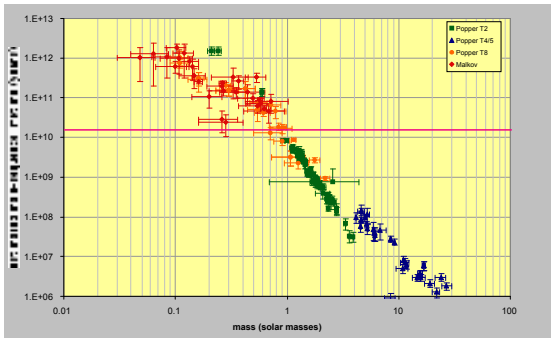
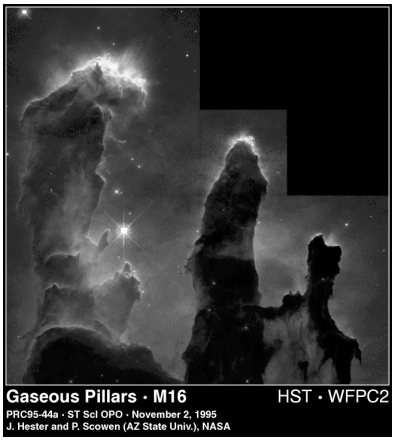
Star Birth

- Most of the bright stars we see have lifetimes much less than the age of the Solar System
  - star formation is an ongoing process
  - how does it happen?
  - are stars born now different from older stars?
  - what about planetary systems?



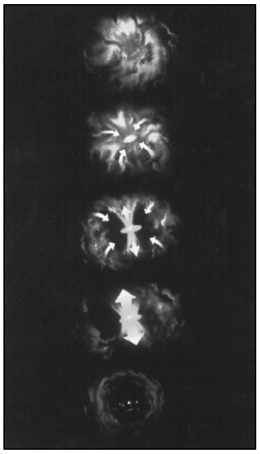
How are stars born?



- Space is not empty, but filled with very rarefied gas
- Gas pressure depends on temperature: cool, dense gas may not have high enough pressure to balance inward gravitational force
- Cool, dense molecular gas can collapse to form stars

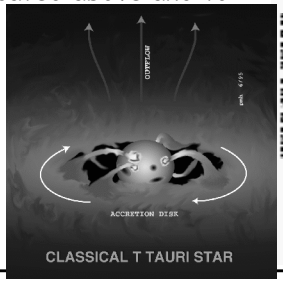
Stages in star birth

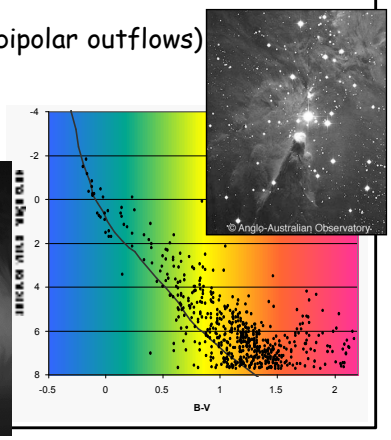
- As gas cloud collapses
  - its rotation causes the formation of a disc around the young star
  - the gas forming the young star heats up as the star contracts
  - the increased pressure causes jets of gas to be emitted from the poles of the young star
  - conversion of gravitational energy to radiation (electromagnetic energy) causes young star to shine, even though fusion has not started
  - eventually fusion reactions turn on in the centre of the young star: it has now reached the main sequence



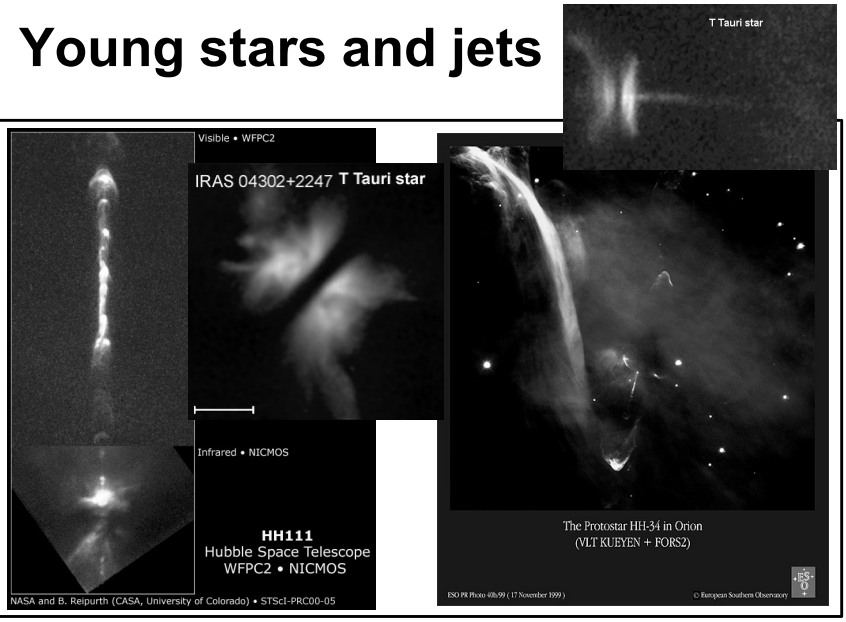
Recognising young stars

- They will be surrounded by warm gas and dust, which gives off infra-red radiation
- They may emit jets of material (bipolar outflows)
- They are unstable, and hence may have variable light output
- They are located above and to the right of the main sequence (they are large and cool)



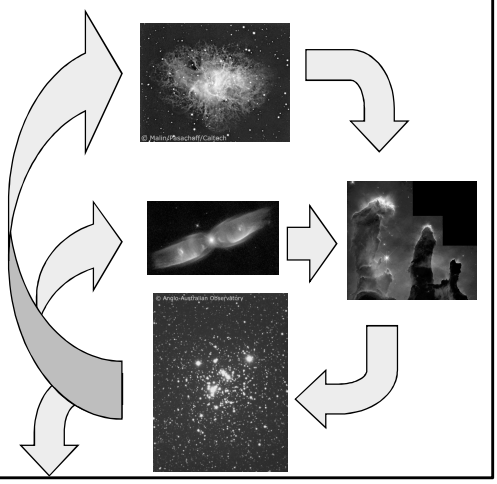


Young stars and jets

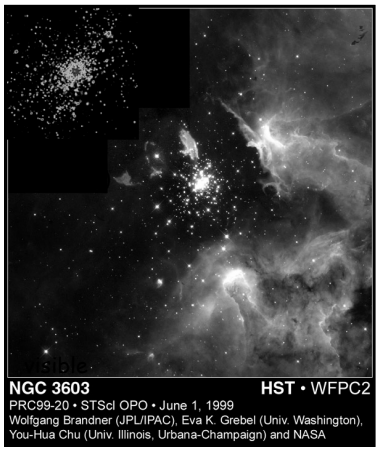


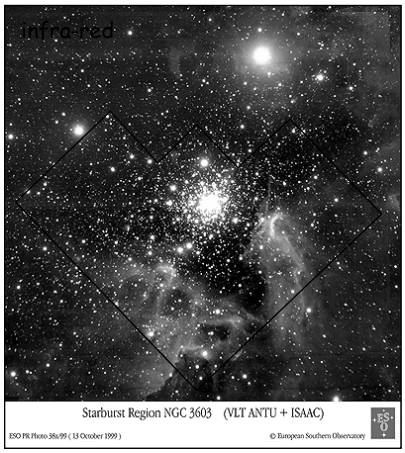
Galactic recycling

- Supernovae and planetary nebulae replenish interstellar gas
  - enriched with heavy elements from fusion
- Very low mass stars are landfill!
  - lifetime >> age of universe

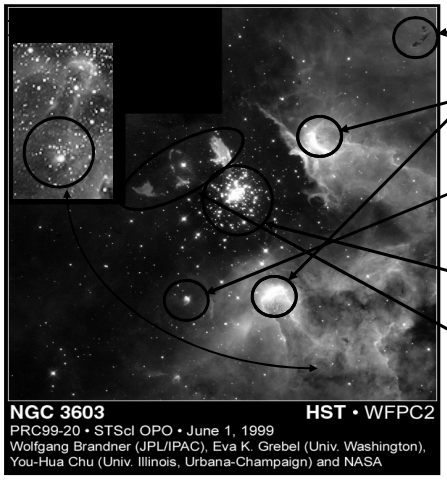


A star formation region





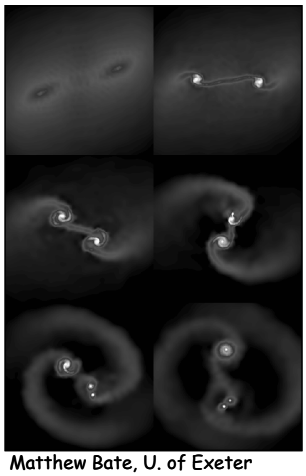
Star formation in action: NGC3603



- Dark, opaque **Bok globules** of cold dense gas
- **Gas pillars** caused by the presence of a dense clump of gas at the tip
- A massive **protoplanetary disc** around a newly formed massive star
- A **young cluster** of massive blue stars
- An evolved **blue supergiant**, probably about to explode as a supernova

Binary systems

- Most stars are members of binary or multiple systems
  - of 30 nearest stars, 12 are in binary systems and 6 in triples
- How does this happen?
  - clouds spin faster as they collapse
    - above critical speed cloud will break up into smaller clumps
    - these clumps form individual stars, still gravitationally bound together (since clump was)
  - picture shows simulation which produced triple system

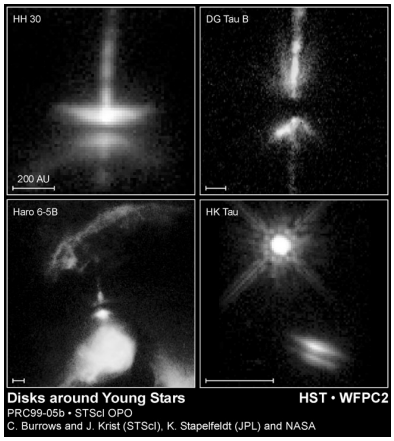


Matthew Bate, U. of Exeter

Planetary systems

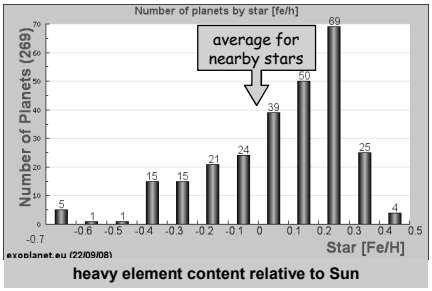
- Many young stars are seen to be surrounded by dusty discs ("protoplanetary discs" or "proplyds")
  - the Solar System is believed to have developed from such a disc
  - dust grains clump together to form larger objects, eventually planets

➔ Planetary systems common?



Recycling and planets

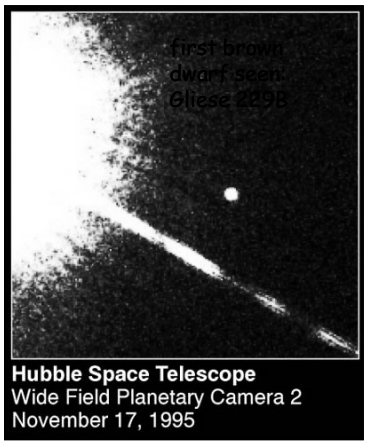
- Many extrasolar planets have now been discovered (see later)
- Heavy element content of stars with planets systematically higher than typical sample, though some low-heavy-element stars do have planets
  - not surprising if planets form from build-up of dust grains into rocky bodies
  - implies planets commoner around second-generation stars formed from enriched material
  - indeed, no planets seen in transit search in globular cluster 47 Tucanae



heavy element content relative to Sun

Brown dwarfs

- Stars must have masses at least 8% of the Sun's
  - otherwise fusion never starts (not hot enough)
- Jupiter is only 0.1% of Sun's mass
- Between the two are sub-stellar **brown dwarfs**
  - in theory brown dwarfs form "like stars", not "like planets"
  - observationally hard to define boundary!



Hubble Space Telescope
Wide Field Planetary Camera 2
November 17, 1995

What have we learned?

- Star formation is an ongoing process
  - many of the bright stars we see are much younger than the Sun
- Stars form when a clump of dense, cool gas collapses under gravity
  - rapidly rotating clouds may fragment to produce binary systems
  - heavy-element-rich clouds yield stars with planets
- Supernovae and planetary nebulae recycle material to the interstellar gas
  - this is enriched in heavy elements
  - shocks from supernovae may also encourage stars to form
- Where is all this happening?
  - only in certain regions of our Galaxy

…next lecture!