MOLECULAR GAS IN YOUNG DEBRIS DISKS

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ABSTRACT

Gas-rich primordial disks and tenuous gas-poor debris disks are usually considered as two distinct evolutionary phases of the circumstellar matter. So far only a very few debris disks with measurable gas component have been known. We carried out a survey with the APEX radio telescope (3-3.2 GHz) of the secondarily debris disks with residual molecular gas. This poses a serious question to the current paradigm, since the age of the system (30 Myr) significantly exceeds model predictions for disk clearing and the ages of the oldest transitional disks.

INTRODUCTION

• According to the current paradigm, disks around young stars evolve from gas-rich primordial to gas-free debris disks on a timescale of ~10 Myr. Debris disks are composed of second generation dust, the product of collisions between planetesimals.
• Indeed, very few debris disks with detectable gas component have been found. Comparing both molecular and atomic gas, 49 Comet (40 My-A type), Zuckerman et al., 1996, Sibersky, R., et al., 2003; IP (13 Myr, A type), Roberts, et al. 2006. Containing only atomic gas: HD 32297 (20 Myr, A-type), De纳税ion et al., 2011, and HD 172955 (12 Myr, A5, Restor-Morteral et al. 2013).
• We carry out a survey with the APEX radio telescope in search for CO gas in 28 prominent, young (10-100 Myr) debris disks, and discovered two new gaseous systems around HD 21979 and HD 131835.

RESULTS OF THE APEX SURVEY

• For a long time, only one debris disk, 49 Comet, was known to harbour cold CO gas detectable at mm wavelengths (Zuckerman et al., 1995). Our survey revealed two new gaseous debris disks around HD 21979 (30 Myr, Columbia moving group, A4-type, Moór et al., 2013) and HD 131835 (16 Myr, Upper Centaurus Lupus, A5-type, Moór et al., 2013).
• Almost all systems seem to harbour unusually massive debris disks. Interestingly, β Pic and HD 32297, two disks where gas was detected at other wavelengths, also show this property.

• The origin of gas in debris disks likely:
  - The gas in β Pic system is claimed to be secondary (Farnaecki et al., 2006).
  - Origin of gas in 49 Comet disk is debated, however recent papers (Zuckerman & Song, 2012, Robinson, et al., 2015) proposed that the observed CO is of secondary origin.
  - Disks around β Pic, 49 Comet, and HD 131835 show similar Me/Me ratio suggesting that their gas component has a common origin.
  - For HD 21979 the Me/Me ratio is significantly higher and indeed, based on our ALMA observations we found that it may rather harbour primordial gas.
  - BUT NOTE, for HD 21979 the CO mass estimate was derived from the ALMA CO(1-0) observation, while 49 Comet and HD 131835 were detected only in CO and their CO mass was calculated assuming optically thin emission. Thus their real CO mass could be higher!

CONCLUSIONS

• By carrying out a survey with the APEX radio telescope we discovered two debris disks, HD 21979 and HD 131835 that show submillimeter CO emission.
• For HD 21979 we performed follow-up observations with the ALMA and Herschel Space Observatory. Considering the distribution and the physical properties of the dust component, HD 21979 looks like a normal debris disk system. However, our ALMA free observations revealed a large amount of CO gas. Its mass is comparable to the dust mass, and significantly exceeds the CO content of other debris disks. Based on our results, we suggest that HD 21979 harbours a hybrid disk in which secondary dust and residual primordial gas co-exist. If the observed gas in the HD 21979 system was of primordial origin, it poses a serious question to the current paradigm of disk evolution, since the age of the system (30 Myr) significantly exceeds model predictions for disk clearing and the ages of the oldest transitional disks.

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ALMA AND HERSCHEL OBSERVATIONS OF HD 21979

ALMA results (Kospáll et al., 2013; Moór et al., 2013a)
- The continuum emission is clearly resolved into a ring-like structure encircling the star, but it is not circular. The morphology can be filled with an elliptical ring with an outer diameter of 4.5’ (300 AU).
- Spatially resolved CO emission was observed in all transitions. The molecular gas is in Keplerian rotation. Disk angle position: 22.6’±0.5’, inclination: 32.6’±3.1’ (based on the analysis of first moment maps).
- The disk was spatially resolved at all PACS wavelengths (Moór et al., 2013a).
- Non-detection of CO (J=1-0, 2-1).

Conclusions
- CO and 13CO lines are optically thick, MCO ~ 0.05 Msun, based on the optically thin CO line measurement.
- CO brightness distribution could be reproduced by a gas disk with inner and outer radii of ~250M and 139 AU.
- Inner and outer radii of the dust disk is ~55 and ~150 AU respectively, with a dust mass of 0.09 Msun in this region. Our data supported by modelling hints at an extended cold outer disk of the ring.
- Thus, dust and gas are only co-located in the disk between 55 and 140 AU, but within 55 AU there is a dust poor inner region.
- Origin of gas: secondary source would require unrealistically high gas production rate and would not explain why gas and dust are (partially) not co-located.

RELATED LITERATURE

Kospáll, A., et al., 2013, submitted
Moór, A., et al., 2013a, submitted

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ACKNOWLEDGMENT
This research was partly funded by the Hungarian OTKA grants K101939 and the PECS-98073 program of the ESA.