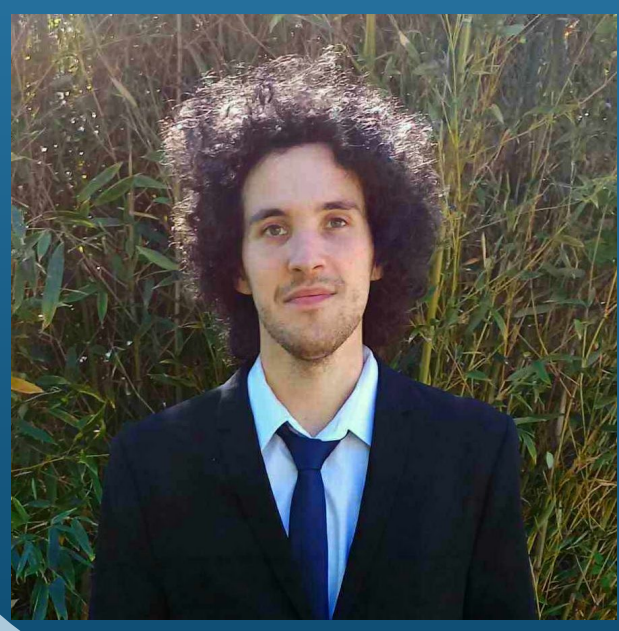




A STUDY OF X-RAY POINT SOURCES IN THE HEILES CLOUD 2 AND L1251 MOLECULAR CLOUDS

Bendegúz Koncz, Nóra Varga, Andras Peter Joo, L. Viktor Tóth

Eötvös Loránd University, Department of Astronomy, Budapest, Hungary



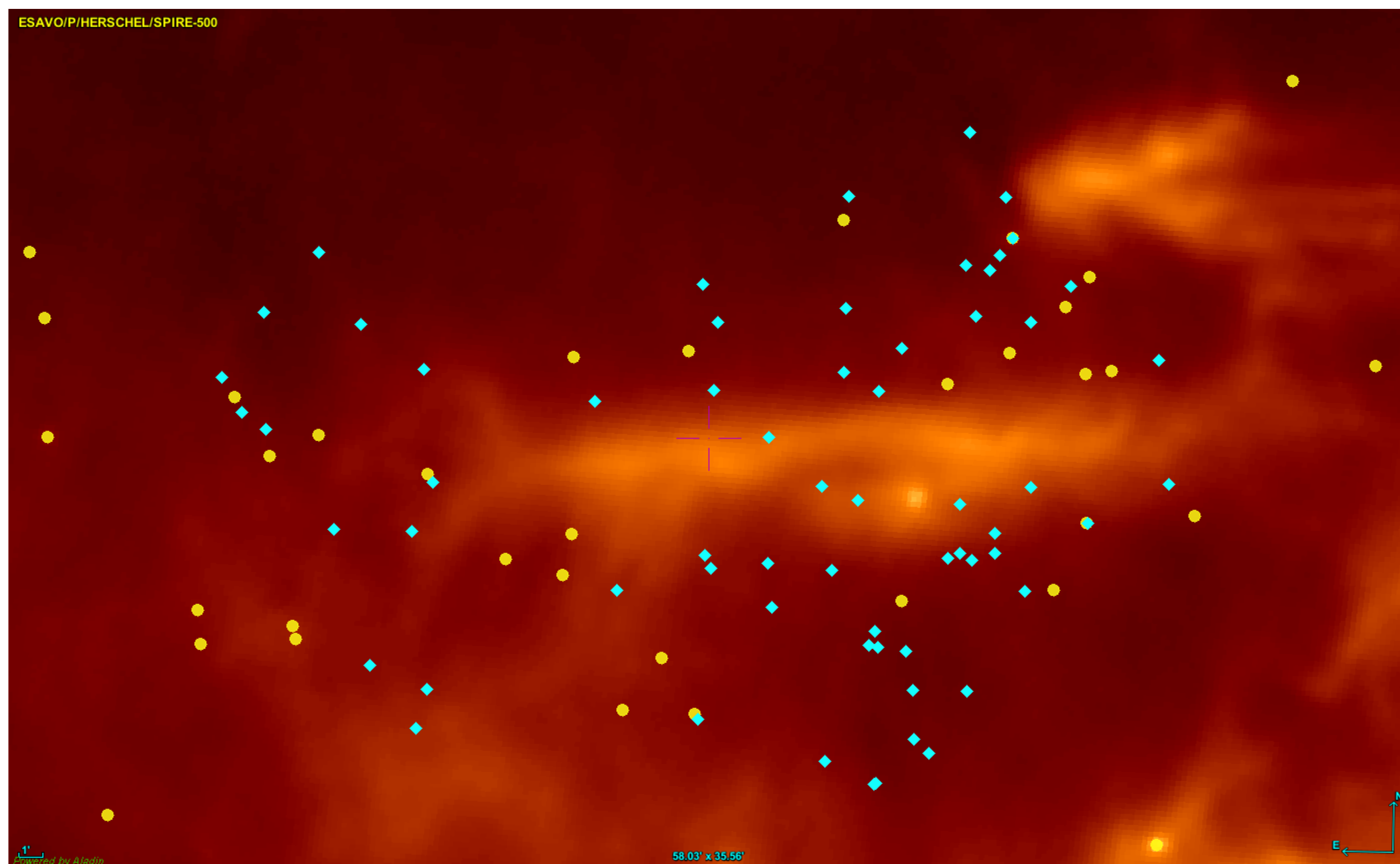
Introduction

Star formation takes place in the coldest parts of molecular clouds. It can be spontaneous or generated by a sudden rise in external pressure. For a better understanding of the process, it is important to explore the collapse and fragmentation of a molecular cloud. Pre-main sequence stars are luminous X-ray sources, so to explore the whole process it is useful to study X-ray emission as well. In our study, we examine the distribution of X-ray point sources in two nearby molecular clouds with different structures. Heiles Cloud 2 (HCL2) is a ring-like molecular cloud complex in the Taurus region, while the cometary-shaped L1251 is one of the prominent molecular clouds of the Cepheus region. We also pair the X-ray point sources with known YSOs.

Heiles Cloud 2

One of the closest, low-mass star-forming regions is the Taurus molecular cloud (TMC), a dense part of the HCL2. We use infrared data from the Herschel SPIRE at 500 μm and add the Gaia DR3 YSO sample. For the X-ray point sources we add the XMM-OM Serendipitous Source Survey Catalog X-ray data [1]. To further confirm and to find additional X-ray observations we add XMM-Newton Extended Survey of Taurus Molecular Cloud [2]. While cross-matching these data we found two matching sources.

At a distance of 140 pc the TMC-1, a collapsing, fragmented part of the HCL2 cloud contains 62 X-ray point sources with three matches to the YSO catalogue.

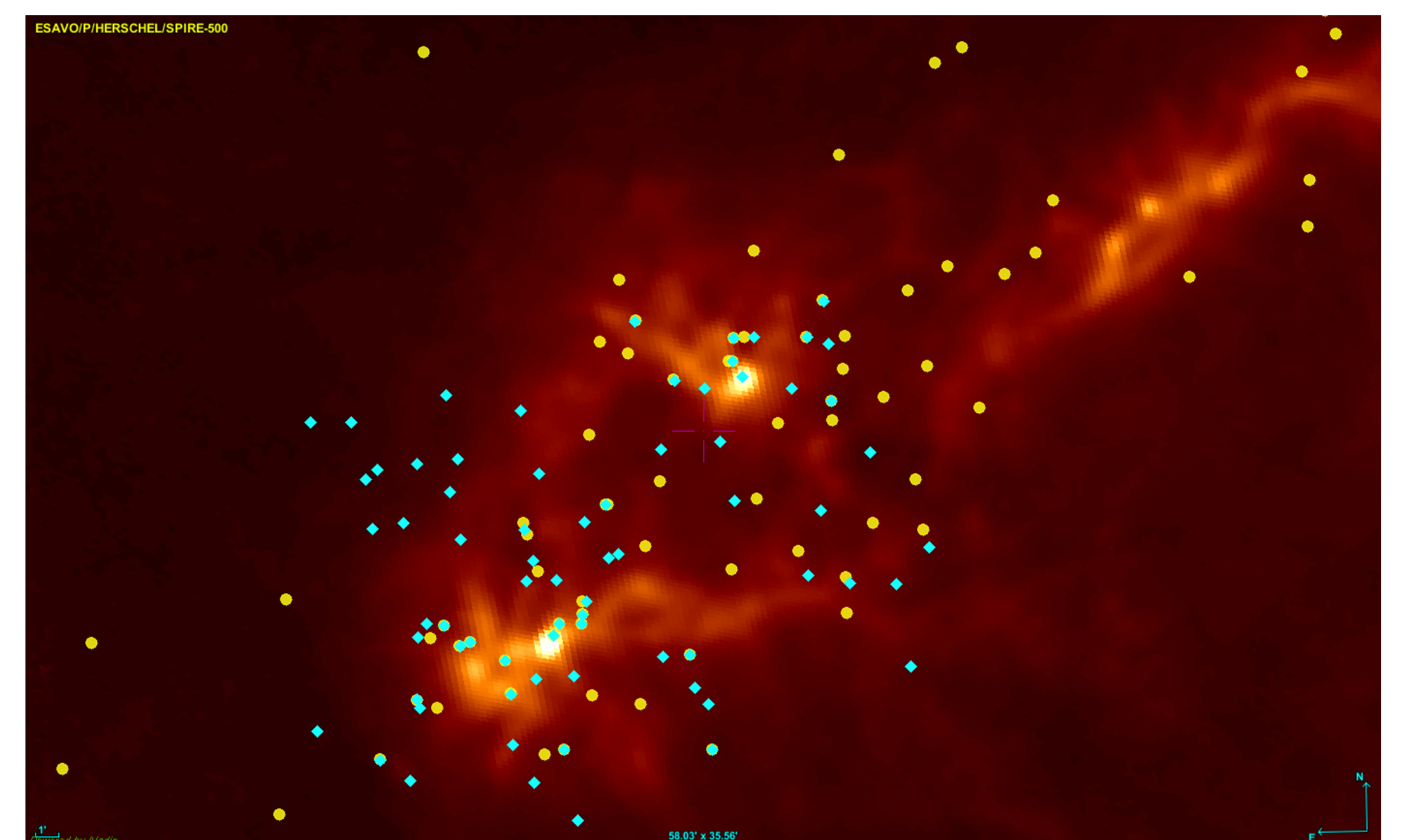


On the Herschel 500 μm infrared image of the Heiles Cloud 2, we can see the X-ray point sources (blue rhomb) and the YSOs (yellow circle).

L1251

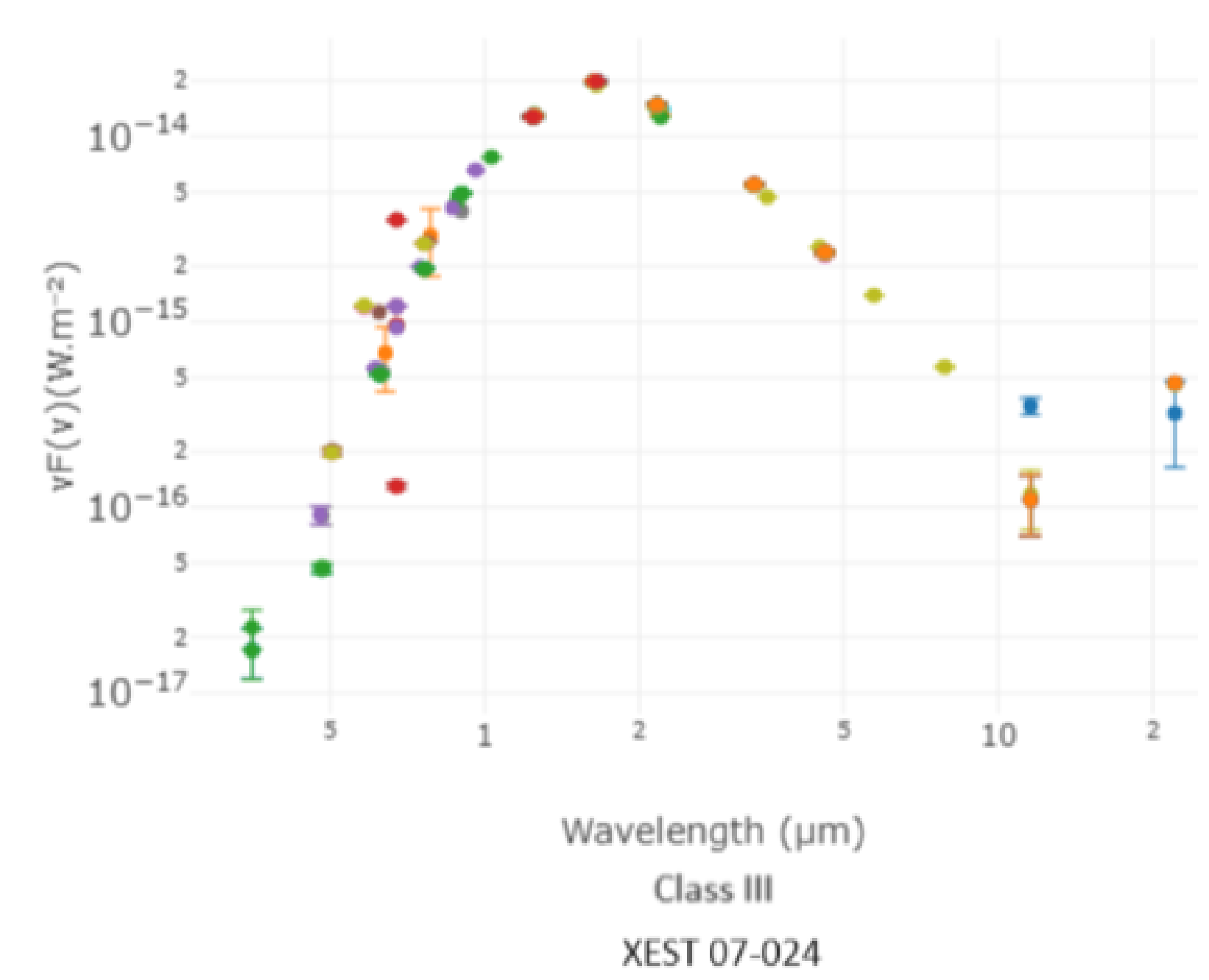
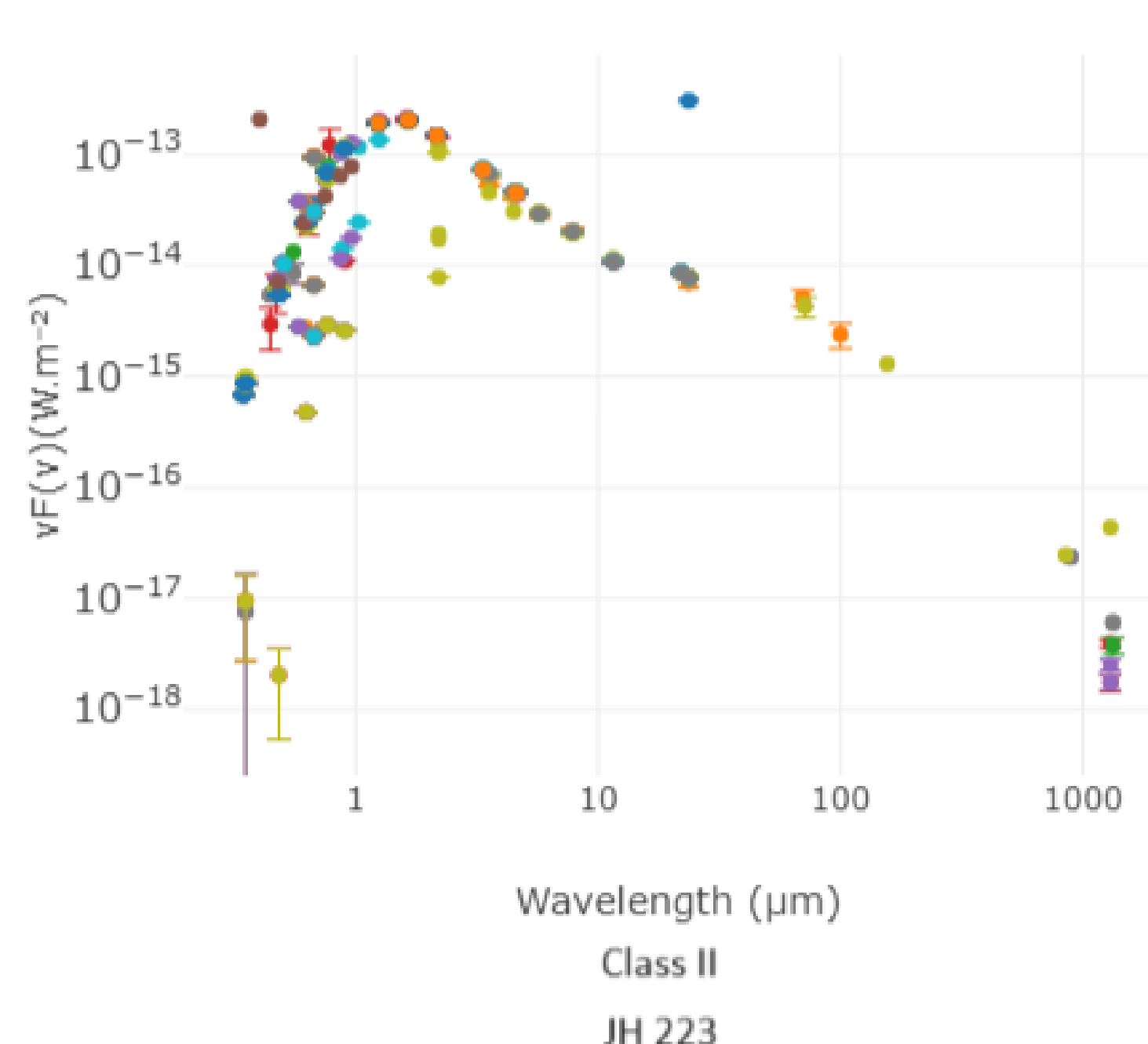
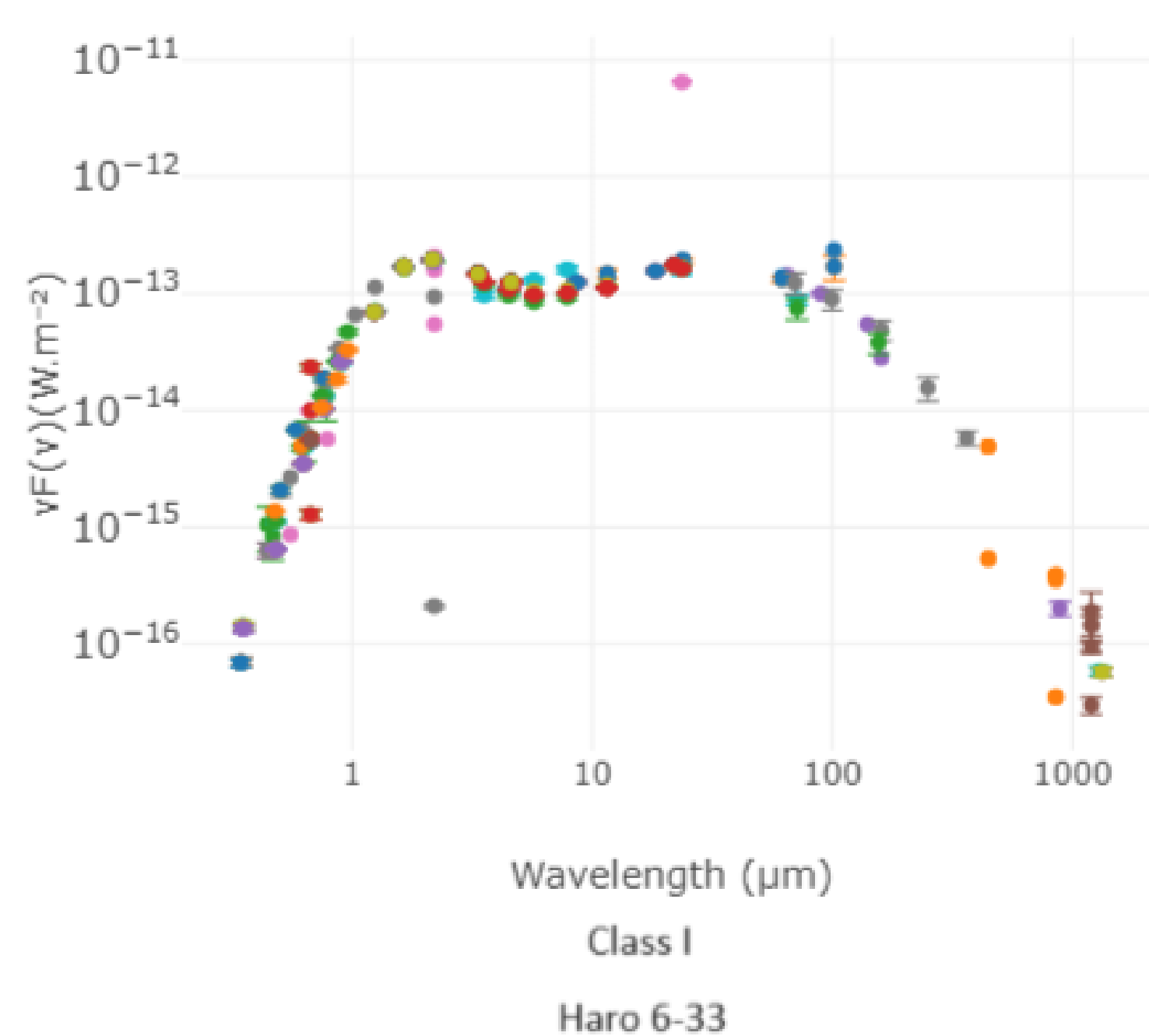
Heiles Cloud 1, also known as L1251 is a dark molecular cloud in the Cepheus region. We examine the cloud in infrared at 500 μm made with Herschel and add the Gaia DR3 YSO sample. For the X-ray data we use the MORX (Millions of Optical-Radio/X-ray Associations) catalogue [3], which contains the LASS, LoTSS, RACS, FIRST, NVSS, and SUMSS radio surveys, and Chandra, XMM-Newton, Swift, and ROSAT X-ray surveys. As a result of the cross-matching, we found a lot of matching sources with different spectral energy distributions.

L1251's distance is 351 pc. In the cloud, we found 69 X-ray point sources, from which 17 matched with YSOs.



The gas' structure in L1251 on a Herschel 500 μm infrared image with the X-ray point sources (blue rhomb) and the YSOs (yellow circle) in this region.

YSO classification



For the classification of the YSOs, we examine their spectral energy distribution (SED). For the determination of the state of the star formation, we look at the infrared excess, that comes from the dust in the ISM surrounding the object, and is superimposed on the YSO's black body radiation [4]. In the Heiles Cloud 2, we found three matching YSOs and X-ray point sources with different stages of star formation. In the image on the left, we can see a class I object. These are protostars that are accreting material onto their thick circumstellar disk and have regular outflows at the poles. The two-peaked SED shows a large infrared excess on the YSO's blackbody radiation. In the middle we can see a class II object, still embedded but with a thinner disk with less infrared excess. The image on the right shows a class III object, a pre-main sequence star with only a faint disk.

References

- [1] M. J. Page et al. "The XMM—Newton serendipitous ultraviolet source survey catalogue". In: *Monthly Notices of the Royal Astronomical Society* 426.2 (Oct. 2012), pp. 903–926.
- [2] Güdel, M. et al. "The XMM-Newton extended survey of the Taurus molecular cloud (XEST)". In: *A&A* 468.2 (2007), pp. 353–377. DOI: 10.1051/0004-6361:20065724.
- [3] Eric Wim Flesch. "The Millions of Optical-Radio/X-ray Associations (MORX) Catalogue, v2". In: *The Open Journal of Astrophysics* 7 (Jan. 23, 2024).
- [4] Großschedl, Josefa Elisabeth et al. "VISION – Vienna survey in Orion - III. Young stellar objects in Orion A*". In: *A&A* 622 (2019), A149.