



之江实验室
ZHEJIANG LAB

天文大数据智能计算与服务 平台

张旭

2022.07.19

国家战略科技力量



浙江省人民政府



浙江大学



阿里巴巴集团

计算天文团队：

目前全职，博士后，项目聘用等共25人

研究目标：

依托国家大科学装置FAST，利用FAST历史最强绝对灵敏度，深度、智能挖掘射电观测数据，引领国际的宇宙“时间前沿”瞬变天体物理研究

研究方向：

“快速射电暴及脉冲星搜寻探测模型”

“天文实时算法与终端研制”

“天文数据处理模型及算法”

“可视化数据服务平台搭建”



FAST in Space

*Di Li, Pei Wang, Lei Qian, Marko Krco, Alex Dunning,
Peng Jiang, Youling Yue, Chenjin Jin, Yan Zhu,
Zhichen Pan, and Rendong Nan*

Having achieved “first light” immediately prior to the ceremony introducing it on 25 September 2016, China’s 500-m aperture spherical radio telescope (FAST) is now being kept busy with commissions. Its innovative design requires ~1,000 points to be measured and driven instead of just the two axes of motion, e.g., azimuth and elevation for most conventional antennas, to realize pointing and tracking. We have devised a survey plan to exploit the full sensitivity of FAST, while minimizing the complexities involved during system operation.

Di Li (dili@nao.cas.cn), Pei Wang (wangpei@nao.cas.cn), Lei Qian (lqian@bao.ac.cn), Marko Krco (marko@nao.cas.cn), Peng Jiang (pjiang@nao.cas.cn), Youling Yue (ylyue@nao.cas.cn), Chenjin Jin (cjin@bao.ac.cn), Yan Zhu (zhuyan@nao.cas.cn), Zhichen Pan (panzc@bao.ac.cn), and Rendong Nan (nrnd@bao.ac.cn) are with the National Astronomical Observatories, Chinese Academy of Sciences, Beijing. Alex Dunning (Alex.Dunning@csiro.au) is with the Commonwealth Scientific and Industrial Research Organization (CSIRO), Astronomy and Space Science, Epping, New South Wales, Australia.

Digital Object Identifier 10.1109/MMM.2018.2802178
Date of publication: 6 April 2018

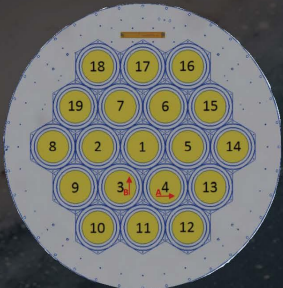
Commensal Radio Astronomy FAST Survey



unprecedented commensality
pulsar, galaxy, imaging, and FRB

利用高时频噪声注入自主专利技术，**世界首创**了脉冲星搜索、中性氢成像、星系搜索和快速射电暴同时观测巡天。

FAST 'big data' stream
pulsar: $19 \times 8\text{bit} \times 4 \times 4\text{k} \times 2 \times 10^4$ per second
HI: $19 \times 8\text{bit} \times 4 \times 1\text{M} \times 2 / \text{s}$



- 6 GB/s
- 25TB/h
- 550TB/day
- 10 PB/ year



FAST in Space

Di Li, Pei Wang, Lei Qian, Marko Krco, Alex Dunning, Peng Jiang, Youling Yue, Chenjin Jin, Yan Zhu, Zhichen Pan, and Rendong Nan

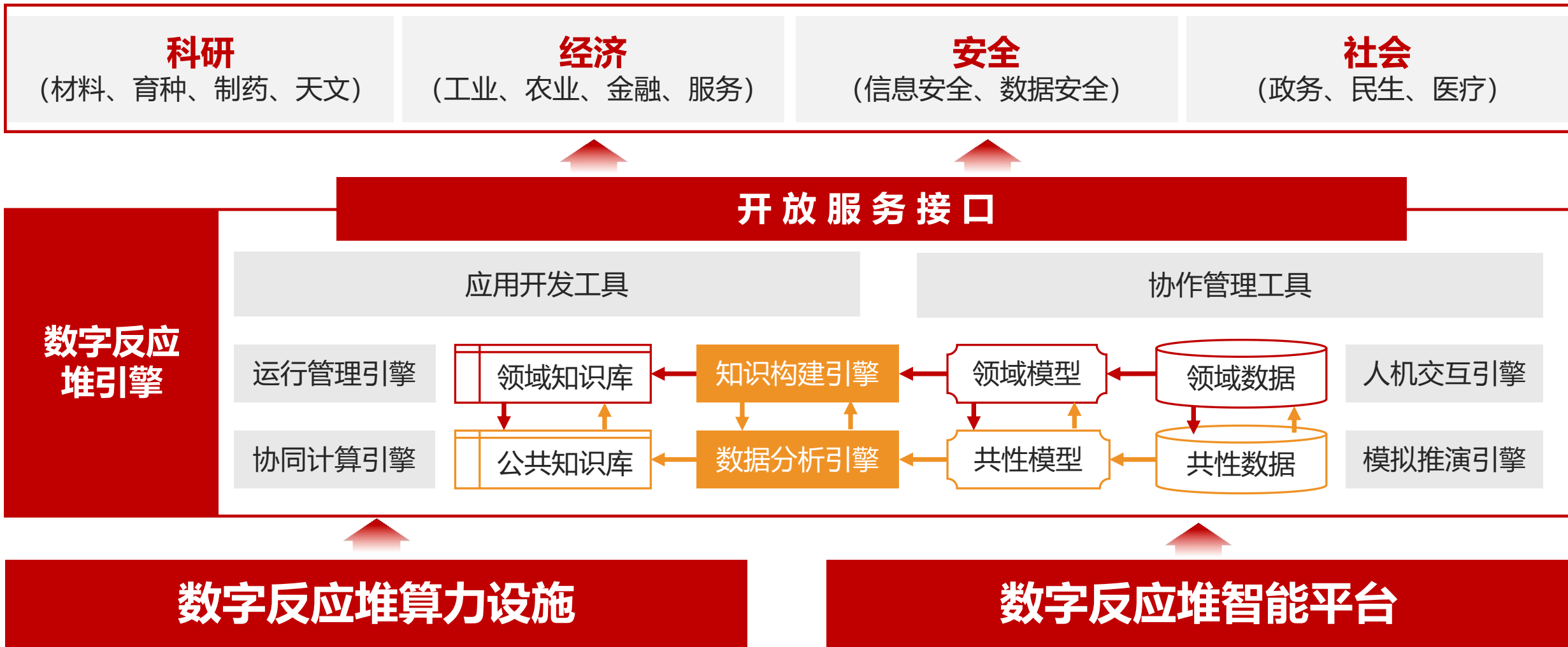
Having achieved "first light" immediately prior to the ceremony introducing it on 25 September 2016, China's 500-m aperture spherical radio telescope (FAST) is now being kept busy with commissions. Its innovative design requires ~1000 points to be measured and driven instead of just the two axes of motion, e.g., azimuth and elevation for most conventional antennas, to realize pointing and tracking. We have devised a survey plan to exploit the full sensitivity of FAST, while minimizing the complexities involved during system operation.

Di Li (dli@nenu.cn), Pei Wang (wangpe@nenu.cn), Lei Qian (lqian@nenu.cn), Marko Krco (marko@nenu.cn), Peng Jiang (jiangp@nenu.cn)

The Commensal Radio Astronomy FAST Survey
 FAST多科学目标同时扫描巡天

Li et al. 2018, Invited Review
 IEEE Microwave, Vol 19, Issue 3, p112

智能计算数字反应堆的功能形态



国家实验室平台

总体目标 / Vision & Mission

01

整合协同一批重大科学基础设施

02

汇聚一批全球顶尖的研发团队

03

打造一个国际一流的基础研究基地

04

取得一批具有影响力的重大共性技术成果

05

支撑引领具有世界竞争力的创新型产业集群发展

06

建成国家实验室

申请国家天文科学数据中心之江实验室分中心

- 接受国家天文科学数据中心的指导
- 提供充足的数据储存和计算分析能力
- 以分中心名义积极参与各类科技计划
- 计算天文团队基于反应堆不断迭代建设分中心

nature

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Article | [Open Access](#) | Published: 08 June 2022

A repeating fast radio burst associated with a persistent radio source

C.-H. Niu, K. Aggarwal, ... B. Zhang + Show authors

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HOME > SCIENCE > VOL. 375, NO. 6586 > FREQUENCY-DEPENDENT POLARIZATION OF REPEATING FAST RADIO BURSTS—IMPLICATIONS FOR THEIR

REPORT RADIO ASTRONOMY

Frequency-dependent polarization of repeating fast radio bursts—implications for their origin

YI FENG, DI LI, YUAN-PEI YANG, YONGKUN ZHANG, WEIWEI ZHU, BING ZHANG, WENBIN LU, PEI WANG, SHI DAI, LEI ZHANG +17 authors Authors Info & Affiliations

nature

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nature > articles > article

Article | Published: 04 November 2020

No pulsed radio emission during a bursting phase of a Galactic magnetar

L. Lin, C. F. Zhang, P. Wang, H. Gao, X. Guan, J. L. Han, J. C. Jiang, P. Jiang, K. J. Lee, D. Li, Y. P. Mei, C. C. Mao, C. M. Ni, L. B. Ni, C. Sun, B. L. Wang, T. J. Wang, M. Xu, J. L. Xu, L. M. Xu, X. M. Yang, X. D.

nature

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nature > articles > article

Article | Published: 13 October 2021

A bimodal burst energy distribution of a repeating fast radio burst source

D. Li, P. Wang, ... Y. Zhu + Show authors



2021年度中国科学十大进展
Top 10 Scientific Advances of 2021, China

主办单位：中国科学院北京中关村实验室（基础科学部）
协办单位：《中国科学》编辑部 《科技日报》编辑部
《中国科学报》编辑部 《中国科学报》编辑部
《科学网》编辑部

06 FAST捕获世界最大快速射电暴样本

FAST captures the largest set of FRB events ever detected

主要完成人：李 菂、王 培、朱炜玮、段 然、谢晓尧
主要完成单位：中国科学院国家天文台；中国科学院大学





Science 2020
BREAKTHROUGH of the YEAR

Viruses, microscopy and fast radio bursts: 10 remarkable discoveries from 2020

Highlights from News & Views published this year.

nature research



The international journal of science / 6 January 2022

nature

FIELD GUIDE

Magnetic structure of the interstellar medium reveals how stars start to form



四个主要研究方向：

“快速射电暴及脉冲星搜寻探测模型”

“天文实时算法与终端研制”

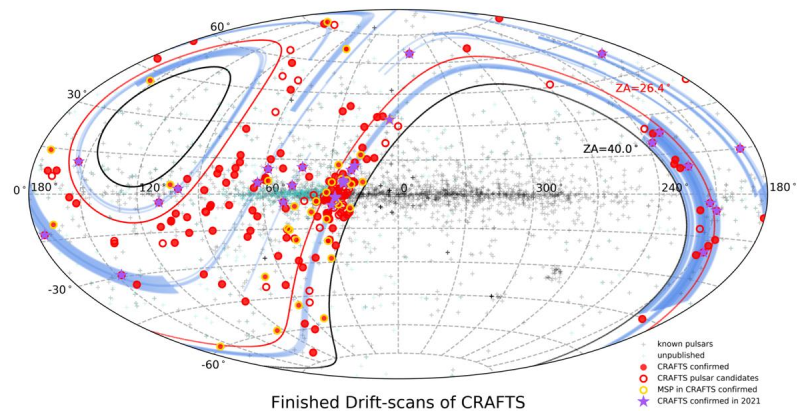
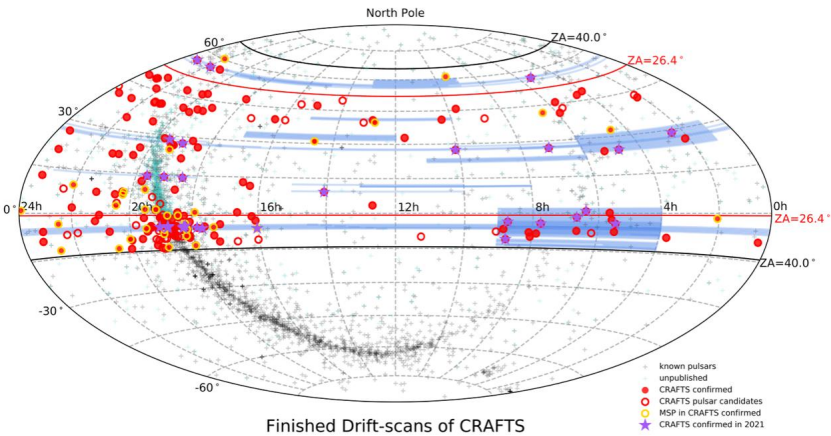
“天文数据处理模型及算法”

“可视化数据服务平台搭建”

FAST-CRAFTS 脉冲星搜索进展

验证 170颗脉冲星发现

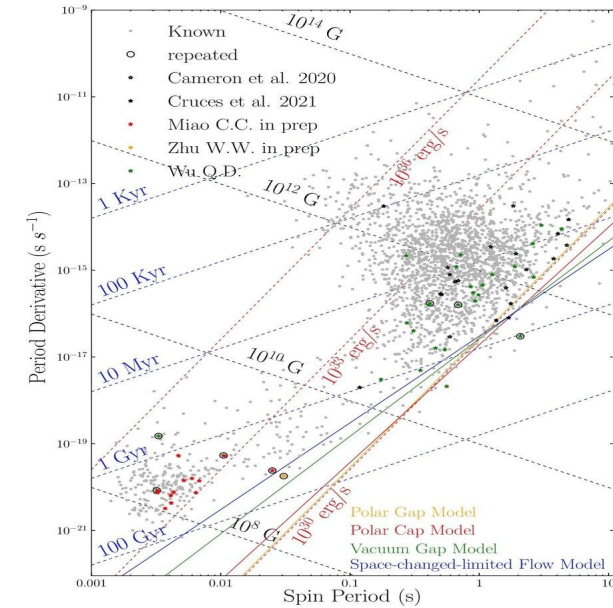
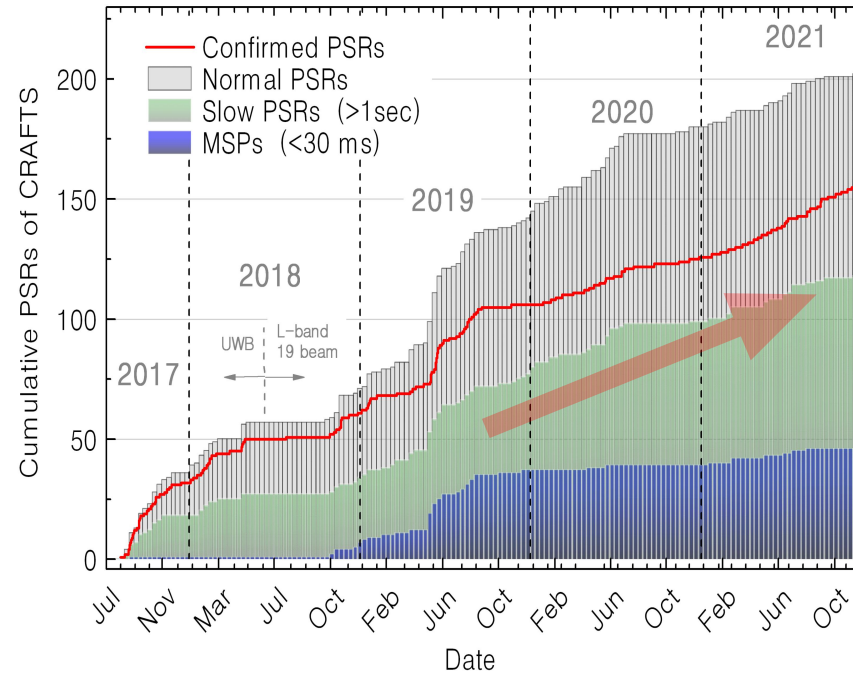
- >40 毫秒脉冲星
- >20 双星系统 (包含1个双中子星系统)
- ~30 旋转射电暂现源



国际多设备脉冲星计时

FAST, Parkes, GBT, Arecibo, Effelsberg
获得 >45 颗脉冲星计时解

FAST-CRAFTS pulsar catalogue
<https://crafts.bao.ac.cn/pulsar/>



An in-depth investigation of 11 pulsars discovered by FAST

A. D. Cameron^{1,2*}, D. Li^{1,3*}, G. Hobbs^{1,2}, L. Zhang^{1,2,3}, C. C. Miao^{1,3},
J. B. Wang^{4,5,6}, M. Yuan^{1,3}, S. Wang^{1,3}, G. Jacobs Corban^{2,7}, M. Cruces⁸, S. Dai^{1,2},
Y. Feng^{1,2,3}, J. Han^{1,3}, J. F. Kaczmarek^{2,9}, J. R. Niu^{1,3}, Z. C. Pan¹, L. Qian¹,
Z. Z. Tao^{1,10,11}, P. Wang¹, S. Q. Wang^{2,3,4}, H. Xu^{1,3}, R. X. Xu^{12,13}, Y. L. Yue¹,
S. B. Zhang^{2,3,14,15}, Q. J. Zhi^{10,11}, W. W. Zhu¹, D. J. Champion⁸, M. Kramer^{8,16},
S. Q. Zhou^{1,3}, K. P. Qiu¹⁷ and M. Zhu¹

Cameron et al. MNRAS 2020

FAST early discoveries: Effelsberg follow-up

M. Cruces,^{1*} D. Champion,¹ D. Li,² M. Kramer,¹ W. W. Zhu,² P. Wang,² A. D. Cameron^{3,4,5},
G. Hobbs,³ P. Freire,¹ E. Graikou,¹ Y. Mao,² and the CRAFTS collaboration

¹Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany
²CAS Key Laboratory of FAST, NAOC, Chinese Academy of Sciences, Beijing 100101, China
³CSIRO Astronomy and Space Science, PO Box 76, Epping, NSW 1710, Australia
⁴Centre for Astrophysics and Supercomputing, Swinburne University of Technology, Mail H39, PO Box 218, VIC 3122, Australia.
⁵ARC Center of Excellence for Gravitational Wave Discovery (OzGrav), Swinburne University of Technology, Mail H111, PO Box 218, VIC 3122, Australia.

Cruces et al. MNRAS 2021

中德合作项目 (CAS-MPG)

FAST-CRAFTS 快速射电暴搜索进展

发现 **6** 例快速射电暴 (FRB)

- FAST 首个 FRB 发现:

FRB 181123

- 5 例新 FRBs:

FRB 181017

FRB 181118

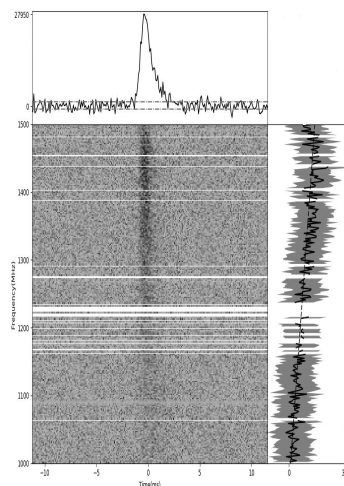
FRB 181130

FRB 190520 (repeater)

FRB 210112

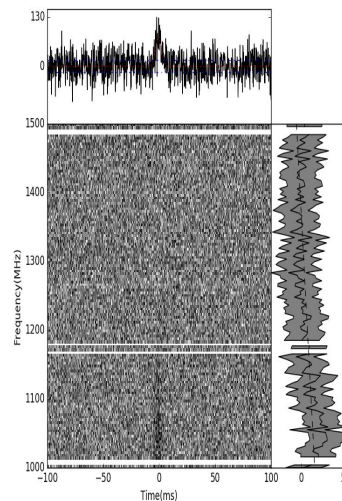
FRB210112

DM: 2550(3)



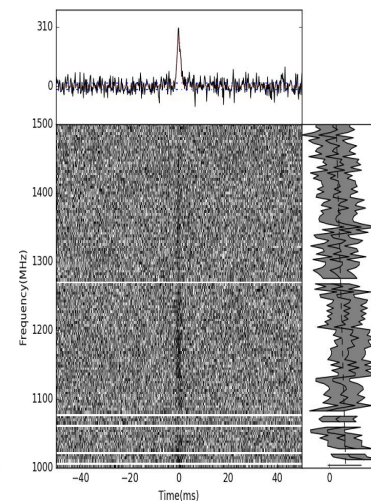
FRB181118

DM: 1187.7(3.3)



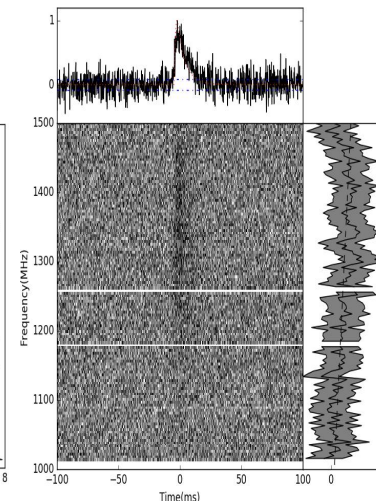
FRB181017

DM: 1845.2(1)



FRB181130

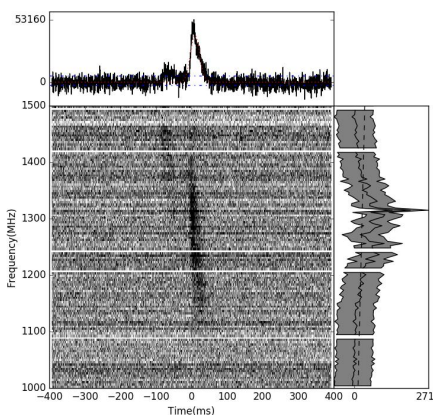
DM: 1705.5(6.5)



Weiwei Zhu et al, 2020, ApJL

Chen-hui Niu et al, 2021, ApJL

多波段 FRB 重复暴观测

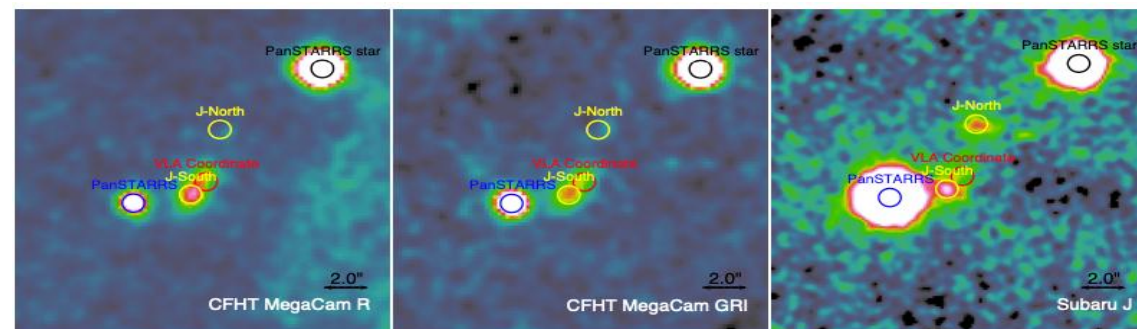


FRB190520
(repeater)

DM: 1214.2 pc cm⁻³

国际多波段设备观测,
定位宿主星系

光学对应体:



四个主要研究方向：

“快速射电暴及脉冲星搜寻探测模型”

“天文实时算法与终端研制”

“天文数据处理模型及算法”

“可视化数据服务平台搭建”



- 依托之江，**发挥智能计算天文应用潜力**
- 天文所需的**线性与非线性结合**的终端计算需求，应用Hybrid XPU+FPGA 联合算法
- 针对FAST及拓展阵观测数据，实现：
高参数空间(如高时间分辨率；高频率分辨率)的实时搜索
- 发展FRB与脉冲星单脉冲快速搜寻方法：
实时处理 FAST 19波束脉冲星巡天数据(达到**50TB/天**)
- 研制与建设**FAST拓展先导阵**

之江实验室-天文数据处理算力支撑

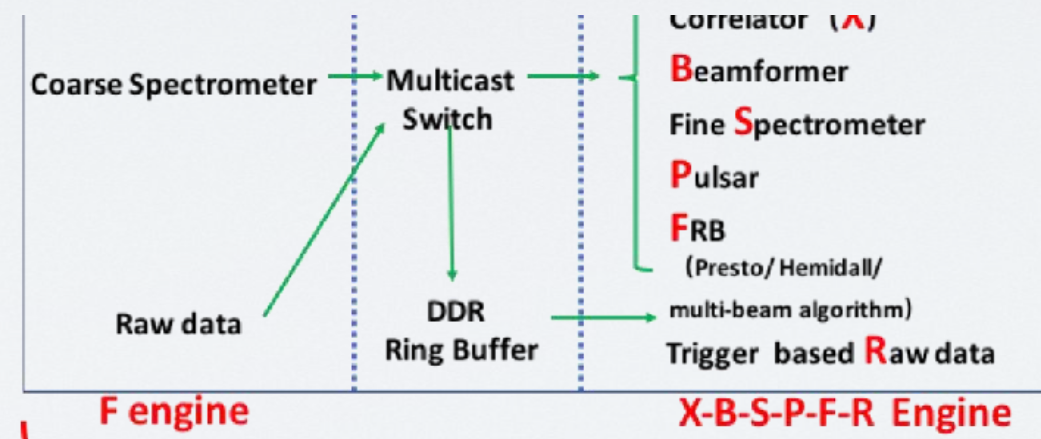
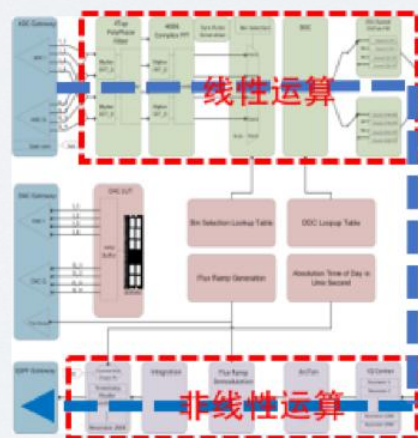
算力参考	天文级数据处理，算力需达到百量级 PFLOPS
存储参考	FAST每月产生的数据量在 3PB左右 ，假设只存储其中的十分之一，则一年的存储量为 4PB/年

算法专利中美授权



美国专利证书

中国专利证书



发挥之江智能计算潜力

发展空间巨大，无人区

四个主要研究方向：

“快速射电暴及脉冲星搜寻探测模型”

“天文实时算法与终端研制”

“天文数据处理模型及算法”

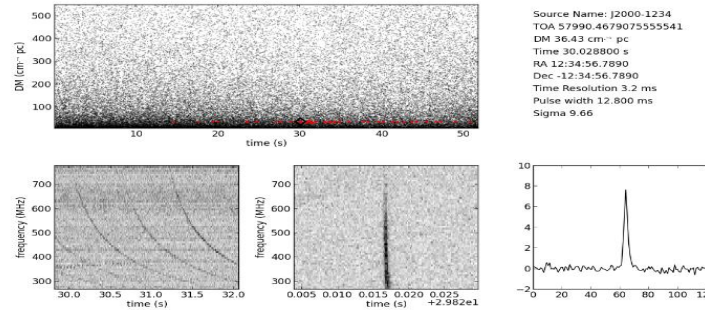
“可视化数据服务平台搭建”

FAST-CRAFTS 脉冲星/快速射电暴发现能力建设

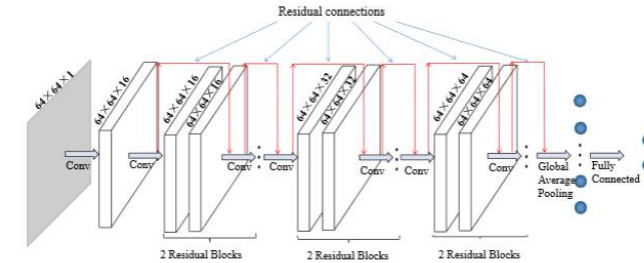
自主创新技术研发

- 发展基于GPU的脉冲星快速搜寻方法：**准实时处理19波束脉冲星巡天数据** (约100TB/天)
- 大规模并行GPU计算提高脉冲星搜寻效率；**国际领先的脉冲星搜寻数据库建立** (已申请专利2项)
- 开发基于深度学习的人工智能技术用于脉冲星候选体筛选 (发表RAA 1篇, AI顶会文章 2篇)

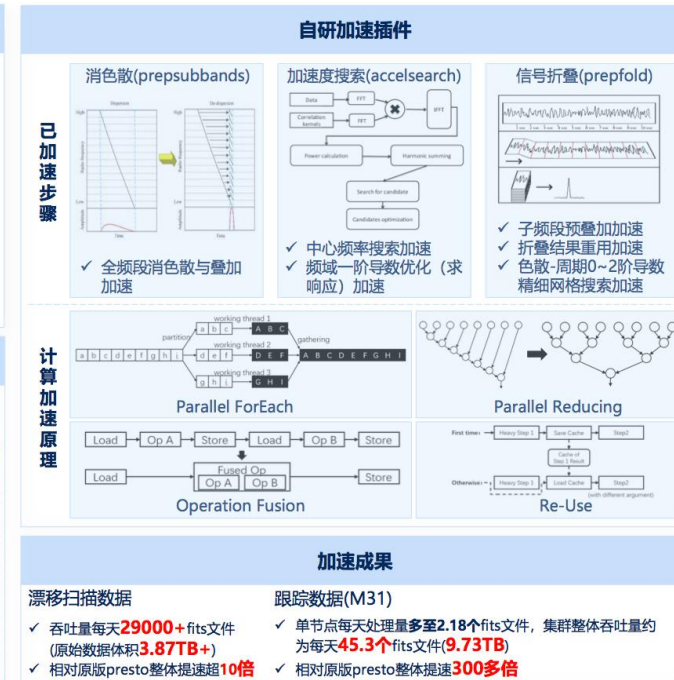
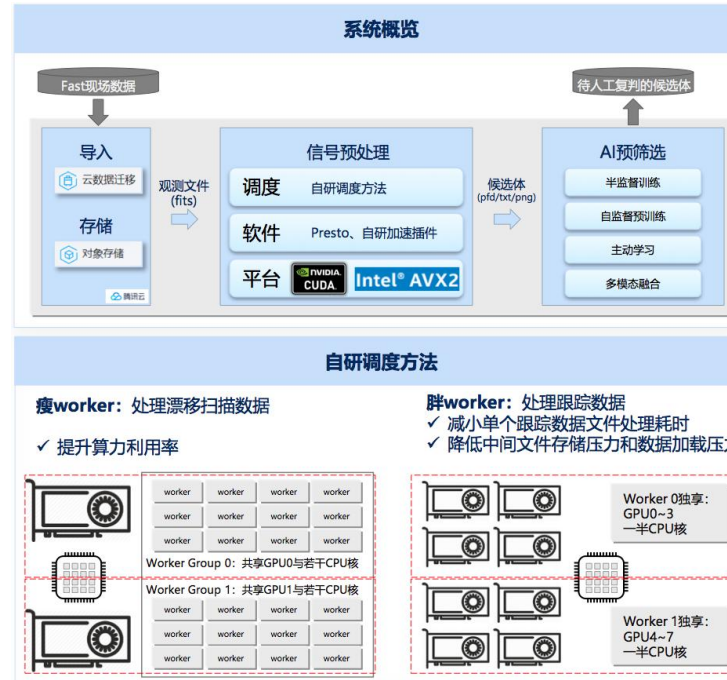
单脉冲快速搜索方法



AI 辅助筛选技术



GPU并行搜索流程



国际合作成果和望远镜时间获得

- FAST-Fermi卫星合作：发现FAST首颗毫秒脉冲星
- FAST 公开申请获得时间
- 每年100小时Effelsberg(国际合作)，每年500小时Parkes(购买)，每年50小时Green Bank, 251.5小时Parkes (公开申请7项)，240小时Arecibo (公开申请13项)

四个主要研究方向：

“快速射电暴及脉冲星搜寻探测模型”

“天文实时算法与终端研制”

“天文数据处理模型及算法”

“可视化数据服务平台搭建”

平台建设目标：天文数据分析可视化，加速科研成果产出，科普天文知识

平台能力

科研支持
数据处理、智能分析

科普宣导
天文社区、资源交换

实现路径

找数据 选模型 调参数 得结果

平台产出
内容

自主内容
输出

用户算力/平
台资源置换

基础建设

数据触达

数据服务

天文数据

模型算法

算力支撑

社区建设

功能价值

缩短用户接触天文数据的路径

支撑天文数据处理与分析，实现结果可视化

激发公众参与天文探索的热情

10.101.6.27:27017

4 DBS 3 COLLECTIONS

☆ FAVORITE

HOST
10.101.6.27:27017

CLUSTER
Sharded
1 Mongos

EDITION
MongoDB 4.2.3 Community

My Queries

Databases

Filter your data

Burstlists

FRB121102A

FRB20180916

FRB20201124

admin

config

local

+

> _MONGOSH

Documents
Burstlists.FRB121102A

Burstlists.FRB121102A

2.3k 1
DOCUMENTS INDEXES

Documents Aggregations Schema Explain Plan Indexes Validation

FILTER {Telescope:"Fast"}

▶ OPTIONS

FIND

RESET

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VIEW

Displaying documents 1 - 20 of 1652

FRB121102A

	_id String	Reiever String	Observing_band String	MJD String	DM_alig Mixed	Flux_peak Double	Flux_peak_err Double	Fluence Double
1	"640"	"19-beam"	"1000-1500 "	"58724.877562614"	567.3	0.01283	0.00022	0.0787
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16	"655"	"19-beam"	"1000-1500 "	"58724.916557571"	564.2	0.02349	0.00155	0.0684
17	"656"	"19-beam"	"1000-1500 "	"58724.91718347"	567.3	0.0227	0.00117	0.1221
18	"657"	"19-beam"	"1000-1500 "	"58724.917184175"	565	0.0251	0.00096	0.2028
19	"658"	"19-beam"	"1000-1500 "	"58724.920825548"	566.1	0.01064	0.0024	0.0161
20	"659"	"19-beam"	"1000-1500 "	"58724.922237735"	565.4	0.03514	0.00174	0.0815

^

总结

1. 研究团队规模达25人以上，计算数字反堆提供E次级的算力
2. 借助国家大科学装置FAST以及CRAFTS巡天数据优势，开展脉冲星和快速射电暴研究
3. 依托国家实验室，打造天文大数据可视化平台，服务天文工作者