Star Formation, Binary Fractions, Binary Characteristics

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Topics

1. Star Formation
2. Star Formation Rates
3. Binary Systems
   (a) Binary Characteristics
   (b) Binary Formation
   (c) Close Binaries

Abbreviations

AIC	Accretion Induced Collapse
CE	Common Envelope
HRD	Hertzsprung-Russell-Diagram
IMF	Initial Mass Function
ISM	InterStellar Medium
MS	Main Sequence
SFR	Star Formation Rate

Star Formation

Star formation in molecular clouds

- gravitational pull overpowers gas pressure $\Rightarrow$ collapse
- Jeans' gravitational instability (1902, J.H. Jeans)
  $R_{cloud} < \frac{1}{5}\frac{G\mu M}{RT}$
  critical mass $M > 3.7 \left(\frac{RT}{\mu G}\right)^{\frac{3}{2}} \frac{1}{\sqrt{\varrho}}$
- different relation for globules ("hot" constrictions):
  $M > 1.2 \left(\frac{RT}{\mu}\right)^2 \frac{1}{\sqrt{G^3 P_s}}$
- turbulences (due to SNe or magnetic fields) can aid by locally compressing ISM

Star Formation

- slow contraction; optically thin $\Rightarrow$ only slow rise in temperature
- cloud breaks up into fragments
- a higher density core forms, that becomes optically thick $\Rightarrow$ faster heating
- at $T_c \approx 2000\,\mathrm{K}$ $\mathrm{H_2}$ dissociates
- core gathers more material; temperature rise
- cloud becomes optically thick $\Rightarrow$ protostar becomes invisible
- cloud becomes less dense $\Rightarrow$ optically thin again
- contraction until MS

Star Formation Rates

- SFRs range from almost zero in old elliptical galaxies to on the order of $100\,\mathrm{M}_\odot\mathrm{a}^{-1}$, largely depending on the availability of interstellar gas
- disks of typical spiral galaxies convert $\approx 5\,\%$ of their gas mass into stars within $10^8\,\mathrm{a}$
- highest SFRs (up to $1000\,\mathrm{M}_\odot\mathrm{a}^{-1}$) are seen in dense circumnuclear regions - starbursts
  higher conversion efficiency ($\approx 30\,\%$)
- strong bars of some spiral galaxies are assumed to facilitate mass transfer to circumnuclear regions

Binary Systems

- field star population in the solar neighborhood consists of 50 $\%$ binary stars
- far away only wide binaries can be separated - $\approx 25\,\%$
- numerical simulations show that binary formation is a likely result of fragmentation during the (assumed) normal star formation process
- additionally capture processes are expected in globular clusters

Binary Characteristics

- orbital periods cover a wide range from little more than 10 minutes to thousands of years
- binary separations correspondingly reach down to only $\approx 130000\,\mathrm{km}$
- mean separation: $\approx 50\,\mathrm{AU}$
- wide binaries have little or no mass transfer, and (apart from orbiting) behave like single stars
- tidal forces tend to circularize eccentrical orbits

Binary Formation

- long-period binaries can be formed by fragmentation of the molecular cloud
- most likely result: clusters of 3-10 members
- single stars are later ejected; binaries remain behind
- gravitational disruption of binaries controls the binary fraction $\Rightarrow$ dependence on stellar density

Binary Formation

Rotating ellipsoidal protostars can split in the middle to form binaries

Opposing results:

- Tohline: these seem to be stable against remerging
- Bate: development of bar instabilities hinders binary formation

Close Binaries

- the heavier star (primary) will evolve faster, and will then generally transfer matter onto its companion
- this secondary now evolves and eventually transfers mass back
- during evolution a common envelope (CE) phase is possible - the compact object actually orbits within a giant's outer layer - "spiral in"
- oftentimes an accretion induced collapse (AIC) happens, and a neutron star forms
- neutron stars in turn can undergo AIC to form a black hole

Radiation from Binary Systems

- binaries that are close to us can be visually separated
- close binaries (or far away) can possibly be detected by periodic doppler shifts in their spectra
- (partial) eclipses indicate binaries

Types of radiation

- MS spectra are visible
- accretion onto compact objects yields X-ray luminosity

Accretion sources

- Roche Lobe overflow occurs during normal evolution
- common envelope phases
- stellar wind (Wolf-Rayet stars)
- tidal shear of compact object

Bibliography

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