Topic E

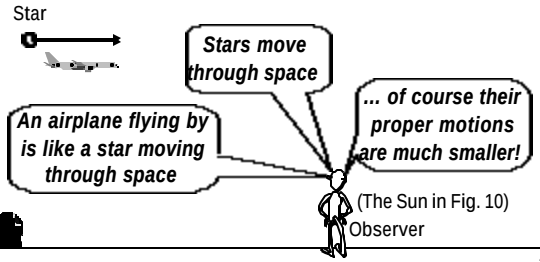
"Part 3. The Doppler Effect"

(Web Version: 03-23-01)

1

Space Motion

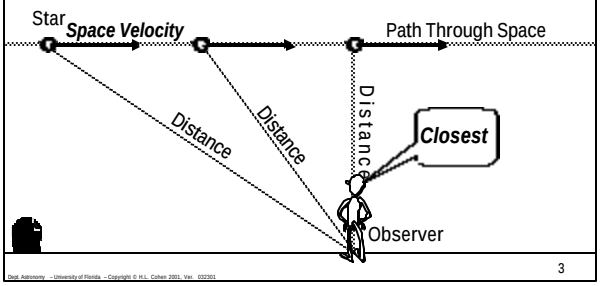
See ***Study Guide*** Fig. 10



2

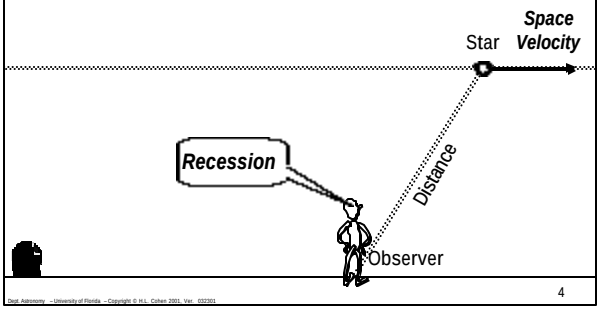
Space Velocity

Watch Distance Change



3

Space Velocity



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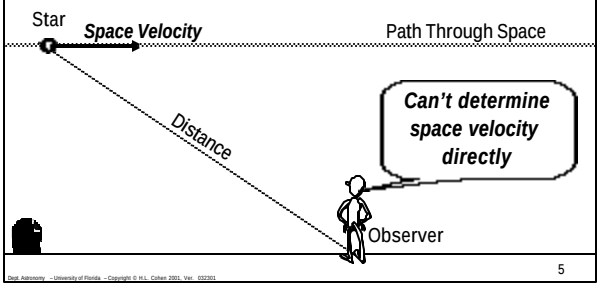
What's Going On?



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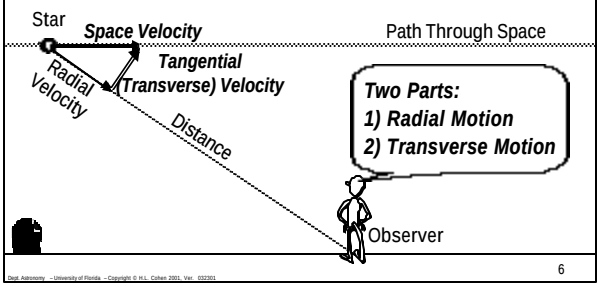
What's Going On



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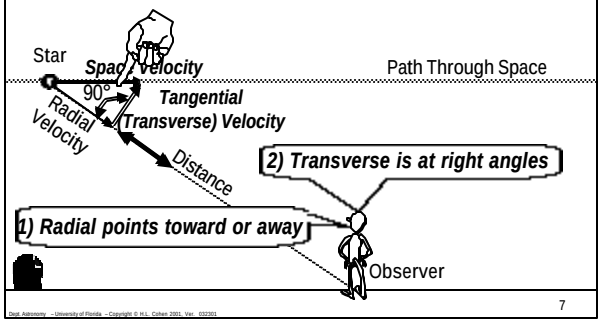
What's Going On



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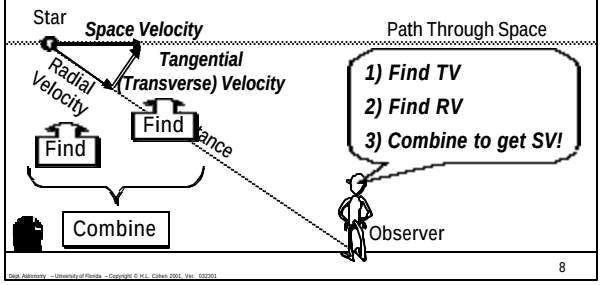
Procedure



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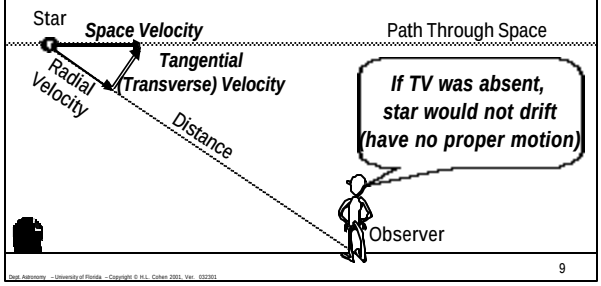
How?

Each component causes a separate, observable effect



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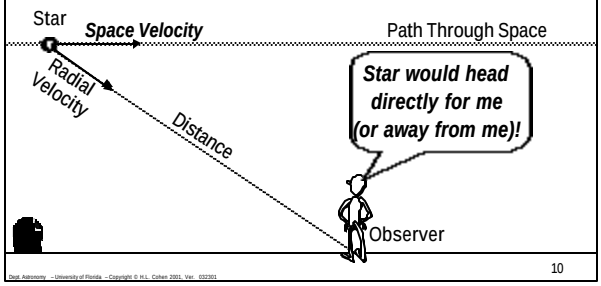
Result: Collision!



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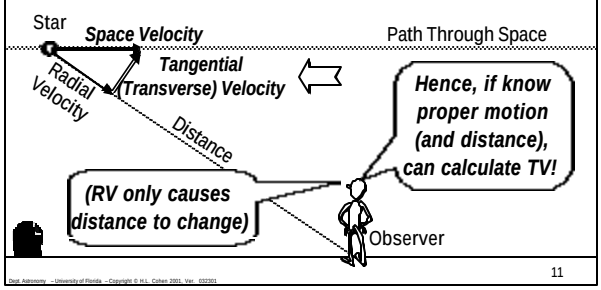
Proper Motion Yields TV

So TV causes proper motion



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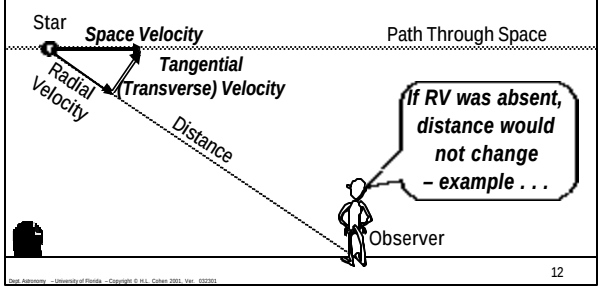
The Radial Component

No RV, No Approach



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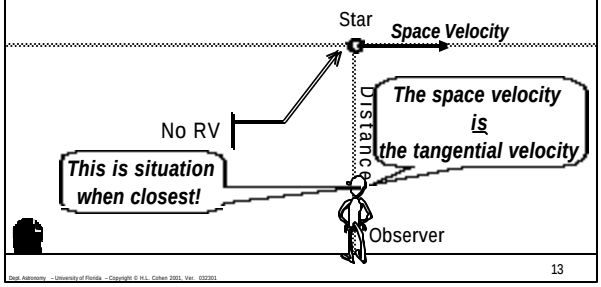
Example: No RV If Closest

Space Velocity = Tangential Velocity



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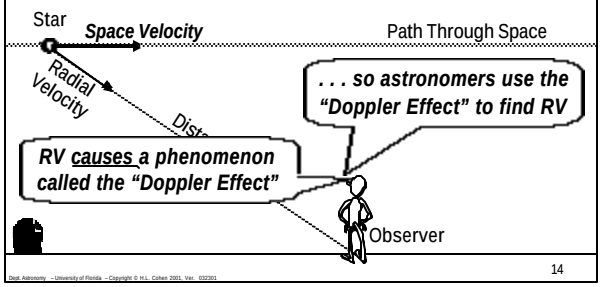
How Find RV?



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Summary

Cause		Effect
Space Velocity → Tangential Velocity	→	Proper Motion
Space Velocity → Radial Velocity	→	Doppler Effect

To Find TV, RV and hence SV . . . Turn around

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Summary

Cause		Effect
Space Velocity → Tangential Velocity	←	Proper Motion*
Space Velocity → Radial Velocity	←	Doppler Effect

* Note: To determine TV also need distance

(recall distance also affects proper motion)

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The Doppler Phenomenon

- Enunciated by Christian Doppler (1842)
- A phenomenon occurring with waves
  - Water waves
  - Sound waves
  - EM waves (radiation)
  - etc.

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Doppler Effect Summary

Cause: ***Distance changes*** between observer & source

Effect: ***Apparent*** change of wavelength (or frequency)

Distance	Observer	"Observer Sees"	Source
1 ***Constant***		***WL Unchanged***	
2 ***Decreases***		***WL Decreases***	←
3 ***Increases***		***WL Increases***	→

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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 ***Constant***	*WL Unchanged*	
2 ***Decreases***	*WL Decreases*	
3 ***Increases***	*WL Increases*	

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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 ***Constant***			0
2 ***Decreases***		Approach	–
3 ***Increases***		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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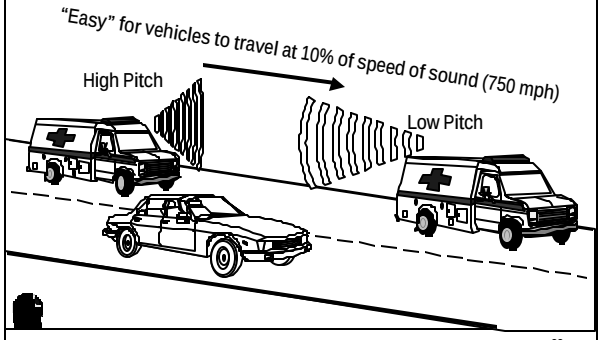
Speed of Sound "Slow"



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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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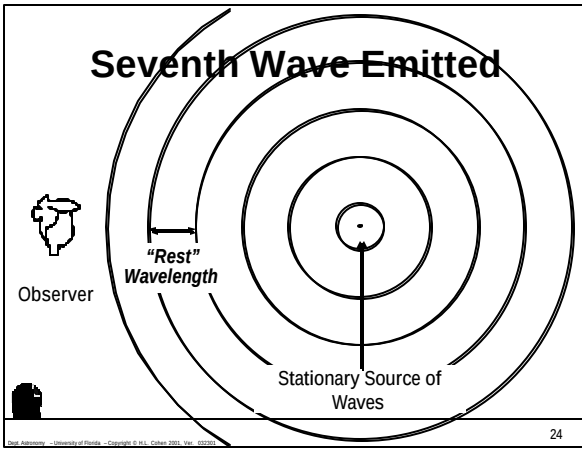
Seventh Wave Emitted



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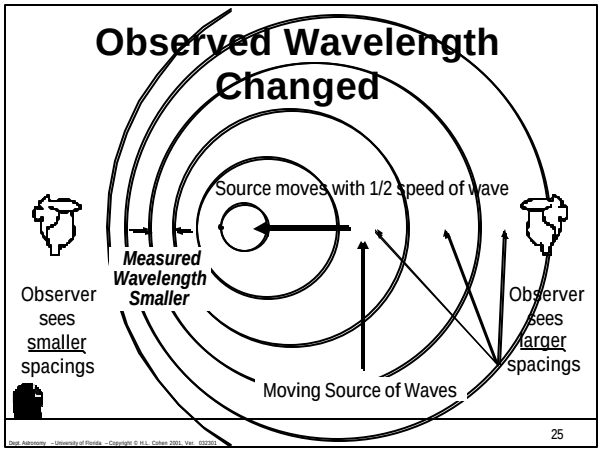

EM Radiation & Doppler Effect

- 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 μ 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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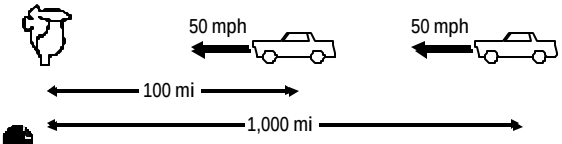
1) Doppler Effect & Distance

Which car shows largest Doppler Shift?

Answer: ?

Why?



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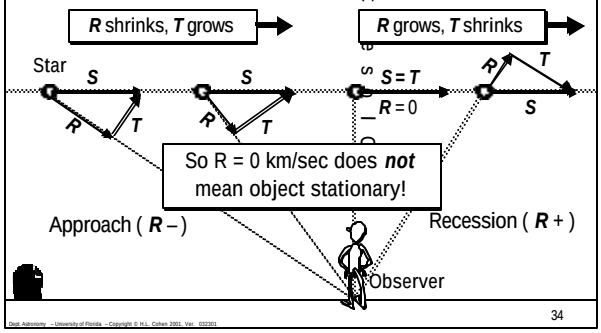
2a) Zero Radial Velocity

(See ***Study Guide*** Fig. 10)



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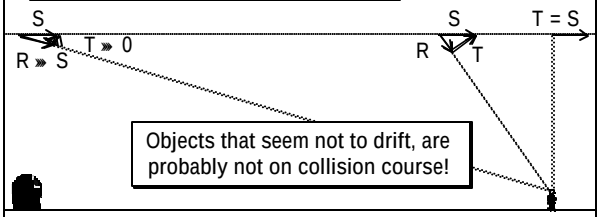
2b) Collisions

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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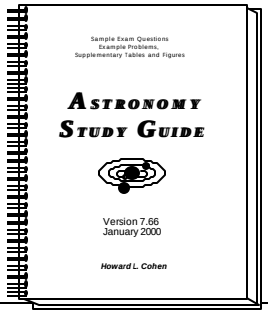
See Study Guide

Topic E Questions #28–30



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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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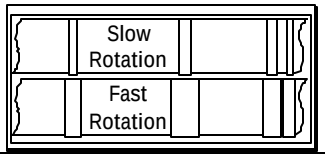
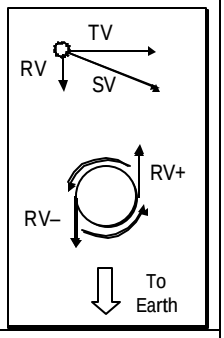
Example Applications

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





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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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