

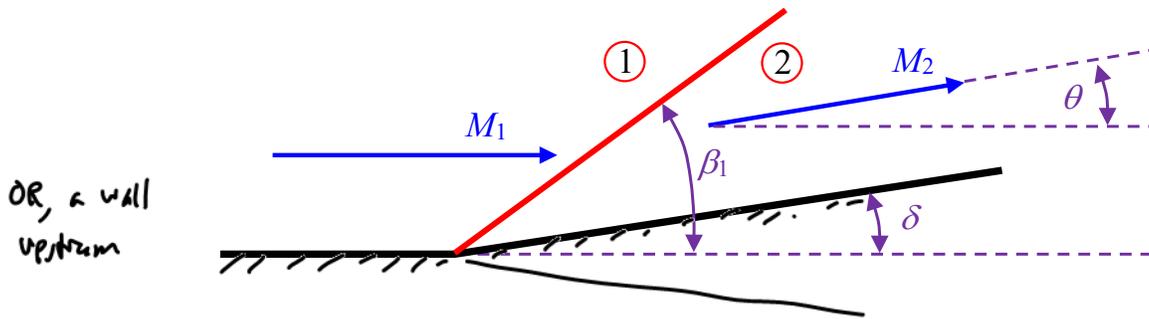
**Today, we will:**

- Continue discussing oblique shocks: curved walls, bow shocks, oblique shock reflections

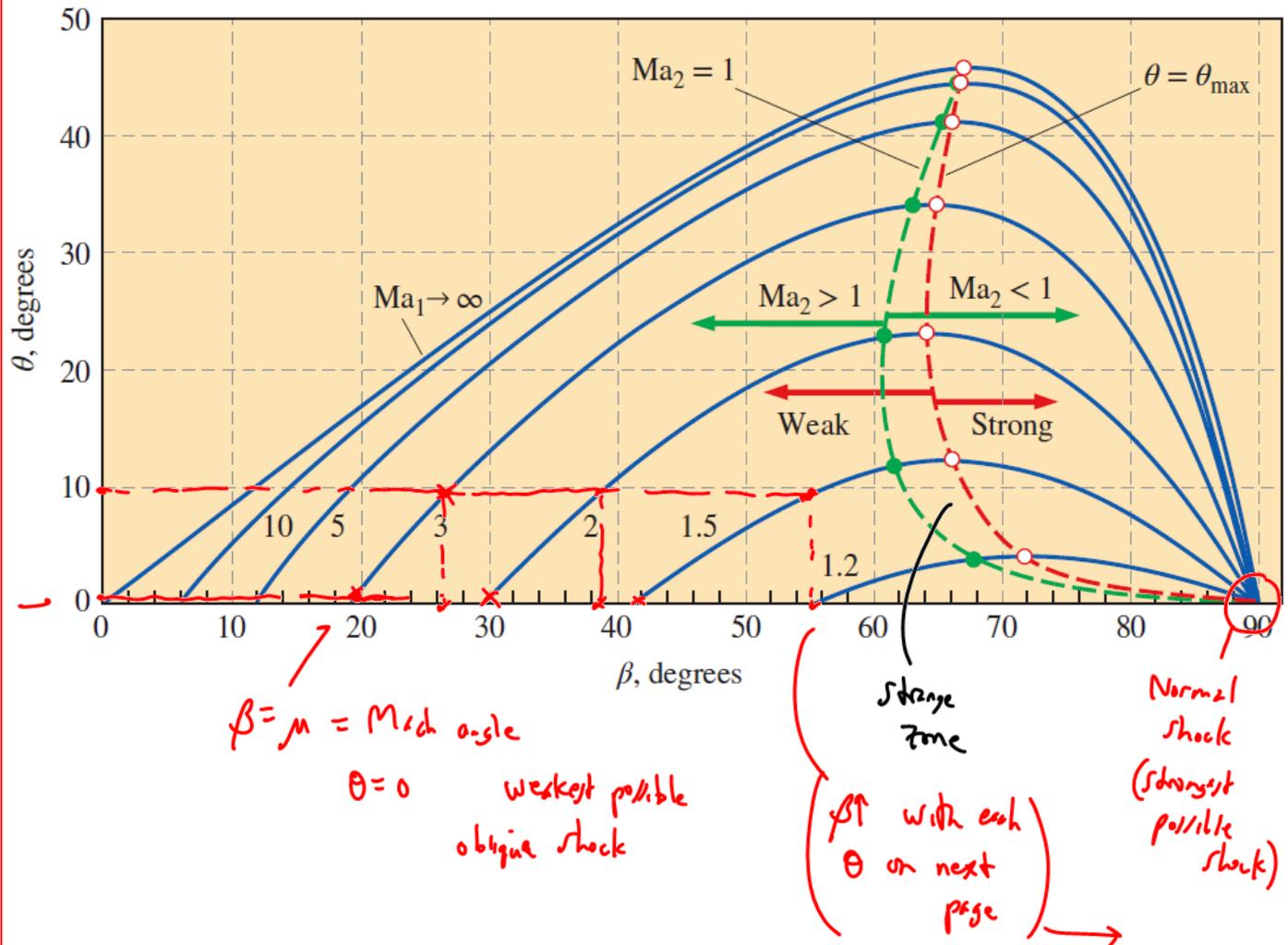
$\beta$  = shock angle  
 $\theta$  = turning angle  
 $\delta$  = wedge half-angle

Recall, angle definitions for an oblique shock:

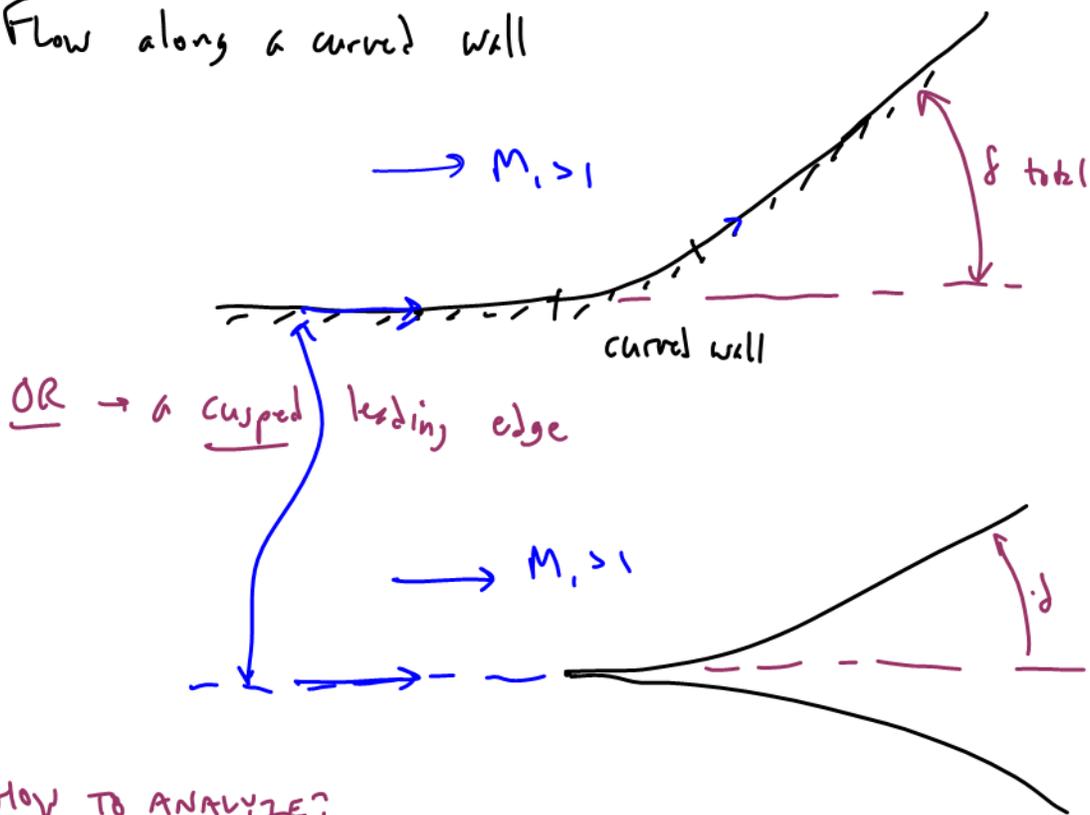
QUICK REVIEW:



Recall, the  $\theta$ - $\beta$ - $M$  relationship and plot:

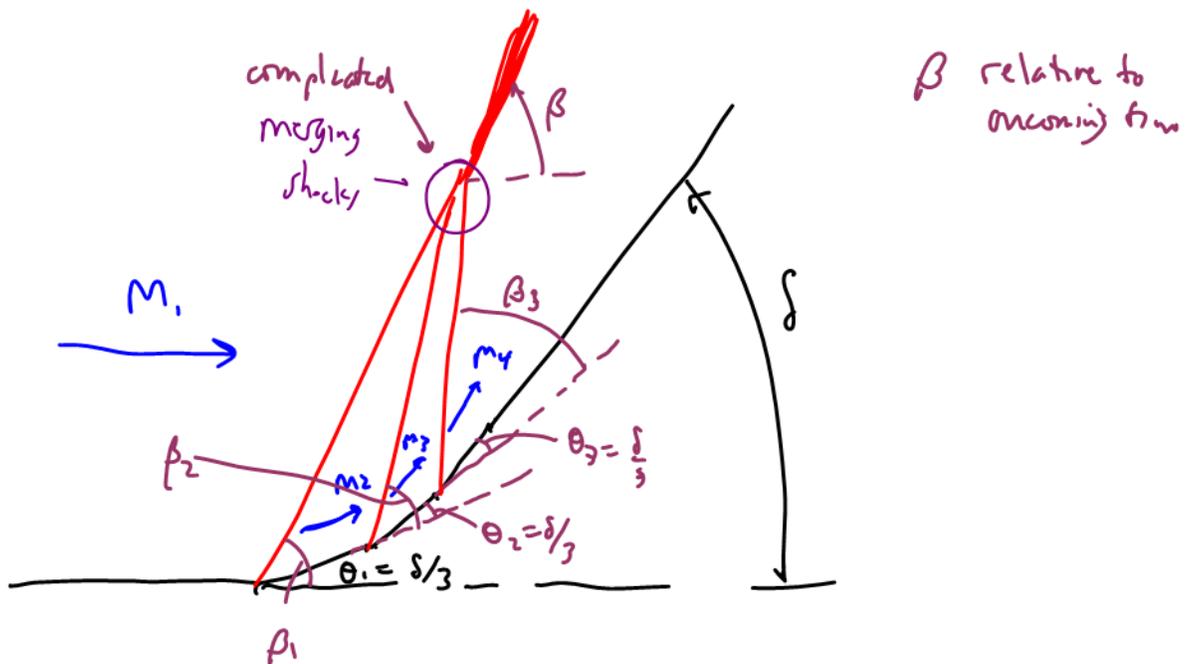


# Flow along a curved wall



## HOW TO ANALYZE?

Consider first 3 small increments in  $\delta$  instead of curved

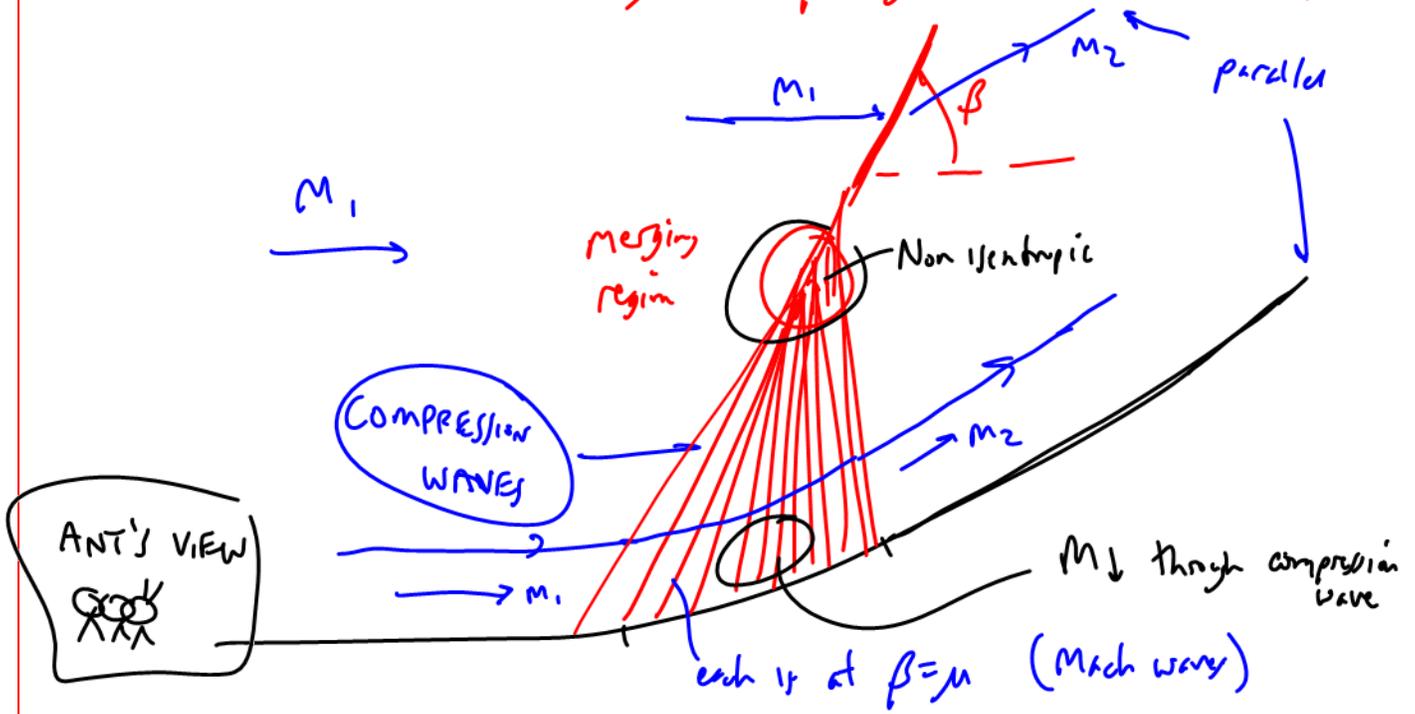


$M_2 < M_1$ , but still supersonic  
 $M_3 < M_2$  - - -

For the same  $\theta$  ( $\theta = \delta/3$  here)  
 $\beta \uparrow$  as  $M \downarrow$  (see  $\theta$ - $\beta$ - $M$  plot)

Now Let there be 10, 100, 1000, ...  $\infty$  small increments of  $\delta$   
 (Smooth curves well)  
 $\theta_1, \theta_2, \theta_3 \rightarrow 0^+$

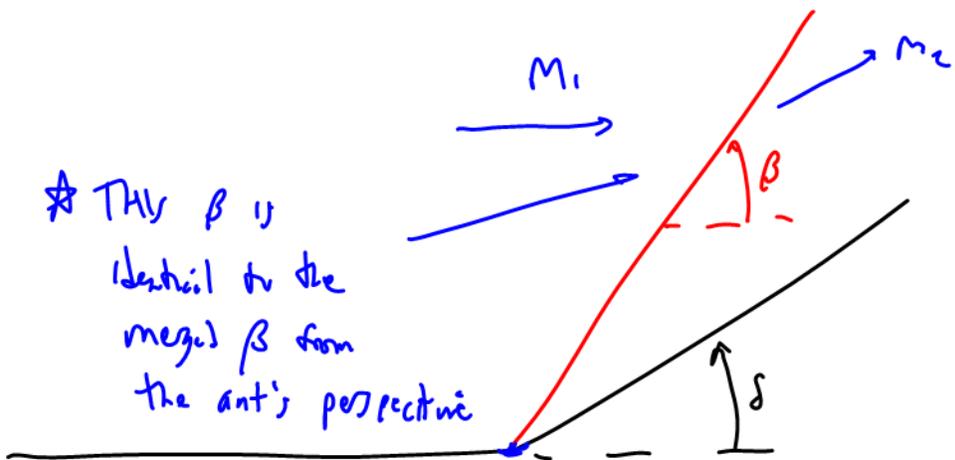
$\beta$  still  $\uparrow$  as wall curves, but  $\beta \rightarrow \mu$  for each  $M$   $M \downarrow$



These compression waves are isentropic until they start merging  
 $M = \sin^{-1} \frac{1}{M}$   $\mu \uparrow$  as  $M \downarrow$

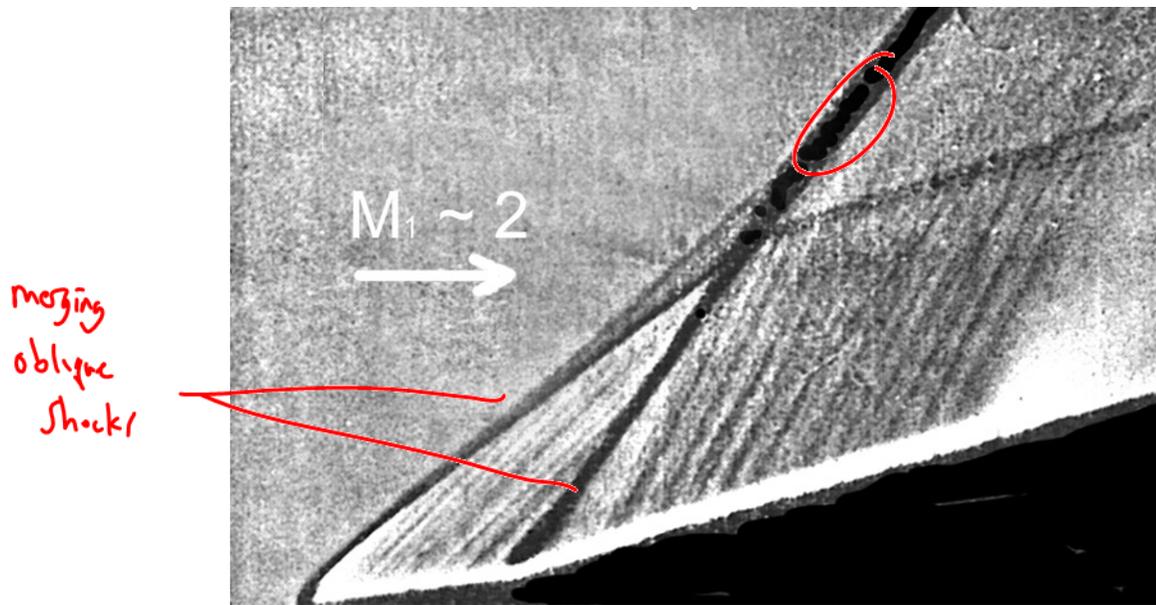
GIANT'S VIEW

\* This  $\beta$  is identical to the merged  $\beta$  from the ant's perspective



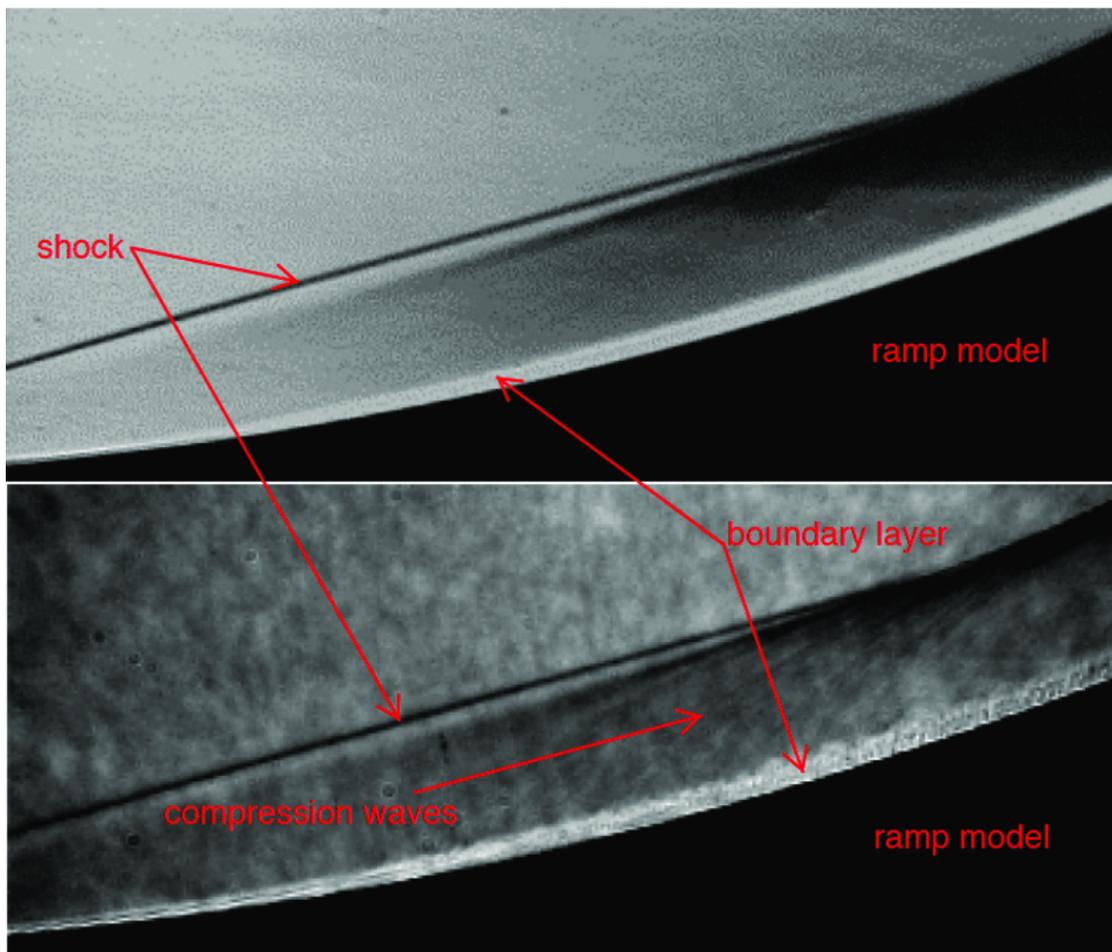
## Examples of merging oblique shocks:

### Two-step wedge:



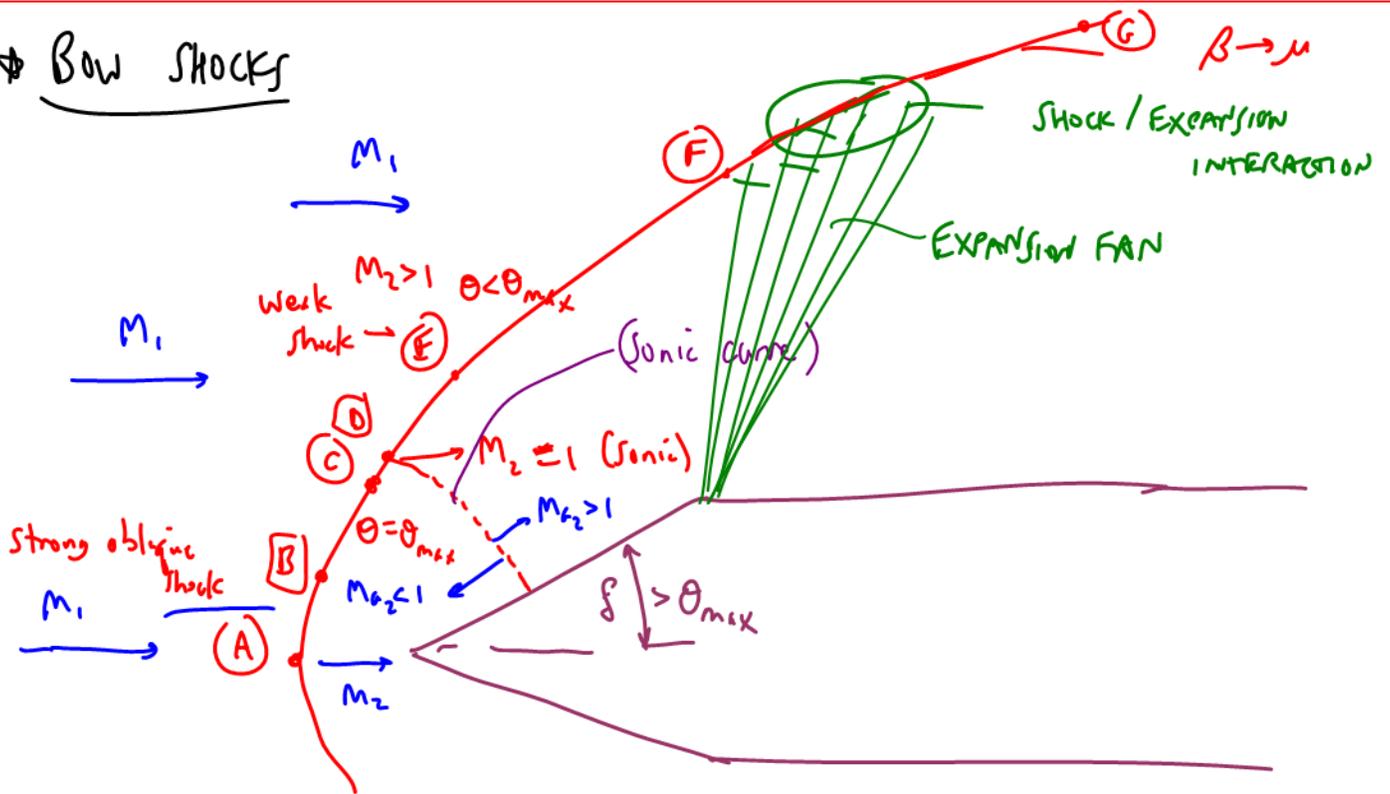
From Johannesen, N. H., "Experiments On Two-Dimensional Supersonic Flow in Corners and over Concave Surfaces" *Philosophical Magazine*, Series 7 Vol. 43, 1952.

### Cusped ramp:

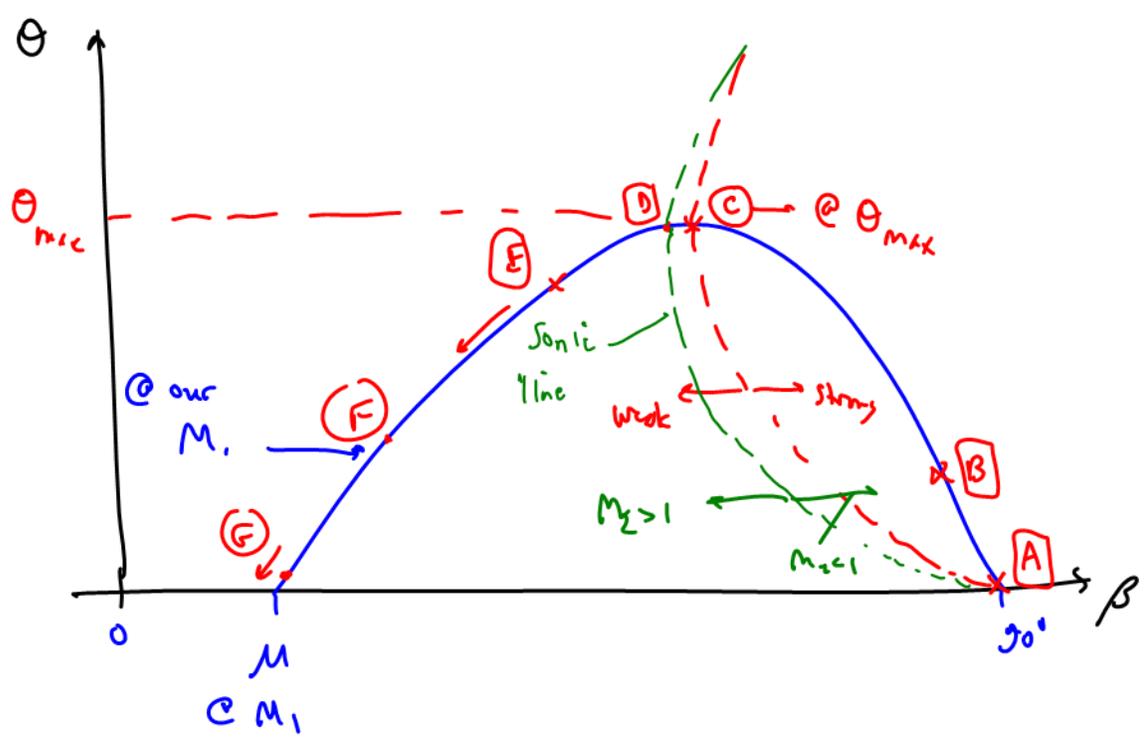


From Nick Parziale, Bryan Eric Schmidt, J S Damazo, J E Shepherd. Pulsed Laser Diode for Use as a Light Source for Short-Exposure, High-Frame-Rate Flow Visualization. Jan. 2015.

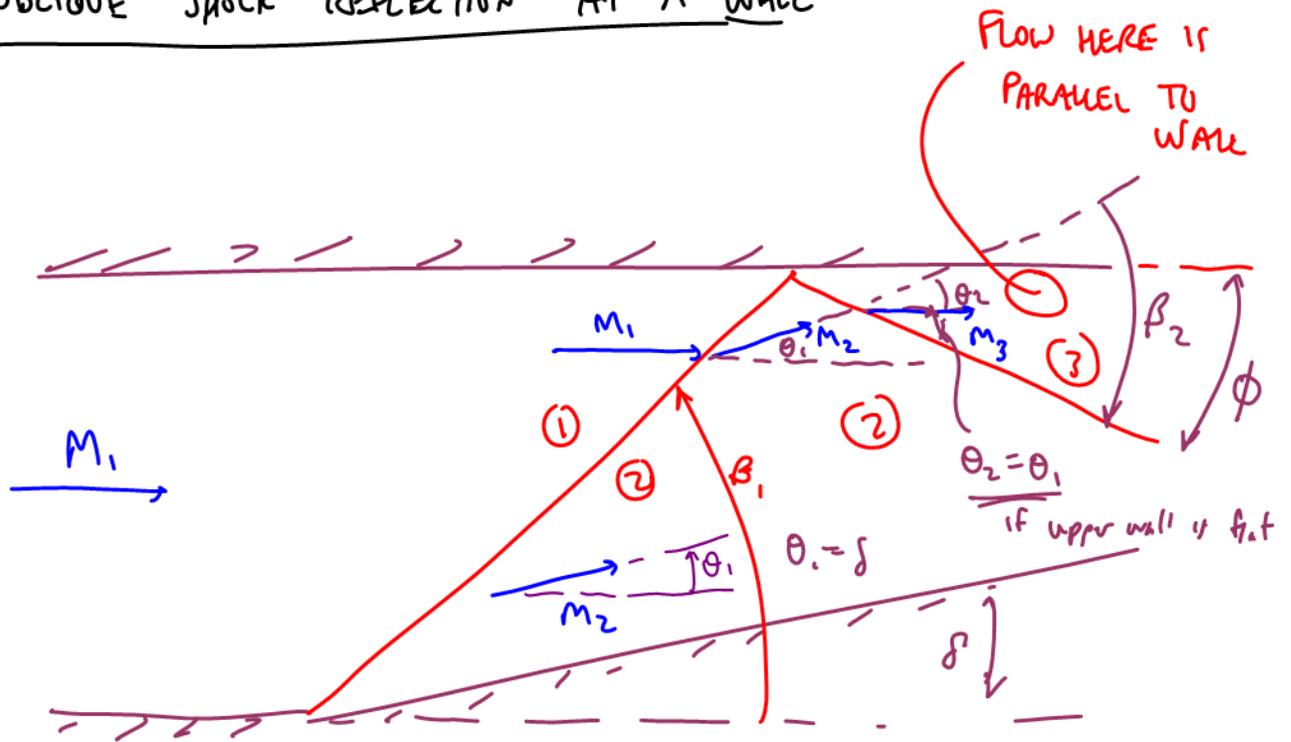
# Bow Shocks



**A** = Normal shock,  $\beta = 90^\circ$ ,  $\theta = 0$ ,  $M_2 < 1$

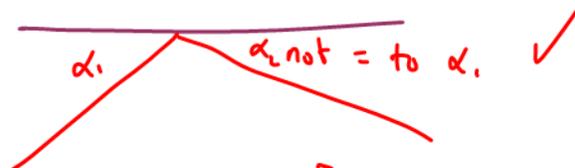
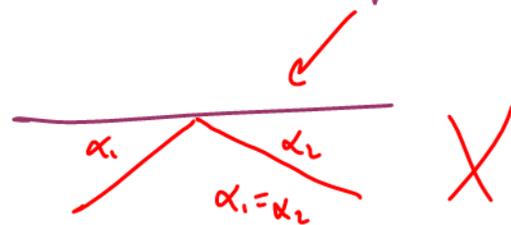


# \* OBLIQUE SHOCK REFLECTION AT A WALL



\* DEFINE  $\phi = \beta_2 - \theta_2$

Angle of reflection is not "specular"



[THIS IS OUR CASE]