HINODE observation :

Solar Wind

Takeru K. Suzuki
(Physics dept., Nagoya University)

Outline

Upward Motion (Direct observation of flows)

- **Open Flux Tubes near Active Regions** (New Generation)
  - **EIS** (Imada et al.2007; Hara et al.2008; Harra et al.2008)
  - **XRT** (Sakao et al.2007)
- **Polar Jets** (New Generation)
  - **EIS** (Kamio et al.2007)
  - **XRT** (Cirtain et al.2007; Shimojo et al.2007)
- **Upward Motions in Polar Coronal Holes** (Old Generation)
  - **EIS** (Tian et al.2010)

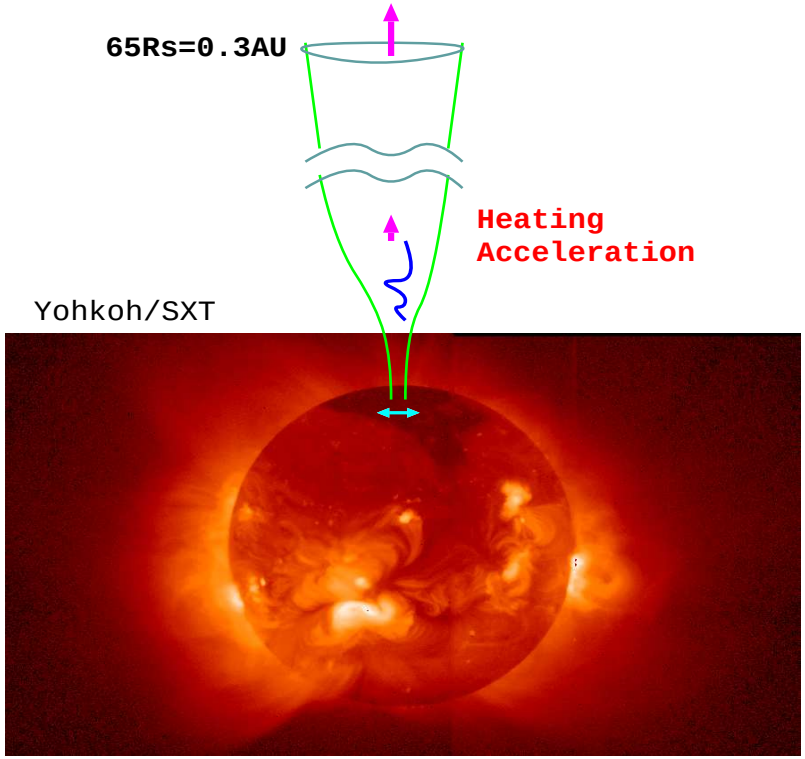
Alfven(ic) motions (Energy Source)

- **SOT (Phase correlation of B & v)** (Fujimura & Tsuneta 2009)
- **EIS (Nonthermal Broadening)** (Banerjee et al.2009)

Configuration of Magnetic Field (Environment)

- **Poles** (Tsuneta et al.2008)
- **Active Regions** (Harra et al.2008)

Solar Winds



- Fast Wind from Polar Coronal Holes
  - Quasi-steady Component
- Slow Wind from ? (Streamer ?)

Outline

Upward Motion (Direct observation of flows)

- **Open Flux Tubes near Active Regions** (New Generation)
  - **EIS** (Imada et al.2007; Hara et al.2008; Harra et al.2008)
  - **XRT** (Sakao et al.2007)
- **Polar Jets** (New Generation)
  - **EIS** (Kamio et al.2007)
  - **XRT** (Cirtain et al.2007; Shimojo et al.2007)
- **Upward Motions in Polar Coronal Holes** (Old Generation)
  - **EIS** (Tian et al.2010)

Alfven(ic) motions (Energy Source)

- **SOT (Phase correlation of B & v)** (Fujimura & Tsuneta 2009)
- **EIS (Nonthermal Broadening)** (Banerjee et al.2009)

Configuration of Magnetic Field (Environment)

- **Poles** (Tsuneta et al.2008)
- **Active Regions** (Harra et al.2008)

Outline

Upward Motion (Direct observation of flows)

- **Open Flux Tubes near Active Regions** (New Generation)
  - **EIS** (Imada et al.2007; Hara et al.2008; Harra et al.2008)
  - **XRT** (Sakao et al.2007)
- **Polar Jets** (New Generation)
  - **EIS** (Kamio et al.2007)
  - **XRT** (Cirtain et al.2007; Shimojo et al.2007)
- **Upward Motions in Polar Coronal Holes** (Old Generation)
  - **EIS** (Tian et al.2010)

Alfven(ic) motions (Energy Source)

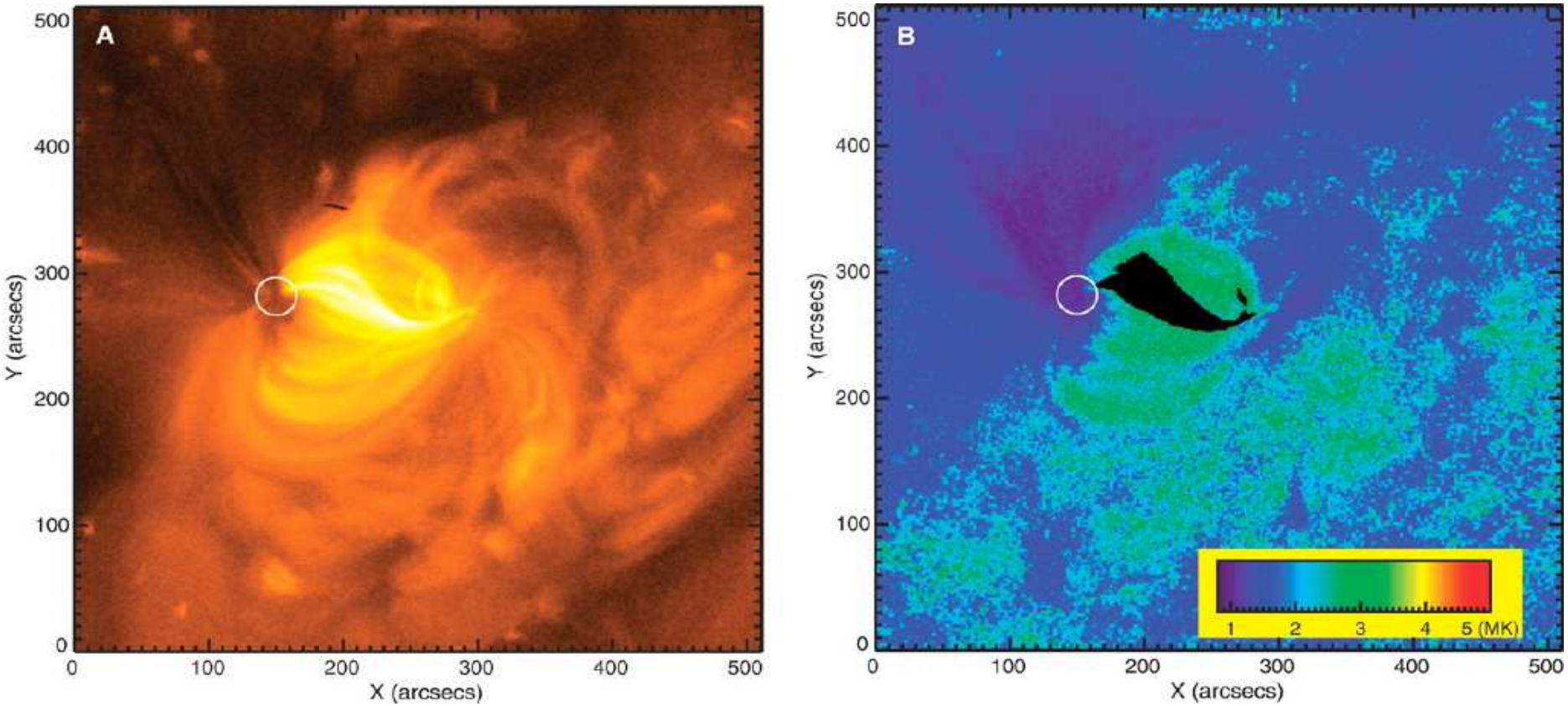
- **SOT (Phase correlation of B & v)** (Fujimura & Tsuneta 2009)
- **EIS (Nonthermal Broadening)** (Banerjee et al.2009)

Configuration of Magnetic Field (Environment)

- **Poles** (Tsuneta et al.2008)
- **Active Regions** (Harra et al.2008)

Open flux tubes near Active Regions

Sakao et al.2007

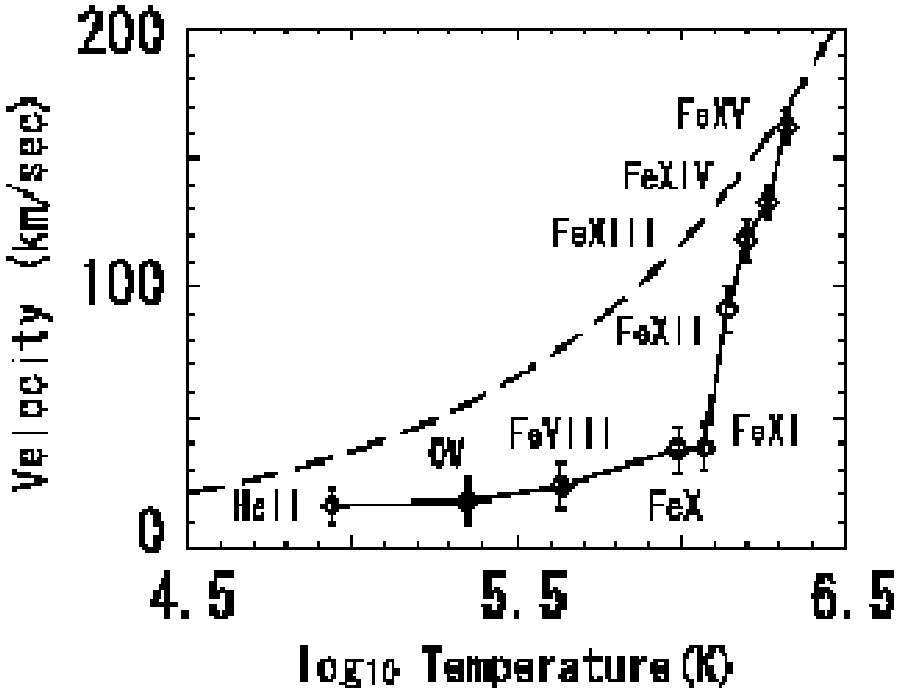


EIS obs by Harra et al

- **~>100km/s at ~1.1Rsun**

Plage near Active Regions

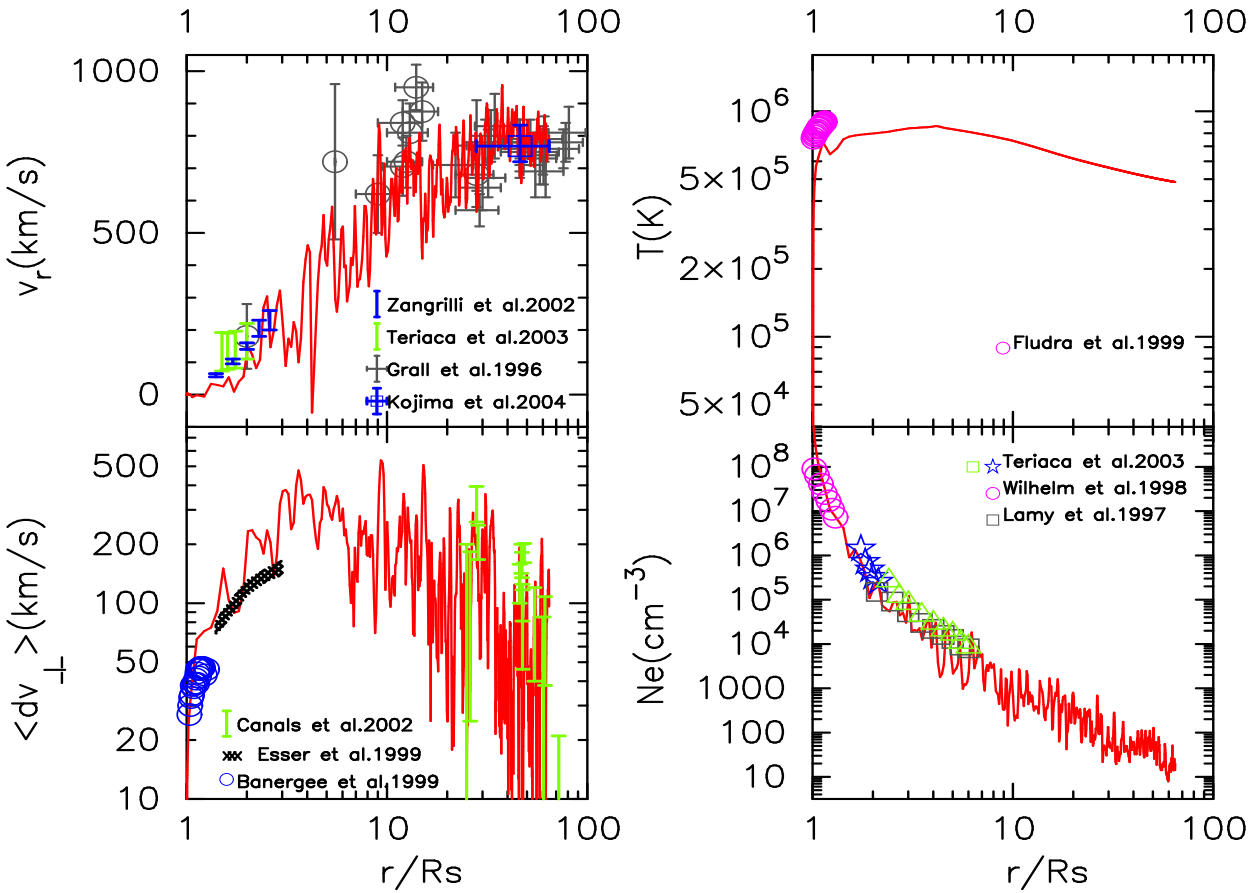
Imada et al.2007 (EIS)



~>100km/s in the low corona (<<2 Rsun)

Solar Wind Simulation

Suzuki & Inutsuka 2005



- **Difficult to explain >100km/s at << 2Rsun**
  - **Other 1D models** (Cranmer & van Ballegooijen 2007; Verdini & Velli 2007) **: Same**

Outline

Upward Motion (Direct observation of flows)

- Open Flux Tubes near Active Regions (New Generation)
  - EIS (Imada et al.2007; Hara et al.2008; Harra et al.2008)
  - XRT (Sakao et al.2007)
- **Polar Jets (New Generation)**
  - **EIS (Kamio et al.2007)**
  - **XRT (Cirtain et al.2007; Shimojo et al.2007)**
- Upward Motions in Polar Coronal Holes (Old Generation)
  - EIS (Tian et al.2010)

Alfven(ic) motions (Energy Source)

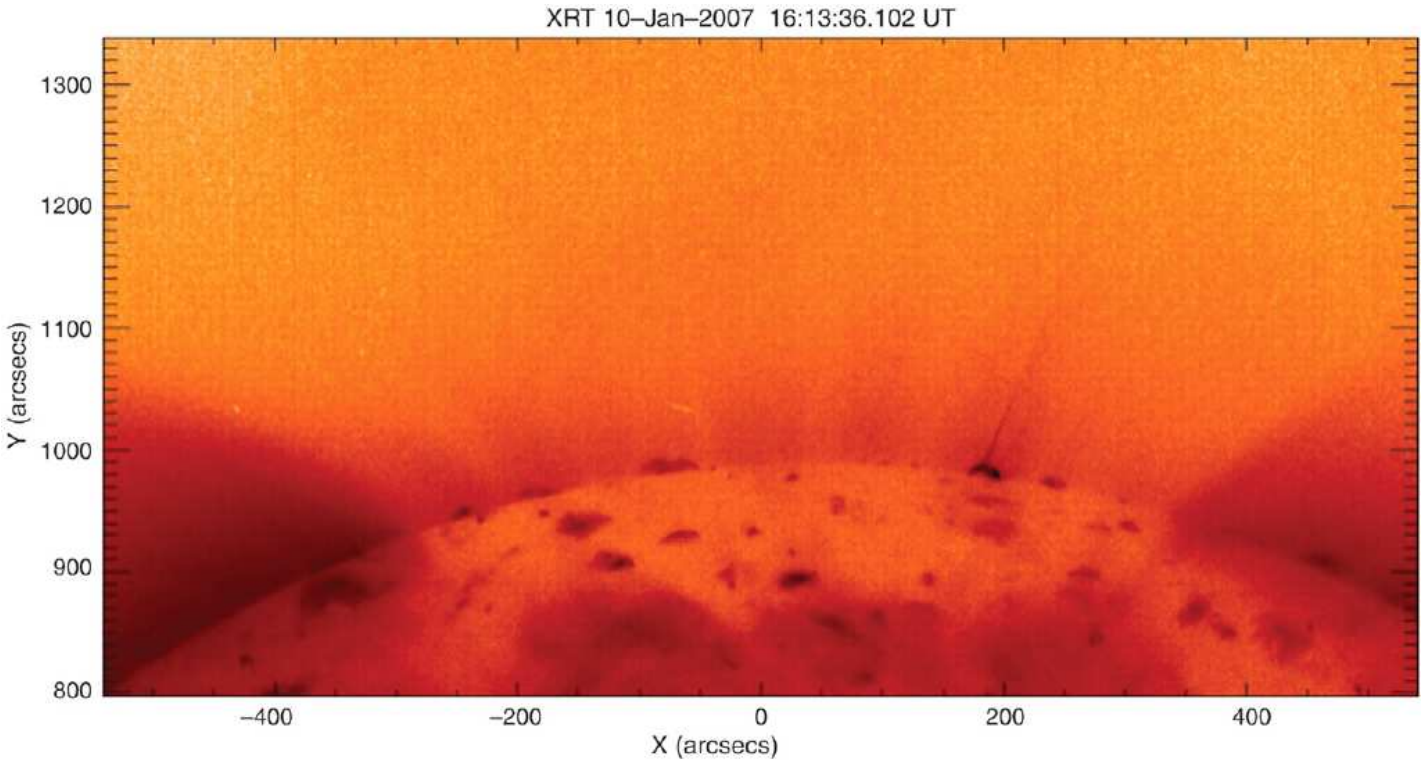
- SOT (Phase correlation of B & v) (Fujimura & Tsuneta 2009)
- EIS (Nonthermal Broadening) (Banerjee et al.2009)

Configuration of Magnetic Field (Environment)

- Poles (Tsuneta et al.2008)
- Active Regions (Harra et al.2008)

Polar Jets

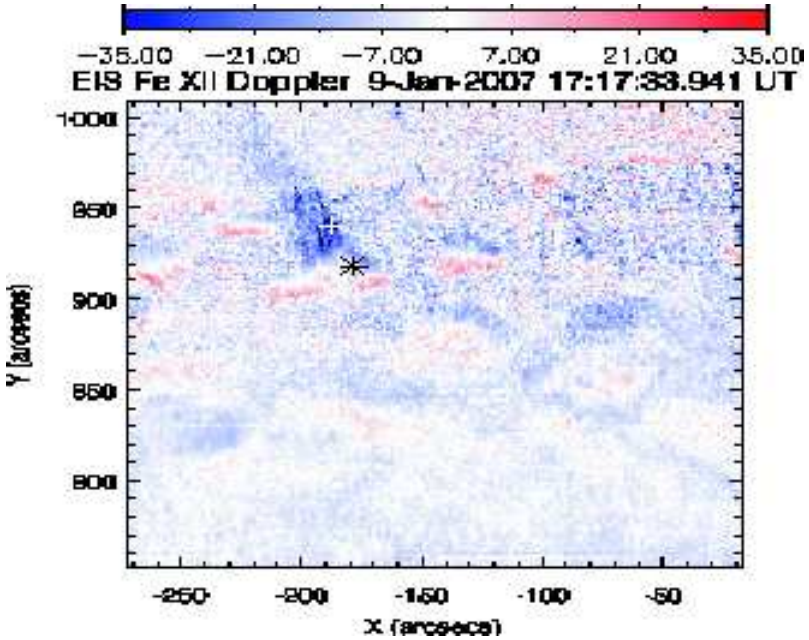
Cirtain et al.2007



- **Outflows**
  - **~800km/s(~Alfven speed; Initial Phase)**
  - **~200km/s(~Sound Speed; Frequently Observed so far)**
- **Wave propagation as well**

Polar Jets

Kamio et al.2007



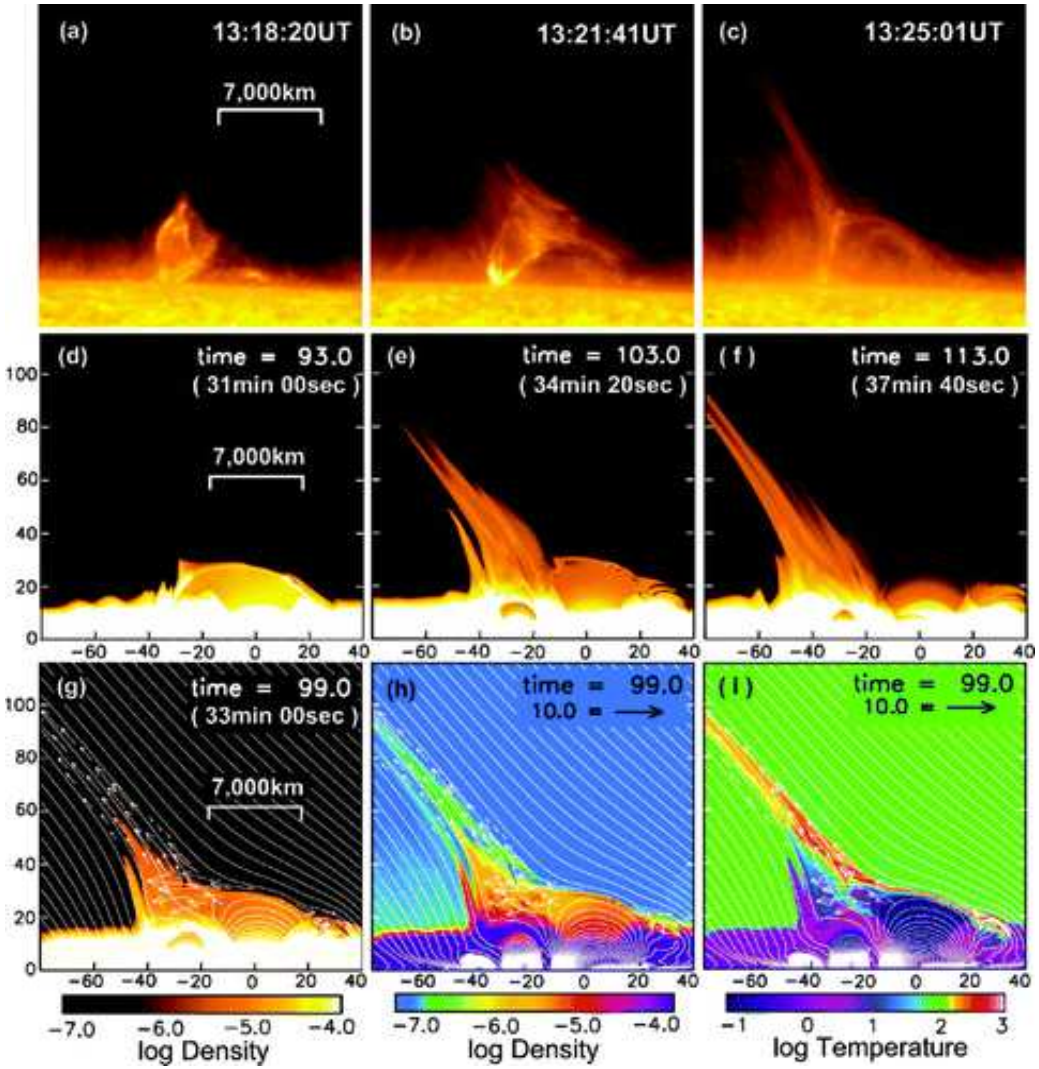
- **Blue shift with ~ 30km/s**

  => up to~300km/s with LoS effect

  - **Difficult to explain by 1D Solar Wind Calculations**

2D Simulations

Nishizuka et al.2008



Mass Loss Rate from ‘New Generations’

- **Open Flux Tubes near Active Region :**

  1/4 of Total (possibly)

  Sakao et al.2007

- **Polar Jets :**

  1/10 of Total

  Cirtain et al.2007

- **Other Regions ? Coronal Holes**

  <=> ’Classical’ solar winds (Old Generation)

Outline

Upward Motion (Direct observation of flows)

- Open Flux Tubes near Active Regions (New Generation)
  - EIS (Imada et al.2007; Hara et al.2008; Harra et al.2008)
  - XRT (Sakao et al.2007)
- Polar Jets (New Generation)
  - EIS (Kamio et al.2007)
  - XRT (Cirtain et al.2007; Shimojo et al.2007)
- **Upward Motions in Polar Coronal Holes (Old Generation)**
  - **EIS (Tian et al.2010)**

Alfven(ic) motions (Energy Source)

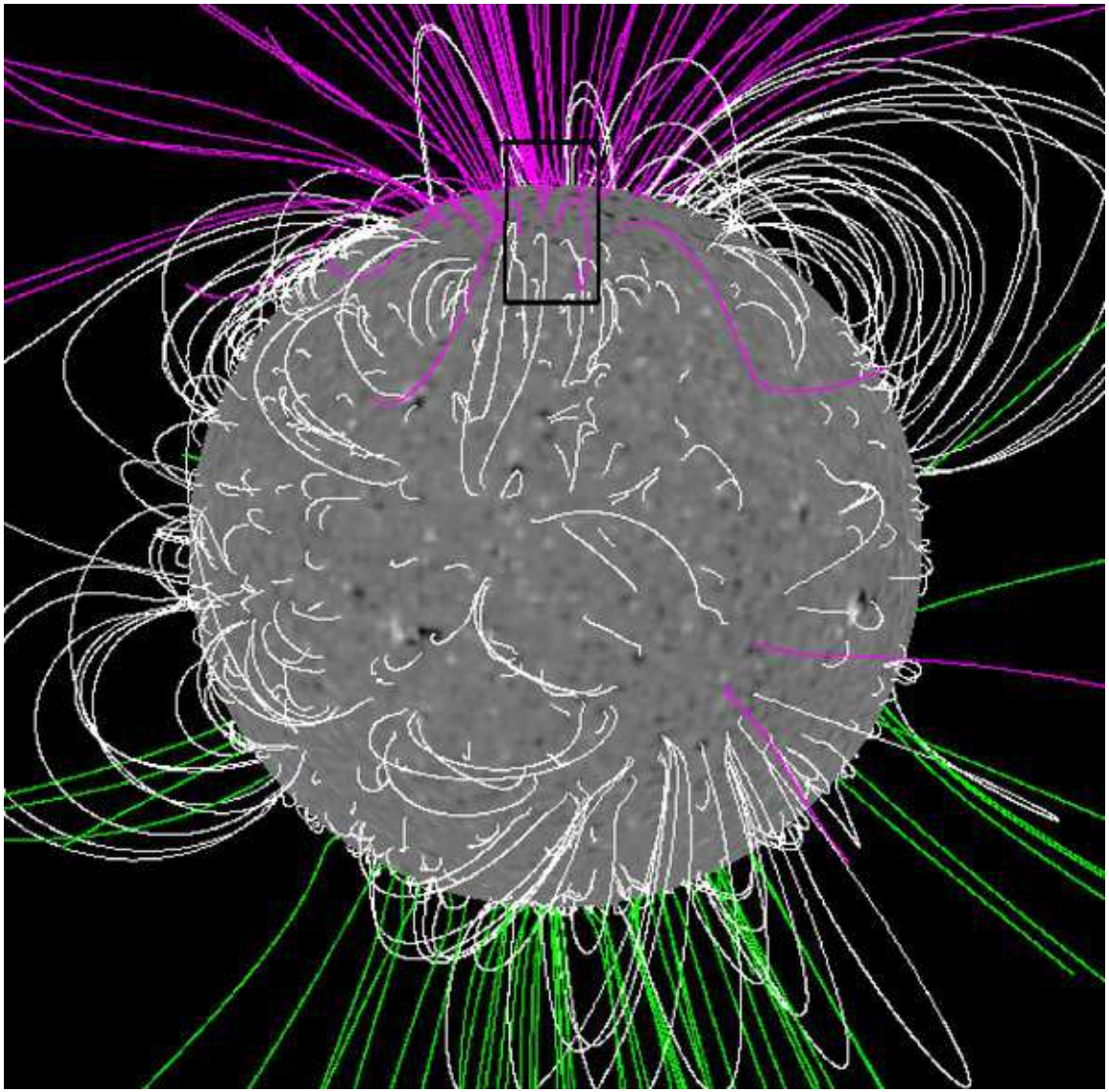
- SOT (Phase correlation of B & v) (Fujimura & Tsuneta 2009)
- EIS (Nonthermal Broadening) (Banerjee et al.2009)

Configuration of Magnetic Field (Environment)

- Poles (Tsuneta et al.2008)
- Active Regions (Harra et al.2008)

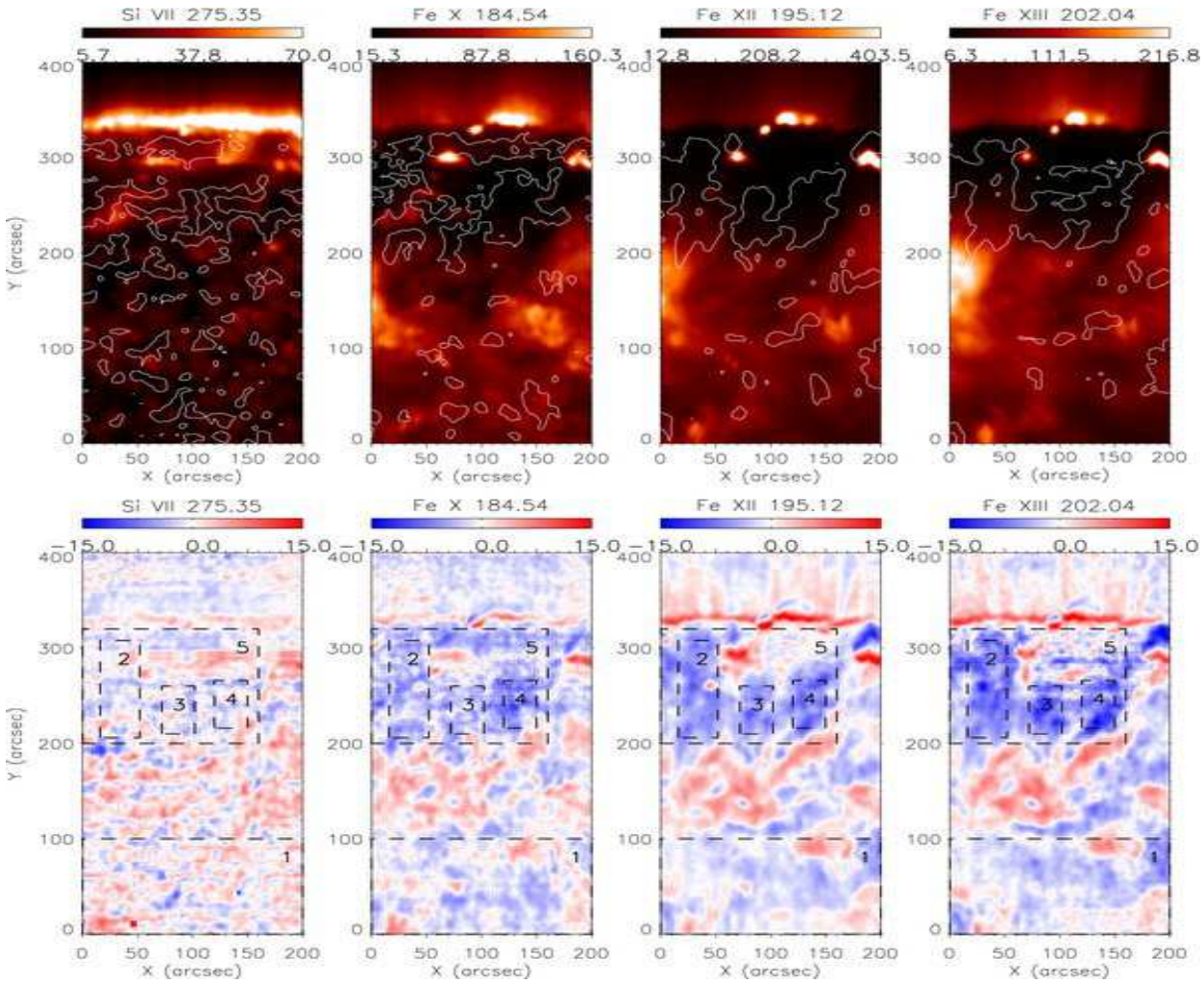
Polar Coronal Holes

Observation by EIS (Tian et al.2010)



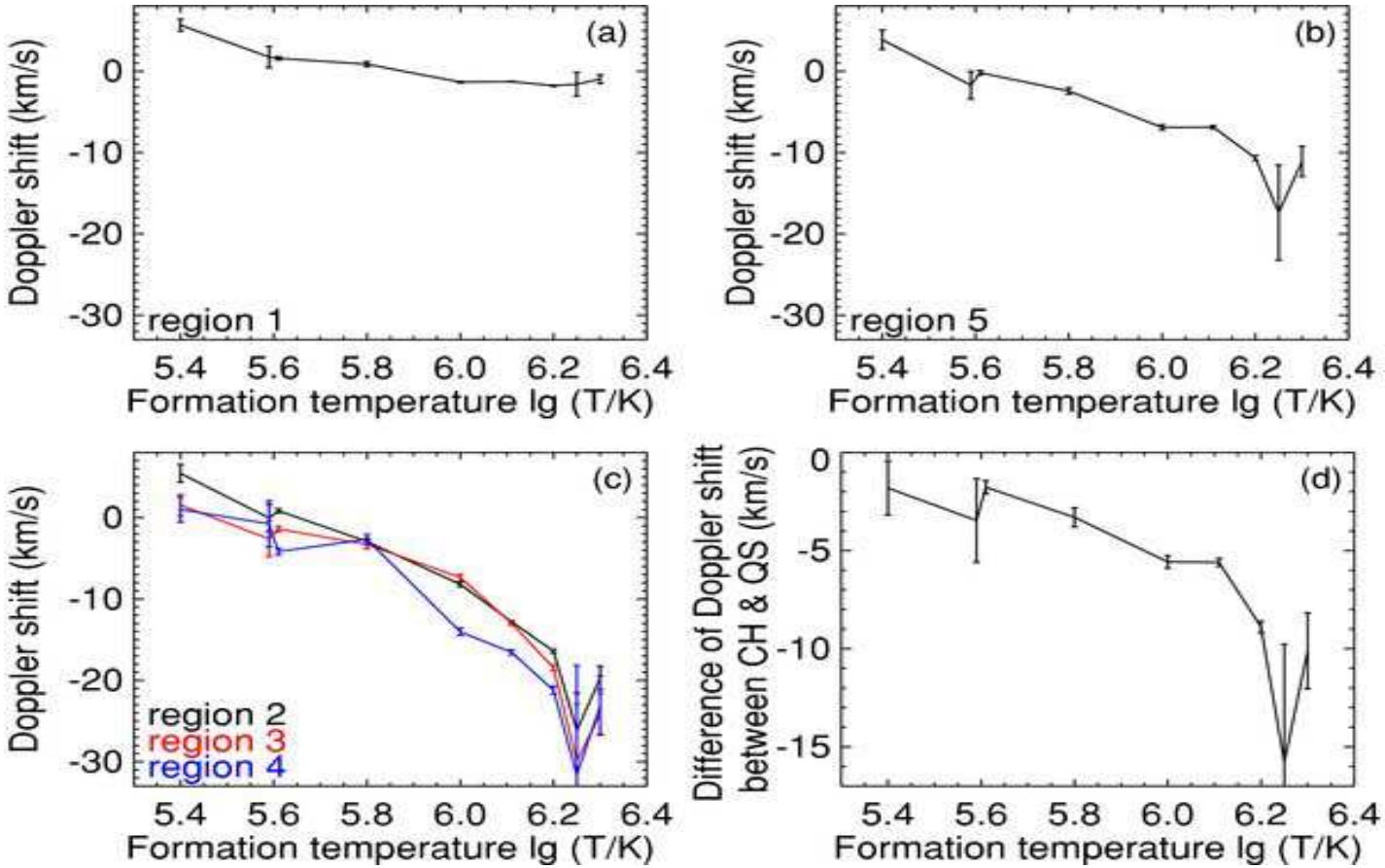
Polar Coronal Holes -cont.-

Blue (& Red) Shifts for Different Temperature (Tian et al.2010)



Fine Structure => Smooth Structure as T increases

Polar Coronal Holes -cont.-



(Tian et al.2010) **LoS effect is taken into account**

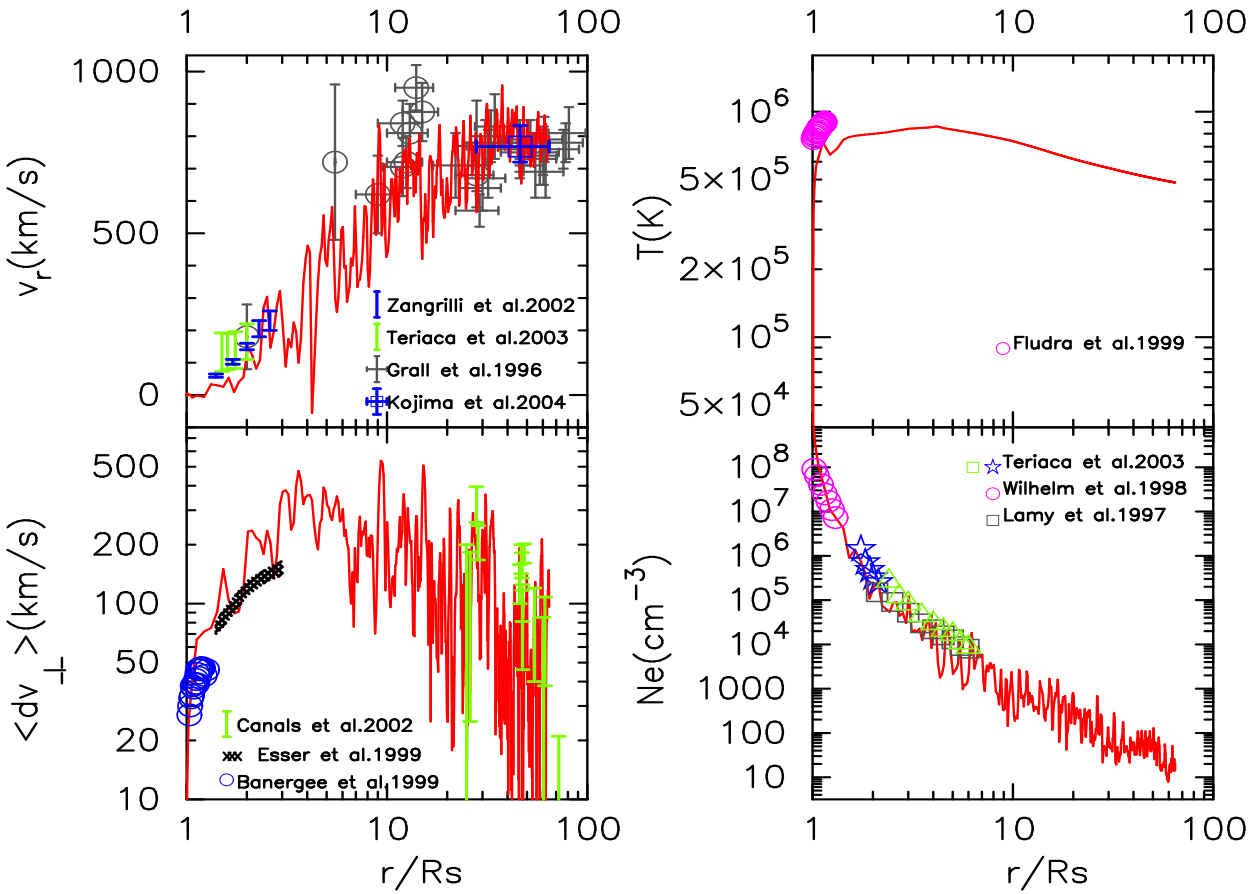
- **~30km/s at Low Coronal Height :**

  Slower than Sakao Event & Polar Jets

  Consistent with 1D solar wind calculations

Solar Wind Simulation

Suzuki & Inutsuka 2005

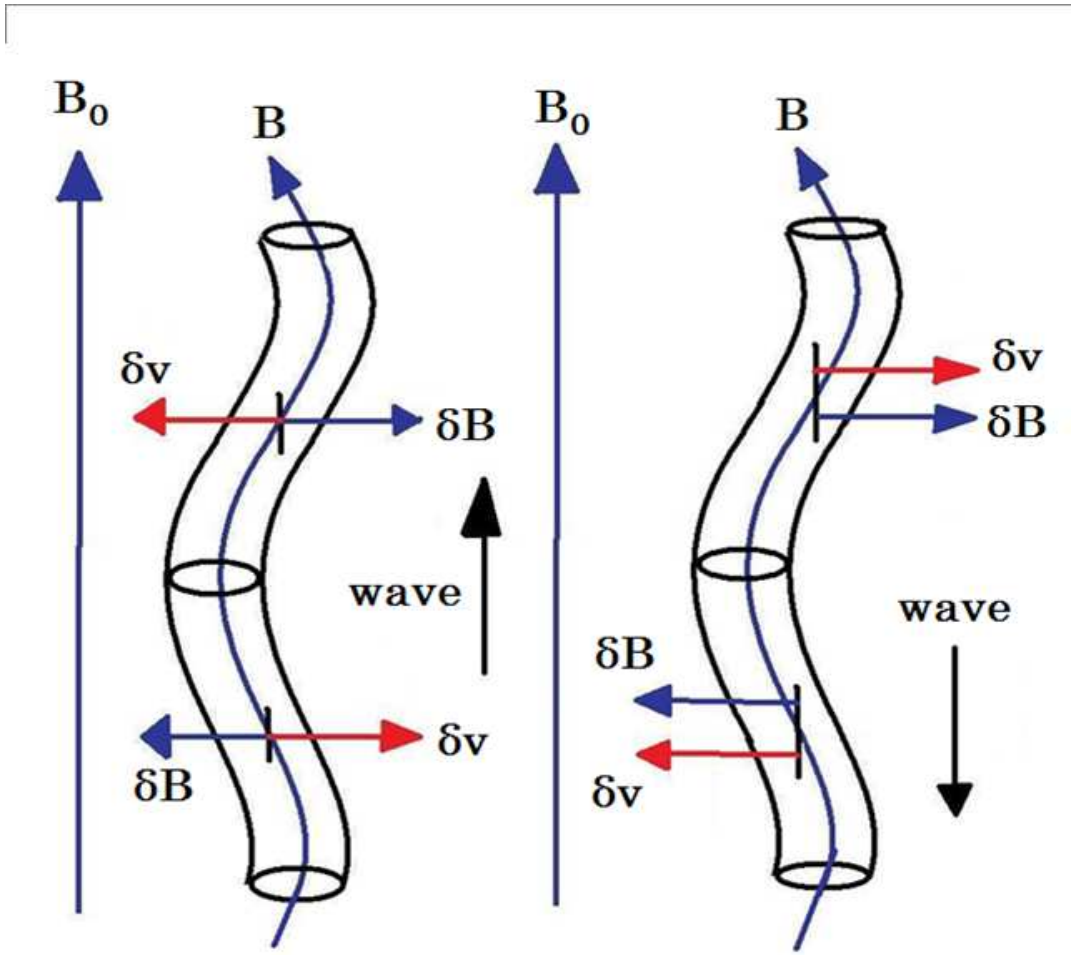


Outline

- Upward Motion (Direct observation of flows)
  - Open Flux Tubes near Active Regions (New Generation)
    - EIS (Imada et al.2007; Hara et al.2008; Harra et al.2008)
    - XRT (Sakao et al.2007)
  - Polar Jets (New Generation)
    - EIS (Kamio et al.2007)
    - XRT (Cirtain et al.2007; Shimojo et al.2007)
  - Upward Motions in Polar Coronal Holes (Old Generation)
    - EIS (Tian et al.2010)
- **Alfven(ic) motions (Energy Source)**
  - **SOT (Phase correlation of B & v)** **(Fujimura & Tsuneta 2009)**
  - **EIS (Nonthermal Broadening)** **(Banerjee et al.2009)**
- Configuration of Magnetic Field (Environment)
  - Poles (Tsuneta et al.2008)
  - Active Regions (Harra et al.2008)

Alfven Wave at Photosphere

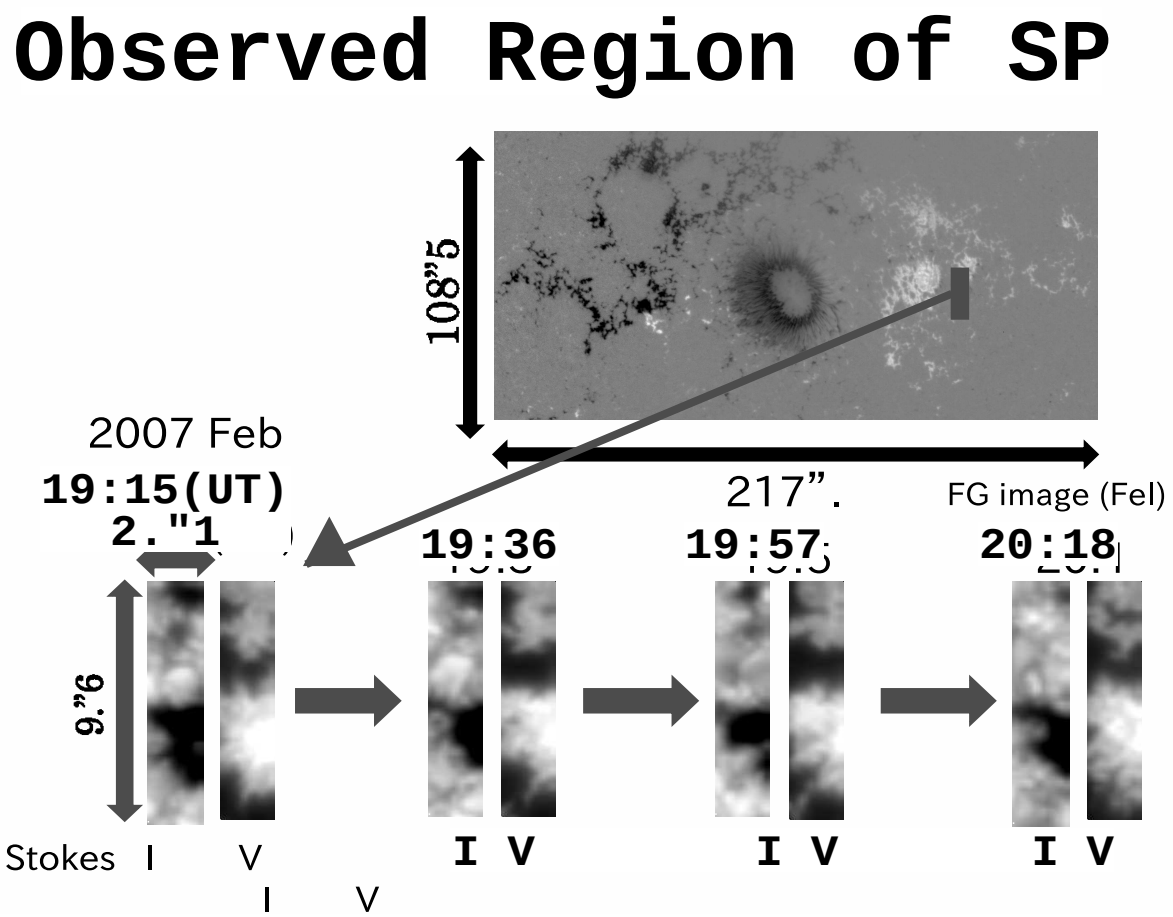
Fujimura & Tsuneta 2009 (from Fujimura's presentation)



- Correlation of B & v => Direction of Alfvenic Waves

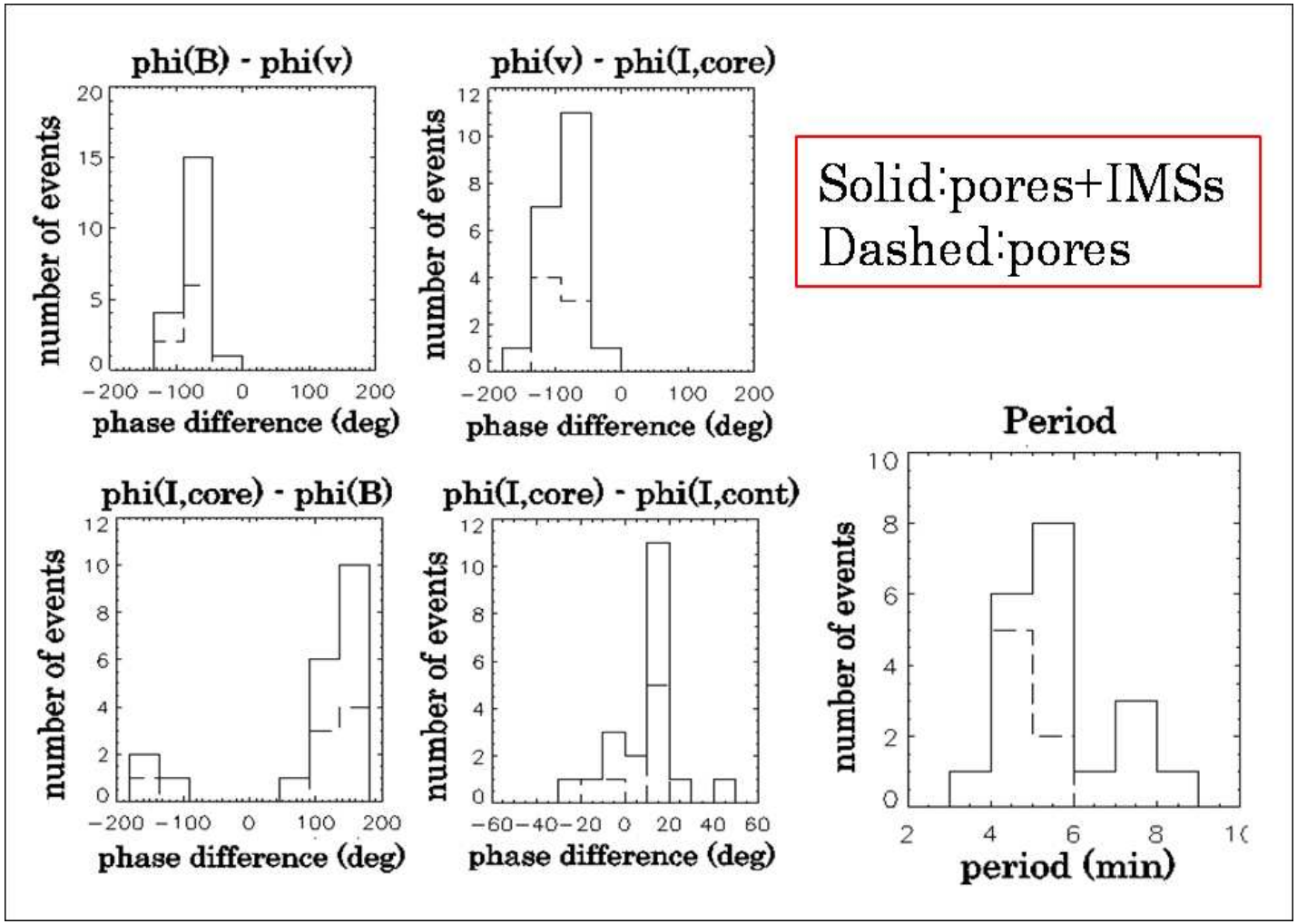
Alfven Wave at Photosphere -cont.-

Fujimura & Tsuneta 2009 (from Fujimura's presentation)



- **Obtain Correlation of, Intensity, B, & v**
  - **Pores & Intergranule Magnetic Concentration**

Alfven Wave at Photosphere -cont.-



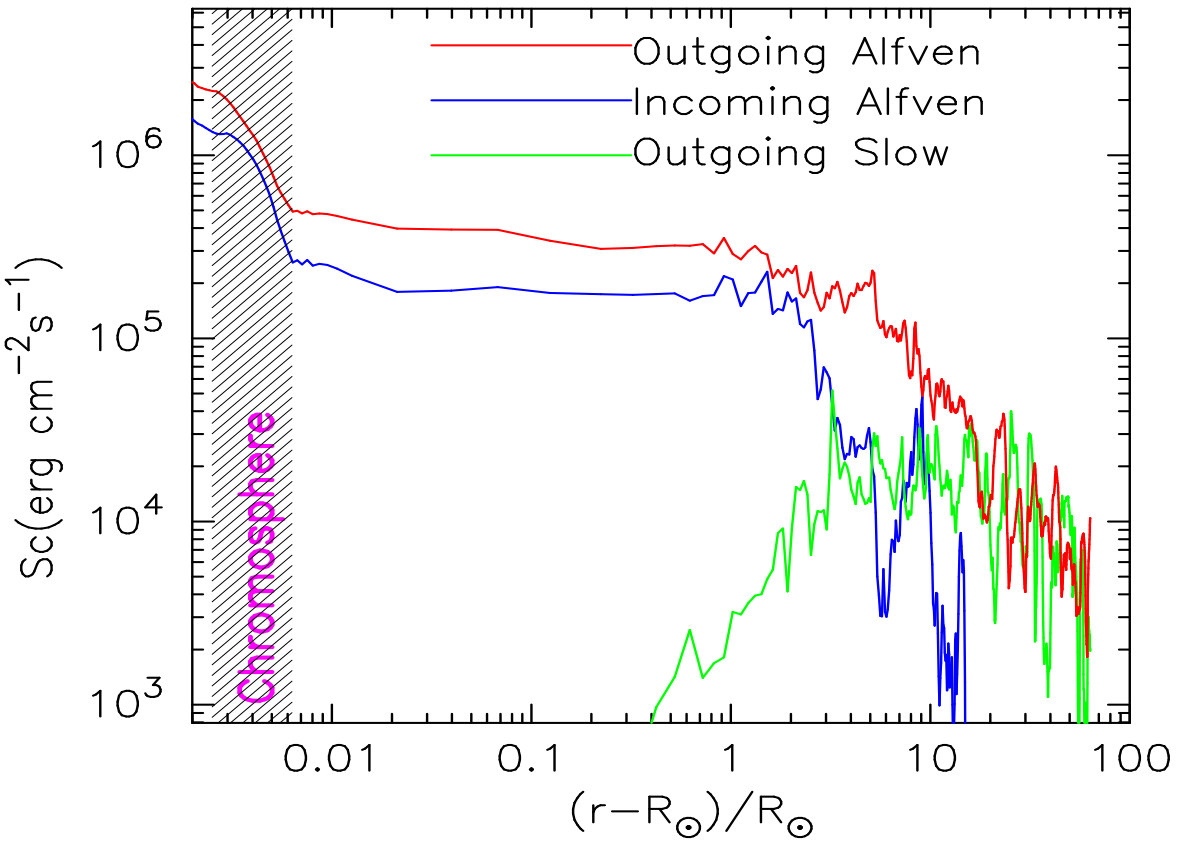
- **Phase correlation of dB & dv : (+/-)90 deg.**

  => Upward component ~ Downward component

Dissipation of Alfven Waves

(Wave Action Normalized at 1.02Rs for Superradial Expansion of Flux Tube)

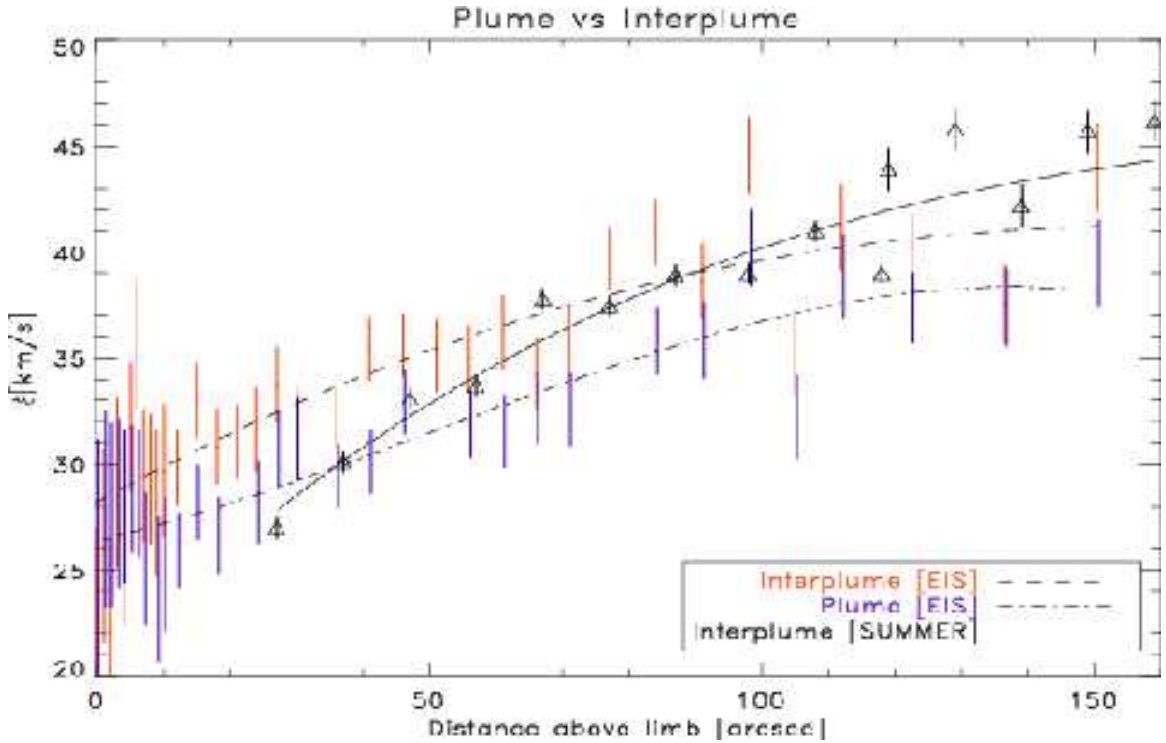
Suzuki & Inutsuka 2005, ApJ, 632, L49



- **85% is reflected back before reaching corona**
- **(Qualitatively) Consistent with Fujimura & Tsuneta**

Alfven waves in Corona? (Nonthermal broadening)

Banerjee et al.2009

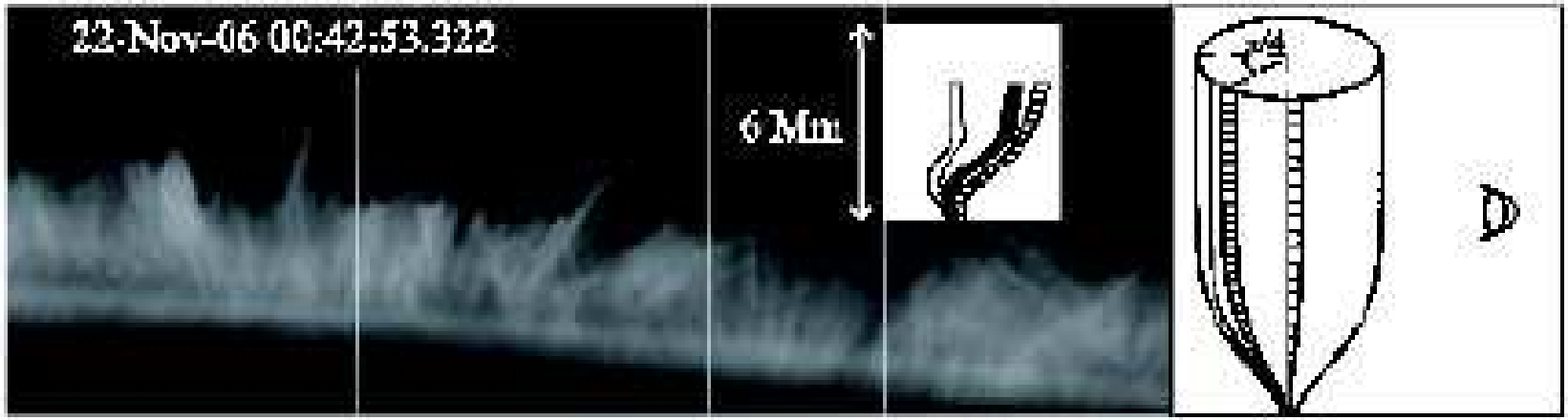


- Consistent with non-dissipative Alfven waves

  <=> Simulations

Alfvenic Wave-driven Spicules

Matsumoto & Shibata 2010



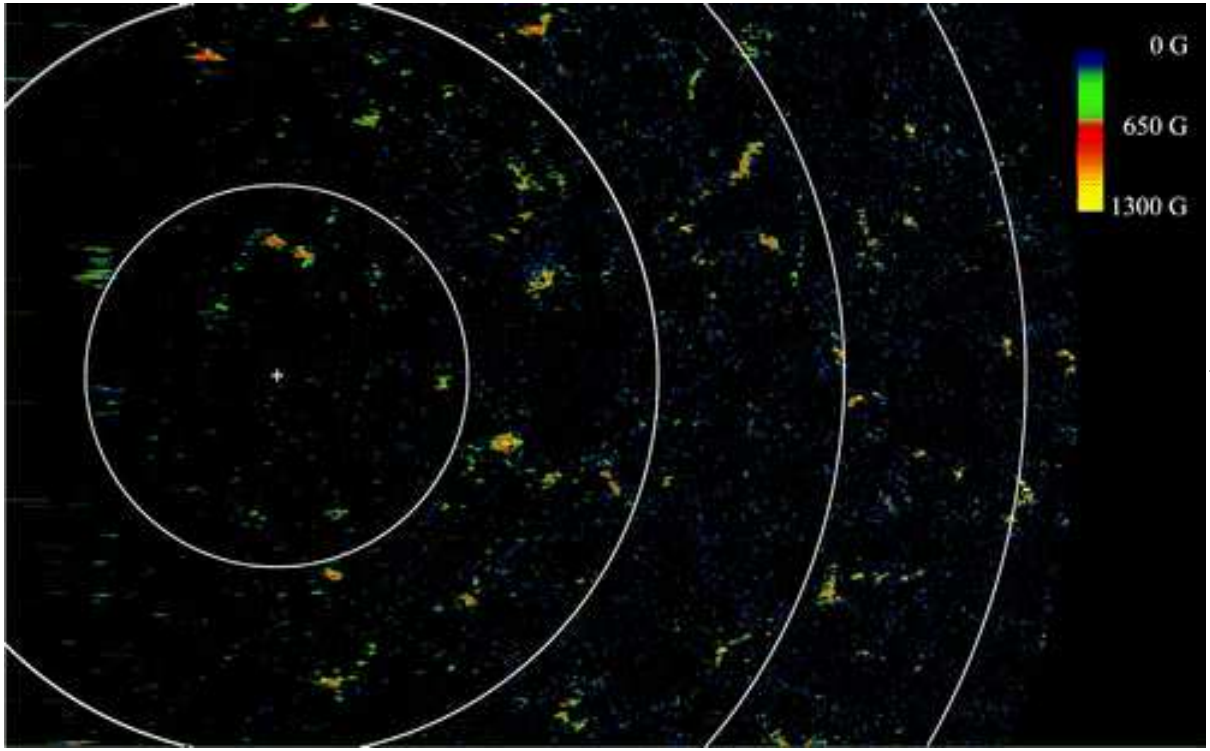
- Photospheric Motion from SOT => Spicules

Outline

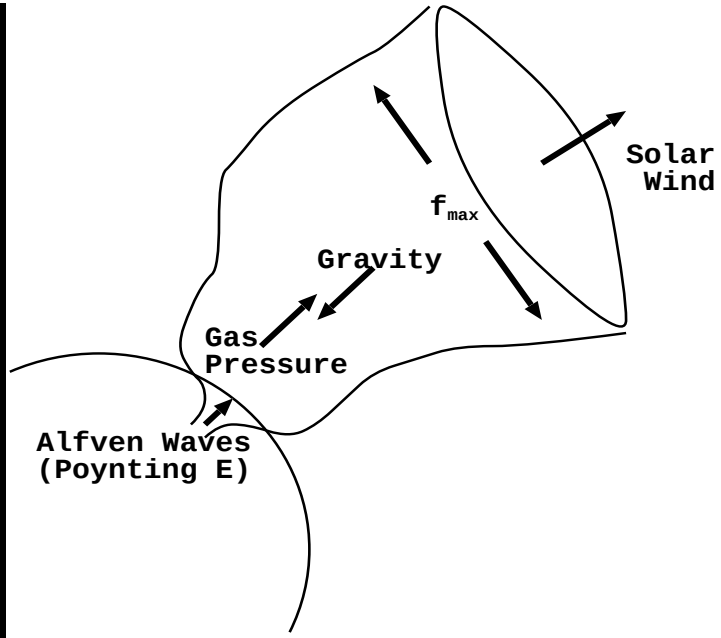
- Upward Motion (Direct observation of flows)
  - Open Flux Tubes near Active Regions (New Generation)
    - EIS (Imada et al.2007; Hara et al.2008; Harra et al.2008)
    - XRT (Sakao et al.2007)
  - Polar Jets (New Generation)
    - EIS (Kamio et al.2007)
    - XRT (Cirtain et al.2007; Shimojo et al.2007)
  - Upward Motions in Polar Coronal Holes (Old Generation)
    - EIS (Tian et al.2010)
- Alfven(ic) motions (Energy Source)
  - SOT (Phase correlation of B & v) (Fujimura & Tsuneta 2009)
  - EIS (Nonthermal Broadening) (Banerjee et al.2009)
- **Configuration of Magnetic Field (Environment)**
  - **Poles (Tsuneta et al.2008)**
  - Active Regions (Harra et al.2008)

Flux Tube

Tsuneta et al.2008, ApJ, 688, 1374



Suzuki 2006, ApJL, 640, L75



- kG patches
  - ~1000 times super-radial expansion
- Consistent with the flux tubes adopted in the solar wind calculations

Summary

- **Observation of Flows**
  - Near-Active Regions & Polar Jets (New Generations)
    - High Speed near Surface
  - Coronal Holes (Old Generations)
    - Consistent with ‘Classical’ Solar Wind Calculation
- **Observation of Energy Source (Poynting Flux)**
  - Alfvenic Motions at Photosphere
    - Downward Comp ~ Upward Comp: Reflected Waves
  - Nonthermal Broadening in Corona
    - Coinsistent with Nondissipative Alfven Waves
- **Observation of Environment (B-Field Configuration)**
  - Pole(s): Super-radial Expansion of Open Flux Tubes

Missing:

Simultaneous Observations of Flow, Poynting Flux, & B-field Environment

A vs. B

Option A

- **Flows & Velocity Profile in Various Regions**
- **Large-scale Structure of Solar Winds**

Option B

- **Propagation / Reflection / Dissipation of Alfvenic Waves in Chromosphere & Transition Regions (Phase Correlation of B,v,Intensity)**
- **Details of Density and Velocity Structure at Low Corona**