JCMT and FAST





Ming Zhu FAST science group,NAOC 2016-4-19, Mitaka

Complete by 2016-09-26?



Quick Bird Fly Oct. 6, 2005

2. General Technical Specification

Spherical reflector: Radius \sim 300m, Aperture \sim 500m, Opening angle 110~120° Illuminated aperture: D_{ill}=300m Focal ratio: f/D = 0.467Sky coverage: zenith angle 40° (up to 60° with efficiency loss) tracking hours 0~6h Frequency: 70M ~ 3 GHz (up to 8GHz in future upgrading) Sensitivity (L-Band) : A/T~2000, T~20 K Resolution (L-Band) : 2.9' Multi-beam (L-Band) : 19 beam Slewing: <10min Pointing accuracy: 8"



Frequency range



FAST sciences

- Neutral Hydrogen line (HI) survey
- Pulsar research
- VLBI network

(SETN

- Molecular line study (including recombination lines, masers)
 - Search for Extraterrestrial Intelligence

HI studies with FAST

Extent of HI Disk - truncation Extended rotation curve to extreme large distance Cold Dark Matter Satellite (ACDM) **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 megamaser

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

FAST all-sky HI survey

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 $M_{HI} < 10^{11} M_{\odot}$ out to z ~ 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.)

Carl Heiles 2015

This cloud is deficient in 12 micron emission, which is produced by tiny grains (PAHs). It is <u>not</u> deficient in ordinary grains. <u>Conclusion: it's just the PAHs—not all the grains—that heat the ordinary diffuse ISM</u>!







HISA as a tool to constrain T,N,n (D. Li et al. 2015

HISA: HI self-absorption

$$T_{\rm s} = T_{\rm c} + \frac{p \cdot T_{\rm HI} - [T_{\rm ab} / (1 - e^{-\tau})]}{1 - \tau_{\rm f}}$$
$$N(HI) = 1.94 \times 10^{18} \tau \Delta \upsilon T_{\rm s} \ cm^{-2}$$
$$n = N(HI) / d$$





ALFA 观测频带内 12 条α-RRL 能级及频率

Num	n	Hnα MHz	Henα MHz	Cnα MHz	Center Freq.
1	163	1504.608	1505.221	1505.359	1504.9145
2	164	1477.335	1477.937	1478.072	1477.6360
3	165	1450.716	1451.307	1451.440	1451.0115
4	166	1424.734	1425.314	1425.444	1425.0240
5	167	1399.368	1399.938	1400.066	1399.6530
6	168	1374.600	1375.161	1375.286	1374.8805
7	169	1350.414	1350.964	1351.088	1350.6890
8	170	1326.792	1327.333	1327.454	1327.0625
9	171	1303.718	1304.249	1304.368	1303.9835
10	172	1281.175	1281.697	1281.815	1281.4360



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, H₂O, CH₃OH, H₂CO, SiO, HCN, CH, NH₃,etc.)
- Masers can be pumped by collision or radiation
- Masers can be used for astrophysical and astrometry studies, such as BeSSeL project

- 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

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Some galaxies far, far away have OH MEGAMASERS!

- $L_{OH}/L_{\odot} = 10^{1-4}$
 - 100 billion times L_{OH} of Galactic OH masers!
 - Found only in (U)LIRGs ($L_{FIR}/L_{\odot} > 10^{12}$)
 - Powered by starbursts or AGN.
 - Observed out past z ~ 0.20.
- Emission primarily in 1667 MHz line.
 - 1665 MHz emission is either weaker or absent.
 - Hardly any 1612 or 1720 MHz satellite lines.



FAST HI survey: simulation



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



ALFALA -SDSS data crossmatch











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



Tully & Fisher 1977

$$v_{CMB} = H_0 imes d + v_{peculiar radial}$$
 (1)

$$m - M = 5 \log_{10}(d(Mpc)) + 25$$
 (2)

Accurate HI + photometry

- 2 M \leftrightarrow Tully-Fisher relation: $L \propto v_{HI}^{\alpha}$ Calibrations (Tully & Fisher 1977)

 $\hookrightarrow \mathbf{d} \to \mathbf{v}_{peculiar \ radial} \to \text{Cosmic Flows}$

local Cosmic Web features

Courtois et al. 2013



21cm HI at low surface brightness

- 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 saterllites

assume dv=30 km/s, S/N =10





Deep mapping of Nearby Galaxies

- 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 x10¹⁷ cm⁻² per 5 km/s channel.
- Select regions of different environments,
 - void, big galaxies, clusters ...
- 4.3x 10^5 M_sun@ 10Mpc,
 1.0 x 10^5 M_sun @ 5 Mpc (4 sigma)



NGC 925



Preliminary reduction yields 3σ , 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...600x10¹⁸ cm⁻². See signs of extended HI around NGC 925, but no filamentary structures.

Nearby galaxies-NGC925

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