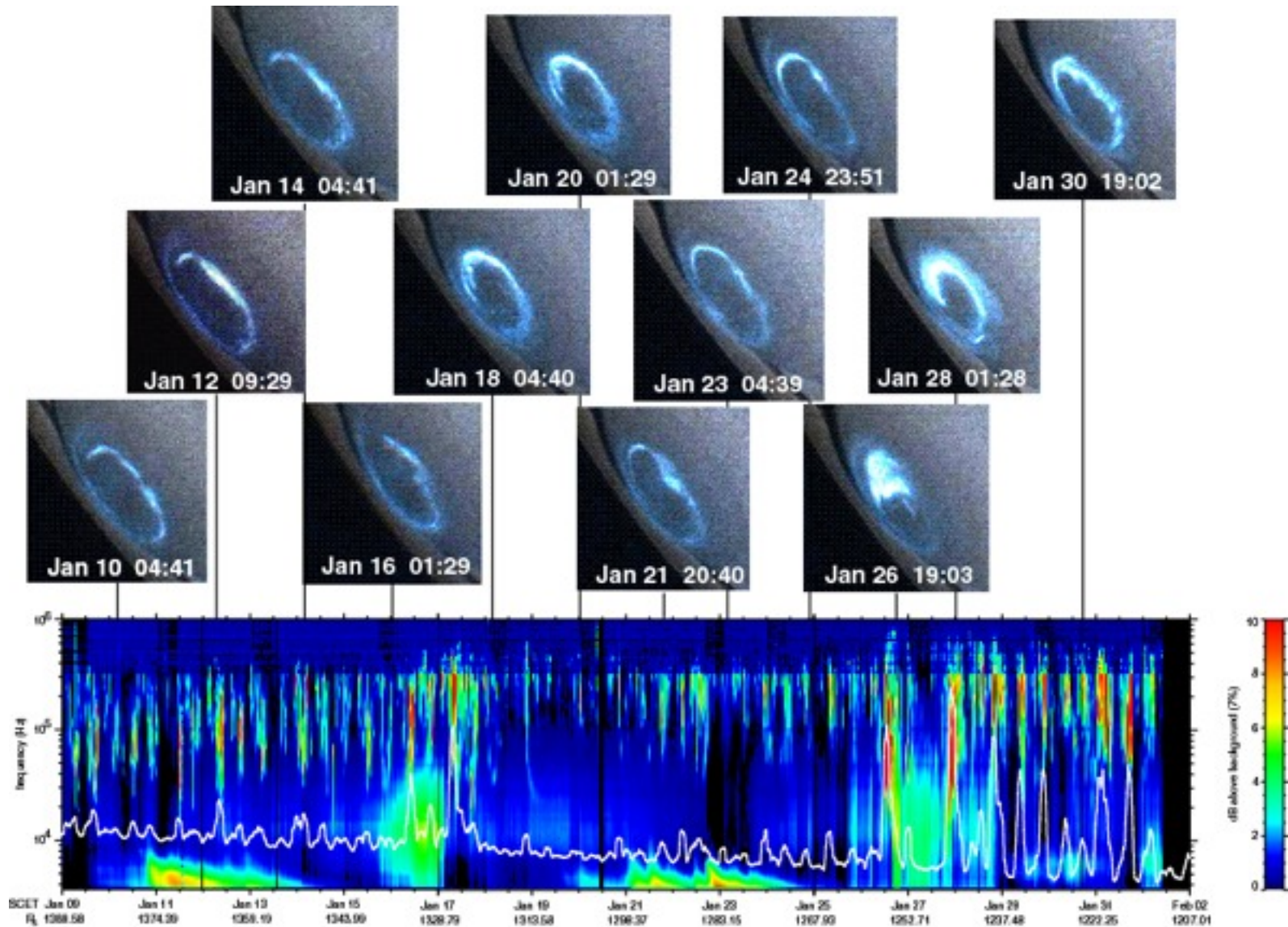
- KHI « sources » versus LT as a function of V , B , ρ



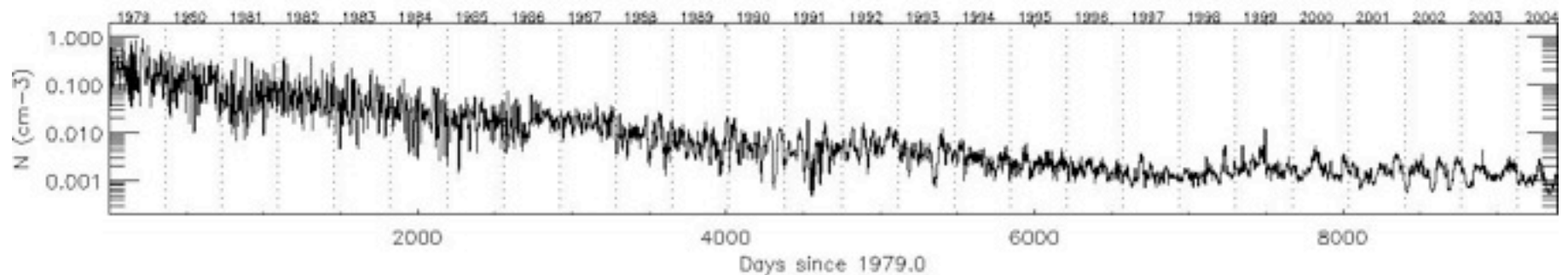
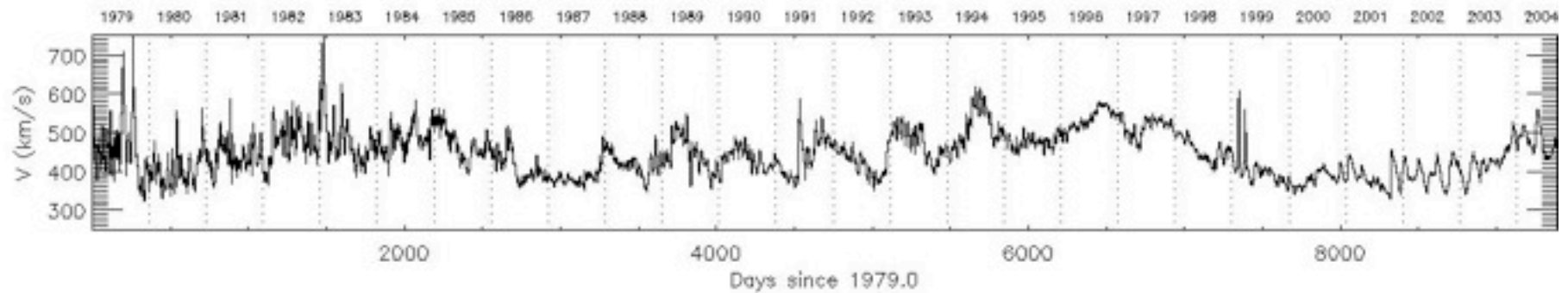
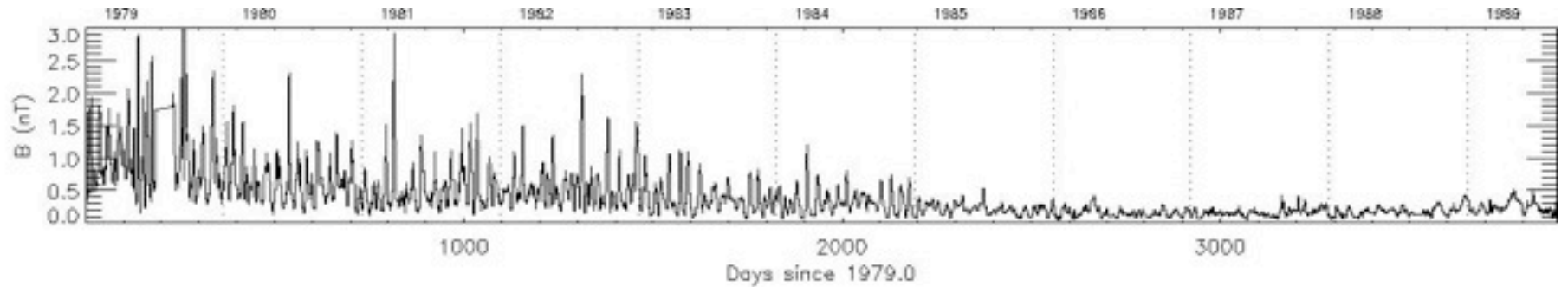
- Stereo observations of SKR by Voyager 1 & 2



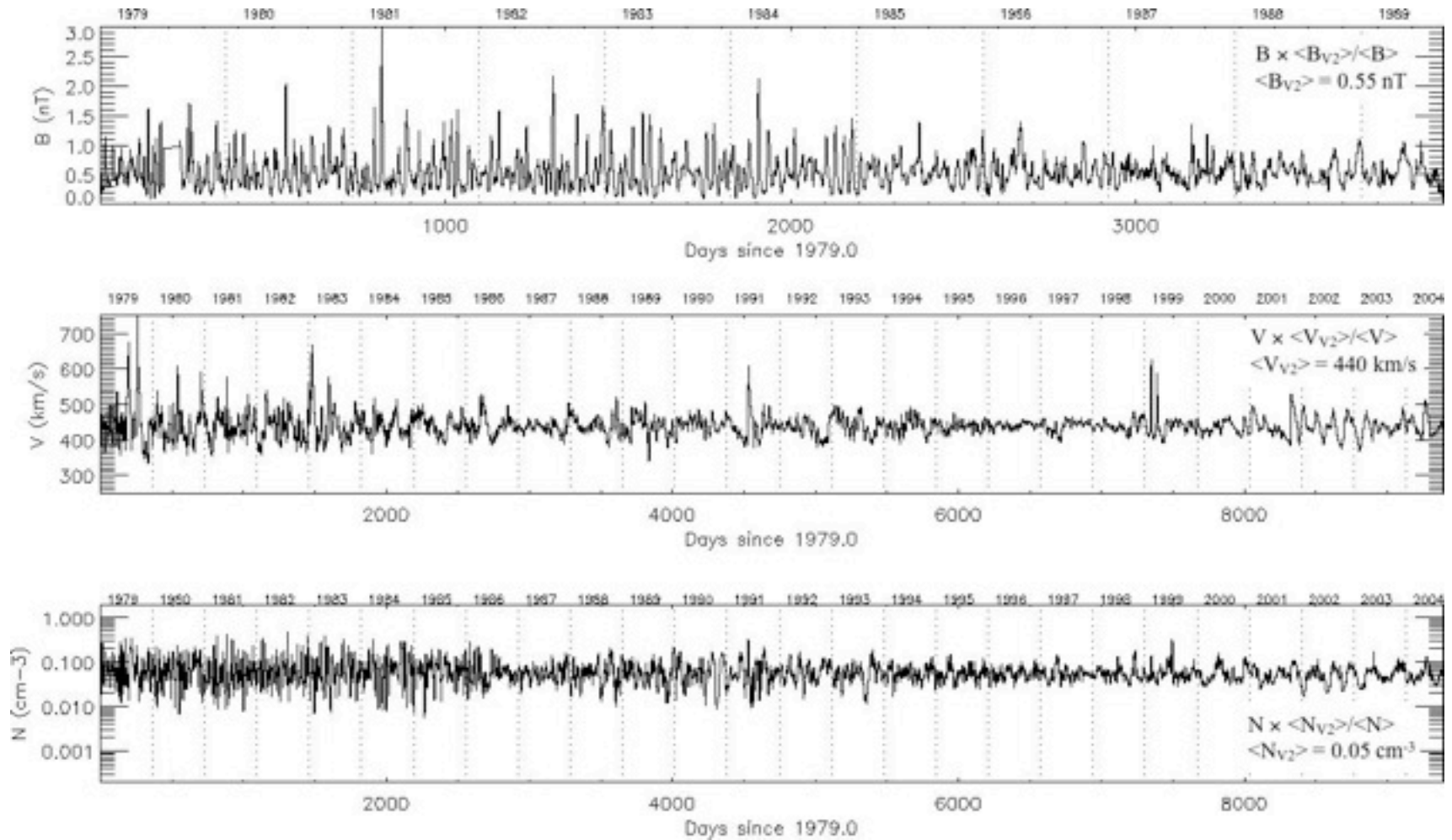
- Sub-corotation of UV aurora, correlated with SKR



- Long-term variations of SW parameters



- Long-term variations of SW parameters (detrended)



- Confirmation of model #2 using Voyager SW & SKR data (in progress...)

