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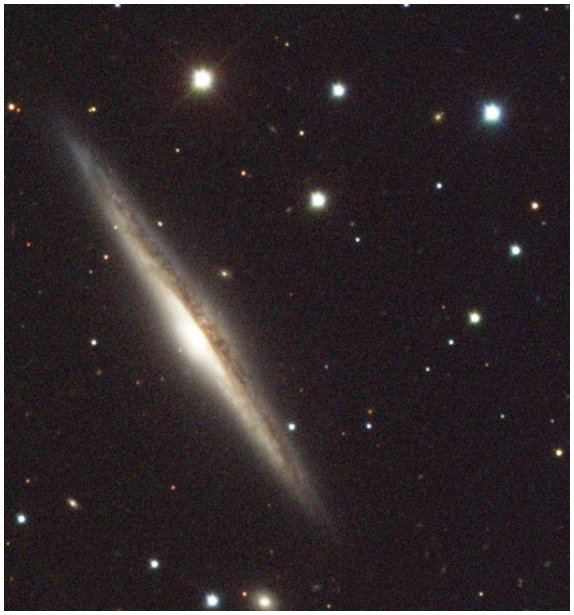
Godzilla Geometry aka Cosmic Distance Ladder

Determining Size & Distance Indirectly



Randall H. Landsberg

Director Education & Outreach- KICP
Director Public Outreach Dept. Astronomy
KICP- University of Chicago

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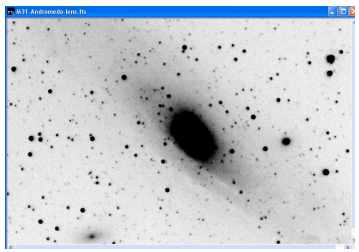
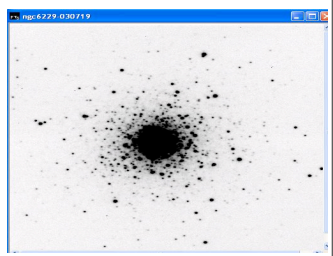
Outline

- Context of the Godzilla Geometry Lab
- Empirically Determining the Relationship of Apparent Size to Distance
  - Data Collection
  - Student Data
  - Testing the Model

- Extending the Lesson to Celestial Objects





Space Explorers Science Enrichment Program

- Multi Year Commitment to Inner-City Middle & HS Students
- Weekly Hands-On Laboratories
  - On U. Chicago Campus
  - Graduate Student Instructor
- Enrichment Trips
- **Residential Institutes** @ Yerkes Observatory (WI)
  - Winter Institute 3 Days
  - Summer Institute 1 Week
    - 3 Day Labs, 3 PM Labs, & Presentations
  - Theme 2003 ***"How Big is the Universe?"***
- SMET Success Stats. 500% Better CPS/ National

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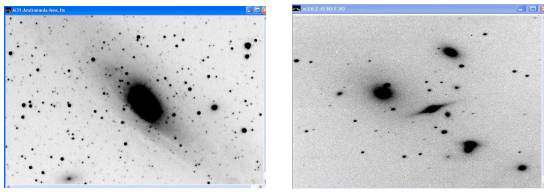
Apparent Size & Distance

- Distance Ladder = Pillar of Astronomy
  - **BIGGER** = Closer
  - smaller = Further



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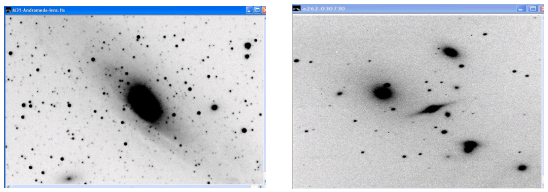

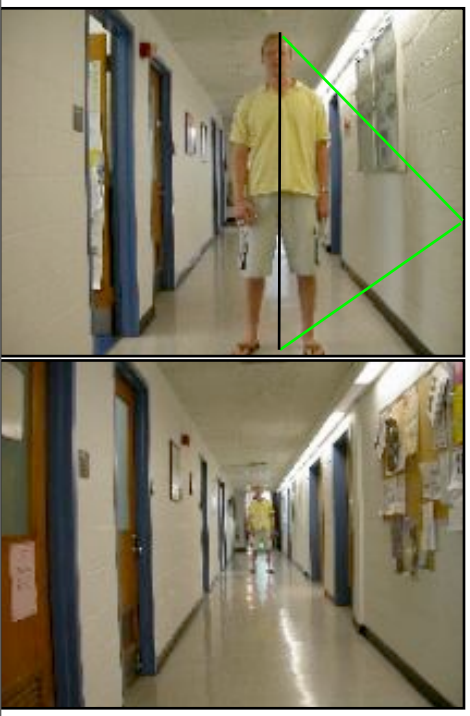

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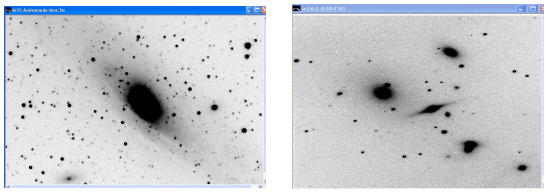

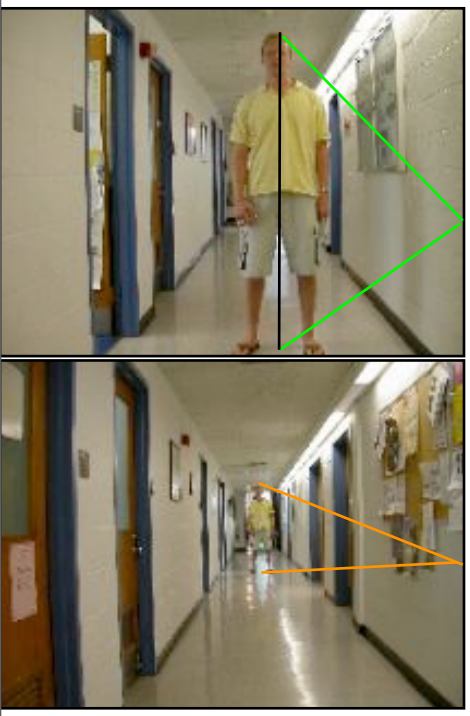

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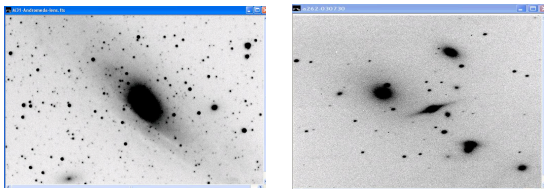

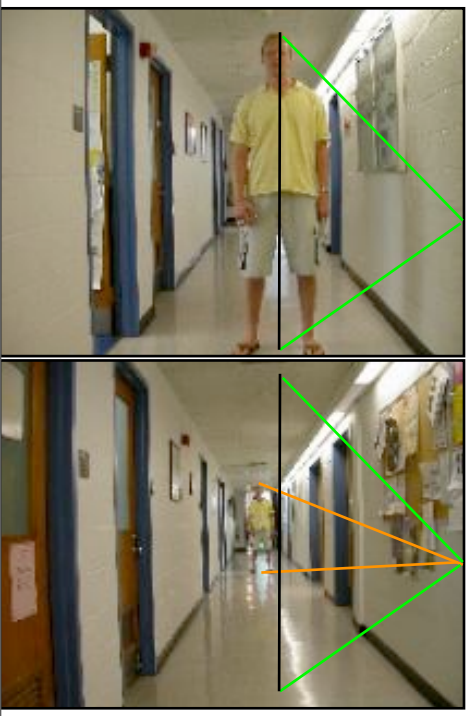

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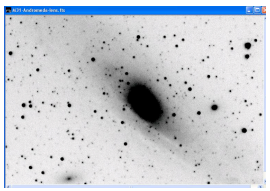

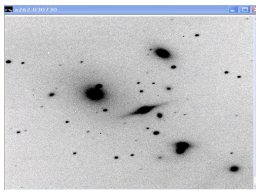

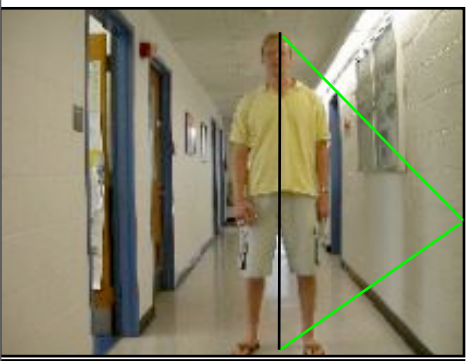

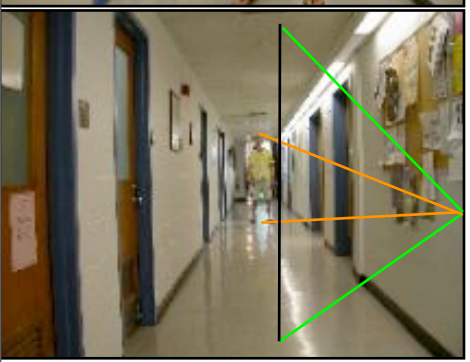

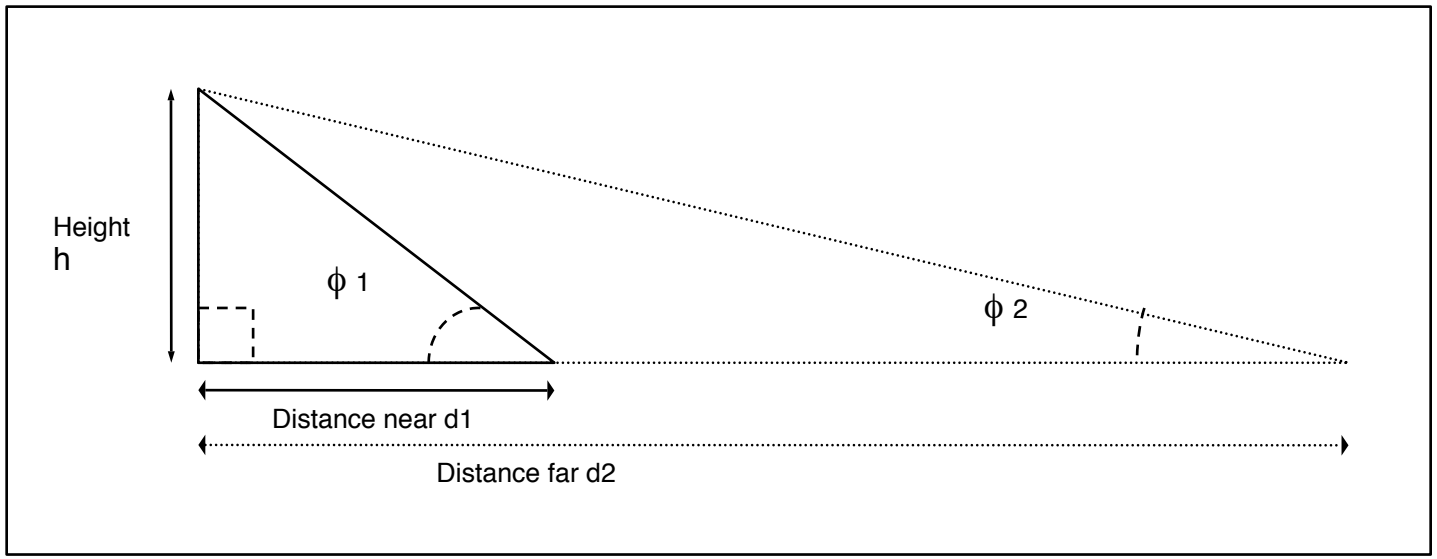

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Empirically Measure Apparent Size Vs. Distance

- Objects of Know Size
  - Godzilla & Golf Flag
- Know Distances
  - 10 to 500 feet
- Digital Camera
  - Focus Fixed at Infinity
- Student Challenges
  - Indexing Photos
  - Mechanics of Measuring Big Distances & Pixels
  - Graphing

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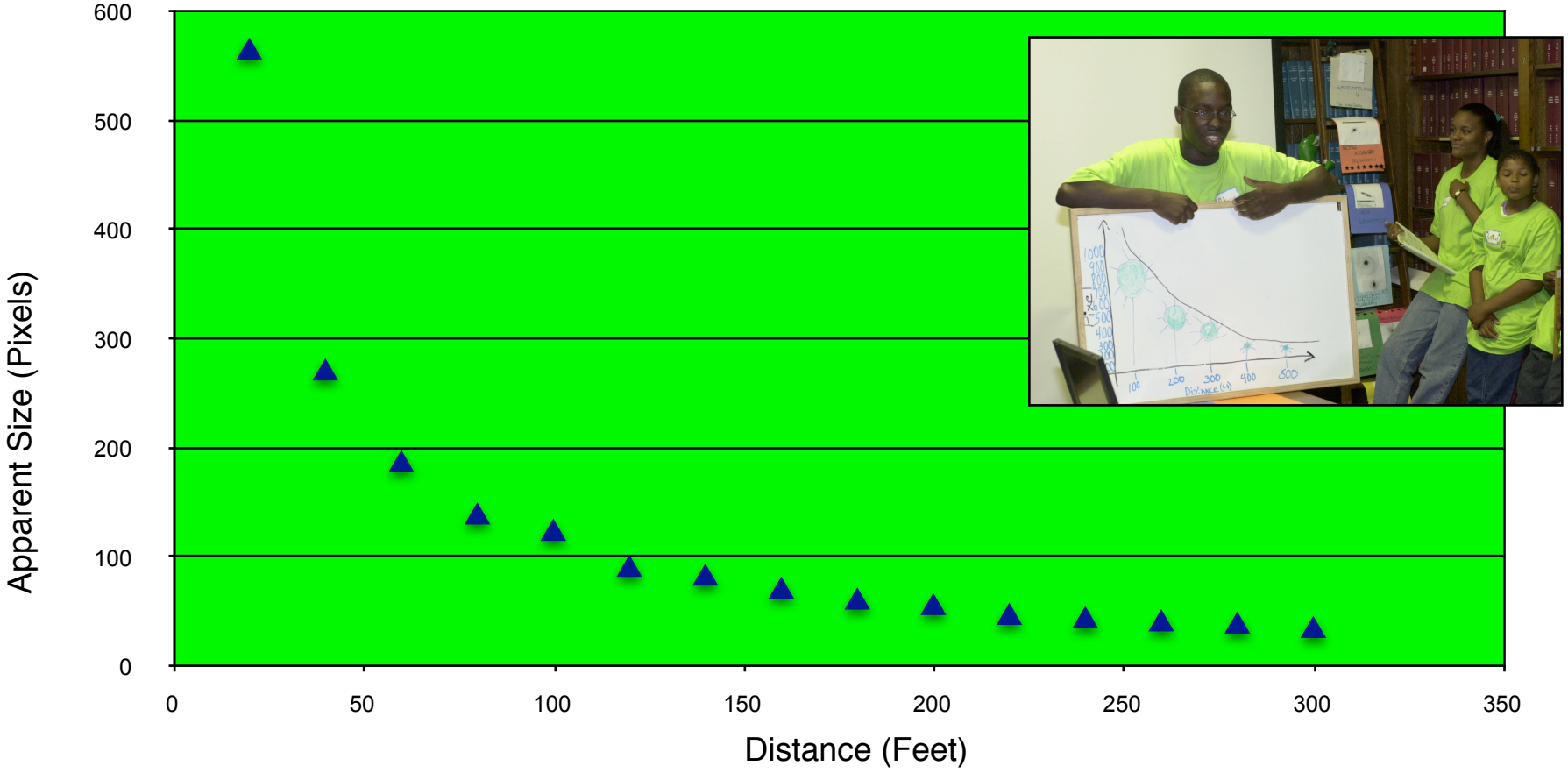
Data Collection

Graphing & Data Analysis

- Apparent Size - Pictures to Numbers of Pixels
  - Any Program that Counts Pixels
    - Hands On Universe (1st converted jpeg's to fits)



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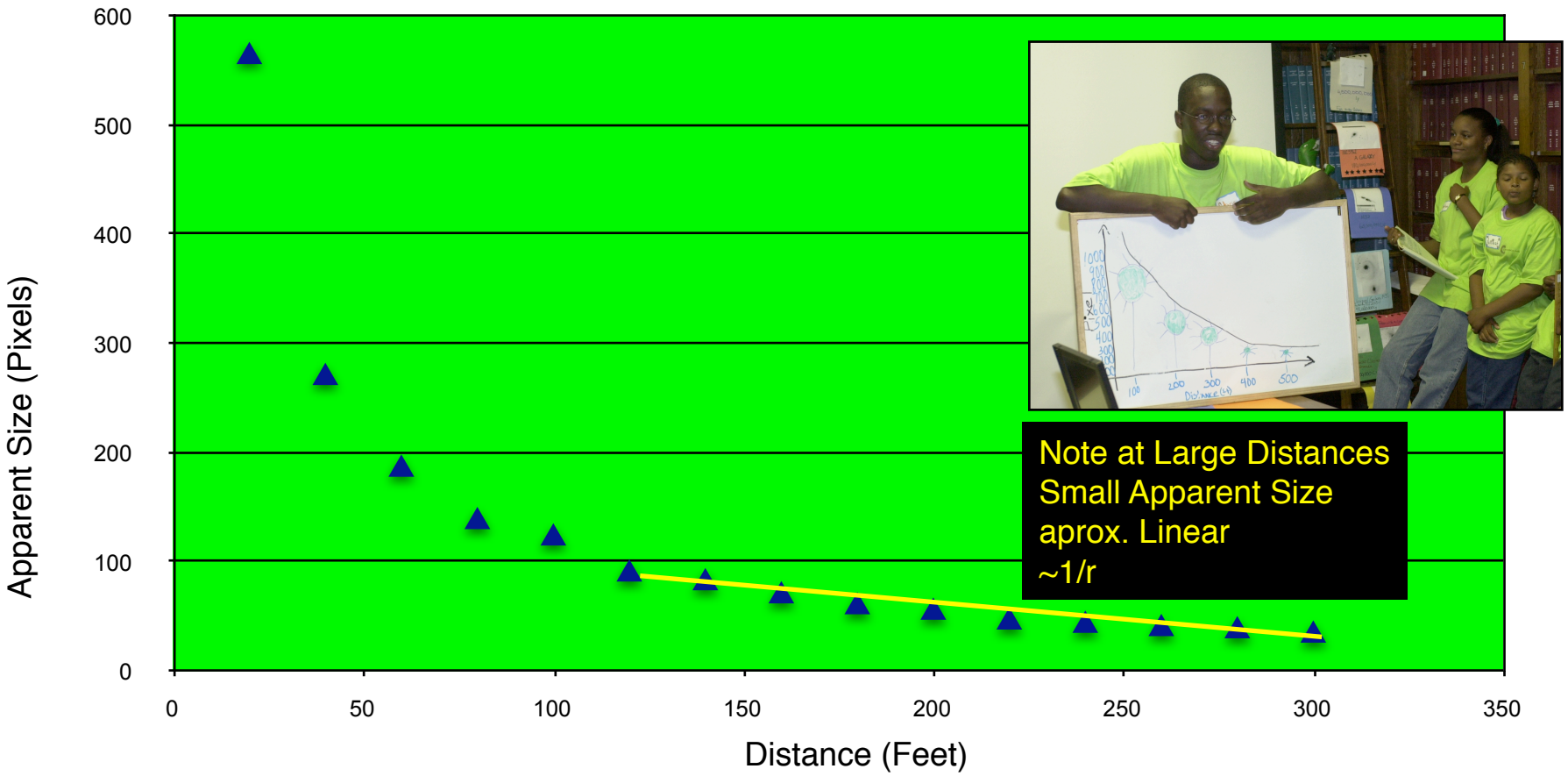

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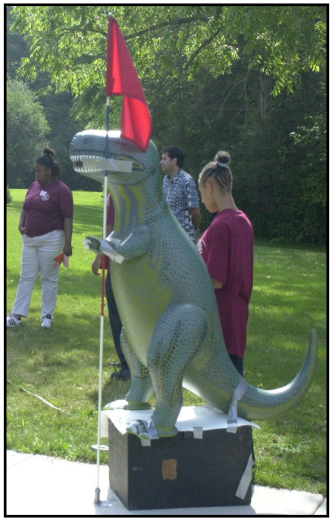
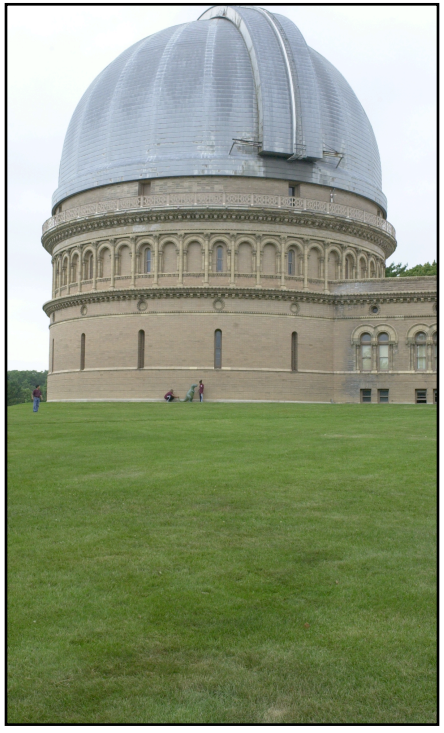
Confirming Indirect Distance & Size Determination

- Same Godzilla – "Unknown" Distance
  - Photo With Same Conditions
    - Mark Location
  - Measure Apparent Size (# Pixles)
  - Determine Distance via Graph
    - Where # Pixels Hit Curve
  - Compare to Marker Distance





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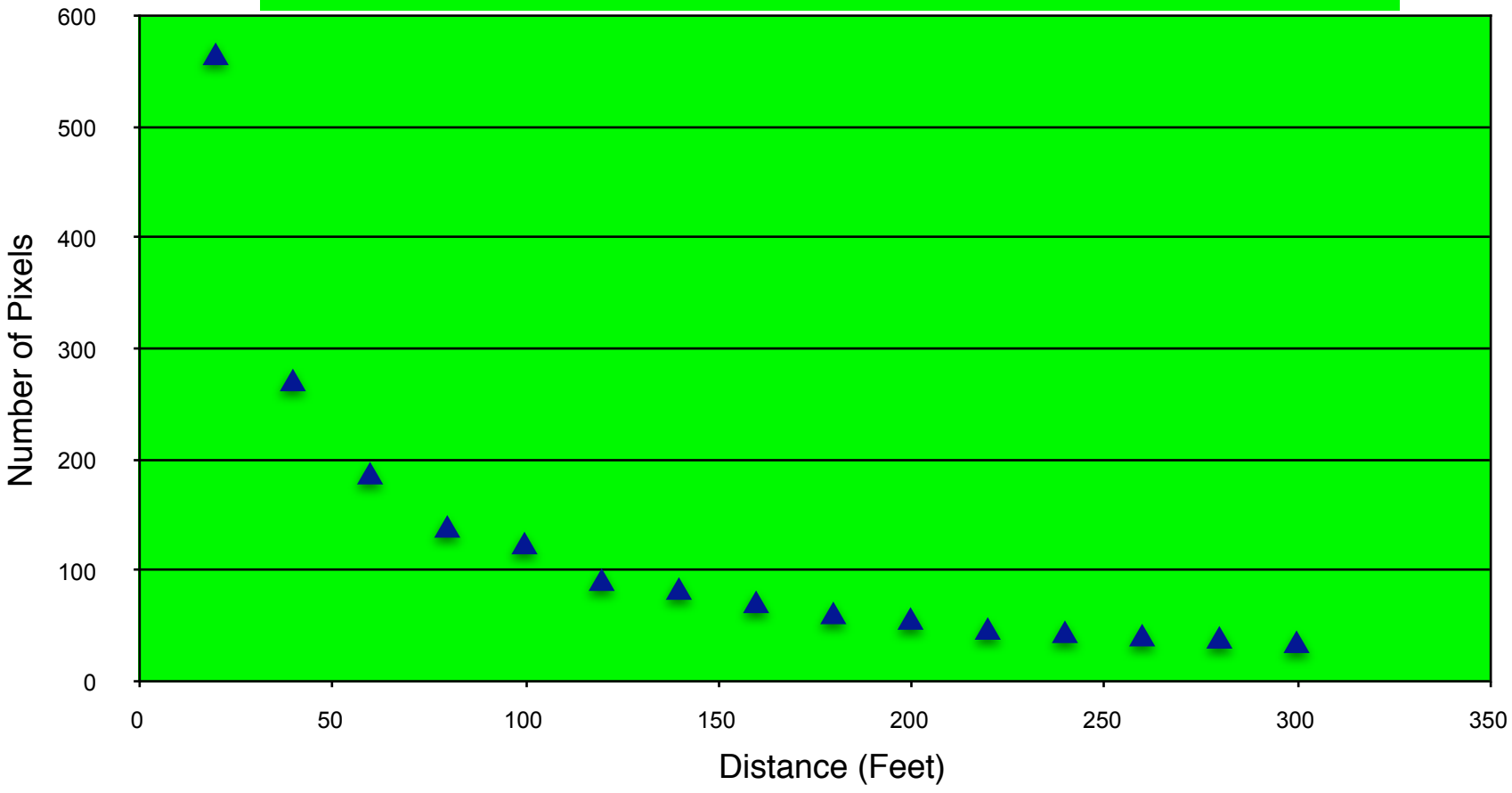

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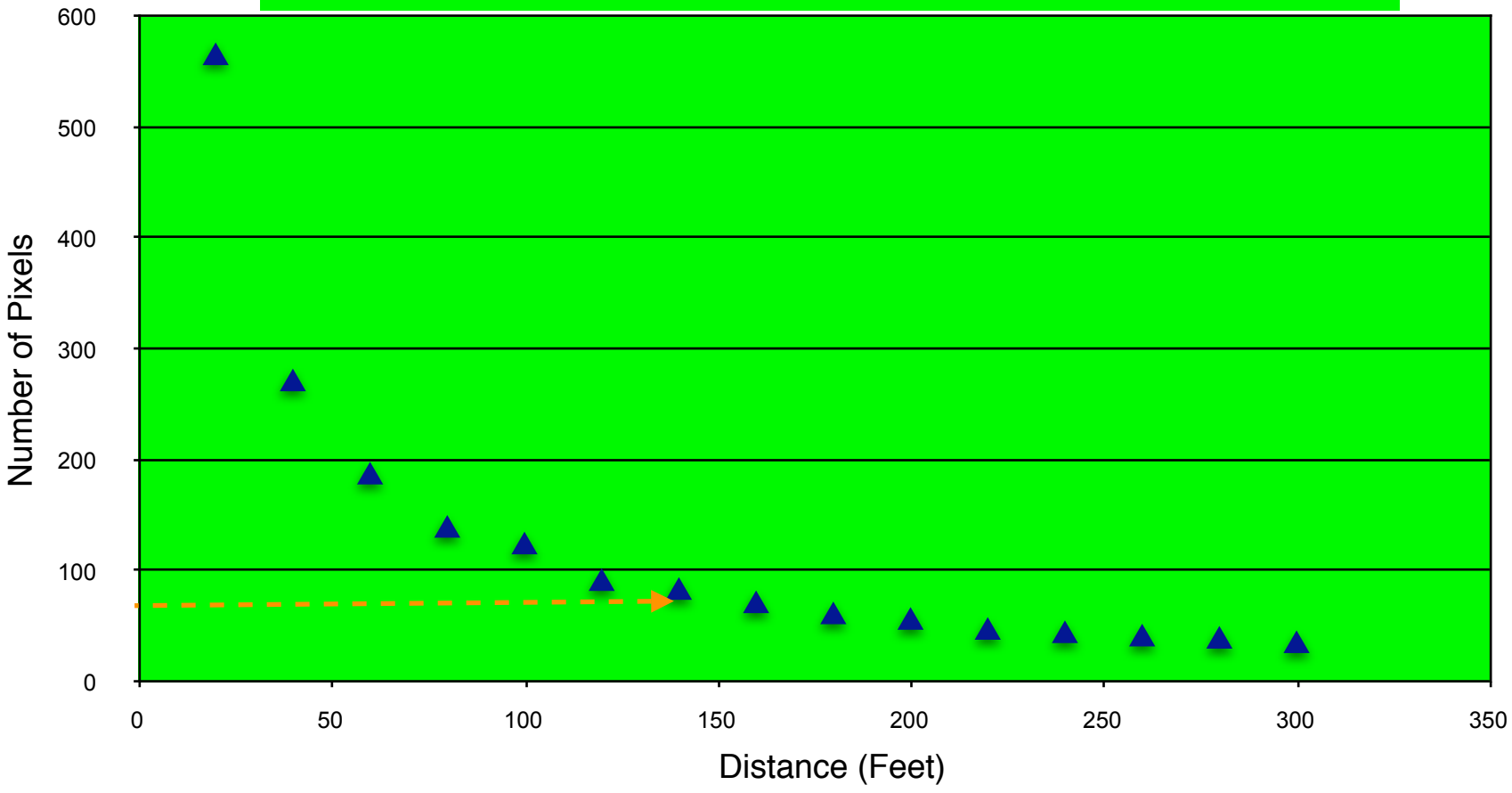

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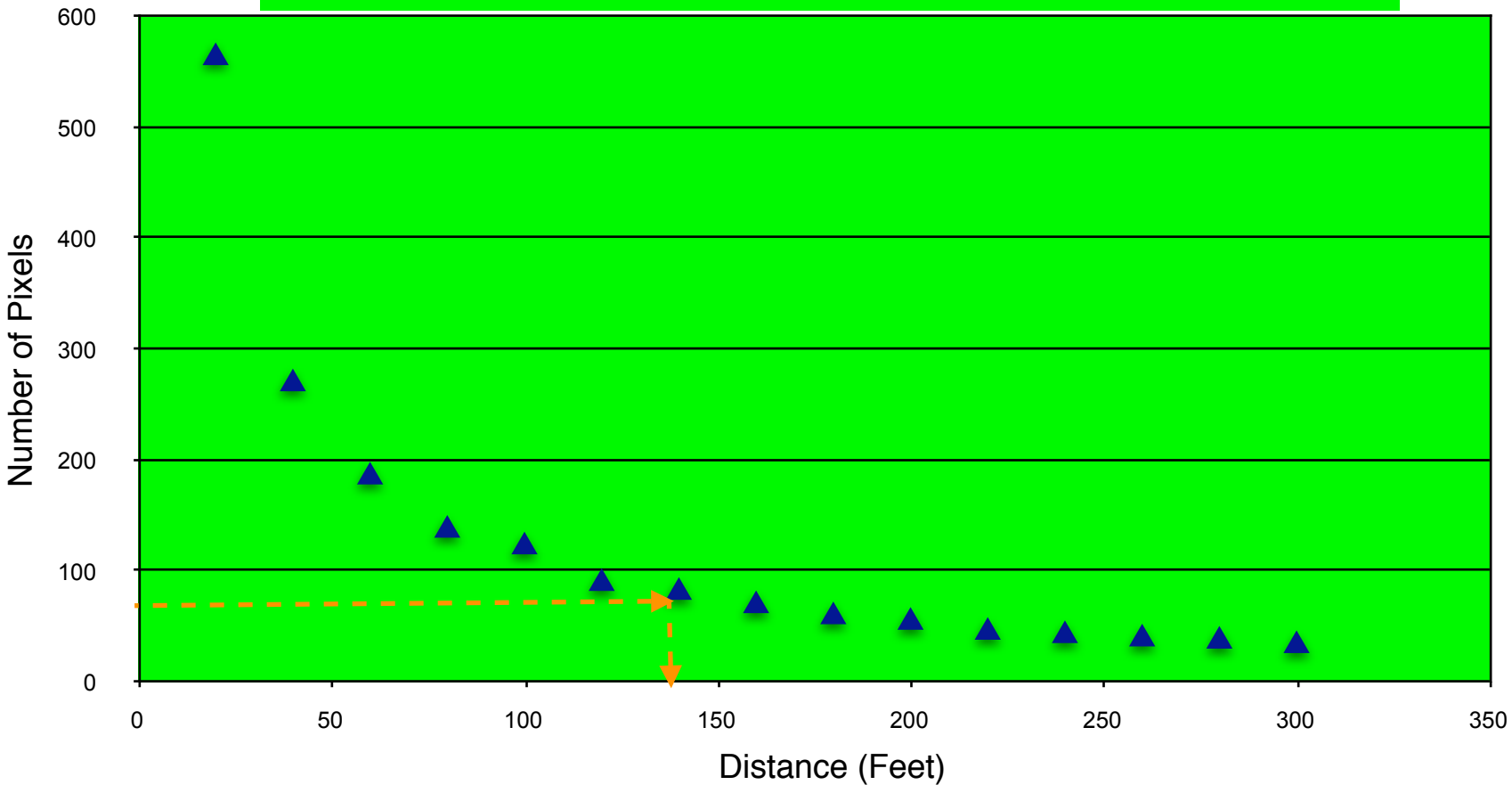
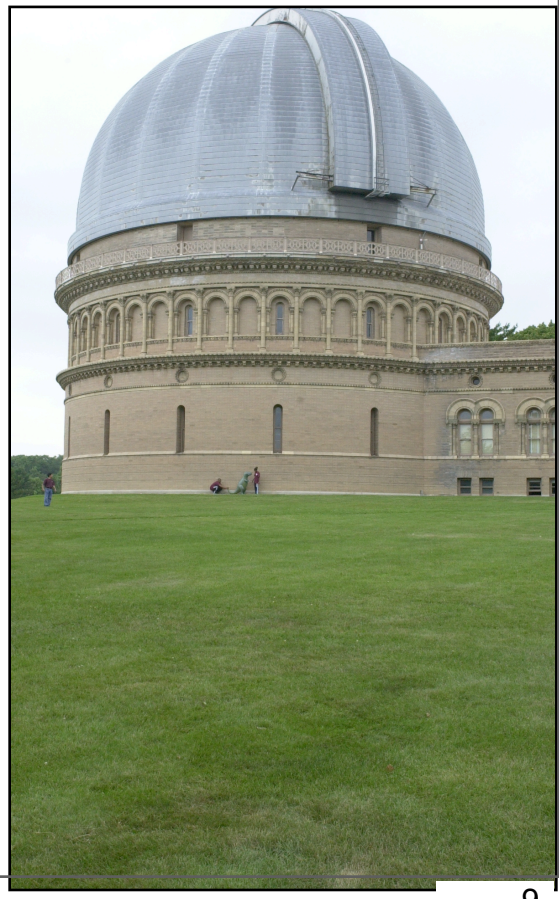


Climbing the Ladder: Indirect Size Determination

- "Different" Godzilla – Known Size
  - Analogous to Astronomy (e.g., different galaxy)
    - Assumes All Godzillas Are Same Size
- Determine Height of Great Refractor Dome
  - Relative Apparent Size
    - # Pixels
    - Vs # Pixels for Know Object Next to it
- Compare to Known Dome Height

Warning!
Small Angle Approximation
apparent size ~1/r



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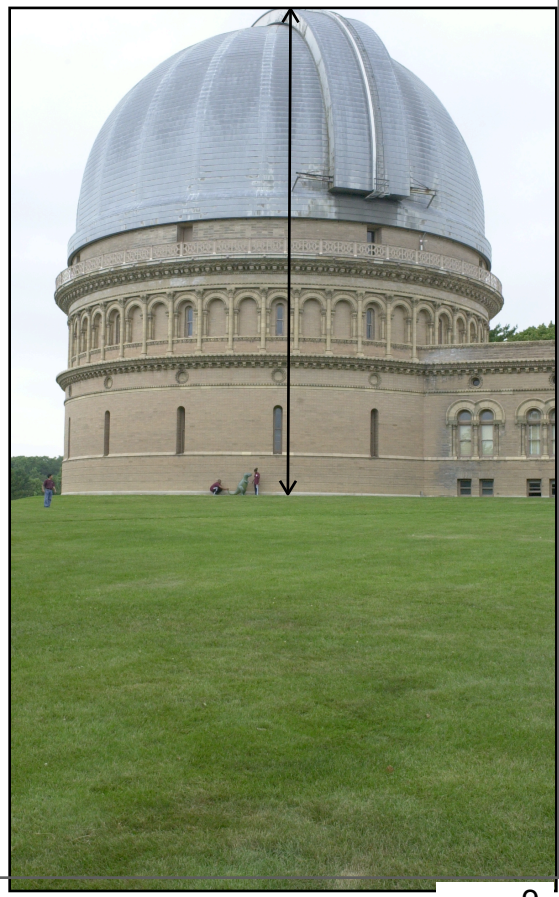

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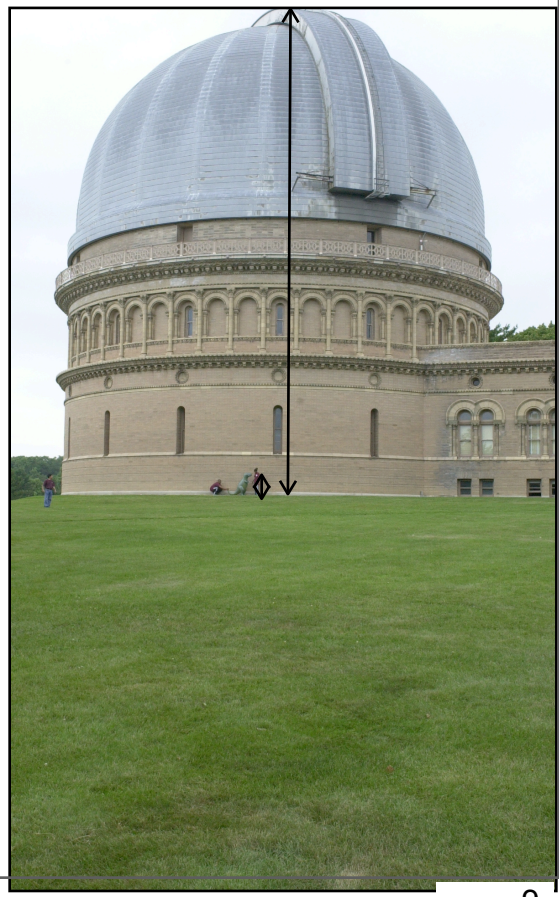

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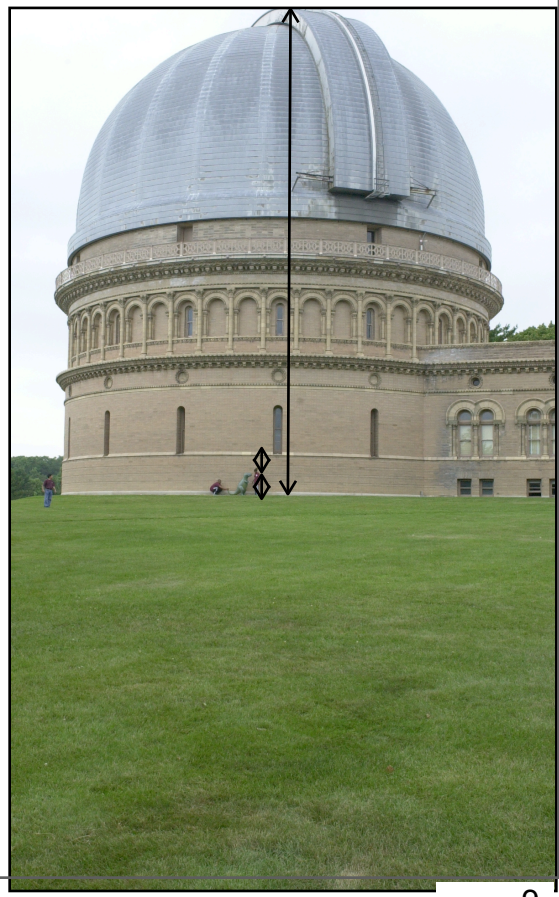

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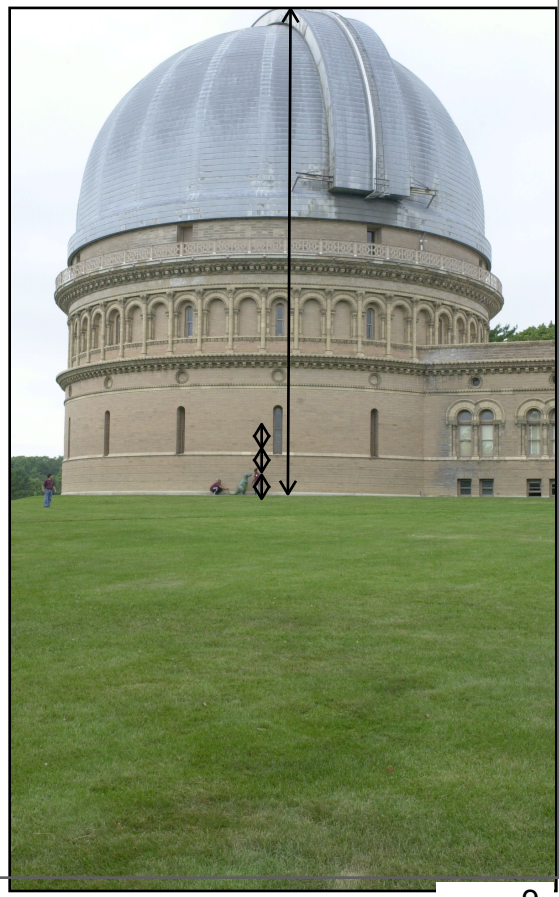

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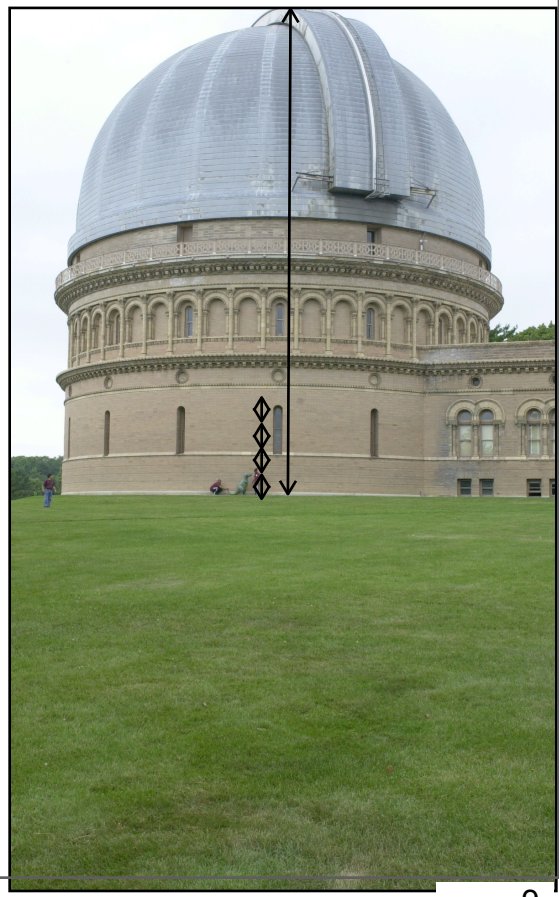
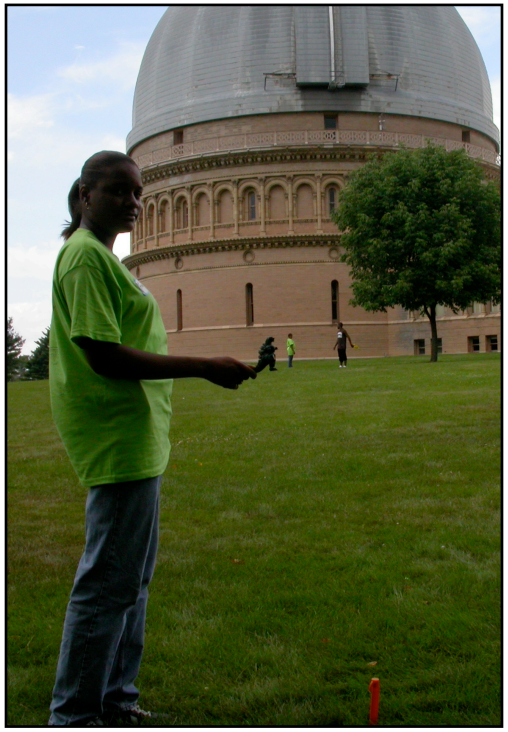


Reinforcing Challenges

- Monster Movie Challenge
  - Make a 3” Godzilla Model Appear as Big as a Person
    - Determine Apparent Size 3” (pixels)
    - Estimate Necessary Separation
    - Test with Camera
- Distance to Another Golf Flag on Golf Course
  - Calculate Distance & Then Measure
    - Assume Similar Objects Same Size
    - Like Rung of Cosmic Distance Ladder



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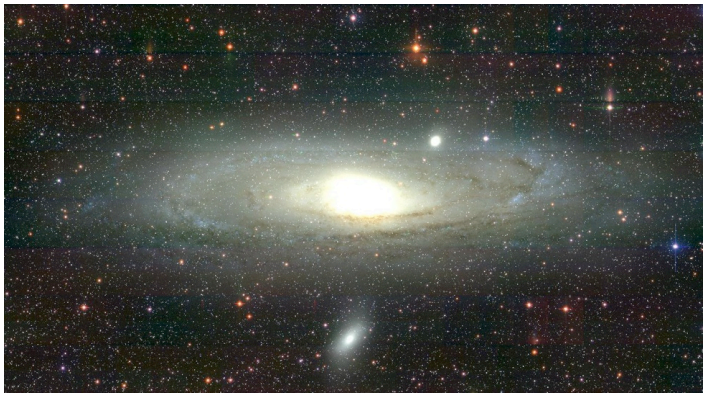
Climbing the Distance Ladder



- Determine Distance to M31(Andromeda)
  - Assume Globular Clusters Belonging to M31 & the Milky Way are of Comparable Size
- Translate to Absolute Distances
  - Given Exact Distance to Original Globular Cluster
- Determining Distance to Galaxy Clusters
  - Assume Galaxies in Distant Clusters of Galaxies are of Similar Size to M31

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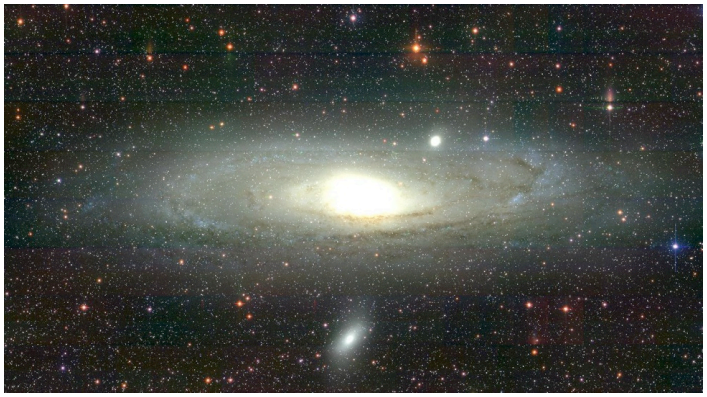
Climbing the Distance Ladder



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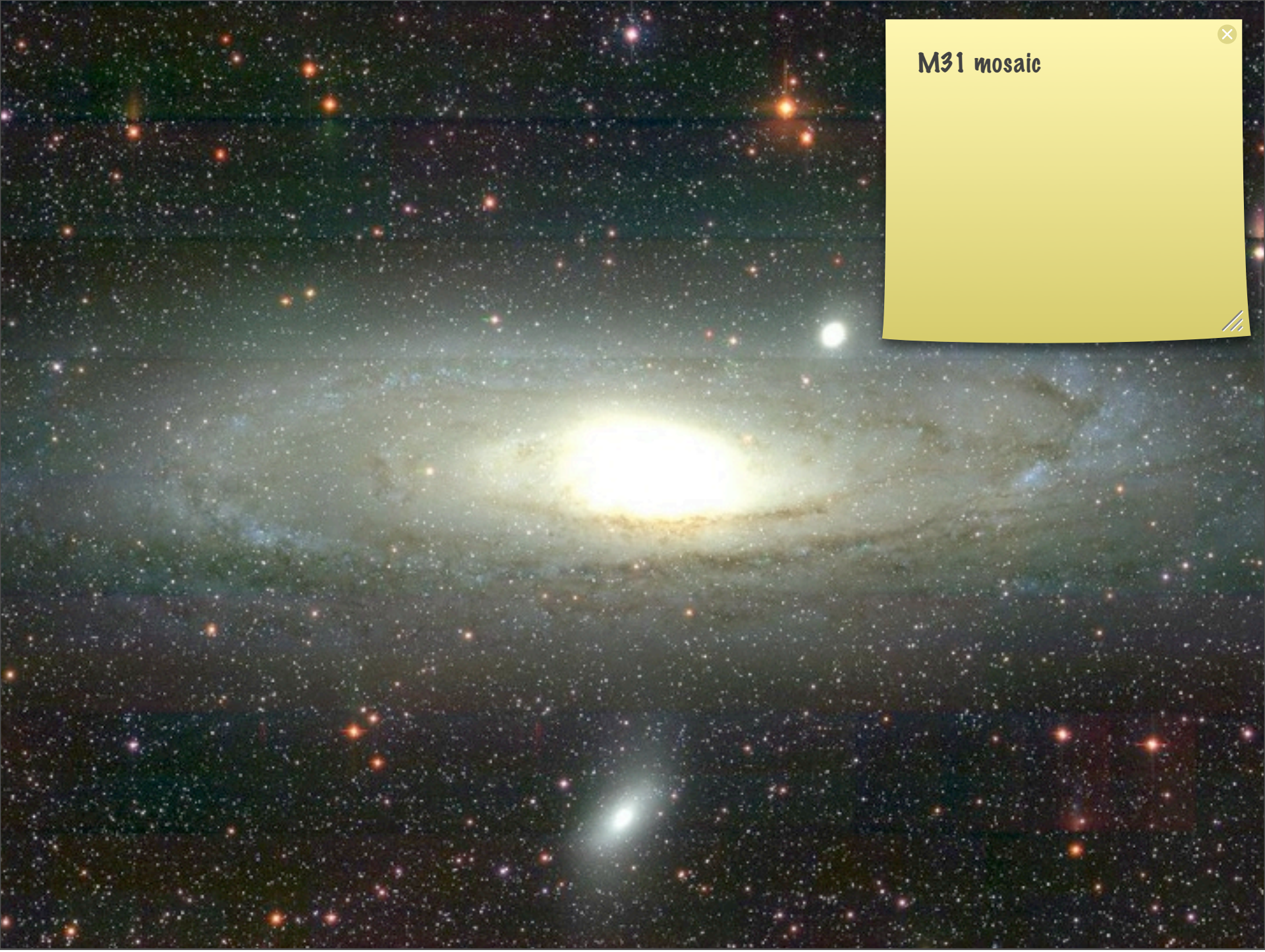
M31 Lab: In a Nutshell

1. Assemble Massive M31 Mosaic
2. Identify Globular Clusters
3. Measure Average Size of Globular Clusters
4. Measure the Size of a Nearby Globular Cluster in the Milky Way Galaxy (M3)
5. Assume: Small Angle Approximation Valid, SDSS Data Constant Conditions
6. Determine Relative Distance (Apparent Sizes)
7. Determine Absolute Distance Given Distance to M3/NGC5272 (33,900 Lyr, 10.4kpc)


M31 mosaic

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SDSS Mosaic
M31
76 - images
hint align by run number
and column

HUGE!

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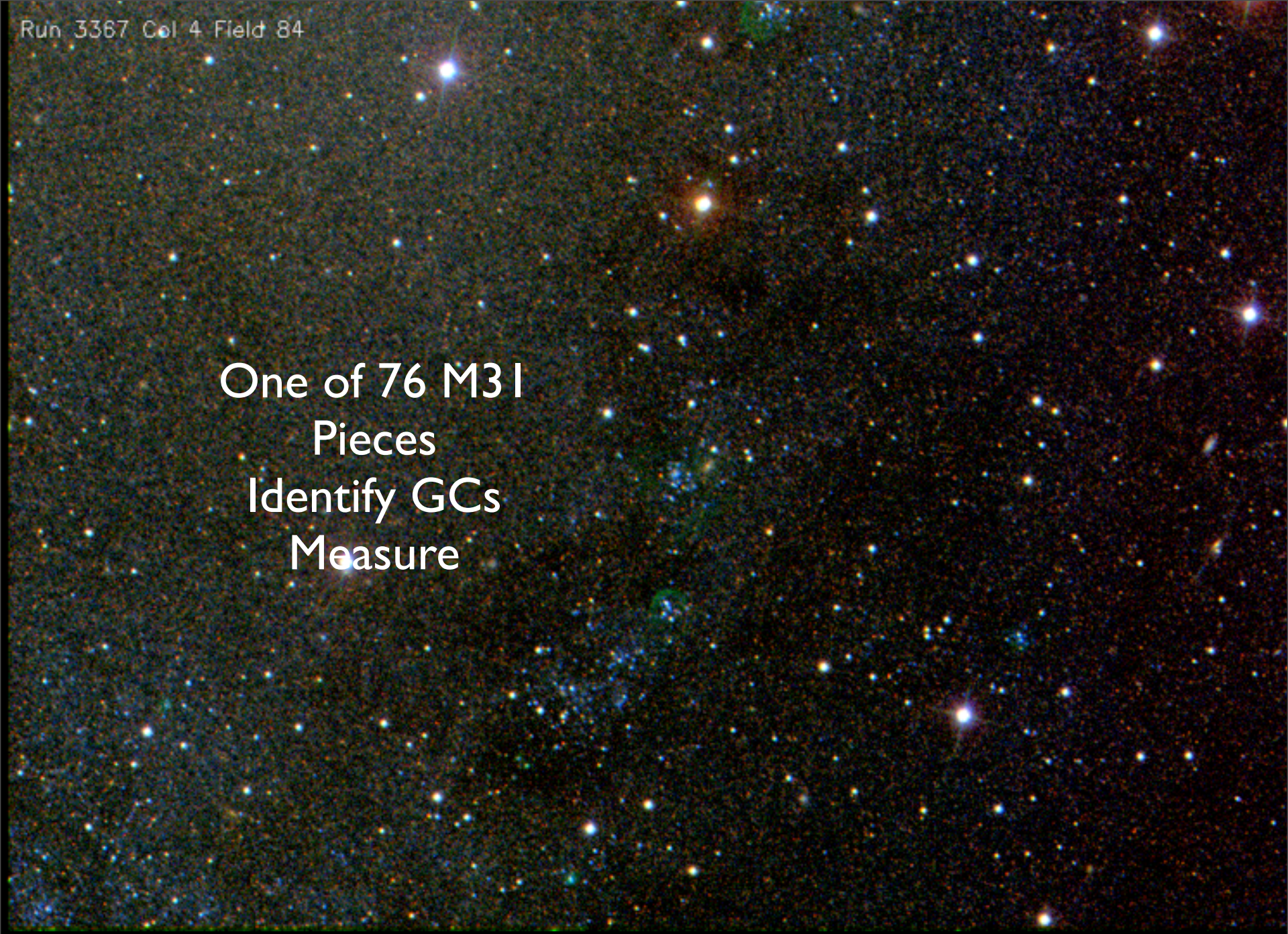
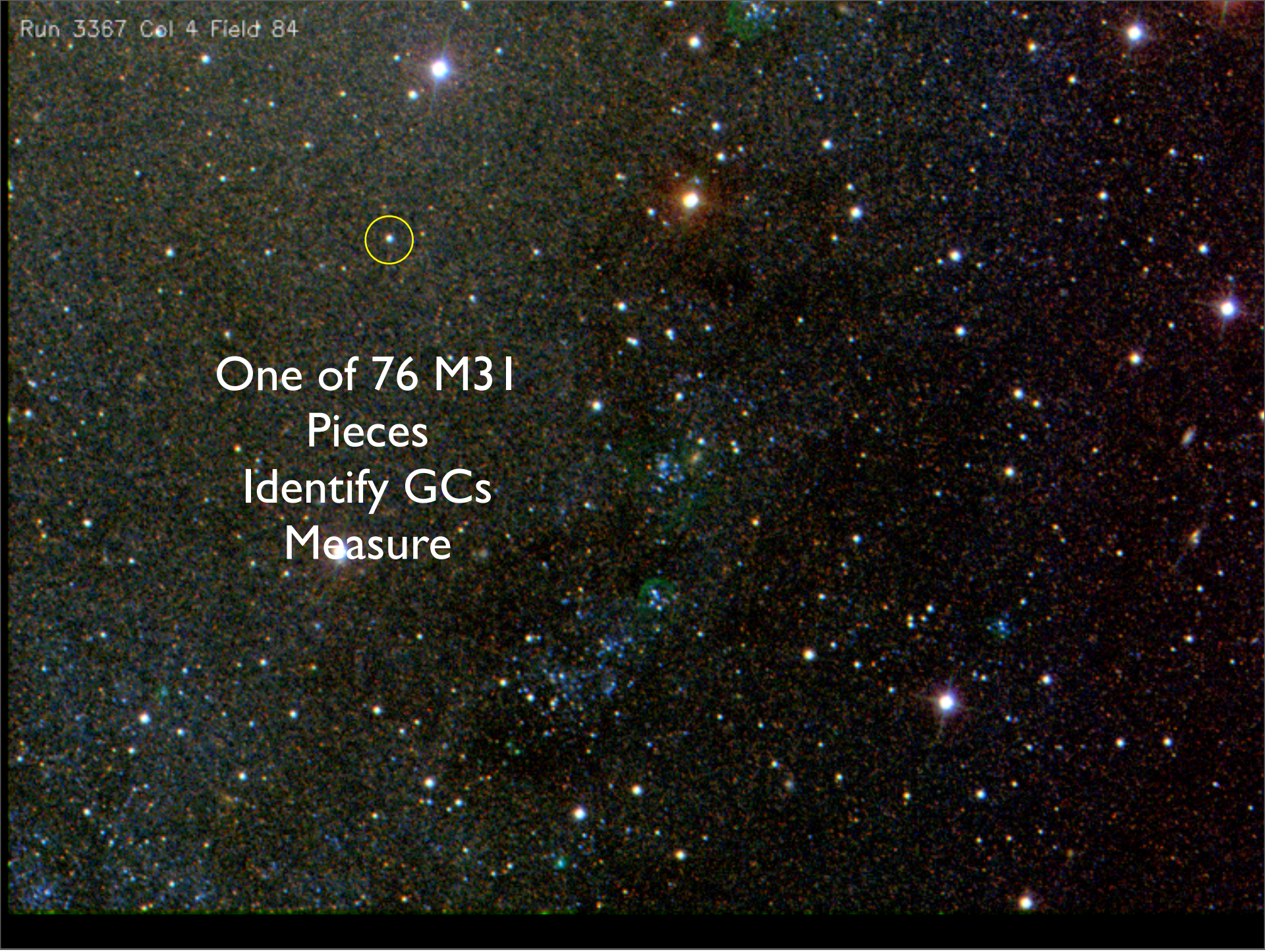

Run 3367 Col 4 Field 84
One of 76 M31
Pieces
Identify GCs
Measure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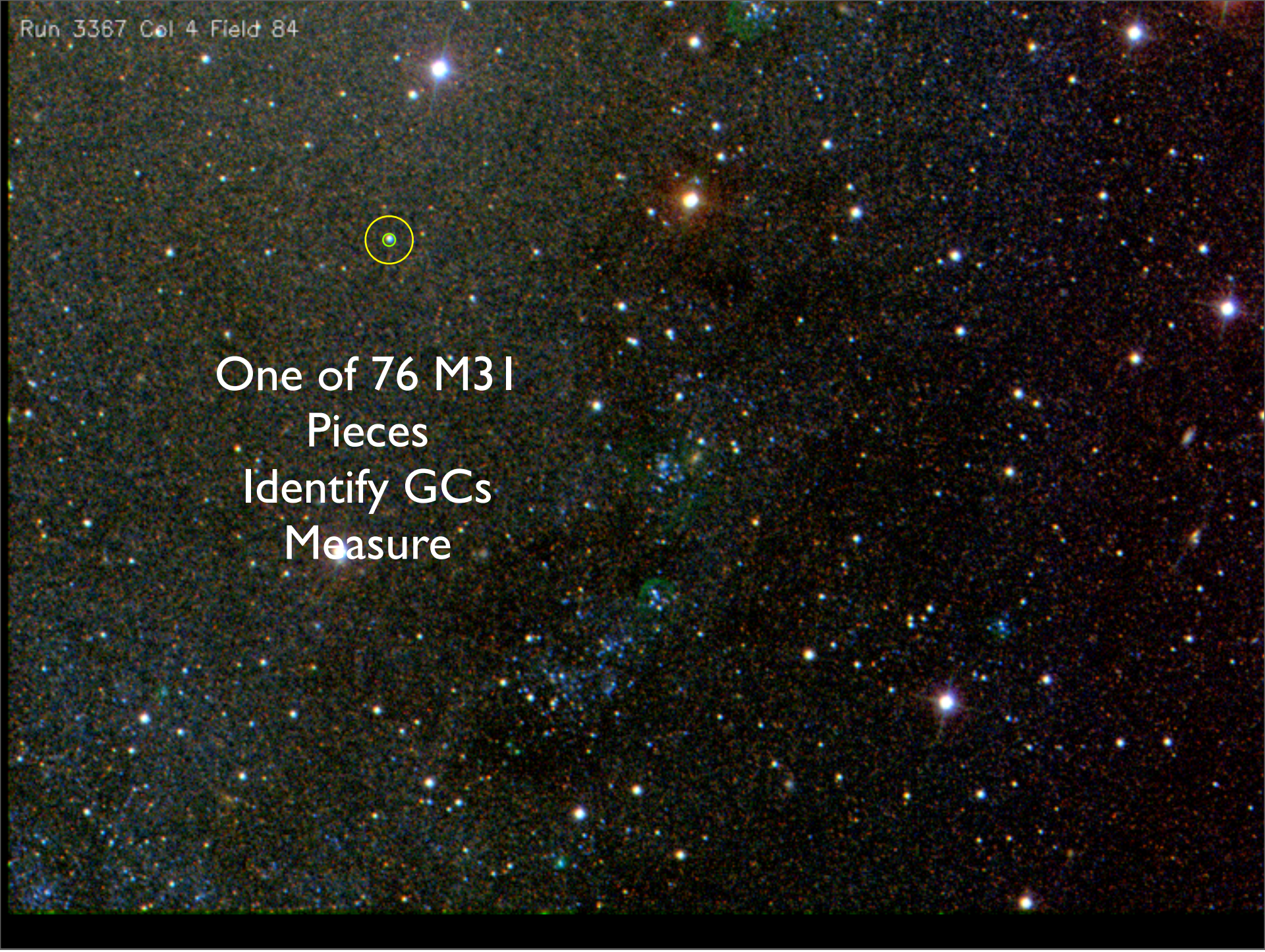
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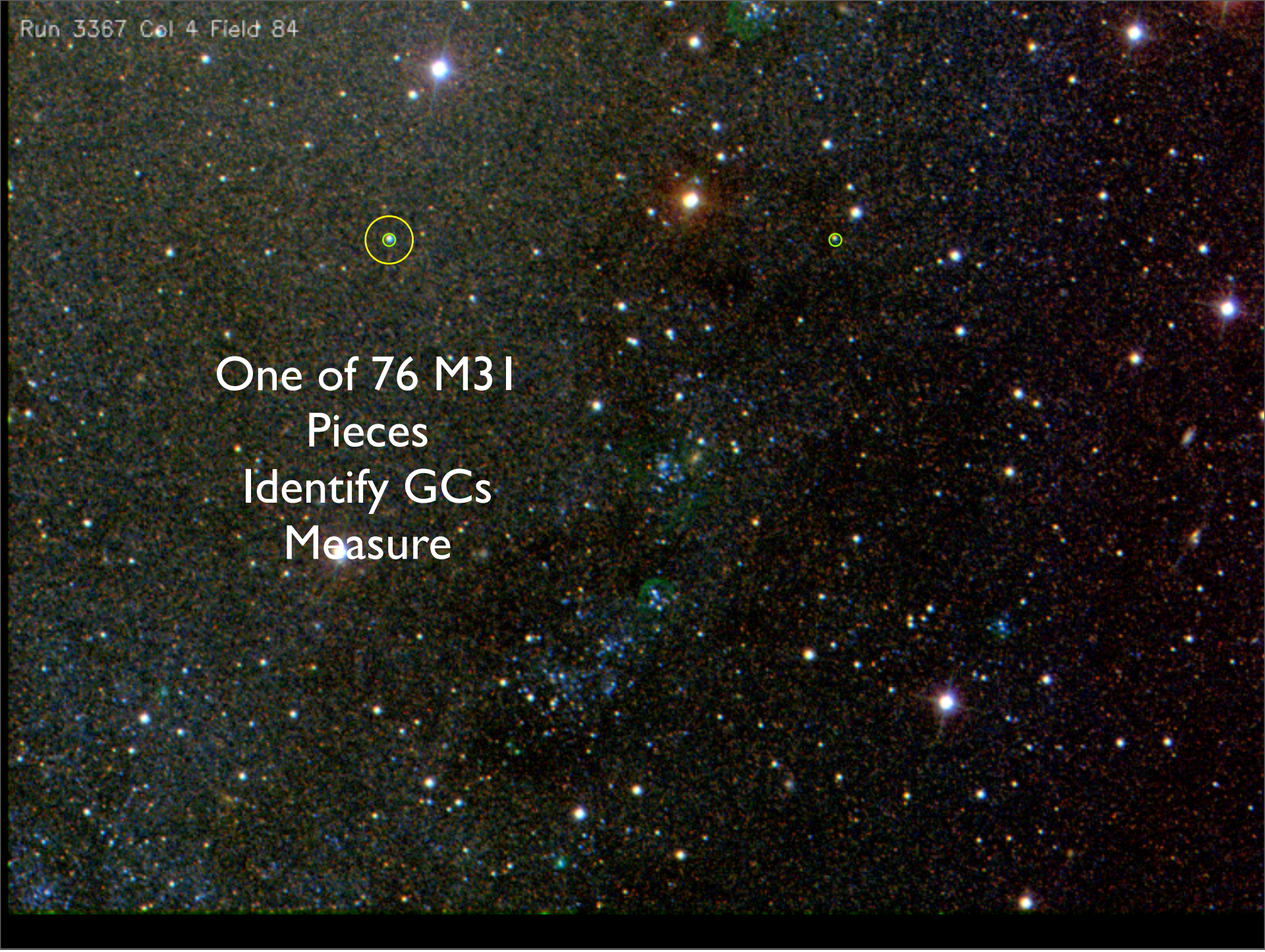
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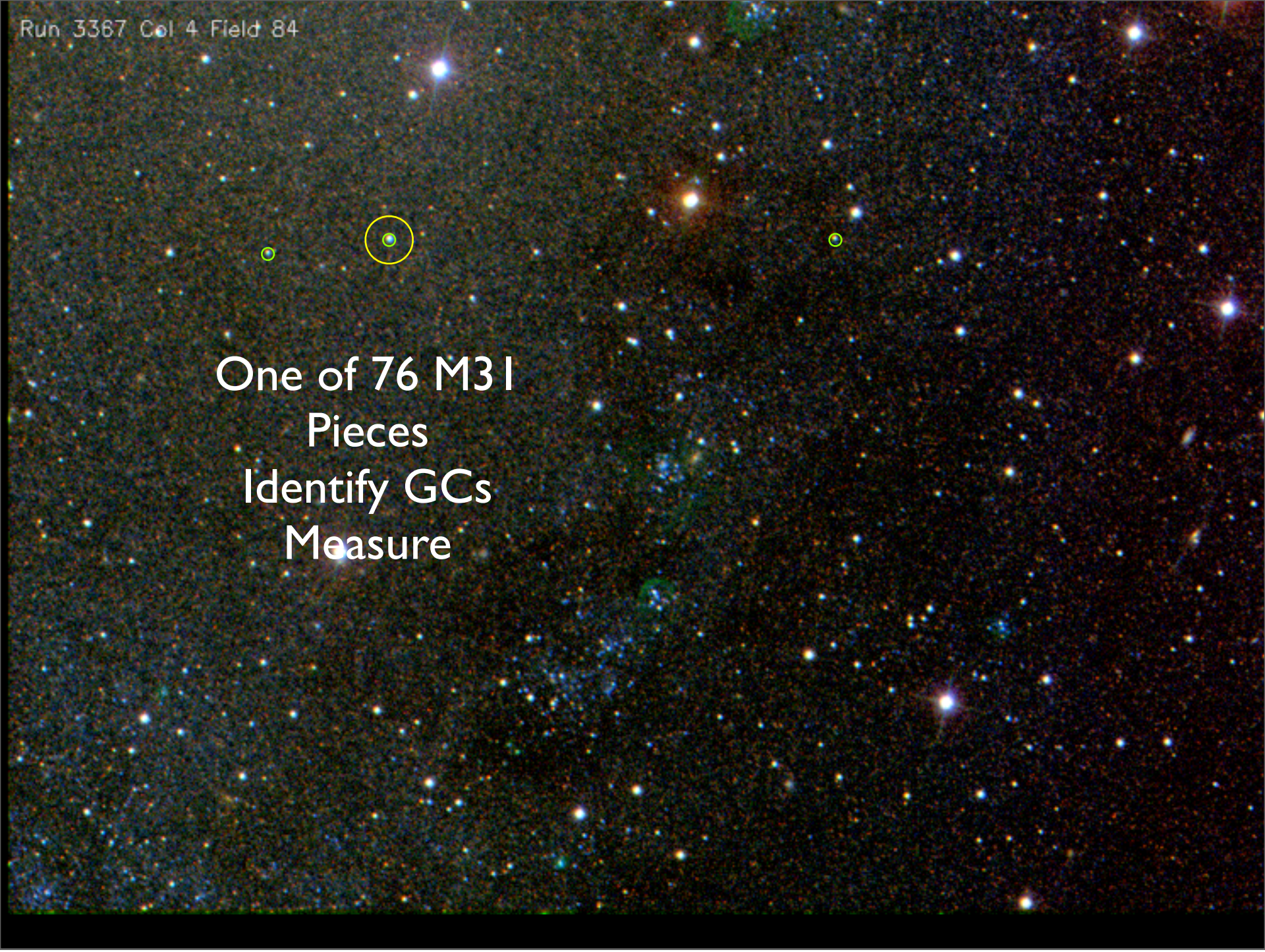
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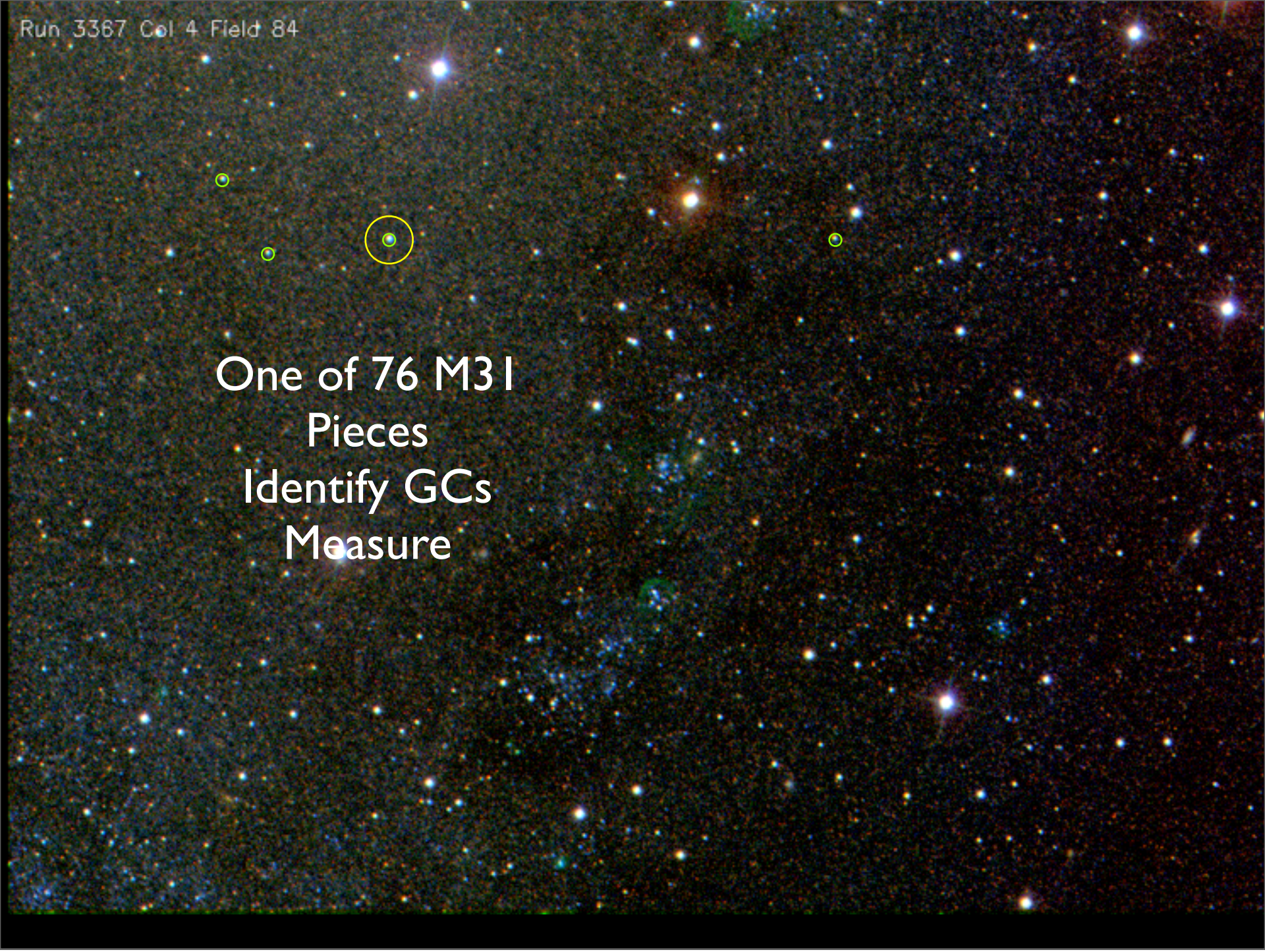
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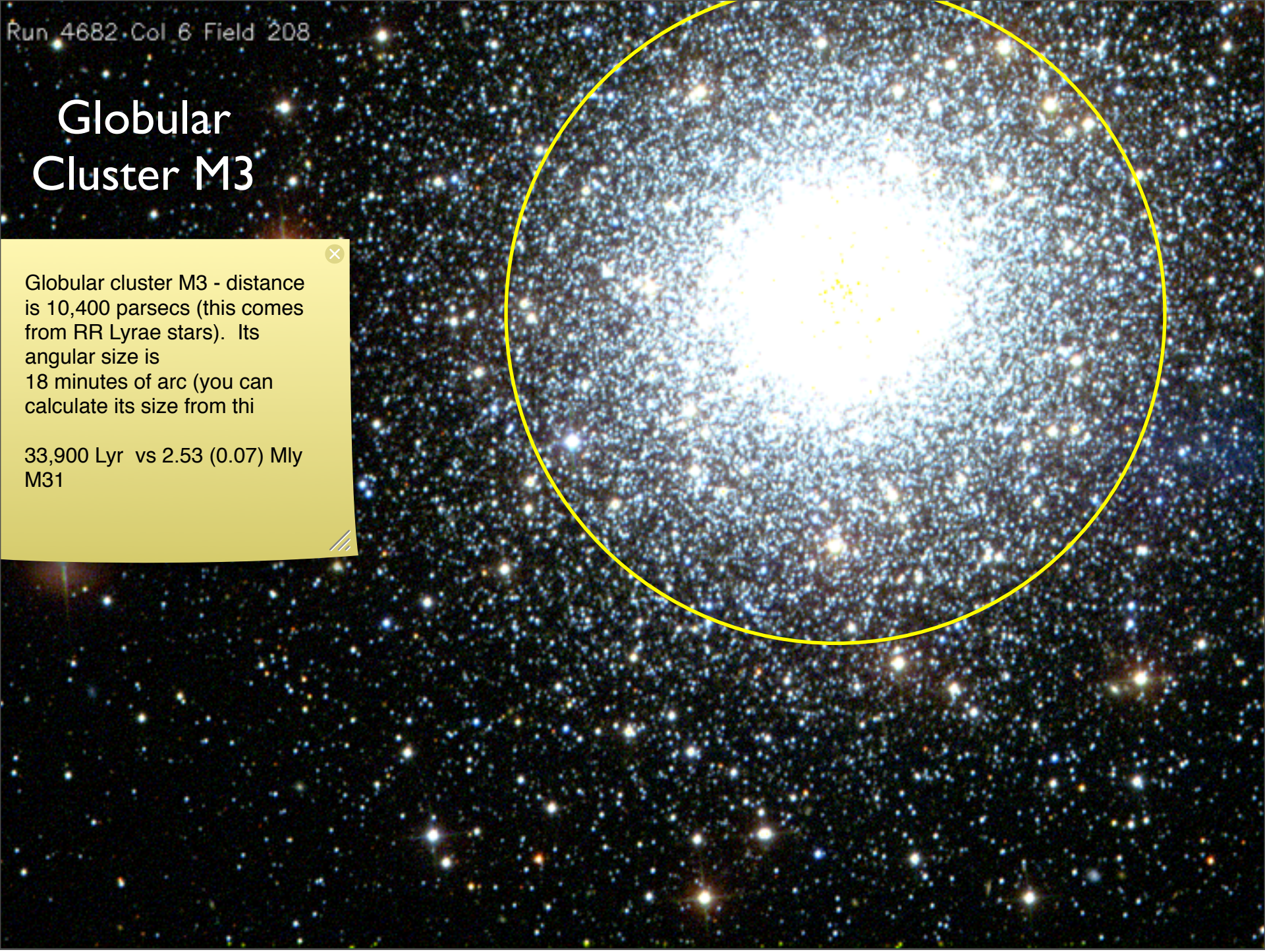
Globular Cluster M3

Globular cluster M3 - distance is 10,400 parsecs (this comes from RR Lyrae stars). Its angular size is
18 minutes of arc (you can calculate its size from thi

33,900 Lyr vs 2.53 (0.07) Mly M31



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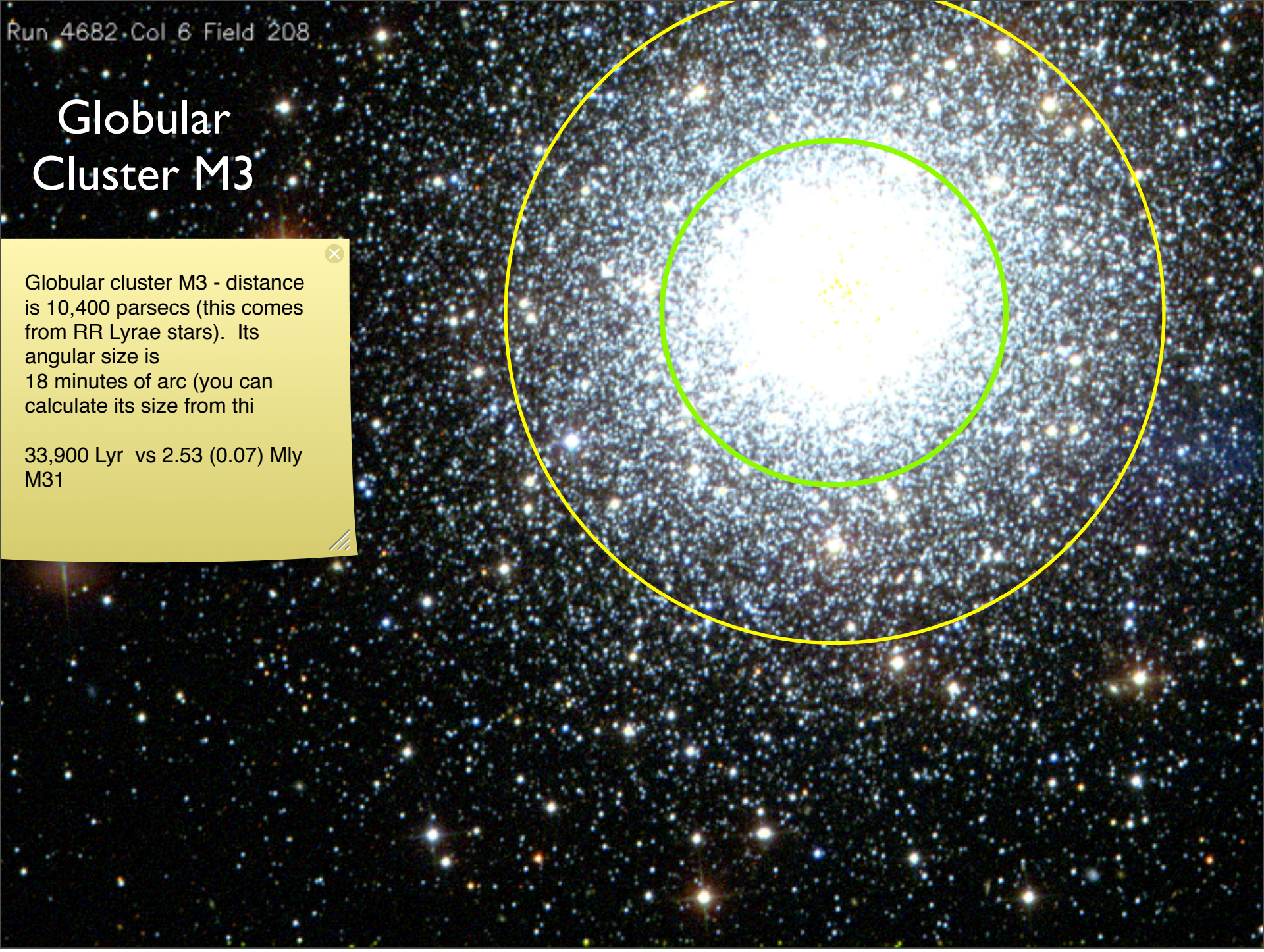

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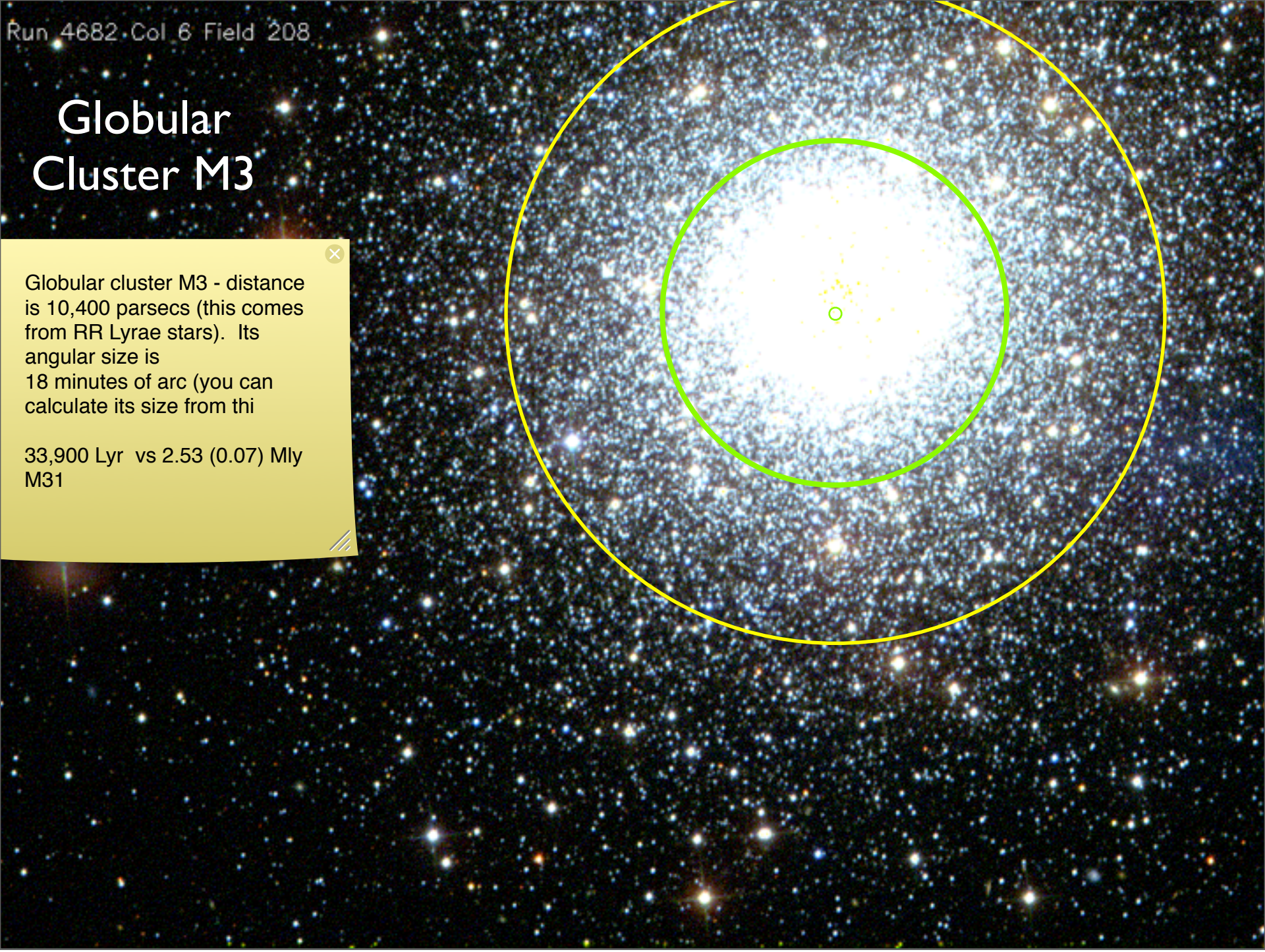

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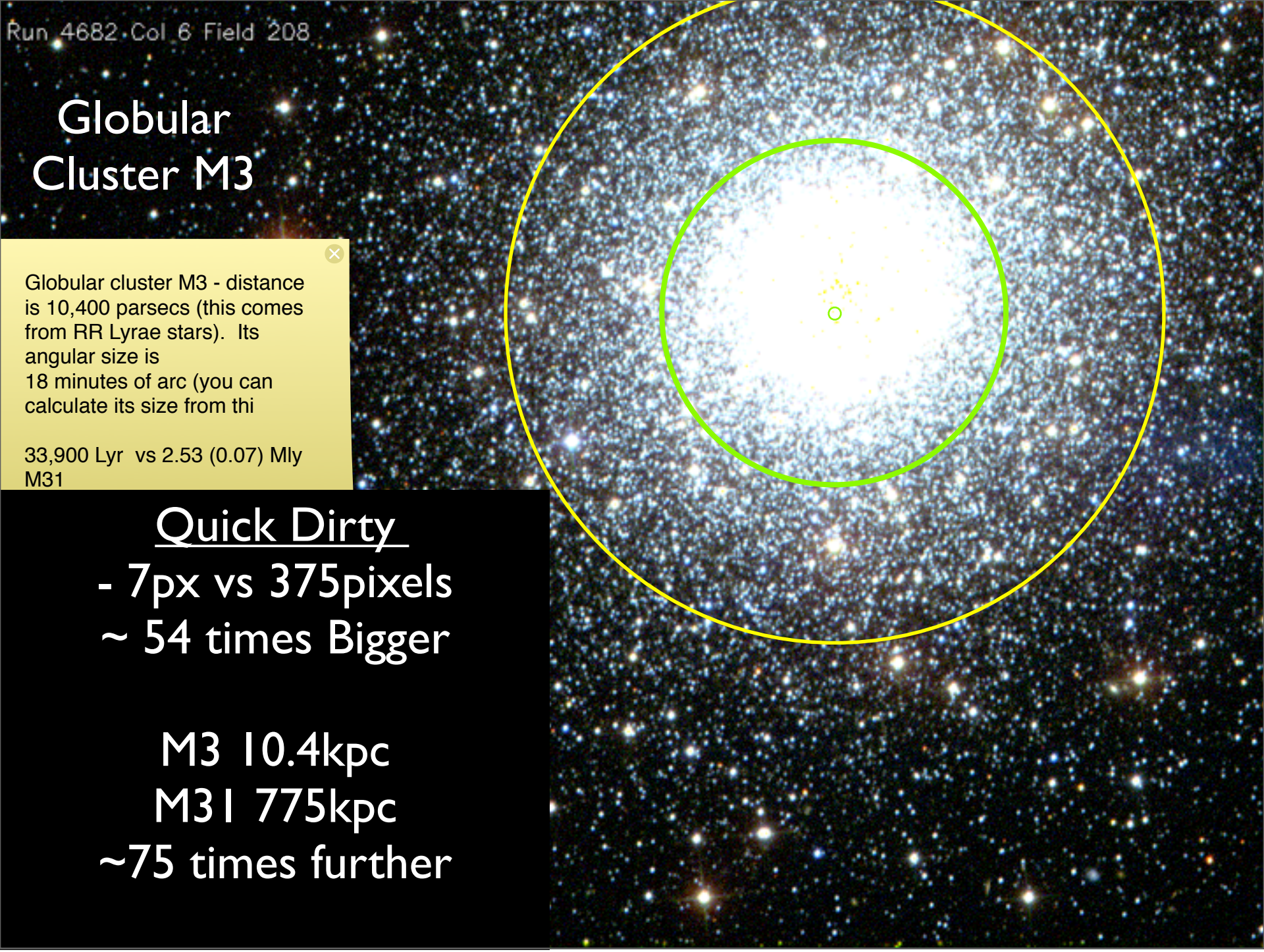
33,900 Lyr vs 2.53 (0.07) Mly M31



Globular Cluster M3

Globular cluster M3 - distance is 10,400 parsecs (this comes from RR Lyrae stars). Its angular size is
18 minutes of arc (you can calculate its size from thi

33,900 Lyr vs 2.53 (0.07) Mly M31

Quick Dirty

- 7px vs 375pixels
~ 54 times Bigger

M3 10.4kpc
M31 775kpc
~75 times further

Important Limits

- Break Down of Small Angel Approximation
  - Too BIG, Too Close (typically not a problem in astronomy - huge distances)
- Lens Distortions - (not flat)
  - take photo to demo (eg brick wall)
- Data Needs to be Taken w/Same Conditions (Apples to Apples)
  - Camera Must Be Set Same Way (zoom to infinity)
  - Homogenous Survey Data Set Like SDSS

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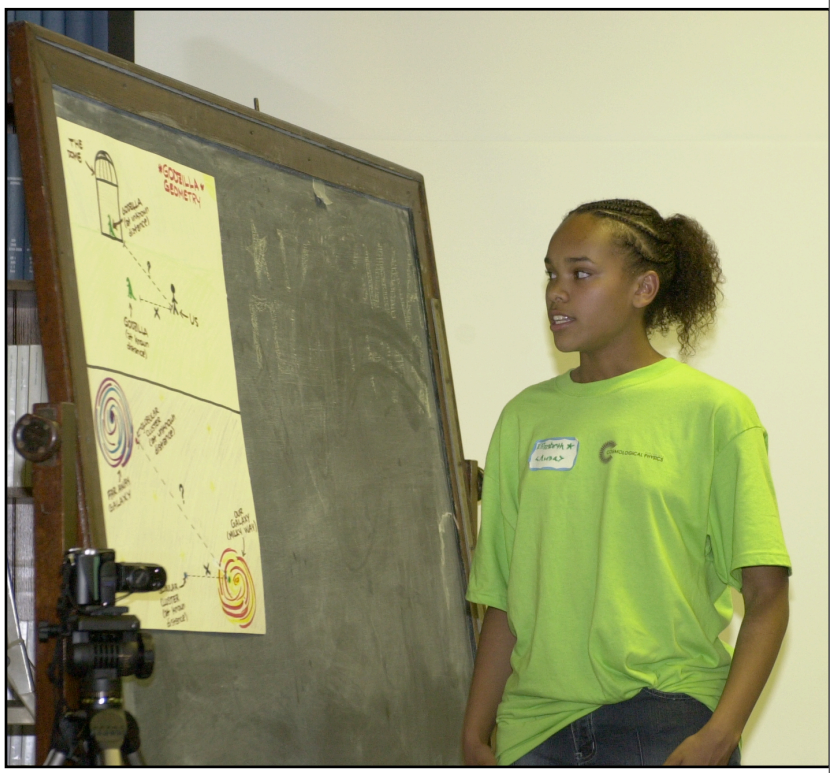
Summing Up

- Visceral Feel for Abstract Concept
  - Demonstrates Indirect Determinations
- Areas for Extensions
  - Angular Scale
  - Small Angle Approximation
  - Resolution
- Real Data Available
  - SDSS Skyserver
- Documented on Web
  - http://kicp.uchicago.edu/nsta



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  - Partners Space Explorers Program
- Mark SubbaRao (UC/Adler)
  - Co-taught

Online resources
http:kicp.uchicago.edu/nsta

The End

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Angular Size & Small Angles

- Favorite of Astronomers
- Do Not Need Distance
- Independent of Telescope
- (far far away – limit of small angle approximation)

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Determining Pixels/Degree

- Angular Scale ϕ
  - Photo - Know Height & Know Distance
  - tan (ϕ) = opposite/adjacent= height/distance
  - ϕ(radians) = arctan (opposite/adjacent)
    - ϕ(degrees)= ϕ(radians)x180/π
  - ϕ(degrees)= arctan (opposite/adjacent) x180/π
- Pixels
  - Count the number of vertical pixels image takes up
- Pixels/Degree
  - (angular size ϕ) = (number of pixels)

Nikon CoolPix 4500

38 pixels/ degree

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Pictures to Pixels to Apparent Angles

- Camera – Nikon CoolPix 4500
- "4" Mega Pixel
  - CCD Chip 2,272 wide x 1,704 tall
  - 2,272x1,704 = 3,871,488 pixels