Properties of Interstellar Dust in the MBM 18-19 High-Latitude Cloud Complex

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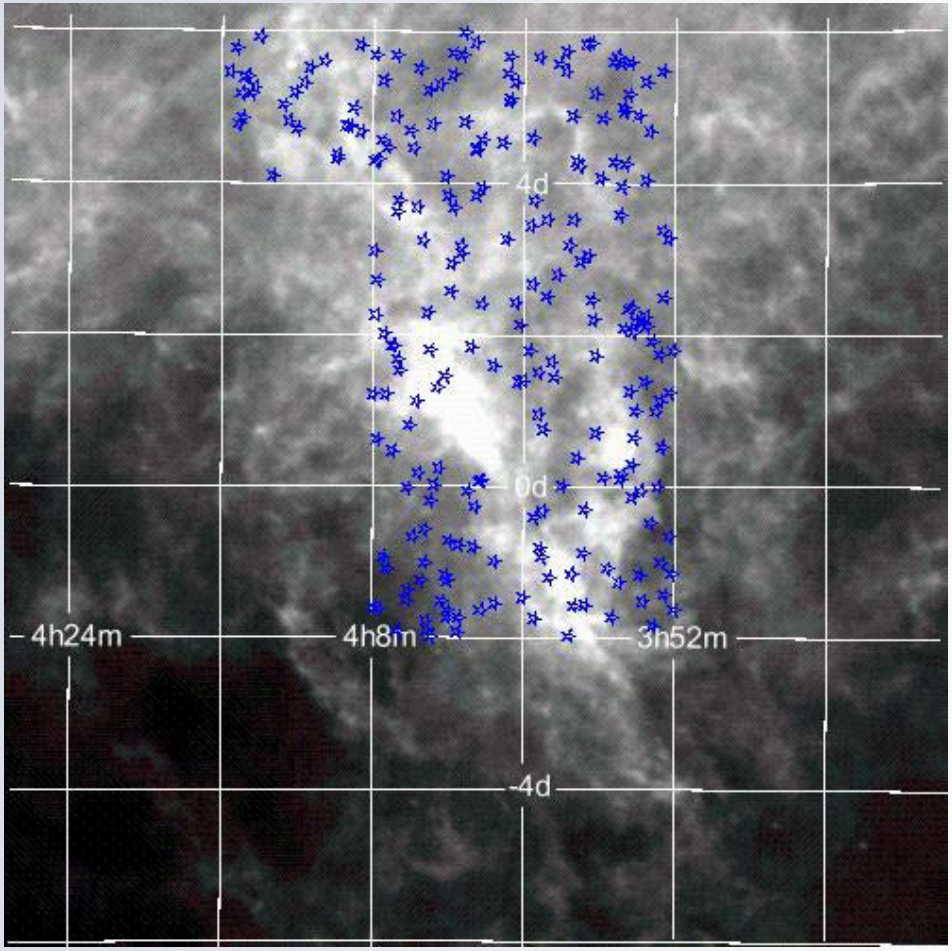
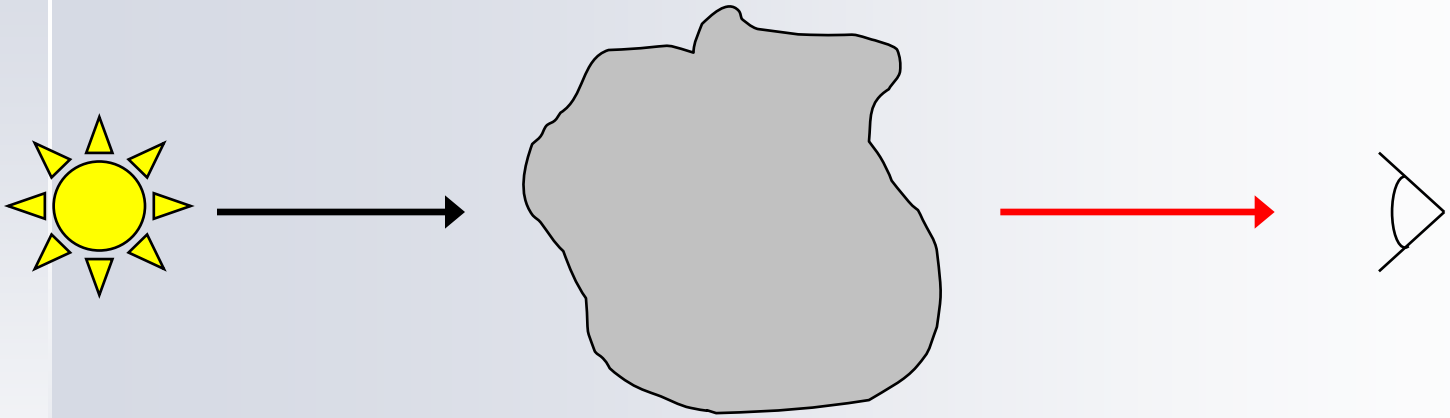
Stars Studied in the MBM 18-19 Region



Interstellar Clouds

- Made up of gas and small dust particles
- Dust scatters and absorbs light from stars, changing the brightness and color that we observe

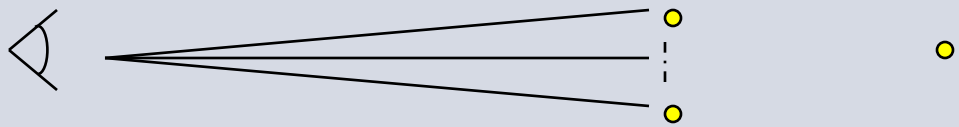


- Interstellar dust clouds are the location of new star formation in our galaxy
- We study cloud properties by looking at the effect dust grains have on starlight

Studying Stars

- Stars emit light at many different wavelengths across the electromagnetic spectrum
- We can measure the level of emission at individual wavelengths
  - Systems of "passbands" designate specific wavelength ranges
    - Johnson Photometric System: **U** {**B V R**} {**I J H K L M**}

      Visual Infrared
- Magnitude System:
  - Originally created by either Ptolemy or Hipparchus to classify the apparent luminosities of stars
  - Numerically small magnitude = bright star
  - Numerically large magnitude = dim star



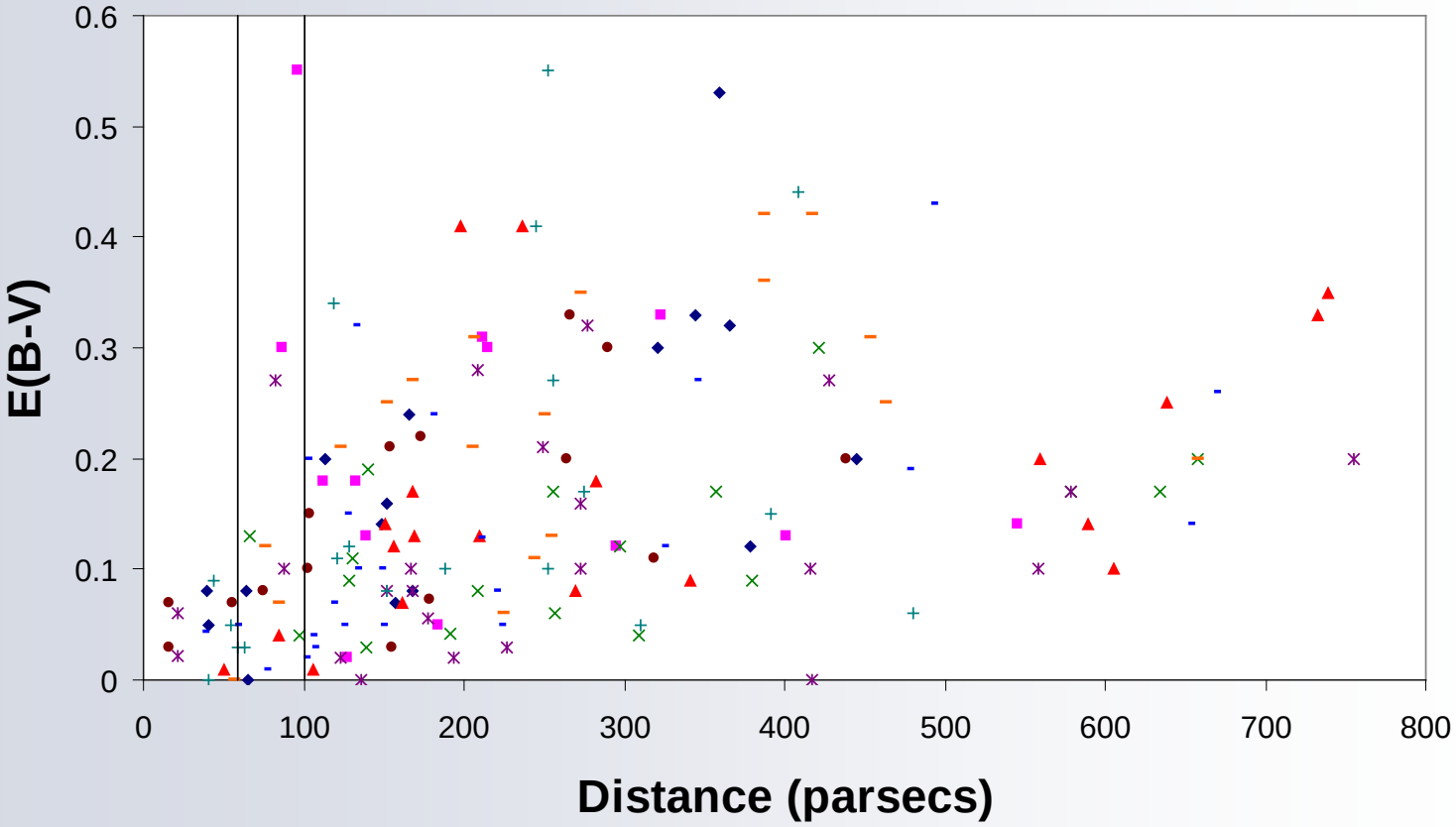
Finding the distances to stars

- Apparent visual magnitude (**V** or $\mathbf{m_V}$)
  - Measures how bright a star appears from earth
- Absolute visual magnitude ($\mathbf{M_V}$)
  - Measures the star's actual luminosity
  - Defined as the apparent magnitude the star would have at a distance of 10 parsecs
  - $\mathbf{M_V}$ can be found from a star's spectral type
- $\mathbf{V} - \mathbf{M_V} - \mathbf{A_V} = 5 \log \mathbf{d} - 5$
- The distance to an interstellar dust cloud such as MBM 18-19 can be estimated by plotting the reddening vs. distance for stars in the direction of the cloud

Effects of Dust on Stars

- Star color is the difference in a star's magnitudes at two different wavelengths
  - E.g. **B** – **V**
- Dust changes the color of starlight by extinguishing shorter wavelengths of light more effectively
  - This process is known as reddening
- Color Excess: the change in a star's apparent color caused by the dust
  - E.g. $\mathbf{E_{B-V} = (B-V) - (B-V)_{std}}$
  - Color excesses can be used to estimate the total visual extinction ($\mathbf{A_V}$)
  - Two estimates based on galactic averages are:
    - $\mathbf{A_V} \approx 3.05\ \mathbf{E_{B-V}}$
    - $\mathbf{A_V} \approx 1.1\ \mathbf{E_{V-K}}$ (we used this approximation in our calculations)

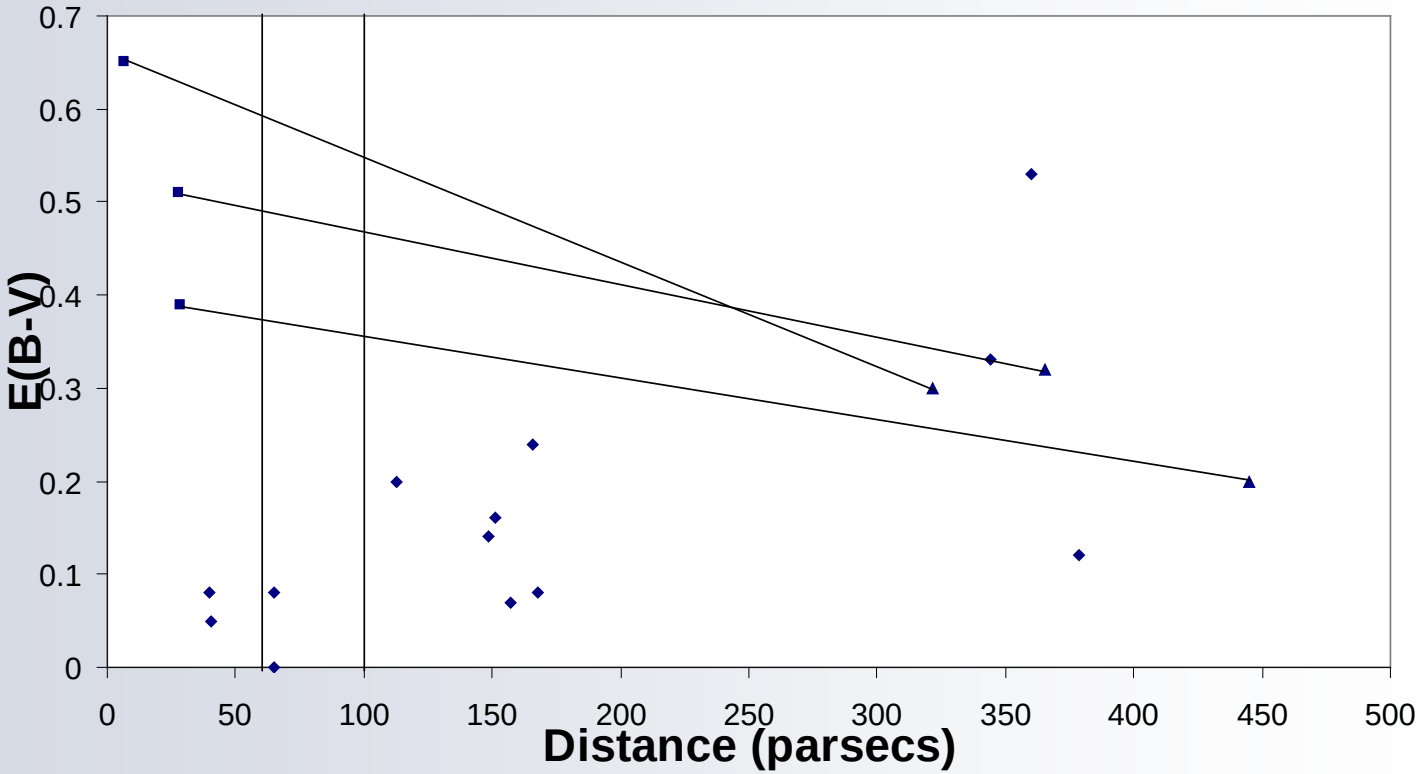
Reddening vs. Distance



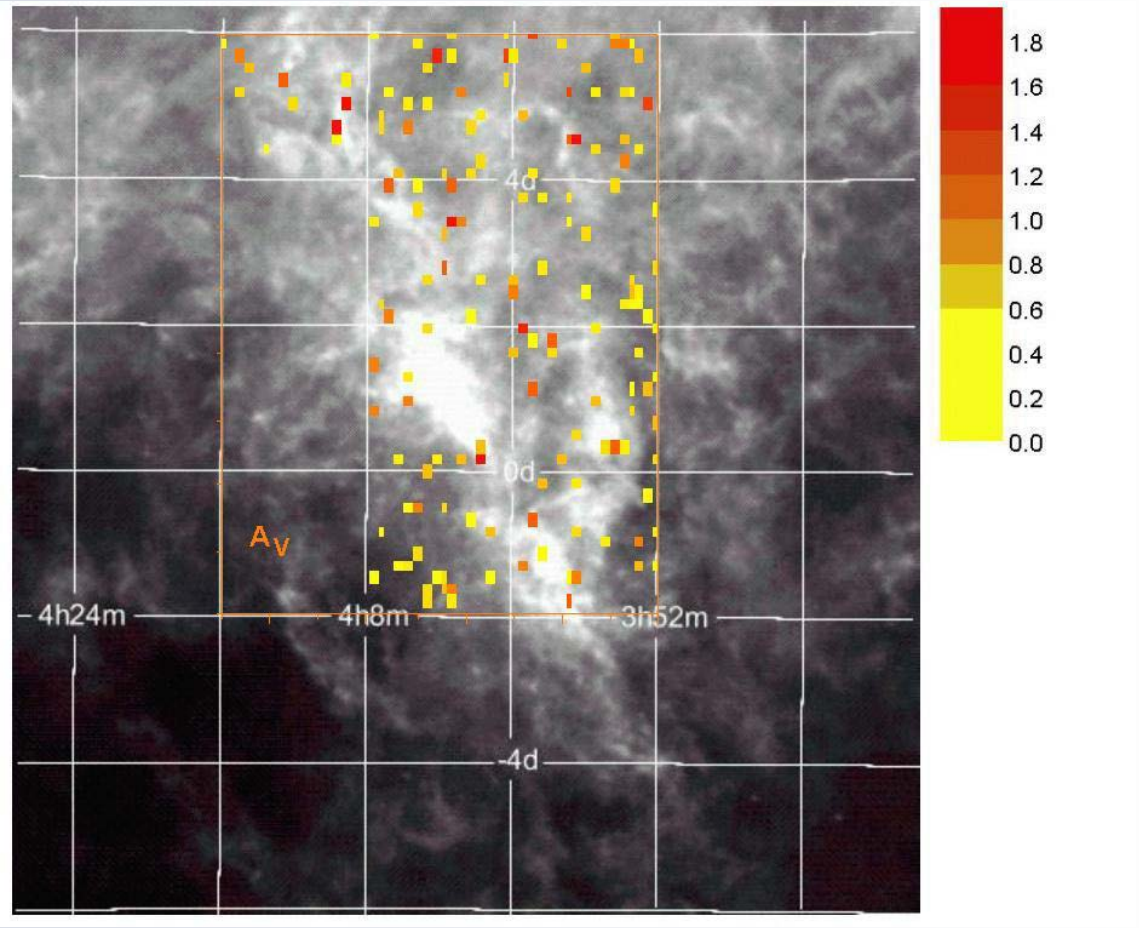
Difficulties in Finding the Distance to the Cloud

- Original graphs contained many near (less than 50-60 parsecs), highly reddened stars
  - We know that there are no interstellar dust clouds this close to earth, so either our distance or reddening calculations had to be erroneous
- In addition to having spectral types, stars are grouped into five luminosity classes
  - Supergiants (I, II), Giants (III), White Dwarfs (IV), Dwarf/normal stars (V)
- We realized that the anomalous stars in the graphs were probably giants, so we had severely underestimated their distances
  - $\mathbf{d} = 10\text{^}((\mathbf{V} - \mathbf{M_V} - \mathbf{A_V} + 5) / 5)$

The Effect of Assuming the Presence of Three Class III Giants in one sub-region studied



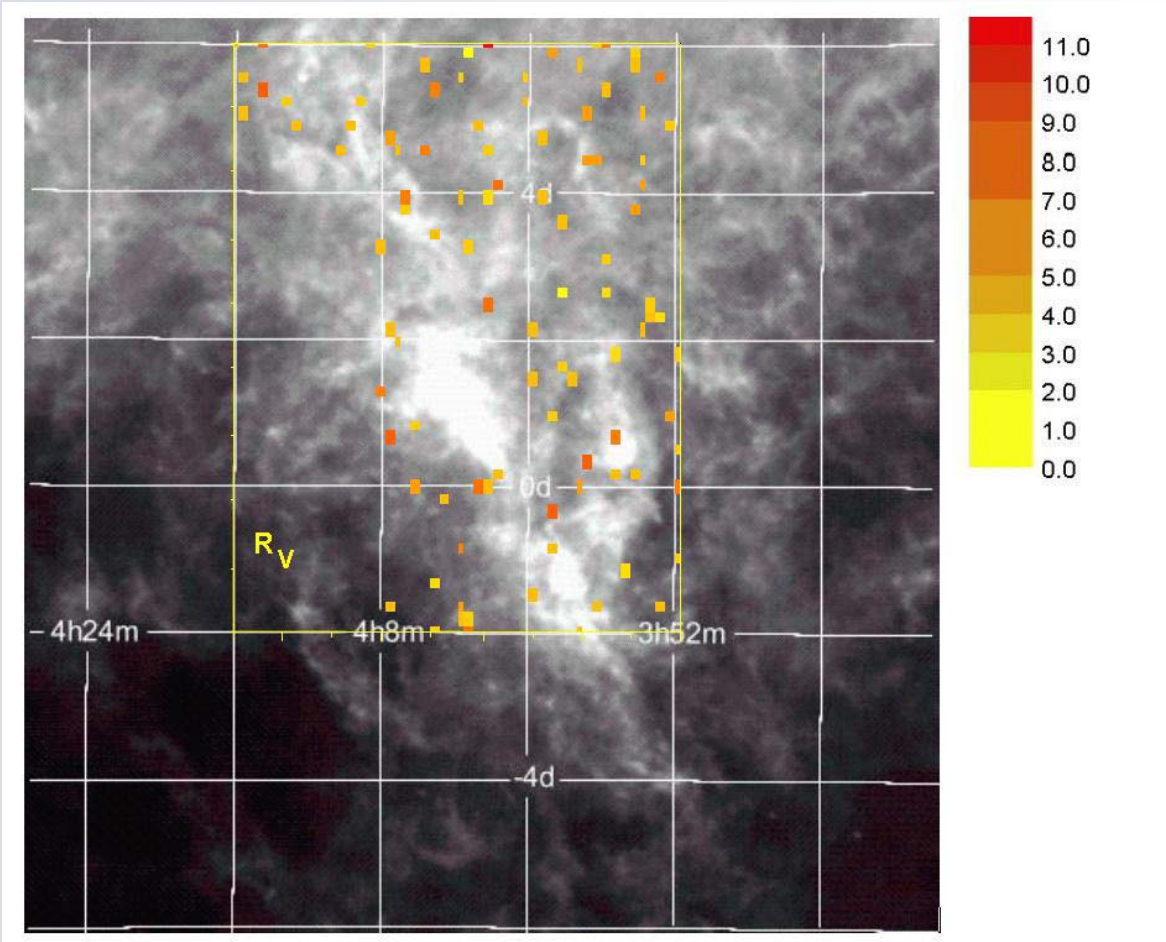
Map of Total Visual Extinction



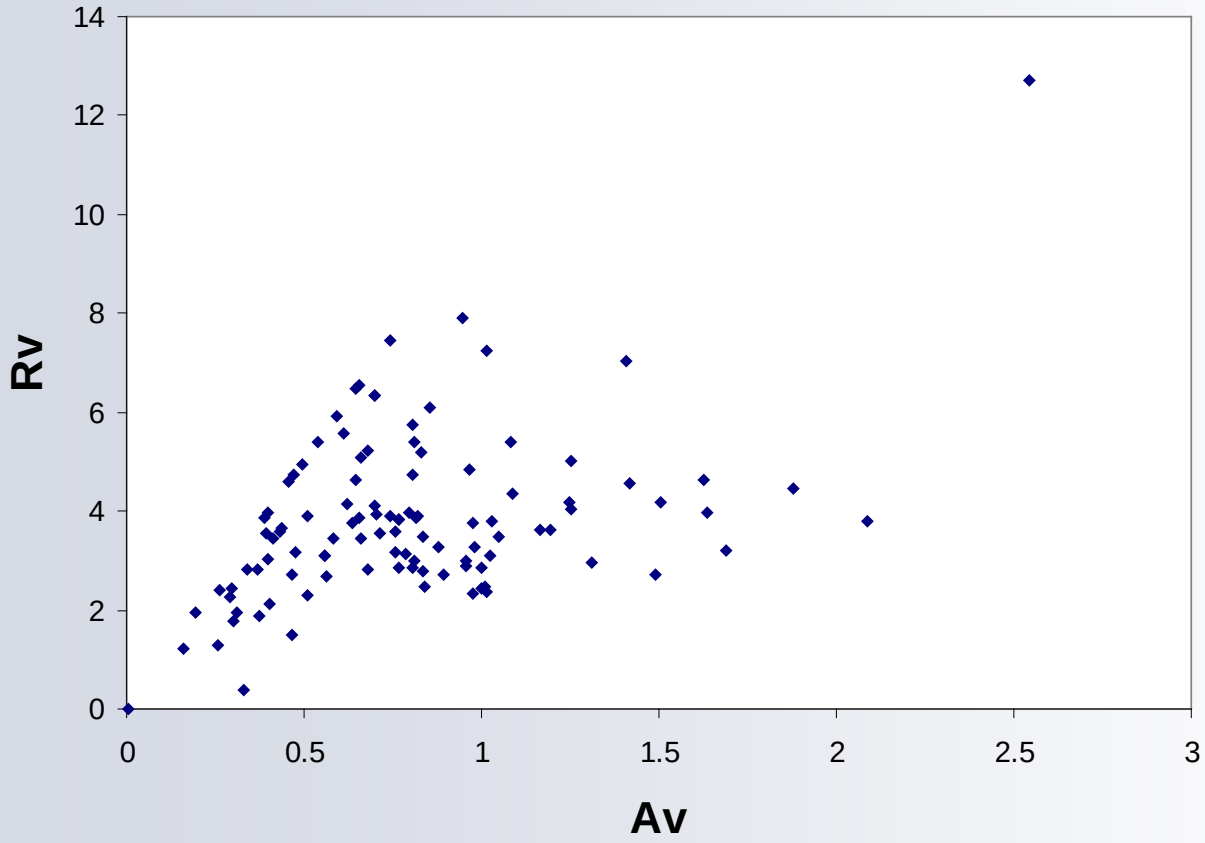
The Ratio of Total to Selective Visual Extinction (R_V)

- $\mathbf{R_V} = \mathbf{A_V} / \mathbf{E_{B-V}}$
- Because $\mathbf{A_V}$ is difficult to determine directly, knowing an accurate value for $\mathbf{R_V}$ can be very important
- $\mathbf{R_V}$ also gives us information about the properties of dust grains in a cloud
  - Bigger $\mathbf{R_V}$ implies bigger dust particles
- One way to calculate $\mathbf{R_V}$ is to independently calculate $\mathbf{A_V}$ and $\mathbf{E_{B-V}}$ using an approximation such as $\mathbf{A_V} \approx 1.1\ \mathbf{E_{V-K}}$
- Another, potentially more precise method is to use extinction curves

Map of R_V

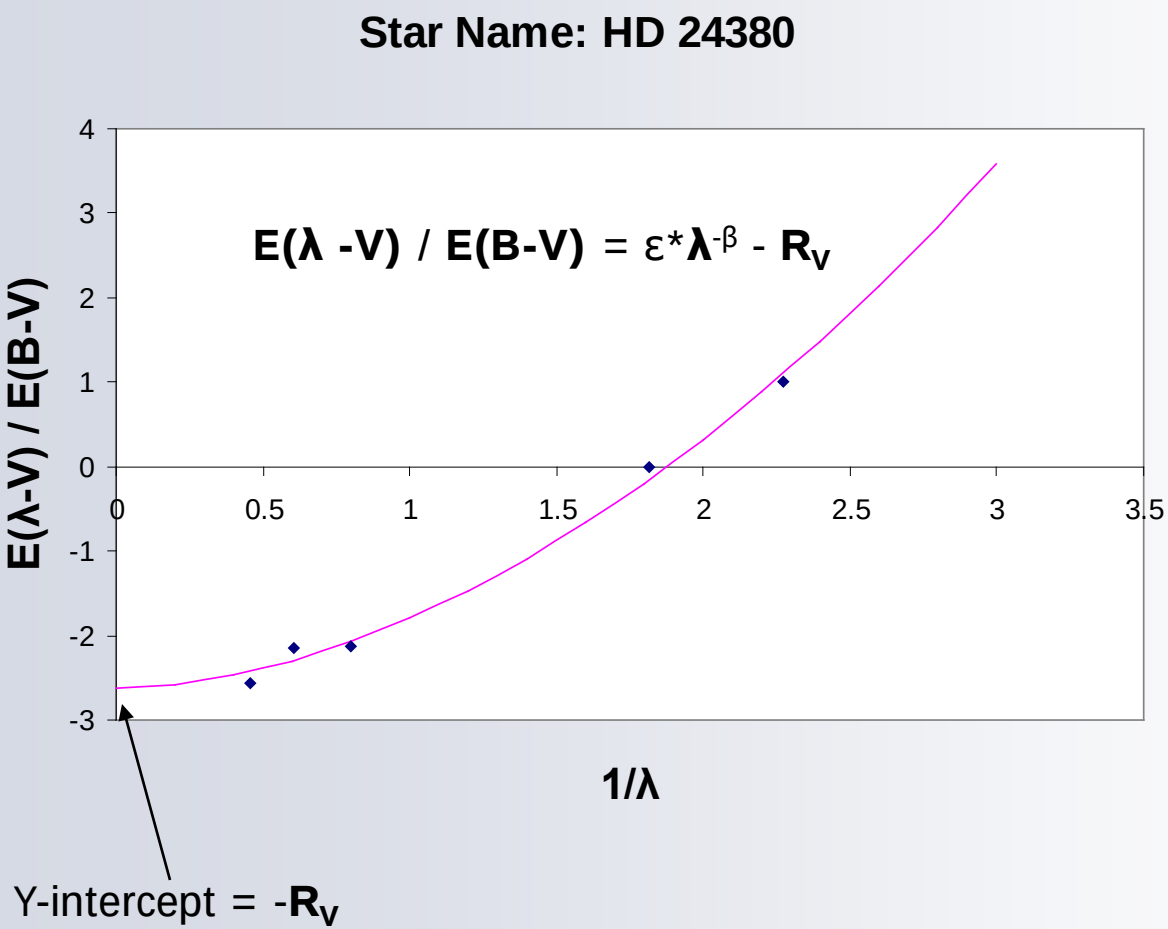


R_V vs. Total Visual Extinction



R_V is generally expected to increase in regions of high **A_V**, as dust particles grow by accretion in the densest regions of the cloud. However, we observed only a slight correlation in MBM 18-19.

Calculating R_V from an Extinction Curve

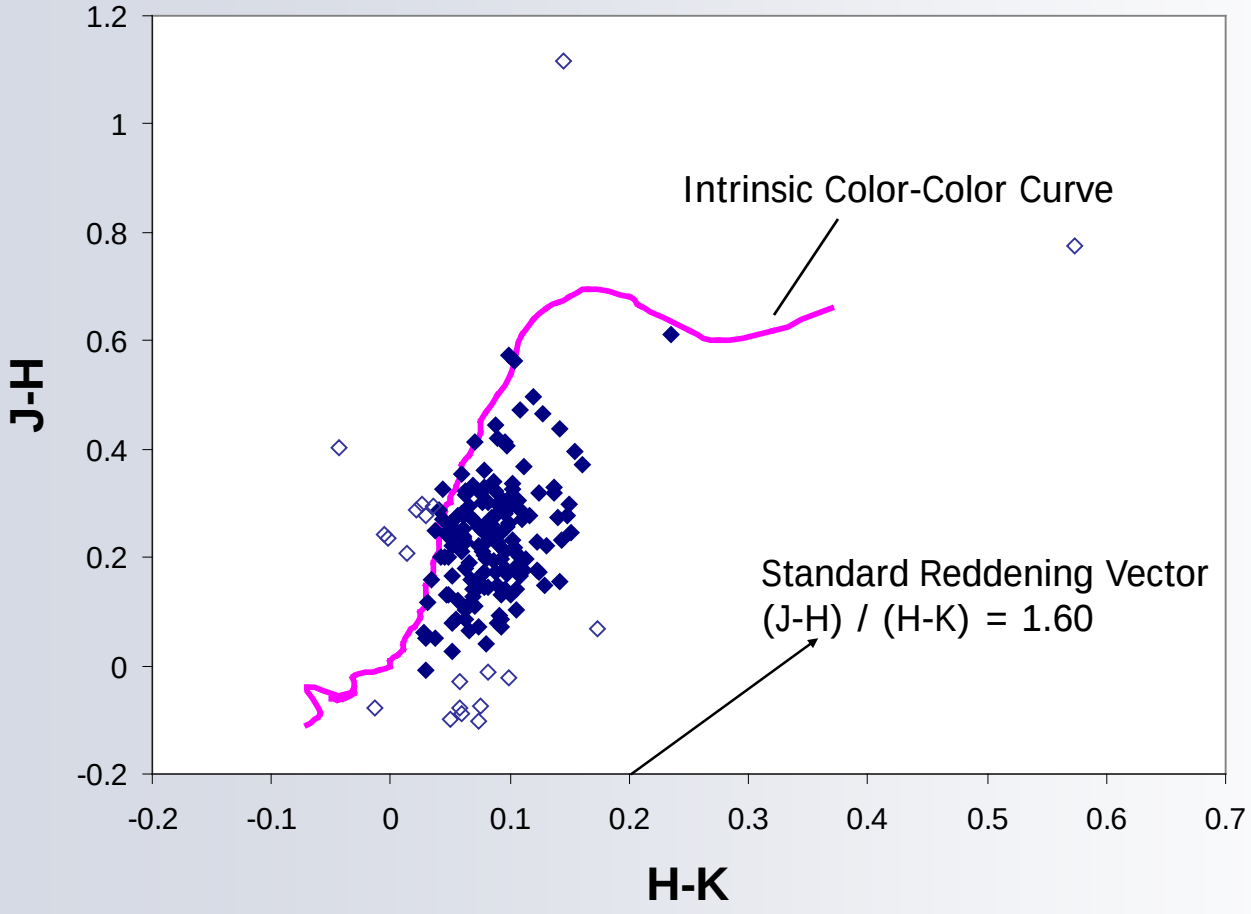


Unfortunately, we had too many free parameters and too few data points for most stars to perform an accurate curve fit, so we had to settle for our earlier estimated $\mathbf{R_V}$ values.

Star Formation

- Interstellar clouds such as MBM 18-19 are the location of star and planet formation in our galaxy
- In the early years of its life, a star is surrounded by a disk of gas and dust particles which scatter and absorb photons and emit radiation in the infrared
- Interstellar dust affects the color of stars in a predictable way
  - Therefore, we can detect young stars by identifying stars which have abnormal reddening

Infrared Color-Color Diagram



20 potentially newly forming stars were found

Conclusions

- Increasing the size of the data set from previous studies has led us to a better understanding of the distance to the cloud
- Our maps of $\mathbf{A_V}$ and $\mathbf{R_V}$ show that these parameters have their highest values along the brightest region of the infrared emission map
- Unlike the nearby Taurus Dark Cloud Complex, little correlation between $\mathbf{A_V}$ and $\mathbf{R_V}$ exists in MBM 18-19
  - Different cloud structure and grain properties
- MBM 18-19 is an active star-forming region

Future Work

- Further observations are required to fill in missing pieces from our study
- Data regarding the polarization of starlight by the dust will help us to further understand dust properties
- Further photometric data is also needed for precise calculations of $\mathbf{R_V}$ in individual lines of sight
- MBM 18-19 is an ideal region for the study of nearby new star formation

Acknowledgements

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