
Solar Radio Observations
Relationships to:
White-Light Observations
In-Situ Plasma Data
Evolutionary
and
Source Region Models
M. J. Reiner

Players in the Solar Radio Drama

Radiation Characteristics

Type III radio emissions	Type II radio emissions
e⁻ beams from flare sites	e⁻ acceleration at CME-driven shock fronts
fast frequency drift	slow frequency drift
intense, continuous	weak, diffuse/sporadic
wide frequency band	narrow frequency band

M. J. Reiner, 1st STEREO Workshop, March, 2002, Paris

Generation Mechanism

Type III radio emissions

Type II radio emissions

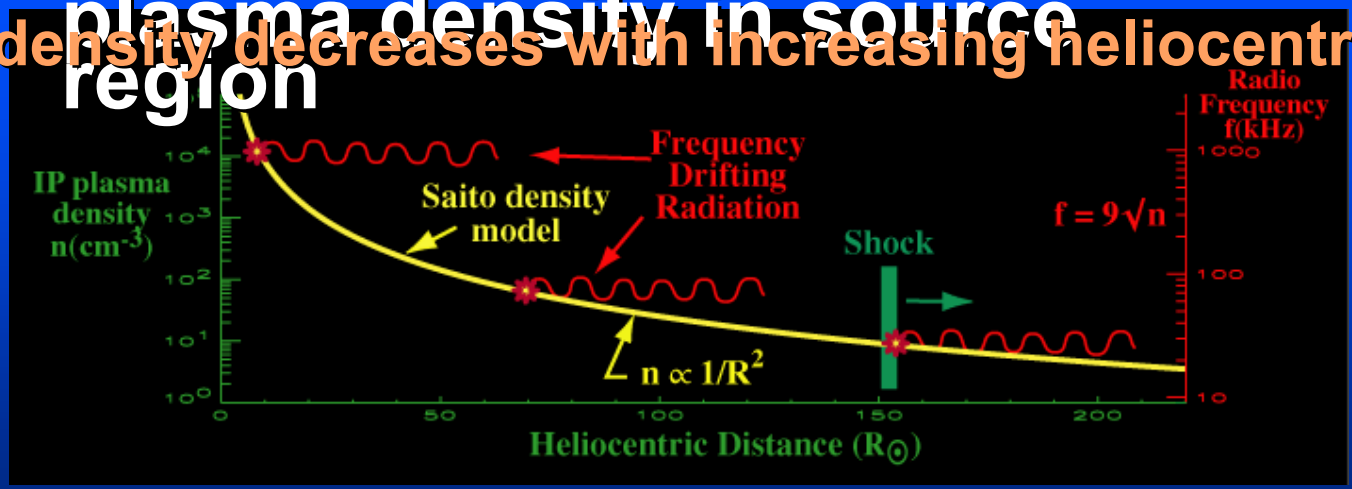
- **Both** generated by the plasma emission mechanism at frequency:

$f = f_p(kHz) = 9 \div n(cm^{-3})$ or $f = 2\ f_p(kHz)$

i.e., fundamental and/or harmonic of the plasma frequency

fi **Radio emissions remotely measure plasma density in source region**

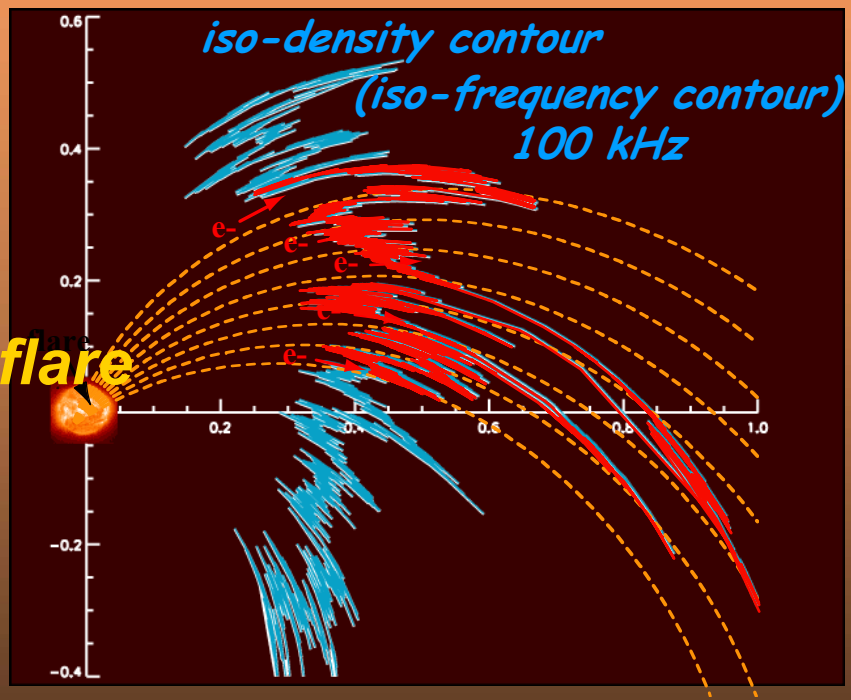
- **Plasma density decreases with increasing heliocentric distance**



fi **Explains the observed frequency drift**

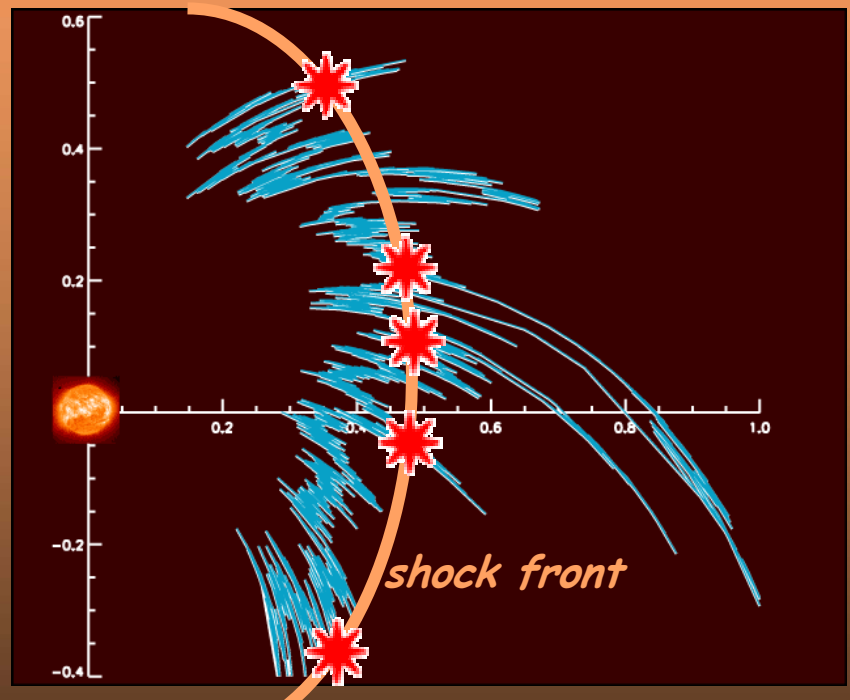
Source Region Models

Type III radio emissions



confined beam/ radio source

Type II radio emissions



wide beam/ radio source

what they can be used for

Type III radio emissions

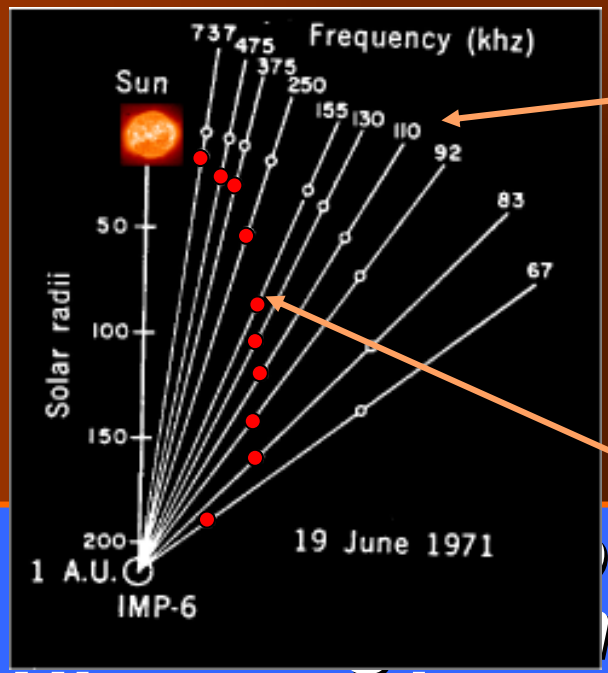
Study characteristics of electron beams and topological structure of the IMF

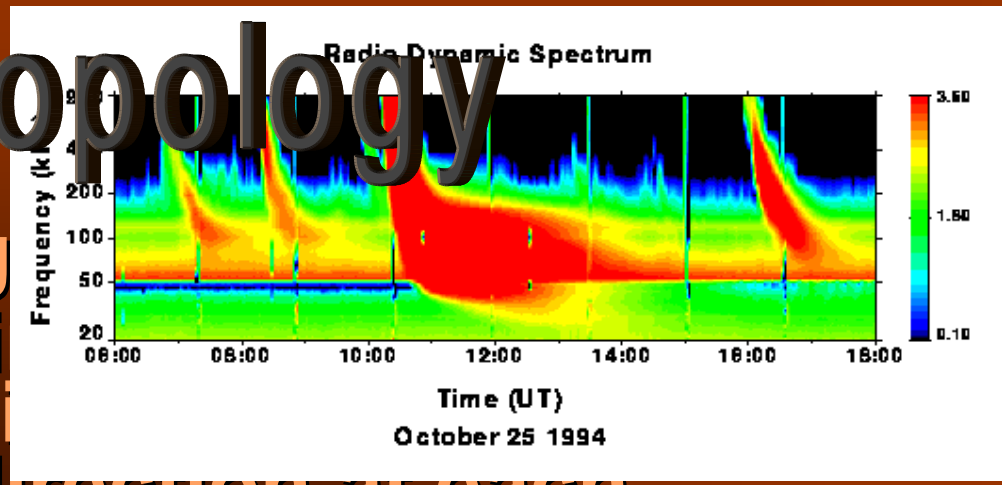
Type II radio emissions

Study evolution and dynamics of CMEs, Sun to Earth

Remote Type III Observations

IMF Topology





U
fi
si
direction at each
observing frequency

Use density law to determine radio source location along line of site at each frequency

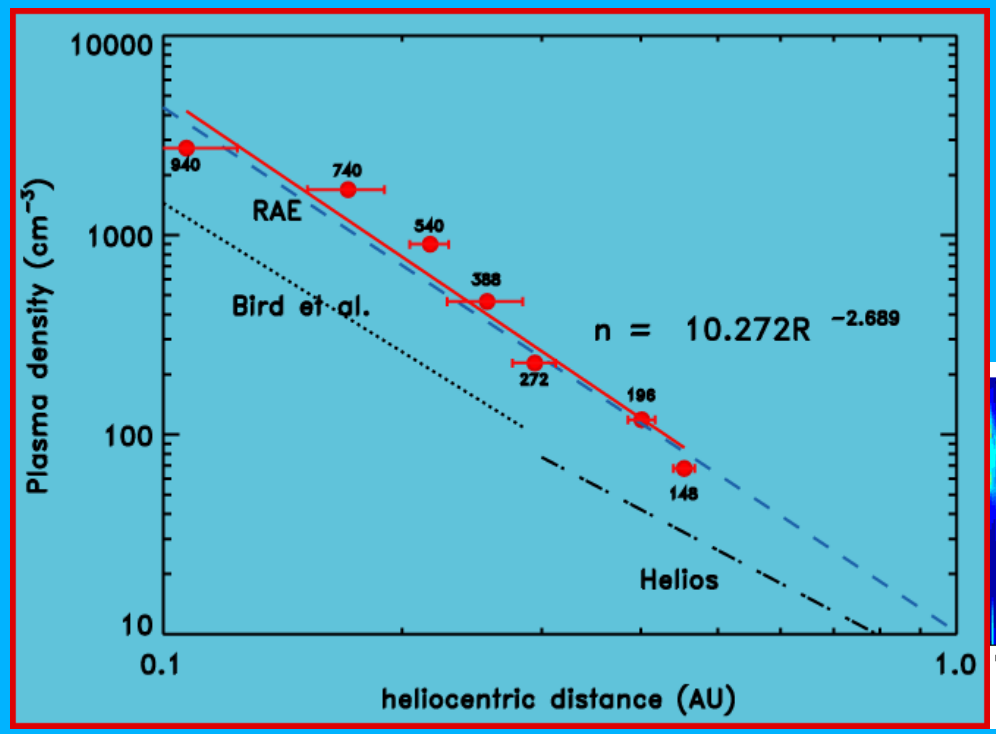
Ulysses gives 2-D trajectory without using a density model

urce centroid
rchimedean
spiral path

Wind/Ulysses (Stereo) Triangulation

(simultaneous radio source direction-finding from two widely separated s/c)

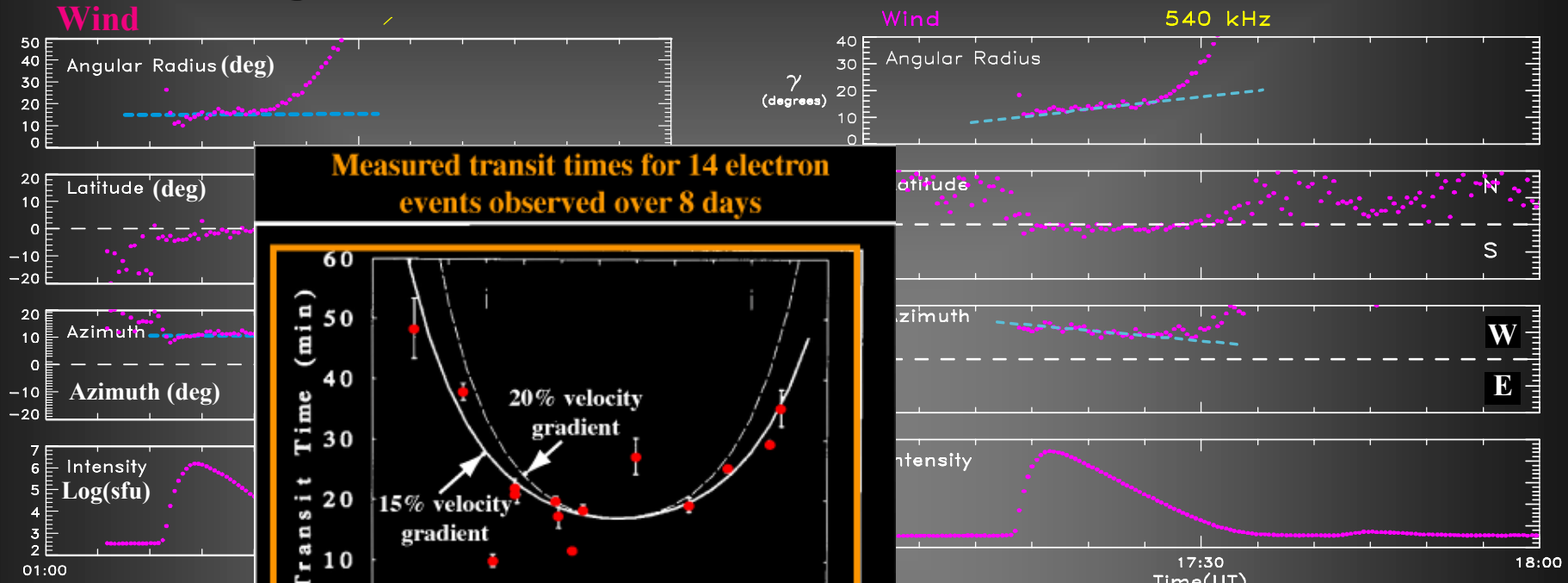
- *Two s/c triangulation can give the 3-D radio source trajectory, without the need for a density model*



- *plasma density profile along type III trajectory*
- *"true" radio source intensity*
- *radiation propagation times*

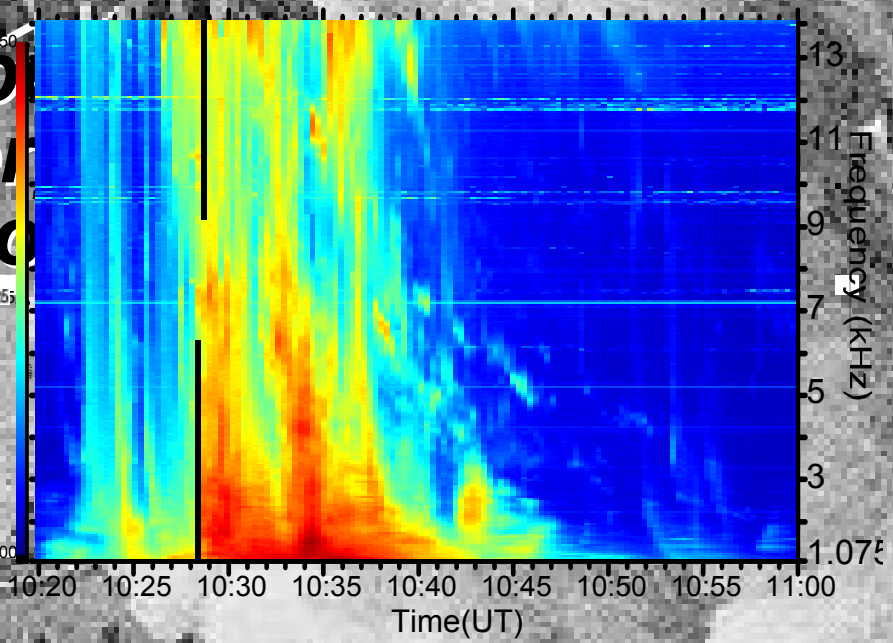
Remote Type III Observations

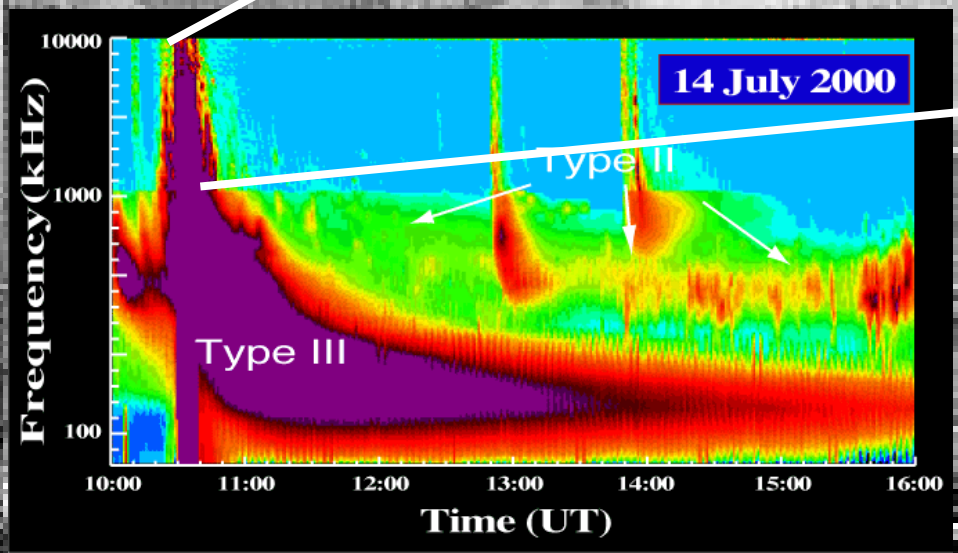
Source region & electron beam characteristics



Bastille Day Event 2000

Lift off of CMEs and typ
usually preceded by ver
complex type III emissio





These complex type IIIs have unusual characteristics in the 1 to 15 MHz band

- ***diminution in intensity near 7 MHz***
- ***very narrow band features below 7 MHz***

Remote Type II Observations

CME Dynamics & Evolution: 1/f tracking

$f = 9 \div n$

$n \sim 1/R^2$ → $f \sim 1/R$

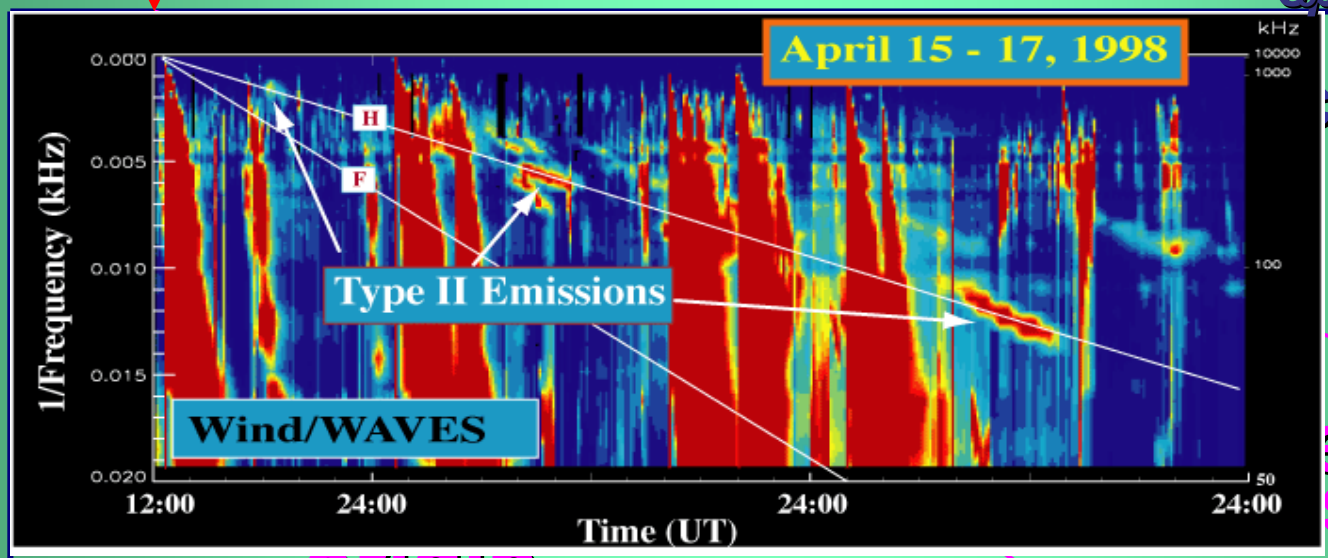
$$1/f \sim R = (v_s/9 \div n_o)(t - t_o)$$

(CME) liftoff time, t_o

time

v_s = shock speed

t_o = liftoff time



1/f

Spectrum

ed

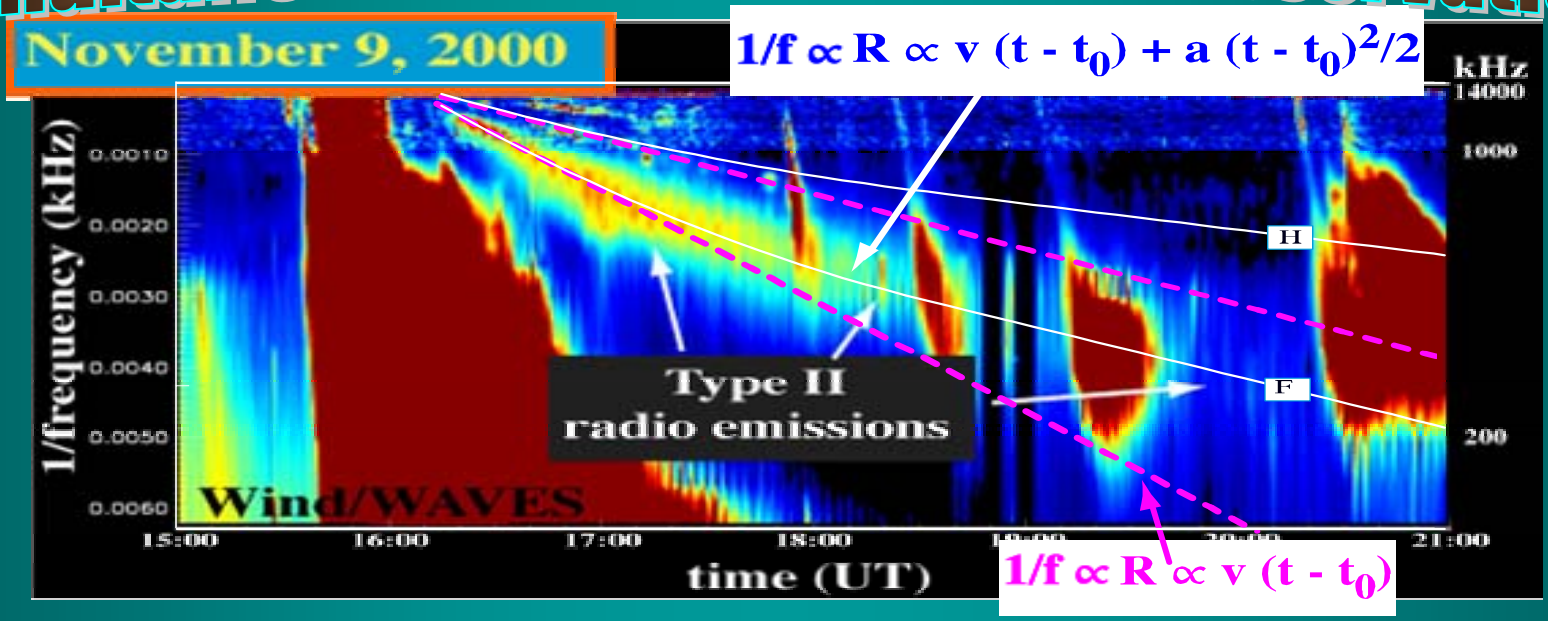
solar

origin

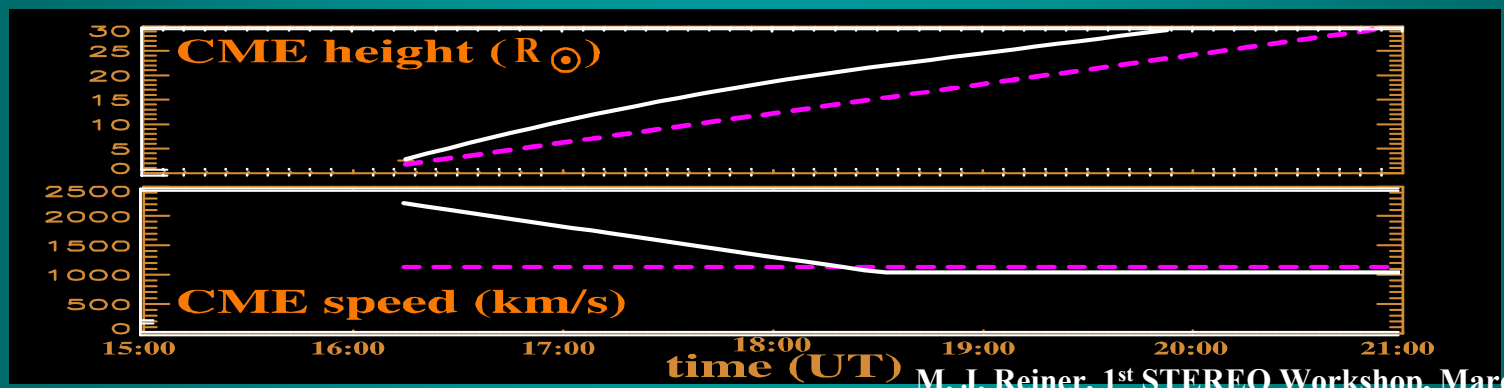
fi

CMEs propagate at ~ constant speed through IPM

Constraints on CME Dynamics & Evolution by Simultaneous In-situ and Radio Observations



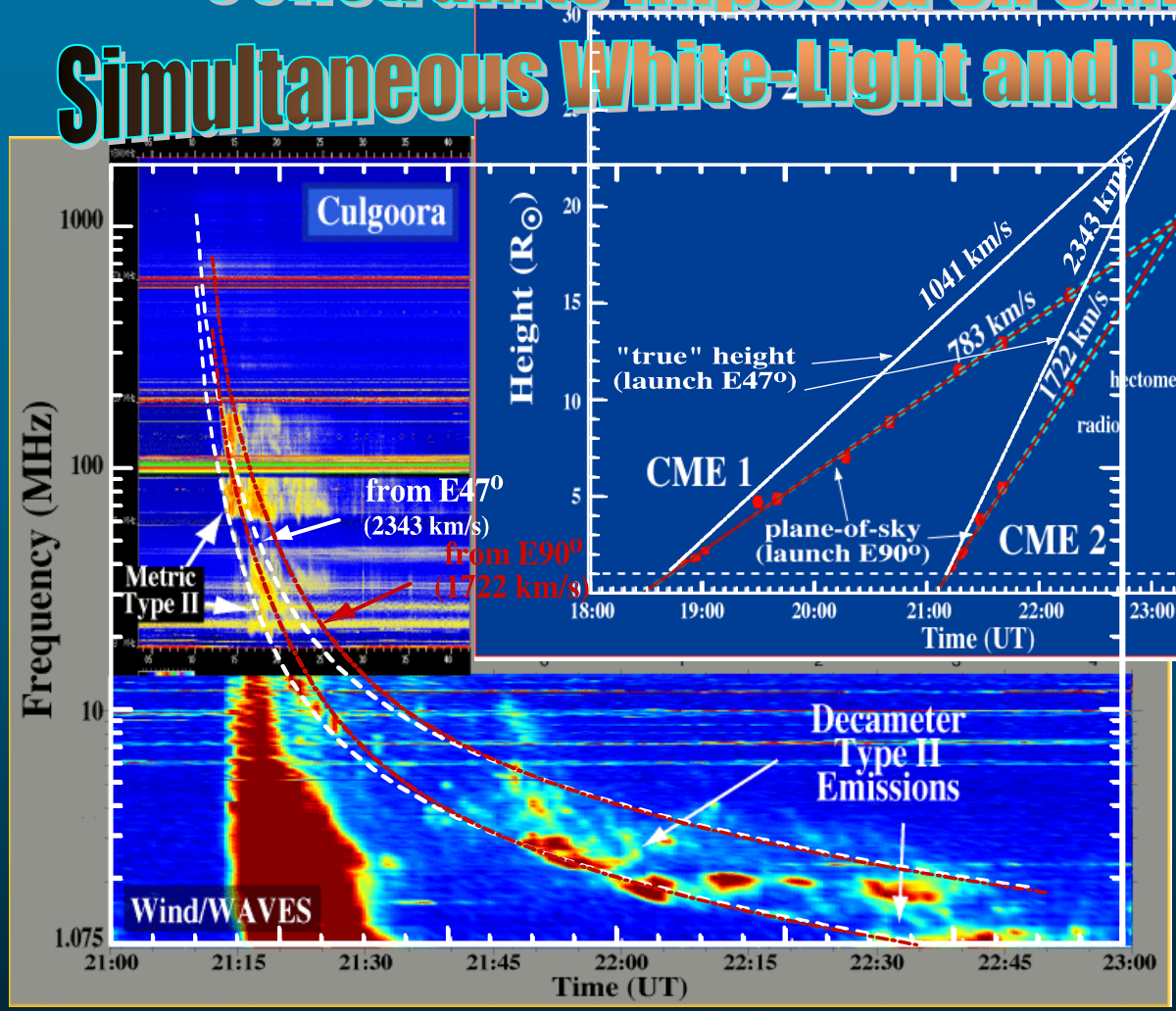
Knowing the shock speed at 1 AU and by fitting the radio frequency drift, we get the "true" height & speed profile of the CME from Sun to 1 AU

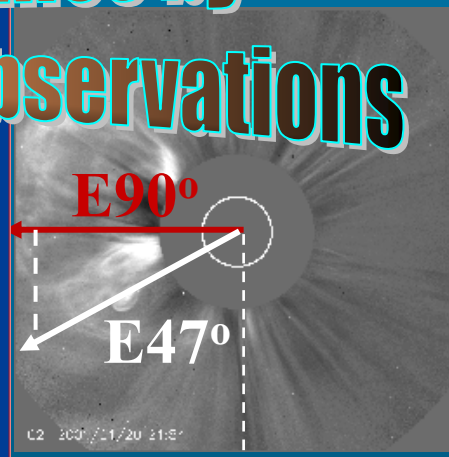


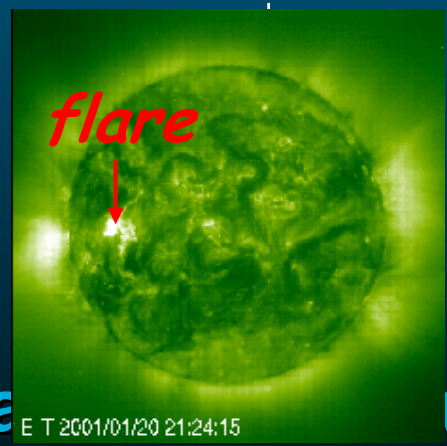
Comparison of Radio/White-Light Observations

white-light		Radio
White-light images at consecutive times	€	*Type II radio emissions at decreasing frequency*
Measure height vs. time	€	*Measure frequency drift*
→ Plane-of-sky height & speed of CME	€	*"true" (radial) height & speed of radio source*
Coronal density profile can be measured	€	*Coronal density profile "unkown"*

Constraints Imposed on CME Dynamics by Simultaneous White-Light and Radio Observations







Consistency between White-Light & Ra
fi Radial propagation from 47° ± 3°E ("launch angle")

Flare site ≈ N7°E46°

STEREO Radio Observations

Radio Measurements

- Radio dynamic spectra (intensities) from two viewpoints
- 3-D radio source location routinely deduced by triangulation
- In-situ e- beams, Langmuir waves and Local radiation

New and unique physics

- *Intrinsic nature & characteristics of type II & III source*
  - true source intensities
  - beaming effects
  - propagation time & effects
- *Evolution & dynamics of solar transient phenomena*
  - direct 3-D tracking of radio sources from Sun to Earth
  - relationship of radio sources to white-light features
- *Remote radio probing of interplanetary plasma properties*
  - plasma density profiles along radio source trajectories
  - global 3-D reconstruction of IMF from active regions
  - relationship of radio source region to interplanetary structures
- *Characteristics of e- beams related to radio emissions*
  - exciter speed profiles
  - injection times & path lengths
  - relation to Langmuir waves & local radiation