Onsala Proposal

Ligterink 0108.F-9317

Characterizing the Very Low Luminosity Object DC3272+18

Semester: may2021 **Science Cat.: ISM and star formation**

Abstract

Very Low Luminosity Objects (VeLLOs) are a class of protostellar objects whose nature is poorly understood. They have been suggested to be extremely young protostars or in a quiescent stage during the episodic accretion. DC3272+18 is a particularly interesting VeLLO for studying the complex interplay of gas-phase and ice chemistry. Its ice composition is well characterized throughout the envelope, outflow, and toward the VeLLO itself and shows high abundances of complex molecules in the ice. Unfortunately, little is known about the chemical complexity in the gas surrounding the VeLLO. Here, we propose to characterize the central source in DC3271+18 with APEX by carrying out a deep search for methanol, the simplest complex organic molecule, to test for hot corino type chemistry, in combination with a census of physics tracers such as H2CO, CO, HNC and HCN isotopologues, and SiO to trace outflow activity.

The proposed observations will not only shed light on the methanol abundance in a VeLLO, for which so far only one single detection is available, but also prepare for future JWST and ALMA observations.

Applicants

Name	Affiliation	Email	Country		Potential observer
Dr. Niels Ligterink	University of Bern	niels.ligterink@csh.unibe.ch	Switzerland	Pi	
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Is this a long term proposal: No

No overall scheduling requirements

Observing runs

run	telescope	instrument	time request (minimal)	frequency (GHz)	weather (pwv)	LST range	comments/constraints
A	APEX	nFLASH230 (200-270 GHz)	16h (16h)	245.0	1-2 mm	11-21	Main target line CH3OH(5-4) at 241.791431 GHz in LSB.
B	APEX	nFLASH230 (200-270 GHz)	14h (14h)	221.0	1-2 mm	11-21	Main target line H2CO(3-2) at 218.22242 GHz in LSB.

Targets

Source	RA	Dec	Epoch	Vlsr (km/s)	Duration (min)	Runs	Comments
DC3272+18	15:42:16.99	-52:48:02.2	J2000	0.0	1794	A B	

Scientific Rationale

Very Low Luminosity Objects (VeLLOs) are a class of protostars that are characterized by internal luminosities of $L_{\rm bol} < 0.1 L_{\odot}$. Since their first detection rougly two decades ago [1], research has primarily focussed on determining the physical nature of these objects. VeLLOs have been suggested to be extremely young protostars, proto brown dwarfs, or quiescent periods of a protostar during an episodic accretion process [2]. Studies of their chemical complexity are limited and typically target small di- and tri-atomic species that trace physical conditions. Larger Complex Organic Molecules (COMs, molecules consisting of six or more atoms and at least one carbon atom) have generally not been studied toward VeLLOs. In the literature, there is only one detection of a COM - methanol (CH_3OH) - which is found at a distance of $\sim$1000 au from the VeLLO L1521F and suggested to originate in a shocked region [4].

Studies of COMs toward VeLLOs are crucial for two main reasons. First, **the detection of COMs toward protostars provides information on the kind of molecules that end up in planet forming regions and make up their initial chemical composition.** To fully understand the chemical diversity from low- to high-mass protostars and from high to low luminosity objects, VeLLOs are a unique and essential link in how chemical complexity arises and evolves in protostars. Second, many VeLLOs are hosted in cloud cores that are known to have high COM abundances in the ice, as for example shown for sources covered by the Spitzer Space Telescope Legacy Project "From Molecular Cores to Planet Forming Disks" (c2d) [5, 6]. **Gas-phase observations of VeLLOs in these clouds do not only have a higher likelihood for detecting COMs, but make it possible to study transition of COMs from ice to gas.**

This is the motivation behind studying the central embedded VeLLO ($L_{\rm internal}$ $\sim$0.04 $L_{\odot}$) in the isolated cloud core DC3272+18, first discovered with Spitzer [7]. Its bolometric temperature of 105 K suggests it is an early Class I protostar, slightly more evolved than other VeLLOs. Located in the southern hemisphere, the physical characteristics of DC3272+18 are less well studied than those of other VeLLOs. Both ^{13}CO (1-0) and C^{18}O (1-0) show extended emission up to $\sim$1500 au, which is believed to be sublimated material from its last accretion burst (see Fig. 1, [3]). In addition, extended C^{18}O emission toward the south-west might trace an outflow while the arc structure toward the north-east might be related to the outflow cavity [8]. In addition, C^{17}O (1-0) is marginally detected, suggesting a high-density surrounding envelope.

Furthermore, Spitzer spectra have been recorded toward the DC3272+18 cloud at the embedded VeLLO position and toward three background stars. These spectra show clear spectroscopic signatures of water, carbon dioxide (CO_2) and methanol ice, but also hints of more complex molecules, such as ethanol ice (CH_3CH_2OH) [6]. The methanol ice abundance is found to be as high as $\sim$50% w.r.t. water toward the VeLLO and the background stars (see Fig. 1). This sets the ice in the DC3272+18 cloud apart as particularly COMs rich compared to the average of the c2d sample. However, its gas-phase COMs abundances have not yet been measured. **The combined physical and chemical evidence makes the DC3272+18 VeLLO an excellent target for a first look into the evolution of COMs toward VeLLOs.** This proposal aims at closing the gap in our knowledge of the gas-phase molecular composition in DC3273+18.

Proposed observations: APEX observations of the DC3272+18 VeLLO are requested, which will target the 5-4 lines of the COM methanol and the 3-2 transition of the chemically related molecule formaldehyde (H_2CO). These two molecules are abundant toward star-forming regions [9]. A detection of either one of these molecules will provide clues to how enriched the gas around this source is with COMs. Non-detections will set stringent upper limits and set this source aside as an unusually COMs-poor object, providing a peculiar contrast with its rich ice chemistry.

In the spectral setup several small molecules, such as HCN, HNC, SiO, and CO are covered, which trace physical conditions, such as gas density and kinetics, temperature, radiation field, and outflow shocks. These physics tracers will make it possible to compare the physical conditions of this VeLLO with those found around other protostars. This will help us to understand the (non-)detection of COMs in the context of the local physical conditions of this source.

Observations of the DC3272+18 VeLLO will provide a key puzzle piece about the evolution of interstellar chemistry and will pave the way for follow-up observations of this source with JWST and ALMA.

Facilities Requested

Observations with the Atacama Pathfinder EXperiment (APEX) with the nFLASH230 receiver are requested.

Observing Requirements

The main scientific deliverable of these observations is the detection of methanol toward the VeLLO in DC3272+018 (d ~260 pc). Due to the low luminosity ($L_{internal}$ ~0.04 $L_{\odot}$) of the protostar and comparatively low gas densities, the methanol column density is predicted to be low and thus deep observations are necessary.

Methanol abundances toward objects such as hot corinos are generally found in the order of 5–50$\times10^{-7}$ [CH_3OH]/[H_2]. The H_2 column density is estimated to be around 10^{21} cm^{-2} toward this object [3]. Methanol column densities of a few 10^{14} cm^{-2}, with the exact value depending on parameters such as source size, line width, and excitation temperature equal [CH_3OH]/[H_2] abundances of 1–5$\times10^{-7}$. These methanol column densities results in line intensities of ~15 – 30 mK. Therefore, a 5 mK noise level will ensure that these methanol lines can be detected at 3 – 6 σ certainty.

Two setups at 221.0 GHz and 245.0 GHz, respectively, are used. The 221.0 setup primarily targets the H_2CO 3–2 transition, whereas the 245.0 GHz setup focuses on the CH_3OH 5–4 transitions. Because typical line widths in this source are found to be around 0.4 km s^{-1} [3], a velocity resolution of 0.1 km s^{-1} is requested to ensure the line profiles can be resolved with at least 3–4 resolution elements. For both setups a sensitivity of 5 mK per 0.1 km s^{-1} bin width is requested, which results in a total observation time of 14.2 and 15.7 hours, including overhead, for the 221.0 and 245.0 setup, respectively, assuming a pwv of 2 mm and a typical elevation of 45°. These observations can be carried out in worse weather conditions, provided the observing time is adjusted accordingly to reach the required sensitivity.

Observing Plan

Observations of the VeLLO in the DC3272+18 cloud, located at α_{J2000} = 15:42:16.99, δ_{J2000} = -52:48:02.2, are conducted in a single pointing. Two frequency setups employing the APEX nFLASH230 receiver are used at tuning frequencies of 221.0 and 245.0 GHz. In case time is limited the 245.0 GHz setup that covers the methanol lines should be prioritized.

References

[1] Young et al., ApJS, 154, 396 (2004); [2] Dunham et al., PPVI, 914, 195-218 (2014);

[3] Hsieh et al., ApJ, 854:15 (2018); [4] Favre et al., A&A 635, A189 (2020);

[5] Evans et al., PASP, 115, 965 (2003); [6] Boogert et al., ApJ, 729:92 (2011);

[7] Dunham et al., ApJS, 179, 249 (2008); [8] Kim et al., ApJS, 240:18 (2019);

[9] Herbst & van Dishoeck, Annu. Rev. Astron. Astrophys. 47:427-80 (2009)

Figures

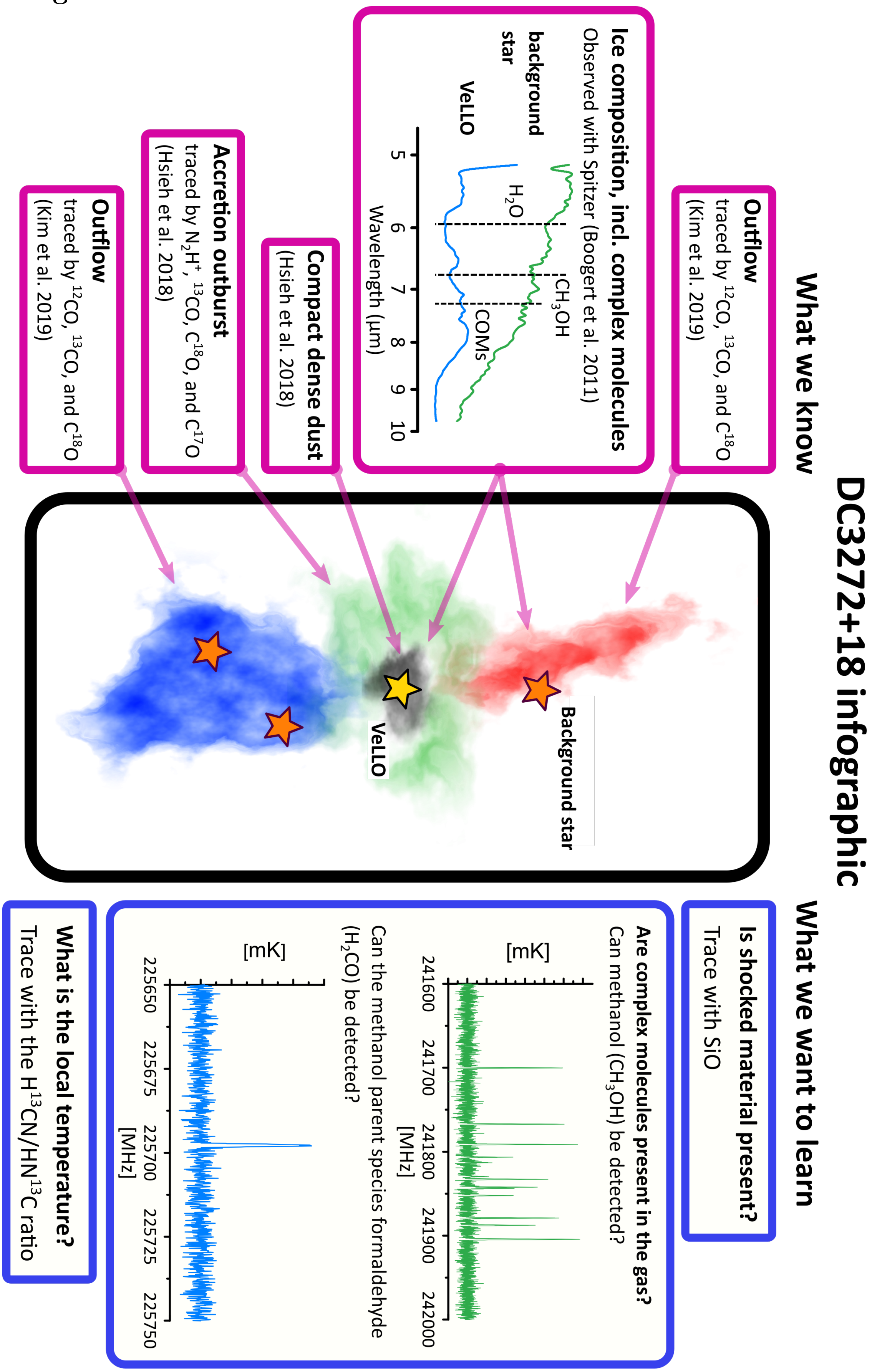

Figure 1: Infographic depicting the DC3272+18 cloud, what we currently know about this source, and what we would like to learn from these APEX observations.

Students involved

Student	Level	Applicant	Supervisor	Applicant	Expected completion date	Data required
Beatrice Kulterer	Doctor	Yes	Dr. Maria Drozdovskaya	Yes	2023/02	No

Linked proposal submitted to this TAC: No

Linked proposal submitted to other TACs: No

Relevant previous Allocations: No

Additional remarks

ESO=<nielsl>

Observing run info :

Run: A backup strategy: This observation could also be carried out in worse weather (> 2mm PWV) if the observing time is adjusted accordingly.
Run: B backup strategy: This observation could also be carried out in worse weather (> 2mm PWV) if the observing time is adjusted accordingly.