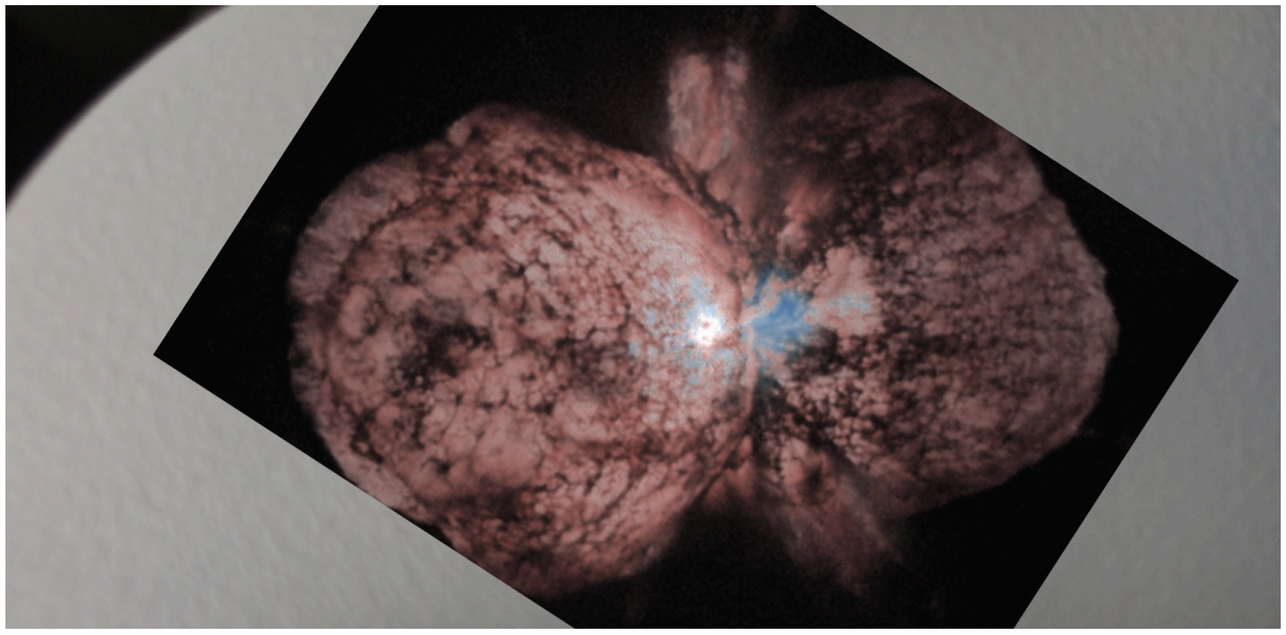


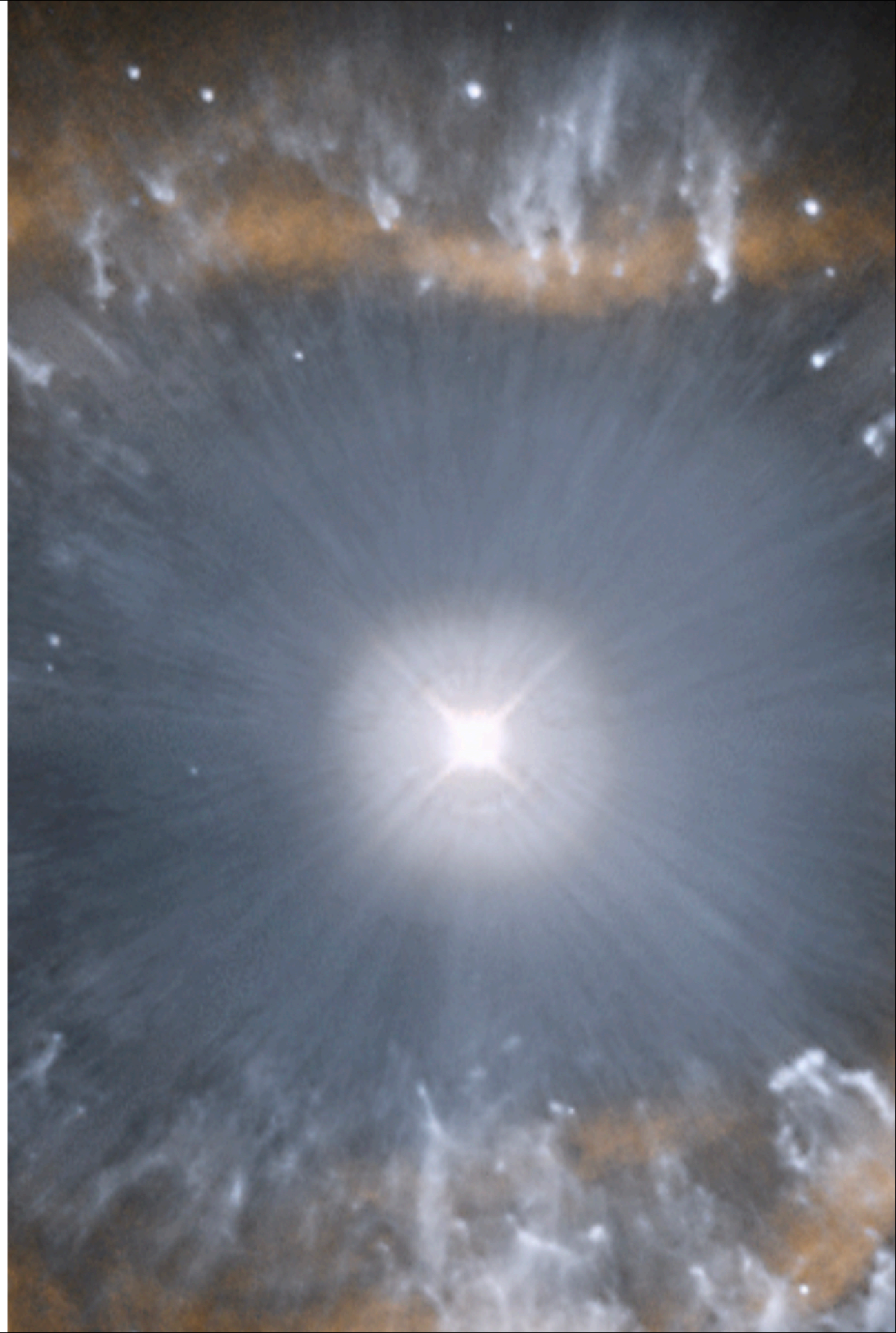
NIKA2 observations around LBVs stars

J. Ricardo Rizzo
Centro de Astrobiologia (CAB), Madrid

In collaboration with:
Alessia Ritacco (IRAM)
Cristóbal Bordiú (CAB)

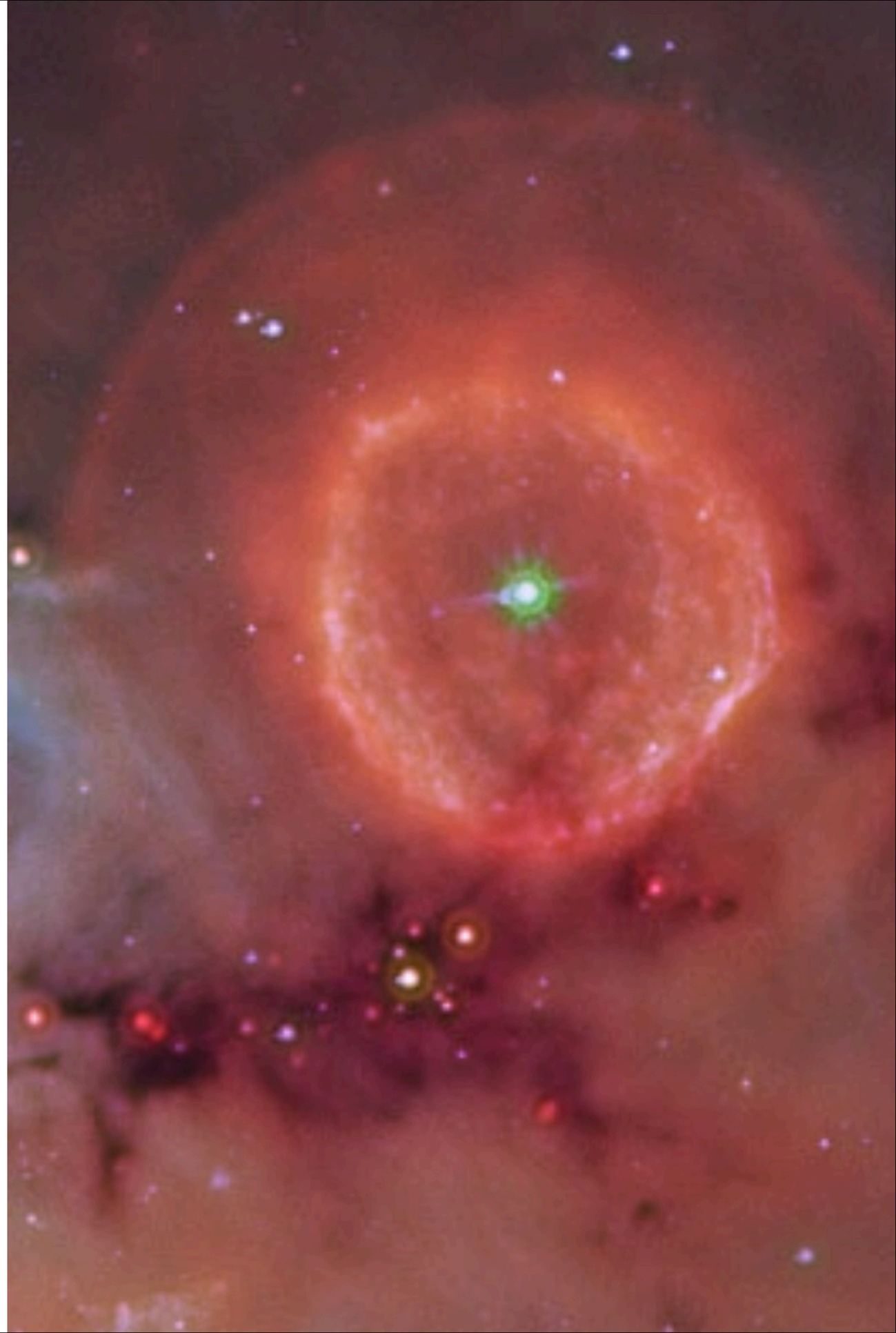
Overview

- About LBV stars
- Relevance of NIKA2
- Observations
- Results: maps, spectral indexes
- Origin of emission
- Overall conclusions



LBV stars

- The most massive evolved stars. log(L) > 5, log(Teff) > 4
- Controversy: pre-WR vs. pre-SN
- Close to Eddington limit → instabilities
- Episodic, violent outbursts (P Cyg, eta Carina). Several Mo ejected
- Often surrounded by dust and nebulae, rich in CNO-processed material
- In short: strong winds, high UV field, shocks, dust formation, rich chemistry.



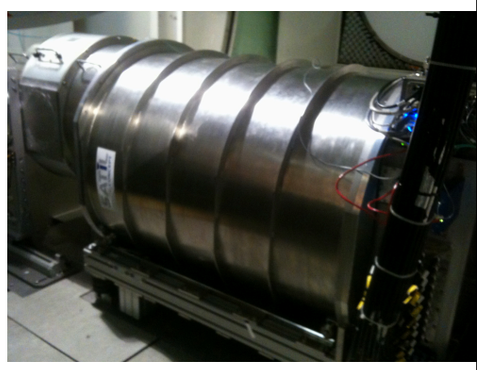
Importance of NIKA2

- Key to learn the most possible about LBV's environments, at different scales.
- Large FoV, allowing maps of CSM associated with LBVs
- High sensitivity, which permits simultaneous observations of stars AND circumstellar material
- Two bands, so relative estimates of importance of different physical mechanisms (free-free, thermal dust)
- Polarization capabilities, to follow up the most promising cases.

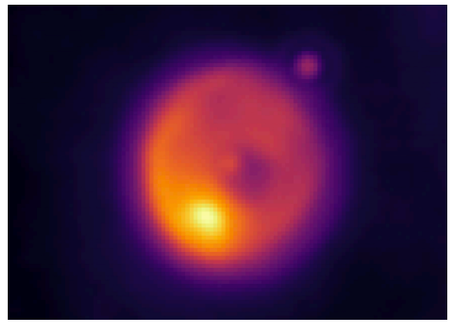
Observations

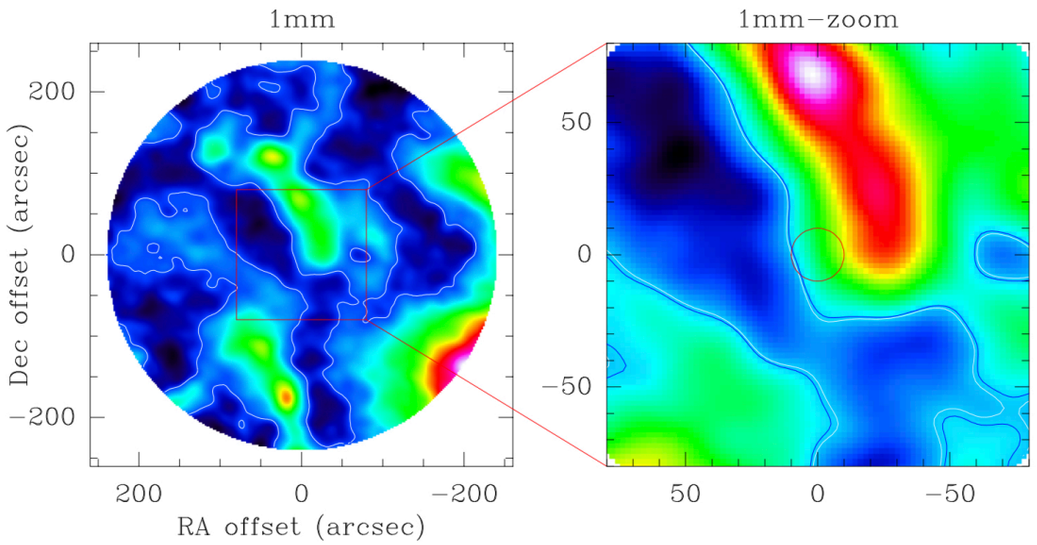
- Pool run during October 2017
- 4 fields including 5 LBVs (the most promising)
- Acceptable and stable weather (especially for 2mm).

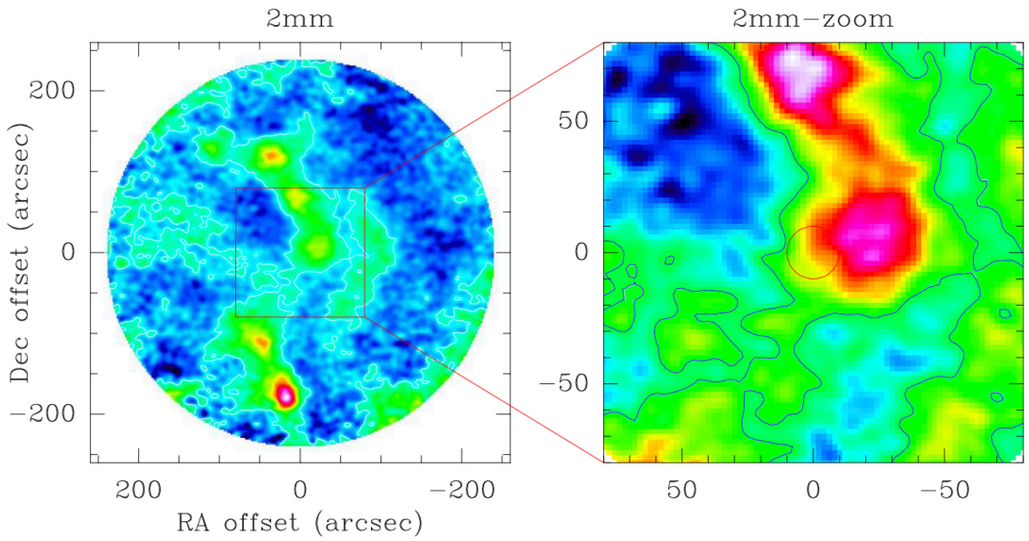
Source	scans	size	time	tau			elev	rms 1mm	rms 2mm
		arcmin	hr	225GHz	1mm	2mm	deg	mJy/beam	
G79.29+0.46	12	12	1.1	0.25	0.30	0.17	67.9	5.2	1.3
MGE 042	60	2.5	2.0	0.27	0.39	0.24	55.6	1.6	0.5
MGE 027	30	2.5	0.9	0.23	0.34	0.23	47.6	2.7	0.8
HD 168625	24	2.5	1.0	0.29	0.33	0.20	36.4	2.1	0.6
HD 168607	—	“	—	“	“	“	“	“	“



Results: MGE 027

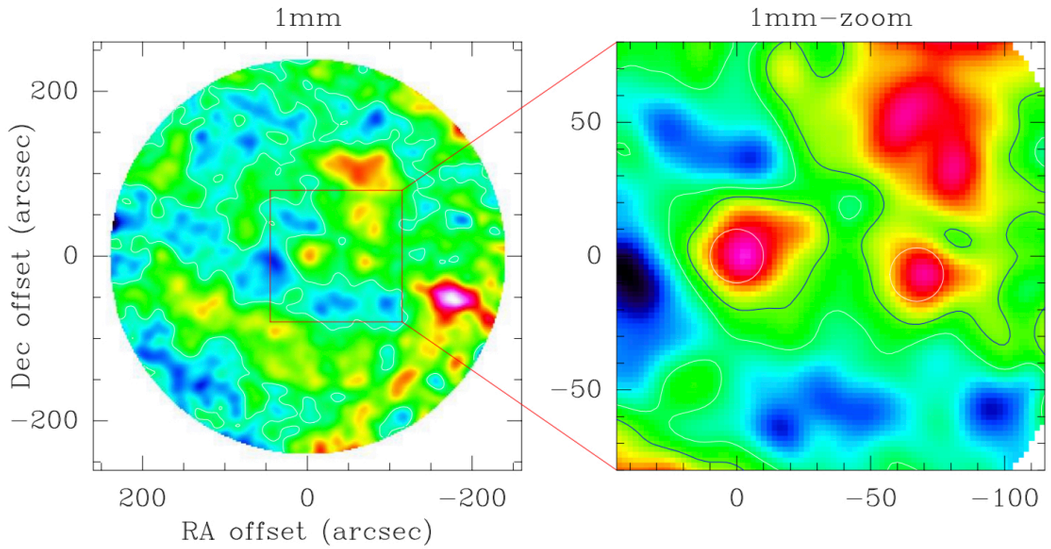


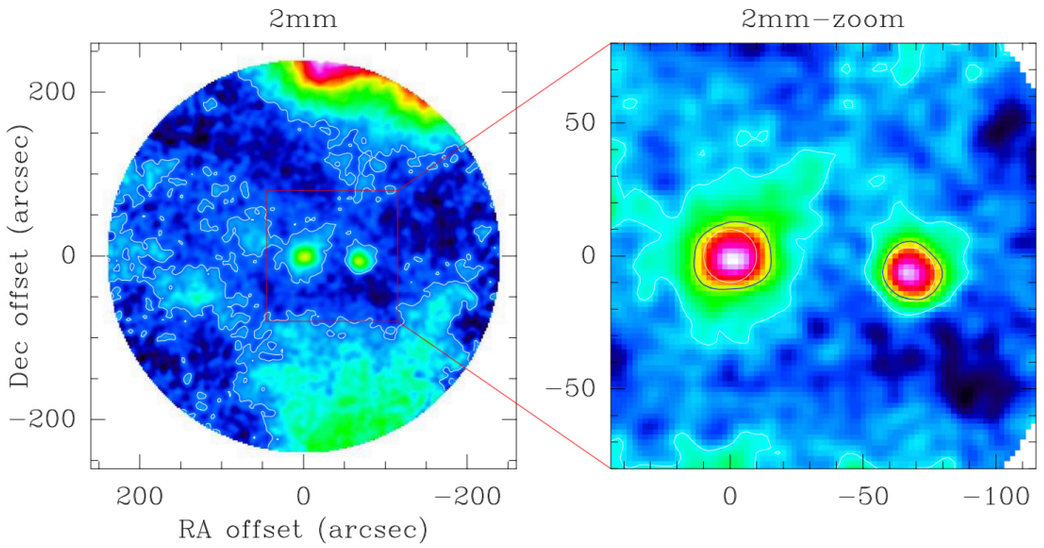


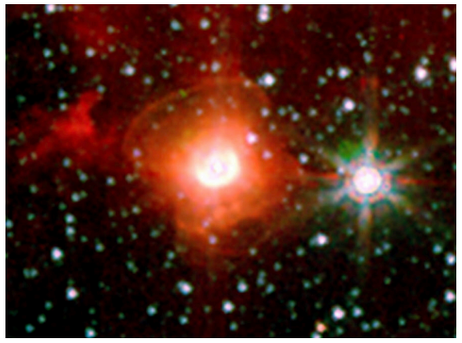


- candidate LBV, with a prominent nebula in mid-IR (Mizuno et al. 2010)
- Extended emission only, apparently not related to the star
- Clouds are clumpy and more intense in 1mm.

Results: HD 168625 / 607

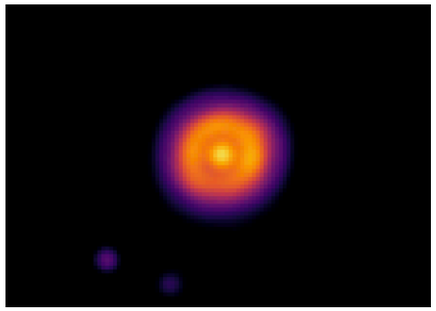


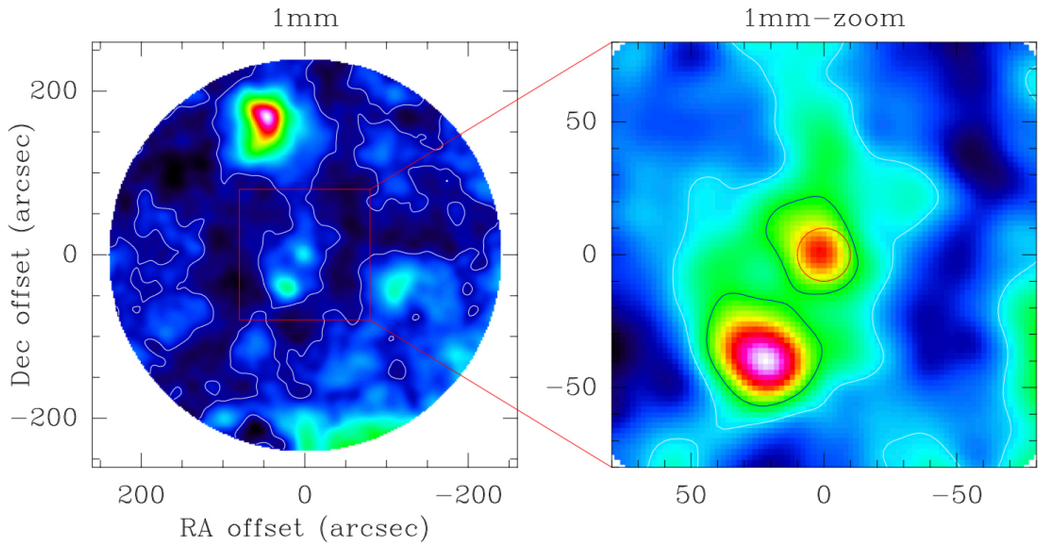


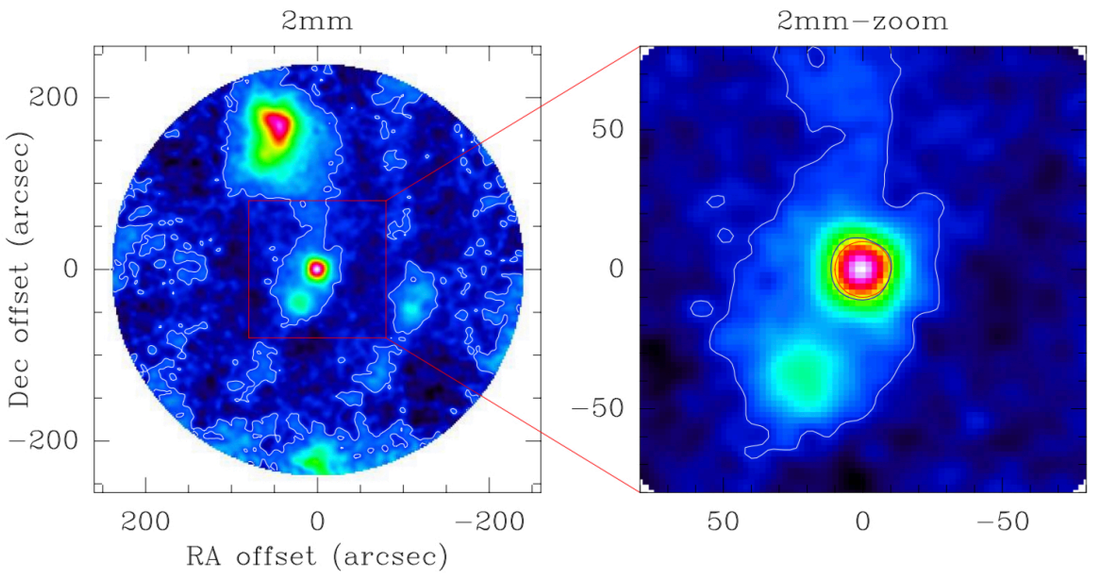


- Two confirmed LBVs in the same field.
- HD168625 (center) with a ring nebula visible from IR to radio
- HD168627 only in optical/IR spectra
- Comparable emission of both sources in both frequencies
- Extended emission only in HD168625. Central emission not resolved
- Also some clouds at 100” — 200”, probably not related.

Results: MGE 042

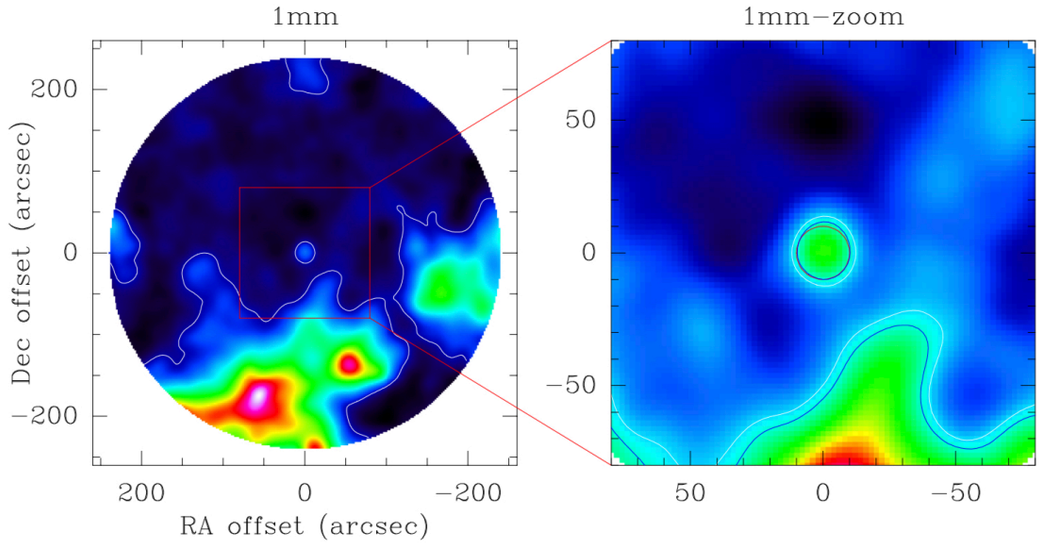


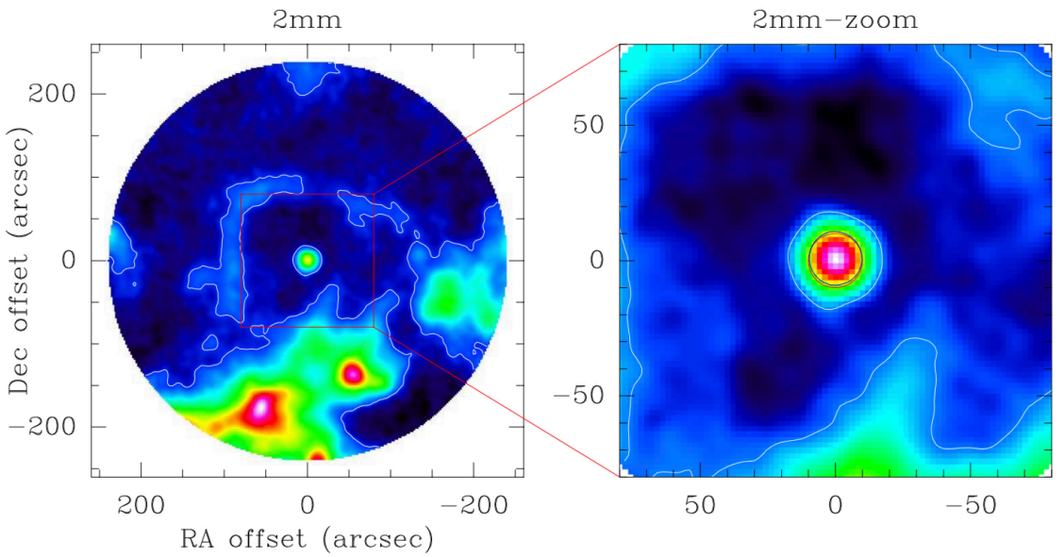




- Recently confirmed LBV (Flagey et al. 2014, Bordiu et al. 2019)
- Infrared ring nebula of 200” seen in mid-IR (Mizuno et al. 2010). CO expanding torus enshrouding ring nebula (Bordiu et al. 2018)
- Point source immersed in a plateau at both NIKA2 frequencies
- Also some intense and circumstellar emission at 1mm only
- Note bright cloud at SE, especially at 1mm. Located beyond a brigthning in IR

Results: G79.29+0.46





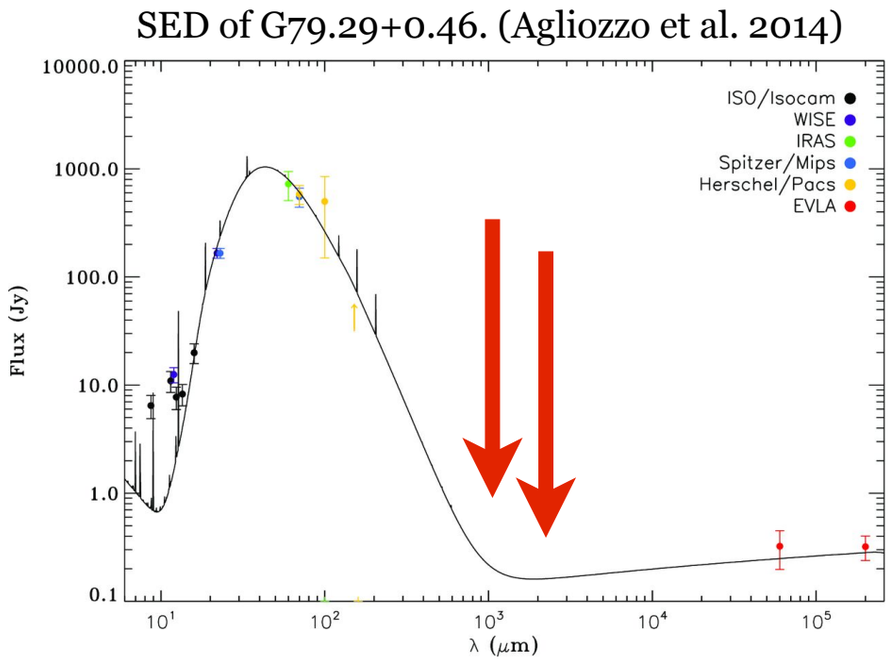
- Together with eta Carina, the best studied case (Rizzo et al 2008, 2010, 2014; Umana et al. 2011; Agliozzo et al. 2014)
- Three concentric shells, corresponding to recent outbursts (some 10^4 yr).
- CO counterparts in the two inner shells, one of them clearly shocked
- Possible interaction with a nearby IRDC
- Inner shell clearly detected with NIKA2, especially at 1mm
- Point source detected at both frequencies

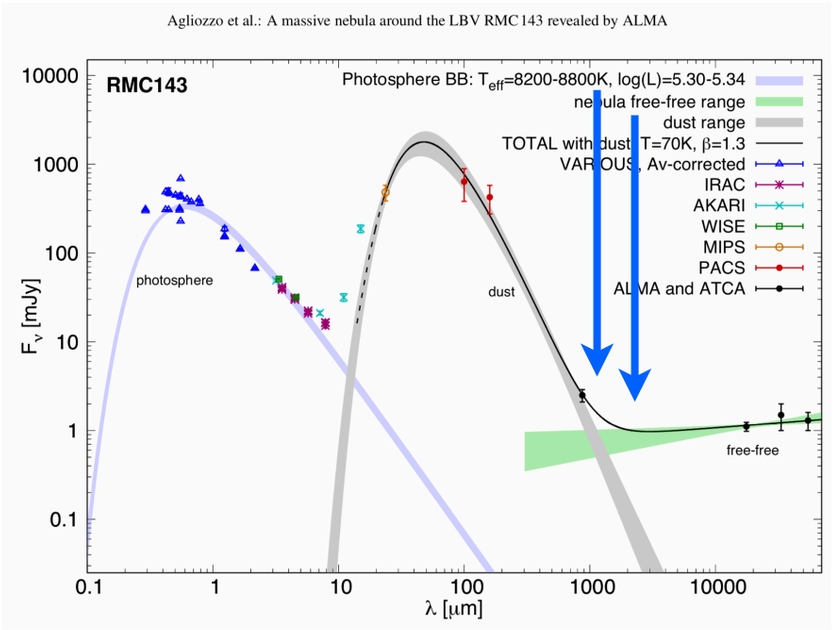
Morphology

Field	Star		CS mat		Plateau		Shell		DC	
	1mm	2mm	1mm	2mm	1mm	2mm	1mm	2mm	1mm	2mm
MGE 027	❌	❌	❌	❌	❌	❌	❌	❌	✅	✅
HD168625	✅	✅	✅	✅	✅	✅	❌	❌	✅	✅
HD168607	✅	✅	❌	?	✅	✅	❌	❌	✅	✅
MGE 042	✅	✅	✅	✅	✅	✅	❌	❌	✅	✅
G79.29+0.46	✅	✅	❌	❌	❌	❌	?	✅	✅	✅

- Large variety of morphologies → more complex than initially expected
- Like in CO gas, similar stars do not have similar circumstellar material

Mechanisms of emission



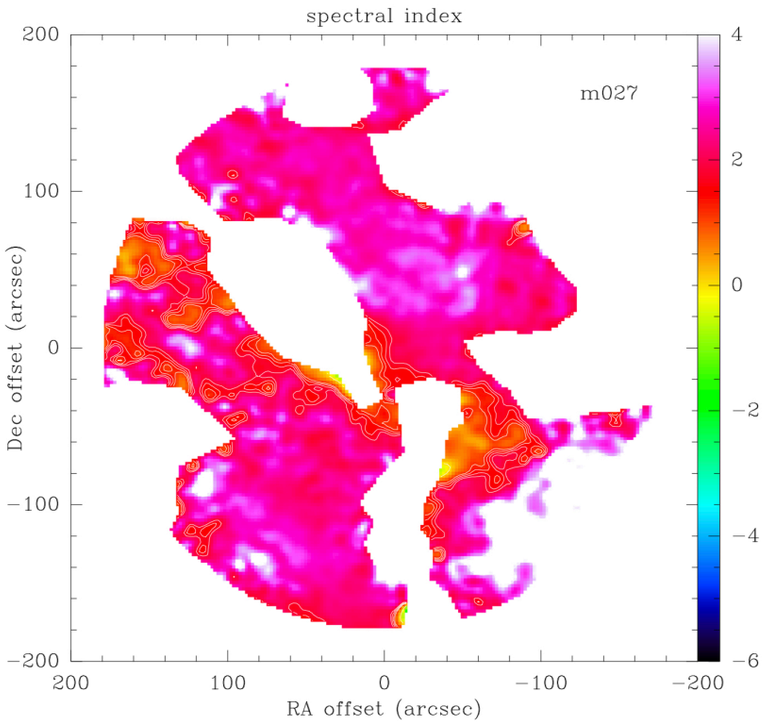


- NIKA2 frequencies are those where free-free and thermal dust can compete
- In LBVs and their surroundings, we expect important contribution from both mechanisms
- To test prevalence of free-free vs. thermal dust, we compute spectral indexes, assuming:

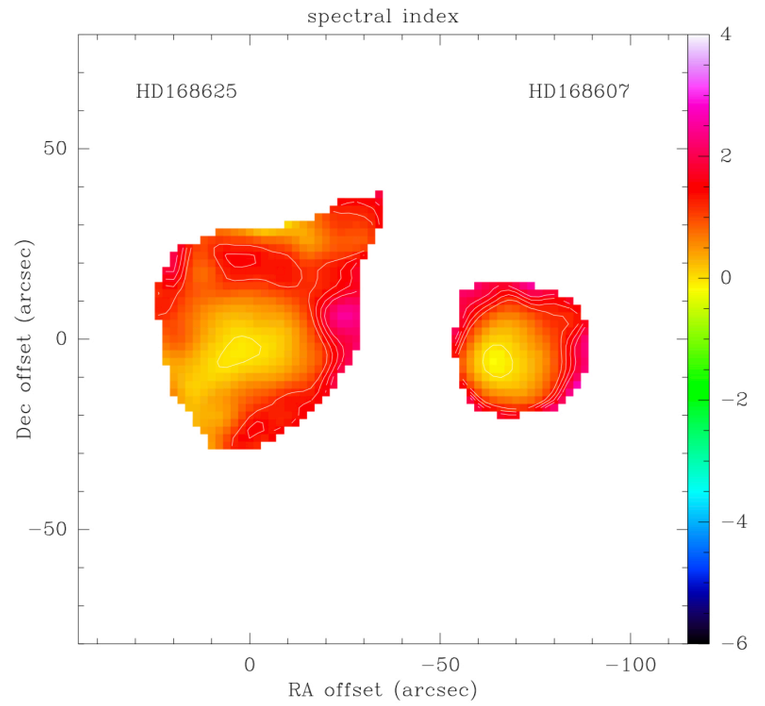
$$S_\nu \propto \nu^\alpha$$

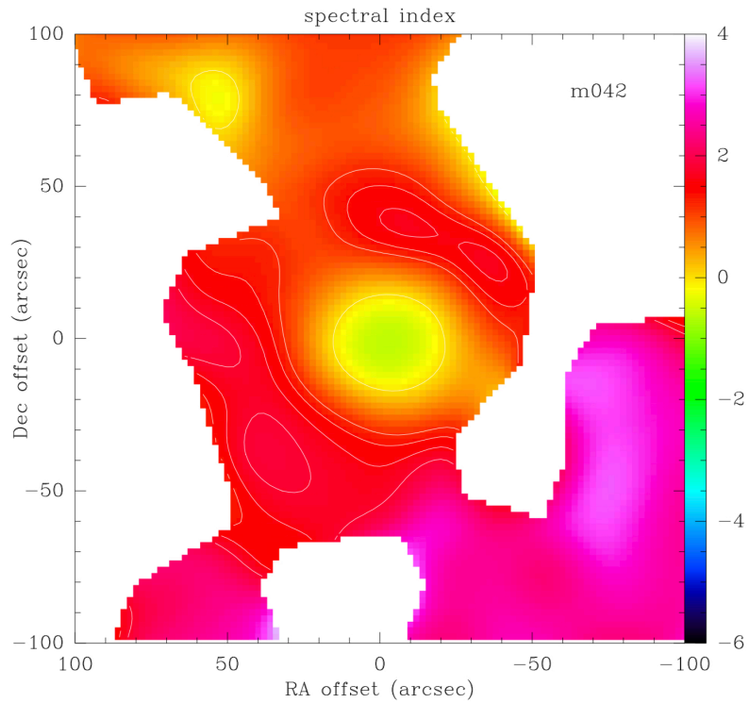
- Under simple assumptions, we get:
  - = -0.1 for expanding HII region
  - = 0.6 for evolved stellar wind
  - = 2 for ideal thermal emission
  - = 2+(beta) for modified black body

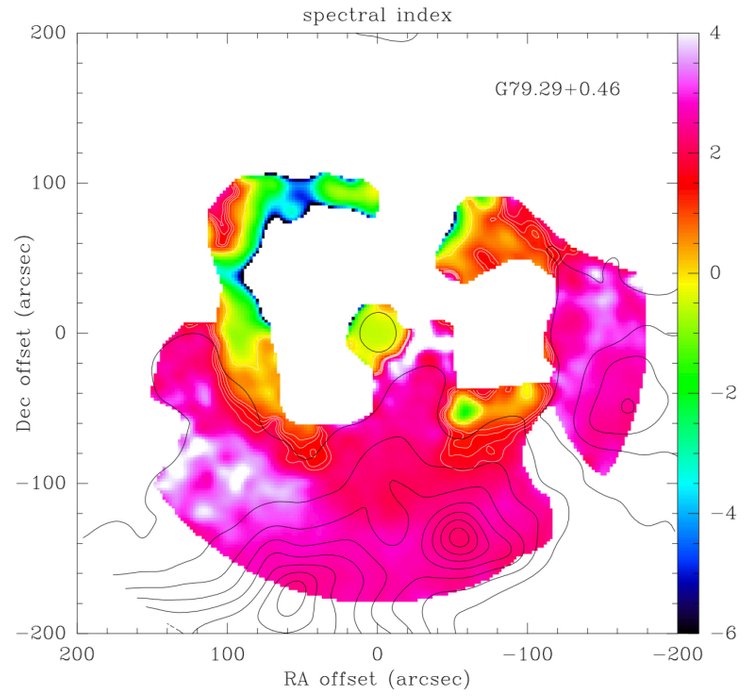
Spectral indexes



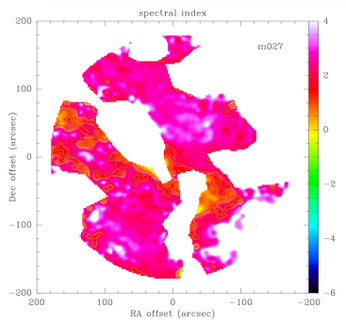
- MGE 027: (ambient) dark cloud, sp.idx around 4
- HD168625/607: star + CSM, sp.idx between 0 - 1
- MGE 042: star (-2), CSM (0), shell (1.5), DC (4)
- G79.29+0.46: star (0), shell (-1.5), IRDC (-4)

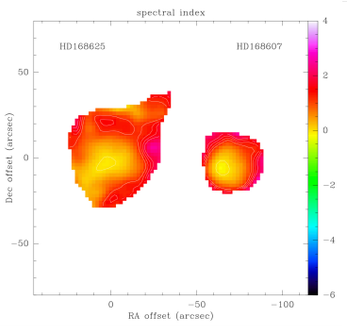


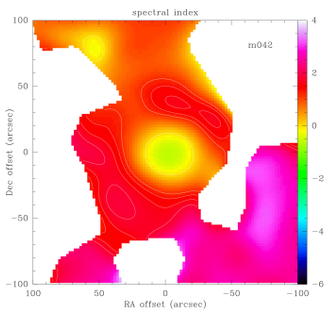


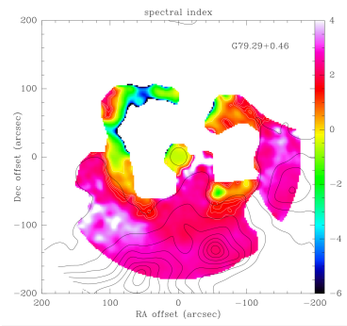


Findings & final thoughts









- Complex and varied morphology
- Stars detected in all but one case, in both bands
- Discovery of circumstellar emission and a new shell in spectral index only
- Clear differentiation in spectral index

- Need for further modeling and SED analysis
- Three-fold follow up observations:
  - Improve S/N
  - Enlarge sample
    - Go to 90 — 100 GHz
- NIKA2 highly satisfactory for this science case

THANKS NIKA2 team for the impressive work!