X-ray Observations of Gamma-ray Binary of LMC P3

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Abstract: Spectral analysis was preformed on an archival X-ray observation from XMM-Newton of the High-Mass Gamma-ray Binary (HMGB) LMC P3 inside the supernova remnant (SNR) DEM L241, which is part of the Large Magellanic Cloud (LMC). The LMC is a small neighboring galaxy approximately 50 kpc (Macri et al. 2016) from the Milky Way, which is an active star forming region. We used the Science Analysis System (SAS) to preform the analysis on LMC P3. From our analysis the X-ray photon index (Γ) is found to be $\Gamma = 1.57 \pm 0.04$ and the flux as $F_x = 5.6 \pm 0.2\times10^{-13}$ ergs cm^{-2} s^{-1}. We froze $N_H^{gal} = 3.3\text{x}10^{21}\text{cm}^{-2}$ and $N_H^{LMC} = 5.56\text{x}10^{20}\text{cm}^{-2}$ to our analysis (Bamba et al. 2006).

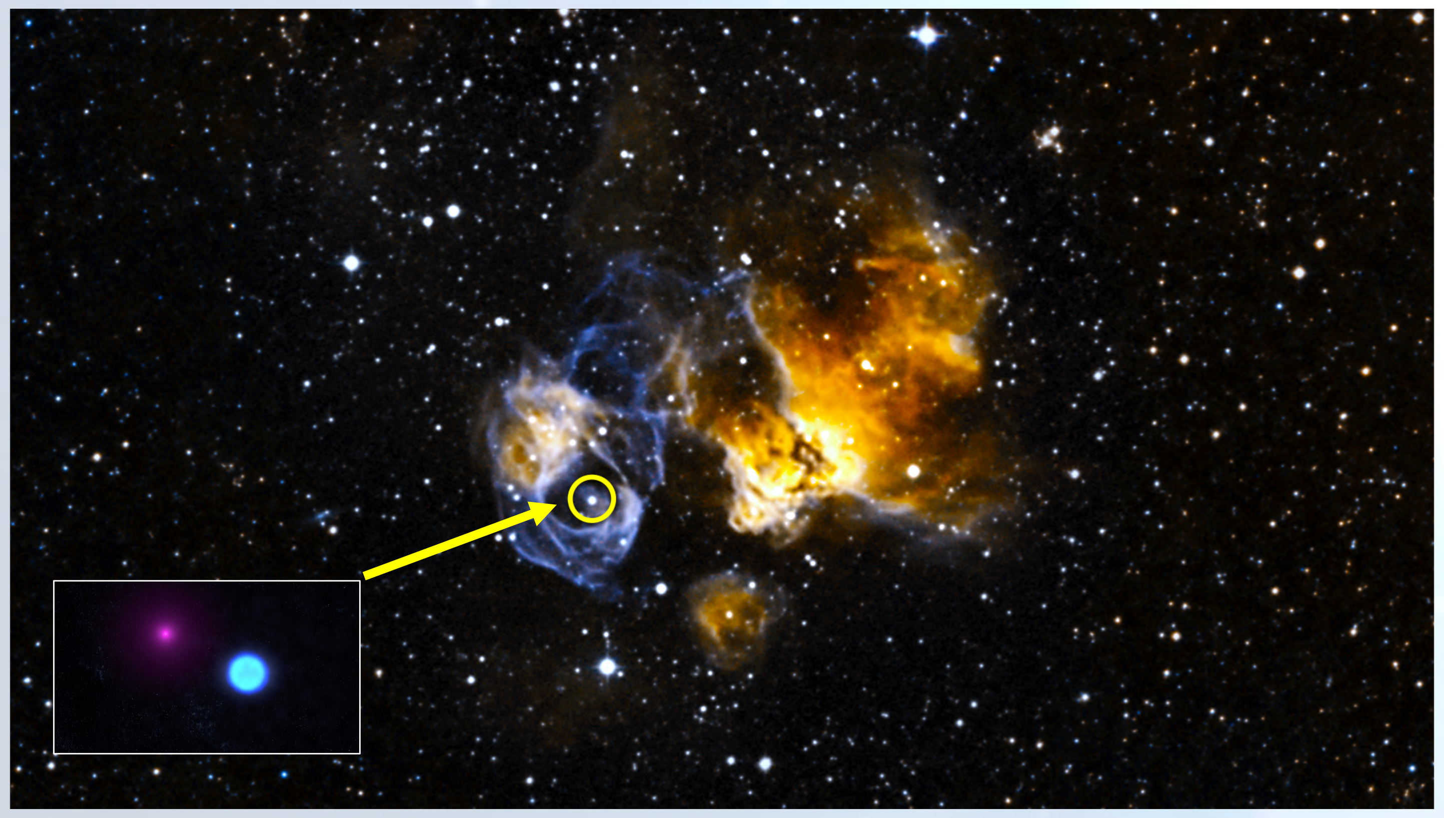

Figure 1: Image of DEM L241 with LMC P3 enclosed within the yellow circle, which is inside the Large Magellanic Cloud, showing an artist's representation of the binary.

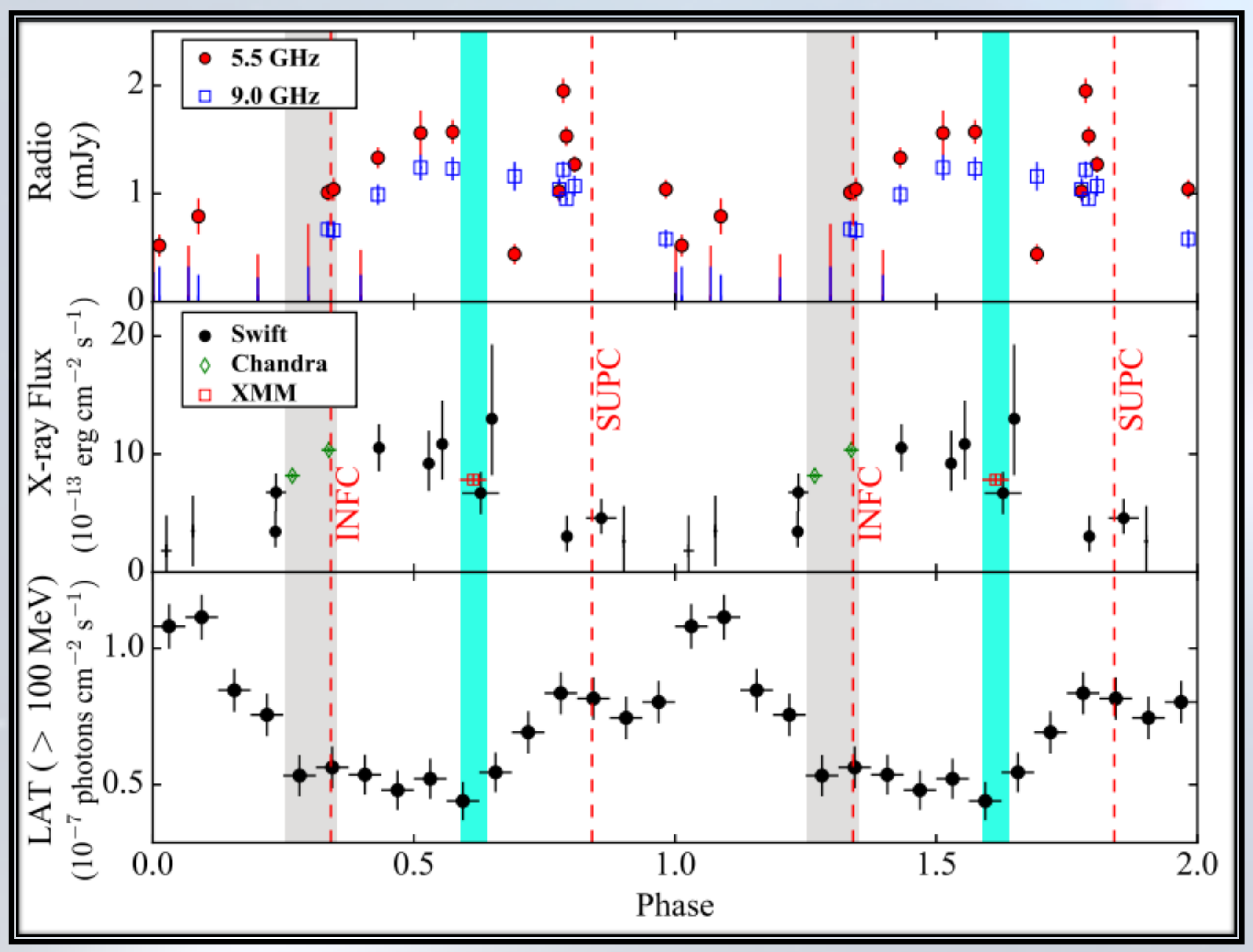

Figure 2: Modified figure from Corbet et al. (2016) Radio flux (top), X-ray flux (middle) Gamma-ray flux (bottom) from LMC P3, all folded upon the 10.3 day orbit of the Neutron star and the Optical companion. The XMM data analyzed here is indicated by the cyan shaded region. Similarly the grey shaded region indicates the Chandra observation analyzed in Seward et al. (2012). INFC is inferior conjunction , while SUPC is superior conjunction, under the assumption of a circular orbit.

Method: We are using *edetect* within SAS to find the source at (05:35:59.93, -67:35:09.72). The extraction area is a circle with a radius of 15'' around the source, while the background is an annulus with an inner radius of 20'' and an outer radius of 70''. The redistribution matrix (RMF) and Ancillary file (ARF) are created within SAS using the source and background extraction areas. We rebin the spectral files to have a minimum of 30 counts using *FTOOL grppha*. The grouped data goes through XSPEC where the energy band that was looked at for EPIC MOS1 and EPIC MOS2 was 1.5-8.0keV while EPIC PN had the energy band of 1.5-10.0keV. The model that provides a good fit to the spectrum is a power law modified by galactic absorption. The two absorption values used were $N_H^{gal} = 3.3\text{x}10^{21}\text{cm}^{-2}$ and $N_H^{LMC} = 5.56\text{x}10^{20}\text{cm}^{-2}$ (Bamba et al. 2006). The N_H values were frozen due to the fact that we could not look below 1.5 keV because of DEM L241.

***Data*:** After the SAS data analysis mentioned in the method section, the photon index as well as the x-ray flux was found to be $\Gamma = 1.57 \pm 0.04$ and $F_x = 5.6 \pm 0.2\times 10^{-13}\text{ergs cm}^{-2}\text{s}^{-1}$. The reduced χ^2 are consistent with hardness ratios being constant. EPIC MOS1 and EPIC MOS2 had values of 1.29 and 1.45 with 43 degrees of freedom each. The EPIC PN reduced χ^2 value was 0.935 with 42 degrees of freedom.

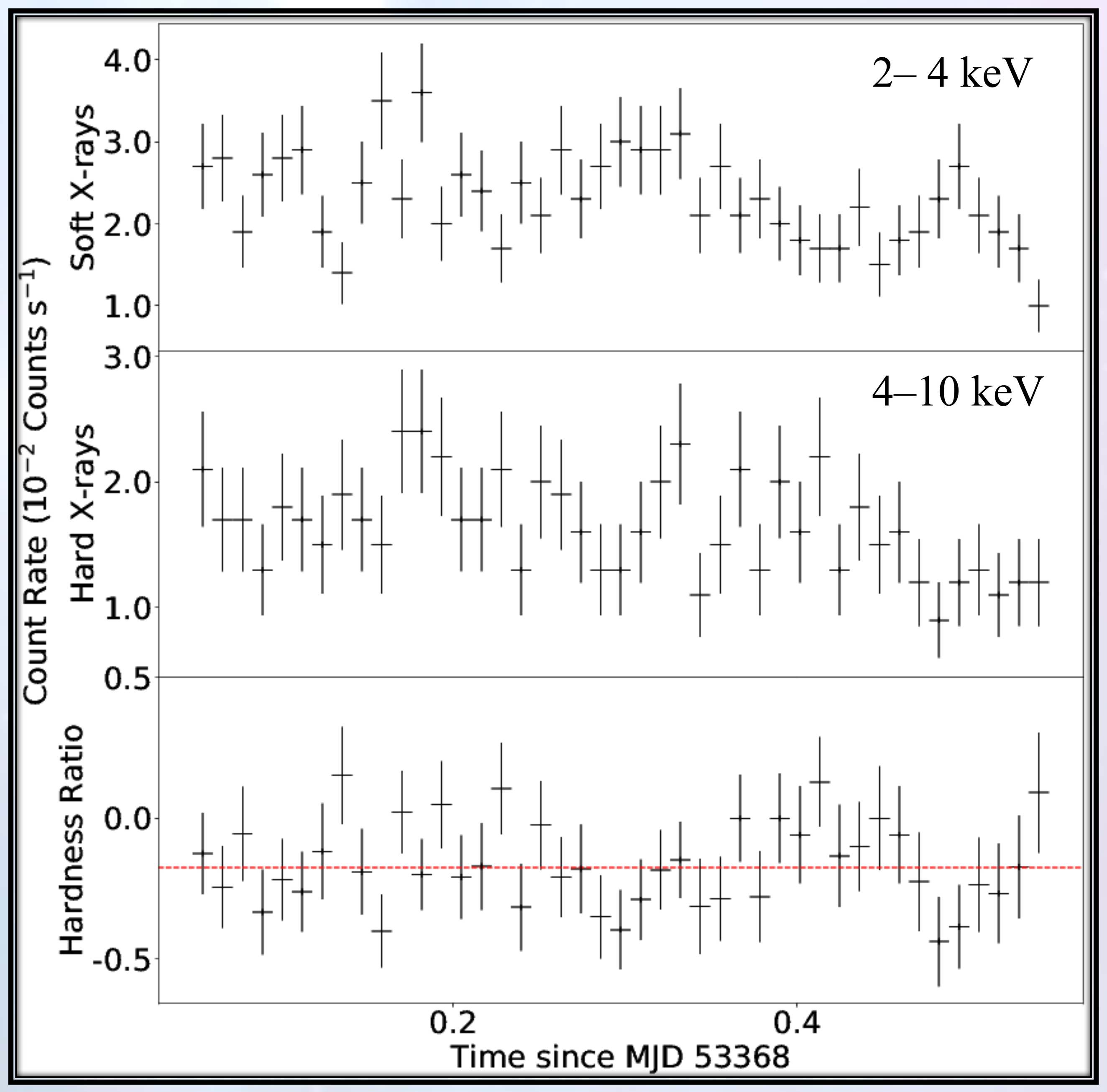

Figure 3: Light curves of the soft (top, 2-4 keV) and hard (middle, 4-10 keV) X-rays for the EPIC PN with hardness ratio (bottom). We define the hardness ratio as (H-S)/(H+S), where a soft spectrum is indicated by negative values and a hard spectrum indicated by positive values.

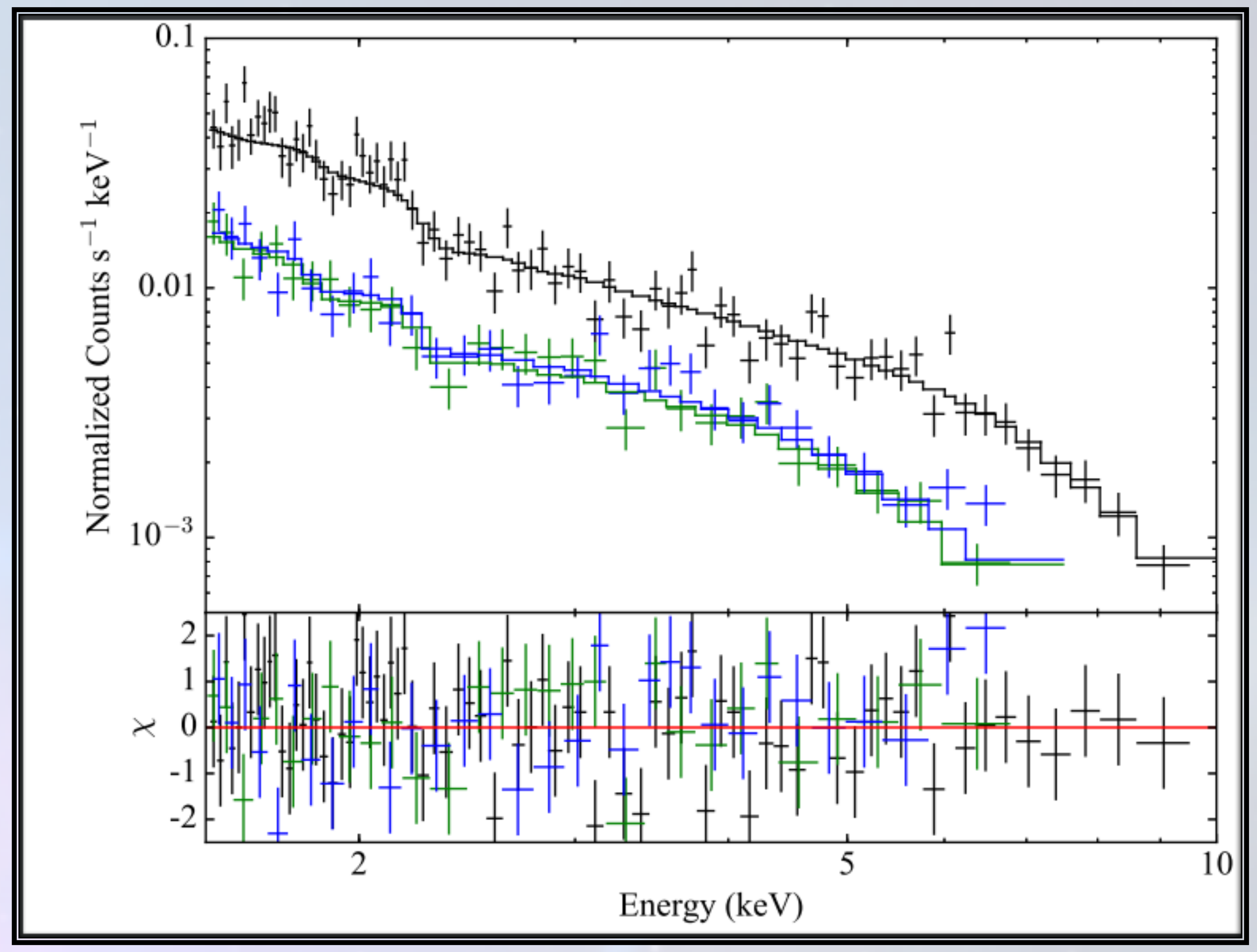

Figure 4: Spectrum of all three instruments on the XMM-Newton. Green is EPIC MOS1, Blue is EPIC MOS2, while Black is EPIC PN.

Conclusion: Though MeV-GeV photons dominate the spectral energy distribution, X-ray observations are important due to the information that they give us on the physical process that are used in finding the photon index and the column density of the source in question. We found the photon index to be $\Gamma = 1.57 \pm 0.04$ modified by galactic and LMC absorption, which is frozen because of the SNR limiting our spectrum to 1.5 -10.0 keV energy band. The X-ray flux was found to be $F_x = 5.6 \pm 0.2\times10^{-13}$ for the 1.5 – 10.0 keV bandpass. With the data collected here along with the approved XMM AO16 and NuSTAR Cycle 3 observations we hope to be able to obtain some insight into the variability of the photon index, flux, and column density. Because LMC P3 is embedded inside DEM L241 SNR it gives a unique opportunity to study SNR evolution as well as the properties of the progenitor star. Since the age of the SNR is known and if the binary is indeed associated, then the age of the binary is known.[2] From the age of the SNR and the O5 III(f) optical companion star one could possibly obtain a better understanding of stellar evolution of high mass stars at this important phase in its lifetime.

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References:

1) Bamba, A., et al. 2006, A&A, 450, 585
2) Corbet, R., et al. 2016, ApJ, 829, 10
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4) Seward, F. D., et al. 2012, ApJ, 759, 123