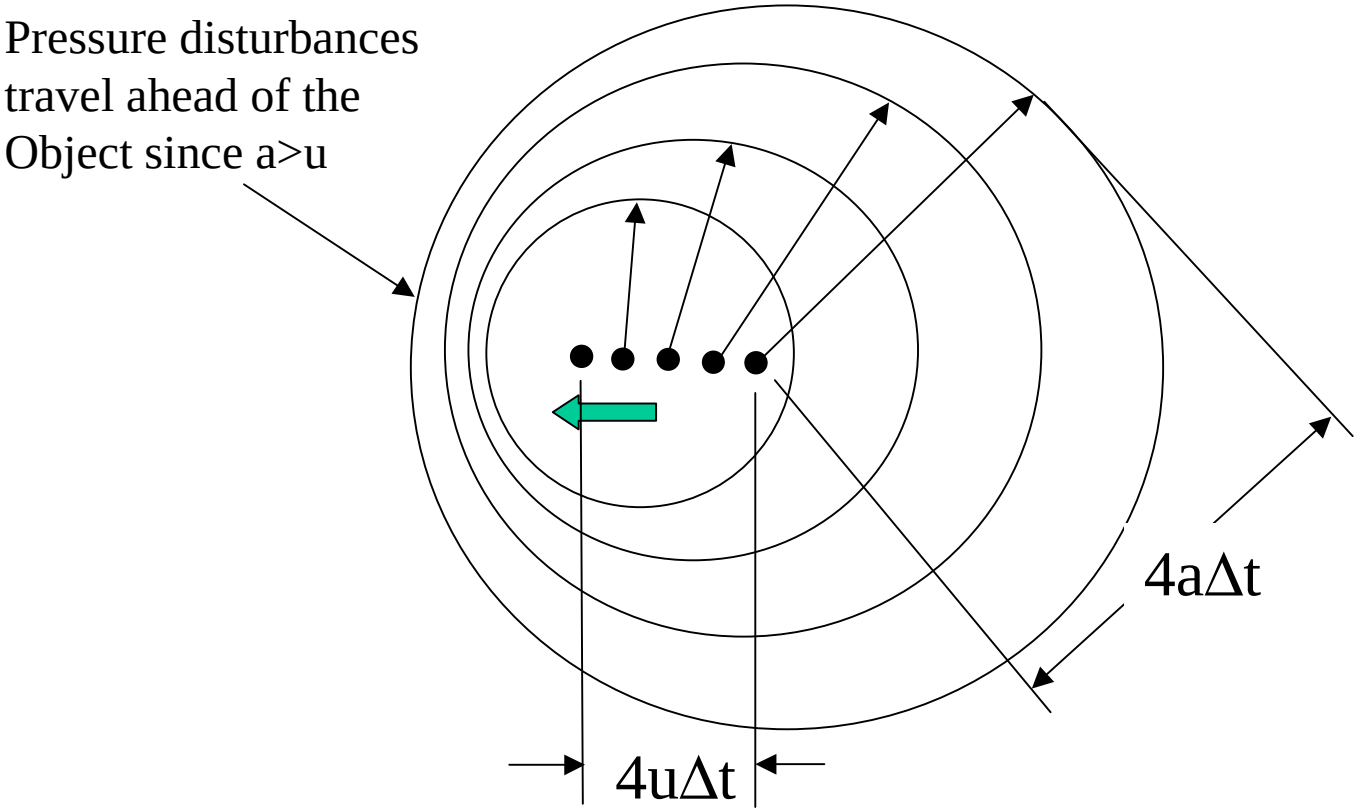
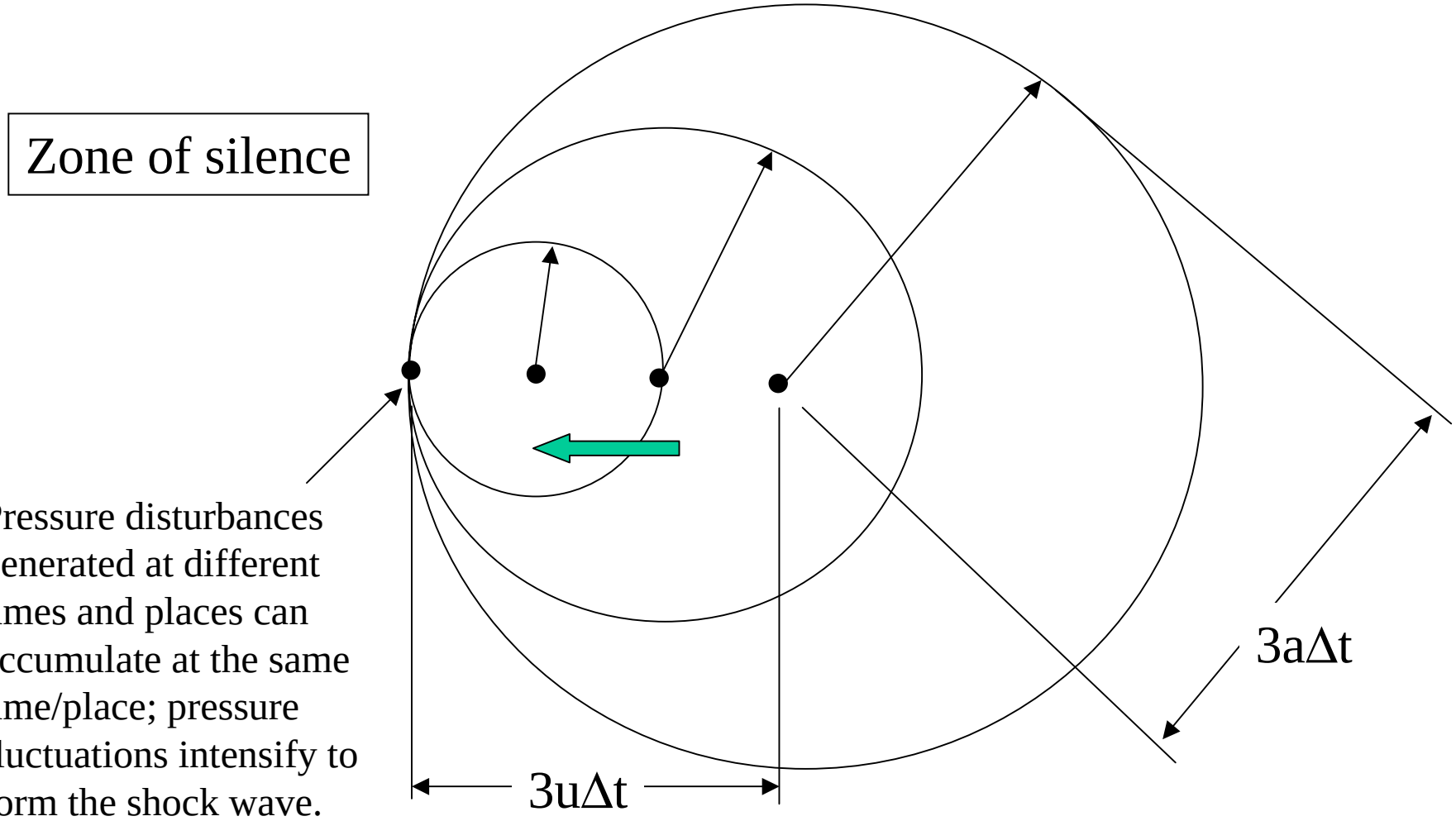
Mach Waves and Shock Waves

- Sound waves can be considered as small pressure disturbances and they travel at the speed of sound (a) relative to the velocity of the object that generates the disturbances.
- Assume an object moving to the left at a speed of u (subsonic u<a) as shown below:



Mach Line

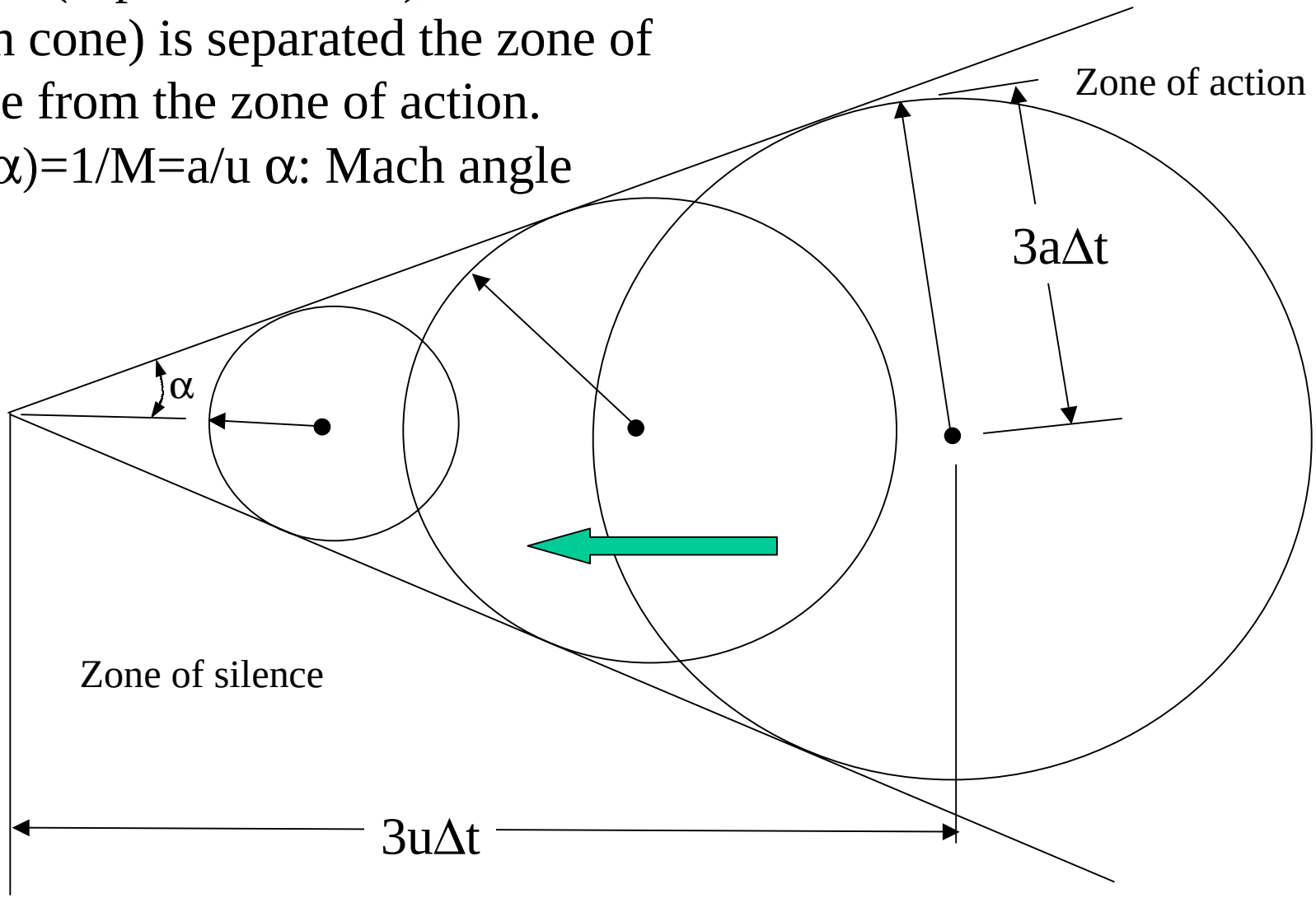
• Pressure disturbances can not move ahead of the object if u=a (sonic flow). Therefore, there is no warning about the approaching object; a shock can appear.



Mach Line

• If u>a (supersonic flow), a cone (Mach cone) is separated the zone of silence from the zone of action.

• sin(α)=1/M=a/u α: Mach angle

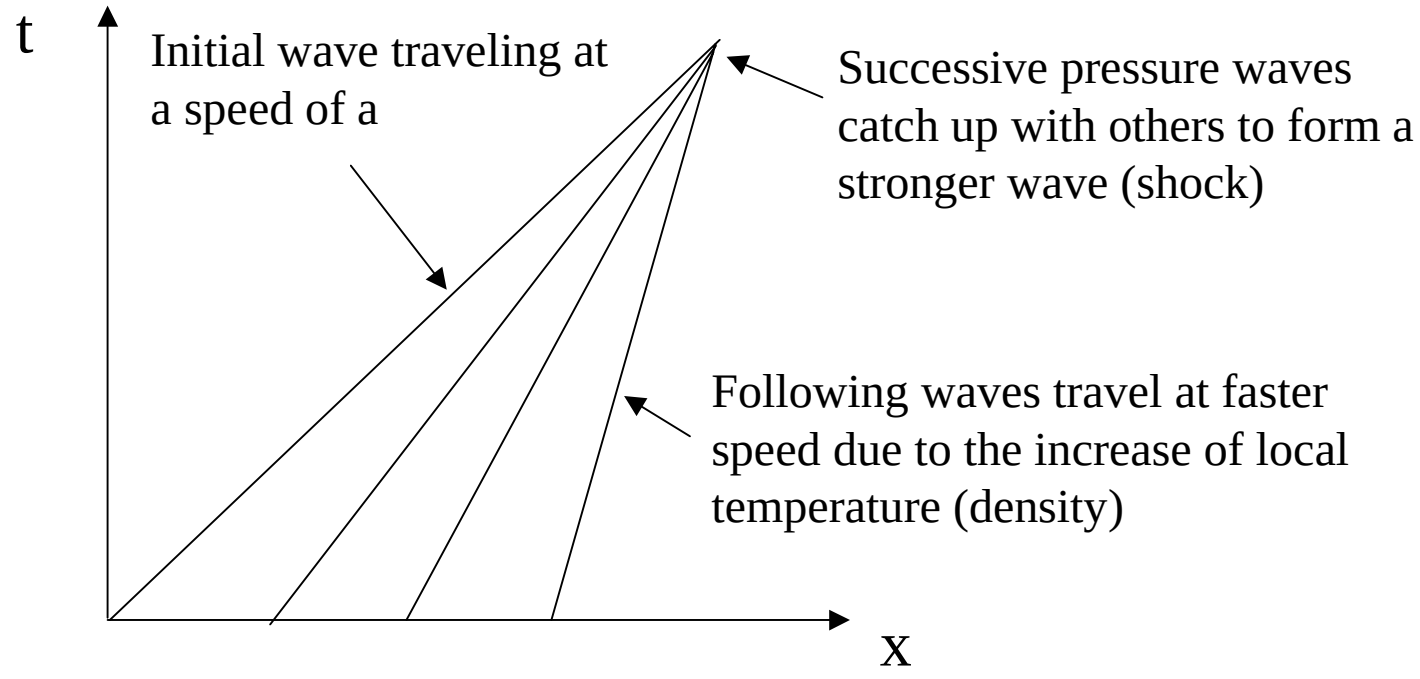


Shock Formation and Choking

- Due to the fact that the object is moving faster than the pressure disturbances it generated, there is a chance that disturbances generated at different times and places can accumulate at the same location instantaneous (see the Mach line from previous slide) to produce a much stronger pressure wave (shock wave).
- No communication of pressure information can be propagated ahead of the Mach cone and there is the zone of silence.
- Similar phenomenon can be expected from a duct flow when it reaches the speed of sound somewhere inside the duct. There is no more communication between the flow change downstream of the sonic region to its upstream counterpart.
- Choking occurs since further reduction of downstream condition has no influence of the flow rate.

Shock Formation

• When a compression wave is propagating through space, the local density and temperature will increase, consequently, the local speed of sound will increase ($a = \sqrt{\gamma RT}$). As a result, the waves following the initial compression will move faster and eventually catch up with the initial wave. This phenomenon is called wave steepening and it leads to the formation of a strengthening compression wave (shock wave).



Expansion Waves

• Based on the same argument, an expansion wave can induce a decrease of local density and temperature, leading to a decrease of the local speed of sound. The following waves tend to travel at a lower speed and the wave is going to spread out further apart. Consequently, changes through an expansion wave are usually more gradual as compared to that of a compression wave.