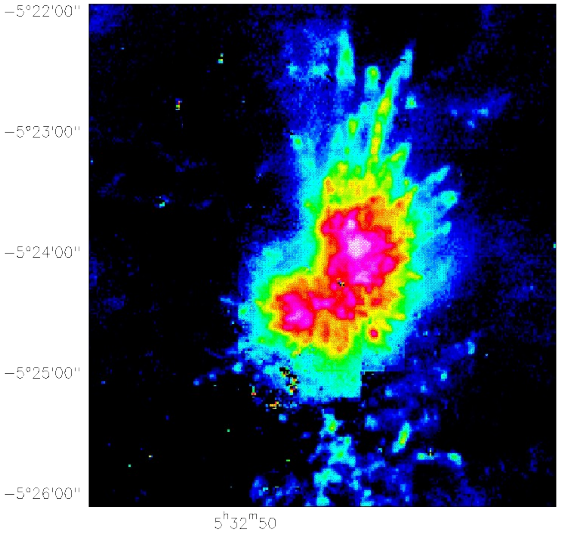
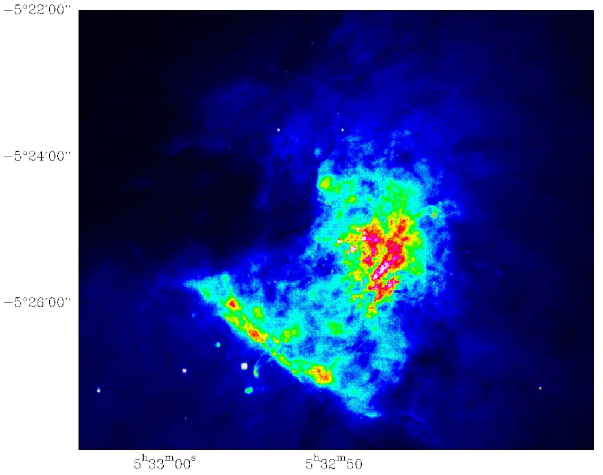
Star formation

Shock impact

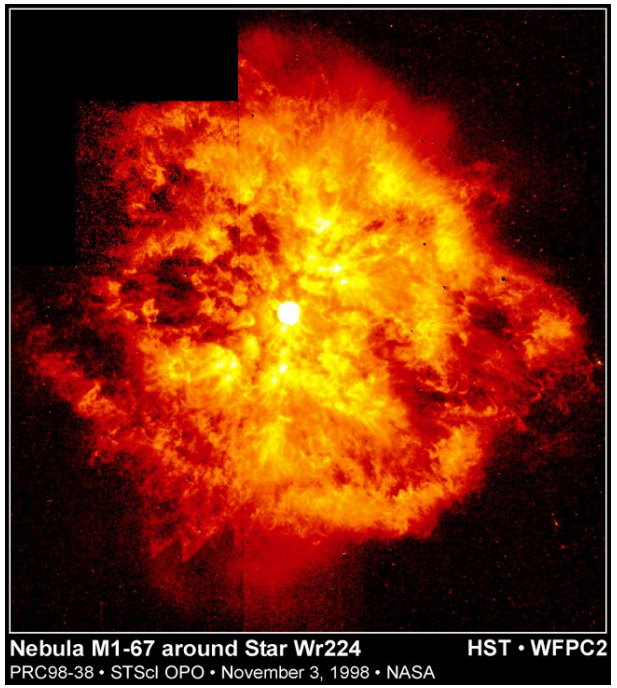
Interaction of young stars with their environment



Outflows
(Orion Pk 1)



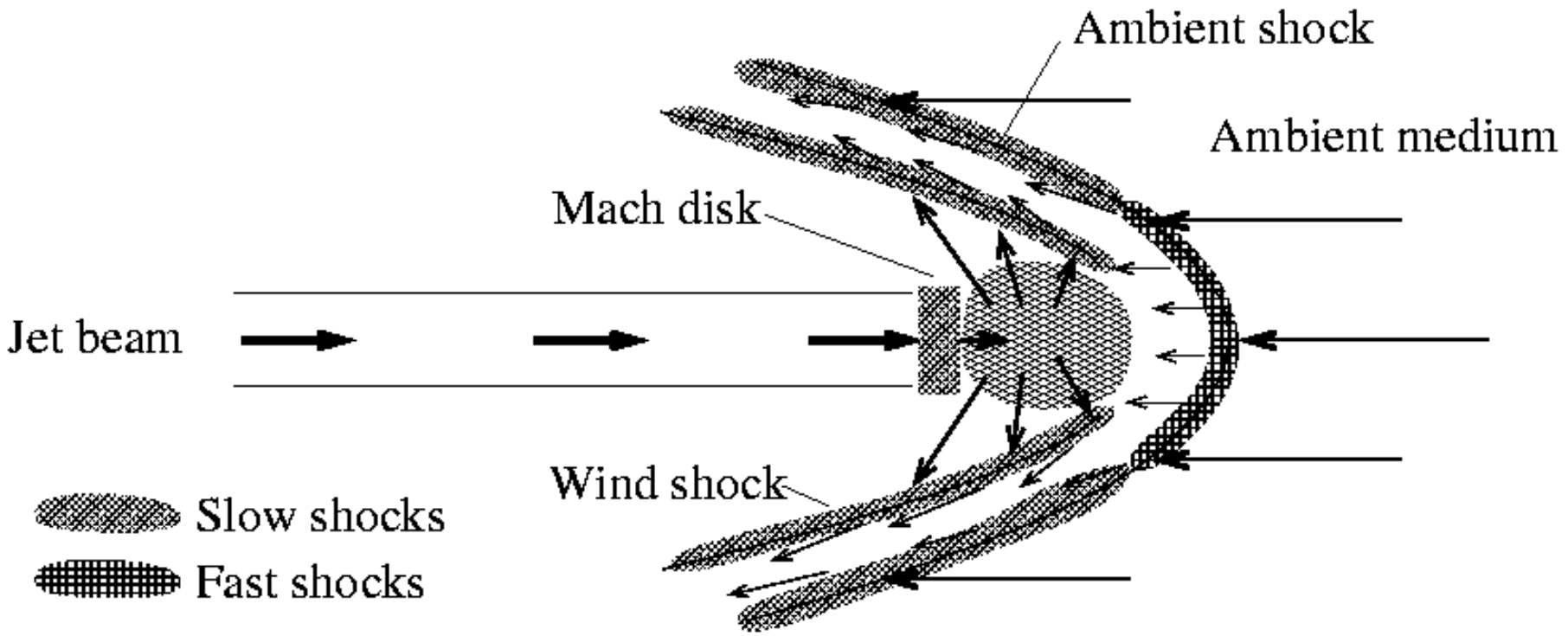
UV radiation
(M42)



Stellar winds
(WR224)

Supernovae
(Crab nebula)

Bowshock from outflow



Specific outflow chemistry

Shock chemistry

- Sputtering of grain mantles
  - dust grain disruption
  - SiO enhanced by up to 6 orders of magnitude
- Compression through shock
- High-temperature chemistry
  - molecular dissociation
  - endothermic reactions
  - ice sublimation (e.g. lot of CH_3OH released)
- Ion-neutral chemistry in ambipolar diffusion zone of C-shocks

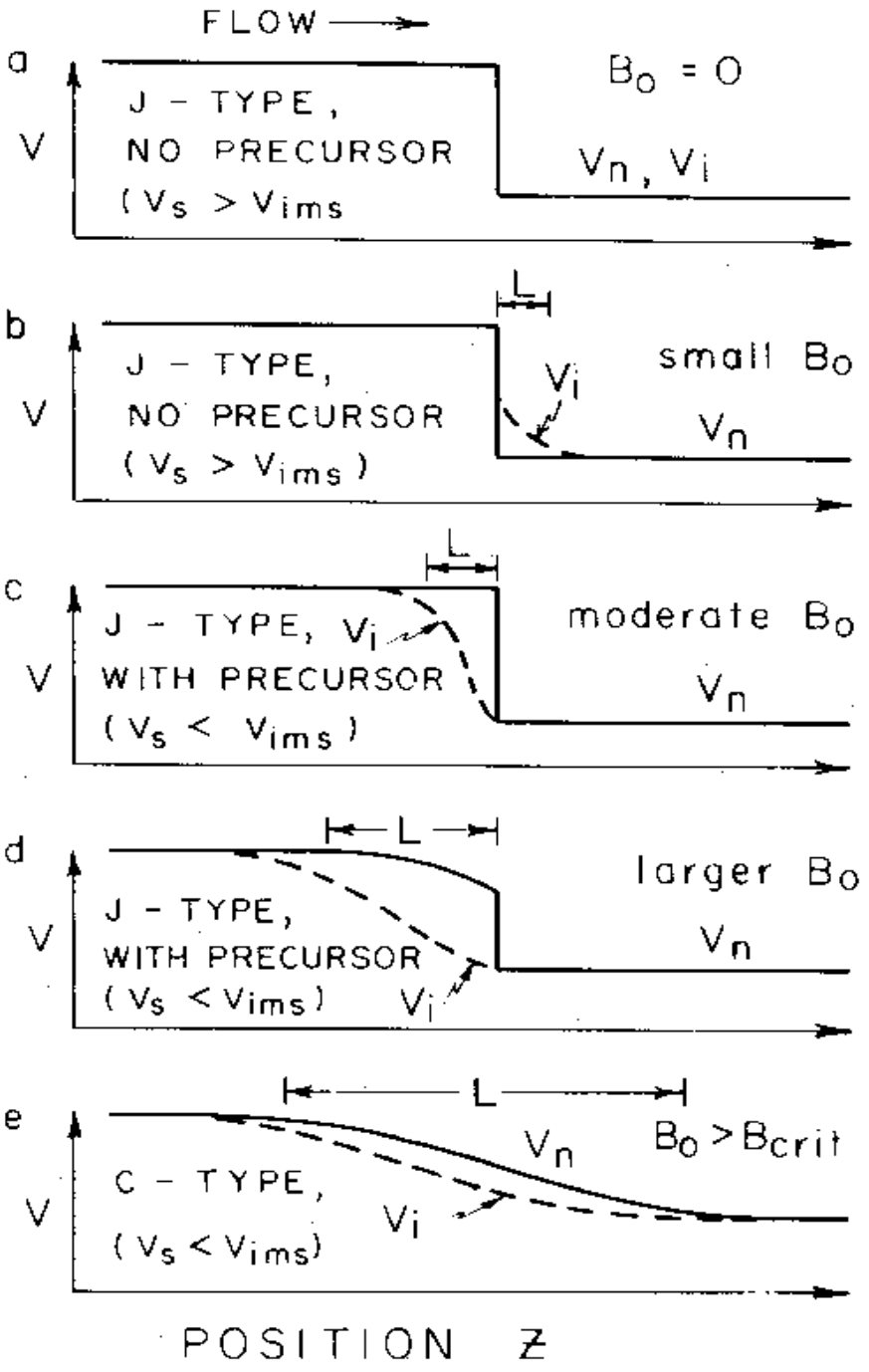
Some of these processes have short time scales

$\longrightarrow$ possibility to use them as chemical clocks

Types of shocks:

- J-shocks
  (jump shocks)
  - very high temperatures (10,000 K)
  - dissociative
  - molecule reformation in post-shock gas
  - cooling by molecular radiation

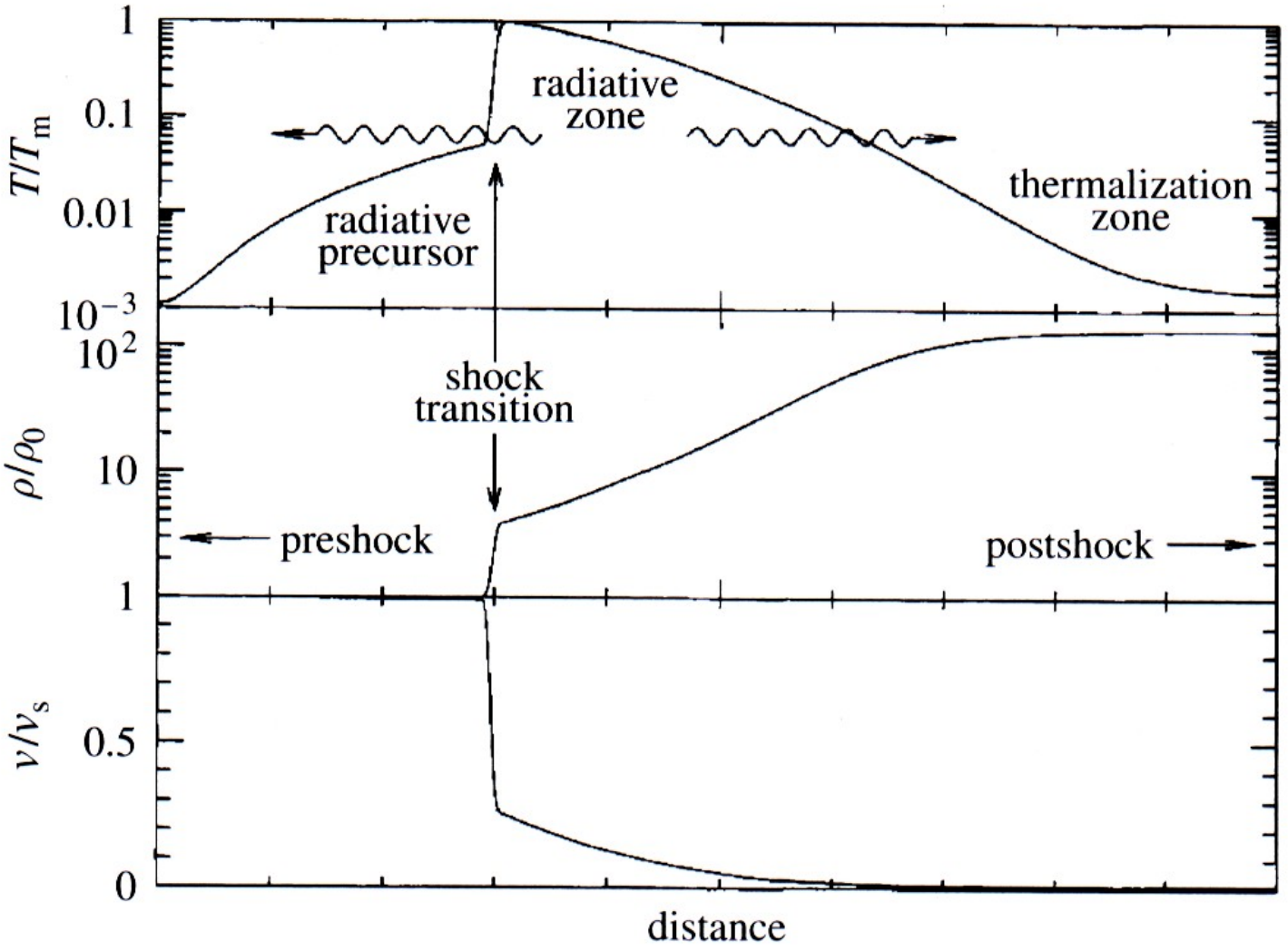
- C-shocks
  ("continuous" shocks)
  - in presence of magnetic fields
  - broad shocks with moderate temperatures (100-1000 K)
  - ambipolar diffusion in shock



Shock physics

J shock:

- Strong heating from shock compression
- Interaction of pre-shock gas with post-shock gas through
  - Radiation
  - Magnetic field



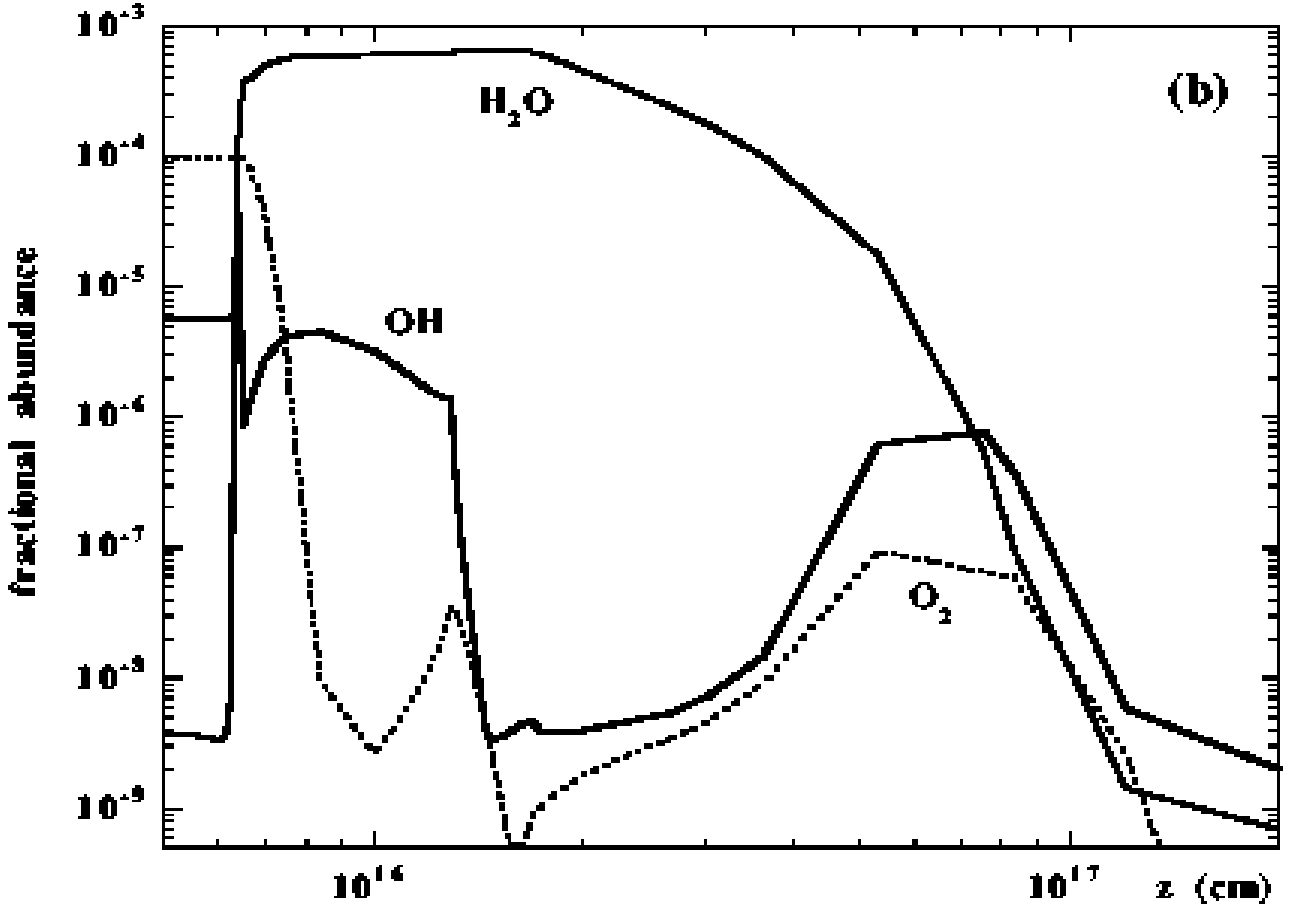
Shock chemistry

Example:

Water production in shock by neutral-neutral reactions initiated by

$O + H_2 + 2980\ K \rightarrow OH + H$

$OH + H_2 + 1490\ K \rightarrow H_2O + H$



Shock chemistry

Full example of OH chemistry in C shock: