Student Work Annotations
Based upon the Science ERQ Rubric

Star Lifespan and Luminosity

Grade Level:
9, 10, 11, 12

Designed and revised by Kentucky Department of Education staff
in collaboration with teachers from Kentucky schools and districts.

Background Information About the Task

Task Overview

Students will:

- **Construct an explanation** about how we get *evidence of stars' life spans when we cannot watch a star* go through it due to long (by human standards) lives
- Articulate the *balancing pressures between inward-pulling force of gravity and outward pushing force caused by release of energy via nuclear fusion*
- **Develop an initial model** (a piece of an H-R diagram) to represent *range of star luminosity.*

Dimensions

Disciplinary Core Idea (DCI)

- ESS1.A The Universe and Its Stars
    - The star called the sun is changing and will burn out over a life span of approximately 10 billion years.
    - The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements and their distances from Earth.

Science and Engineering Practice (SEP)

- Developing and Using Models
    - Develop and model based on evidence to illustrate the relationships between systems or between components of a system
- Obtaining, Evaluating and Communicating Information
    - Communicated scientific ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats

Crosscutting Concepts (CCC)

- Scale, Proportion and Quantity
    - The significance of a phenomenon is dependent on the scale, proportion and quantity at which it occurs.

Performance Expectations (PE) to which task is correlated

- **HS-ESS1-1**
    - Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.
- **HS-ESS1-3**
    - Communicate scientific ideas about the way stars, over their life cycle, produce elements.

Star Lifespan and Luminosity

The original version of this Earth/Space science high school task may be found at: https://louisville.edu/education/centers/crimsted/cea-examples/grade-9-12-cea-examples/HS-ESS1-1_Star-lifespan-and-luminosity.pdf

UNIVERSITY OF LOUISVILLE

CENTER FOR RESEARCH IN MATHEMATICS & SCIENCE TEACHER DEVELOPMENT

Star Lifespan and Luminosity

Because our Sun is the foundation of all life on Earth, it has played a large role in humankind's thinking since prehistoric times. For example, some historic cultures thought of the Sun as a god of sorts, and all people paid attention to influences of the Sun such as day/night (for hunting, farming, various life activities) and temperature. Even today in a technological culture with artificial light and temperature-controlled living spaces, we think of how the Sun connects to big complex issues such as climate change or smaller personal decisions such as using sunblock or clothing to prevent skin cancer.

Although we know the Sun does vary sometimes, beyond Earth-related interactions such as weather that can make the Sun appear brighter or dimmer, or Earth's tilt in its annual orbit that can make the Sun feel hotter or colder at different seasons, the Sun itself tends to not vary too dramatically. Year after year, century after century, the Sun more or less goes on in a steady fashion with only small variations.

Which leads to us wondering… is the Sun basically static (unchanging in major ways) forever, or is there a pattern to how the Sun might change over many, many, many years. Connecting with how we know people change in systematic ways over years, from an infant, to a young child, to a teenager, to adult, to old age – we can outline in broad ways how this change across a person's lifespan is predictable, even though the details vary with every person.

What is the lifespan of our Sun? or more generally, What is the lifespan of stars?

GETTING EVIDENCE OF STAR LIFESPAN

Since the Sun (or other stars) don't appear to change dramatically from year to year, maybe it just takes longer? But how can we get evidence to understand a star's lifespan if we can't watch a particular star go through all of it during our own lifetime?

Let's explore how we might get that evidence by first considering a fictional story of …

The Supergenius Fruit Fly!

(*important fact: a fruit fly lifespan is approximately 45 days*)

Author: Dr. Thomas Tretter, University of Louisville

UNIVERSITY OF LOUISVILLE

CENTER FOR RESEARCH IN MATHEMATICS & SCIENCE TEACHER DEVELOPMENT

The Supergenius Fruit Fly

Once there was a supergenius fruit fly who was curious about lots of things. She was particularly curious about the large humans who were constantly in her space while she was busy in the tabletop fruit bowl trying to reproduce the next generation before her 45-day lifespan was over. She wondered, "*Do these large creatures stay the same forever, or do they also undergo regular changes over the course of a lifespan like I do*?" But in her noticings in the first 3 weeks of her life, which was now half over, she did not notice any big differences in the one person who kept checking the fruit bowl.

Thinking that maybe those changes happen over a much longer lifespan, she devised a way to get evidence to figure out what a human lifespan might be like. She observed many DIFFERENT people, and over a few days this is what she saw, and used this evidence to construct a lifespan of a human.

The End

(OK, so this story won't win any prizes…)

1. Explain how you can use this fruit-fly-technique to get evidence of stars' lifespans. Include:
   a) what types of evidence you would collect, and why? ______________________________

   ____

   ____

   ____

1b) In addition to the specific evidence you collect, what else is needed in order to describe a star's lifespan? ____
____
____
____

One thing we know about most stars is that they are HUGE – over 1,000,000 Earths could fit inside the Sun, and our Sun is only a medium-sized star!

With all of that mass, that means gravity is also strong, especially inside the Sun when you are close to the core, with all of that mass being gravitationally pulled toward the core. But because the mass doesn't continue to be pulled directly into the Sun's core, there must be something 'pushing back' inside the Sun to balance out the gravitational pull.

2. What deep inside the Sun is balancing the strong inward-pulling force of gravity so that the overall Sun stays essentially the same size for a long time? *(Hint – it is related to the nuclear fusion idea we recently explored.)* Explain your thinking about how that works.
____
____
____
____

In addition to other possible evidence about individual stars that scientists might collect, one obvious and important feature is its **brightness**. The idea of 'star brightness' is actually a bit tricky since we have to collect that evidence from Earth – if a bright star were far away, it would look relatively dim. And, if a dim star were nearby, then it might appear bright in comparison to most other stars.

Scientists also have techniques for estimating distances of stars, and so knowing the distance lets us take the observed brightness from Earth and transform it into actual brightness of the star itself – as if you could see the star from right next to it. Rather than brightness, which can be an unclear term, astronomers usually use the term "***luminosity***," which is the amount of energy (or light) being emitted from the star's surface. Scientists are also able to get estimates of a star's mass by observing how it gravitationally interacts with nearby objects.

In addition to luminosity and mass, astronomers can use that data plus other information such as a star's rotation rate (which varies at known rates depending on the age of a star) and light spectrum (which gives information about its composition) to compute an estimated age of a star.

Table 1 has data for a few select stars that the work of many astronomers over time have contributed to.

Table 1. Approximate Quantities for a few Select Stars

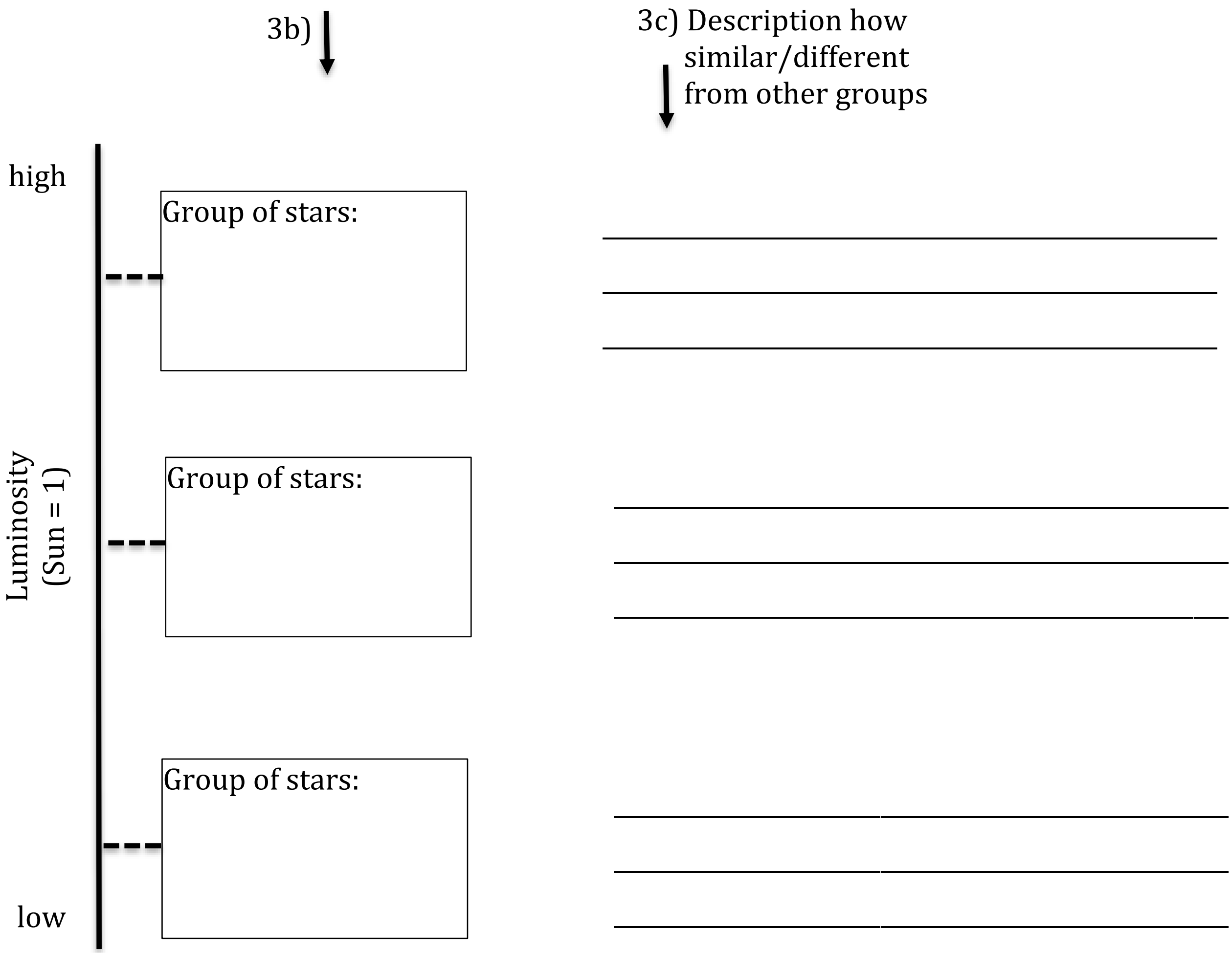
Star	**Luminosity** (in "solars" where 1 solar = luminosity of our Sun)	Approx. **mass** (in "solar masses" using mass of our Sun as reference)	**Age** (millions of years)	**Diameter** (in "solar diameters")
Our Sun	1	1	4,600	1
Betelgeuse	140,000	18	10	700
Antares	100,000	15	11	700
Sirius B	0.0025	1	250	0.008
Alpha Centauri A	1.5	1.1	5,500	1.22
51 Pegasi	1.3	1.11	7,000	1.24
Procyon B	0.00055	0.6	1,880	0.012
Tau Ceti	0.45	0.8	5,800	0.8
G240-72	0.000085	0.81	5,690	0.0098

3. As a first step for exploring possibilities for modeling the lifespan of the Sun, use the data in Table 1 to:
   a) Arrange the 9 stars in Table 1 into 3 "mostly similar" groups (*put in boxes below*)

   b) Order the groups by luminosity (lowest on bottom, highest luminosity on top) on the vertical axis (*next page*)

   c) Write brief descriptions for each of the 3 groups, comparing how they are similar or different from the other groups (*next page*).

Author: Dr. Thomas Tretter, University of Louisville



d. For one of the 3 groups, one of the variables in Table 1 still varies quite a bit within the group. Identify which group and which variable ranges widely.

which group:_________________________ which variable:______________________

e. Offer any thoughts, guesses, or questions that might help you start to explain why that one particular variable might vary so widely for this one group.

____

____

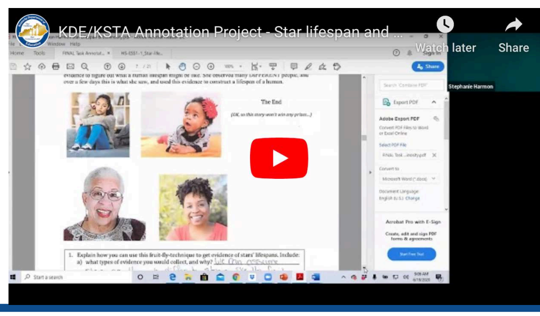
____

____

Author: Dr. Thomas Tretter, University of Louisville

Star Lifespan and Luminosity

A video recording discussing this annotation may be found at: https://www.youtube.com/watch?v=FGI5k4NhEds&t=93s



UNIVERSITY OF
LOUISVILLE.

CENTER FOR RESEARCH IN
MATHEMATICS & SCIENCE
TEACHER DEVELOPMENT

The Supergenius Fruit Fly

Once there was a supergenius fruit fly who was curious about lots of things. She was particularly curious about the large humans who were constantly in her space while she was busy in the tabletop fruit bowl trying to reproduce the next generation before her 45-day lifespan was over. She wondered, "*Do these large creatures stay the same forever, or do they also undergo regular changes over the course of a lifespan like I do*?" But in her noticings in the first 3 weeks of her life, which was now half over, she did not notice any big differences in the one person who kept checking the fruit bowl.

Thinking that maybe those changes happen over a much longer lifespan, she devised a way to get evidence to figure out what a human lifespan might be like. She observed many DIFFERENT people, and over a few days this is what she saw, and used this evidence to construct a lifespan of a human.

The End

(OK, so this story won't win any prizes...)

Scale

Obtaining, Evaluating and Communicating Information

1. Explain how you can use this fruit-fly-technique to get evidence of stars' lifespans. Include:
   a) what types of evidence you would collect, and why? ______________________

____

____

____

Author: Dr. Thomas Tretter, University of Louisville

UNIVERSITY OF LOUISVILLE
CENTER FOR RESEARCH IN MATHEMATICS & SCIENCE TEACHER DEVELOPMENT

1b) In addition to the specific evidence you collect, what else is needed in order to describe a star's lifespan?

DCI-ESS1.A

The study of stars light spectra and brightness is used to identify compositional elements of stars, their movements and their distances from Earth.

One thing we know about most stars is that they are HUGE – over 1,000,000 Earths could fit inside the Sun, and our Sun is only a medium-sized star!

With all of that mass, that means gravity is also strong, especially inside the Sun when you are close to the core, with all of that mass being gravitationally pulled toward the core. But because the mass doesn't continue to be pulled directly into the Sun's core, there must be something 'pushing back' inside the Sun to balance out the gravitational pull.

DCI- HS-ESS1-3 Communicate scientific ideas about the way stars, over their life cycle, produce elements.

2. What deep inside the Sun is balancing the strong inward-pulling force of gravity so that the overall Sun stays essentially the same size for a long time? *(Hint – it is related to the nuclear fusion idea we recently explored.)* Explain your thinking about how that works.

Obtaining, Evaluating + Communicating Information

In addition to other possible evidence about individual stars that scientists might collect, one obvious and important feature is its **brightness**. The idea of 'star brightness' is actually a bit tricky since we have to collect that evidence from Earth – if a bright star were far away, it would look relatively dim. And, if a dim star were nearby, then it might appear bright in comparison to most other stars.

Scientists also have techniques for estimating distances of stars, and so knowing the distance lets us take the observed brightness from Earth and transform it into actual brightness of the star itself – as if you could see the star from right next to it. Rather than brightness, which can be an unclear term, astronomers usually use the term "***luminosity***," which is the amount of energy (or light) being emitted from the star's surface. Scientists are also able to get estimates of a star's mass by observing how it gravitationally interacts with nearby objects.

Author: Dr. Thomas Tretter, University of Louisville

In addition to luminosity and mass, astronomers can use that data plus other information such as a star's rotation rate (which varies at known rates depending on the age of a star) and light spectrum (which gives information about its composition) to compute an estimated age of a star.

Table 1 has data for a few select stars that the work of many astronomers over time have contributed to.

Table 1. Approximate Quantities for a few Select Stars

Star	**Luminosity** (in "solars" where 1 solar = luminosity of our Sun)	Approx. **mass** (in "solar masses" using mass of our Sun as reference)	**Age** (millions of years)	**Diameter** (in "solar diameters")
Our Sun	1	1	4,600	1
Betelgeuse	140,000	18	10	700
Antares	100,000	15	11	700
Sirius B	0.0025	1	250	0.008
Alpha Centauri A	1.5	1.1	5,500	1.22
51 Pegasi	1.3	1.11	7,000	1.24
Procyon B	0.00055	0.6	1,880	0.012
Tau Ceti	0.45	0.8	5,800	0.8
G240-72	0.000085	0.81	5,690	0.0098

Developing and Using Models

3. As a first step for exploring possibilities for modeling the lifespan of the Sun, use the data in Table 1 to:
   a) Arrange the 9 stars in Table 1 into 3 "mostly similar" groups (*put in boxes below*)

   b) Order the groups by luminosity (lowest on bottom, highest luminosity on top) on the vertical axis (*next page*)

   Obtaining, Evaluating and Communicating Information

   c) Write brief descriptions for each of the 3 groups, comparing how they are similar or different from the other groups (*next page*).

   Developing and Using Models

3b)

3c) Description how similar/different from other groups Developing and Using Models

high

Luminosity (Sun = 1)

Group of stars:

Group of stars:

Group of stars:

low

d. For one of the 3 groups, one of the variables in Table 1 still varies quite a bit within the group. Identify which group and which variable ranges widely.

DCI ESS1.A

which group:________________ which variable:________________

e. Offer any thoughts, guesses, or questions that might help you start to explain why that one particular variable might vary so widely for this one group.

Obtaining, Evaluating and Communicating Information

Author: Dr. Thomas Tretter, University of Louisville

UNIVERSITY OF
LOUISVILLE.

CENTER FOR RESEARCH IN
MATHEMATICS & SCIENCE
TEACHER DEVELOPMENT

Sample 1
Synthesis +
Understanding

The Supergenius Fruit Fly

Once there was a supergenius fruit fly who was curious about lots of thin curious about the large humans who were constantly in her space while she was bowl trying to reproduce the next generation before her 45-day lifespan was ove *these large creatures stay the same forever, or do they also undergo regular changes over the course of a lifespan like I do*?" But in her noticings in the first 3 weeks of her life, which was now half over, she did not notice any big differences in the one person who kept checking the fruit bowl.

Thinking that maybe those changes happen over a much longer lifespan, she devised a way to get evidence to figure out what a human lifespan might be like. She observed many DIFFERENT people, and over a few days this is what she saw, and used this evidence to construct a lifespan of a human.

The End

(OK, so this story won't win any prizes...)

1. Explain how you can use this fruit-fly-technique to get evidence of stars' lifespans. Include:
   a) what types of evidence you would collect, and why? We can assume stars go through different stages like the fruit fly did the human. The evidence we could use is how the stars look now.

Author: Dr. Thomas Tretter, University of Louisville

1b) In addition to the specific evidence you collect, what else is needed in order to describe a star's lifespan? What the star is around. How the Star interacts with one another. Do different types of Stars go through the Same Change

One thing we know about most stars is that they are HUGE – over 1,000,000 Earths could fit inside the Sun, and our Sun is only a medium-sized star!

With all of that mass, that means gravity is also strong, especially inside the Sun when you are close to the core, with all of that mass being gravitationally pulled toward the core. But because the mass doesn't continue to be pulled directly into the Sun's core, there must be something 'pushing back' inside the Sun to balance out the gravitational pull.

2. What deep inside the Sun is balancing the strong inward-pulling force of gravity so that the overall Sun stays essentially the same size for a long time? *(Hint – it is related to the nuclear fusion idea we recently explored.)* Explain your thinking about how that works.
It can be assumed that the gravity from other planets are pulling, but the planets are not deep inside the Core. There has to be another force that is pushing gravity away.

In addition to other possible evidence about individual stars that scientists might collect, one obvious and important feature is its **brightness**. The idea of 'star brightness' is actually a bit tricky since we have to collect that evidence from Earth – if a bright star were far away, it would look relatively dim. And, if a dim star were nearby, then it might appear bright in comparison to most other stars.

Scientists also have techniques for estimating distances of stars, and so knowing the distance lets us take the observed brightness from Earth and transform it into actual brightness of the star itself – as if you could see the star from right next to it. Rather than brightness, which can be an unclear term, astronomers usually use the term "***luminosity***," which is the amount of energy (or light) being emitted from the star's surface. Scientists are also able to get estimates of a star's mass by observing how it gravitationally interacts with nearby objects.

Author: Dr. Thomas Tretter, University of Louisville

UNIVERSITY OF LOUISVILLE.

CENTER FOR RESEARCH IN MATHEMATICS & SCIENCE TEACHER DEVELOPMENT

In addition to luminosity and mass, astronomers can use that data plus other information such as a star's rotation rate (which varies at known rates depending on the age of a star) and light spectrum (which gives information about its composition) to compute an estimated age of a star.

Table 1 has data for a few select stars that the work of many astronomers over time have contributed to.

Table 1. Approximate Quantities for a few Select Stars

Star	**Luminosity** (in "solars" where 1 solar = luminosity of our Sun)	Approx. **mass** (in "solar masses" using mass of our Sun as reference)	**Age** (millions of years)	**Diameter** (in "solar diameters")
Our Sun our sun 1	1	1	4,600	1
Betelgeuse high 2	140,000	18	10	700
Antares high 2	100,000	15	11	700
Sirius B Low 3	0.0025	1	250	0.008
Alpha Centauri A our sun 1	1.5	1.1	5,500	1.22
51 Pegasi our sun 1	1.3	1.11	7,000	1.24
Procyon B Low 3	0.00055	0.6	1,880	0.012
Tau Ceti Low 1	0.45	0.8	5,800	0.8
G240-72 Low 3	0.000085	0.81	5,690	0.0098

3. As a first step for exploring possibilities for modeling the lifespan of the Sun, use the data in Table 1 to:

   a) Arrange the 9 stars in Table 1 into 3 "mostly similar" groups (*put in boxes below*)

Our Sun Alpha Centauri A 51 pegasi Tau ceti	Betelgeuse Antares	Sirius B Procyon B G240-72

   b) Order the groups by luminosity (lowest on bottom, highest luminosity on top) on the vertical axis (*next page*)

   c) Write brief descriptions for each of the 3 groups, comparing how they are similar or different from the other groups (*next page*).

Author: Dr. Thomas Tretter, University of Louisville

3b) ↓

3c) Description how similar/different from other groups ↓

Luminosity (Sun = 1)

high

Group of stars:
Betelgeuse
Anatares

The stars must be very bright compared to other stars

Group of stars:
Alpha centauri A
51 pegias
Oursun

These stars almost have the same brightness as our sun

Group of stars:
1ay
Sirus B
Procyon B
G240-72

These stars are not very bright

low

d. For one of the 3 groups, one of the variables in Table 1 still varies quite a bit within the group. Identify which group and which variable ranges widely.

which group: 3 which variable: Mass

e. Offer any thoughts, guesses, or questions that might help you start to explain why that one particular variable might vary so widely for this one group.

I think the reason the vary is so wide because of the luminosity of the stars. Betelgeuse and Anatares both have very high luminosity. Betelgeuse has a luminosity of 140,000 while Anatares has a lumnosity of 100,000

Author: Dr. Thomas Tretter, University of Louisville

Sample 1

Question #3

The student demonstrates a general synthesis and understanding of complex ideas. The data in Table 1 is used to develop a model which is a portion of an H-R diagram. This demonstrates a general understanding of the SEP of Developing and Using Models and the CCC of Scale, Proportion and Quantity.

3a. Stars are correctly grouped based on similarities.

3b. Star groups are correctly arranged in order from low luminosity to high luminosity.

3c. Evidence of general synthesis is in the description of the similarities and differences in the groups. The student correctly compares the brightness (luminosity) of each group to our Sun but does not mention mass or age.

3d/3e The student correctly identifies Group 3 as the group with the most variance in one of the variables. This indicates a general coherence of the DCI: ESS1.A. The student identifies mass as the variable with the most variance then discusses luminosity in part e. This indicates the student understands the relationship between mass and luminosity (more massive, the brighter). It does not indicate whether the student understands the relationship between these variables and age and diameter.

Sample 2
Coherence

UNIVERSITY OF
LOUISVILLE.
CENTER FOR RESEARCH IN
MATHEMATICS & SCIENCE
TEACHER DEVELOPMENT

The Supergenius Fruit Fly

Once there was a supergenius fruit fly who was curious about lots of things. S
curious about the large humans who were constantly in her space while she was busy
bowl trying to reproduce the next generation before her 45-day lifespan was over. She
these large creatures stay the same forever, or do they also undergo regular changes over the course of a lifespan like I do?" But in her noticings in the first 3 weeks of her life, which was now half over, she did not notice any big differences in the one person who kept checking the fruit bowl.

Thinking that maybe those changes happen over a much longer lifespan, she devised a way to get evidence to figure out what a human lifespan might be like. She observed many DIFFERENT people, and over a few days this is what she saw, and used this evidence to construct a lifespan of a human.

The End

(OK, so this story won't win any prizes...)

1. Explain how you can use this fruit-fly-technique to get evidence of stars' lifespans. Include:
   a) what types of evidence you would collect, and why? We often Wonder if a Star really has a "life Cycle". And they do, just like us they go through many Changes in their Lives.

Author: Dr. Thomas Tretter, University of Louisville

1b) In addition to the specific evidence you collect, what else is needed in order to describe a star's lifespan? Information from other stars that are like the one we are studying.

One thing we know about most stars is that they are HUGE – over 1,000,000 Earths could fit inside the Sun, and our Sun is only a medium-sized star!

With all of that mass, that means gravity is also strong, especially inside the Sun when you are close to the core, with all of that mass being gravitationally pulled toward the core. But because the mass doesn't continue to be pulled directly into the Sun's core, there must be something 'pushing back' inside the Sun to balance out the gravitational pull.

2. What deep inside the Sun is balancing the strong inward-pulling force of gravity so that the overall Sun stays essentially the same size for a long time? *(Hint – it is related to the nuclear fusion idea we recently explored.)* Explain your thinking about how that works.

The mass of gravity gets stronger the closer ~~to~~ the core you are.

In addition to other possible evidence about individual stars that scientists might collect, one obvious and important feature is its **brightness**. The idea of 'star brightness' is actually a bit tricky since we have to collect that evidence from Earth – if a bright star were far away, it would look relatively dim. And, if a dim star were nearby, then it might appear bright in comparison to most other stars.

Scientists also have techniques for estimating distances of stars, and so knowing the distance lets us take the observed brightness from Earth and transform it into actual brightness of the star itself – as if you could see the star from right next to it. Rather than brightness, which can be an unclear term, astronomers usually use the term "***luminosity***," which is the amount of energy (or light) being emitted from the star's surface. Scientists are also able to get estimates of a star's mass by observing how it gravitationally interacts with nearby objects.

Author: Dr. Thomas Tretter, University of Louisville

In addition to luminosity and mass, astronomers can use that data plus other information such as a star's rotation rate (which varies at known rates depending on the age of a star) and light spectrum (which gives information about its composition) to compute an estimated age of a star.

Table 1 has data for a few select stars that the work of many astronomers over time have contributed to.

Table 1. Approximate Quantities for a few Select Stars

Star	**Luminosity** (in "solars" where 1 solar = luminosity of our Sun)	Approx. **mass** (in "solar masses" using mass of our Sun as reference)	**Age** (millions of years)	**Diameter** (in "solar diameters")
Our Sun	1	1	4,600	1
Betelgeuse	140,000	18	10	700
Antares	100,000	15	11	700
Sirius B	0.0025	1	250	0.008
Alpha Centauri A	1.5	1.1	5,500	1.22
51 Pegasi	1.3	1.11	7,000	1.24
Procyon B	0.00055	0.6	1,880	0.012
Tau Ceti	0.45	0.8	5,800	0.8
G240-72	0.000085	0.81	5,690	0.0098

3. As a first step for exploring possibilities for modeling the lifespan of the Sun, use the data in Table 1 to:

a) Arrange the 9 stars in Table 1 into 3 "mostly similar" groups (*put in boxes below*)

1	2	3
Our Sun Alpha Centauri A 51 Pegasi Tau Ceti	Sirius B Procyon B G240-72	Betelgeuse Antares

b) Order the groups by luminosity (lowest on bottom, highest luminosity on top) on the vertical axis (*next page*)

c) Write brief descriptions for each of the 3 groups, comparing how they are similar or different from the other groups (*next page*).

Author: Dr. Thomas Tretter, University of Louisville

3b) ↓

3c) Description how similar/different from other groups ↓

high

Luminosity (Sun = 1)

low

Group of stars: 1
Our Sun
Alpha Centauri A
51 Pegasi
Tau Ceti

Group 1 has the middle highest Lumens.

Group of stars: 2
Sirius B
Procyon B
G240-72

Group 2 has the lesser Lumens.

Group of stars: 3
Betelgeuse
Antares

Grap 3 has the highest Lumens.

d. For one of the 3 groups, one of the variables in Table 1 still varies quite a bit within the group. Identify which group and which variable ranges widely.

which group: Group 3 which variable: Lumens

e. Offer any thoughts, guesses, or questions that might help you start to explain why that one particular variable might vary so widely for this one group.

It is in the honded thousands range, all the others are Ones and decimals.

Author: Dr. Thomas Tretter, University of Louisville

Sample 2

The student demonstrates limited understanding of the SEP and CCC. Stars are correctly groups in 3a but incorrectly arranged by luminosity in 3b. The response in 3c indicates some coherence of the CCC – the groups are numbers in 3a and correctly described by luminosity in 3c (student refers to luminosity in terms of the unit lumens).

Limited coherence is evident in 3d/3e. In 3d, the wrong star group is identified but the correct variable (units) is identified. 3e is not coherent.

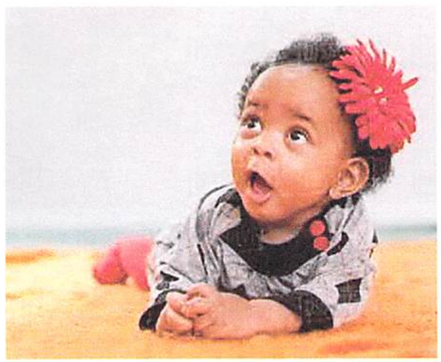
UNIVERSITY OF
LOUISVILLE.
CENTER FOR RESEARCH IN
MATHEMATICS & SCIENCE
TEACHER DEVELOPMENT

Sample 3
Logic

The Supergenius Fruit Fly

Once there was a supergenius fruit fly who was curious about lots of things. S
curious about the large humans who were constantly in her space while she was busy
bowl trying to reproduce the next generation before her 45-day lifespan was over. Sh
these large creatures stay the same forever, or do they also undergo regular changes
lifespan like I do?" But in her noticings in the first 3 weeks of her life, which was now half over, she did not notice any big differences in the one person who kept checking the fruit bowl.

Thinking that maybe those changes happen over a much longer lifespan, she devised a way to get evidence to figure out what a human lifespan might be like. She observed many DIFFERENT people, and over a few days this is what she saw, and used this evidence to construct a lifespan of a human.



The End

(OK, so this story won't win any prizes...)

1. Explain how you can use this fruit-fly-technique to get evidence of stars' lifespans. Include:
   a) what types of evidence you would collect, and why? You Could look at New Stars, Old Stars, Stars that are about to explode, ones that havalready exploded

Author: Dr. Thomas Tretter, University of Louisville

1b) In addition to the specific evidence you collect, what else is needed in order to describe a star's lifespan? Pictures, Detail description or different aged stars.

One thing we know about most stars is that they are HUGE – over 1,000,000 Earths could fit inside the Sun, and our Sun is only a medium-sized star!

With all of that mass, that means gravity is also strong, especially inside the Sun when you are close to the core, with all of that mass being gravitationally pulled toward the core. But because the mass doesn't continue to be pulled directly into the Sun's core, there must be something 'pushing back' inside the Sun to balance out the gravitational pull.

2. What deep inside the Sun is balancing the strong inward-pulling force of gravity so that the overall Sun stays essentially the same size for a long time? *(Hint – it is related to the nuclear fusion idea we recently explored.)* Explain your thinking about how that works.
The Sun takes gases and takes an electron and does something and it pushes back with the same force as it pushes back.

In addition to other possible evidence about individual stars that scientists might collect, one obvious and important feature is its **brightness**. The idea of 'star brightness' is actually a bit tricky since we have to collect that evidence from Earth – if a bright star were far away, it would look relatively dim. And, if a dim star were nearby, then it might appear bright in comparison to most other stars.

Scientists also have techniques for estimating distances of stars, and so knowing the distance lets us take the observed brightness from Earth and transform it into actual brightness of the star itself – as if you could see the star from right next to it. Rather than brightness, which can be an unclear term, astronomers usually use the term "***luminosity***," which is the amount of energy (or light) being emitted from the star's surface. Scientists are also able to get estimates of a star's mass by observing how it gravitationally interacts with nearby objects.

Author: Dr. Thomas Tretter, University of Louisville

In addition to luminosity and mass, astronomers can use that data plus other information such as a star's rotation rate (which varies at known rates depending on the age of a star) and light spectrum (which gives information about its composition) to compute an estimated age of a star.

Table 1 has data for a few select stars that the work of many astronomers over time have contributed to.

Table 1. Approximate Quantities for a few Select Stars

Star	**Luminosity** (in "solars" where 1 solar = luminosity of our Sun)	Approx. **mass** (in "solar masses" using mass of our Sun as reference)	**Age** (millions of years)	**Diameter** (in "solar diameters")
Our Sun	1	1	4,600	1
Betelgeuse	140,000	18	10	700
Antares	100,000	15	11	700
Sirius B	0.0025	1	250	0.008
Alpha Centauri A	1.5	1.1	5,500	1.22
51 Pegasi	1.3	1.11	7,000	1.24
Procyon B	0.00055	0.6	1,880	0.012
Tau Ceti	0.45	0.8	5,800	0.8
G240-72	0.000085	0.81	5,690	0.0098

3. As a first step for exploring possibilities for modeling the lifespan of the Sun, use the data in Table 1 to:

   a) Arrange the 9 stars in Table 1 into 3 "mostly similar" groups (*put in boxes below*)

A	B	C
Our Sun Alpha Centauri A 51 Pegsi	Procyon B tau ceti G240-72 Sirius B	Betelgeuse Antares

   b) Order the groups by luminosity (lowest on bottom, highest luminosity on top) on the vertical axis (*next page*)

   c) Write brief descriptions for each of the 3 groups, comparing how they are similar or different from the other groups (*next page*).

Author: Dr. Thomas Tretter, University of Louisville

3b) ↓

3c) Description how similar/different from other groups ↓

Luminosity (Sun = 1)

high

Group of stars: Group C

They are only in the double digit for age. All have reletivly low Mass.

Group of stars: Group A

Group A's lumosity is a Single digit. Almost all are around the Same age.

Group of stars: GroupC

There lumosity are decimals. Almost all in Close age.

low

d. For one of the 3 groups, one of the variables in Table 1 still varies quite a bit within the group. Identify which group and which variable ranges widely.

which group: B which variable: luminosity

e. Offer any thoughts, guesses, or questions that might help you start to explain why that one particular variable might vary so widely for this one group.

With group B's luminosity the decimal Places vary alot the all are diffrent

Sample 3

The student demonstrates understanding of the SEP. In 3a all stars except Tau Ceti are correctly grouped. In 3b Group C is listed twice, Group B is not included. The responses in 3c indicate flaws in logic – even if the assumption is made that Group C is correctly identified as the Group with the highest luminosity, the relationship between Group C's luminosity and mass is incorrect.

3d is correct based on the identity of Group B in 3a and luminosity is correctly identified as the variable with the most variance. However, the explanation in 3e does not clearly explain this which indicates a limited understanding of the DCI and CCC.