The circumstellar medium around five LBV stars through the light of NIKA2 and the Virtual Observatory

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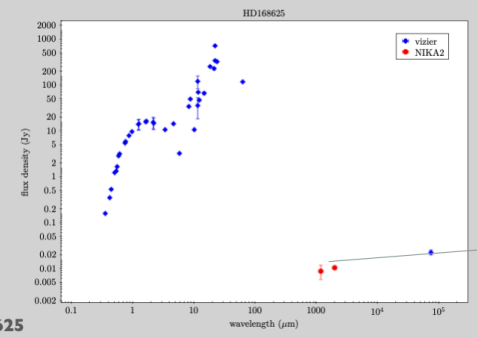
SUMMARY

Luminous Blue Variable (LBV) stars are post-main sequence massive objects in a very fast (10^4 a) transitional stage characterized by dense winds and impressive mass eruptions. These factors create ionized and dusty nebulae, sometimes surrounded by molecular gas. LBVs are great infrared emitters and have also been detected at cm-wavelengths, dominated by non-thermal emission. The mm/submm regime, however, has not been much investigated.

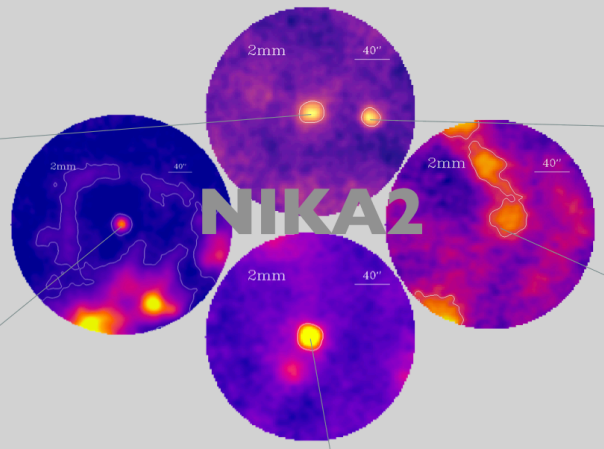
NIKA2 is a continuum camera installed at the IRAM 30m radio telescope near Pico Veleta, Granada. The camera provides images at 150 and 260 GHz, with a field of view of 6.5 arcmin. These frequencies are of great interest in the study of LBVs, where thermal and non-thermal processes compete in their contribution to the SEDs.

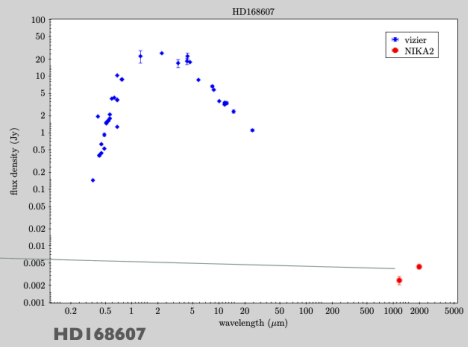
In this work we present the results achieved towards a sample of five galactic LBVs obtained using NIKA2. SEDs were built using many surveys (PAN-STARRS, 2MASS, UKIDSS, Gaia, allWISE, MSX, AKARI, MIPSGAL, THOR, and VLASS, among others), available in vizier.

Results

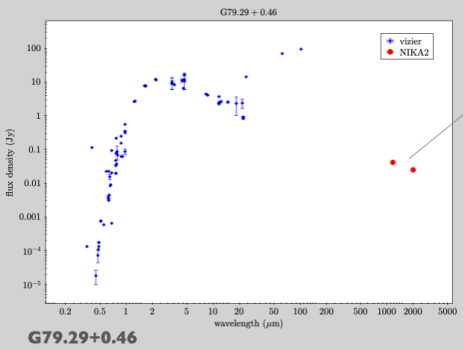


HD168625
- LBV with a bipolar nebular, probably a binary star
- The strongest source of the sample, visible at blue wavelengths
- Its nebula is also detectable from mid-IR to radio
- Central emission not resolved, indicating the presence of warm circumstellar material
- The SED clearly separates the three components: extended chromosphere, thermal emission from warm dust and ionized gas, with hints of partial non-thermal emission.

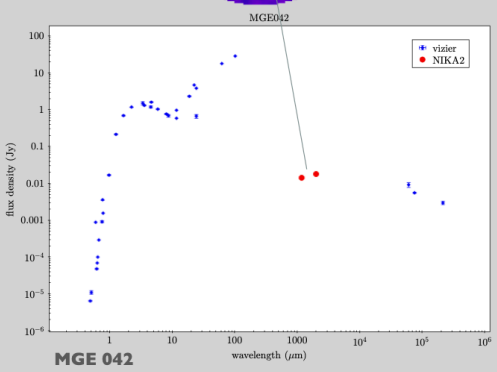




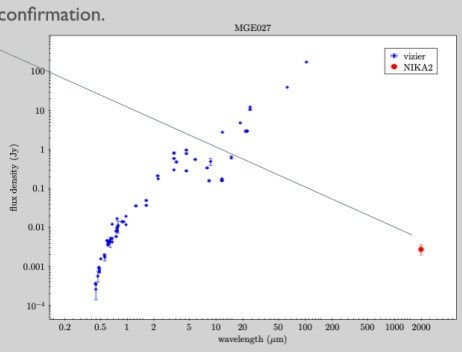
HD168607
- One of the few confirmed LBVs detected only through optical and IR spectra. There is not a dust nebula like in most other cases
- Not evidently related to HD 168625, or the local clouds
- This apparent isolation is confirmed by NIKA2, which seems to demonstrate the presence of faint material close to the star, which needs further confirmation.



G79.29+0.46
- Candidate LBV depicting several concentric shells, visible at infrared, cm-wavelengths and CO gas
- Several recent mass-loss events (some 10^4 a old) related to the shells
- Confirmed cases of shocked gas and interaction with a nearby IRDC
- Innermost shell clearly detected with NIKA2
- Its SED demonstrates the relative importance of the circumstellar gas and dust
- The only source more intense at 1mm than at 2mm, probably indicating the presence of cold gas detached from the star.



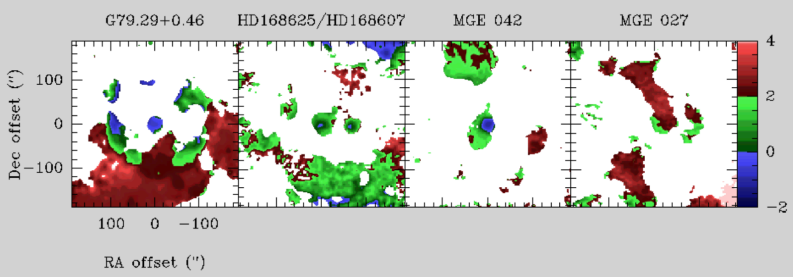
MGE 042
- Confirmed LBV which displays a 200" highly symmetric ring nebula, noted at mid-IR wavelengths
- There is also an out torus traced by CO, with a slow expanding velocity
- Extended circumstellar emission of warm dust, and a local cloud probably excited by radiation and winds from the star
- The SED shows a clear separation of the three components: photosphere, circumstellar dust and ionized wind
- NIKA2 data indicate a non-clear dominance of the thermal dust over the ionized gas, as in other cases



MGE 027
- This source depicts a clearly detached dust nebula, notably detected at mid-IR wavelengths
- There is not an evident counterpart of molecular gas
- The SED demonstrates a large emission at near- and mid-IR wavelengths, probably arising in the approaching and receding parts of a dust shell with low opacity.
- This is the only source not detected at 1mm with NIKA2, probably indicating the lack of important amounts of ionized gas, and a high temperature of the surrounding dust
- The point at 2mm arises from a non-resolved feature, probably a nearby cold clump.

NIKA2 "colors" (spectral indices)

- To test prevalence of free-free vs. thermal dust, we compute spectral indexes α, assuming $S_\nu \propto \nu^\alpha$
- Three 'colors' are clearly distinguished:
  - in red, values from 2 up to 4, normally thought as dominated by thermal emission from cold dust
  - in green, values from 0 to 2, typical of warm dust and free-free emission from gas
  - in blue, puzzling values below 0, probably associated to clumpy stellar wind, with some contribution from non-thermal processes.
- Different distribution is found, with presence of different components: ambient cold dust (the reddest), emission from the stars (in blue), a 'plateau' of intermediate values of α, and gas heated by the LBV like in G79.29+0.46



Final remarks

This is an ongoing project, aiming to exploit the capabilities of NIKA2 to fill a gap in a key part of the electromagnetic spectrum.

We detected emission from the stars themselves, in and outside the IR nebulae. All these components depict very different morphologies and spectral indexes, pinpointing that diverse mechanisms coexist, such as free-free gas emission, thermal dust and synchrotron radiation.

We complemented these findings by building the SEDs of the LBV stars, where the contribution from the extended photosphere is clearly separated from warm black (grey) body emission, and non-thermal flux in some cases.

Like in the many cases observed in CO and other molecules, the stars and their environments are far from being similar among them.

These efforts will be continued through the observations of more cases, with more angular resolution to separate the immediate surroundings of the LBVs, and by modeling the whole SEDs, case by case.