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A semiotic analysis of the disciplinary affordances of the Hertzsprung-Russell diagram in astronomy

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Overview

Astronomy is special

History of HR diagram

Potential problems for learning

Research project

Some preliminary results



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Astronomy

Astronomy is special kind of science

No experiments

Can only observe

**Time scales and distances are difficult to
comprehend**

Eriksson et al. (2014)



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The Hertzsprung Russell Diagram



Ejnar Hertzsprung
1863-1967



Henry Norris Russell
1877-1957



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The HR diagram

Semiotic analysis of the disciplinary affordances of Hertzsprung-Russell (HR) diagram.

This is a semiotic resource used in astronomy that can be used to plot all known stars

Stars are formed, develop and evolve.

The position of a star on the HR diagram tells us its evolutionary stage and its final "fate"



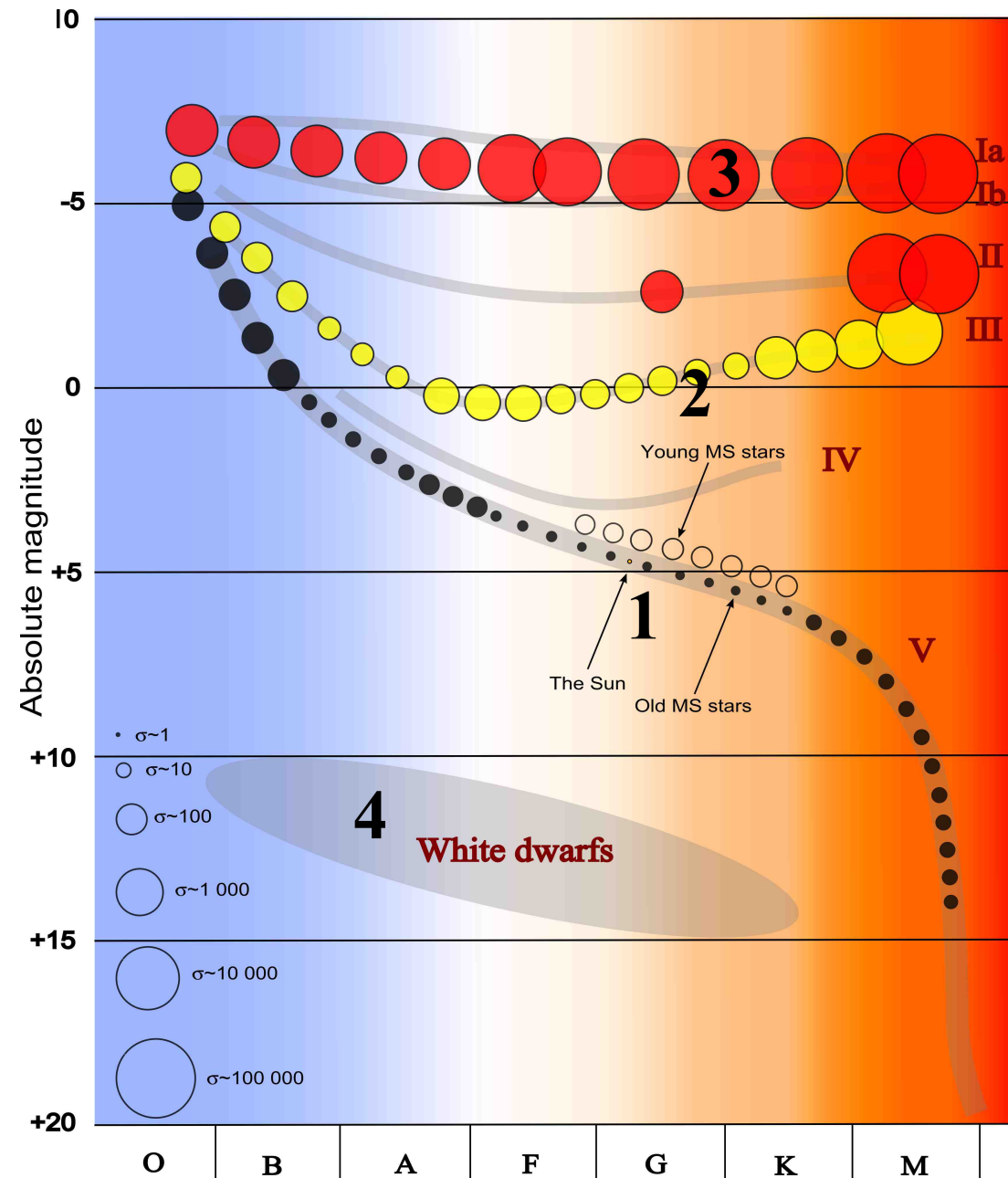
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The HR diagram

What is an HR diagram?

A plot of how bright stars are against their surface temperature.

Major advance in understanding the "lives of stars"





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What do students experience?

- Complicated diagram**
- Impossible to immediately interpret**
- The disciplinary affordances are hidden**



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Disciplinary affordance

**Fredlund *et al.* (2012) suggest the term
disciplinary affordance for semiotic resources**



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Disciplinary affordance

Definition:

The potential of a given semiotic resource to provide access to disciplinary knowledge

Fredlund et al. (2012:658)

Deals with individual semiotic resources

Focuses on the *discipline's interpretation* of the resource rather than the learner's experience



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Disciplinary learning

- Students need the diagram to be *unpacked* or *reverse-rankshifted* for them Fredlund (2014)
- Learning
- Students' experience of the HR diagram needs to move towards the disciplinary interpretation
- Need to start to experience the disciplinary affordances of the diagram.



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What are the disciplinary affordances?

Why does the diagram look like it does?

Need a little history lesson...



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Annie Jump Cannon



Born: 1863, Died: 1941



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Annie Jump Cannon



Astronomer from Harvard
Catalogued nearly 400 000 stars
Discovered 300 variable stars
First woman to gain a honorary
doctorate from Oxford

Worked for at Harvard for 40
years but only received tenure
two years before retirement.



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Annie Jump Cannon



Oh Be A Fine Girl Kiss Me



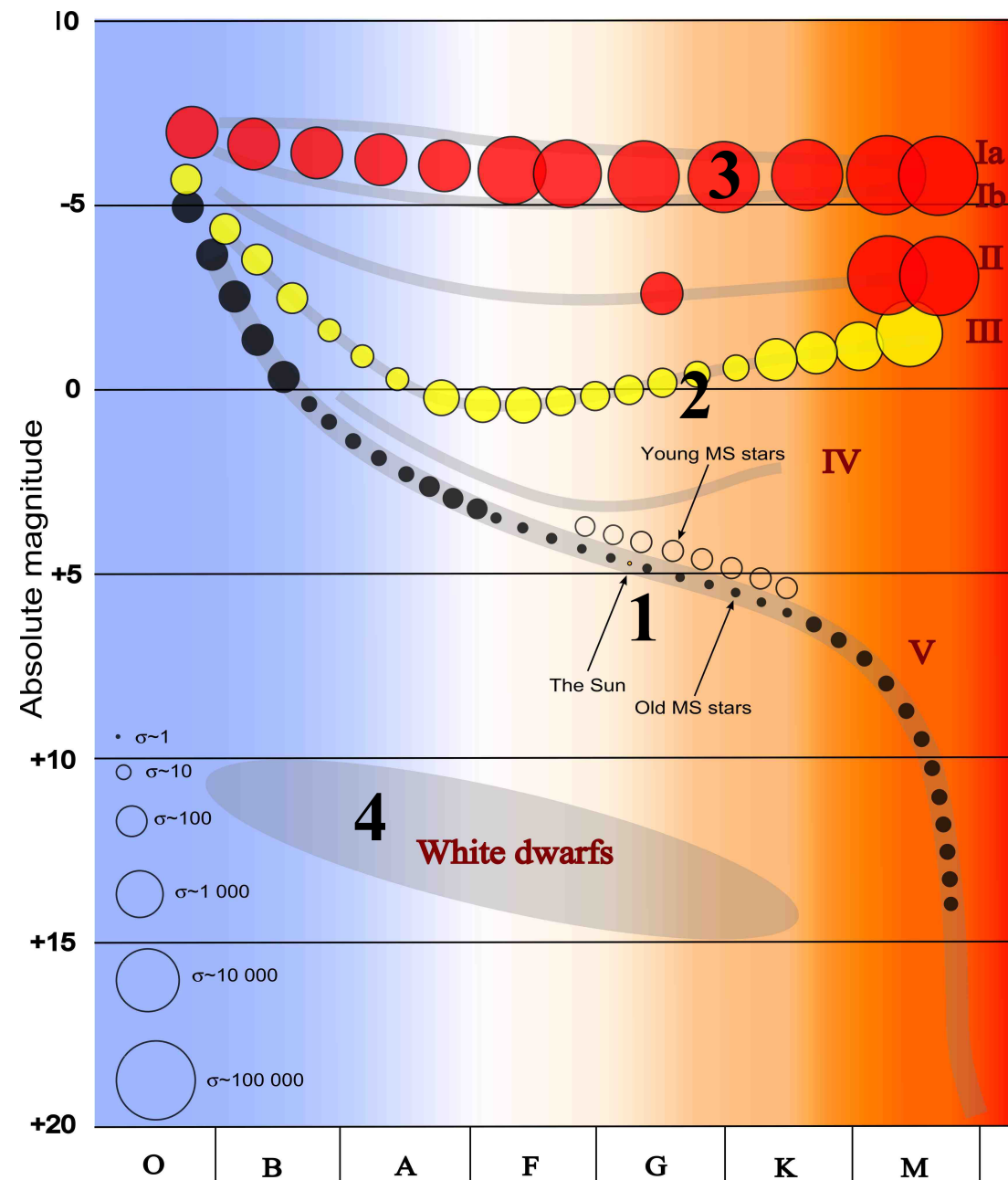
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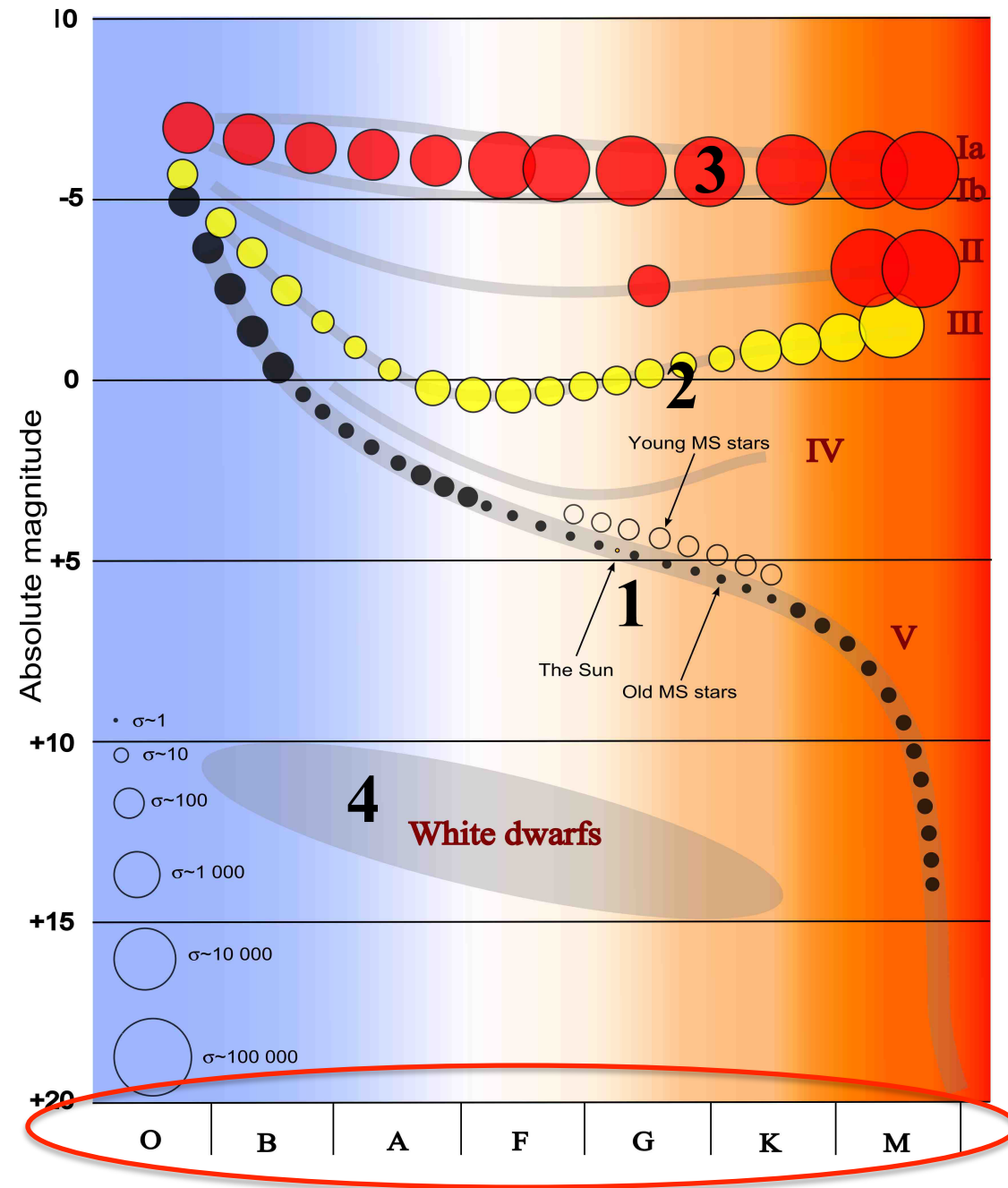
Annie Jump Cannon



Oh Be A Fine Girl Kiss Me

O B A F G K M







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Reordering the horizontal axis

The colours of stars (their spectra) were originally classified alphabetically A-Q

Cannon realised that these essentially arbitrary categories could be rationalized and re-ordered to make more sense from an astrophysical point of view

The original 17 alphabetical categories became seven ordered O B A F G K M



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New meaning for the horizontal axis

Discoveries in physics later showed that this ordering on the horizontal axis of the HR diagram was related to the **surface temperature** of stars.

Blue occurs at higher temperatures, while red occurs at lower, cooler, temperatures.

When our everyday lives when we think of colour we think of ***reflected light***



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New meaning for the horizontal axis

Surface temperature of stars decreases we as move through Cannon's classification from O to M

Right on the HR diagram means colder

This means the HR diagram has a doubly counter-intuitive horizontal axis



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New meaning for the horizontal axis

Opposite to the cultural associations attributed to colors, in which "red" is "hot", and "blue" is "cold".

In astronomy blue is *very* hot



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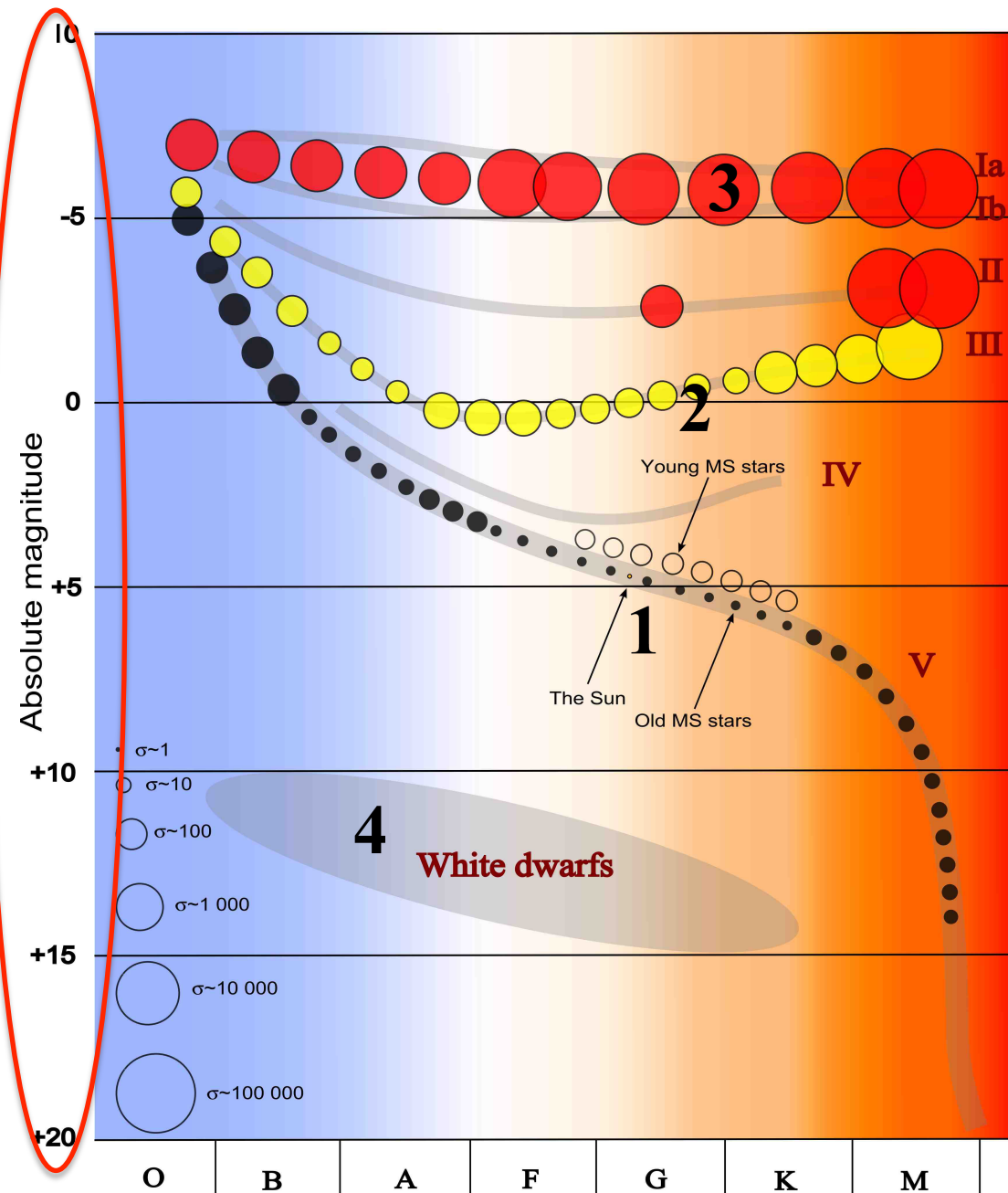
Counter-intuitive

Culturally we expect red to be hot and blue to be cold

Semiotically we expect graphs to move from lower quantities on the left to higher quantities on the right.

So history leaves us with essentially random labelling OBAFGKM of a counter-intuitive temperature scale

What about the vertical axis ?





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Brightness

The vertical axis on the HR diagram is linked to how bright a star is—its *Apparent magnitude*

Apparent magnitude

Hipparchos (≈ 150 B.C.)

Six levels:

Brightest: magnitude 1

Faintest: magnitude 6



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Brightness

Stars are at different distances from us.

Astronomers want a brightness value that is comparable.

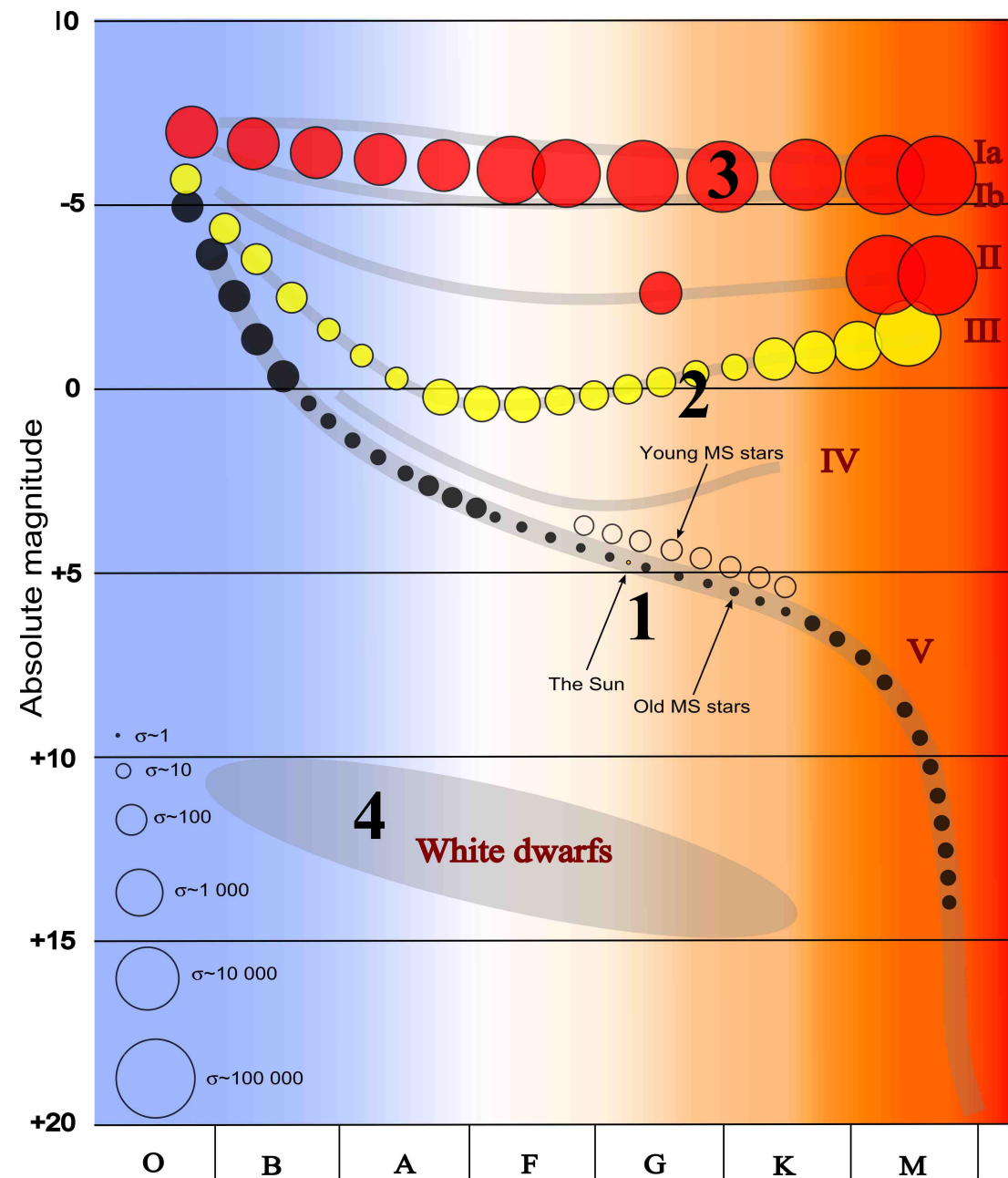
Absolute magnitude: how bright a star would be at a standard distance.

(10 parsec about 31000000000000 km)



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The lives of stars





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The lives of stars

One further counter intuitive element.

The anthropomorphic idea of the lives of stars.

When people die they get cold-right?

But when stars 'die' they have a hotter surface temperature



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The study

Interested in how students experience the HR diagram

Online study

Students shown the diagram and asked questions about it.

Do the historical ‘remnants’ and the counterintuitive aspects of the diagram cause barriers to student learning?



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Preliminary data

ADD

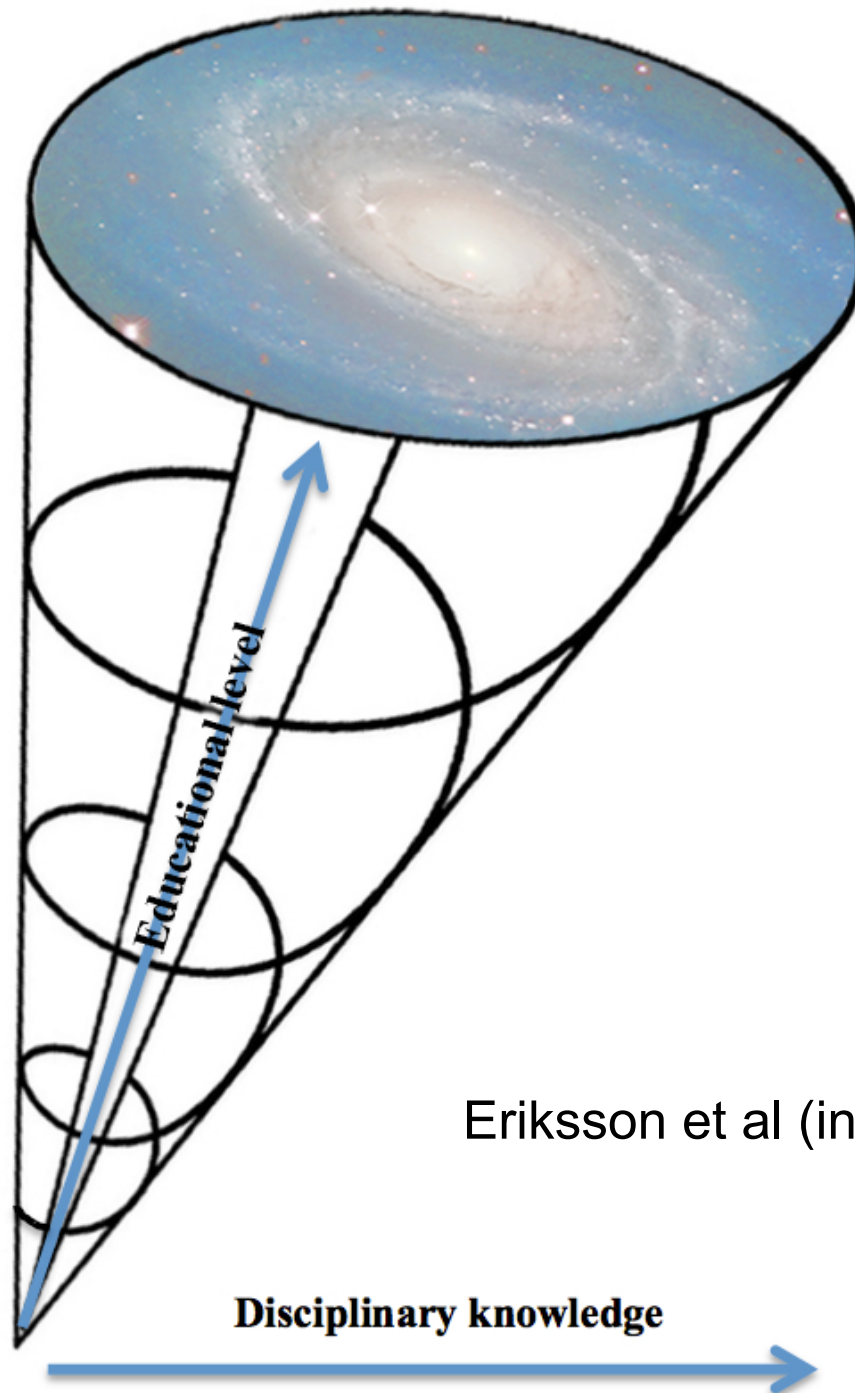
Disciplinary Evaluation
(Critique of the affordances of the representation)

Disciplinary Appreciation
(Acknowledge the value of the affordances of the representation)

Disciplinary Explanation
(Assign disciplinary *meaning*—‘discover’ the affordances of the representation)

Disciplinary Identification
(Naming, recognising salient disciplinary objects)

Non-Disciplinary Discernment





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