FORMATION OF CIRCUMSTELLAR DUST AROUND AN OXYGEN-RICH AGB STAR W HYA: AlO AND SiO OBSERVATIONS WITH ALMA

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Astromineralogy before ALMA: Presolar grains are survivors of circumstellar dust grains formed around evolved stars such as Asymptotic Giant Branch (AGB) stars, Red Giants, and supernovae (SNe). Mineralogical, crystallographic, and isotopic studies on presolar grains provide us quantitative information on individual circumstellar dust grains and implication on the formation and evolutional history of each grain [1-5]. Mid-infrared (MIR) spectroscopy of mass-loss stars have been playing important roles for revealing size, crystallinity, and a variety of chemical compositions, and the spatial distribution of circumstellar dust around evolved stars with different masses and mass-loss histories [6, 7]. It is very important to combine the microscopic studies on presolar grains with the telescopic studies on circumstellar dust for better understanding of dust formation around evolved stars and the origin of the presolar grains. Nevertheless, the formation condition of circumstellar dust has not yet been well clarified because MIR observation covers emissions from all observable dust grains in the dust shell due to limitation of spatial resolution and provides us little information about the dust-forming environment close to the central star.

Astromineralogy with ALMA: Silicates are the most abundant dust species around oxygen-rich AGB stars and also the most abundance presolar grains [8]. Alumina (Al_2O_3) is minor but important refractory dust that condenses prior to silicates at higher temperatures. MIR observations, however, showed that oxygen-rich AGB stars with silicate-poor and alumina-rich dust shells are as common as silicate-rich stars [e.g., 9].

Condensation of silicate and alumina grains consumes Si- and Al-bearing molecules in the gas phase and changes the spatial distribution of the gases. Therefore, the distributions of Si- and Al-bearing molecules could be another proxy for circumstellar dust formation. Little attention, however, have been paid to the gas species forming dust grains due to limited spatial resolution of the observations. The high spatial resolution of Atacama Large Millimeter/sub-millimeter Array (ALMA) makes it possible to resolve dust formation regions in envelopes around nearby oxygen-rich AGB stars. In order to discuss the dust formation in a circumstellar envelope from the distribution of gas species forming dust, we observed the spatial distribution of AlO and SiO molecules around W Hya with ALMA.

Observation: W Hya is a well-studied alumina-rich star and is one of the closest semiregular variables located at the distance of ~98 pc. We made observations of ^{29}SiO (343.0 GHz, J=8-7), AlO (344.5 GHz, N=9-8), ^{12}CO (345.8 GHz, J=3-2), and ^{13}CO (330.6 GHz, J=3-2) lines simultaneously to resolve the dust formation region around an oxygen-rich AGB star W Hya with ALMA for the cycle 3 observation (project code: 2015.1.01446.S).

Results: Long baseline observations were performed on November 30, December 5, and 6, 2015 using 31, 33, and 41 of the 12-m antennas, respectively. After the data delivery in March 2016, the data was calibrated and imaged with the Common Astronomy Software Applications (CASA) package. At least thirteen different molecular lines were detected including ^{29}SiO, AlO, ^{12}CO, and ^{13}CO. Significant expansions of ^{12}CO and ^{29}SiO molecules, and slightly extended emissions of AlO and ^{12}CO were confirmed. The emission of the molecular AlO line was observed within a few stellar radii, while SiO molecules distribute even beyond ten stellar radii, indicating the differences in the formation regions of silicates and alumina dust. The comparison between the distributions of the AlO molecules and sub-micron sized dust observed by visible polarimetric imaging [9] suggests that the polarimetrically-observed dust is not silicate but alumina. which is consistent with the low abundance of silicate dust around W Hya expected from MIR observations [10].

References: [1] Zinner E. et al. (1987), *Nature* 330, 730-732. [2] Nittler L. R. et al. (1994), *Nature*, 330, 443-446. [3] Hoppe P. and Zinner E. (2000), *Journal of Geophysical Research*, 105, 10371-10385. [4] Bernatowicz T. J. et al. 2003, *Geochimica et Cosmochimica Acta*, 67, 4679-4691. [5] Takigawa A. et al. (2014) *Geochimica et Cosmochimica Acta*, 124, 309-327. [6] Speck A. K. et al. (2000) *Astronomy & Astrophysics Supplement Series*, 146, 437-464. [7] Nguyen A. et al. (2007), *The Astrophysical Journal* **656**, 1223-1240. [8] Sloan G. C. & Price S. D. (1998), *The Astrophysical Journal Supplement Series* **119**, 141-158. [9] Ohnaka K. et al. (2016) *Astronomy & Astrophysics*, 589: A91. [10] Heras A. M. & Hony S. (2005) *Astronomy & Astrophysics*, 439, 171-182.