DIFFUSE ULTRA-VIOLET OBSERVATIONS NEAR TAURUS MOLECULAR CLOUD

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Layout of today's presentation

- Introduction & Literature:
  - The diffuse UV background
  - Diffuse UV studies in the region
- GALEX observations in the Taurus region
  - GALEX Observations
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  - Diffuse UV maps of the region
- Modeling the dust-scattered radiation
  - Monte Carlo method
  - Modified dust-distribution in the region
  - Results
- Correlation between diffuse UV & E(B-V)
  - Confirmation of observed anti-correlation
  - Interpretation of observed anti-correlation

Diffuse UV background

- It's diffuse [1], not point sources !!
- Sources of diffuse UV background
  - Instrumental Background
  - Airglow:- from the upper atmosphere
  - Zodiacal Light:- scattered sunlight from interplanetary space
  - Diffuse Galactic Light
    - Gas Emissions: H_2 fluorescence, other line emissions
    - Interstellar-dust Scattering
  - Cosmic Background
    - Integrated light of galaxies
    - AGN, IGM

[1] Leinert et al. 1998

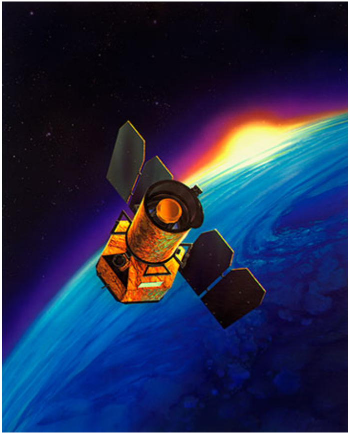
Previous studies in TMC

- Using the BEST (Berkeley Extreme Ultraviolet Shuttle Telescope) instrument, on the Space Shuttle (STS-61C) in 1986 as part of the UVX payload [2]
- Using the observations made by SPEAR/FIMS instrument [3]
- The continuum emission was inversely correlated with the optical depth suggesting that the diffuse background originated behind and was shadowed by the dense molecular cloud.

[2] Hurwitz 1994
[3] Lee et al. 2006

The GALEX space-craft

- NASA Small Class mission
- Launched on April 28th, 2003 and decommissioned on June 28th, 2013.
- The FUV and NUV detectors observe the region 1350-1800$\AA$ and 1200-3200$\AA$ respectively.
- All observations are publicly available at MAST



The Galaxy Evolution Explorer (GALEX)

Extracting the diffuse GALEX data

Extraction of diffuse GALEX data involves a number of steps.

- Masking the point sources
- Removing the edge effects
- subtracting the foreground contribution [4]
- Co-adding the observations to obtain diffuse UV map
- Murthy 2016 reprocessed the entire GALEX data

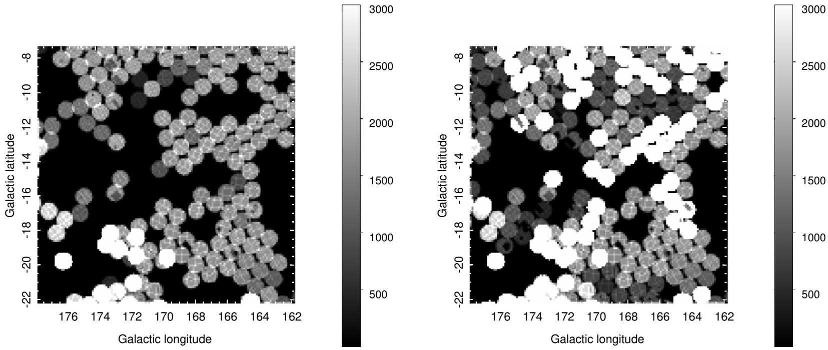
[4] Murthy 2014a

Diffuse GALEX data in the Taurus region

- There were a total of 159 FUV and 258 NUV visits near the TMC region taken over a range of 9 years from 2003 to 2012 (2003-2007 for the FUV)
- Most of the observations were taken as part of the AIS (All-sky Imaging Survey) with an exposure time of about 100 seconds per visit
- A few observations were as part of specific science programs[5] with correspondingly greater exposure times
- We have downloaded all the data of Murthy 2014b within 8 degrees of the nominal centre of the TMC (170.0, -14.0) and binned into 6 arc-minute bins, weighting each observations by its exposure time

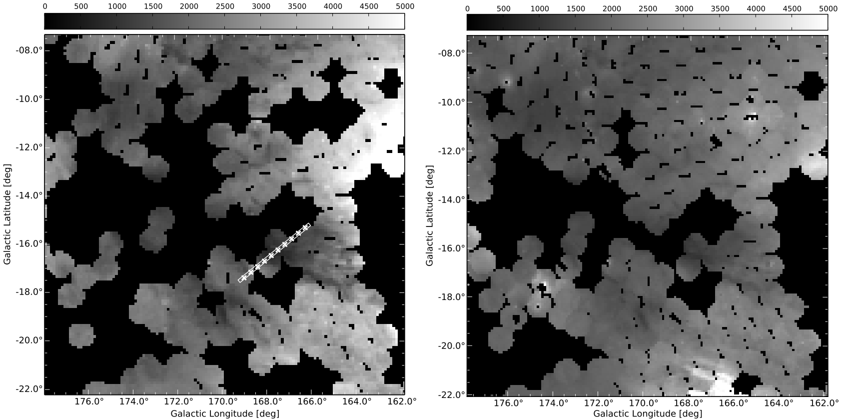
[5] Findeisen & Hillenbrand 2010

Exposure-time map



GALEX FUV & NUV exposure time map from left to right respectively. The exposure time is expressed in units of seconds.

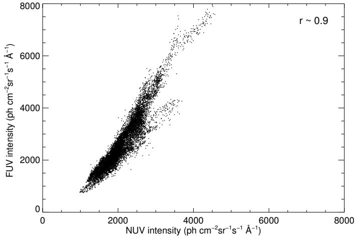
Diffuse UV map



GALEX diffuse FUV & NUV maps are shown from left to right respectively. The UV image is in units of ph cm^{-2} s^{-1} sr^{-1} Å^{-1}

Diffuse UV as a proxy to analyze dust-properties

- A strong correlation of about 0.90 between diffuse FUV and NUV
- H_2 fluorescence is present only in the FUV waveband
- TMC lies more or less towards the galactic plane, implies minimum extra-galactic contribution



Correlation between diffuse FUV and NUV intensity

The Monte Carlo code (very similar Murthy 2016 code)

- We have used the HIPPARCOS stars as the sources of UV photons and assumed that photons are emitted isotropically
- Dust distribution in the Milky-way galaxy [6]
- We have incorporated Sun's local cavity in our model[7]

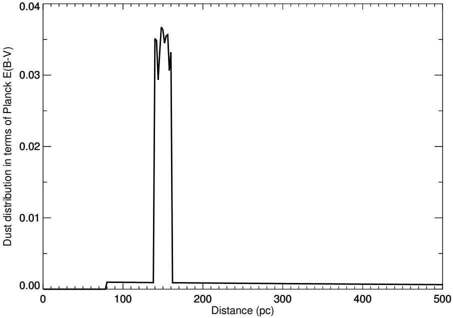
[6] Murthy 2014b
[7] Marshall et al. 2006

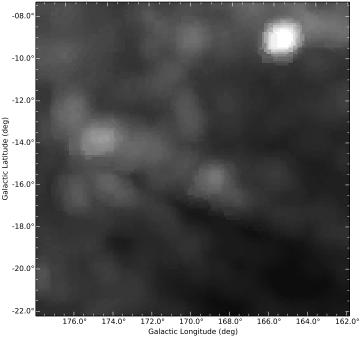
Modified the dust distribution in the Taurus region

- We have made use of the PLANCK[8] as well as the GSF[9] reddening data, separately, to modify dust distribution in the vicinity of TMC region
- The PLANCK data has an advantage that it is in agreement with Arce & Goodman 1999 observations in the Taurus region
- Model 1: with PLANCK data
- Model 2: with GSF data

[8] Planck Collaboration et al. 2014
[9] Green et al. 2015

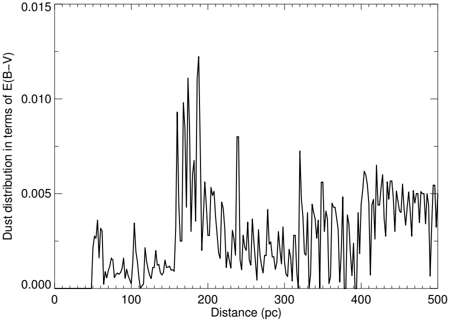
Dust distribution: Model 1

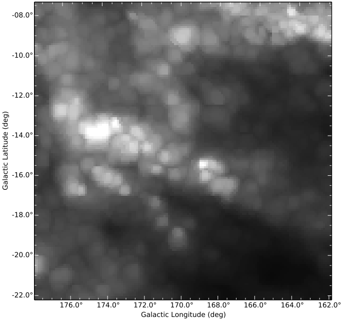




Left: Dust distribution along a representative line of sight in model 1. Right: Modeled spatial distribution

Dust distribution: Model 2



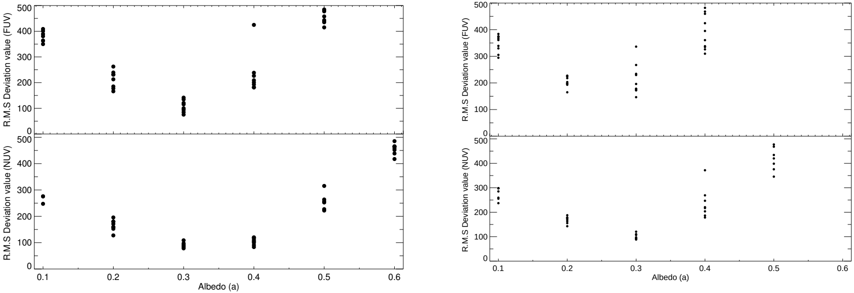


Left: Dust distribution along a representative line of sight in model 2. Right: Modeled spatial distribution

Running the code

- Our main objectives of the modeling were to obtain the dust Grain properties in the Taurus region
- We have run the code for different combinations of albedo (**a**) & phase-factor (**g**)
- R.M.S deviation of the flux as a function of galactic longitude as a metric of goodness of fit of the model
- Dust-distributions have little effects on final results

R.M.S deviation as a function of ALBEDO



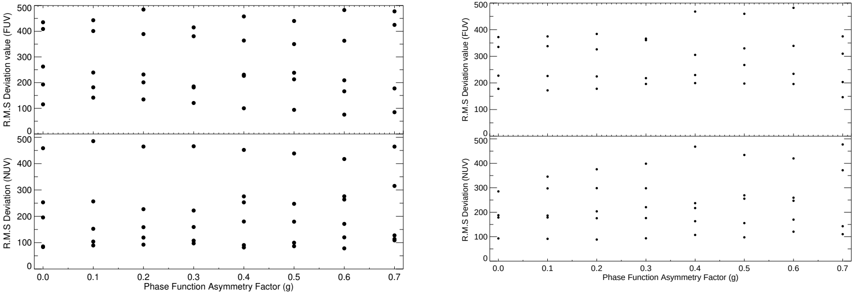
R.M.S Deviation of flux is shown as a function **a** for different **g** values at 1500 $\AA$ (top) and at 2300 $\AA$ (bottom). Left : Model-1 and Right: Model-2

R.M.S deviation as a function of ALBEDO

- Dust albedo is 0.3
- Comparison with other regions in the sky[10]
- Underestimation of albedo in clumpy medium[11]
- Requires a much sophisticated model

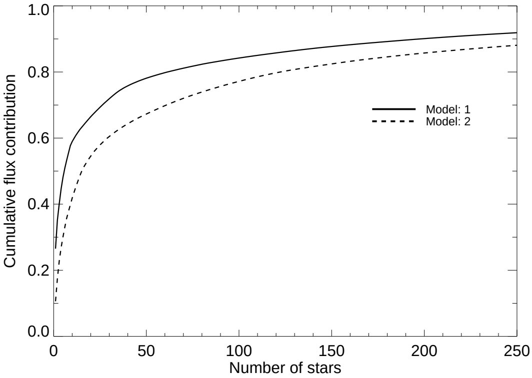
[10] Murthy 2016
[11] Gordon et al. 1994

R.M.S deviation as a function of PHASE-FACTOR



R.M.S Deviation of flux is shown as a function **g** for different **a** values at 1500 $\AA$ (top) and at 2300 $\AA$ (bottom). Left: Model-1 and Right: Model-2

Complicated stellar-cloud geometry



Cumulative flux as a function of number of contributing stars.

Complicated stellar-cloud geometry

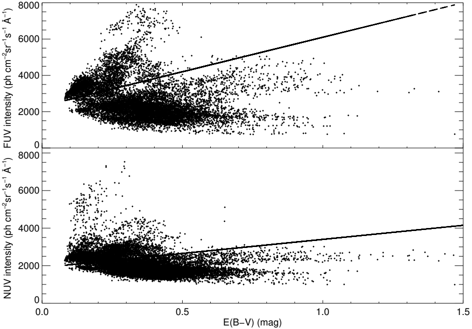
Table 4.1: Properties of brightest stars near the TMC region with stellar flux contribution at three different g values.

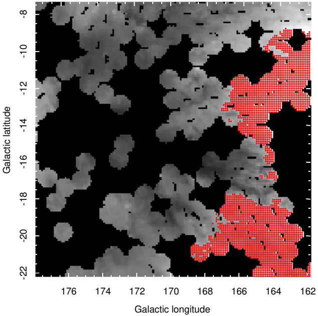
HIP number	l (°)	b (°)	Spectral type	V mag[a]	Distance[b] (pc)	% Total Flux [c]		
						g=0.0	g=0.5	g=0.7
18246	162.3	-16.7	B1	2.84	301	7.7	14.7	23.8
18532	157.4	-10.1	B1.5	2.89	165	7.7	10.2	7.2
26727	206.5	-16.6	O9.7	1.79	226	4.3	4.3	2.2
24661	166.2	2.2	—	11.6	211	3.1	4.1	0.0
26311	205.2	-17.2	B0	1.69	412	2.7	3.8	2.3
25930	203.9	-17.7	B0	2.41	281	2.3	2.8	1.5
27366	214.5	-18.5	B0.5	2.06	221	2.3	1.7	0.8
4427	123.6	-02.2	B0.5	2.39	188	2.3	1.2	0.5
21881	176.7	-15.1	B3	4.26	123	2.2	1.8	2.0
24436	209.2	-25.3	B8	0.13	237	1.6	1.3	0.9
17448	160.4	-17.7	B1	3.84	452	1.3	2.6	4.6
17702	166.7	-23.5	B7	2.85	113	1.3	0.9	0.8
25336	196.9	-16.0	B2	1.64	75	1.3	0.3	0.2
26451	185.7	-5.6	B1	3.03	136	1.2	0.6	0.5
60718	300.1	-0.4	B1	0.81	98	1.2	0.3	0.1
18614	160.4	-13.1	O7.5	4.01	544	1.1	3.3	4.0
18724	178.4	-29.4	B3	3.41	114	1.1	0.5	0.0
30324	226.1	-14.3	B1	1.97	153	1.0	0.4	0.2
68702	311.8	1.3	B1	0.60	161	1.0	0.3	0.1
26207	195.1	-12.0	O8	3.66	324	0.8	1.4	0.9

R.M.S flux as a function of PHASE-FACTOR

- **g** is independent of the level of scattered flux
- Due to complicated stellar-cloud geometry
- We could not constrain **g** in the region

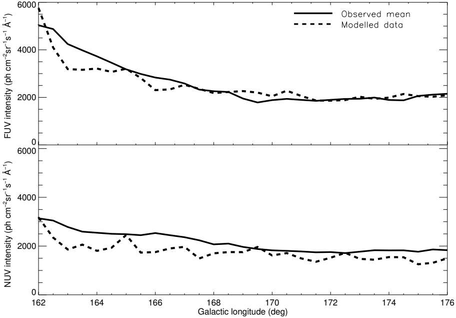
Correlation between diffuse UV and dust reddening

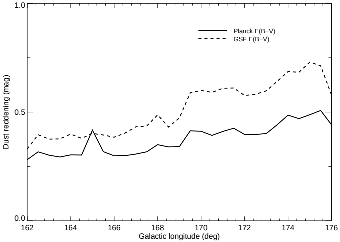




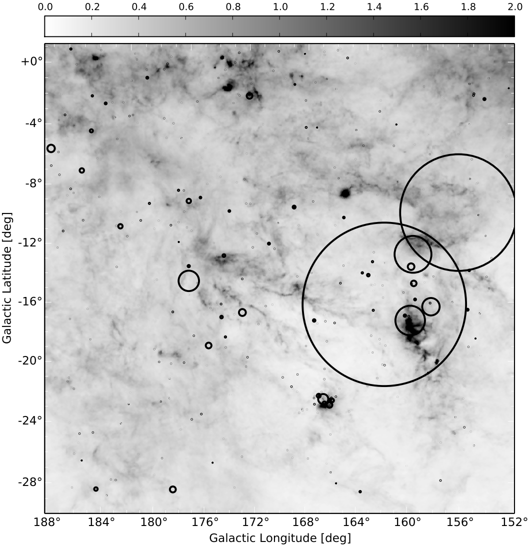
Left: Diffuse FUV and NUV intensity plotted against E(B-V). The black line separates two different regions. Right: Regions with different relationship between the diffuse UV and the E(B-V) on the diffuse FUV map.

Interpretation of observed anti-correlation





Left: Mean diffuse UV as a function of GL.
Right: Mean reddening as a function of GL



Contributing stars as circles on the PLANCK reddening map.

Result & Conclusions

- We have modeled the dust-scattered radiation by modifying the dust-distribution in the region using the PLANCK & GSF reddening data
- The dust-grain albedo is found to be 0.3
- We could not constrain the phase-factor values, due to complicated stellar-cloud geometry
- We have confirmed the observed anti-correlation between the diffuse UV and dust-reddening in the region
- We find that the observed anti-correlation, which is due to self shadowing of the diffuse background by the thick molecular cloud, is exacerbated by the presence of bright stars on the optically thin side of the cloud complex

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