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# The OH 1612 MHz maser pump rates of stellar, interstellar and post-AGB OH masers

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**Abstract**

(Pseudo) radiative pumprate of OH 1612 MHz masers is defined for a sample of 44 OH/IR sources (infrared sources with OH 1612 MHz maser), irrespective of the real maser pumping mechanisms. The correlation between the (pseudo) maser pumprates and the evolutionary status of the maser sources reveals that the radiative pumprates of stellar OH masers are nearly fixed, which agrees with the theoretical prediction for radiatively pumped OH maser. The (pseudo) radiative pumprates of interstellar OH masers are not only very small but also varying broadly over two orders of magnitude, which is argued to be the manifestation of varying number of quiet absorbing OH cloudlets and/or various OH maser pumping mechanisms and/or competitive gain between mainline and 1612 MHz OH masers and/or anisotropy of the maser emission. The radiative pumprates of post-AGB OH masers very possibly decrease with increasing IRAS $C_{32}$ color indices and distribute in an interim region between the stellar and interstellar OH masers in the pumprate-color diagram.
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## 1. Introduction

OH 1612 MHz masers have been found in different kinds of objects, such as OH Miras, OH/IR stars, Proto-Planetary Nebulae (PPNe), Planetary Nebulae (PNe), Red Supergiants (RSGs), H II regions (H IIs), molecular clouds, and so on (Elitzur, 1992). The OH masers appearing in H IIs or molecular clouds are called *interstellar OH masers* while those appearing in all other types of sources are called *stellar OH masers*, depending on whether the masing molecules originate from interstellar space (by accretion) or from the central star (by stellar wind). Because the OH masers in post-AGB sources, such as post-AGB stars, PPNe and PNe, show peculiar properties, as we will see below in the discussions of this paper, I would like to separate

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them from the stellar OH maser group to form a third group: *post-AGB OH masers*. Up till now, three different pumping mechanisms have been proposed for the OH 1612 MHz masers arising in different astronomical environments: radiative pumping, collisional pumping and chemical pumping. According to the recent developments in the maser pumping theory, more physical effects such as local and non-local line overlap (e.g., Pavlakis and Kylafis, 1996a,b) were recognized to be playing important roles in certain cases. But little effort has been made to directly compare in observations the different pumping mechanisms of the OH 1612 MHz masers that occur in different kind of objects.

Among the different kinds of objects showing OH 1612 MHz maser, late type stars such as OH Miras, OH/IR stars and RSGs are believed to have their OH masers radiatively pumped. Most of these objects have a huge spherical, although perhaps clumpy, circumstellar dust-gas envelope. The OH 1612 MHz maser is formed in the outer part of the huge envelope and is pumped mainly by absorbing the 34.6 and 53.3 μm photons. The physical environments in the three kinds of objects are a little different. For example, OH Miras often have optically thin dust envelope while OH/IR stars are usually embedded in very optically thick dust shell; RSGs have much higher luminosity and their dusty envelopes are harsher than that of OH Miras and OH/IR stars.

PPNe and PNe are objects immediately following the AGB evolutionary stage. The OH 1612 MHz maser inherited from their precursors can still survive for about 1000 years (Sun and Kwok, 1987). But due to the evident changes of the envelope, the survived OH 1612 MHz masers in PPNe or PNe are often found not in a spherical shell but in a circumstellar disk or bipolar outflow (e.g., Zijlstra et al., 2001). The pump mechanism of these remanent OH masers is thought to be mainly radiative one too. However, for PPNe or PNe that show bipolar outflows, the OH masers can also appear in the interaction region between the outflow and the ambient interstellar material (Likkel and Morris, 1988) and, in this case, the OH masers may be pumped by collision.

OH 1612 MHz masers have been found in some H IIs in Star formation Regions (SFRs). They are often found accompanying with the OH main line masers (Caswell, 1999; Szymczak and Gárard, 2004). The physical environment in SFRs is much more complicated than that in the circumstellar envelope of late type stars. The expanding ionized hydrogen sphere creates a geometrically thin but dense layer compressed by shock waves in the inner edge of the huge outer in-falling dust-gas envelope. The OH masers were believed to arise just in the shock compressed layer (Cochran and Ostriker, 1977). Additionally, high velocity bipolar outflow have been found in many SFRs (e.g., Campbell et al., 1986; Shepherd and Churchwell, 1996), but it is not clear whether the OH 1612 MHz masers can be stimulated in the interaction region between the outflow and the ambient interstellar material.

The difference in physical environments results in different OH maser-pumping mechanisms at work. However, it is not easy to directly discriminate the different maser pumping mechanisms from observational aspects. In our previous two papers (He et al., 2005 and He and Chen, 2004, hereafter Paper I and Paper II, respectively), we systematically analyzed the 34.6 and 53.3 μm pumping lines in all Infrared Space Observatory (ISO), Short Wavelength Spectrometer (SWS) and Long Wavelength Spectrometer (LWS) spectra of known OH/IR sources (infrared sources showing OH 1612 MHz maser) and found that the (pseudo) radiative pumprates of OH masers arising in different environments are quite different. This paper continues to discuss another important problem: how the different kinds of 1612 MHz maser sources obey or violate the principle that the input of pumping photons should be proportional to the maser output for a radiatively pumped maser? Although similar job had been done in the past decades by other authors using IR photometrical data (e.g., Le Bertre et al., 1984; Dickinson, 1987; Silva et al., 1993), the available IR spectral data from ISO enable one to perform a more powerful analysis of the OH 1612 MHz maser pump rate by directly comparing the emission of maser photons to the absorption of IR photons. The potential of ISO spectra is dug out to the utmost to constrain the value or a reasonable range of the (pseudo) radiative maser pumprate for all OH/IR sample sources. In Section 2, the data sets are organized and de-

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