Capture the Colorful Cosmos

Kinesthetic Life Cycle of Stars

Goals
- To learn about different types of nebulae
- To create a kinesthetic model of astronomical phenomena

Materials
- Astronomical images of various stellar life cycle stages:
    - star-forming nebula (e.g. Orion Nebula)
    - main sequence star(s) (e.g. Sun, Sirius)
    - red giant (e.g. Betelgeuse)
    - planetary nebula (e.g. Ring Nebula)
    - supernova remnant (e.g. Crab Nebula)
- (Optional) Poster illustrating the life cycle of different mass stars
- Kinesthetic Life Cycle of Stars facilitator information (next page)

Procedure

1. Explain that stars, like nebulae, are made of gas and dust. They are born inside giant star-forming nebulae and when they die they leave behind other types of nebulae. Give an overview of all five stages for a low-mass star before asking the group to imagine that they are clumps of gas in a star-forming nebula.

2. Use the Kinesthetic Life Cycle of Stars facilitator information sheet (next page) to help the group act out the important stages of a low-mass star's life and death.

    - Star Forming Nebula: Clumps of gas are pulled together by the force of gravity, forming stars

    - Star: Fusion in the core of a star creates an outward pressure that balances the force of gravity in the outer layers.

    - Red Giant: fusion overtakes gravity and the outer layers of the star expand

    - Planetary Nebula: The core of the star collapses and the outer layers drift outward into space.

3. Repeat the exercise for a high-mass star (supernova instead of planetary nebula)

    - Supernova (Remnant): The core of a very massive star collapses and the outer layers fall inward and bounce off the core and explode outward, releasing energy.

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Kinesthetic Life Cycle of Stars (adapted from "Kinesthetic Life Cycle of Stars" by Erika Reinfeld (CfA) and Mark Hartment (MKI), *Astronomy Education Review*, 10/08)

Five stages of stellar evolution are described and diagrammed below. In each stage, facilitators should provide a brief narration of the science and physical actions that are about to occur, before "starting the clock." It may be instructive to show a poster illustrating the stages of stellar evolution, or to preview an image that the students will recreate at each stage. Once the action begins, students move into the appropriate formation. Facilitators may need to provide more detailed instruction or hands-on guidance to individual students. Once students have completed the action of a stage, they should stop moving while facilitators summarize the process and begin the next segment of narration.

The "description" column in the table below does not represent verbatim narration, but rather a summary of basic principles involved in each stage. In particular, facilitators should emphasize the interplay between the inward force of gravity pulling the star together and the outward force resulting from fusion in the core.

Stage	**Description**	**Action**
Star-Forming Nebula [Gravity rules.]	A cloud of gas and dust forms many stars. A single star is created when clumps of this material (mostly hydrogen gas) are pulled together by the force of gravity.	Students, scattered randomly throughout the room, point in the direction where "the most other clumps" are, and slowly make their way to that point.
Birth of the Star (Protostar) [Gravity rules. Fusion begins.]	As a region of the cloud collapses, gravity pulls the clumps of gas together. The gas in the center becomes hot enough and dense enough to begin fusion. Hydrogen atoms inside the clumps smash into each other, combining to create helium and releasing light and heat. The star begins to shine.	Students clump together, forming a large ball. Those on the outside ("envelope") continue to move toward the center. When students on the inside ("core") start bumping into each other, they face outward.
Life of the Star (Main Sequence) [Gravity and fusion in balance.]	Fusion in the core generates an outward force to balance the inward gravitational force from the outer layers.	Core students and envelope students gently push against each other, palm-to-palm, elbows bent, balancing. There should be one or two envelope students per core student.

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Red Giant [Fusion overtakes gravity.]	As the core nears the end of its fuel supply, the outer layers continue to push inward, increasing the temperature in the core. This produces a new series of fusion reactions that produce enough outward force to overpower the inward gravitational force and expand the star.	Core students fully extend their arms, pushing the envelope students backwards, expanding the star.
Death of a Low-Mass Star (Planetary Nebula with White Dwarf) [Fusion ends; gravity wins.]	As the core runs out of fuel for fusion, it emits one last push outward, ejecting the star's outer layers, which drift away into space. The core then contracts under its own gravity, forming a white dwarf.	Core students push the envelope outward then move together into a tight blob at the center. The envelope students, in a ring-like shape, drift away from the core.
Death of a High-Mass Star (Supernova, with Neutron Star or Black Hole) [Fusion ends; gravity wins.]	The massive core continues to fuse elements and expands the star so it is even larger. Once the core runs out of fuel, it collapses to form a neutron star. The outer layers then collapse as well. As material falls toward the star's center, it bounces off the core and explodes outward through the star. This explosion is called a supernova. In the most massive stars, the collapsed core will become a black hole.	Core students extend their arms, expanding the star. Then, they stop pushing and scrunch together at the star's center. Envelope students rush inward, and bounce off the packed-together students in the core, exploding outward dramatically, revealing the collapsed core.

To transition between the deaths of low- and high-mass stars, facilitators must rewind the clock, to the original star-forming nebula or to the main sequence stage. Recreating all stages of the activity up to the red giant phase, from students' memory, is most effective because it highlights the parallel paths of the two stars and allows students to review and teach back what they have learned.

Additional information and posters about this topic can be found at
http://imagine.gsfc.nasa.gov/docs/teachers/lifecycles/stars.html

Photographs of students in action can be found at
http://www.flickr.com/photos/24452156@N07/sets/72157605963324609/

Illustration of student motion appears on the next page.

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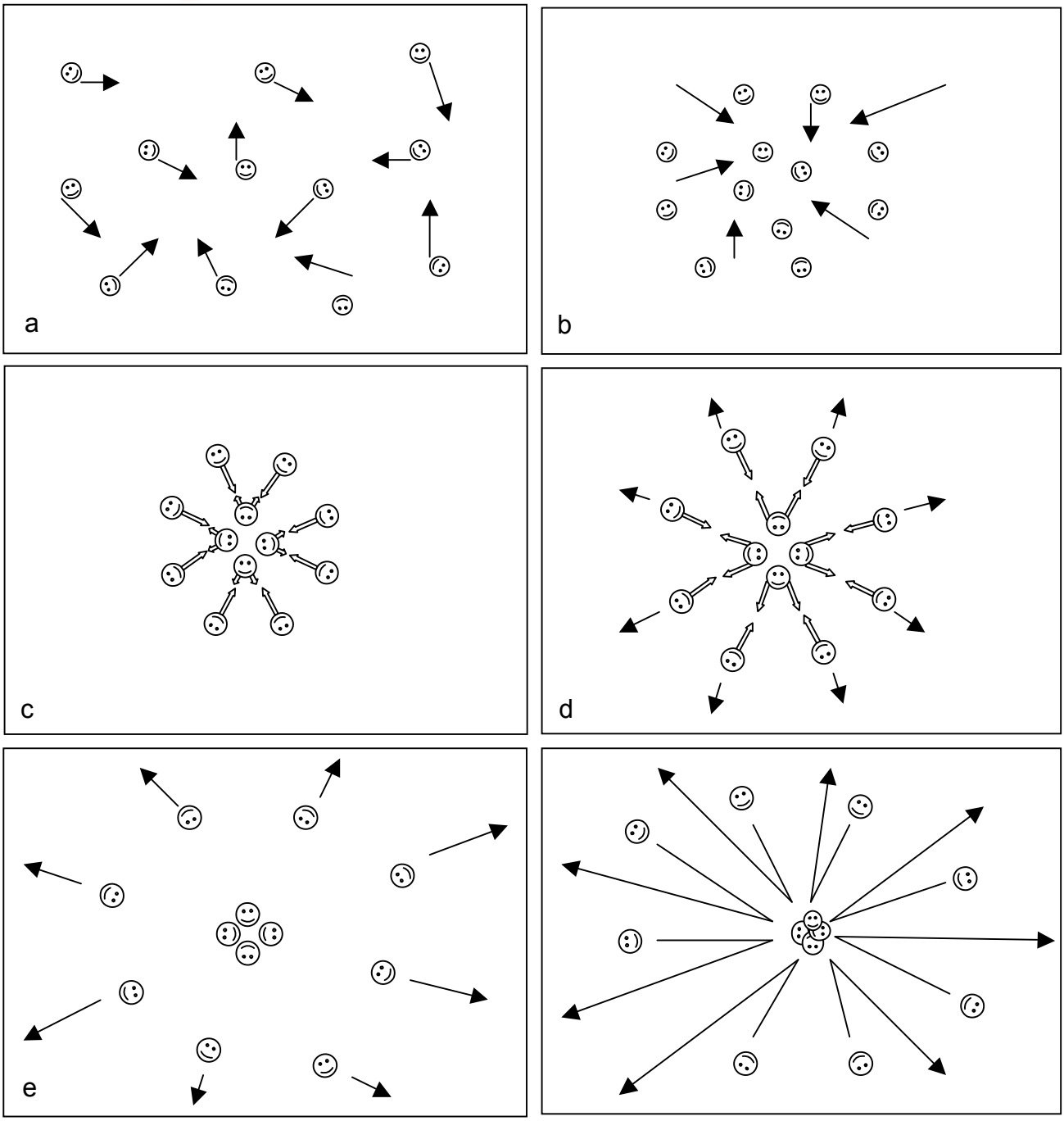

a. Star-Forming Nebula (random motion)
b. Protostar (clumping, motion toward the center, core and envelope start to differentiate)
c. Main Sequence (core and envelope pushing in balance)
d. Red giant (core pushing harder, motion outward)
e. Planetary Nebula (core compacted, all other motion outward)
f. Supernova (core compacted, motion inward then outward)