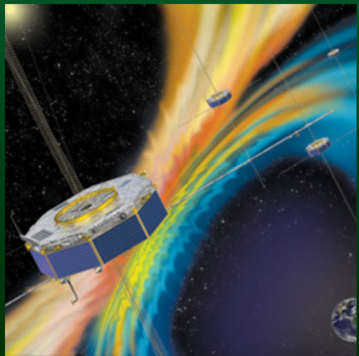
Polynomial reconstruction using data from a range of time

R. E. Denton and Y.-H. Liu,



The original idea

- MMS Jp_{sc} from FPI is very accurate
- Find quadratic B_{model} from fits to B_{sc} and Jp_{sc} (assuming $Jp = \nabla \times B_{model}$)
- Conditions to keep $\nabla \cdot B_{model} = 0$
- Usually use a17 parameter model motivated by the ordering $\partial/\partial n \gg \partial/\partial l \gg \partial/\partial m$

where n, l, and m are the directions of maximum, intermediate, and minimum gradient

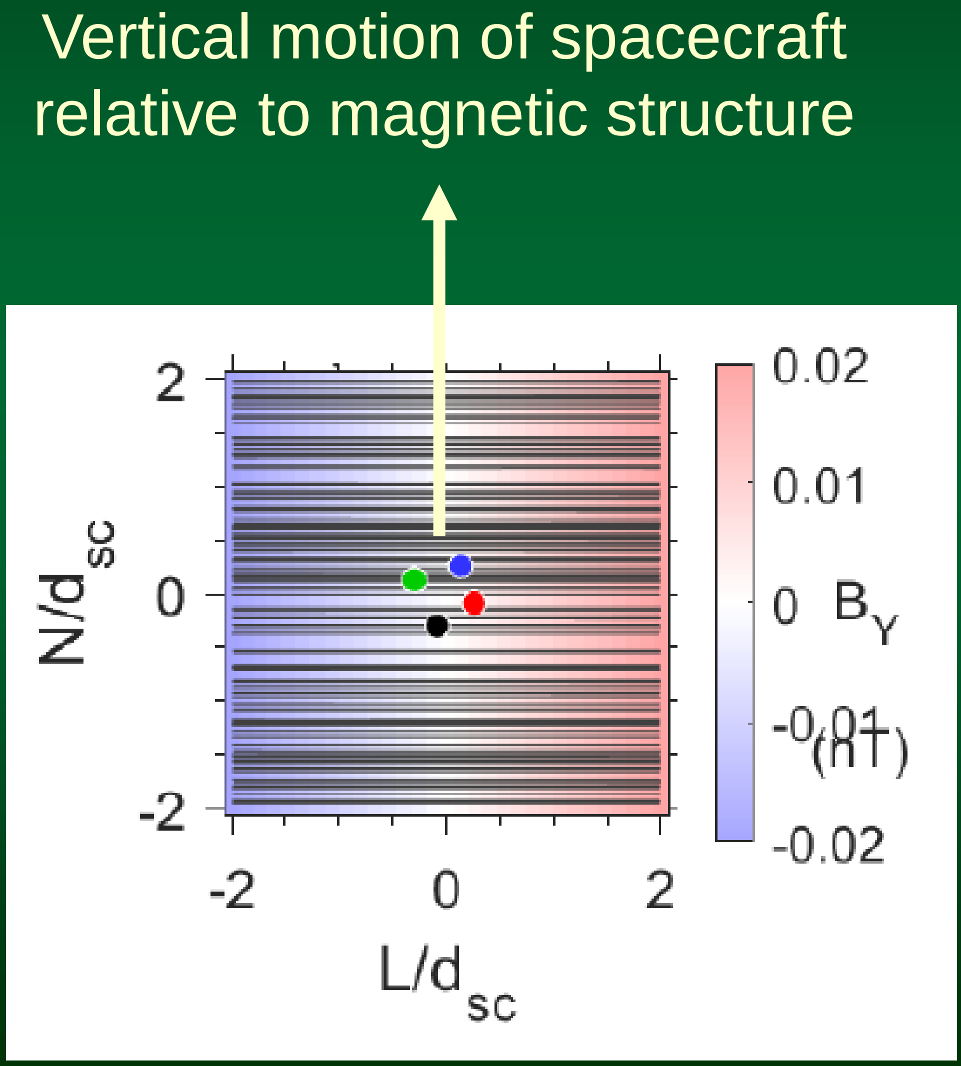
- Find best least-squares fit for model coefficients

Extend to multiple times

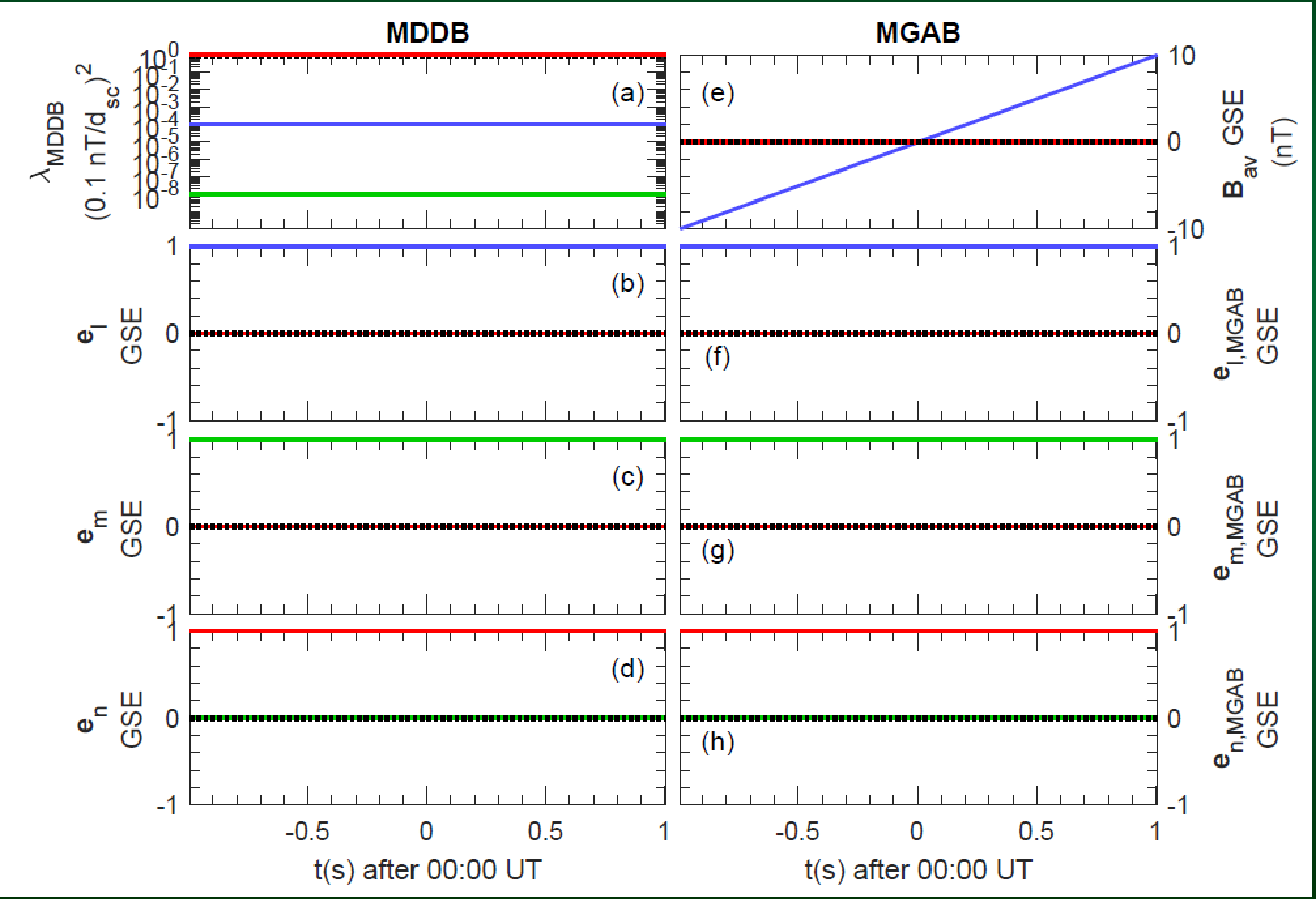
- In the original scheme, the reconstruction is done at each particular time, yielding the reconstructed magnetic field at that time
- Here, we use a sequence of times assuming that a stationary magnetic structure is convecting past the spacecraft with a constant velocity
- We vary the structure velocity and polynomial coefficients of the reconstruction in order to get a best least-squares fit to the magnetic field and particle current density observed by the spacecraft
- By this means, we find not only the reconstructed magnetic field, but also the optimal structure velocity relative to the spacecraft

Test Case

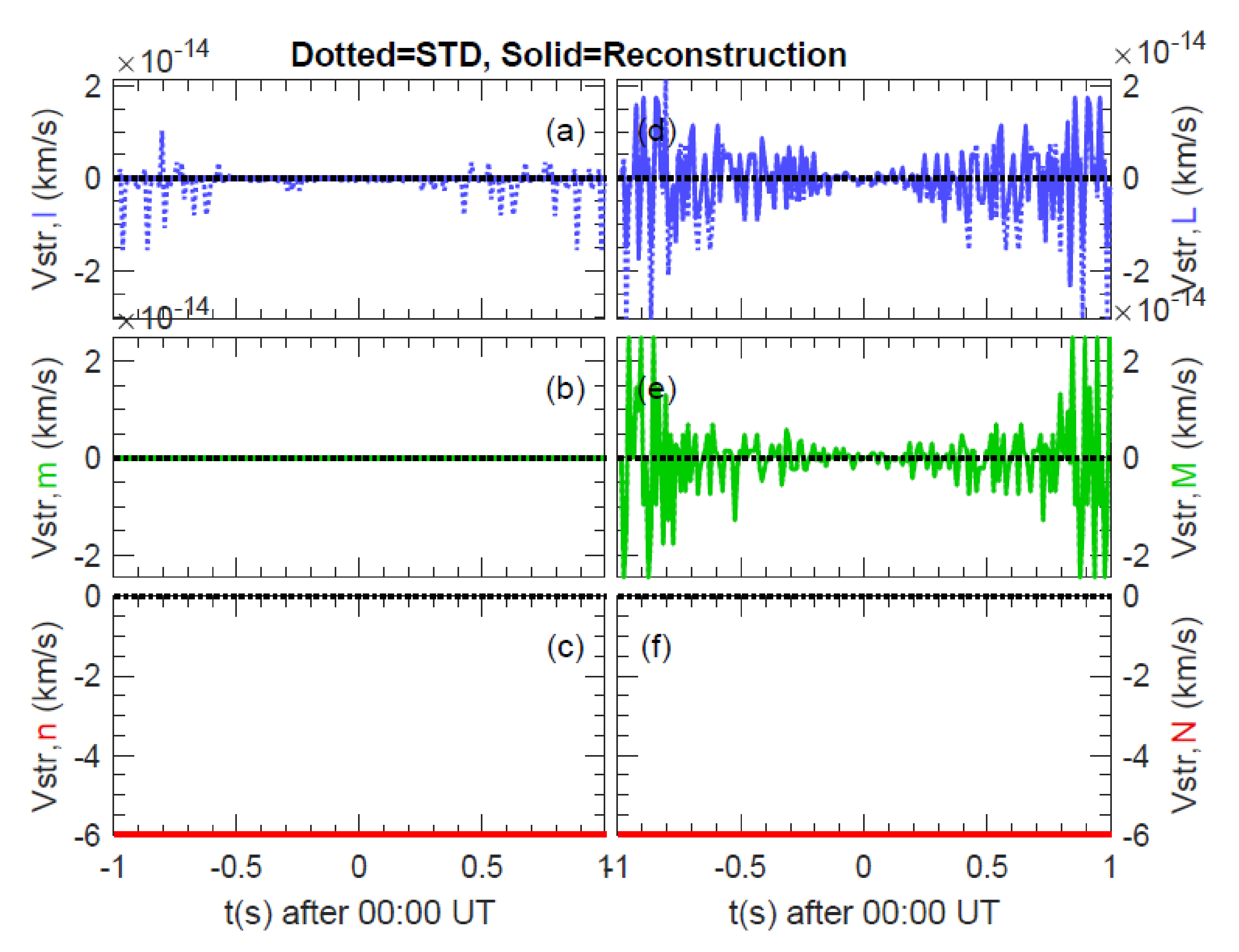
- $B_L = N$
- $B_M = L / 100$
- $B_N = M / 10000$



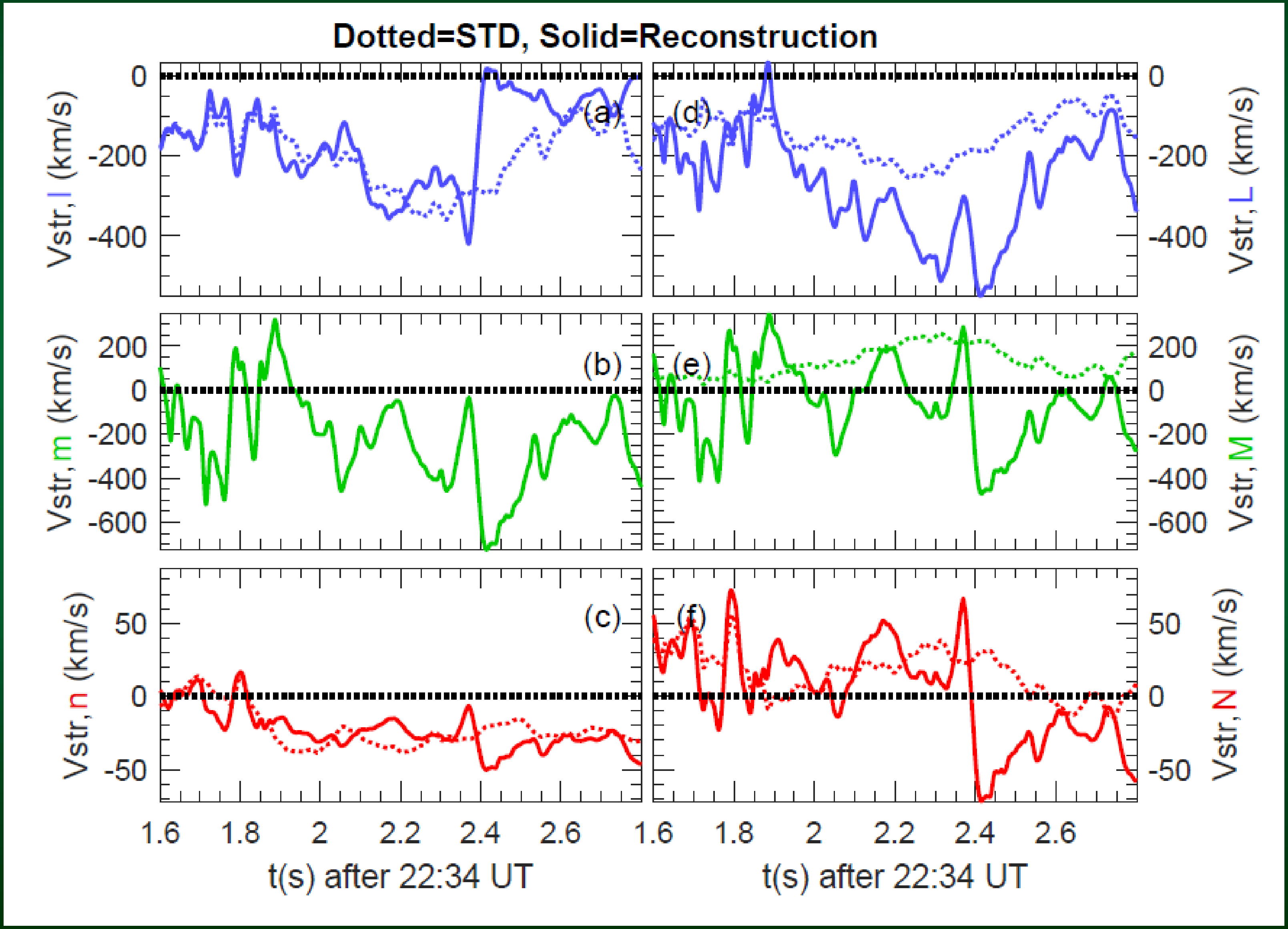
Local gradient (MDD) and variance (MGA) analysis



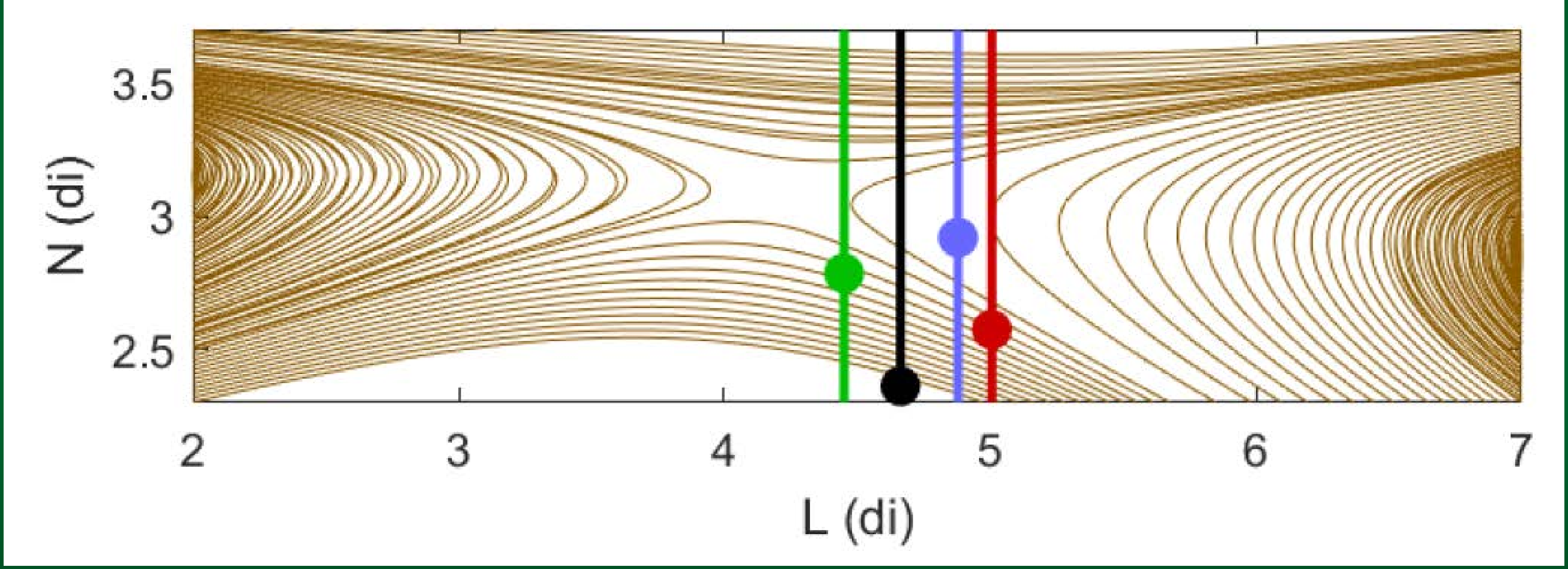
Reconstruction Velocity



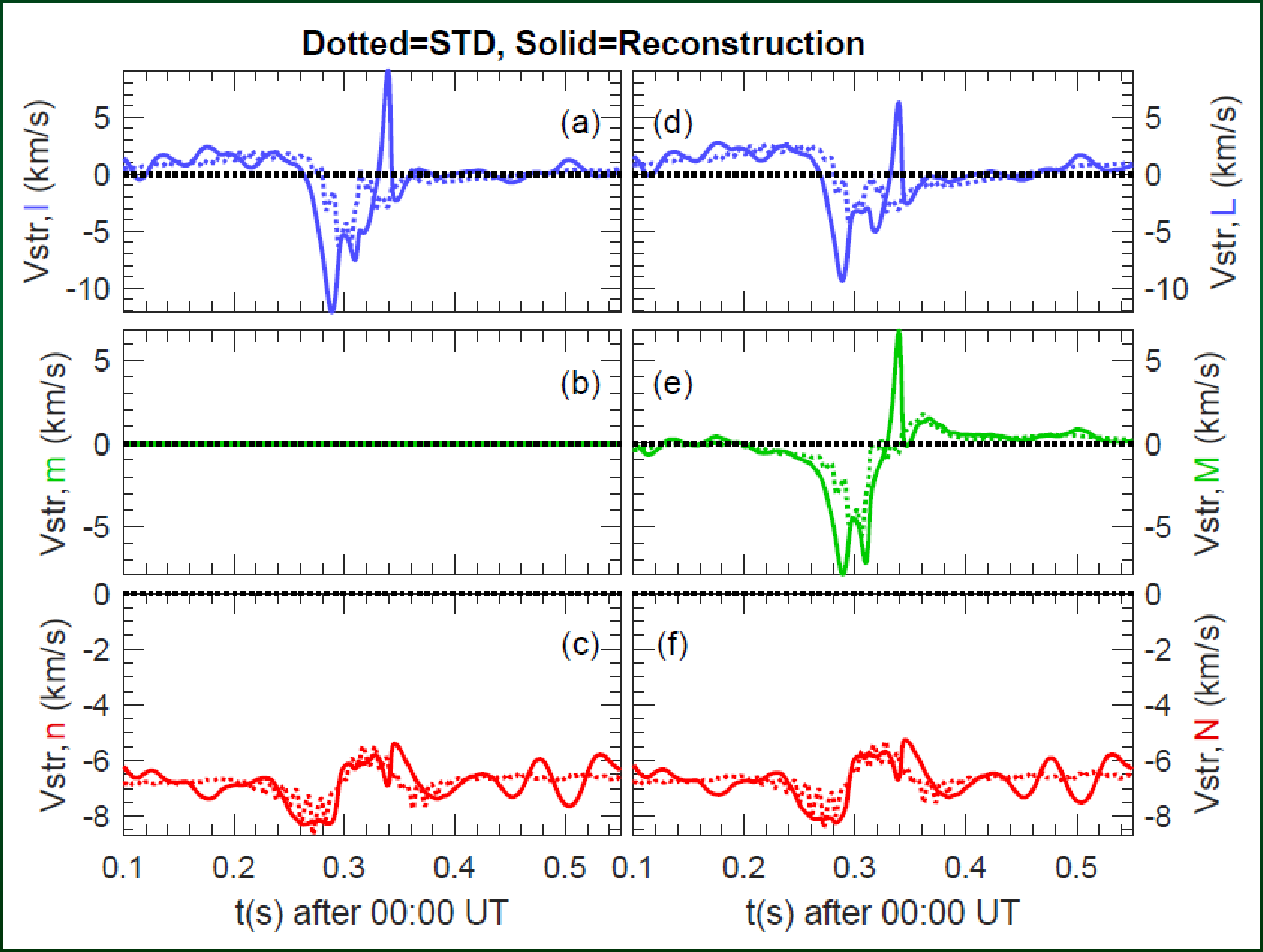
Science paper magnetotail event (Torbert et al., 2018)



Fly through a 3D reconnection simulation



Velocity in simulation fields



Conclusions

- The goal is to reconstruct the magnetic field and get the structure velocity at the same time
- We get exactly the right velocity for a simple test case
- Results using simulation data are promising, but we need to work out some issues

Extras

Equations

$$
\begin{aligned}
B_l &= B_{l,0} + \frac{\partial B_l}{\partial n} n + \frac{\partial B_l}{\partial l} l + \frac{\partial B_l}{\partial m} m + \frac{\partial^2 B_l}{\partial n^2} \frac{n^2}{2} \\
B_m &= B_{m,0} + \frac{\partial B_m}{\partial n} n + \frac{\partial B_m}{\partial l} l + \frac{\partial B_m}{\partial m} m \\
&\quad + \frac{\partial^2 B_m}{\partial n^2} \frac{n^2}{2} + \frac{\partial^2 B_m}{\partial n \partial l} nl + \frac{\partial^2 B_m}{\partial l^2} \frac{l^2}{2} \\
B_n &= B_{n,0} + \frac{\partial B_n}{\partial n} n + \frac{\partial B_n}{\partial l} l + \frac{\partial B_n}{\partial m} m + \frac{\partial^2 B_n}{\partial l^2} \frac{l^2}{2}
\end{aligned}
$$

$$
\frac{\partial B_n}{\partial n} + \frac{\partial B_l}{\partial l} + \frac{\partial B_m}{\partial m} = 0
$$

$$
\begin{aligned}
\mu_0 J_l &= \frac{\partial B_n}{\partial m} \\
&\quad - \left(\frac{\partial B_m}{\partial n} + \frac{\partial^2 B_m}{\partial n^2} n + \frac{\partial^2 B_m}{\partial n \partial l} l \right) \\
\mu_0 J_m &= \frac{\partial B_l}{\partial n} + \frac{\partial^2 B_l}{\partial n^2} n \\
&\quad - \left(\frac{\partial B_n}{\partial l} + \frac{\partial^2 B_n}{\partial l^2} l \right) \\
\mu_0 J_n &= \frac{\partial B_m}{\partial l} + \frac{\partial^2 B_m}{\partial n \partial l} n + \frac{\partial^2 B_m}{\partial l^2} l \\
&\quad - \frac{\partial B_l}{\partial m}
\end{aligned}
$$