JCMT and FAST

Ming Zhu
FAST science group, NAOC
2016-4-19, Mitaka
Complete by 2016-09-26?
### 2. General Technical Specification

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spherical reflector:</td>
<td>Radius ~ 300m, Aperture ~ 500m, Opening angle 110~120°</td>
</tr>
<tr>
<td>Illuminated aperture:</td>
<td>$D_{ill} = 300m$</td>
</tr>
<tr>
<td>Focal ratio:</td>
<td>$f/D = 0.467$</td>
</tr>
<tr>
<td>Sky coverage:</td>
<td>Zenith angle 40° (up to 60° with efficiency loss) tracking hours 0~6h</td>
</tr>
<tr>
<td>Frequency:</td>
<td>70M ~ 3 GHz (up to 8GHz in future upgrading)</td>
</tr>
<tr>
<td>Sensitivity (L-Band):</td>
<td>$A/T \sim 2000$, $T \sim 20$ K</td>
</tr>
<tr>
<td>Resolution (L-Band):</td>
<td>2.9′</td>
</tr>
<tr>
<td>Multi-beam (L-Band):</td>
<td>19 beam</td>
</tr>
<tr>
<td>Slewing:</td>
<td>&lt;10min</td>
</tr>
<tr>
<td>Pointing accuracy:</td>
<td>8″</td>
</tr>
</tbody>
</table>
Opening angle - sky coverage

Sky coverage
FAST vs. Arecibo

Sky coverage
ZA 30 deg
ZA 40 deg
ZA 60 deg
FAST Zenith
ZA 56 deg
Frequency range

0.13 0.327 1.42 3 4 5 8 (GHz)

First phase

Second phase

70MHz

z~20

300MHz

5.2GHz

HCOOH

CH$_3$OH

OH(4)

HC$_5$N(4)

CH(4)

CH$_4$

H$_2$CO(6)

Water hole

S Band

C Band

X Band

In layout 2000

HI surveying

EoR

Pulsar

VLBI

17 Lines

SETI

Space science

OH(4)

H$_2$
FAST sciences

- Neutral Hydrogen line (HI) survey
- Pulsar research
- VLBI network
- Molecular line study (including recombination lines, masers)
- Search for Extraterrestrial Intelligence (SETI)
HI studies with FAST

- Extent of HI Disk - truncation
- Extended rotation curve to extreme large distance
- Cold Dark Matter Satellite (ΛCDM)
- HI Mass Function
- Voids
- Surveying Milky Way (FV, Magellanic Stream ... )
- HI gas in high redshift galaxies
- HI gas in galaxy clusters and groups
- High z OH megamasers
FAST and JCMT

Galactic
- Recombination lines and HII region
- HI absorption and molecular lines
- OH CH molecular lines
- HVCs and high latitude clouds

Galaxies
- HI, molecular lines and dust correlations
- Gas to dust ratios, HI/H2 ratio
- Star formation, galaxy interactions, environments
- Clusters, high z galaxies
Using a 19 beam L-band receiver to map the FAST sky at 20–40 sec per beam, doable in 1–2 yrs. Expect about 1 million detections (Duffy et al. 2008, 2012) with $M_{\text{HI}} < 10^{11} \, M_{\odot}$ out to $z \sim 0.15$ in a range of environments including Coma, Hydra, Ursa Major, Persues–Pisces supercluster plus neighboring voids.
Future All sky HI maps
Figure 7. Line width and $V_{LSR}$ distributions for all clouds. The differently colored symbols correspond to the five populations—HVCs (black triangles), galaxy candidates (red diamonds), cold LVCs (blue Xs), warm LVCs (pink open squares), and warm Q3 LVCs (green filled squares). This plot best illustrates where the populations are separated. See Figure 9 for the velocity and line width distribution for each population.

(A color version of this figure is available in the online journal.)
This cloud is deficient in 12 micron emission, which is produced by tiny grains (PAHs). It is not deficient in ordinary grains. **Conclusion:** it’s just the PAHs—not all the grains—that heat the ordinary diffuse ISM!
Fig. 2. H I, HCO⁺, OH, and CO absorption and emission profiles toward and around four compact extragalactic mm-wave continuum sources. The OH emission spectra are averaged over four positions 20' displaced from the continuum (see Sect. 2a for a description of the observing). Note the components of OH emission which are matched in H I but not in the other profiles.
HISA as a tool to constrain T,N,n (D. Li et al. 2015)

HISA: HI self-absorption

\[ T_s = T_c + \frac{p \cdot T_{HI} - [T_{ab} / (1 - e^{-\tau_f})]}{1 - \tau_f} \]

\[ N(HI) = 1.94 \times 10^{18} \tau \Delta \nu T_s \text{ cm}^{-2} \]

\[ n = N(HI) / d \]
<table>
<thead>
<tr>
<th>Num</th>
<th>n</th>
<th>Hnα MHz</th>
<th>Henα MHz</th>
<th>Cnα MHz</th>
<th>Center Freq.</th>
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<tr>
<td>1</td>
<td>163</td>
<td>1504.608</td>
<td>1505.221</td>
<td>1505.359</td>
<td>1504.9145</td>
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<tr>
<td>2</td>
<td>164</td>
<td>1477.335</td>
<td>1477.937</td>
<td>1478.072</td>
<td>1477.6360</td>
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<tr>
<td>3</td>
<td>165</td>
<td>1450.716</td>
<td>1451.307</td>
<td>1451.440</td>
<td>1451.0115</td>
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<tr>
<td>4</td>
<td>166</td>
<td>1424.734</td>
<td>1425.314</td>
<td>1425.444</td>
<td>1425.0240</td>
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<tr>
<td>5</td>
<td>167</td>
<td>1399.368</td>
<td>1399.938</td>
<td>1400.066</td>
<td>1399.6530</td>
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<tr>
<td>6</td>
<td>168</td>
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<td>7</td>
<td>169</td>
<td>1350.414</td>
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<td>1351.088</td>
<td>1350.6890</td>
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<tr>
<td>8</td>
<td>170</td>
<td>1326.792</td>
<td>1327.333</td>
<td>1327.454</td>
<td>1327.0625</td>
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<td>9</td>
<td>171</td>
<td>1303.718</td>
<td>1304.249</td>
<td>1304.368</td>
<td>1303.9835</td>
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<tr>
<td>10</td>
<td>172</td>
<td>1281.175</td>
<td>1281.697</td>
<td>1281.815</td>
<td>1281.4360</td>
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</table>
图 3-2：W49A 中心区域(G43.175+0.025)的平均α-RRL 谱线

Liu et al. 2013
Astronomical Maser

- Mainly in star forming regions, evolved stars and also Supernova remnants
- More than 10 molecules were found to have maser emissions (OH, H$_2$O, CH$_3$OH, H$_2$CO, SiO, HCN, CH, NH$_3$, etc.)
- Masers can be pumped by collision or radiation
- Masers can be used for astrophysical and astrometry studies, such as BeSSeL project
Mysterium was masing Galactic hydroxyl (OH).

- Main lines at 1665 & 1667 MHz.
- Satellite lines at 1612 & 1720 MHz.
- In the Milky Way, usually see:
  - $I(1665)/I(1667) > 1$
  - FWHM < 1 km/s

Green et al. (2012)
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Some galaxies far, far away have OH MEGAMASERS

A SEARCH FOR OH MEGAMASERS AT \( z > 0.1 \). III. THE COMPLETE SURVEY

Jeremy Darling and Riccardo Giovanelli

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Received 2001 December 6; accepted 2002 April 10
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Some galaxies far, far away have OH MEGAMASERS!

- $L_{\text{OH}}/L_{\text{FIR}} = 10^{-1}$ to $10^{-4}$
- 100 billion times $L_{\text{OH}}$ of Galactic OH masers!
- Found only in (U)LIRGs ($L_{\text{FIR}}/L_{\text{bol}} > 10^{12}$)
- Powered by starbursts or AGN.
- Observed out past $z \approx 0.20$. 

Thompson, Rieke, Schneider, Scoville, & NASA
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  - 100 billion times $L_{OH}$ of Galactic OH masers!
  - Found only in (U)LIRGs ($L_{\text{FIR}}/L_\odot > 10^{12}$)
    - Powered by starbursts or AGN.
    - Observed out past $z \sim 0.20$.
- Emission primarily in 1667 MHz line.
  - 1665 MHz emission is either weaker or absent.
  - Hardly any 1612 or 1720 MHz satellite lines.
Arp 220

(Robishaw 2015)

Heliocentric Velocity (km s\(^{-1}\))

15327+2340

150 mJy

I (mJy)

1600
1400
1200
1000
800
600

5500 5400 5300 5200

1637.0 1637.5 1638.0 1638.5 1639.0

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FAST HI survey: simulation

500,000 galaxies
ALFALFA 40% catalog

- Census of HI in the Local Universe over cosmologically significant volume
  - 15000+ detections in 40% of final area
  - 70% are new detections
Above

\( M^* \approx 5 \times 10^8 \ M_\odot \)

HI mass scales with stellar mass for SF galaxies

(Credit Martha Haynes)
Luke Leisman+ 2015 in prep
(Courtesy of M. Haynes)
Tully-Fisher 关系定星系距离及本速度场（Peculiar Velocity

\[ \nu_{\text{CMB}} = H_0 \times d + \nu_{\text{peculiar radial}} \]  \hspace{1cm} (1)

\[ m - M = 5 \log_{10}(d(\text{Mpc})) + 25 \]  \hspace{1cm} (2)

1. \( m \leftrightarrow \) Photometry Observations
2. \( M \leftrightarrow \) Tully-Fisher relation: \( L \propto v_{\text{HI}}^\alpha \) Calibrations (Tully & Fisher 1977)

\( \leftrightarrow d \rightarrow \nu_{\text{peculiar radial}} \rightarrow \) Cosmic Flows

Accurate HI + photometry
local Cosmic Web features

Courtois et al. 2013
Angular Size: a few arc–min
T_line: few mK
Line Width: few 10s km/s

FAST can detect and resolve this type of structures to about 10 Mpc
More than 1000 times in volume than the local group
Nearby faint sources—missing satellllites

assume $dv=30$ km/s, $S/N = 10$
To map a 4 square degree area, with an integration time of 20 minute per beam, in 40 hours we can reach a 1σ sensitivity of $2 \times 10^{17} \text{ cm}^{-2}$ per 5 km/s channel.

Select regions of different environments,
- void, big galaxies, clusters …

4.3x $10^5 \text{ M}_{\odot}$ @ 10Mpc,
1.0 x $10^5 \text{ M}_{\odot}$ @ 5 Mpc
(4 sigma)
NGC 925

Preliminary reduction yields $3\sigma$, 20 km/s sensitivity $\sim 10^{18}$ cm$^{-2}$. Can see the tidal features near NGC 925, but no connection with companion. Absence of low $N_{HI}$ features probably real, but may be due to distance of source.

Contours at 1, 3, 6, 10...600x$10^{18}$ cm$^{-2}$. See signs of extended HI around NGC 925, but no filamentary structures.

Nearby galaxies—NGC925
FAST and JCMT

- **Galactic**
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