The Promise of a Giant Radio Telescope

射电天文学前沿973

FAST

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Past, Present, Future

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Five-hundred-meter

Aperture

Spherical radio

Telescope

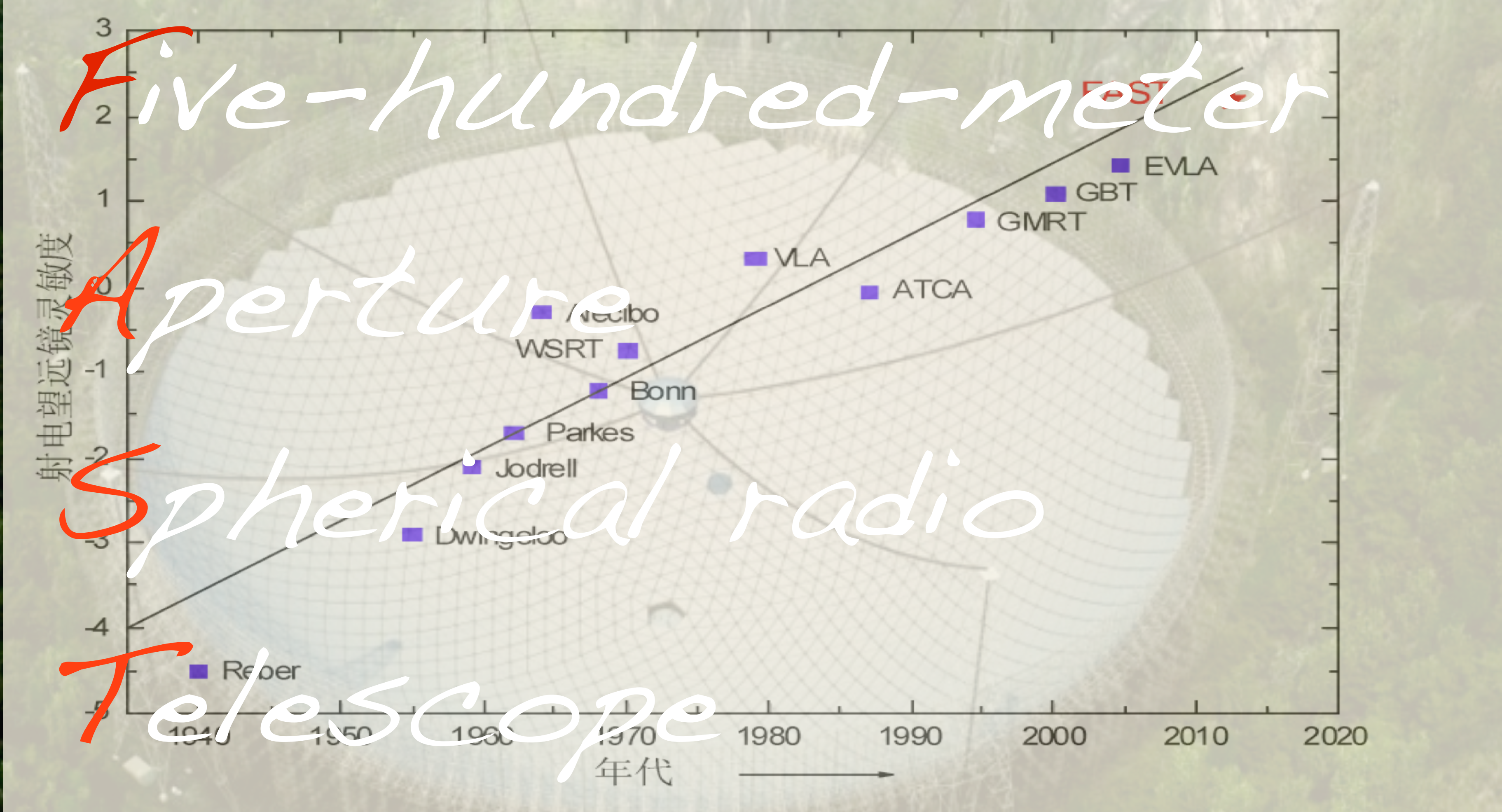


图 1-2 望远镜灵敏度发展曲

Fully Steerable Telescopes

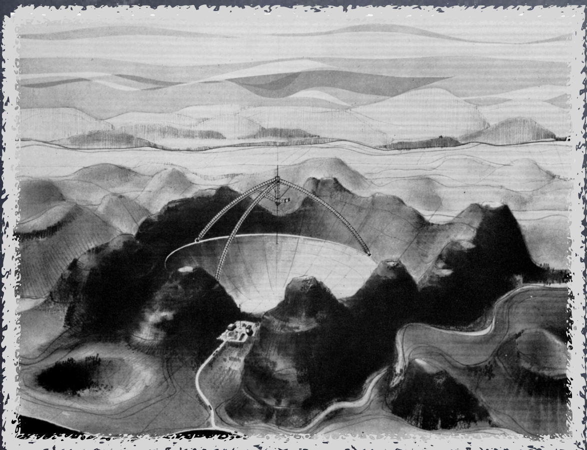
GBT 140foot

Effelsberg

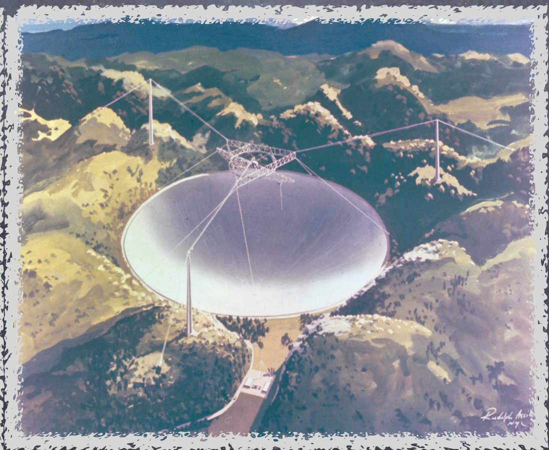
Arecibo: Dream of a Giant

William Gordon proposed the project around 1958 to Advanced Research Projects Agency (ARPA)

- Construction between 1960-1963
- Total cost: $9.3M



1959

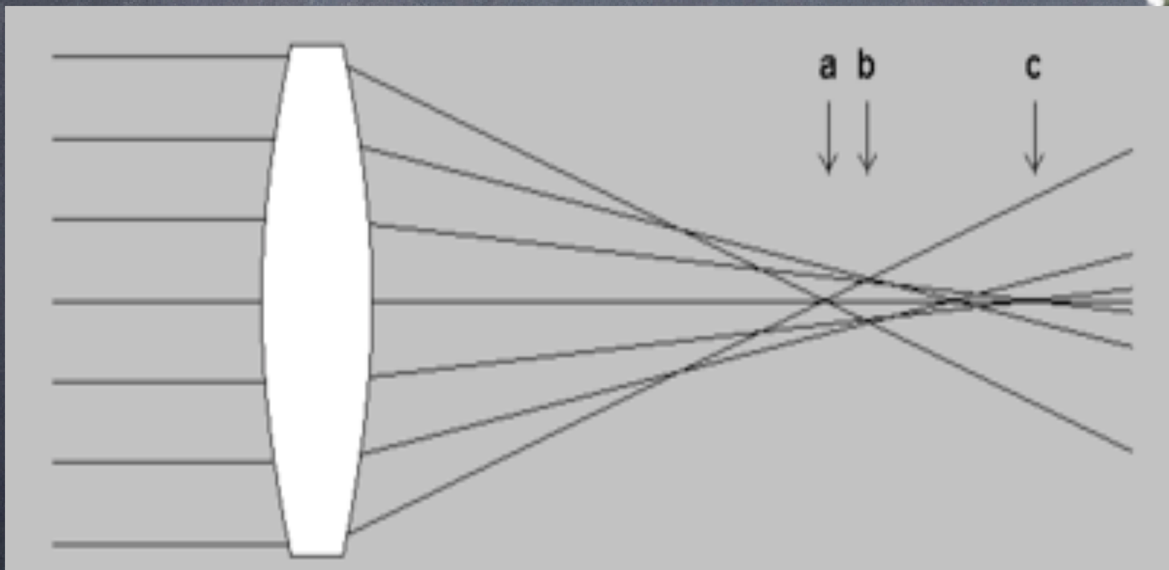


1960.2

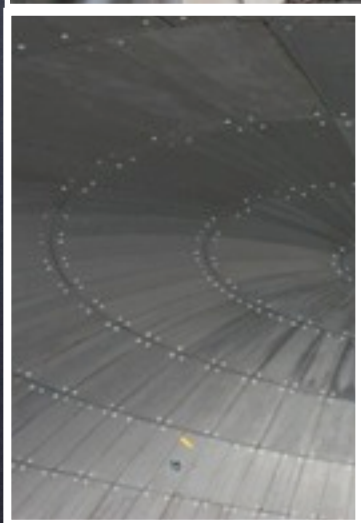
1963

Monday, May 19, 14

Spherical Optics

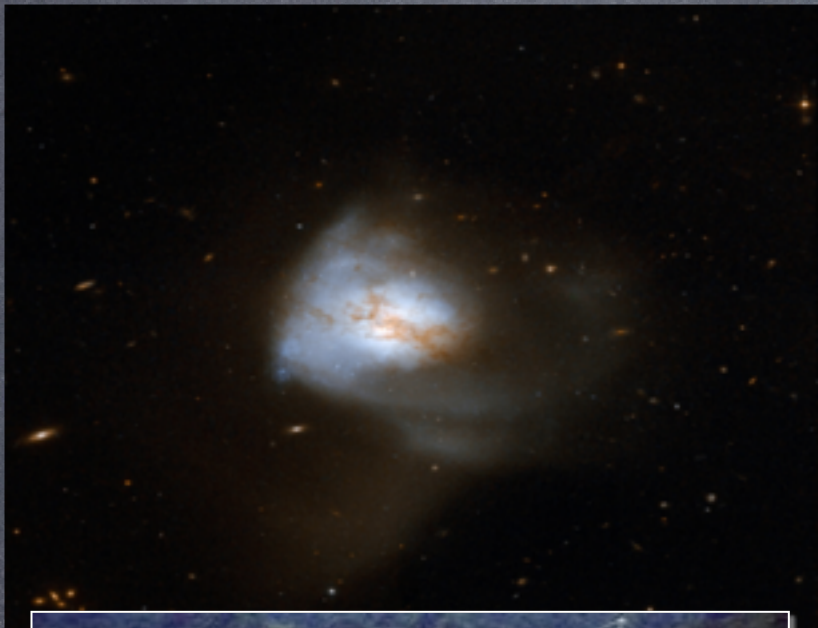


Arecibo Upgrade

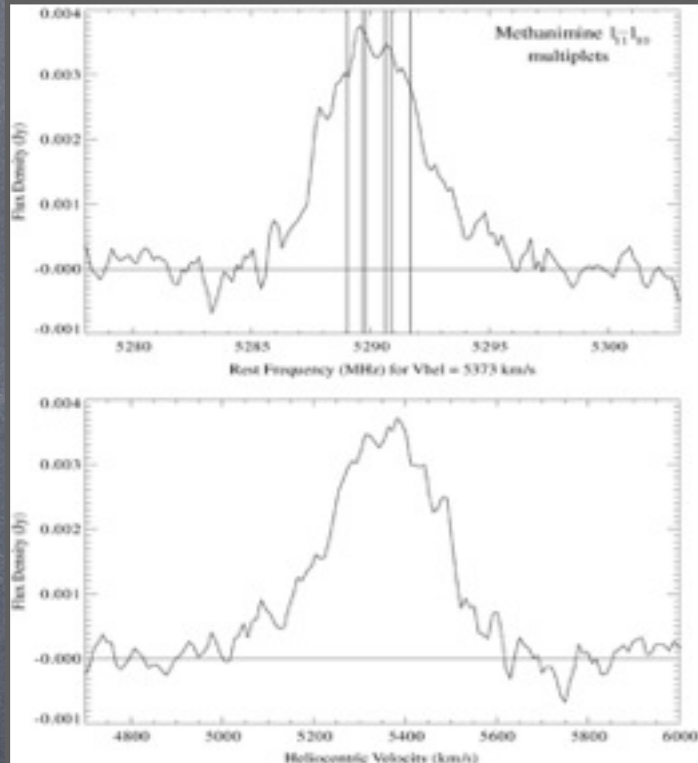


- Secondary, Tertiary => point focus
- Primary readjustment => sensitivity and up to 10 GHz
- Ground Screen => cleaner beam

Pre-biotic Molecules in Galaxies



Arecibo望远镜



2008

Arecibo detects CH_2NH (pre-biotic) in Arp 220

Revolutionary Results

- 1965: The fist measurement of 59 days Mercury spin rate.
- 1960s: First images of surface of Venus.
- 1974: The first pulsar in a binary system was discovered (1974), leading to a Nobel Prize for astronomers Russell Hulse and Joseph Taylor (1993).
- 1982: Discovery of Millisecond Pulsar
- Late 1980s: Distribution of gas galaxies and large scale filamentary structures.
- 1990:The first exoplanets were discovered around Pulsar B1257+12
- 1997: Lunar surface ice in polar regions
- 2008: Detection of pre-biotic molecules in galaxies
- 2011: increase the known gaseous galaxies by ~ 10 fold
- Now: the major timing machine for gravitational wave detection, solving missing satellite problem, search for extraterrestrial intelligence, map the ISM Milkyway ....

Hulse-Taylor Pulsar Survey

- Sept. 1972: JHT proposal to NSF: A High Sensitivity Survey to Detect New Pulsars ($33,557)

"It would be of (very) high significance to find even one *example of a pulsar in a binary system, for measurement of its parameters could yield the pulsar mass, an extremely important number."*

- 2 × 32 × 250 kHz filter bank receiver
- Modcomp II/25 "mini-computer"
  memory 16k words
  32-channel multiplexer, A/D
  8k real-to-complex FFT in 1.9 s
- 2-d digital search (Period, Dispersion)
  Fast TREE algorithm for DM
  Incoherent harmonic summing for P

Giant Single Dish: Why?

- Cosmology
- Galaxy Evolution
- ISM and Star Formation
- Maser and Spectroscopy
- Planetary and Exoplanet

"World's Largest Telescope"

naturenews

nature news home | news archive | specials | opinion | features | news blog

Published online 4 February 2009 | Nature 457, 640 (2009) | doi:10.1038/457640d

News in brief

World's largest telescope under construction

China has begun building the biggest radio telescope in the world, the Five-hundred-meter Aperture Spherical Telescope (FAST). Sitting in a natural bowl-shaped depression in a remote region of Guizhou province, southwestern China, FAST is due to be completed in 2014.

China's National Astronomical Observatories will use the exquisite resolution of the 700-million-yuan (US$102-million) facility to identify distant pulsars and galaxies in the low-gigahertz range of the radio spectrum.

FAST will unseat the Arecibo radio telescope in Puerto Rico as the biggest single eye on the sky — although it will not be able to match the resolution of multiple-antenna telescopes such as the Very Large Array in New Mexico and the Atacama Large Millimeter/submillimeter Array (ALMA) in Chile (currently under construction).

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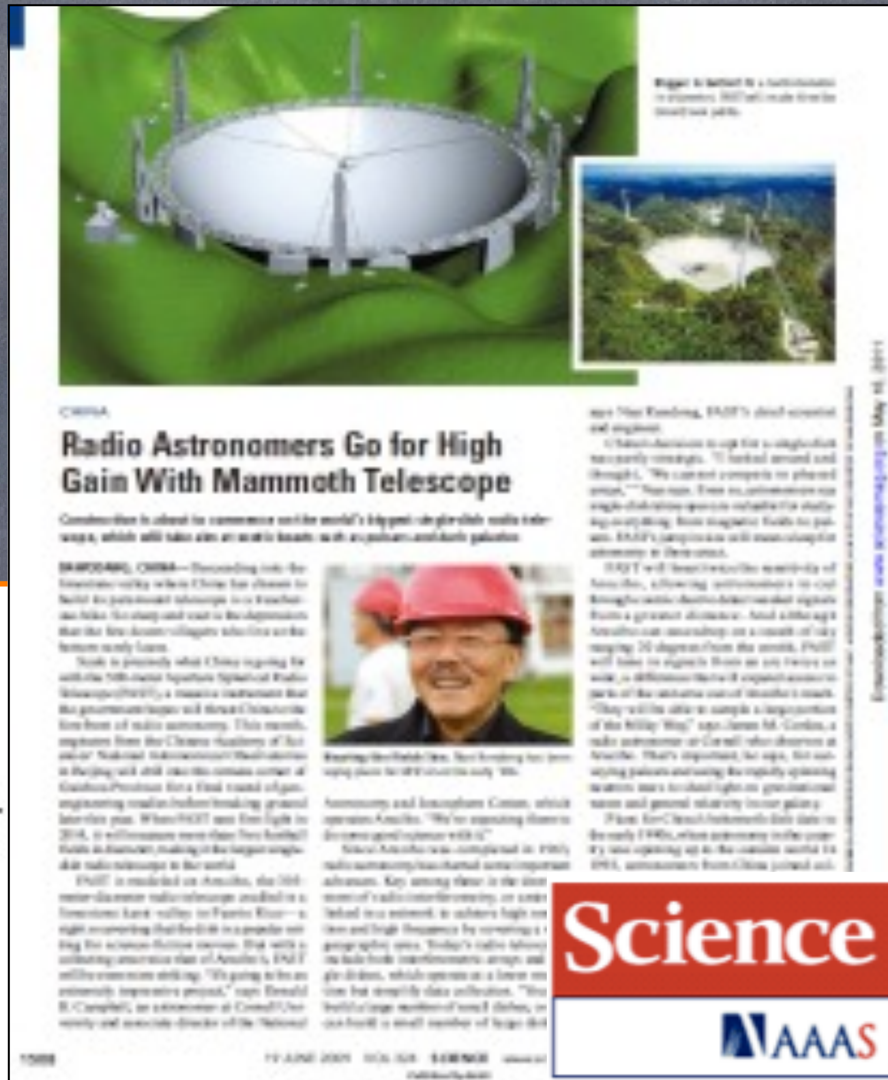


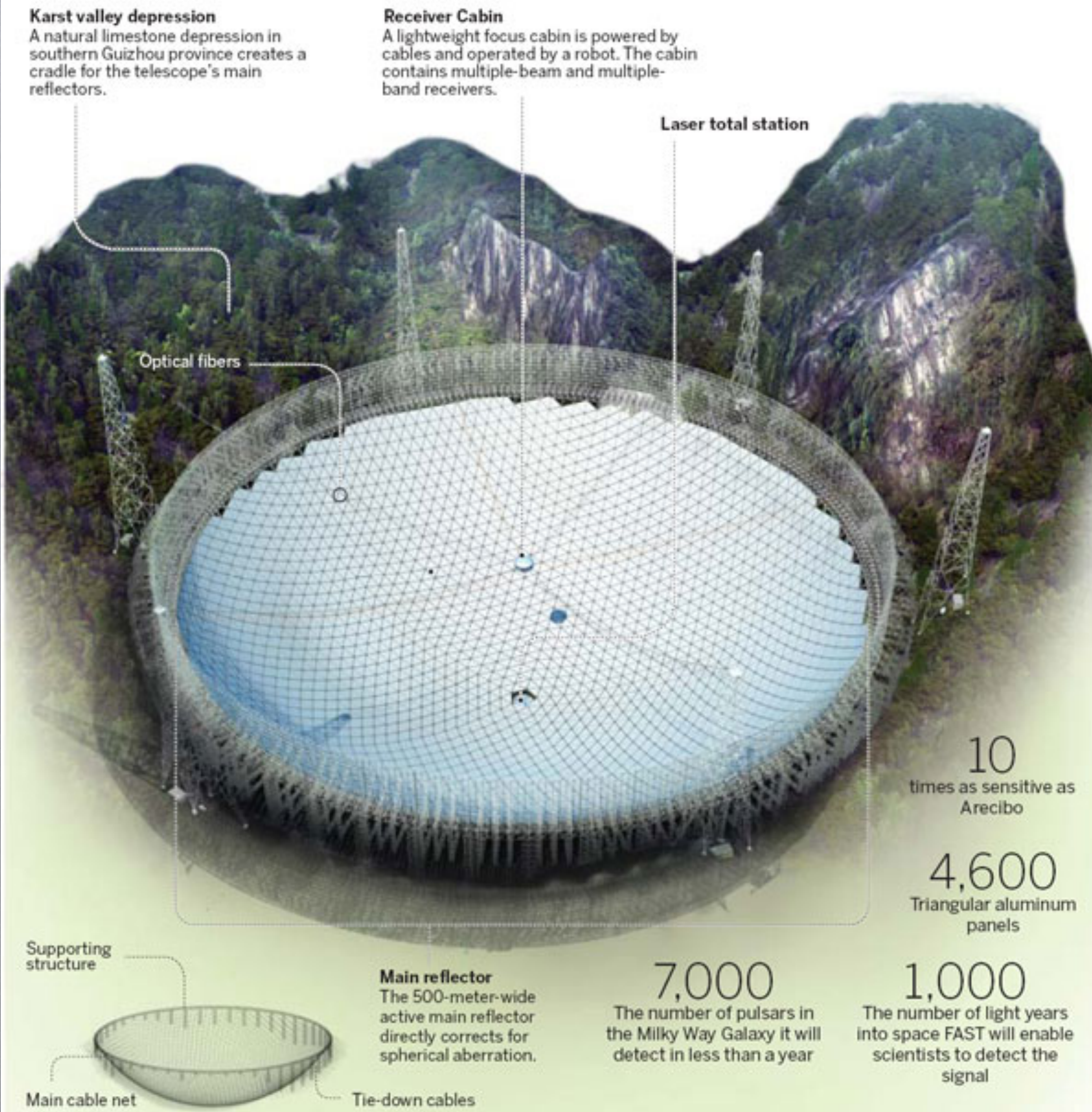
《New Scientist》

"Open the giant eye to the radio sky"

A BIG EYE ON THE SKY

500-meter aperture spherical radio telescope (FAST)

- Surveys neutral hydrogen in the Milky way and other galaxies
- Detects new galactic and extragalactic pulsars
- Finds and researches the first shining stars
- Finds out where extraterrestrial life might exist in space
- Detects dark energy and helps us understand the evolution of galaxies



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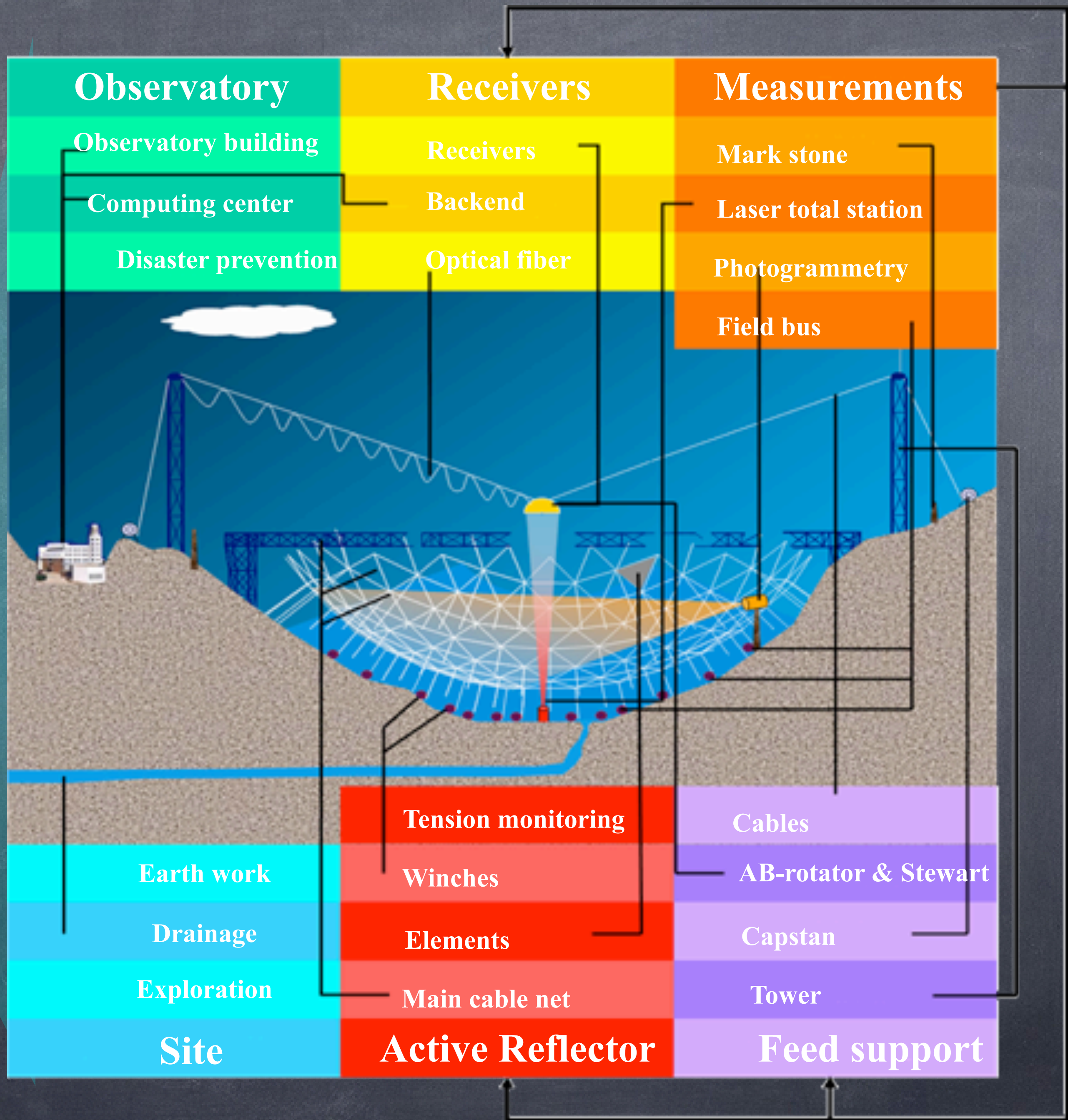
6 Subsystems

- Site
- Active Reflector
- Feed support
- Measurements
- Receivers
- Observatory



Active Reflectors

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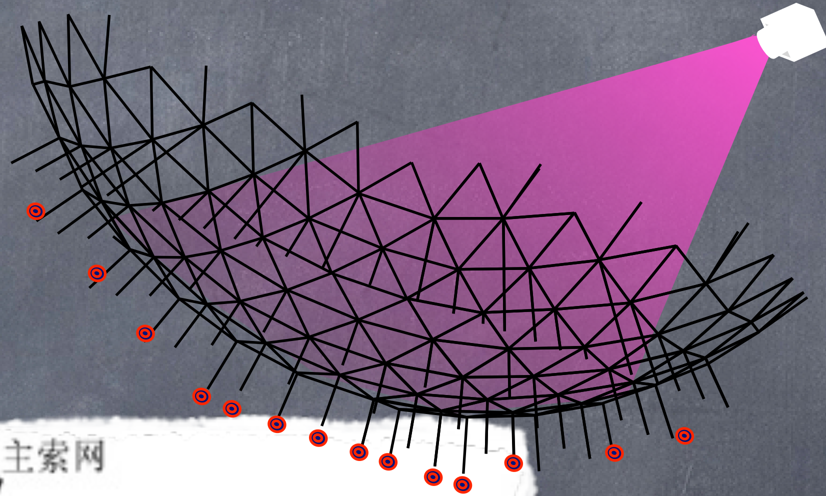
- 500m girder built around hills
- 50 pillars
- Backup consists of 7000 steel strands
- 2300 down tied cables driven by
- winches anchored into ground



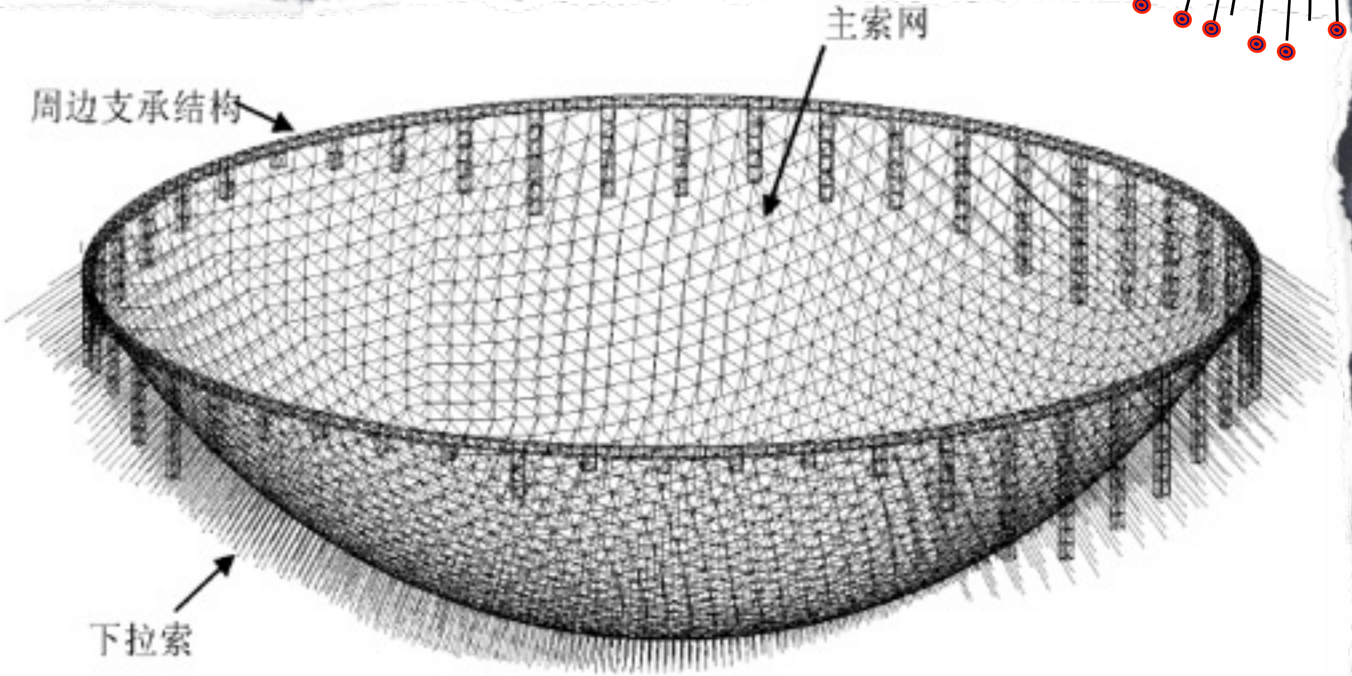
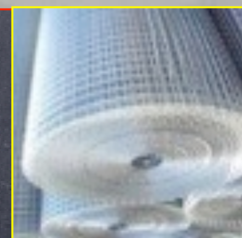
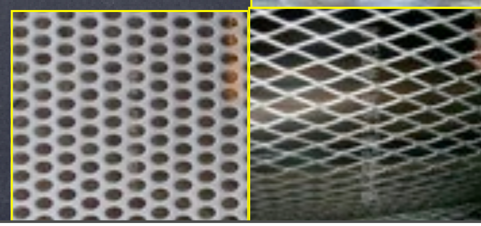


图 2−3 整体索网结构

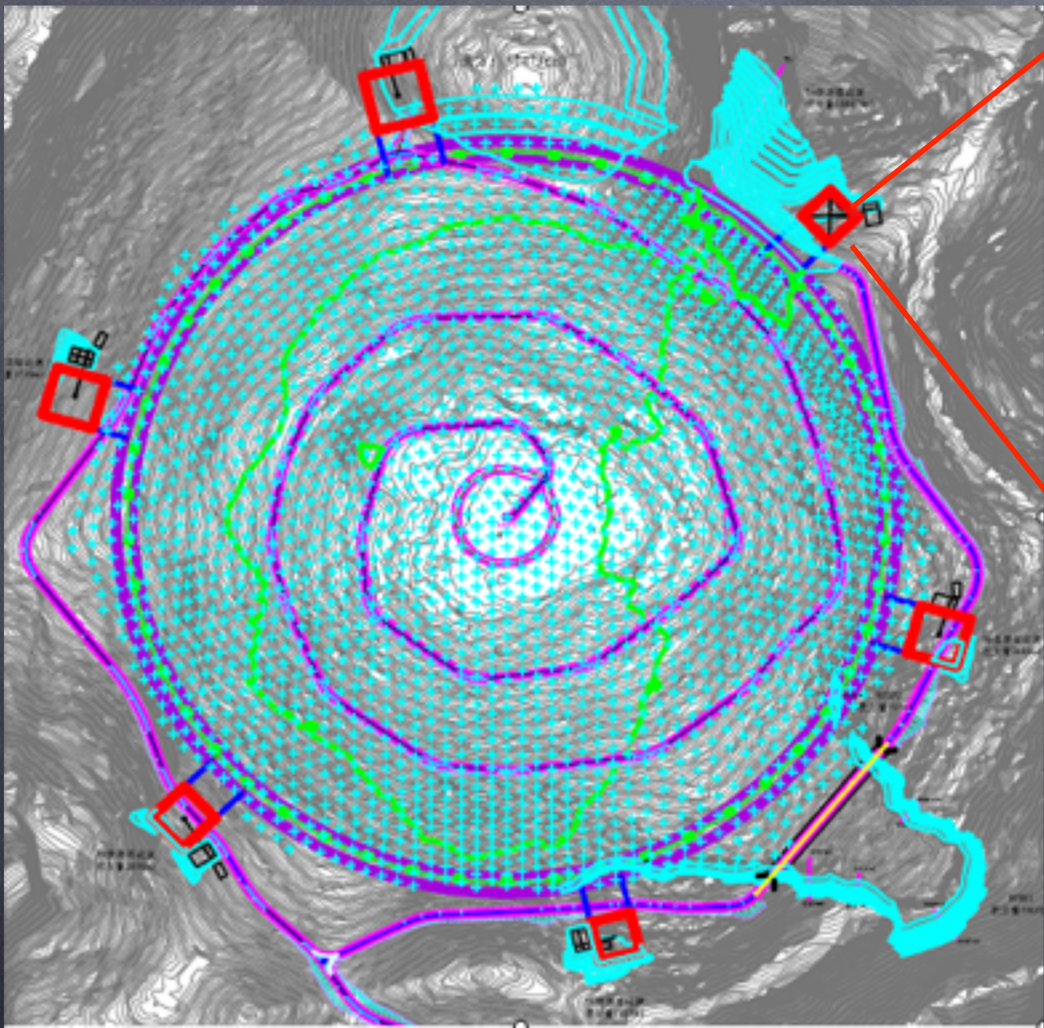
Reflector and prototyping

- triangular panels, side ~11m, manufacturing error ~ 2.0 mm weight ~10kg/m^2
- backup: single rear rib, spatial truss, suspended by cable
- skin: perforated aluminum sheet, expended mesh, or welded stand less steel





Tower Base Layout



顺时针旋转23度六塔开挖布局图

Girder "Ring"

Now...

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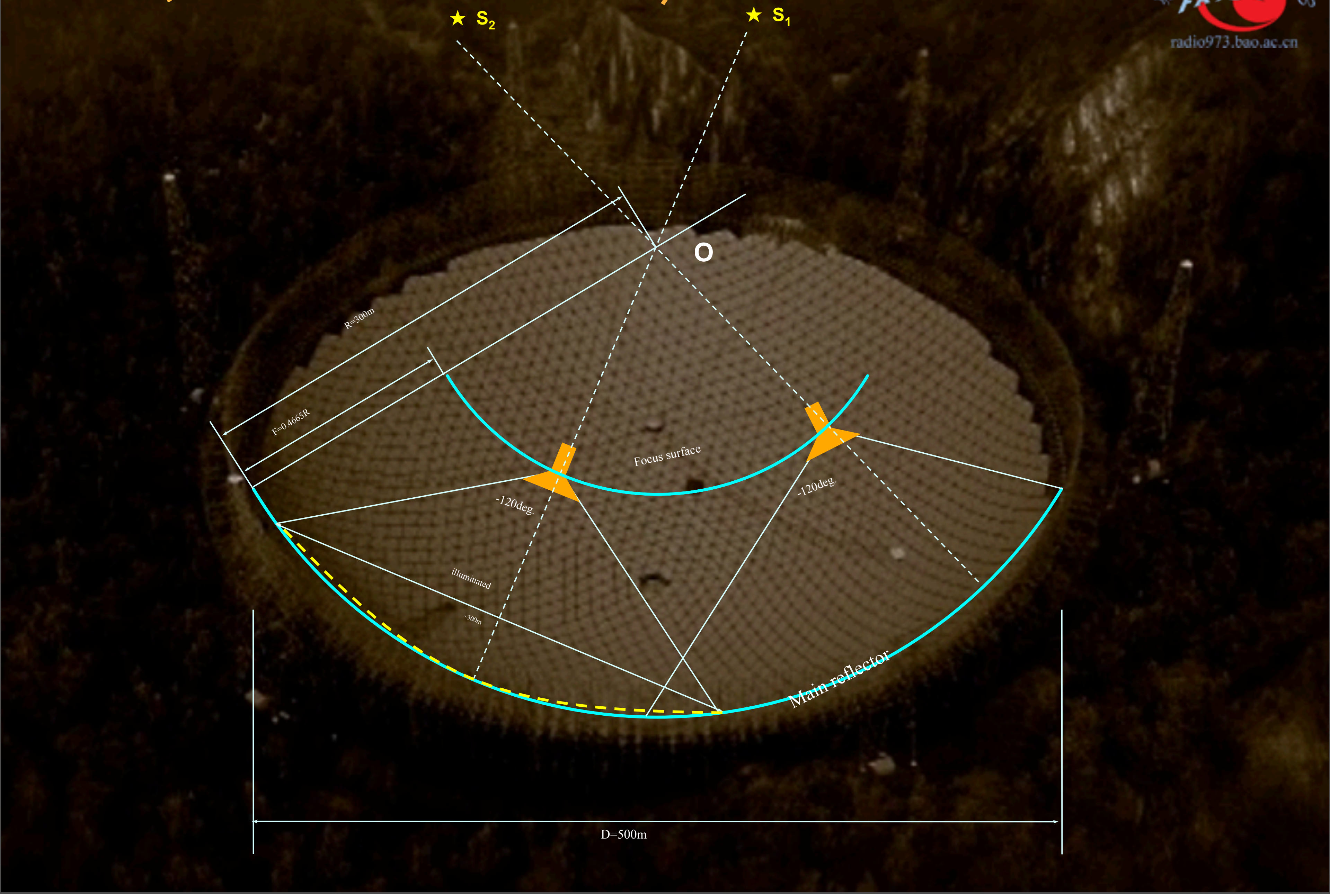
2014-May

Right Now ...

Optical Geometry



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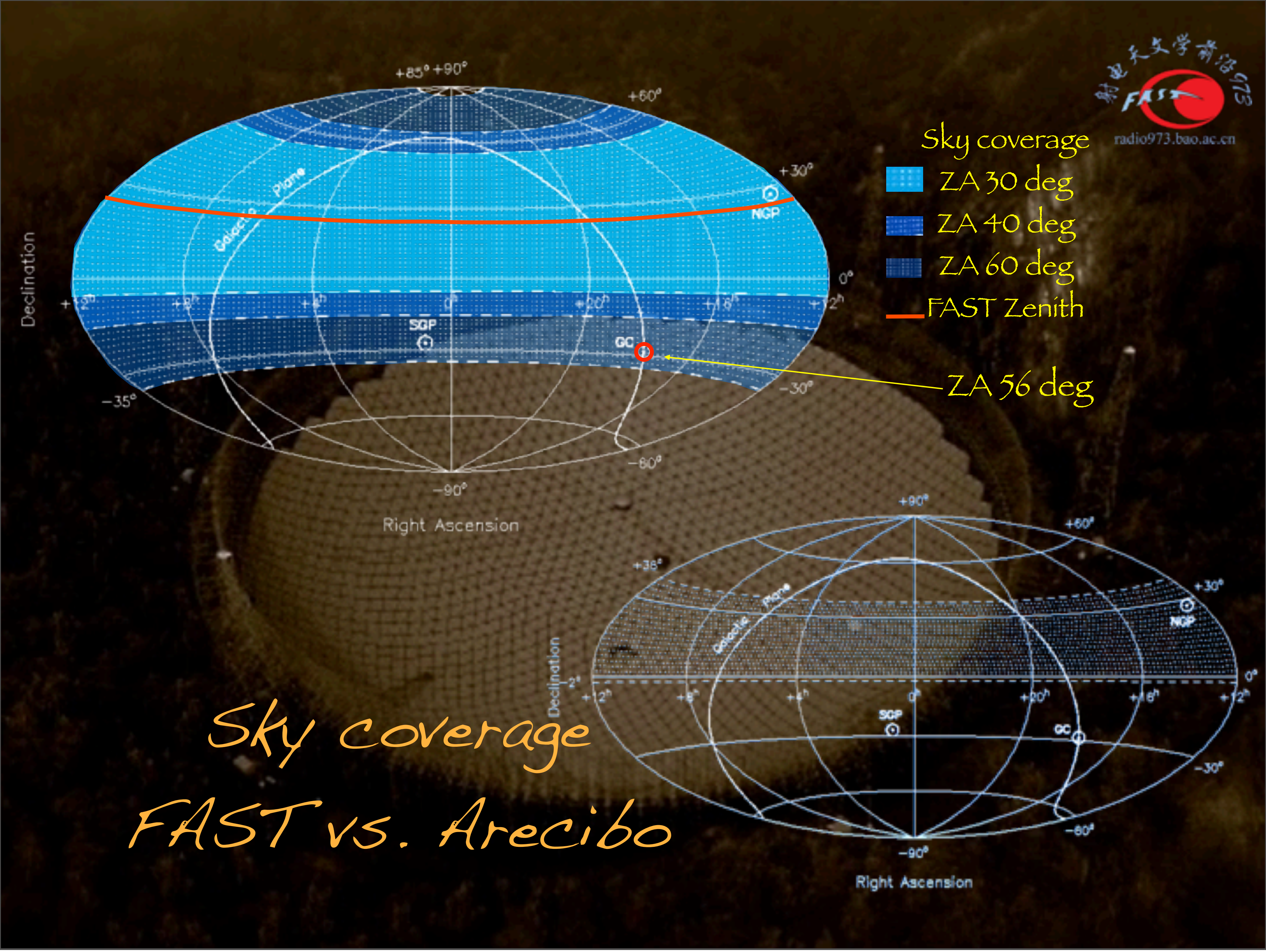

Sky coverage
FAST vs. Arecibo
Sky coverage
ZA 30 deg
ZA 40 deg
ZA 60 deg
FAST Zenith
ZA 56 deg
radio973.bao.ac.cn
+85° +90°
+60°
+30°
0°
-30°
-35°
-60°
-90°
NGP
SGP
GC
Galactic Plane
Declination
Right Ascension
+12h
+8h
+4h
0h
+20h
+16h
+12h
+90°
+60°
+38°
+30°
0°
-2°
-30°
-60°
-90°
NGP
SGP
GC
Galactic Plane
Declination
Right Ascension

Technical Specification

Spherical reflector：Radius~300m, Aperture~500m

Illuminated aperture：D_{ill}=300m

Focal ratio：f/D =0.467

Sky coverage：zenith angle 40° up to 60°with efficiency loss,tracking hours: 6h

Frequency：70MHz ~ 3 GHz, up to 8GHz after upgrade

Sensitivity (L-Band) ：A/T~2000, T~20 K

Resolution (L-Band) ：2.9′

Multi-beam (L-Band) ：19, beam number of future FPA >100

Slewing：<10min

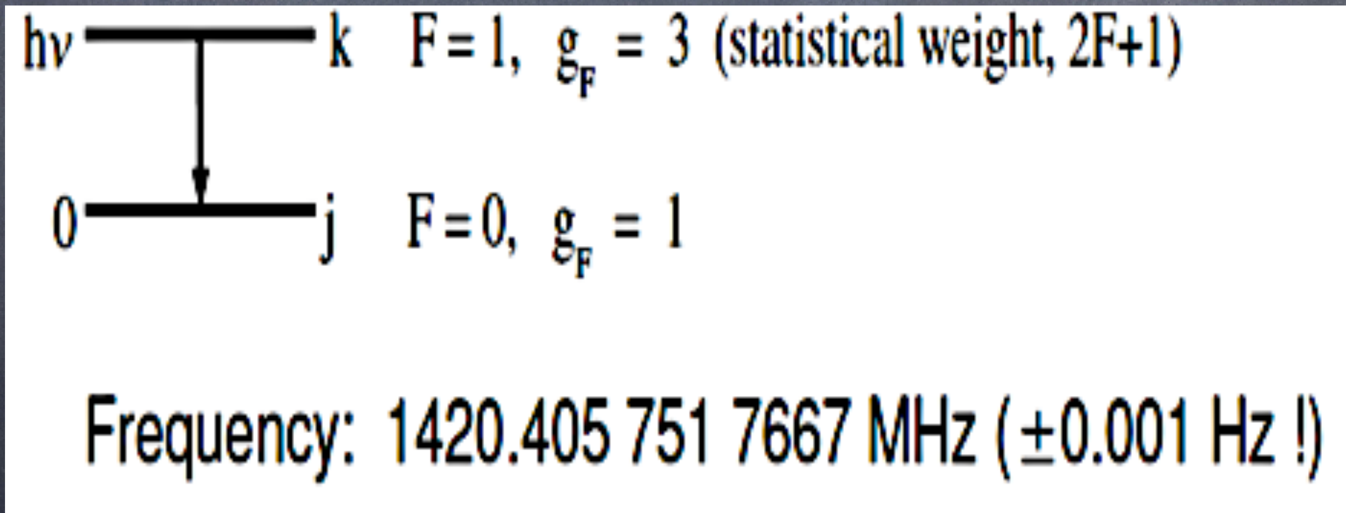
Pointing accuracy：8″

Observables

70MHz~3GHz Complete Coverage

a) Pulsar

b) HI 21cm Hyperfine transition



c) Other atomic and molecular lines, radio continuum, maser

Possible Discoveries

a) special pulsars: pulsar-blackhole system, detection of extra-galactic pulsar beyond LMC

b) HI Disks and halos in dark galaxies and diffuse HI

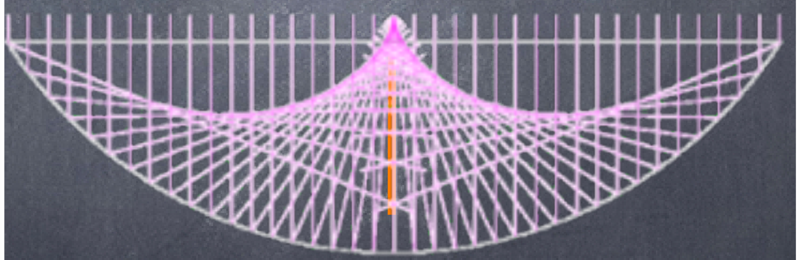
c) New content of the ISM

including new molecules,

especially prebiotic ones

High redshift masers

Early Science
Spherical Optics?



other) First detection of radio emission of exoplanet

Early Science: Challenge

Main Technical Difficulties

Error Budget ~5mm

Light Path ~ 150m/300m

beam shape, calibration, and EMC control

Early Science Targets

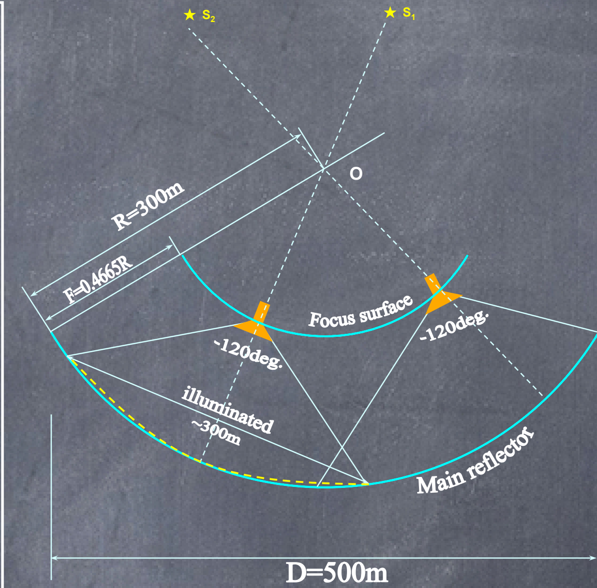
Low Frequency

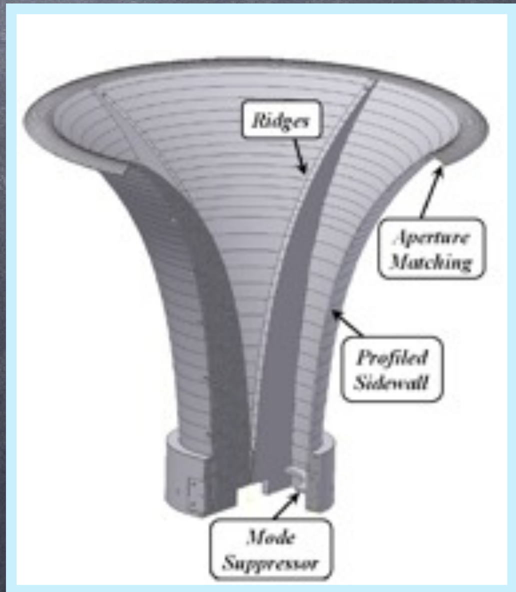
Point Source

Time/Frequency Domain Characteristic

An Ultra-wide Band Recevier

Li, Nan, Pan 2012, IAUS291





Key Early Sciences

a) Pulsar Search in Nearby Galaxies and Globular Clusters

M31 is out of Arecibo Coverage

b) OH Mega-Maser Search

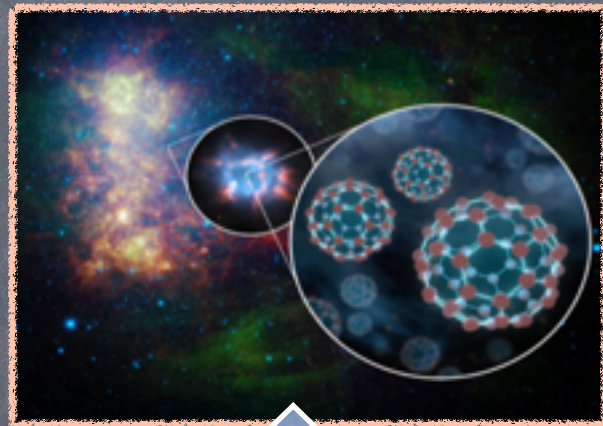
FAST 2.3xArecibo Sky; growing IR Galaxy catalogues

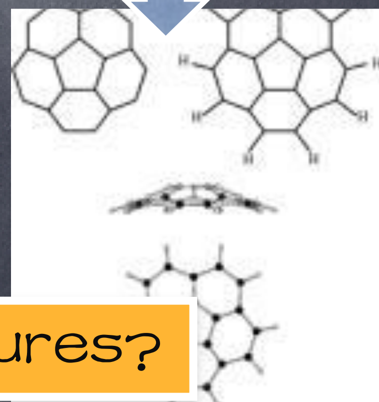
c) Orion Spectral Line Survey

Orion is out of Arecibo Sky; Herschel Orion Source Model

Planetary Nebular: C_{60}和C_{70}

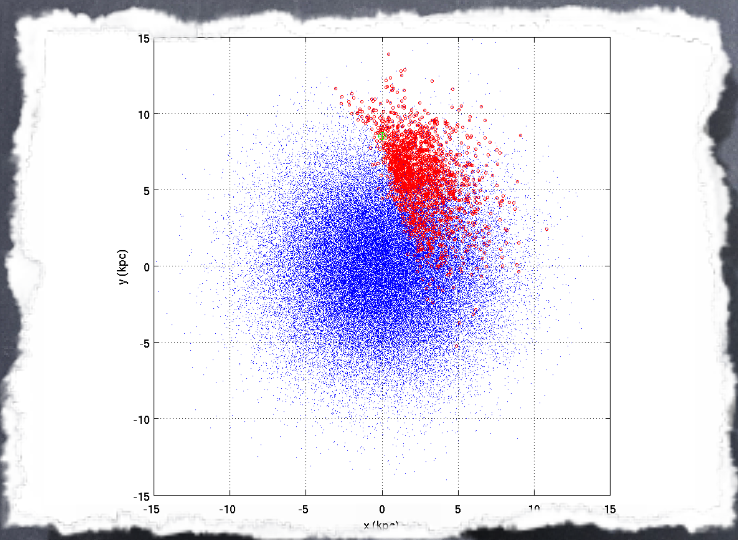
Cami et al. 2010, **Science** 329, 1180





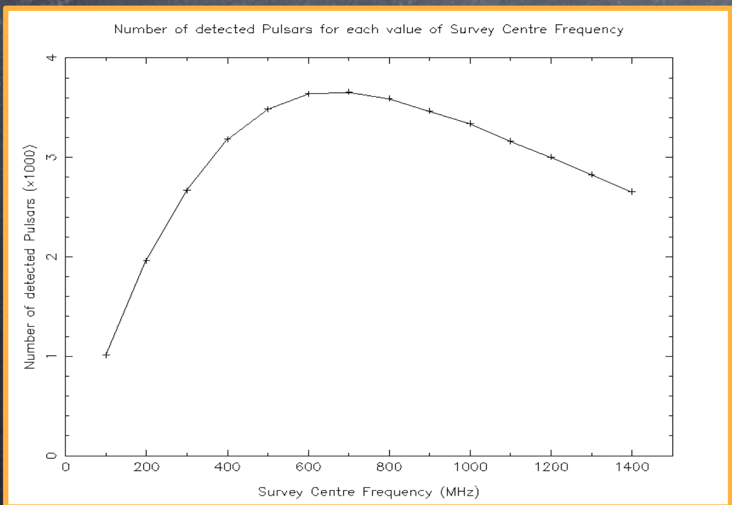
Radio Detection of cosmic carbon structures?

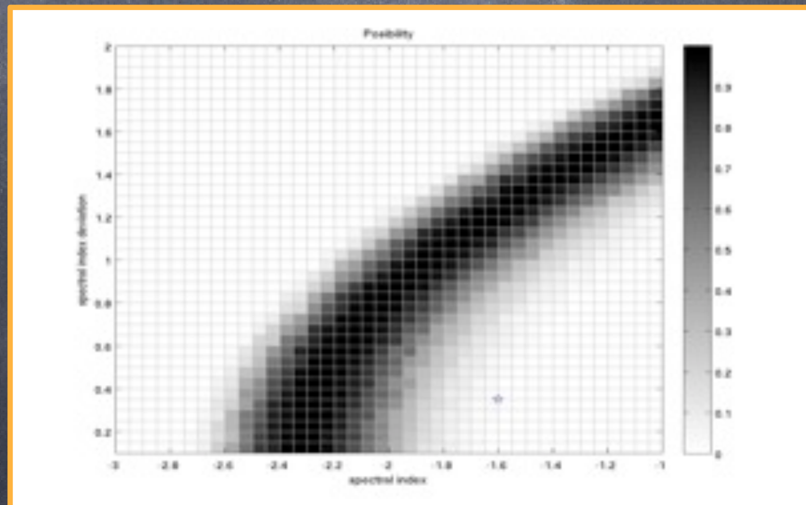
a) FAST Drift Scan Surveys



- Drift scan whole FAST sky (~58% whole sky)
- ~2000 pulsars, 300 MSP
- +5year timing => 3 x improvement over current IPTA

Yue et al. 2014 in prep.
《RAA》 - FAST special issue





6) OH Mega-maser Search

FAST (Nan, Li, Jin et al. 2011, IJMPD, 20, 1)

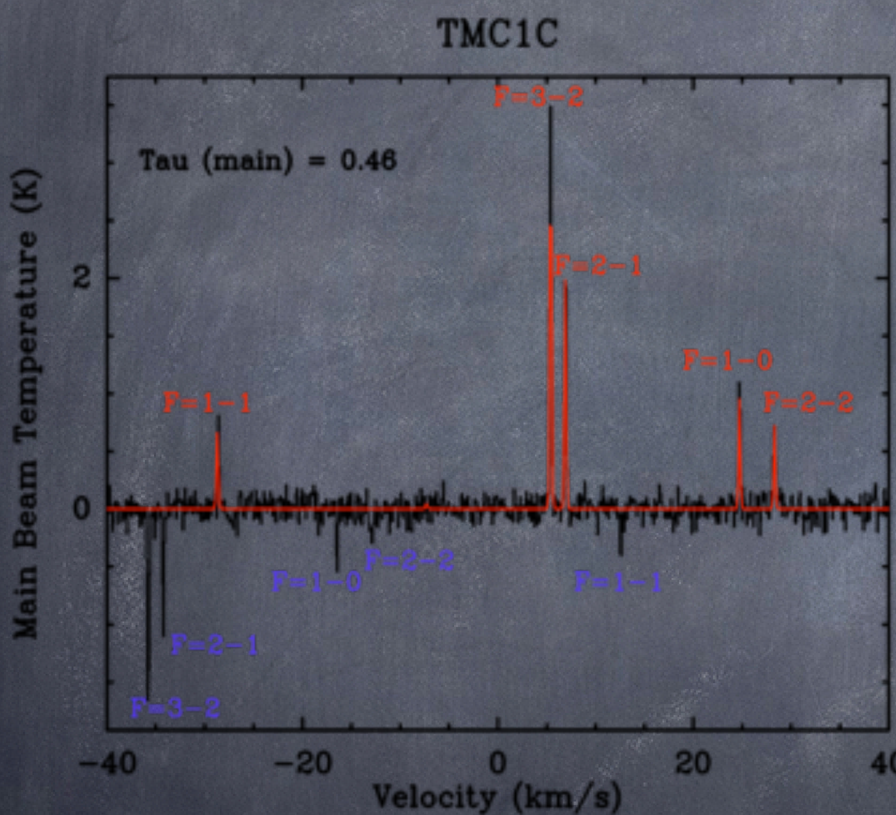
- 3 better raw sensitivity
- ~10 higher surveying speed
- 2-3 times sky coverage $-15^\circ < \delta < 65^\circ$

Expectations of FAST:

Zhang et al. 2014 in prep. 《RAA》 - FAST special issue

- Numbers of OHM: 10~20 times? N>1000
- High z OHM: OHM to z~2; Giga-M: to z~4
- Lensed OHM at z>1

c) Carbon-Chain Molecules



Li & Goldsmith 2012, ApJ

HC_3N

2-1 18.2 GHz

GBT

A&A 553, A119 (2013)
DOI: 10.1051/0004-6361/201220822
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Astronomy & Astrophysics

Formation and evolution of interstellar filaments

Hints from velocity dispersion measurements★,★★

D. Arzoumanian[1,2], Ph. André[1], N. Peretto[1], and V. Könyves[1,2]

small along the crest of the filament (cf. right panel of Fig. 5), with an average velocity dispersion (0.25 ± 0.03) km s^{-1}. This is consistent with previous observations of a few low-density filaments showing that these structures have velocity dispersions close to the thermal velocity dispersion ~0.2 km s^{-1} for T = 10 K (cf. Hily-Blant 2004; Hily-Blant & Falgarone 2009) and which do not vary much along their length (Hacar & Tafalla 2011; Pineda et al. 2011). Recently, Li & Goldsmith (2012) studied the Taurus B213 filament and found that it is characterized by a coherent velocity dispersion of about ~0.3 km s^{-1}.

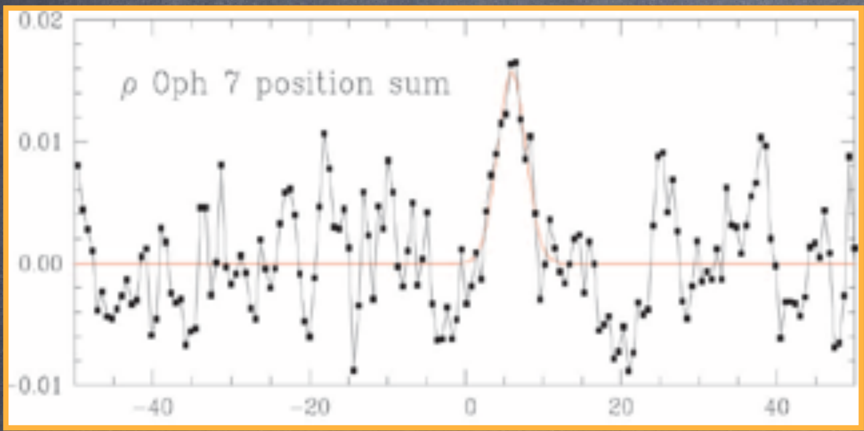
These results suggest that the velocity dispersion observed at a single position toward a filament provides a reasonably good estimate of the velocity dispersion of the entire filament[5]. Nevertheless mapping observations of a broader sample

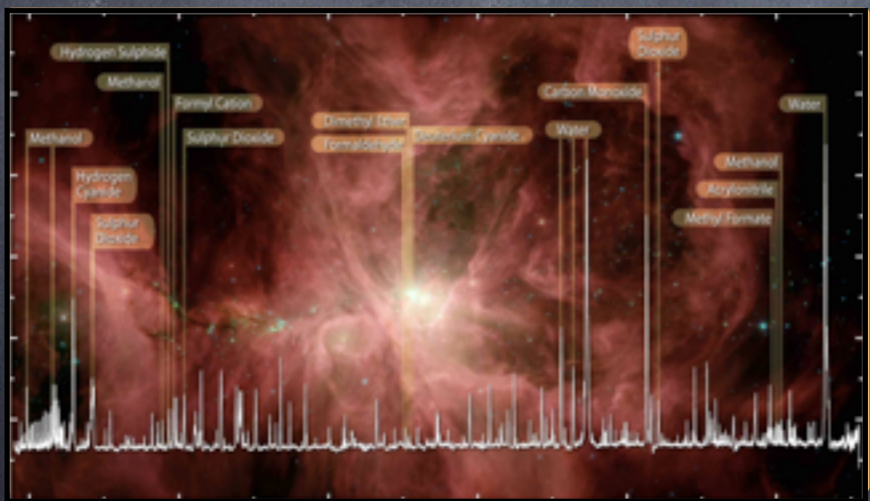
[5] An interstellar filament is an elongated structure characterized by small column density variations along its crest (less than a factor of 3; see Fig. 3-left). Therefore, the velocity dispersion variations induced by the trend $\sigma_{tot} \propto \Sigma_0^{0.5}$ found in Sect. 5 below for supercritical filaments remain small (≪2) along a given filament.

Arzoumanian et al.: Li & Goldsmith (2012) ...Taurus B213 filament is characterized by a coherent dispersion ...

c) Exploring Low Freq. Radio Spectrum

Goldsmith, Li, Bergin et al. 2002, ApJ





HIFI Oxygen Project
Goldsmith et al. 2012

Orion Nebula:
HEXOS (Bergin et al.)

New Molecules

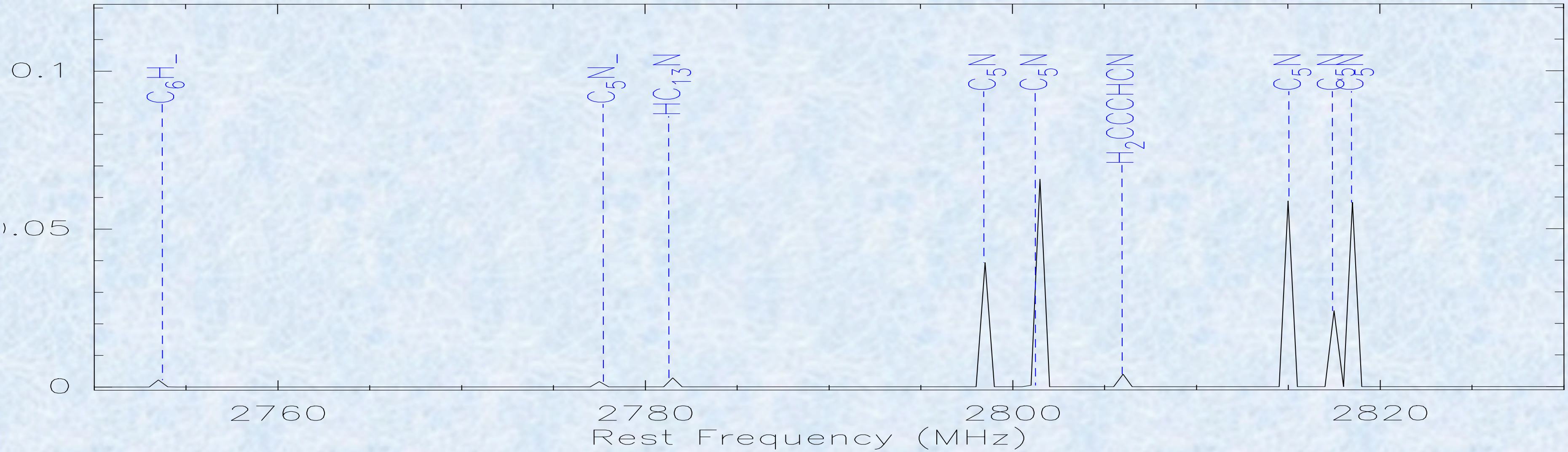
? ? ?

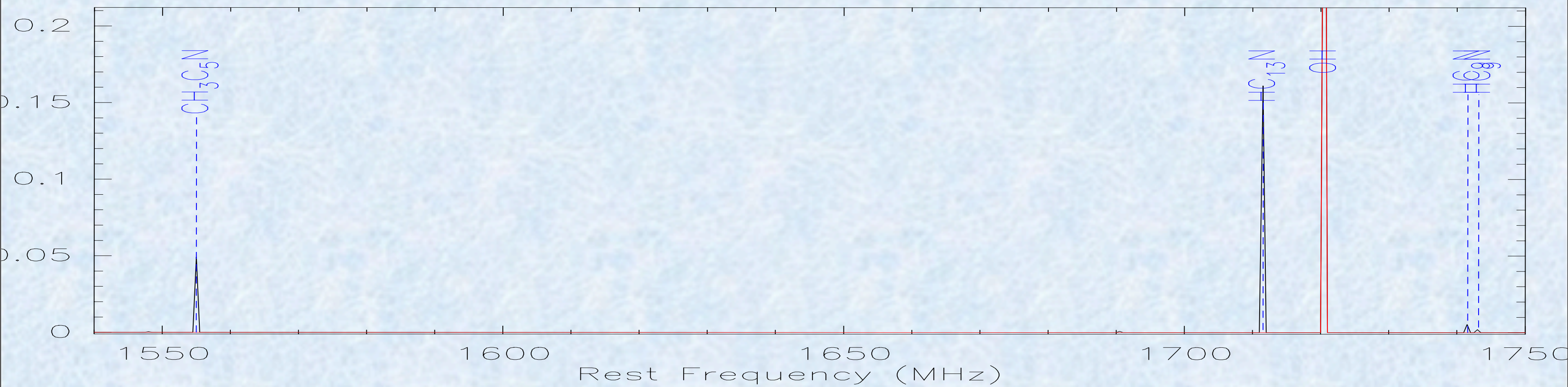
Li, Qin, Bergin in prep.

《RAA》 - FAST special issue

- Carbon chains
- Negative Ions
- Nano-Diamonds and PAH?

The Orion Source Model





FAST Special Issue

Clarify FAST Science Goals and Technical Requirements

=> 《RAA》 Special Issue：ISM, Pulsar, Galaxy Surveys, Cosmology, Spectroscopy, etc.

- 42 proposals
- First authors from 5 countries
- Co-authors from most of the national radio observatories

Research in Astron. Astrophys. 2013 Vol. 0 No. XX, 000–000
http://www.raa-journal.org http://www.iop.org/journals/raa

Research in Astronomy and Astrophysics

Simulation of millisecond pulsar population and FAST sensitivity on gravitational wave detection

Y.L. Yue, K.J. Lee, D.R. Lorimer, F.A. Jenet and D. Li

National Astronomical Observatories, CAS; ylyue@nao.cas.cn

Abstract A new simulation millisecond pulsar (MSP) population using PSRPOP is carried out to estimate FAST sensitivity on gravitational wave detection. The simulation is based on three large sky coverage pulsar surveys: Parkes multi-beam survey, Parkes 70cm survey and Green Bank North Celestial Cap (GBNCC) survey. We found that MSP has

"973" Science Teams

Observers lead, collaborating with theorists, modeling experts, and instrumentalists, work toward a concrete definition of FAST key programs and early science goals.

- Pulsar Observations and Theories (Xu@PKU)
- From Atoms to Star: ISM and Star Formation (Li@NAOC)
- Galaxy Evolution and Structures (Zhu@NAOC)
- Cosmology and Dark Matter (Zhu@BNU)
- Radio Spectroscopy and Masers (Wang@SHAO)
- Multi-beam System and VLBI (Jin@NAOC)

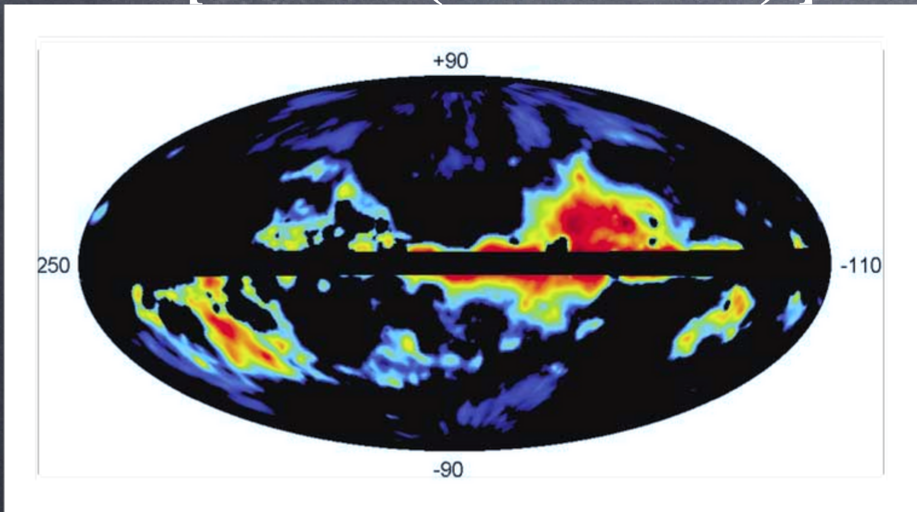
2013.5.14: NRAO

5月14日，国家天文台台长严俊与美国射电天文台台长Anthony Beasley签署了国家天文台与美国国家射电天文台合作备忘录(MoU)。双方的合作覆盖射电天文学科学与技术研究的多个领域，特别是大天线及相关设备的建造运行技术和FAST与GBT、JVLA等NRAO所属设备的协同观测计划。

Dark Molecular Gas?

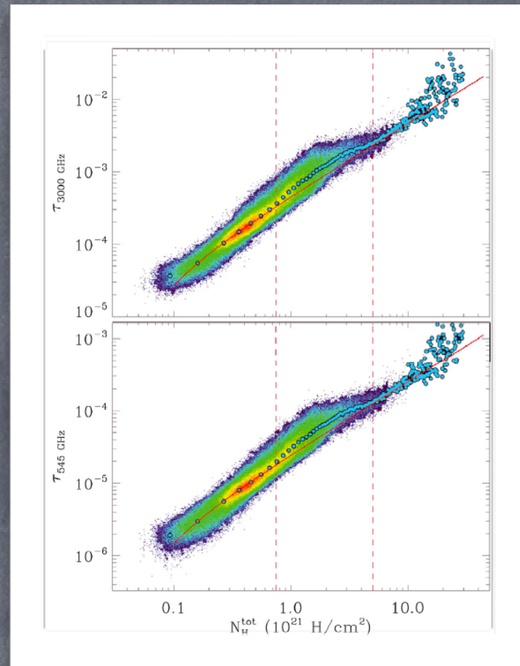
IRAS

[IRAS – (HI + X*CO)]



Planck

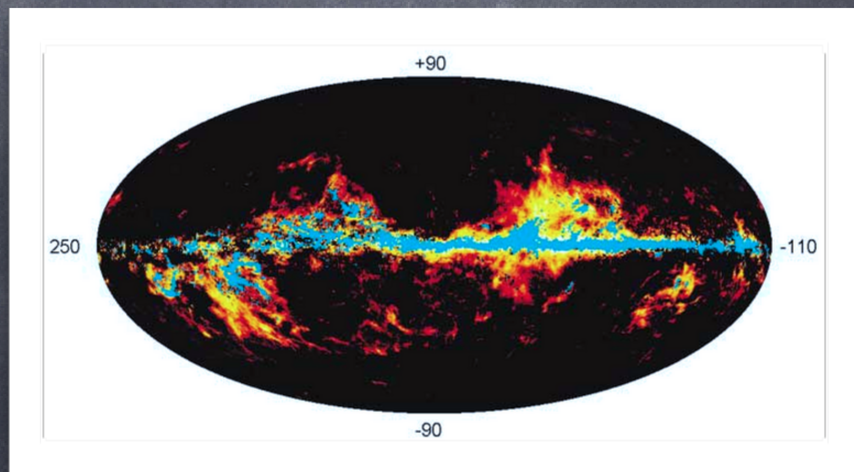
Dust vs [HI+X*CO]



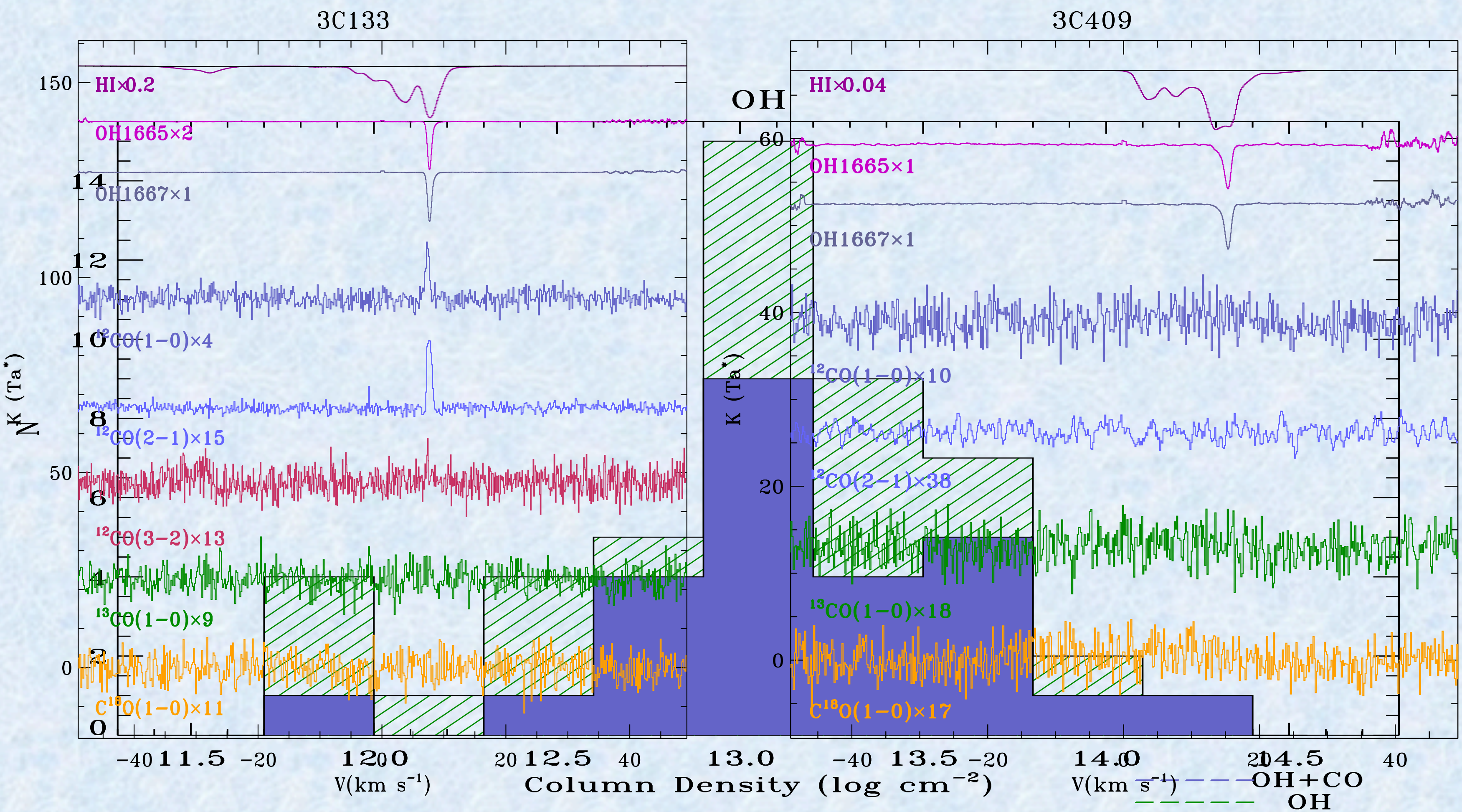
EGRET gamma rays

[CR/H-nuclei] interaction

Grenier et al. 2005 Science



Arecibo+Delingha+CSO



Xu, Li, Heiles 2014, in prep.

"When we were talking about building [the telescope] back in the late '50s, we were told by eminent authorities it couldn't be done. We were in the position of trying to do something that was impossible, and it took a lot of guts. . . . We were young enough that we didn't know we couldn't do it. But we were in the right place at the right time and had the right idea and the right preparation. "

William Gordon, 2003