GST 98 — How Two Stars Become Gravitationally Bound

Formal Description

This module follows one way in which two stars can become gravitationally bound. It distinguishes the encounter that forms the pair, the interaction that maintains it and a later encounter that can separate it.

In the selected example, three initially unbound stars pass close enough to affect one another's motion. Gravity redistributes energy during the encounter. Two stars can be left in a bound orbit while the third departs with enough energy to escape (Atallah et al., 2024).

The two stars form a binary: a pair whose members orbit their common centre of mass. They remain separate bodies. Their continuing orbital relationship is the organisation of interest.

By the end, the learner should be able to explain why a flyby need not produce capture, identify the third star's role and distinguish the persistence of the pair from the persistence of either star.

Plain English Explanation

Assembly

Imagine two stars approaching each other. Their mutual gravity bends their paths and changes their speeds. If they were initially unbound and interact only through Newtonian gravity, they will still have enough energy to travel apart again after a flyby.

Now introduce a third star. Each star changes the motion of the others. In a suitable encounter, the third star can leave with more energy of motion relative to the pair, leaving the pair with only sufficient energy to orbit one another and not enough to separate. Energy is redistributed across the three stars; it is not destroyed.

The departing star helps form the pair without remaining part of it. This is one possible outcome of a three-star encounter. A different encounter can leave all three stars unbound, and binaries can also form by other routes.

Once the third star has left, the two remaining stars continue to attract one another. Both orbit their common centre of mass. They can remain bound without touching, holding a fixed separation or receiving a continuous supply of energy from outside.

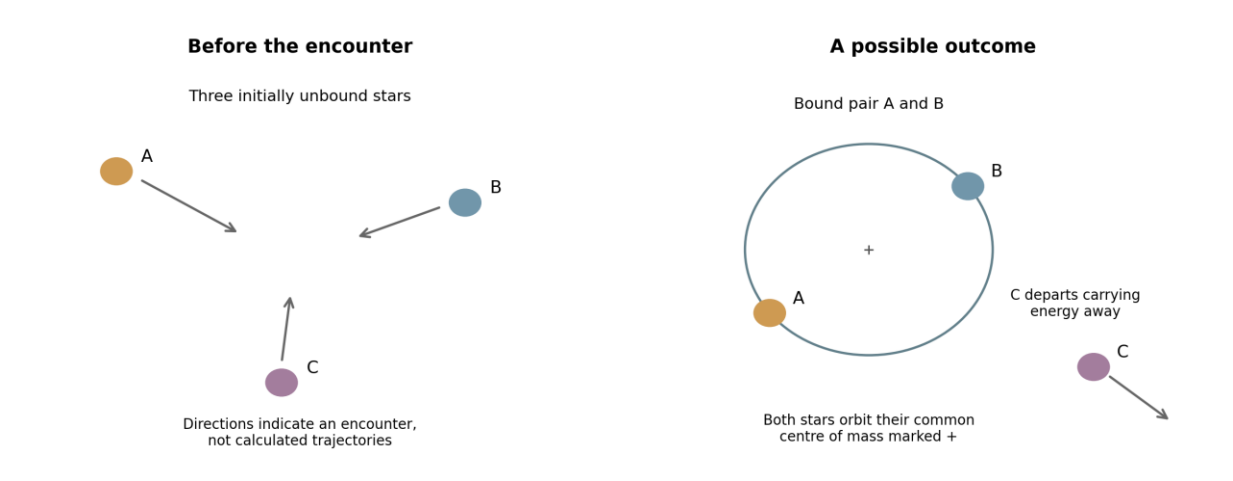
Persistence and Disassembly

Gravity continues to shape the stars' motion after capture. The energy of their relative motion, together with their gravitational potential energy, is below the level required for separation. This energy comparison describes the bound state; mutual gravity is the interaction shaping the orbit.

A later passing star may alter the orbit while leaving the original pair bound. Alternatively, a similar encounter can transfer enough energy to the pair's relative motion for its original members to separate. The original assembly then ceases to exist, while its former components can continue as stars.

Compare this with the hydrogen example in GST 94. In both cases an external participant can carry away energy during formation and need not stay to maintain the result. The stellar pair is held together by gravity; the molecule depends on electromagnetic interactions and quantum behaviour.

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One possible outcome of the encounter. The illustrated orbit shows a continuing relationship after capture. The drawing is schematic and does not predict the stars' paths during the encounter.

Provenance and Links

Foundational Causality provides the account of interactions and transfers. *Causal Assembly Theory: Assembly and Disassembly as Causal Processes* distinguishes the encounter, formation, continuing participation and disassembly. This example uses a simplified Newtonian account of orbital motion and sets aside collisions, mergers and changes inside the stars.

Atallah, D., Weatherford, N. C., Trani, A. A., & Rasio, F. A. (2024). On binary formation from three initially unbound bodies. arXiv. https://arxiv.org/abs/2402.12429

Challoner, J. A. (2026a). Foundational causality. Rational Understanding. https://rational-understanding.com/efgst/

Challoner, J. A. (2026b). Causal assembly theory: Assembly and disassembly as causal processes. Rational Understanding. https://rational-understanding.com/efgst/

Fitzpatrick, R. (2011). Orbital energies. University of Texas at Austin. https://farside.ph.utexas.edu/teaching/336k/Newtonhtml/node42.html

Practical Exercise

Sketch two outcomes: a flyby in which two stars remain unbound, and a three-star encounter that leaves a bound pair. In the second sketch, identify the two components of the binary and show how the departing star contributes to formation.

Explain what keeps the pair bound once the third star has gone. Then describe a later encounter that ends the pair's orbital relationship while leaving both stars intact.

Compare the example with hydrogen in GST 94. Identify one feature shared by the two formation routes and one difference in how the resulting assemblies persist.

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