Mem. S.A.It. Vol. 90, 572

Memorie della

TUPURI: a legacy survey of debris disks with the Large Millimeter Telescope

M. Chavez-Dagostino[1], E. Bertone[1], O. Vega[1], J. Marshall[2] and the TUPURI Team

[1] Instituto Nacional de Astrofísica, Optica y Electrónica Luis Enrique Erro 1, Sta. Maria Tonantzintla, Puebla, Mexico, e-mail: mchavez@inaoep.mx
[2] Institute of Astronomy and Astrophysics, Academia Sinica. Roosevelt Rd, Taipei 10617, Taiwan, R.O.C.

Abstract. We present the TUPURI project, a proposed large survey of debris disks to be carried out with the Large Millimeter Telescope Alfonso Serrano (LMT) in the next years. The TUPURI survey will study a few hundreds of known debris disks and their host stars as well as other nearby targets for which debris disks have not yet been detected. The bulk of observations will be carried out with the full 50m aperture of the LMT, equipped with the soon to be commissioned TolTEC three-band continuum camera. A spectroscopic follow-up at mm wavelengths is also planned and, with ancillary data at other wavelengths, we will investigate the properties of the host stars, with particular emphasis on their age and the structure of the outer atmosphere.

Key words. surveys, circumstellar matter, stars: atmospheric parameters, ages

1. Introduction

Cold debris disks around main sequence stars are the remnants of planet formation processes, analogous to the Solar System's Edgeworth-Kuiper belt. Continuum emission from micron-sized dust grains dominates the observed flux from debris disks, peaking at far-infrared wavelengths, which exhibit typical temperatures of ~30-80 K and radial size scales of 10s-100s au, sometimes with narrow annular architectures. The detection of extended emission from a circumstellar disk is an important factor in the modelling process as it directly constrains the orbital radius of the dust responsible for the observed emission, weakening inherent degeneracies between grain size and radial distance. Observations at longer, (sub-)millimeter (mm), wavelengths trace the emission from larger, mm-sized dust grains and provide a direct measurement of the morphology of parent belt of planetesimals, since large grains are much less affected by the radiation forces than the micron-sized ones. The measured disk extent will, therefore, closely match that of the original dust producing bodies in each system. Since these disks are optically thin, the flux is a proxy for the dust mass (see Matthews et al. 2014, for a review).

2. The goals

TUPURI[1] is an ambitious project aimed at better understanding and characterizing, at the

[1] TUPURI stands for "dust" in the Purepecha language. The Purepecha are the native populations that live in the region of Michoacán, Mexico.

mm regime, known debris disks (DDs), around stars in the field and in clusters, and at discovering new DDs of nearby intermediate- and late-type stars (F- to M-type). Observations with the Large Millimeter Telescope Alfonso Serrano[2] (LMT), in its early science phase, have already been conducted for a few targets (Fig. 1), demonstrating the LMT capabilities. However, the proposed mm-wave observations will be conducted using the LMT full aperture of 50m and the new suite of instruments, especially the TolTEC continuum camera, that can reach an unprecedented flux depth of 0.025 mJy at 5 arcsec spatial resolution (@1.1 mm). TUPURI will also provide a better assessment of the stellar hosts properties, through aside projects briefly described in this contribution[3].

3. The sample

The sample will contain targets observed by DUNES and DEBRIS programs of *Herschel* (Eiroa et al. 2013; Matthews et al. 2014) and within the JCMT SONS survey (Holland et al. 2017). We will better constrain the morphology of the DDs (diameter, width, orientation, homogeneity) and the dust properties (temperatures, mass, emissivity). We also plan to observe targets (including M-type stars) for which no DD has yet been detected, but, because of TolTEC superb sensitivity, we will be able to reach photospheric/chromospheric levels and therefore fractional luminosities similar to that of the Edgeworth-Kuiper belt ($L_{\rm IR}/L_{\rm BOL} \sim 10^{-7}$). We anticipate that the sample will consist of some 200 targets, requiring a total of ~30 hours on source with flux depths of at least 0.2 mJy.

4. TolTEC

TolTEC[4] is an imaging polarimeter for the LMT designed to collect mm-wave data in three bands: 1.1, 1.4 and 2.0 mm. The new KIDS technology and its nearly 7000 detectors will provide fast mapping speed and astounding sensitivity. For the particular case of TUPURI, TolTEC will be able to produce 40 arcmin^2 maps (the smallest feasible) at a depth of 0.2 mJy/beam in merely 3 minutes!, instead of the 18.5 hours needed for a 7.5 arcmin^2 map of the ϵ Eridani DD with its predecessor AzTEC.

5. Molecular contents of DDs

An important segment of the TUPURI survey is to use the new high-resolution (1 km/s or better) spectrometers (the 1mm receiver, B4R, SEQUOIA) of the LMT to search for molecules in DDs. The goal is to contribute to the understanding of the evolution of circumstellar disks and of the planet formation mechanisms, since, in particular, the transition from massive gas-rich proto-planetary disks to the DD phase is still poorly understood (see, for intance Péricaud et al. 2017). TUPURI will shed light on the origin of the gas in DDs, that can be either primordial or generated by secondary processes like out-gassing from exocometary surfaces, planetesimals breakup or impacts (Kóspál et al. 2013; Kral et al. 2017).

6. Stellar properties

Several complementary projects will be developed aimed at homogeneously deriving target parameters and other physical properties that include:

(a) Stellar parameters. Although most of DD hosts are bright objects, there are still uncertainties in their leading atmospheric parameters: effective temperature ($T_{\rm eff}$, surface gravity ($\log g$) and metallicity ([Fe/H]). Available databases (e.g. Soubiran et al. 2016) indicate that, even for the most well known targets (such as ϵ Eridani, β Pictoris, Fomalhaut), very disparate values are provided by different authors. We plan to conduct intermediate (R~2000) and high resolution (R~80000) optical spectroscopic observations to homogeneously derive $T_{\rm eff}$, $\log g$, [Fe/H]

[2] `www.lmtgtm.org`

[3] Full details of the TUPURI project (including team members) can be found in Chavez-Dagostino et al. (in preparation).

[4] `http://toltec.astro.umass.edu/`, see Montaña et al. this volume

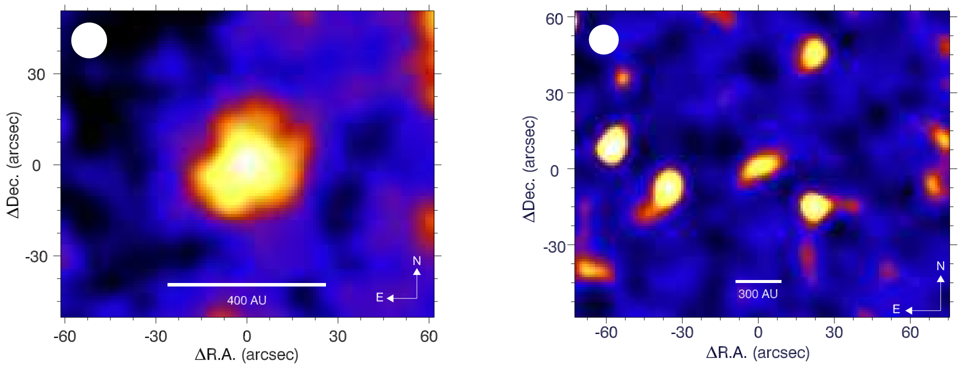

Fig. 1. 1.1mm maps of two spatially resolved DDs of the TUPURI project observed with the continuum camera AzTEC and the LMT in its 32m configuration, that complement the observation of ϵ Eridani presented by Chavez Dagostino et al. (2016). Left panel: the map of Vega (Marshall et al., in prep.) with a depth of about 0.3 mJy. Right panel: the map of HD 48682 (Bertone et al., in prep.) with a depth of 0.4 mJy. The spatial resolution (~11 arcsec) is represented with the white circles.

and abundances of individual chemical species, including lithium.

(b) Stellar ages. Though fundamental to properly establish the evolutionary status of DDs and their hosts, age is still a very difficult parameter to derive for H-fueled isolated targets. We plan to homogeneously apply the gyrochronology technique (Skumanich 1972; Soderblom 2010) based on optical (Ca II H, K) and space ultraviolet (Mg II h, k) proxies of stellar activity. This will be based on proposed observations of open clusters with the MOS MEGARA on the Gran Telescopio Canarias, on archival IUE and HST/STIS high spectral resolution data (see Montez et al., this volume) and proposed observations with the World Space Observatory-UV (see M. Sachkov, this volume).

(c) The outer atmospheres of DD hosts. An interesting and fundamental by-product of studying the surroundings of DD hosts is that we will be able to explore the still poorly studied, at mm wavelengths, upper atmosphere of Sun-like stars. The non-thermal heating of these regions (chromosphere and lower corona) produces an up-turn of the temperature-optical depth structure and has only been observationally identified (at mm wavelengths) in α Cen A and B (Liseau et al. 2015, 2016). Extending the T-τ structure from (sub-)mm to the radio regime will also provide clues on, for instance, stellar winds (Rodriguez et al. 2019).

Acknowledgements. The TUPURI team is grateful to CONACyT for the financial support to the LMT project through variuos grants. MC, EB, OV also acknowledge the invaluable support from CONACyT through grant CB-2015-256961.

References

Chavez Dagostino, M., et al. 2016, MNRAS, 462, 2285
Eiroa, C., et al. 2013, A&A, 555, 11
Holland, W. S., et al. 2017, MNRAS, 470, 3606
Liseau, R., et al. 2015, A&A, 573, L4
Liseau, R., et al. 2016, A&A, 594, A109
Matthews, B., et al. 2014, in Protostars and planets VI, Buether H. et al. eds. (Univ. of Arizona press, Tucson, AZ), 521
Péricaud, J., et al. 2017, A&A, 600, A62
Kóspál Á., et al. 2013, ApJ, 776, 77
Kral, Q. et al. 2017, MNRAS, 469, 521
Rodriguez, L. F., et al. 2019, ApJ, 871, 172
Skumanich, A. 1972, ApJ, 171, 565
Soderblom, D. R. 2010, ARA&A, 48, 581
Soubiran, C., et al. 2016, A&A, 591, A118