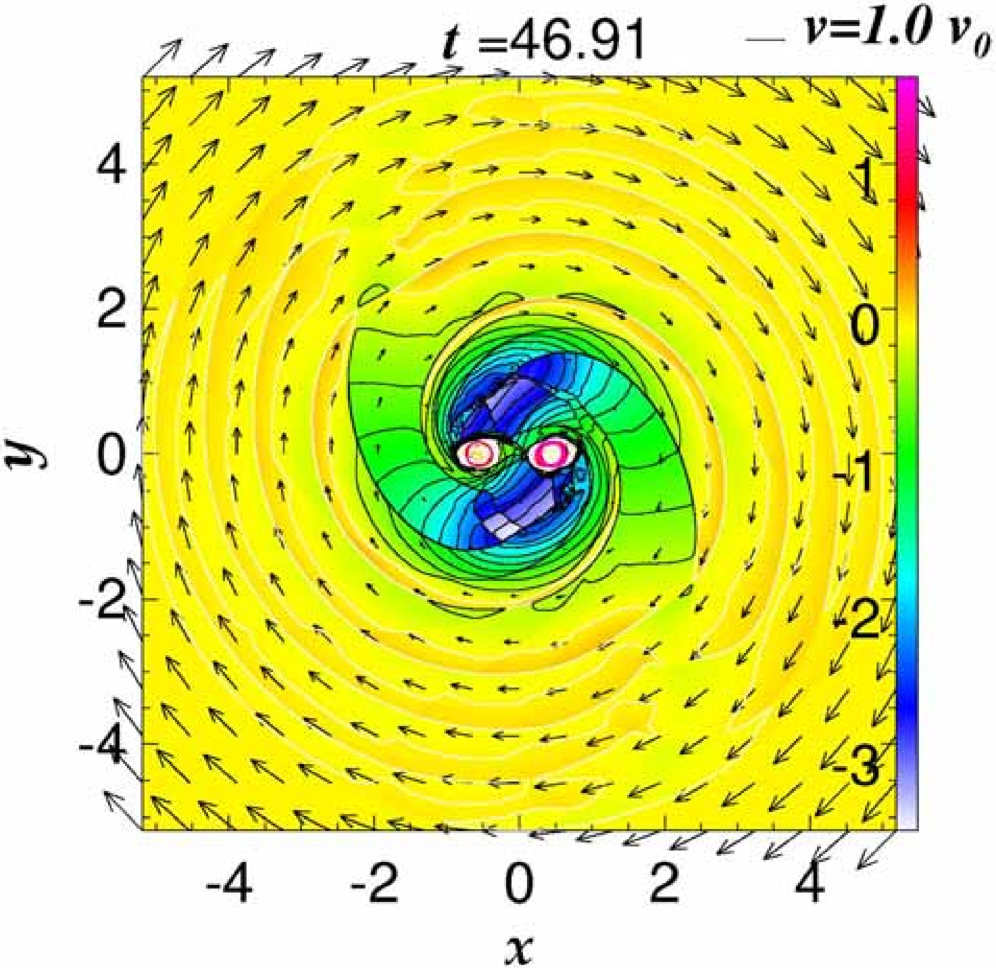
Gas Accretion from Circumbinary Disk



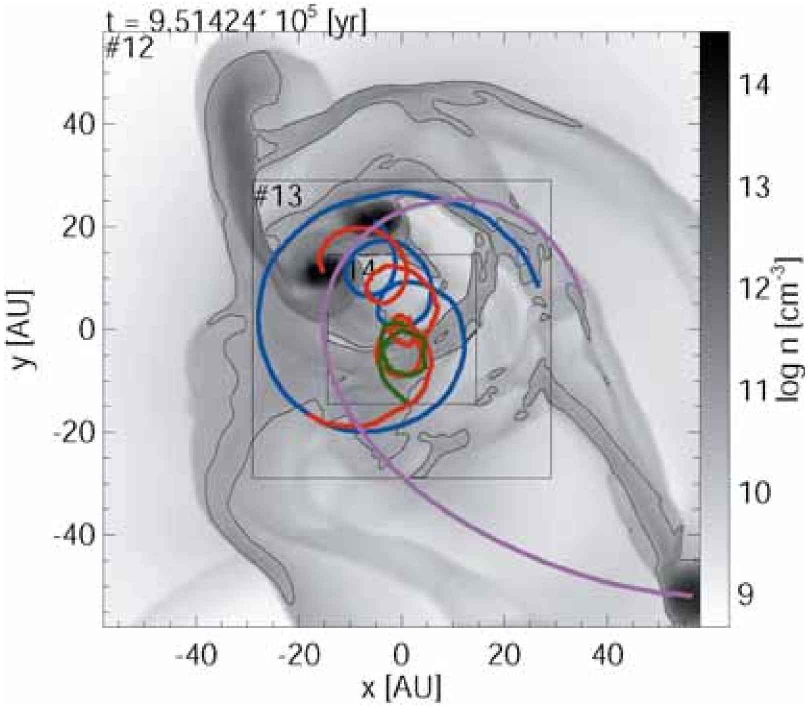
Accretion rate of primary is larger than that of secondary.

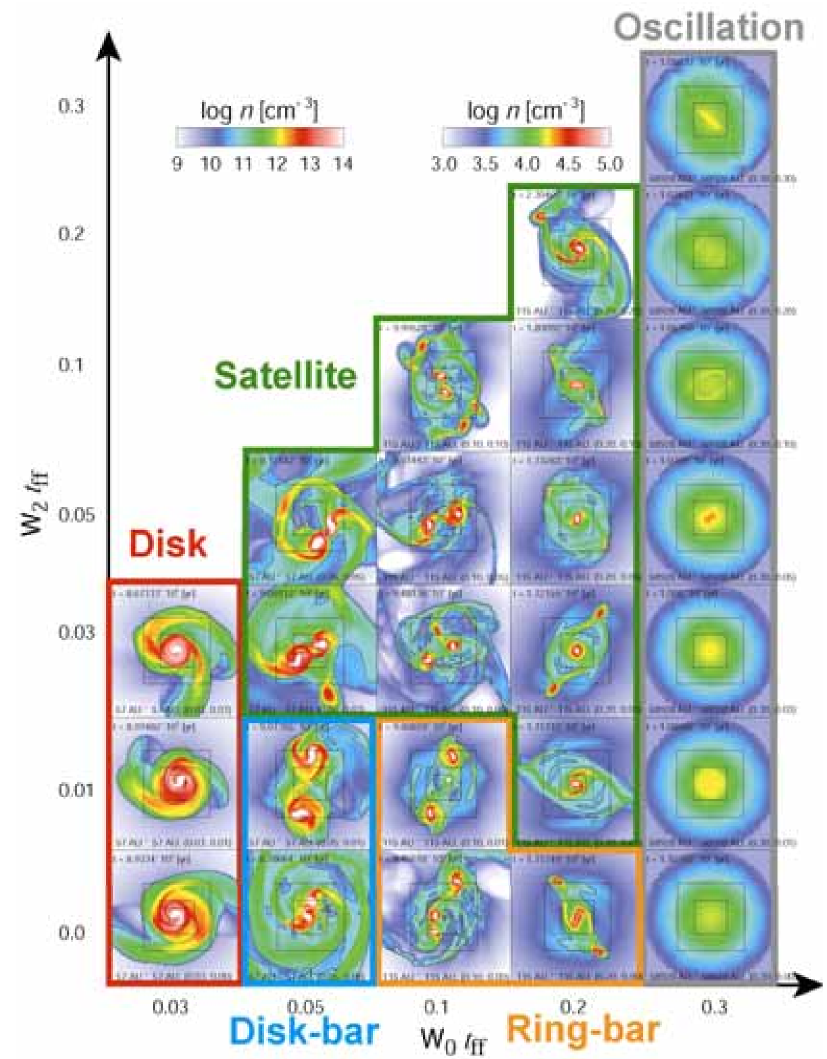
Accretion rate varies with a large amplitude.

T. Hanawa, Y. Ochi, & K. Ando

(Chiba Univ.)

Formation of Binary

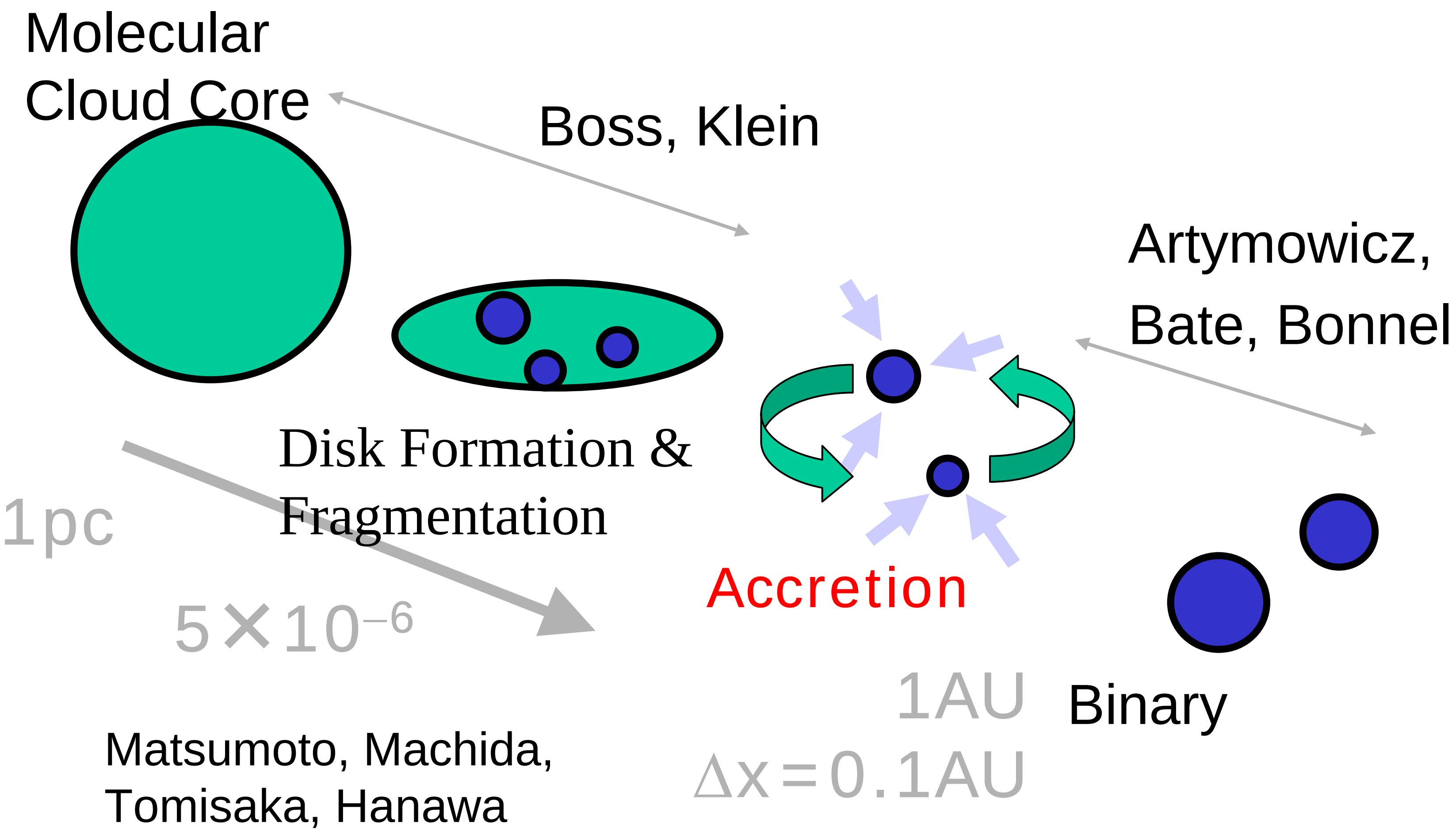




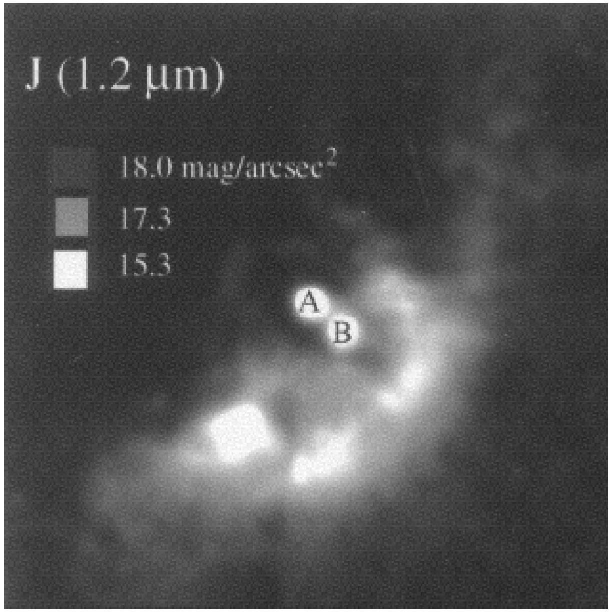
HD: Matsumoto & Hanawa (2003)

MHD: Machida et al. (2005)

Formation of Binary

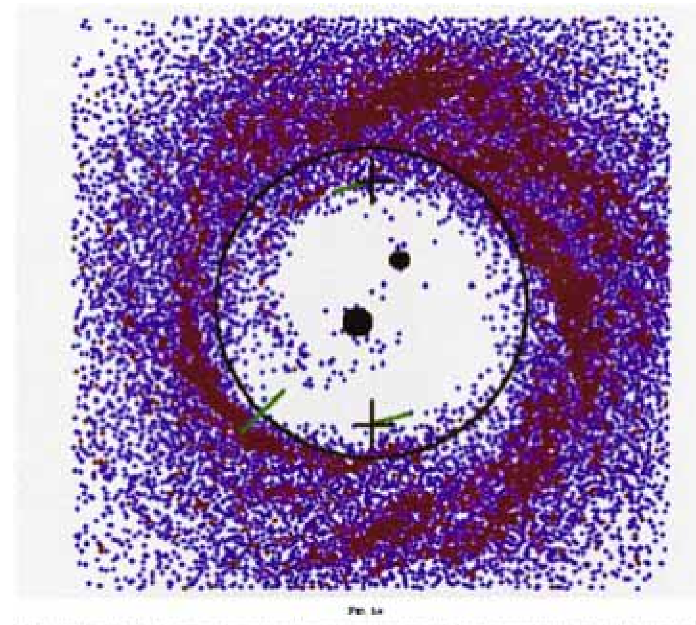


Majority of YSOs are multiple.



UY Aur (Close et al. 1998)

SPH model Artymowicz & Lubow (1996)



Accretion from circumbinary disk should be important for evolution of YSO binaries.

Q1: Does binary motion enhance the disk accretion?

Q2: Which accretes more? Secondary or Primary?

2D model

Fixed Binary orbit (no self-gravity)

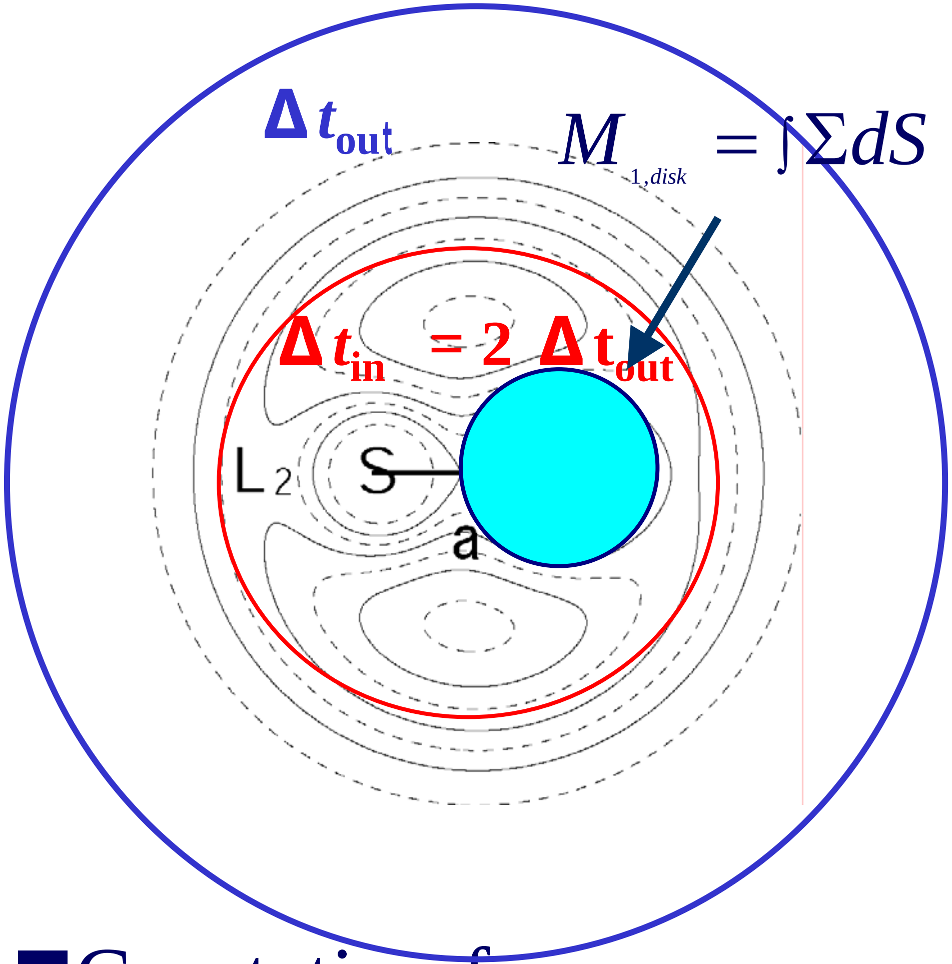
$a = 1$ (mean separation)

$q = M_2/M_1$ (mass ratio)

$\boldsymbol{\omega} = 1$ (mean angular velocity)

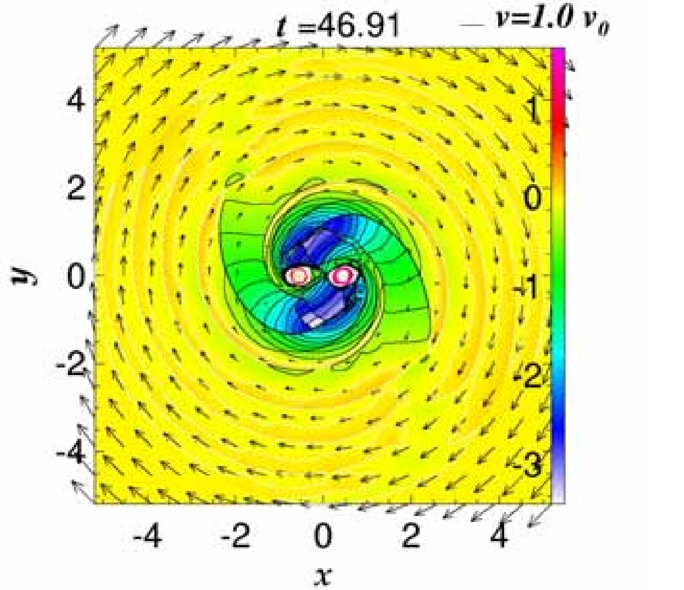
e (eccentricity)

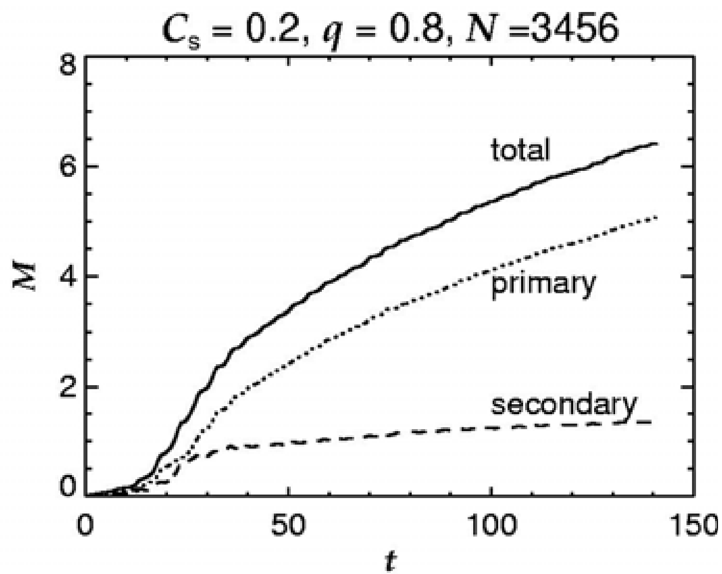
c_s: constant

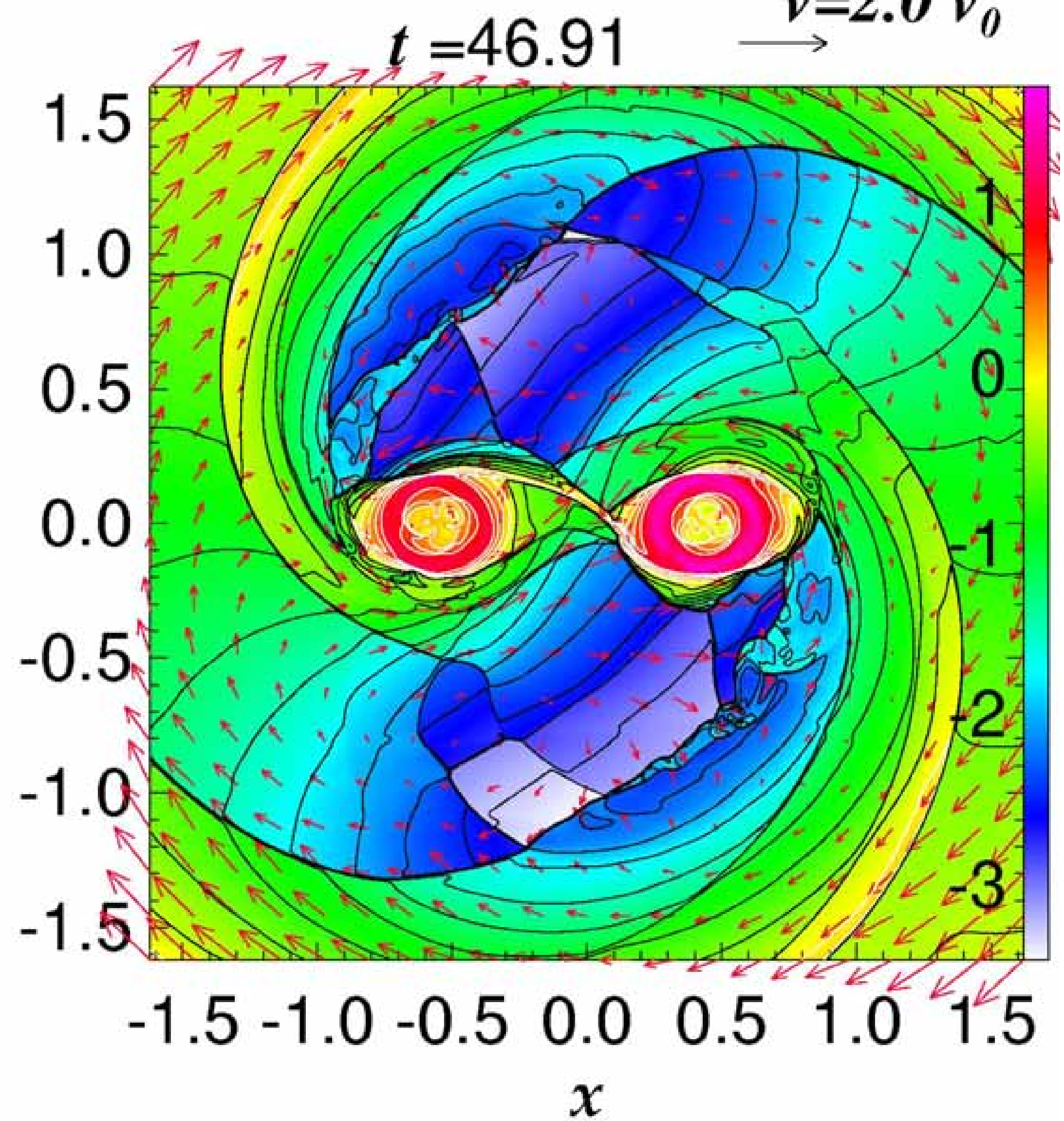


- Corotation frame
- Dual time step $D = \dfrac{\Delta x^2}{\Delta t}$
- $2400^2 \sim 3456^2$ cells

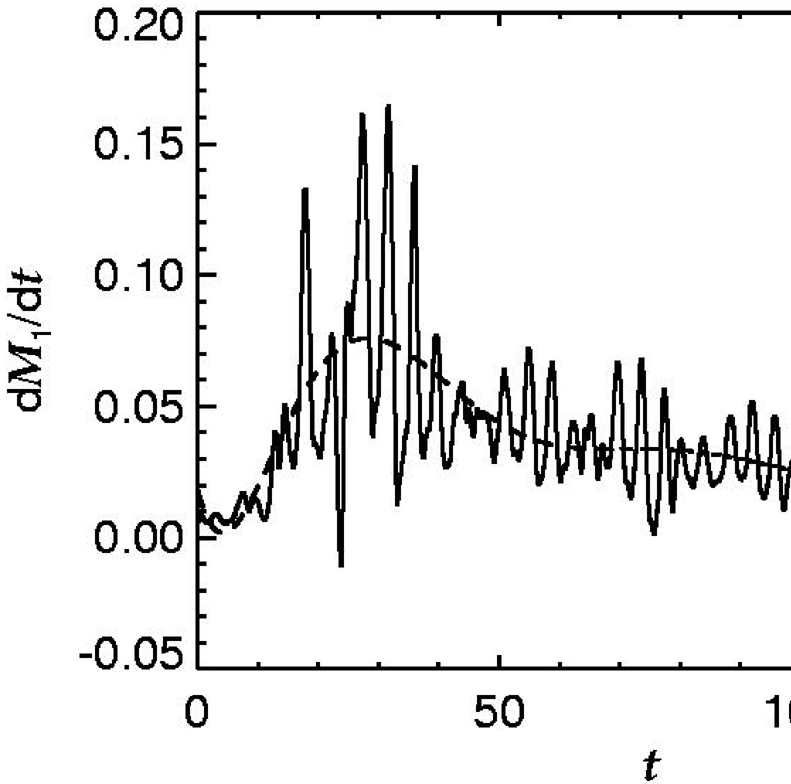
$q = 0.8$, $c_s = 0.2$, $e = 0$, $r_{in} = 1.75$, & $r_{out} = 5.18$





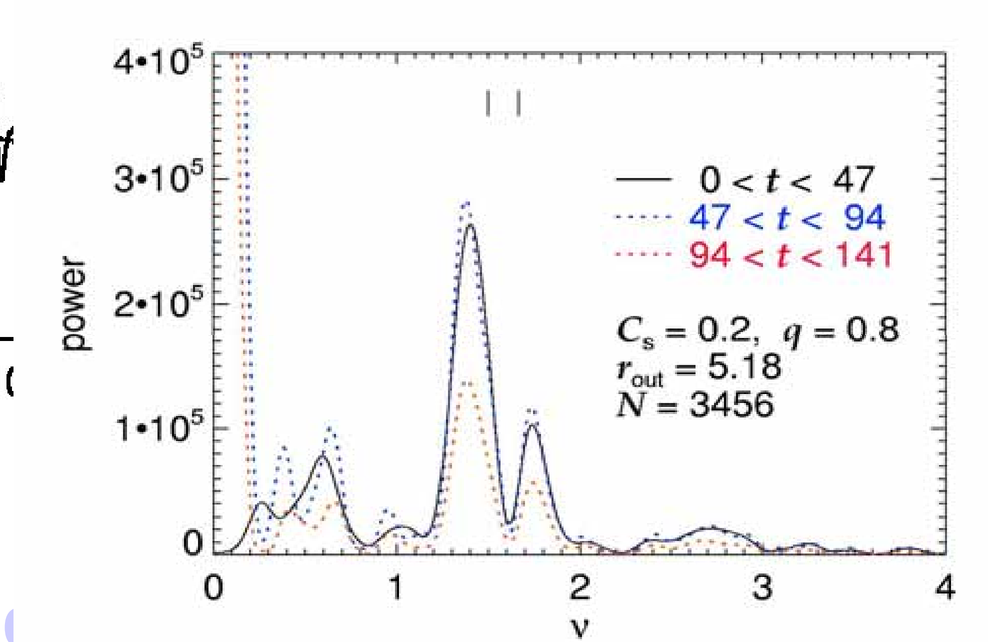


Accretion onto Primary



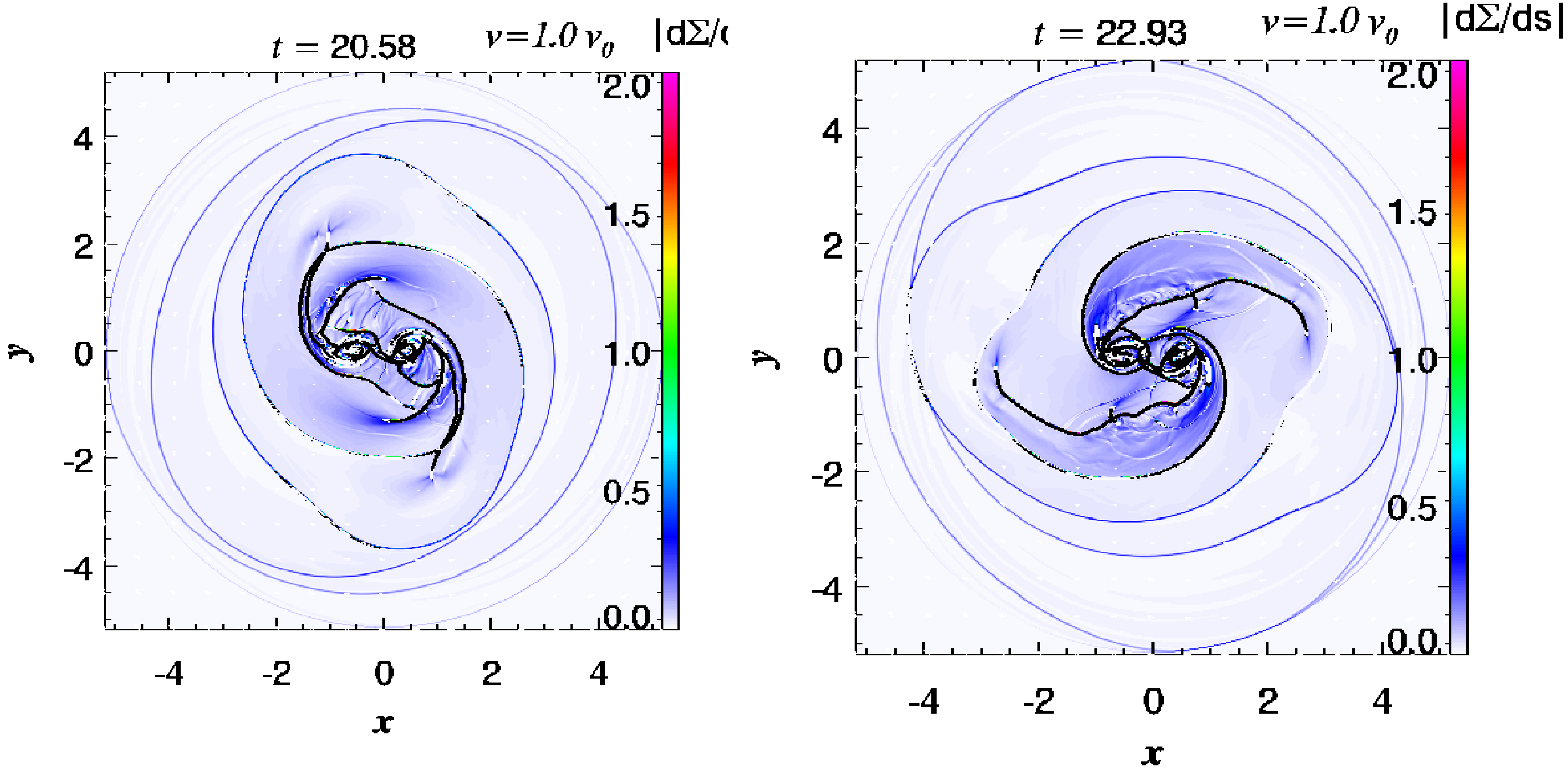
Frequency

$$\nu = \frac{3}{2}$$

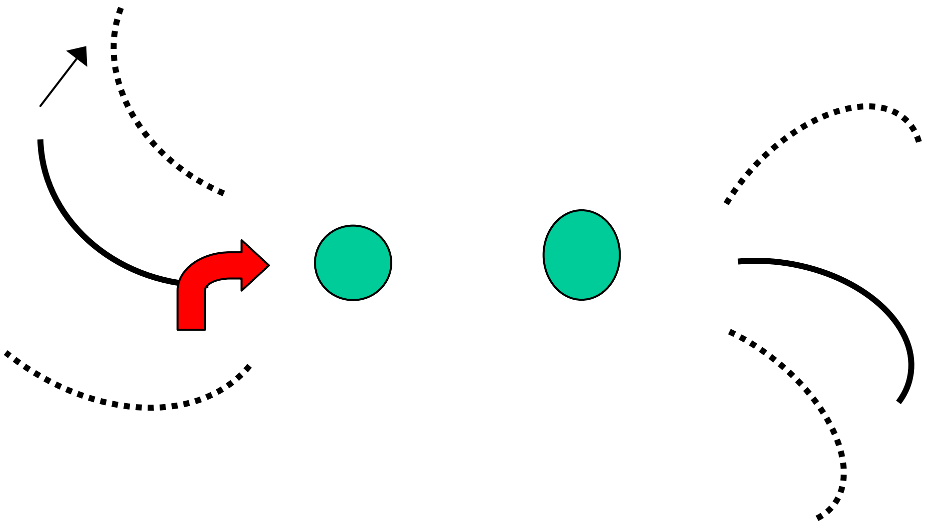


Spiral Shock Waves
excited by Resonanc

Stationary Spirals and Traveling Spirals



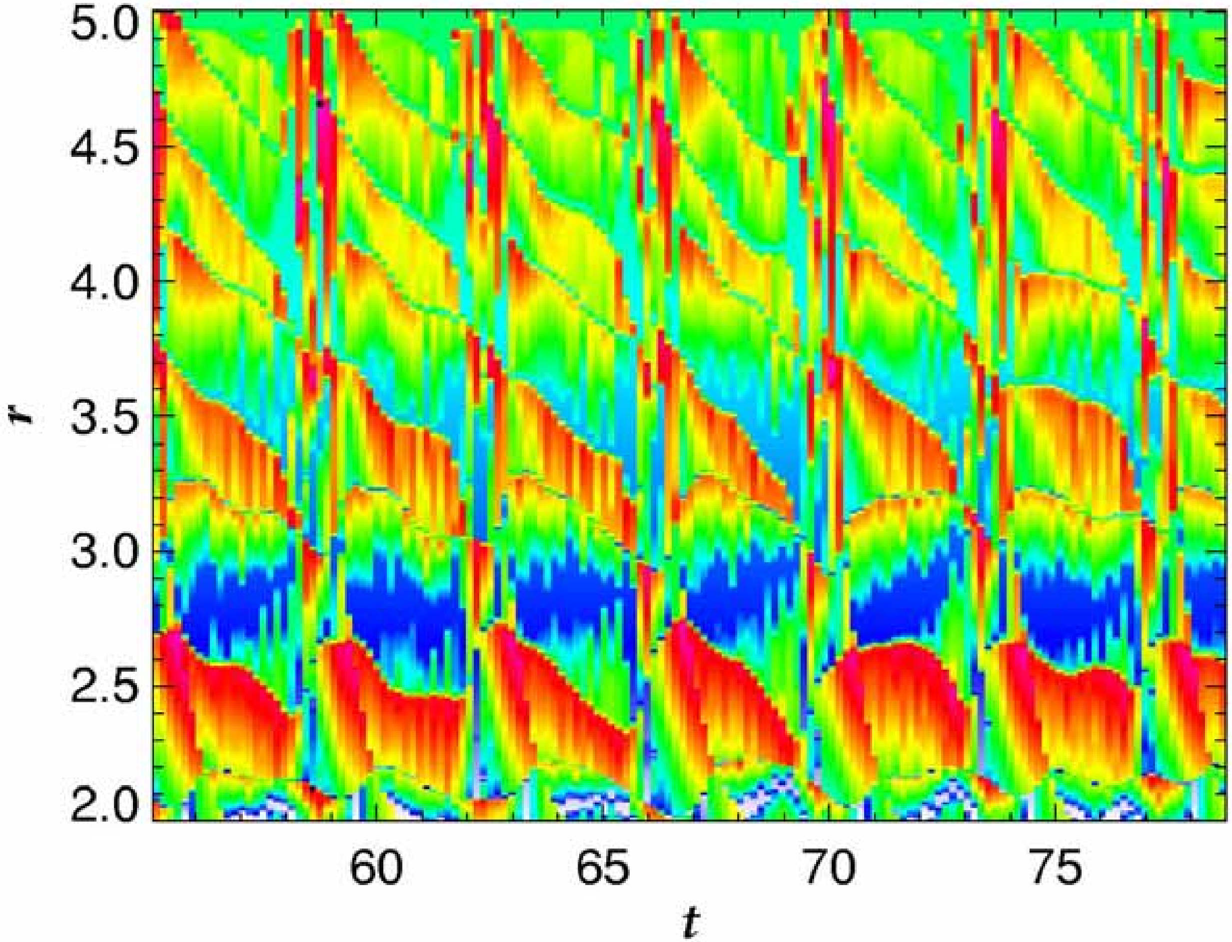
Reason for Oscillation



$$\nu = \frac{\left|\Omega_{sh} - \Omega_{*}\right|}{\pi}$$

Shock Strength

$\nabla \ln \Sigma$
$(\phi = \pi / 2)$



$\leftarrow \Omega_* / 10$

$\leftarrow \Omega_* / 8$

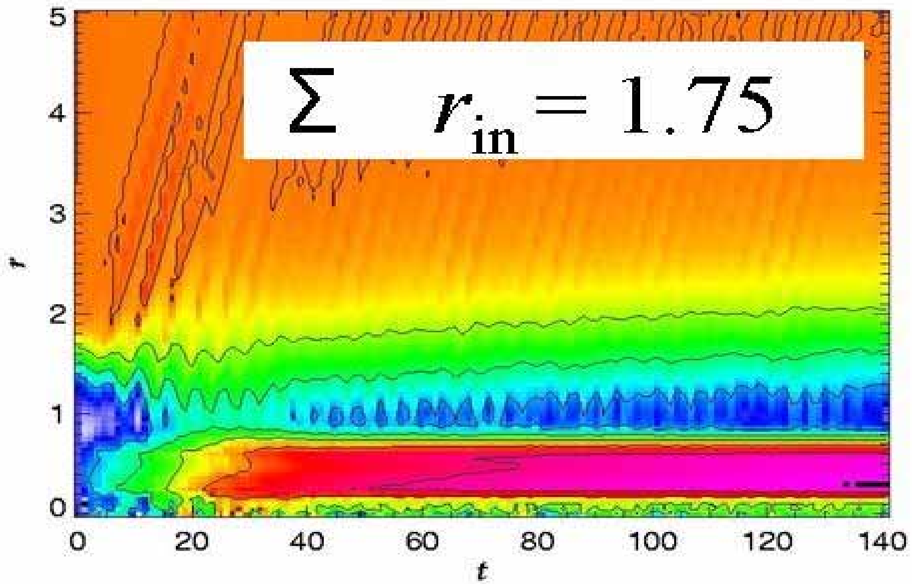
$\leftarrow \Omega_* / 6$

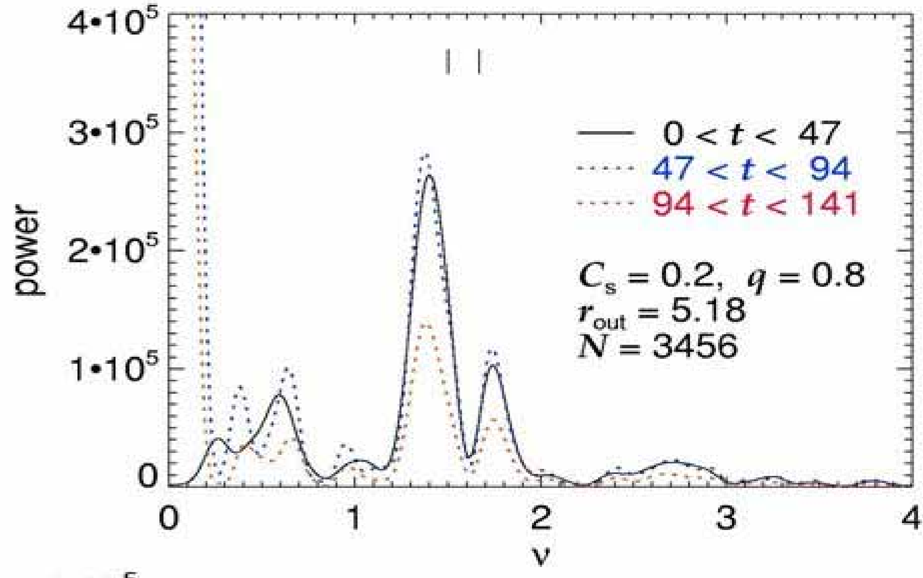
$\leftarrow \Omega_* / 4$

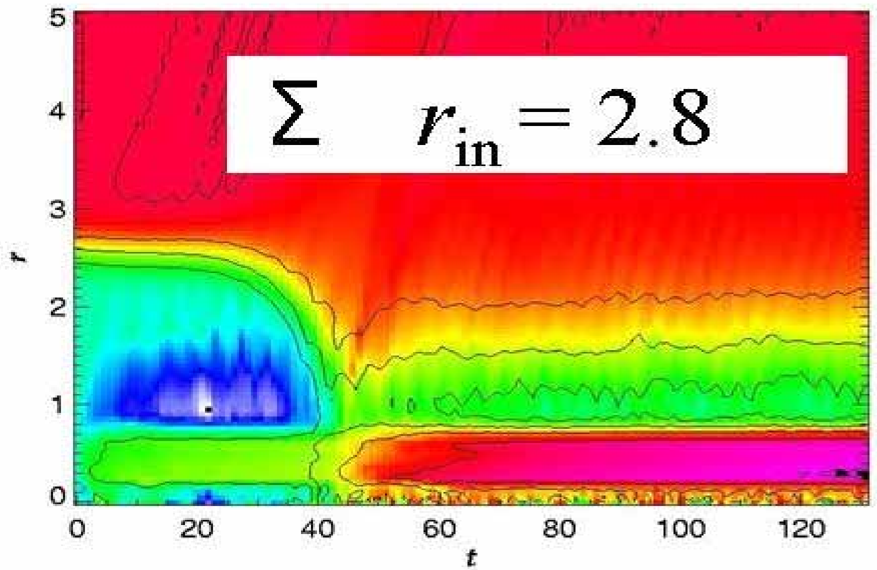
Resonances at $\mathbf{\Omega} = \mathbf{\Omega}_*/4$, $\mathbf{\Omega}*/6$, …, $\mathbf{\Omega}_*/(2n)$

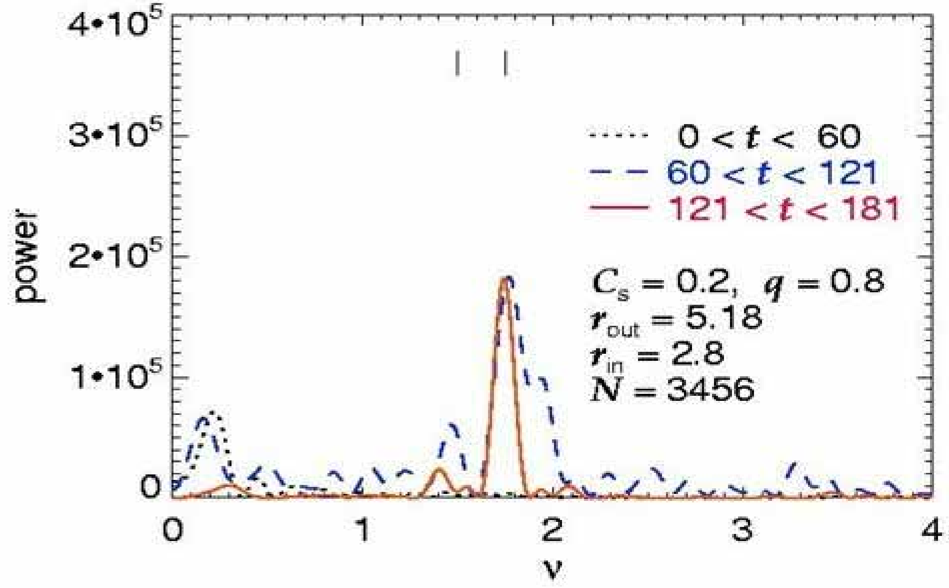
[different from the Lindblad and ultraharmonic resonances]

$\Sigma(r, t)$ and Power Spectrum

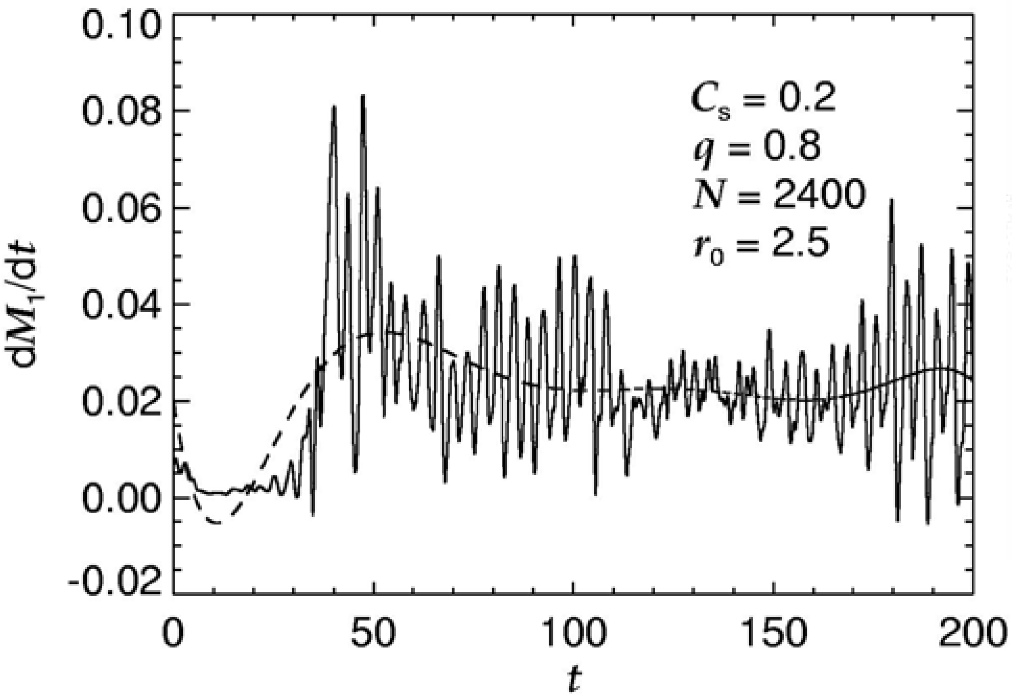


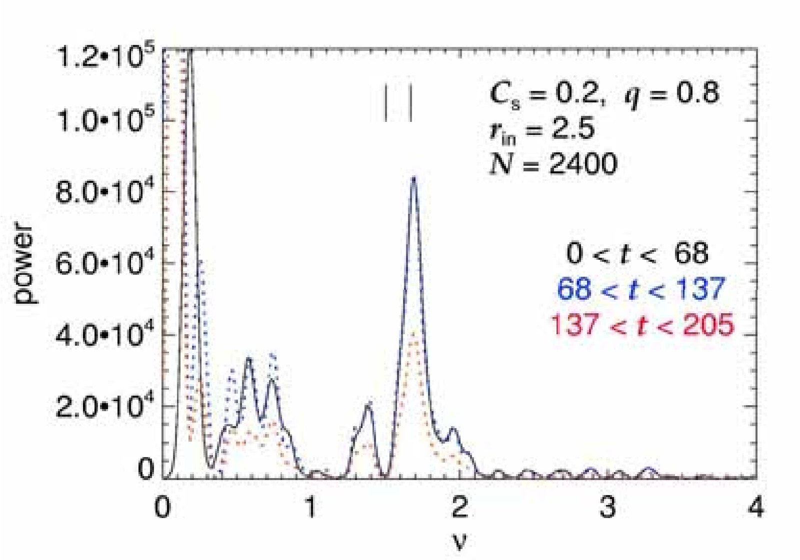






$N = 2400, r_{\text{in}} = 2.5, r_{\text{out}} = 4.2$

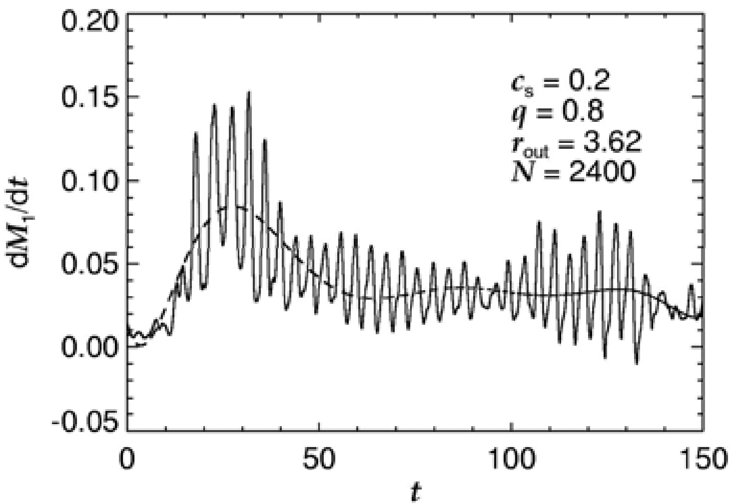


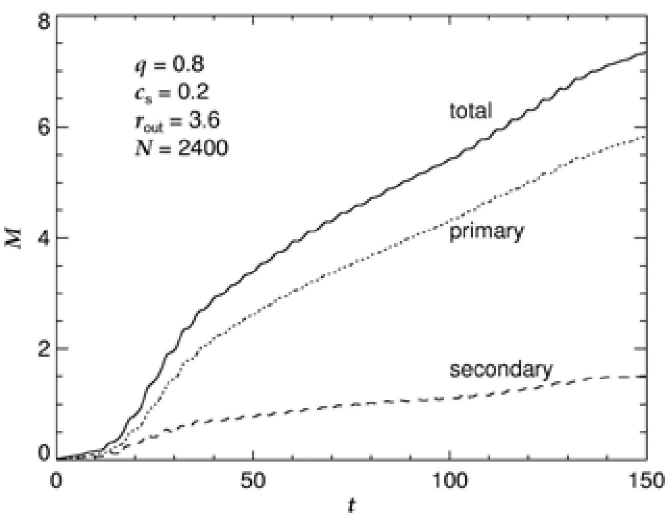


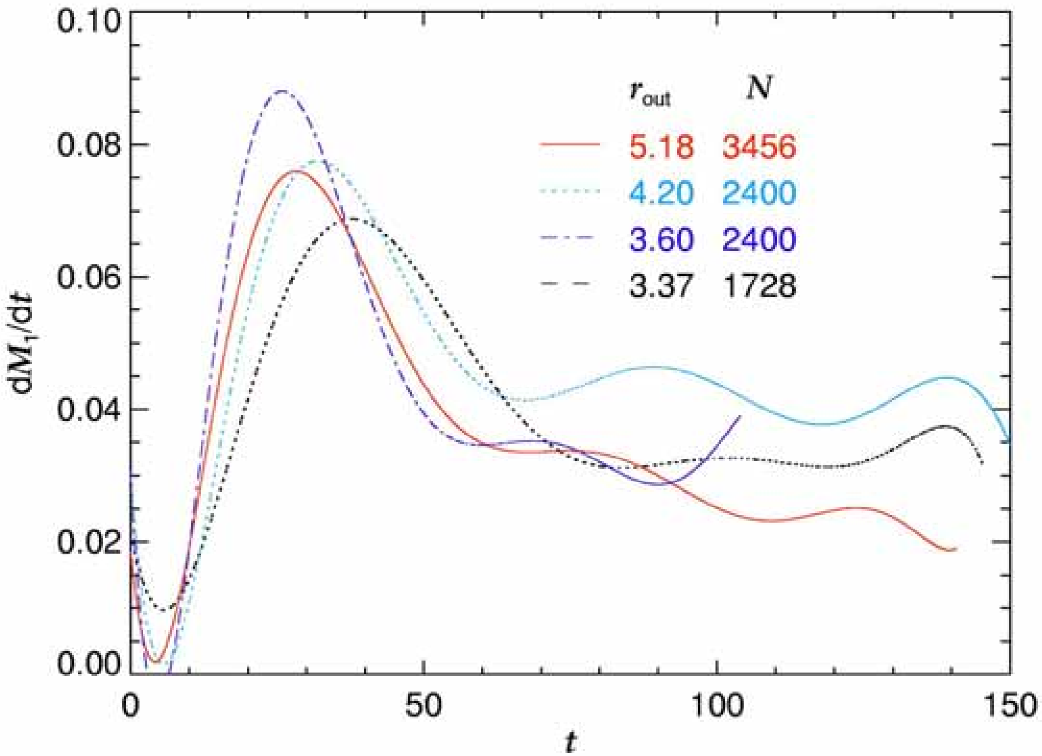
$$\nu_{peak} = \frac{5}{3}\Omega_*$$

Main resonance at $r = 3.30$

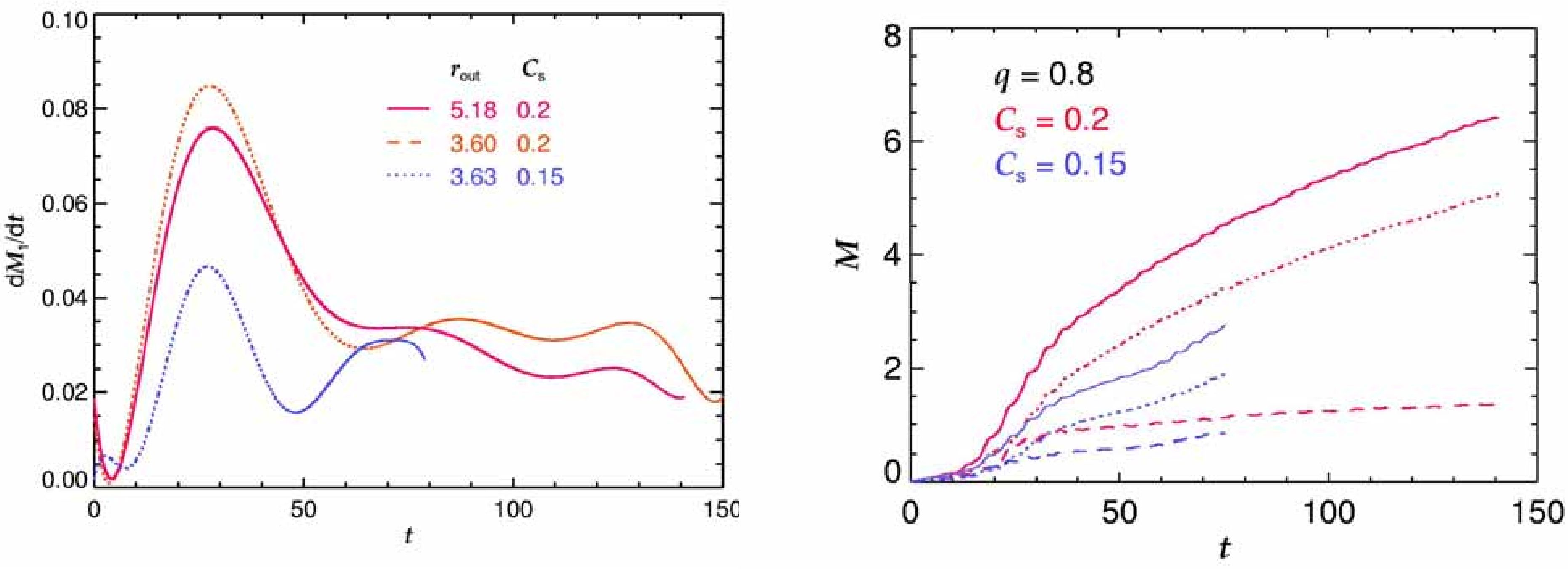
Dependences on N and R_{out}





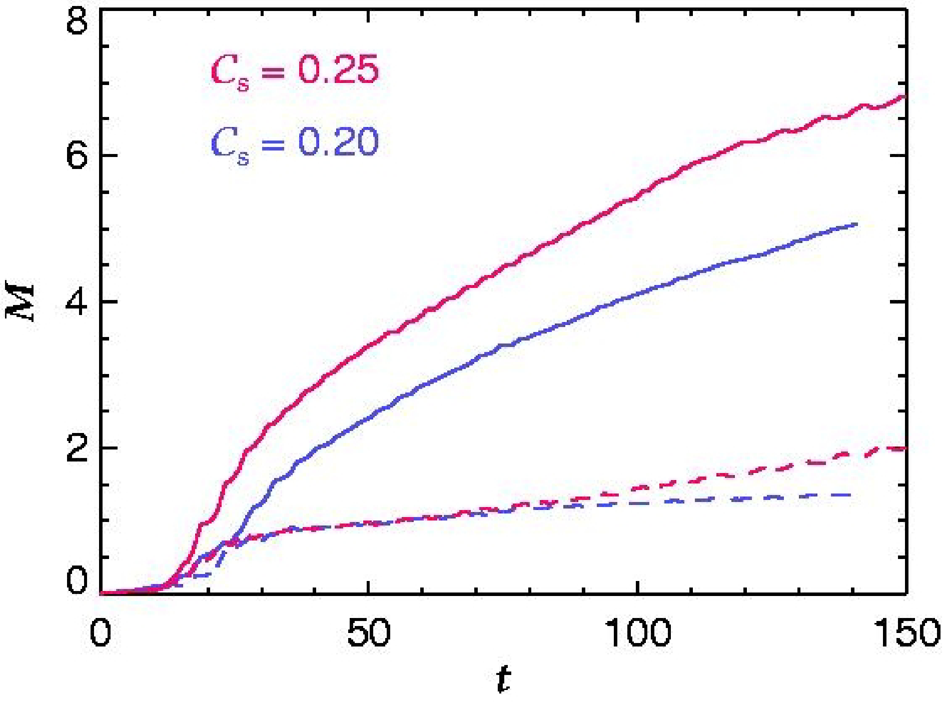


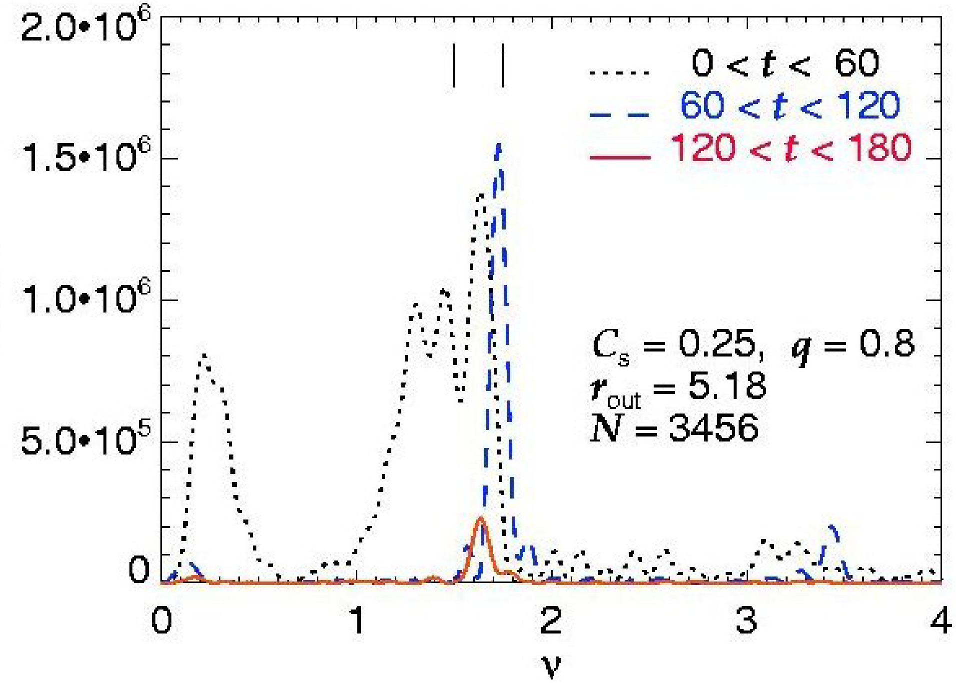
Dependence on C_s



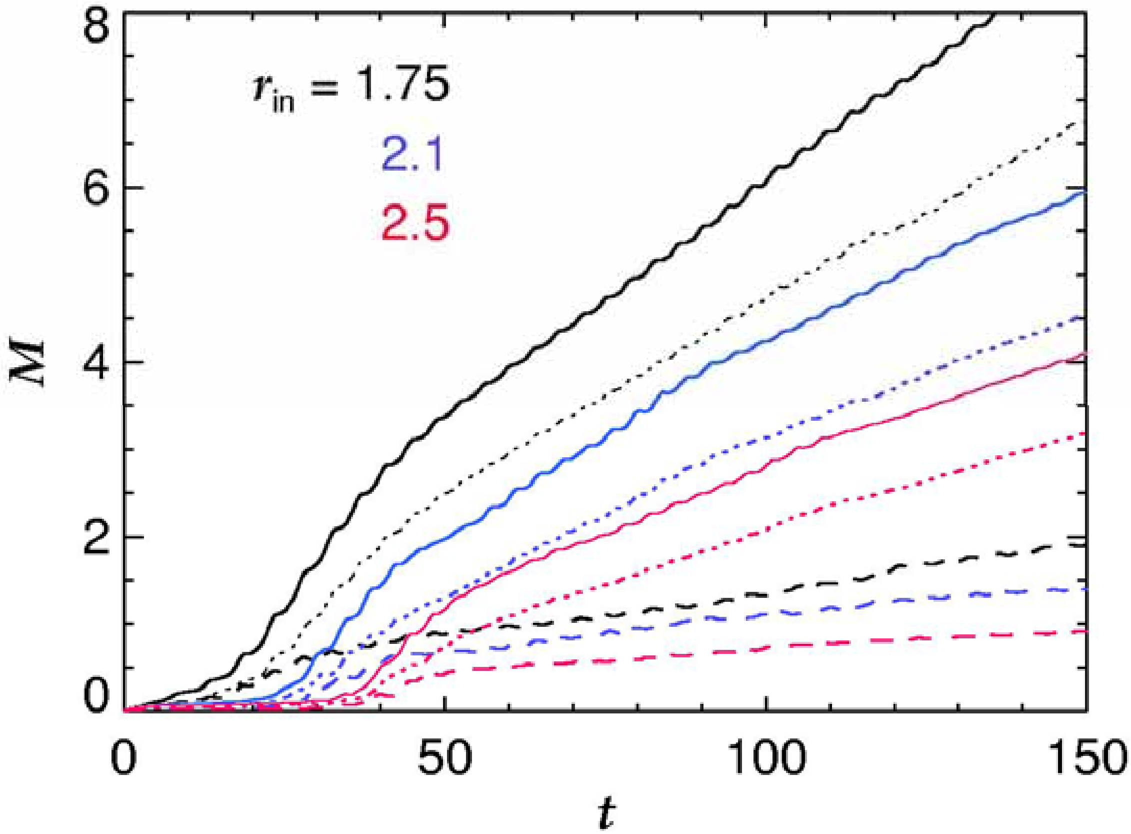
Accretion rate is lower when C_s is lower.

Peak frequency depends little on C_s.





Dependence on $r_{\rm in}$



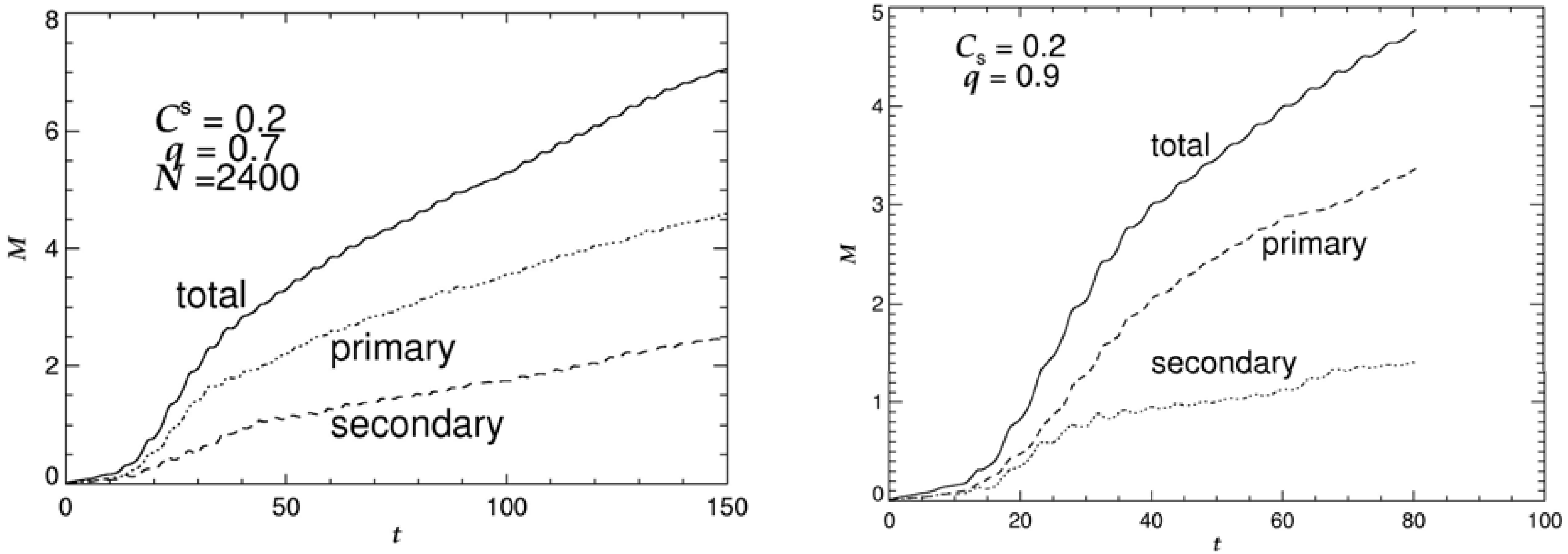
N = 2400, $r_{\rm out}$ = 4.2

Accretion begins later for a larger $r_{\rm in}$.

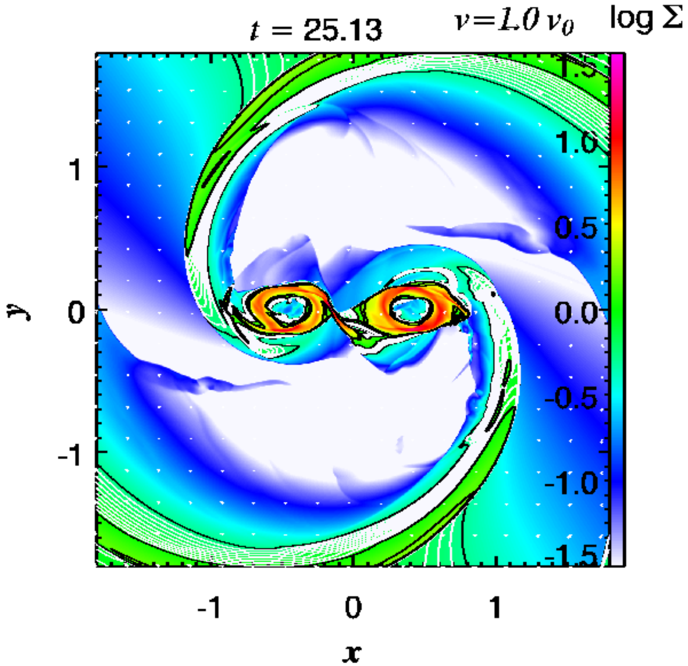
$$v_{drift} \cong -0.04$$

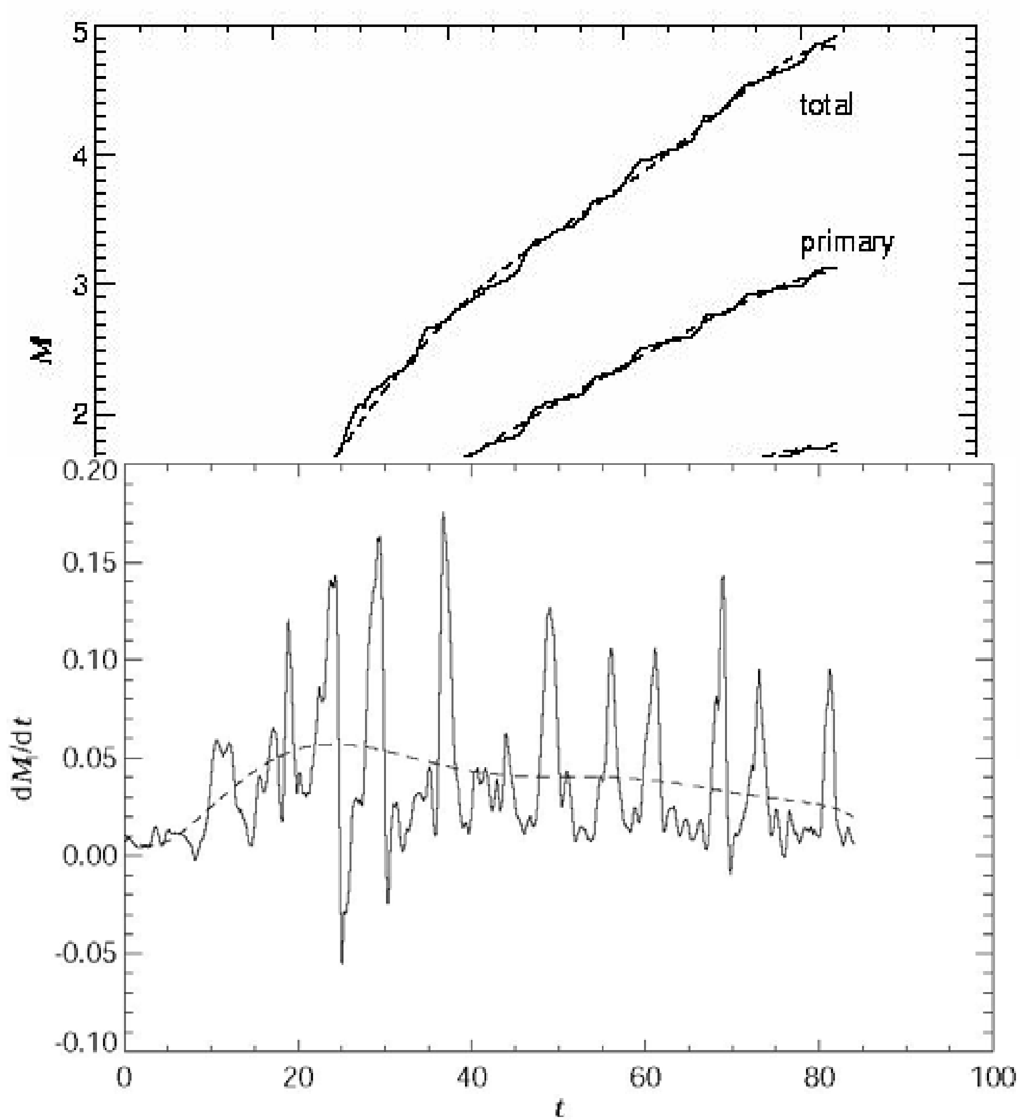
<Vr> $\sim -$ 0.005

Qualitatively independent of *q*



$q = 0.9$, $e = 0.14$, $c_s = 0.2$





R: Primary

L: Secondary

Preferential accretion onto primary: origin of apparently different ages?

- SVS 13 in NGC1333
  - VLA4A is apparently more evolved than VLA4B (0".3).
- YLW 15
  - VLA 1 (embedded) & VLA 2 (Class I)
- IRAS 16293-2422
  - Combinations of protostars with and without outflows

Summary

- Accretion rate of primary is larger than that of the companion, which implies decrease in the mass ratio by accretion.
- Gas flow inside the Roche lobe is important.
- Stationary and traveling spiral waves are excited and resonant with the binary through higher harmonics.
- Accretion rate varies with a large amplitude at a timescale comparable to the rotation period, which denies quasi-stationary accretion flow.