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FAST Maser Surveys

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Abstract. FAST, the Five-hundred meter Aperture Spherical radio Telescope, will become the largest operating single-dish telescope in the coming years. It has many advantages: much better sensitivity for its largest collecting area; large sky coverage due to its innovative design of the active primary surface; extremely radio quiet from its unique location, etc. In this work, I will highlight the future capabilities of FAST to discover and observe both galactic and extragalactic masers.

Key words. Maser—multi-wavelength—statistics—AGN.

1. Introduction

The big single dish radio telescopes of today include Arecibo 305 m, GBT 100 m, Effelsberg 100 m, five ∼70 m ones etc. With respect to these existing telescopes, FAST will be the largest and most sensitive one. It is currently being built by Chinese institutions and industries and the first light is expected to be in 2016. FAST site is located at DaWoDang depression (N25°39′10″ and E106°51′20″) in Pingtang County, which is ∼170 km from Guiyang, the capital of Guizhou province in the southwest of China.

Being the world's largest filled-aperture telescope located at an extremely radio-quiet site, FAST will have extraordinary science impact on astronomy. Many fundamental questions and important science goals will be explored deeply and some possible discoveries are expected, such as HI galaxy survey, pulsar-black hole system, extragalactic pulsar, high redshift megamasers and radio signals from exoplanets (Nan *et al*. 2011). Here FAST maser sciences are investigated and discussed. Due to its frequency coverage (70 MHz to 3 GHz), the main maser object of FAST should be OH maser with its four transitions between the hyperfine levels in the Λ-doublet of the ground rotational state $^2\Pi_{3/2}$ (= 3/2, ν: 1612, 1665, 1667 and 1720 MHz). In addition, another maser candidate should be CH_3OH maser with its transition between the two levels of the lowest K-type doublet ($J_K = 1_1$, ν: 834 MHz).

2. FAST maser sciences

In keeping with the important goals of the FAST telescope, nine sets of receivers are designed to cover the 70 MHz∼3 GHz band continuously. A full coverage of the spectra is good for searching low frequency spectral lines (Nan *et al*. 2011). Among them, the receiver Nos 3 (0.28–0.56 GHz), 4 (0.56–1.02 GHz) and 7 (1.15–1.73 GHz) can be mainly used for maser observations (galactic and extragalactic masers).

2.1 *Galactic OH masers*

Since OH maser emission was detected in galactic molecular clouds in 1960s (Weaver *et al*. 1965), more than 3000 OH maser sources have been detected so far. Observations show that most of the OH masers in our galaxy are located at either dense molecular gas in star formation regions or circumstellar envelopes of evolved giant and super-giant stars. OH masers in star formation regions (interstellar masers) are found to be closely associated with ultra-compact H II regions, embedded IR sources, hot molecular cores, Herbig-Haro objects, and outflows etc., which can be used to probe star formation. And OH masers in circumstellar envelopes (circumstellar masers) were found to be related to outflowing and cool winds from the evolved stars, which is taken as a good tool for VLBI astrometry to measure stellar parameters (e.g., Lo 2005). Another type of interesting OH maser is the 1720 MHz OH maser (other three lines are weak or absent). Since it was first detected toward supernova remnants (SNRs) (Goss & Robinson 1968), about 10% of SNRs ($\sim$20) are detected with this type of OH maser emission. Now this type of OH masers is believed to be one good probe of SNR shock interactions with molecular clouds (e.g., Frail *et al*. 1996; Hewitt *et al*. 2008).

Galactic OH maser surveys were mainly performed in 1970s and 1980s. The telescopes used included Effelsberg 100 m, Parkes 64 m, NRAO 42 m, Onsala 25.6 m etc. (e.g., Caswell *et al*. 1980; Turner 1979). FAST has much bigger collecting area, with a sensitivity at least one order of magnitude bigger than the telescopes used in the 1970s and 1980s galactic surveys. To achieve the same sensitivity limit, the FAST surveying speed would be 2 orders of magnitude better. This brings high efficiency for both sample selection survey and galactic plane blind sky survey. Among FAST planned nine sets of receivers, the single beam L-wide receiver (No. 7, 1.15–1.73 GHz) is good for OH maser surveys. Future proposed multi-beam L-wide receiver will be better for wide area blind surveys. For 1720 MHz OH masers, high sensitivity FAST will help detect much more of this type of OH masers. This will be valuable and helpful to investigate the SNR shock interactions with molecular clouds.

2.2 *Extragalactic OH masers*

Since the first OH megamaser (1665 and 1667 MHz, assumed isotropic luminosities $L_{\rm OH} > 10L_{\odot}$) was detected in Arp 220 (Baan *et al*. 1982), more than 120 OH megamaser sources have been detected to date (e.g., Willett 2012; Fernandez *et al*. 2010; Darling & Giovanelli 2000; Chen *et al*. 2007). A majority of them come from Arecibo detections. Many OH megamaser survey have been undertaken by existing radio telescopes, such as Arecibo 305 m, NRAO 91 m, JB MkIA 76 m, Nancay 300 m and Parkes 64 m etc. However, the detection rate is often low and the survey by upgraded Arecibo telescope (Darling & Giovanelli 2000, 2001, 2002) was

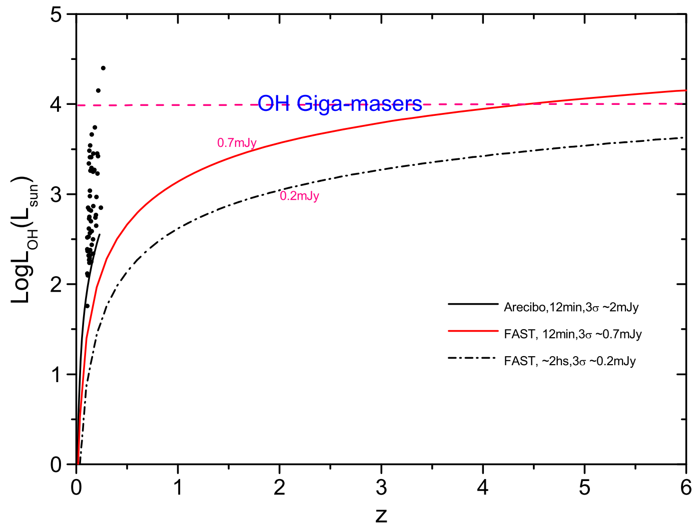

Figure 1. The minimum detectable OH maser luminosity (3σ) versus redshift. Dotted and dashed line: detected OH megamsers and sensitivity of the Arecibo survey; Long solid and dashed line: sensitivity of FAST for 12 min and 2 h integration, respectively.

the most successful one. Among the selected 311 luminous or ultraluminous infrared galaxies (LIRGs or ULIRGs) with a redshift z range of 0.1–0.3, 52 OH megamasers were detected, which doubled the number of known OH megamasers. Recently, one systematic search for high-redshift OH megamaser was carried out with Green Bank Telescope (Willett 2012). A sample of 121 ULIRGs with $0.09 < z < 1.5$ was targeted and nine new OH megamasers were detected with $z < 0.25$. To date, there is no OH megamaser with $z > 0.265$ (the most luminous and distant one being $z \sim 0.25$, IRAS14070+0525, Baan *et al.* 1992). Since OH megamaser host LIRGs or ULIRGs are considered to be related to galaxy merging and the merge rate is proposed as a function of redshift of $(1+z)^m$ ($m : 3 \sim 8$, e.g, Le Fevre *et al.* 2000), the sky density of OH megamasers at high redshift is expected to be much higher. This is a good opportunity for the largest telescope, FAST to be employed.

With respect to the current largest telescope Arecibo, FAST has larger collecting area by a factor of ~3, corresponding to three times better raw sensitivity (assuming other parameters are the same as Arecibo). For the Arecibo survey, the integration time of each source is about 12 min. The typical rms flux density is 0.65 mJy and detection at 3σ level is about 2 mJy. With the same integration time of 12 min, the rms value of FAST is about 0.22 mJy and 3σ level corresponds to 0.66 mJy. So the minimum luminosity at 3σ level FAST detection can be estimated, following the method of Darling & Giovanelli (2002): $L_{\rm OH}^{\rm min} = 4\pi D_{\rm L}^2 \int S\, {\rm d}V \sim 4\pi D_{\rm L}^2 f_{\rm peak} \frac{\Delta\nu_0}{1+z} = 4\pi D_{\rm L}^2 f_{\rm peak} \frac{\nu_0 \Delta V_0}{c(1+z)}$, here, $D_{\rm L}$ the luminosity distance, $f_{\rm peak}$ is the peak flux density, it is 0.66 mJy for FAST with 12 min integration, ν_0 and $\Delta\nu_0$ are the rest-frame frequency and average frequency width and ΔV_0 is the rest-frame velocity width. The luminosity distance was derived using Calculators I provided by the NASA Extragalactic Database (NED), assuming $\Omega_M = 0.270$, $\Omega_{\rm vac} = 0.730$, and $H_0 = 70\,{\rm km\,s^{-1}\,Mpc^{-1}}$ (e.g., Spergel *et al.* 2003). Figure 1 presents the minimum detectable OH maser luminosity by FAST with

12 min integration at different redshift z. For comparison, the results of two hours or so integration (3σ detection, i.e., $f_{\rm peak} \sim 0.2$ mJy) are also presented.

Expectations: For 12 min integration, FAST could detect most OH megamasers with $L_{\rm OH} > 10^3 L_\odot$ to redshift $z\sim1$, even some to redshift $z\sim2$. All gigamasers with $z<4$ can be detected. For the case of two hours integration, much better expectation could be made. All OH megamasers with $L_{\rm OH} > 10^3 L_\odot$ can be detected to $z\sim2$ and all gigamasers can be detected.

2.3 *CH_3OH masers*

As mentioned above, CH_3OH maser with its transition at $\nu = 834$ MHz is another candidate for FAST targets. It was detected towards the galactic center sources Sgr A and Sgr B2, using 140-foot radio telescope at NRAO (Ball *et al.* 1970). However, this happened more than 40 years ago and there has been other detections to date. Maybe the next one will be detected by the powerful FAST.

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References

Baan, W. A., Wood, P. A. D., Haschick, A. D. 1982, *Astrophys. J.*, **260**, 49.
Baan, W. A., Rhoads, J., Fisher, K. *et al.* 1992, *Astrophys. J.*, **396**, 99.
Ball, J. A., Gottlieb, C. A., Lilley, A. E. 1970, *Astrophys. J.*, **162**, 203.
Caswell, J. L., Haynes, R. F., Goss, W. M. 1980, *Australian J. Physics*, **33**, 639.
Chen, P. S., Shan, H. G., Gao, Y. F. 2007, *Astron. J.*, **133**, 496.
Darling, J., Giovanelli, R. 2000, *Astron. J.*, **119**, 3003.
Darling, J., Giovanelli, R. 2001, *Astron. J.*, **121**, 1278.
Darling, J., Giovanelli, R. 2002, *Astrophys. J.*, **572**, 81.
Frail, D. A., Goss, W. M., Reynoso, E. M. *et al.* 1996, *Astron. J.*, **111**, 1651.
Fernandez, M. X., Momjian, E., Salter, C. J., Ghosh, T. 2010, *Astron. J.*, **139**, 2066.
Goss, W. M., Robinson, B. J. 1968, *Astrophys. J.*, **2**, 81.
Hewitt, J. W., Yusef-Zadeh, F., Wardle, M. 2008, *Astrophys. J.*, **683**, 189.
Le Fevre, O., Abraham, R., Lilly, S. J. 2000, *MNRAS*, **311**, 565.
Lo, K. Y. 2005, *Ann. Rew. Astron. Astroph.*, **43**, 625.
Nan, R. D., Li, D., Jin, C. J. *et al.* 2011, *IJMPD*, **20**, 989.
Spergel, D. N. *et al.* 2003, *Astrophys. J. Suppl.*, **148**, 175.
Turner, B. E. 1979, *Astron. Astrophys. Suppl.*, **37**, 1.
Weaver, H., Williams, D. R. W., Dieter, N. H., Lum, W. T. 1965, *Nature*, **208**, 29.
Willett, K. W. 2012, *IAUS*, **287**, 345.