#### Announcements



- New homework on WebWorK posted after class, due Friday
  - The required Nautical Almanac will be posted on our website
- Most of you look like you are keeping up with the WebWorK, so keep it up! For those of you a little behind, ask questions, set aside time, but I highly recommend getting caught up sooner rather than later!
- Polling: rembold-class.ddns.net

## Tonight's Sky



- ISS crossing tomorrow morning
  - About 5:02 am, about 34° above the horizon to the North
- Iridium flare tonight at 10:27pm
  - Almost dead zenith
  - Near the bright star Vega which is basically looking straight up
  - Much brighter ones coming later in the week



### Review Question



What was one of the main reasons for Ptolomy improving Aristotle's geocentric model of the Solar System with his own circles-in-circles model?

- A. The Sun moved opposite through the sky from the planets
- B. Some planets occasionally moved backwards through the sky for part of the year
- C. The orbit of Neptune was observed to be non-circular
- D. The Sun was determined to be in the center of the Solar System.

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### A Detour



We'll return to the Greeks soon, but now for a small aside:

- Finding the circumference of the Earth via Astronomy is great
- Finding your location on the globe via Astronomy is even greater!
  - These techniques are technically a jump forward in the timeline
  - Largely in the spirit of "what can primitive astronomy tell me?"



## The Easy Step: Latitude



- Location in the sky of celestial poles varies with latitude
- Altitude of celestial pole in the local sky gives your latitude
  - Northern Hemisphere North Star / Polaris
  - Southern Hemisphere 4 Lengths from the Southern Cross / Crux



## The Harder Step: Longitude

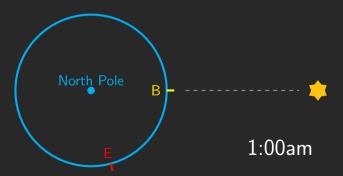


- Our latitude is "fixed" with respect to the stars, so the celestial pole is always as the same angle
- Our longitude is not fixed, because the Earth is rotating
  - You can also think of longitude being determined by where the Prime Meridian is, and that is always rotating
- Requires us to use some different machinery to determine longitude
- We need to add time to our machinery in addition to a view of the sky

## Determining Longitude



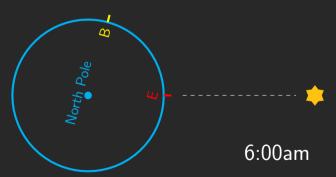
Bert and Ernie are hanging out at the same latitude, but different longitudes. At midnight, Bert sees the star Vega directly overhead. Five hours later, Ernie sees the star Vega directly overhead.



## Determining Longitude



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## Determining Longitude: Part 2



- This 5 hour difference "fixes" their longitude positions on Earth relative to one another
- ullet Recall 1 hour  $pprox 15^\circ$
- ullet If Bert was at the Prime Meridian, Ernie would be  $75^\circ$  West



- This 5 hour difference "fixes" their longitude positions on Earth relative to one another
- Recall 1 hour  $\approx 15^{\circ}$
- If Bert was at the Prime Meridian, Ernie would be 75° West

#### Problem!

But what about when we don't have a friend conveniently located on the Prime Meridian?

### Your New Friend: The Nautical Almanac



- Is very old: since 1767
- Keeps tabs of where important things in the sky should be, every hour, every day
- Values are as if the observer was at the prime meridian
- Many complicated ways to use the almanac
  - Are you moving?
  - Where do you see your reference star?
  - Can you accurately see the horizon?
- We'll take the simplest course of action
  - Not moving, horizon visible, reference star crossing meridian

## Some Vocabulary



- The Hour Angle: the number of degrees West of the meridian an object appears
- GHA = Greenwich Hour Angle: Where the object appears as seen on the Prime Meridian
- ullet LHA = Local Hour Angle: Where the object appears as seen where you are standing
  - We will be using stars crossing our meridian, so the LHA will always be zero for us!
- In general:

LHA = GHA - Longitude W of Prime Meridian



- Listing the GHA of every reference star at every hour of every day would require a huge book
- The stars do not move relative to one another, so most of that information would be redundant
- Almanac gives us a star's SHA (Sidereal Hour Angle)
- This is an angle given relative to the constellation Aries
- Almanac just gives the GHA for Aries, and lets you work it out for the other reference stars

GHA Star = SHA Star + GHA Aries

#### A Note on Time



- Recall that you'll need to use the time to look up the GHA of Aries in the Almanac
- All of these times need to be in UTC (aka Greenwich time GMT)
- This is so we can have a single, synchronized clock
- This method does assume that you have some method of knowing this time
  - This seems reasonable if you go somewhere planning to need to navigate yourself
  - Maybe less reasonable if you suddenly find yourself in a foreign place
- Morale of the Story: Get the almanac tattooed and a tiny watch embedded in your skin...

## Jed's 8 Step Plan to Find Yourself



- A. Are you in the Northern or Southern Hemisphere? (Do you see the North Star or Southern Cross?)
- B. Measure angle to celestial pole to get latitude (negative if Southern Hemisphere)
- C. In opposite direction, find a reference star very near the meridian (North-South line)
- D. What is the time and date? Find the appropriate page and line in the almanac.
- E. Calculate your reference star's GHA
- F. Calculate your raw longitude in degrees West of the Prime Meridian
- G. If larger than 360, subtract 360.
- H. If still larger than 180, you are East of the Prime Meridian instead of West. Subtract 360 again to get your Longitude West of Prime Meridian (it will be negative!)

## Example!

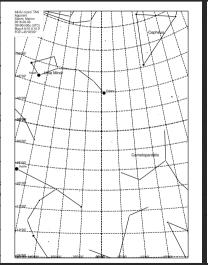


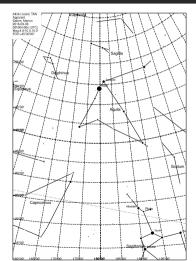
#### Example

Salem is at  $44.9\,^{\circ}$ N and  $123.0\,^{\circ}$ W. At 5:00am on 9/6/2017 UTC, we took two images of the night sky.

# The Images









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- A. Are you in the Northern or Southern Hemisphere? (Do you see the North Star or Southern Cross?)
  - I see the North Star, so Northern Hemisphere
- B. Measure angle to celestial pole to get latitude (negative if Southern Hemisphere)
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- A. Are you in the Northern or Southern Hemisphere? (Do you see the North Star or Southern Cross?)
  - I see the North Star, so Northern Hemisphere
- B. Measure angle to celestial pole to get latitude (negative if Southern Hemisphere)
  - The North Star is barely under 45°. We'll call it 44.5°N
- C. In opposite direction, find a reference star very near the meridian (North-South line)
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- C. In opposite direction, find a reference star very near the meridian (North-South line)
  - Looks like Altair is lying right on the Meridian and is one of our reference options!
- D. What is the time and date? Find the appropriate page and line in the almanac.



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  - Looks like Altair is lying right on the Meridian and is one of our reference options!
- **D**. What is the time and date? Find the appropriate page and line in the almanac.
  - It is September 6, 2016 at 5:00 UTC. This is on page 168 of the almanac.

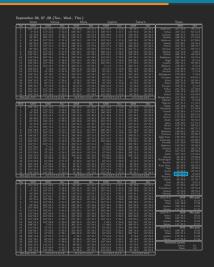


Find Altair





- Find Altair
- Note SHA





- Find Altair
- Note SHA
- Find time line





- Find Altair
- Note SHA
- Find time line
- Read GHA of Aries



### Process Cont'd



E. Calculate your reference star's GHA

F. Calculate your raw longitude in degrees West of the Prime Meridian

G. If larger than 360, subtract 360.



- E. Calculate your reference star's GHA
  - Altair has a SHA of 62°  $5.3'=62.0883^\circ$ . At this time, the GHA of Aries is  $60^\circ$   $28.9'=60.4817^\circ$ . Thus

GHA Altair = 
$$62.0883^{\circ} + 60.4817^{\circ} = 122.57^{\circ}$$

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- F. Calculate your raw longitude in degrees West of the Prime Meridian
  - Since our LHA is 0, our measured GHA of Altair equals our longitude W!
- G. If larger than 360, subtract 360.



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  - Altair has a SHA of  $62^{\circ}$   $5.3' = 62.0883^{\circ}$ . At this time, the GHA of Aries is  $60^{\circ}$   $28.9' = 60.4817^{\circ}$ . Thus

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- F. Calculate your raw longitude in degrees West of the Prime Meridian
  - Since our LHA is 0, our measured GHA of Altair equals our longitude W!
- G. If larger than 360, subtract 360.
  - No need for anything else!



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- G. If larger than 360, subtract 360.
  - No need for anything else!

#### The Final Tally

We determined that Salem is at 44.5 °N and 122.6 °W. Not too shabby!

#### I'd like another!



#### Example

Buenos Aires is located at  $34.57\,^{\circ}$ S and  $58.36\,^{\circ}$ W. You take two images at 23:00 on October 14, 2017 UTC. Find the latitude and longitude of Buenos Aires as determined by your stars and almanac, and compare to the actual value.



The Southern Cross is visible



- The Southern Cross is visible
- A line from the Southern cross to the meridian intersects at about 32°



- The Southern Cross is visible
- $\bullet$  A line from the Southern cross to the meridian intersects at about 32 $^{\circ}$
- The reference star Deneb is visible to the North



- The Southern Cross is visible
- ullet A line from the Southern cross to the meridian intersects at about  $32^\circ$
- The reference star Deneb is visible to the North
- At the time given, the GHA of Aries is 8° 40.5′



- The Southern Cross is visible
- ullet A line from the Southern cross to the meridian intersects at about  $32^\circ$
- The reference star Deneb is visible to the North
- ullet At the time given, the GHA of Aries is  $8^{\circ}$  40.5'
- ullet The corresponding GHA of Deneb at this time is  $58.16^\circ$