

# Topic E

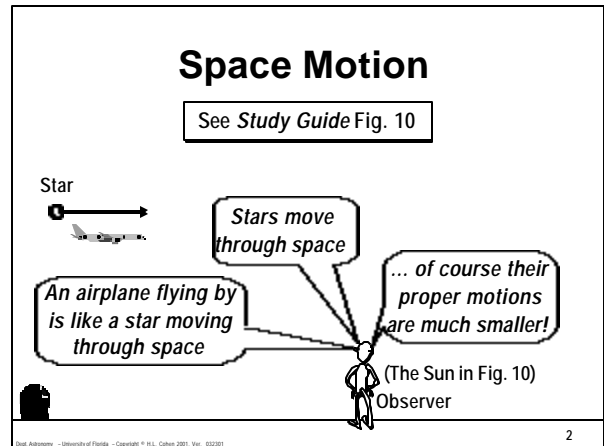
## "Part 3. The Doppler Effect"

(Web Version: 03-23-01)

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## Space Motion

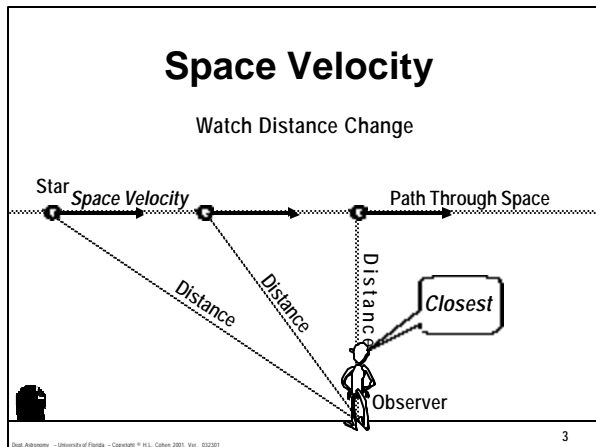
See Study Guide Fig. 10



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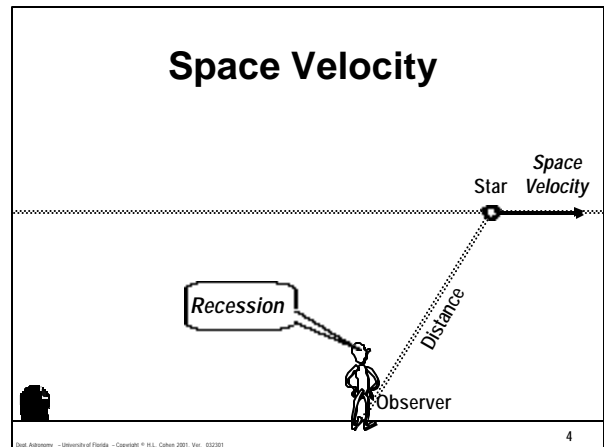
## Space Velocity

Watch Distance Change



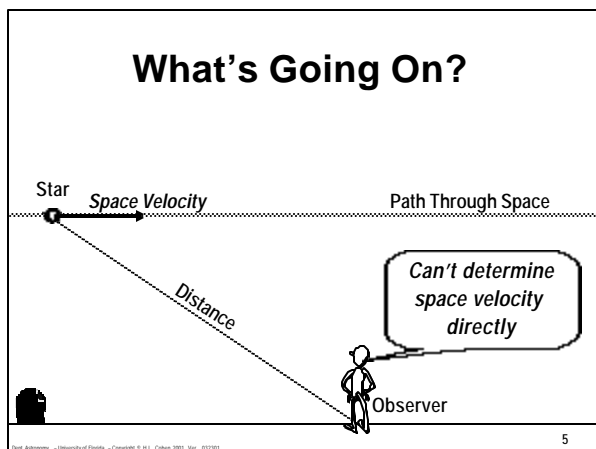
3

## Space Velocity



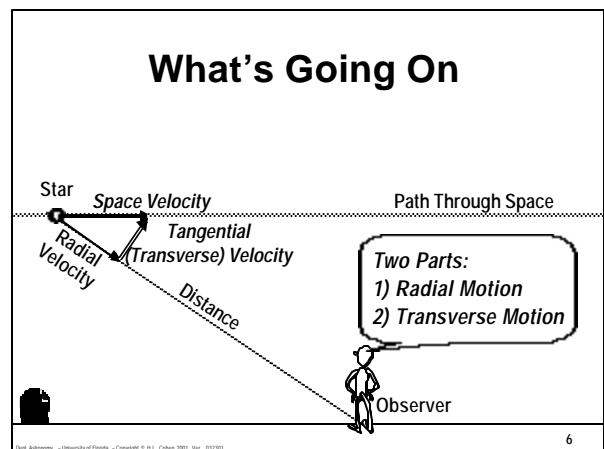
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## What's Going On?



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## What's Going On?



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### What's Going On

The diagram shows a star moving through space. A horizontal dashed line represents the 'Path Through Space'. The star's 'Space Velocity' is shown as a vector pointing up and to the right. This velocity is decomposed into two components: 'Radial Velocity' (pointing towards the observer) and 'Tangential (Transverse) Velocity' (perpendicular to the radial velocity). A 90-degree angle is indicated between these two components. The 'Distance' between the star and the 'Observer' is shown as a dashed line. Two callouts explain: '1) Radial points toward or away' and '2) Transverse is at right angles'.

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### Procedure

This diagram illustrates the procedure for finding Space Velocity (SV). It shows the same star and observer setup as slide 7. The components are labeled 'Radial Velocity' and 'Tangential (Transverse) Velocity'. Two boxes labeled 'Find' are connected to their respective velocity vectors. A larger box labeled 'Combine' is connected to both 'Find' boxes. A callout box lists the steps: '1) Find TV', '2) Find RV', and '3) Combine to get SV!'.

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### How?

*Each component causes a separate, observable effect*

The diagram shows the star's path through space. The 'Space Velocity' vector is horizontal, pointing to the right. The 'Radial Velocity' component is zero. The 'Tangential (Transverse) Velocity' is shown as a vector pointing upwards. A callout box says: 'If TV was absent, star would not drift (have no proper motion)'. The 'Observer' is at the bottom.

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### Result: Collision!

The diagram shows the star's path through space. The 'Space Velocity' vector is horizontal, pointing to the right. The 'Tangential (Transverse) Velocity' is zero. The 'Radial Velocity' is shown as a vector pointing towards the observer. A callout box says: 'Star would head directly for me (or away from me)!'. The 'Observer' is at the bottom.

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### Proper Motion Yields TV

*So TV causes proper motion*

The diagram shows the star's path through space. The 'Space Velocity' vector is horizontal, pointing to the right. The 'Radial Velocity' is shown as a vector pointing towards the observer. A callout box says: '(RV only causes distance to change)'. Another callout box says: 'Hence, if know proper motion (and distance), can calculate TV!'. The 'Observer' is at the bottom.

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### The Radial Component

*No RV, No Approach*

The diagram shows the star's path through space. The 'Space Velocity' vector is horizontal, pointing to the right. The 'Radial Velocity' is zero. The 'Tangential (Transverse) Velocity' is shown as a vector pointing upwards. A callout box says: 'If RV was absent, distance would not change - example...'. The 'Observer' is at the bottom.

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### Rate Distance Changes

Radial Velocity: Rate distance changes (definition)

Units: kilometer per second (about 5800 mph)

Distance	"Observer Sees"	Source
1 <i>Constant</i>		
2 <i>Decreases</i>		
3 <i>Increases</i>		

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### "Signs" of Radial Velocities

Every radial velocity has a "sign" unless zero

Either Negative or Positive

Distance	"Observer Sees"	Source RV
1 <i>Constant</i>		0
2 <i>Decreases</i>		- (Approach)
3 <i>Increases</i>		+ (Recession)

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### Cause of Doppler Effect

- Results from finite speed of waves — examples
  - Sound — about 1000 feet per second
  - Light — about 186,000 miles per second
- Source of waves tries to overtake emitted waves
- Detectable?
  - Obvious — *slow* moving waves (sound)
  - Subtle — *fast* moving waves (radiation)

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### Speed of Sound "Slow"

"Easy" for vehicles to travel at 10% of speed of sound (750 mph)

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### How Doppler Effect Produced

Next two series of slide show

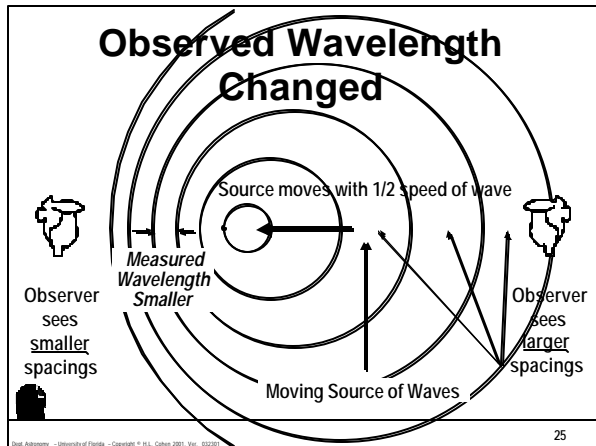
First — *Stationary* source emitting waves  
*then*

Second — *Moving* source emitting waves

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### Seventh Wave Emitted

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### EM Radiation & Doppler Effect

- Speed of light . . . . . 300,000 km/sec
- Typical speed of stars . . . . . 20 km/sec
- Even 3,000 km/sec . . . . . only 1% speed of light
- Conclusion — Doppler effect on light *usually very small*
- Exceptions — Distant galaxies may recede at 90% of speed of light

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### A Stellar Spectrogram

Study Guide Fig. 11

One Eighth Inch Enlargement of Small Section of a Spectrogram!

Comparison (emission line) spectra

Stellar Absorption Line Spectrum

Mark line position

Shorter Wavelengths      Longer Wavelengths

This star has  $RV = 0$  km/sec

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### A Stellar Spectrogram

Study Guide Fig. 11

Comparison (emission line) spectra

Doppler Shift

Shorter Wavelengths      Longer Wavelengths

This star approaches ( $RV$  is negative)

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### A Stellar Spectrogram

Study Guide Fig. 11

- Doppler Shift (- or +) tell if approach (-) or recession (+)
- Radial Velocity  $\mu$  Doppler Shift

Comparison (emission line) spectra

Doppler Shift

Shorter Wavelengths      Longer Wavelengths

This star recedes ( $RV$  is positive)

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### A Stellar Spectrogram

Study Guide Fig. 11

See Fig. 11 to see how to calc.  $RV$  from Doppler Shift

Shorter Wavelengths      Longer Wavelengths


Doppler Shifts may be only 0.01 mm!

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## Measuring Doppler Shifts

Please see/study Figure 11 in *Study Guide*

- Obtain necessary spectra
- Put under "measuring microscope"
- Measure Doppler Shifts (very small)
- Compute radial velocity



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## A Few Misconceptions

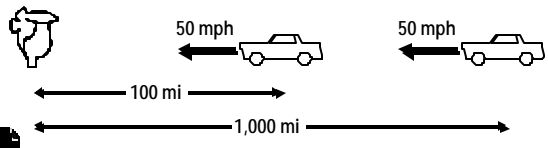
Two Doppler Effect Misconceptions

- 1) Doppler Shift and Distance
- 2) Radial Velocity
  - a. Zero Radial Velocity
  - b. Radial Velocity and Head-On Collisions

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## 1) Doppler Effect & Distance

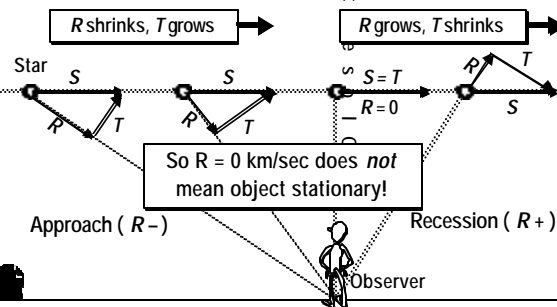
Which car shows largest Doppler Shift?  
Answer: ?  
Why?



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## 2a) Zero Radial Velocity

(See *Study Guide* Fig. 10)



So  $R = 0$  km/sec does *not* mean object stationary!

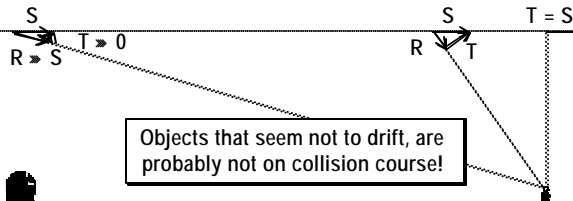
Approach ( $R-$ )      Recession ( $R+$ )

Observer

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## 2b) Collisions

Far off objects appear to head directly toward (or away) from observer!



Objects that seem not to drift, are probably not on collision course!


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## See Study Guide

*Topic E*  
Questions  
#28-30

Sample Exam Questions  
Example Problems,  
Supplementary Tables and Figures

ASTRONOMY  
STUDY GUIDE



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Howard L. Cohen

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### Brief Catalog of Star Data

- See *Study Guide* Table 9
- Data for 16 stars
  - Includes Sun, 12 bright and 3 faint look stars
- Additional pertinent columns
 

Col. 9	Radial Velocity
10	Tangential Velocity
11	Space Velocity

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### Example Applications

- Astronomical
  - Radial velocities of stars
  - Rotation rates of Sun & planets
  - Rotation rates of other stars

	Slow Rotation	
	Fast Rotation	

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### Example Applications

- Astronomical
  - Radial velocities of stars
  - Rotation rates of Sun and planets
  - Rotation rates of other stars
- Other
  - Speed radar
  - Doppler weather radar
  - Speed of military targets

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