

# **STEREO Observations of Strong Ion Cyclotron Waves in the Solar Wind near 1 AU**

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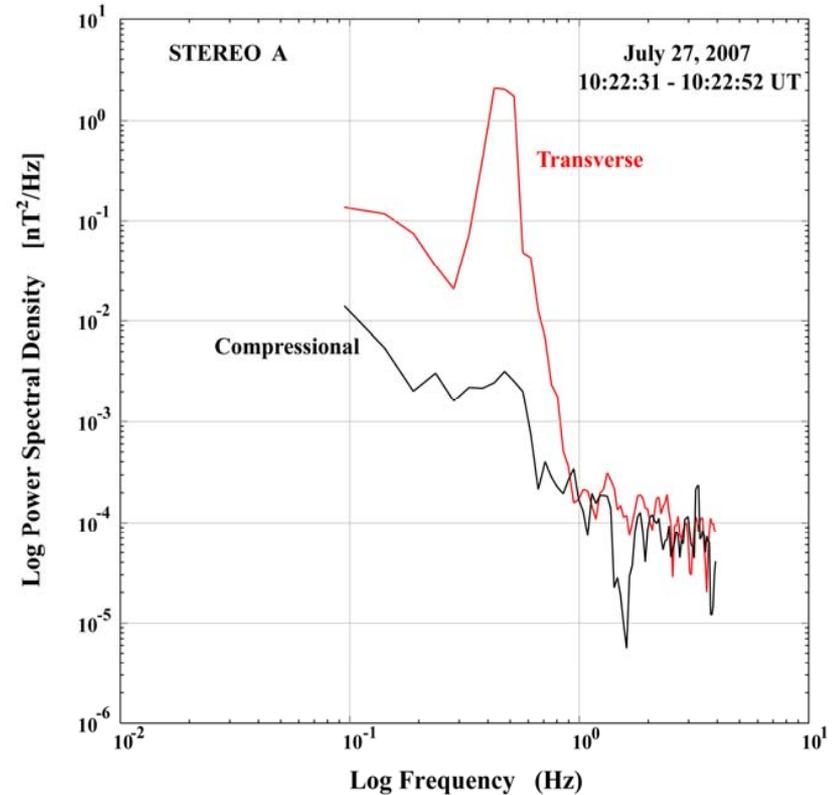
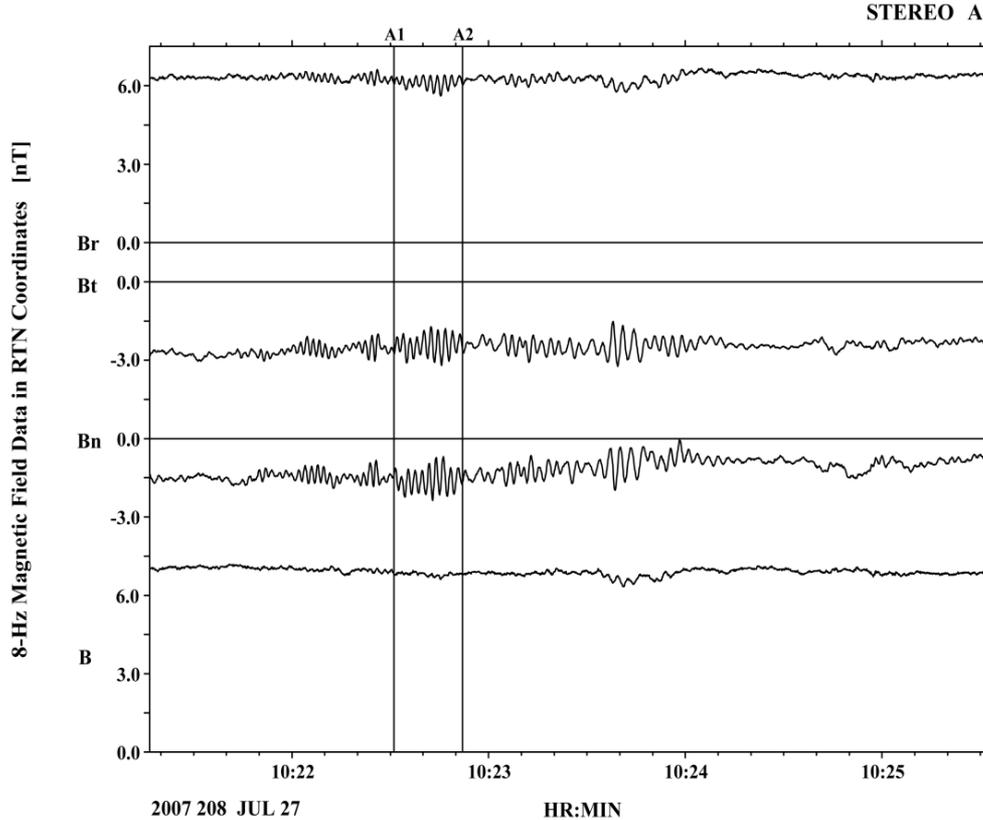
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# Introduction

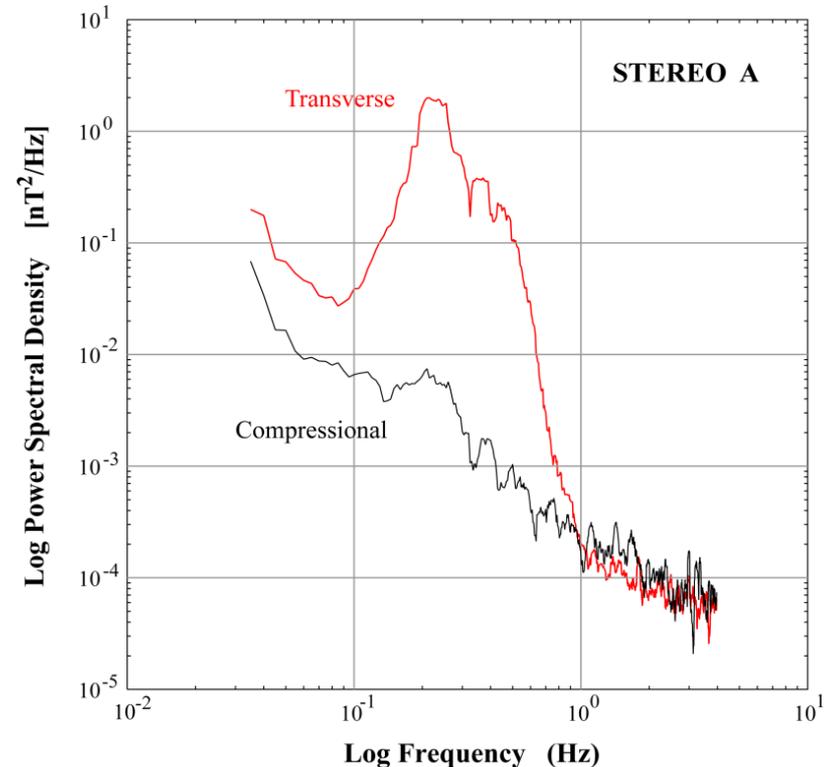
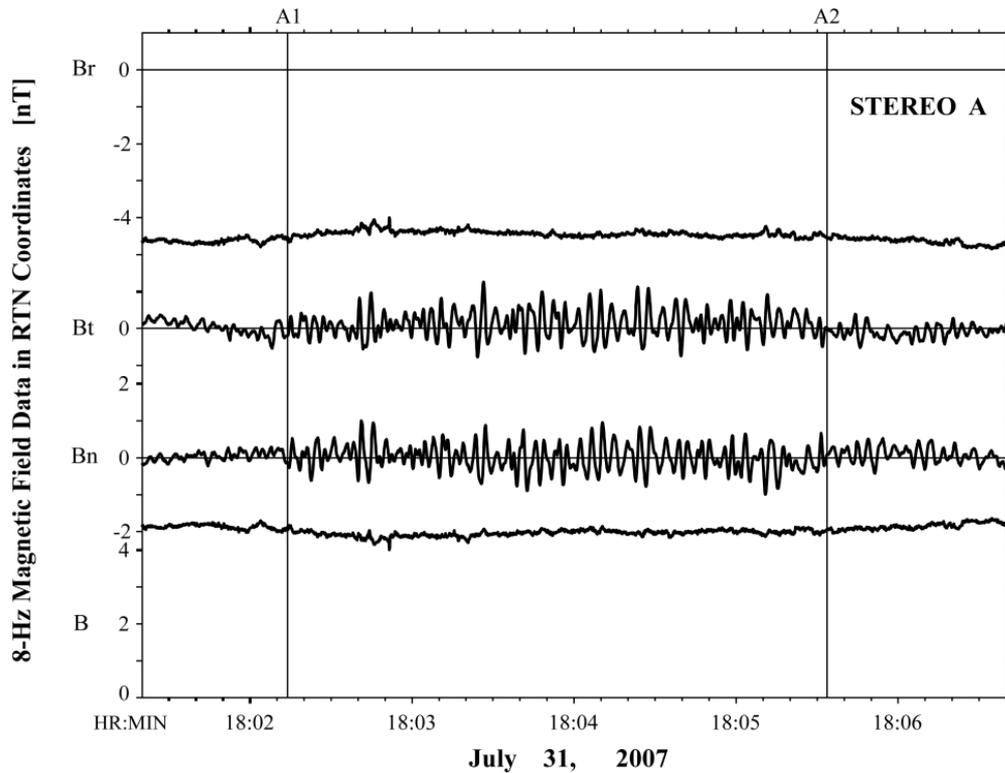
- ✿ Wave-particle interactions has been proposed to heat the solar wind. One likely wave type is the ion cyclotron wave (ICW).
- ✿ ICW is circularly polarized wave and left-handed (LH) in the plasma frame if the ion is positively charged.
- ✿ Based on the power spectra of the solar wind plasma parameters and magnetic field over relatively long periods or large frequency range, the possible presence of ICW activity has been previously inferred.
- ✿ However, this study using high-resolution STEREO magnetometer data, shows direct evidence of the existence of ICW, and also obtains their properties quantitatively.

# Example of Strong ICW - 1



- During the 4 minutes, there are several wave packets. They are well above the strength of other natural signals and the noise level of the instrument.
- Within the interval A1-A2, the transverse power dominates, being 3 orders larger than the compressional power. It has a **wave ellipticity of -0.98** and a **percent polarization of 99.9%**

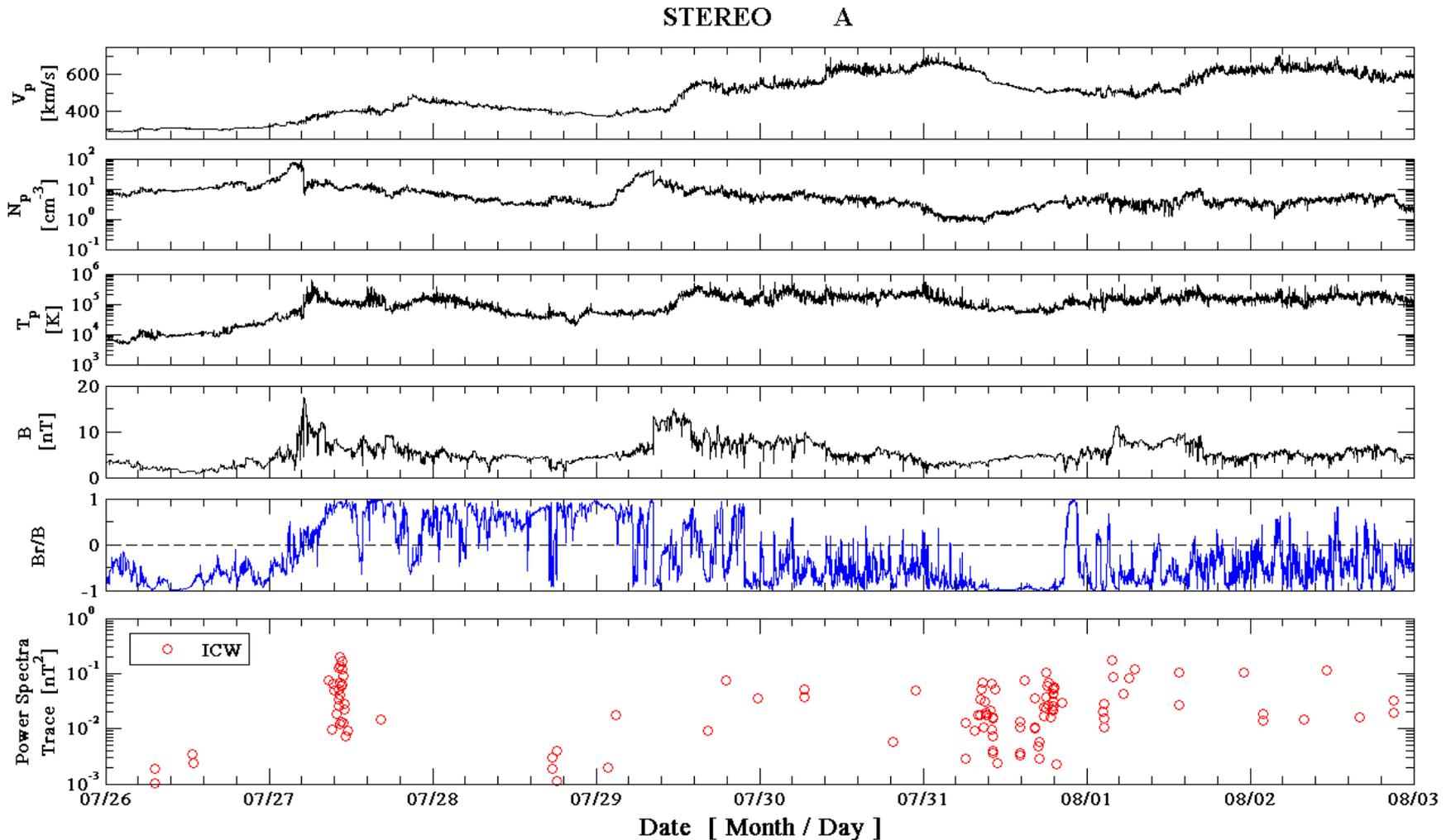
# Example of Strong ICW - 2



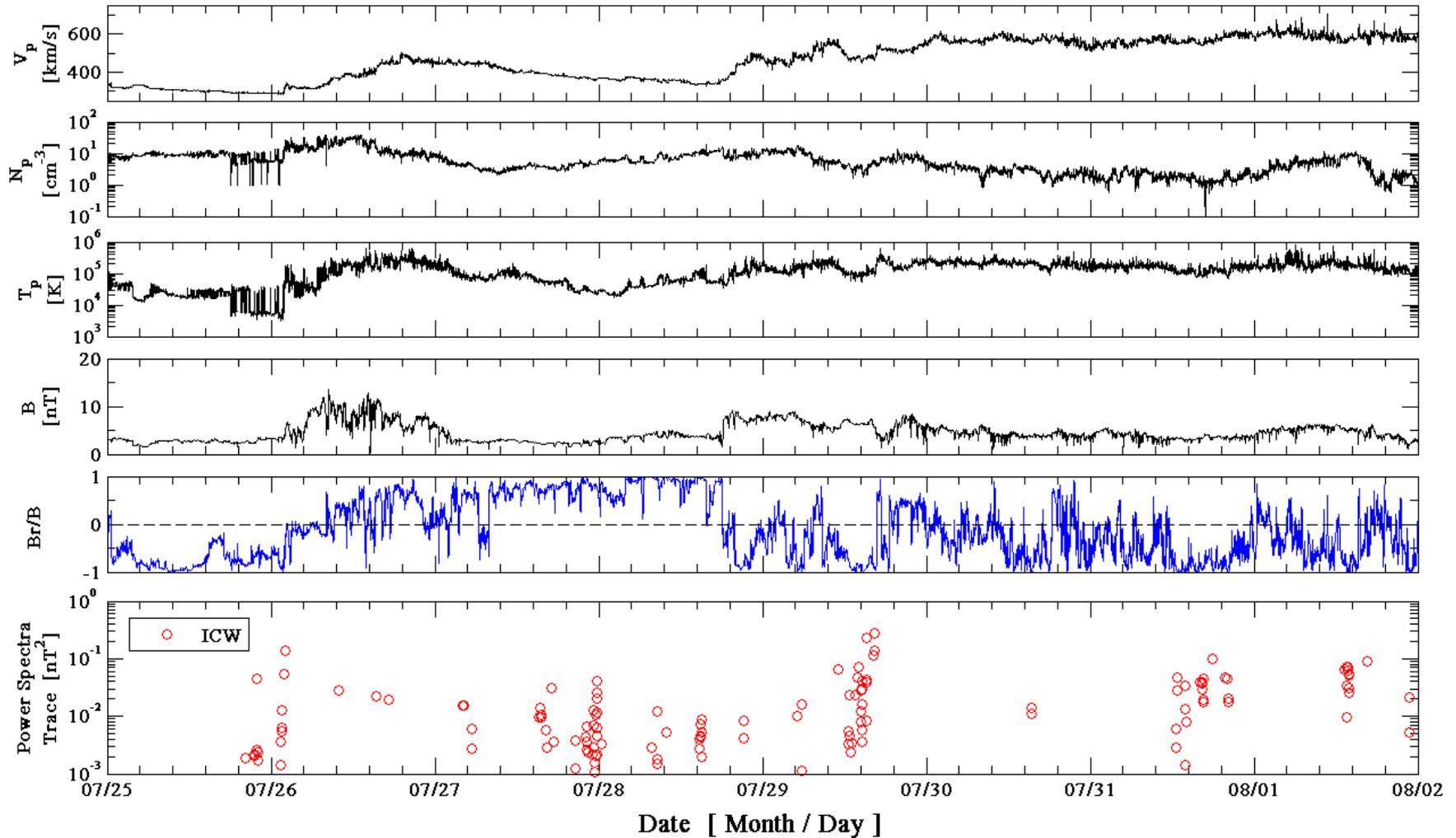
- ❖ a wave ellipticity of -0.95, a percent polarization of 95.2%
- ❖ a propagation angle from magnetic field is 1.2°
- ❖ Using 8-Hz magnetic field data from STEREO, we have observed many waves like the ones shown above.

# 16-Day Survey of STEREO A/B

Criteria:  $|\text{ellipticity}| > 0.7$ , polarization rate  $> 70\%$ ,  
long axis of the elliptic wave is perpendicular to both  $B$   
and propagation direction



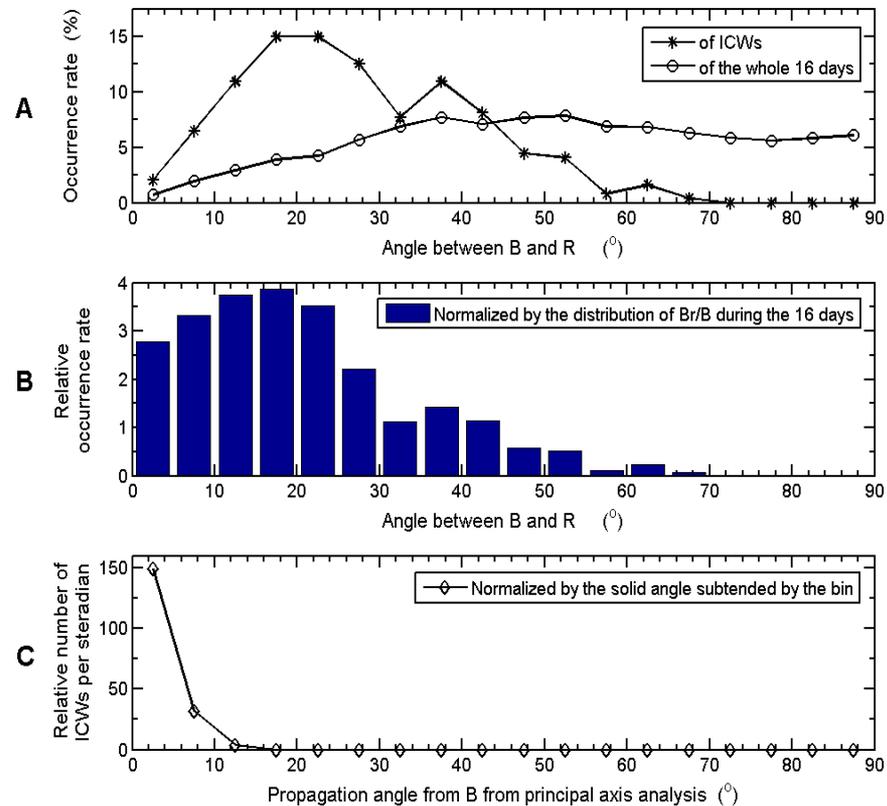
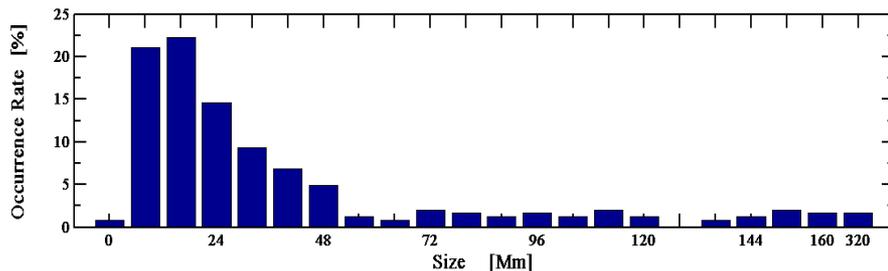
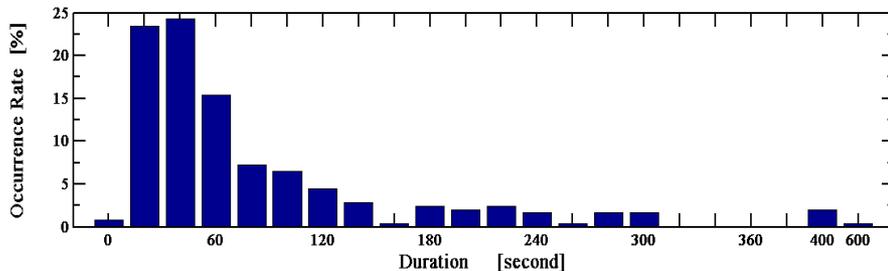
## STEREO B



- They most occur when the field is radial and relatively quiet, but seem not directly dependent on other solar wind conditions
- They are not always present even when the field remains radial

# Statistical Properties

Scales of the ICWs



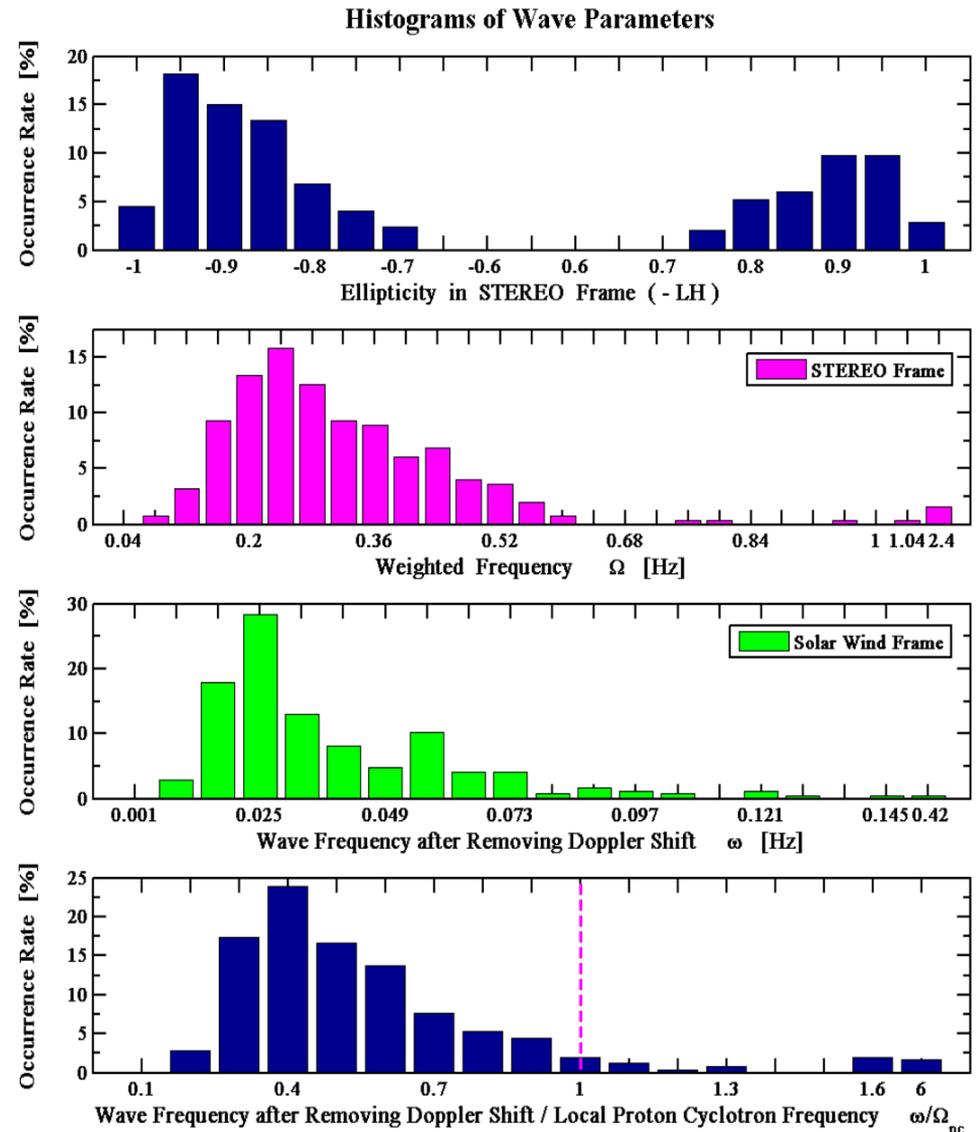
- Based on **247** events, statistically the ICWs are observed when the field is more radial than usual
- The waves mostly propagate **within 5° of B**
- The wave events chosen for analysis have a total power larger than  $0.001 \text{ nT}^2$  (STEREO magnetometer sensitivity is  $0.015 \text{ nT}$ )

# Wave Parameters

- The waves appear left-handed (LH) or right-handed (RH) in STEREO frame, and slightly more as LH waves
- We believe all waves are **intrinsically LH in s/c frame**. The RH waves in the s/c frame are those propagating toward the Sun but being carried outward by the super-Alfvénic solar wind
- After removing the Doppler shift

$$\Omega = \omega - \vec{k} \cdot \vec{v}_{sc} = \omega + \frac{\omega}{v_{ph}} \hat{k} \cdot \vec{v}_{sw}$$

the wave frequency  $\omega$  is generally smaller than local proton gyro-frequency  $\Omega_{pc}$

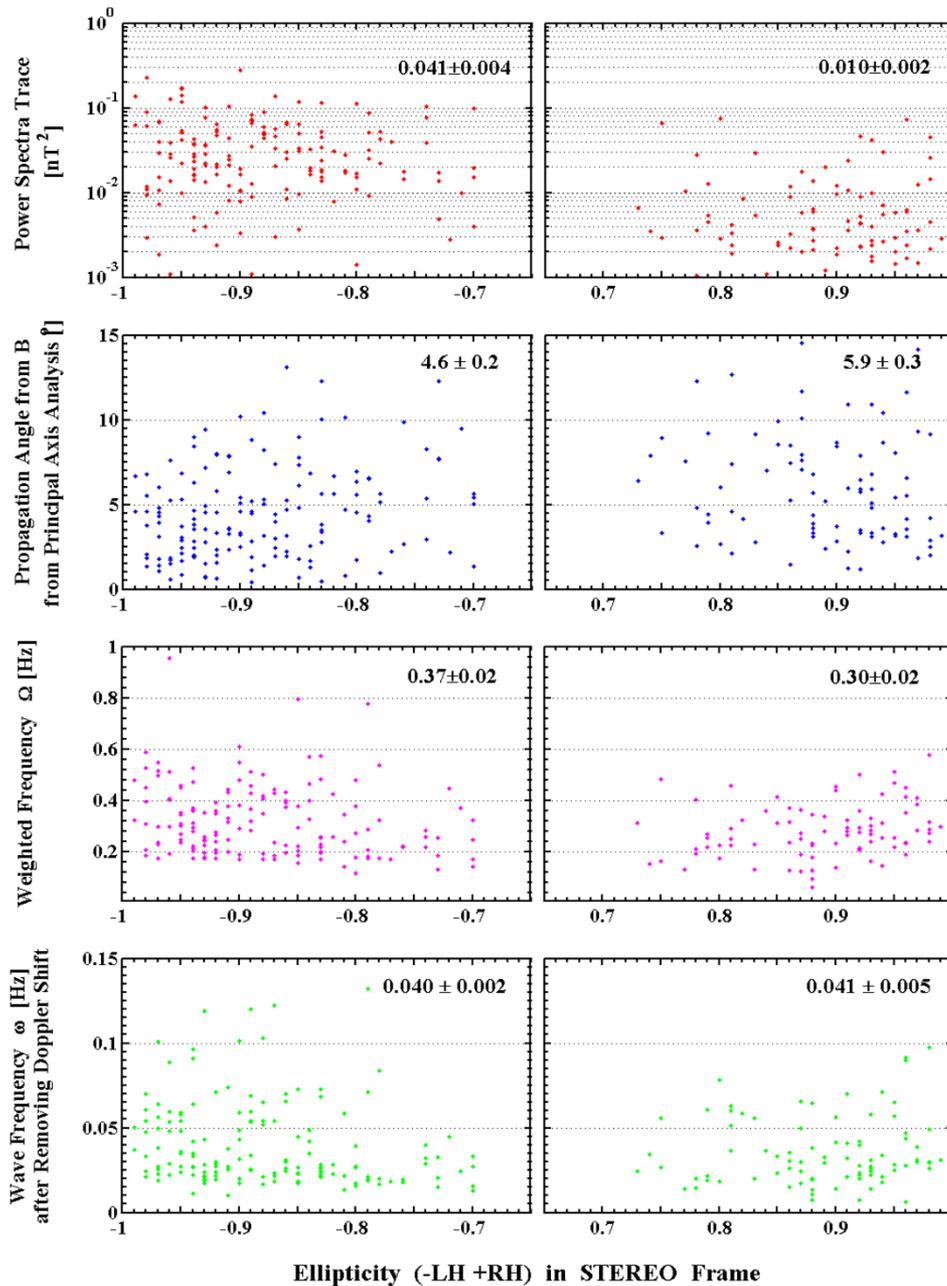


# ICW Statistics

Parameter	Maximum	Minimum	Median
Angle between B and R [°]	66.6	3.1	25.1
Angle between K and R [°]	66.6	0.0	24.1
Propagation Angle from B [°] <ul style="list-style-type: none"> <li>Joe Means</li> <li>Principal Axis</li> </ul>	16.2	0.4	<b>4.7</b>
	14.5	0.4	<b>4.5</b>
Absolute Value of Ellipticity	1.00	0.70	<b>0.90</b>
% Polarization	99.8	70.6	<b>95.4</b>
Power Spectra Trace [nT <sup>2</sup> ]	0.276	0.001	<b>0.016</b>
Compressional Ratio	0.072	0.002	0.013
Duration [second]	547.2	5.8	51.5
Size [Mm]	301.5	2.2	23.4
Local Field B [nT]	10.4	1.2	4.3
Weighted Freq $\Omega$ [Hz]	2.29	0.06	0.28
Wave Freq after Removing the Doppler Shift $\omega$ [Hz]	0.413	0.006	0.030

→ 0.4 nT fluctuation

## Correlation between Handedness in STEREO Frame and Other Wave Parameters



# Properties of LH and RH Waves in STEREO Frame

- As a group, the RH waves in the STEREO frame have a lower power, consistent with a longer propagation time and more damping
- RH waves have a slightly larger propagation angle
- LH and RH waves have similar wave frequency

# Conclusions

- ➡ We have found 247 ICW events during 16-day STEREO observations, which last from several seconds to minutes
- ➡ They propagate at a small angle to  $B$
- ➡ They are both LH and RH in STEREO frame
- ➡ Taking Doppler shift into account, all waves are consistent with **LH waves in solar wind frame**, at a frequency lower than the local proton gyro-frequency
- ➡ To understand their generation mechanism and dissipation process, ICW observations at other heliocentric distances and coordinated modeling work are needed