PROCEEDINGS OF SCIENCE

Observing dust-forming refractory oxides, AlO, TiO, and TiO_2, in circumstellar gas around evolved stars

Tomasz Kamiński[*,a] **Karl M. Menten**,[a] **Mirosław Schmidt**,[b] **Elvire De Beck**,[a] **Carl A. Gottlieb**,[c] **Ken H. Young**,[c] **Nimesh A. Patel**,[c] **Sandra Brünken**,[d] **Holger S. P. Müller**,[d] **and Jan M. Winters**[e]

[a] *Max-Planck-Institut für Radioastronomie, Bonn,*
[b] *N. Copernicus Astronomical Center, Toruń*
[c] *Harvard-Smithsonian Center for Astrophysics,*
[d] *I. Physikalisches Institut, Köln,*
[e] *Institut de Radioastronomie Millimétrique*
E-mail: kaminski@mpifr.de

The first detection of rotational spectra of titanium and aluminum oxides in circumstellar material is presented for three stars, VY CMa, *o* Ceti, and IK Tau. The role of the metal oxides in stardust formation is investigated observationally for the first time.

The Life Cycle of Dust in the Universe: Observations, Theory, and Laboratory Experiments - LCDU 2013, 18-22 November 2013
Taipei, Taiwan

[*] Speaker.

PoS(LCDU 2013)096

The refractory oxides of aluminum and titanium (AlO, TiO and TiO_2) are expected to play a major role in initiating dust formation in oxygen-rich envelopes of cool stars (e.g. [1]). Formed at temperatures above 2000 K, they are thought to provide molecular clusters (or "seeds") on which dust condensation occurs in cooler parts of the envelope. Until recently, these species have been only rarely observed in stellar spectra, almost exclusively at optical wavelengths, which hampered detailed studies of their formation and depletion in circumstellar envelopes. We have obtained and analyzed the first (sub-)millimeter observations of pure rotational transitions of AlO, TiO, and TiO_2 in the circumstellar envelopes of the peculiar red supergiant, VY CMa [2, 3], and two mira stars, Mira itself (*o* Ceti [4]) and IK Tau [5]. The location of the emitting gas was derived from the (sub)-millimeter spectra and from comparing these with the optical electronic bands of the rare species [6, 7]. For VY CMa, the excitation temperatures of the emitting gas were investigated. Linking the information extracted from these first observations to the nature of the stars, we conclude that we are observing shocked material that is strongly influenced by non-equilibrium chemistry and complex excitation conditions. Our first (sub-)millimeter observations followed-up with ALMA at a higher angular resolution, will provide strong constraints on the formation, processing, and destruction of dust in oxygen-rich circumstellar envelopes.

References

[1] Gail, H.-P., Sedlmayr, E. 1998, *Inorganic dust formation in astrophysical environments*, Faraday Discussions 109, 303.

[2] Kamiński, T., Gottlieb, C. A., Menten, K. M., Patel, N. A., Young, K. H., Brünken, S., Müller, H. S. P., McCarthy, M. C., Winters, J. M., Decin, L. 2013. *Pure rotational spectra of TiO and TiO_2 in VY Canis Majoris*, A&A 551, A113.

[3] Kamiński, T., Gottlieb, C. A., Schmidt, M. R., Patel, N. A., Young, K. H., Menten, K. M., Brünken, S., Müller, H. S. P., Winters, J. M., McCarthy, M. C. 2013, *Dust-forming molecules in VY Canis Majoris (and Betelgeuse)*, EAS Publications Series 60, 191-198

[4] Kamiński, T. et al. 2014, in preparation

[5] De Beck, E. et al., 2014, in preparation

[6] Kamiński, T., Schmidt, M. R., Menten, K. M. 2013, *Aluminium oxide in the optical spectrum of VY Canis Majoris*, A&A 549, A6

[7] Kamiński, T., Gottlieb, C. A., Young, K. H., Menten, K. M., Patel, N. A. 2013, *An Interferometric Spectral Line and Imaging Survey of VY Canis Majoris in the 345 GHz Band*, ApJS 209, 38.

PoS(LCDU 2013)096