



SKA1-LOW全尺度仿真与初步评价

徐亦骏 谢扬帆 邓辉 梅盈 王锋

广州大学 天体物理中心

云南 丽江 2022-07-18

目 录

1. SKA科学目标
2. 仿真数据的生成方法
3. 数据仿真结果



SKA科学目标

背景介绍



平方公里阵SKA — 宏伟科学目标驱动的射电望远镜

国际上即将建造的最大综合孔径射电望远镜

三台站；2望远镜 + HQ 1个天文台

Design Phase: > €170M; 600 scientists + engineers

Phase 1 Construction: 2018 – 2024

Construction cost cap: €674.1M (inflation-adjusted)

Operations cost: under development


Phase 2: start mid-2020s

~2000 dishes across 3500km of Southern Africa

Major expansion of SKA1-Low across Western Australia

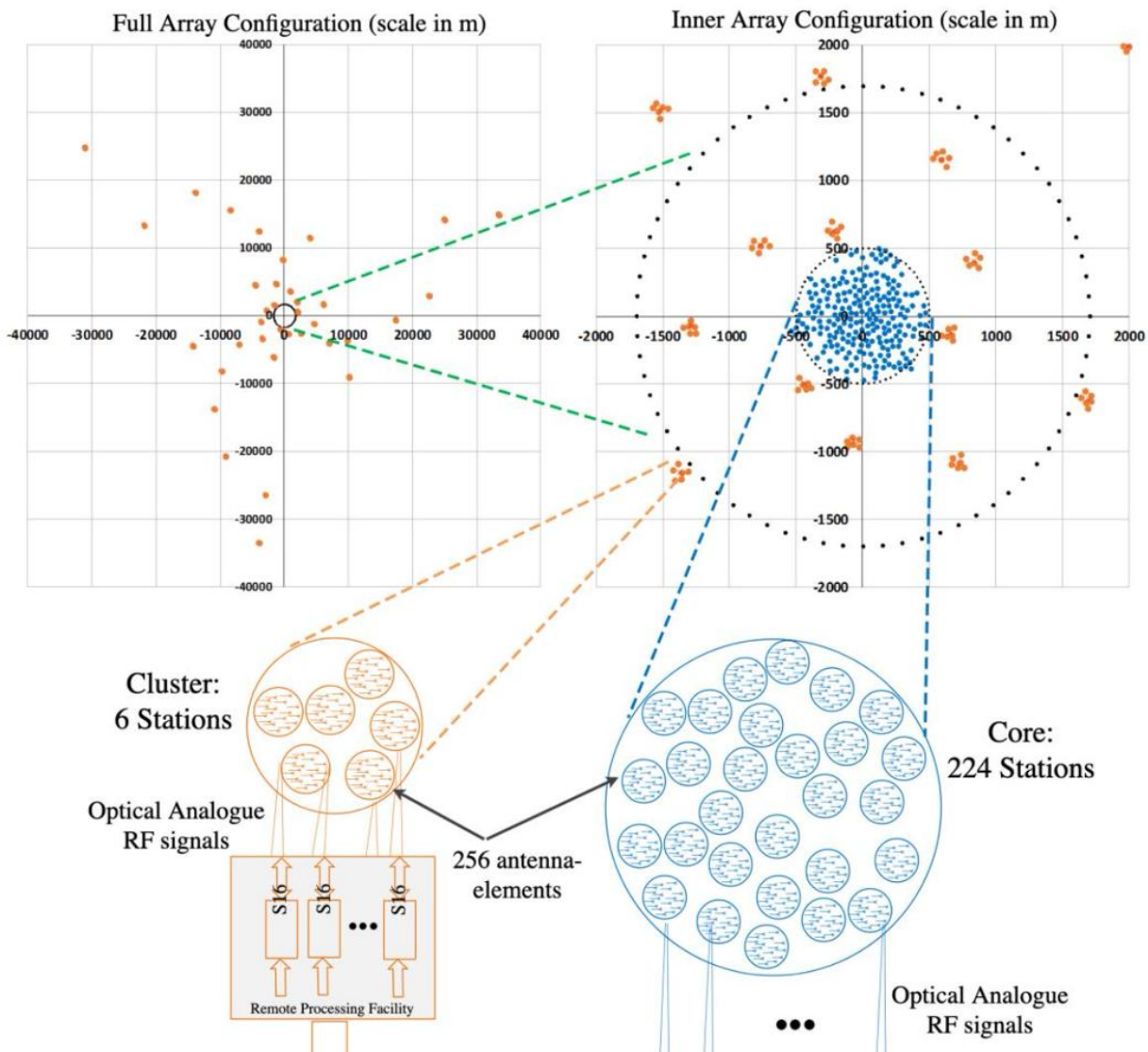


SKA1-LOW: 50 – 350 MHz
Phase 1: ~130,000 antennas
across 65km



SKA1-Mid: 350 MHz – 24 GHz
Phase 1: 200 15-m dishes across
150 km

背景介绍



Core: 224 stations

Cluster: 6 stations

Total: 512 stations

stations之间进行干涉
得到131072个visibility

科学目标与挑战

射电干涉阵宽视场 成像算法

根据不同的视场大小、成像分辨率、可以接受的相位误差等对宽视场成像中**w项的改正问题**进行研究。

高动态成像数据校准关键技术研究

降低包括前景干扰、电磁波路径上地球电离层等离子体干扰、观测站环境背景无线噪声干扰和观测仪器效应等，在**20平方度视场上获得动态范围5个量级**的低频射电优质图像，保证成像的动态范围到 10^6 以上。



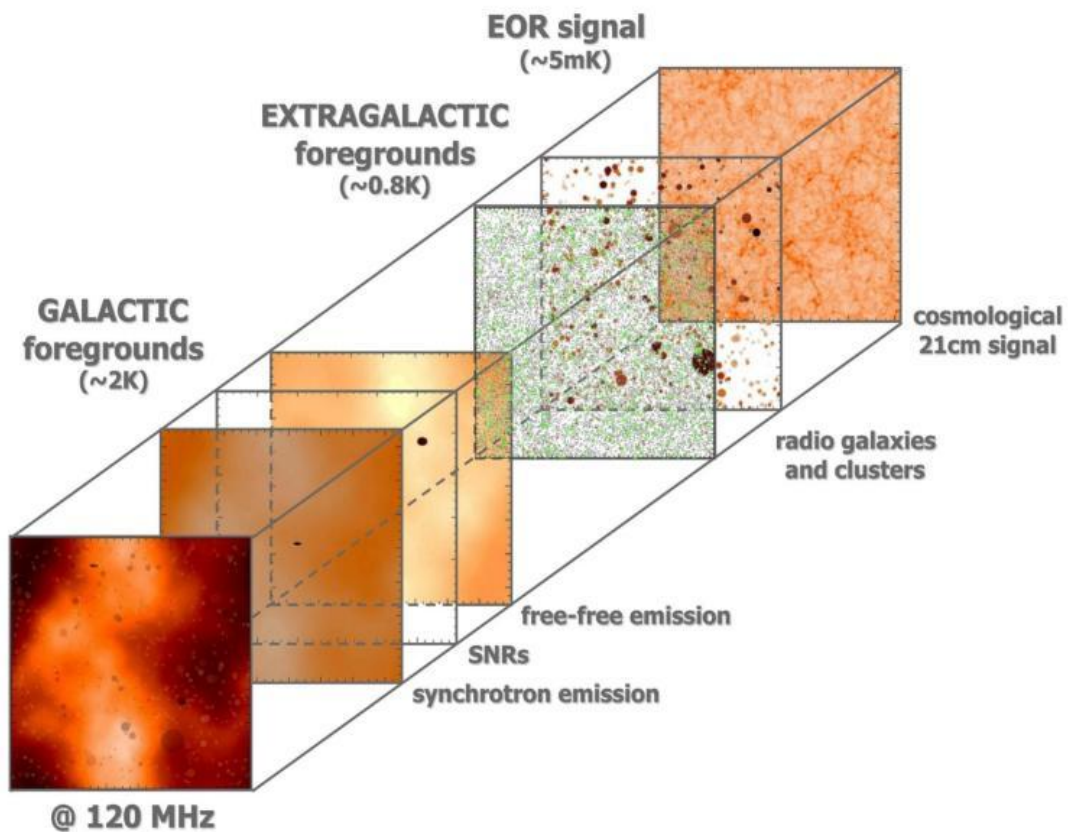
算法的并行与 高性能实现

针对SKA数据级的成像处理，普通的算法实现无法满足需求。**算法的分布式、并行或容器化实现**是需要重点研究的内容。

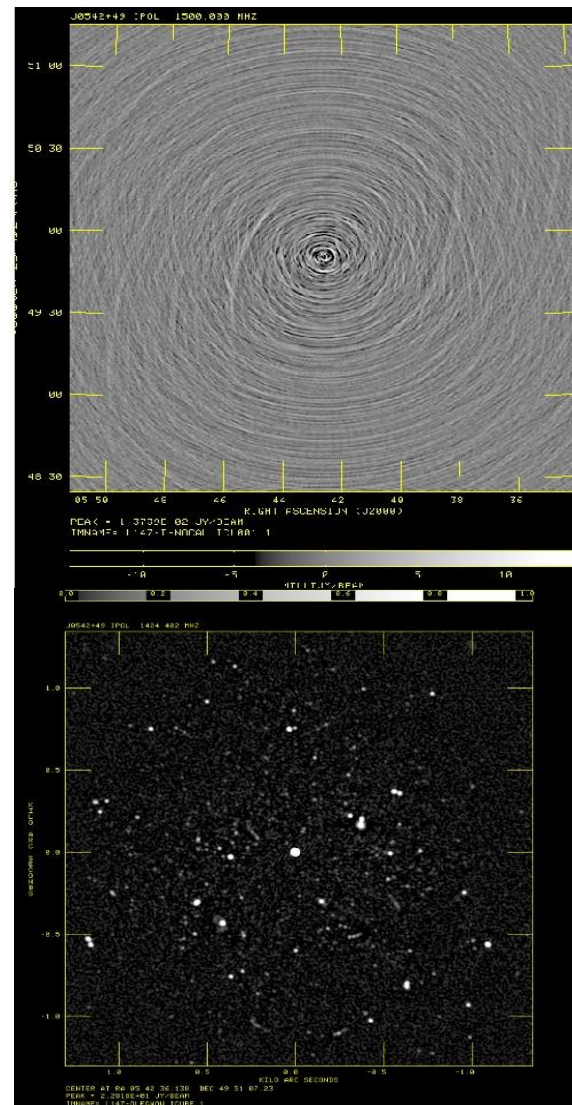
数据处理管线的研究

以 SKA SDP 对数据处理的需求以及科学研究的要求为参考，**研究并实现数据处理管线原型**，力争完成其中的持续成图管线。

科学目标与挑战



SKA的科学目标要求动态范围需大于 10^5
高动态是开展EoR等研究的核心基础





仿真数据生成方法

软件

OSKAR¹:

为SKA做仿真观测开发的软件

提供python调用接口， 并支持GPU加速

生成的数据， 打包成MeasurementSet文件

RASCIL²:

为SKA阵列开发的算法参考库

集成了部分的成图和退卷积算法

1. <https://github.com/OxfordSKA/OSKAR>

2. <https://gitlab.com/ska-telescope/external/rascil>

仿真参数

天区：

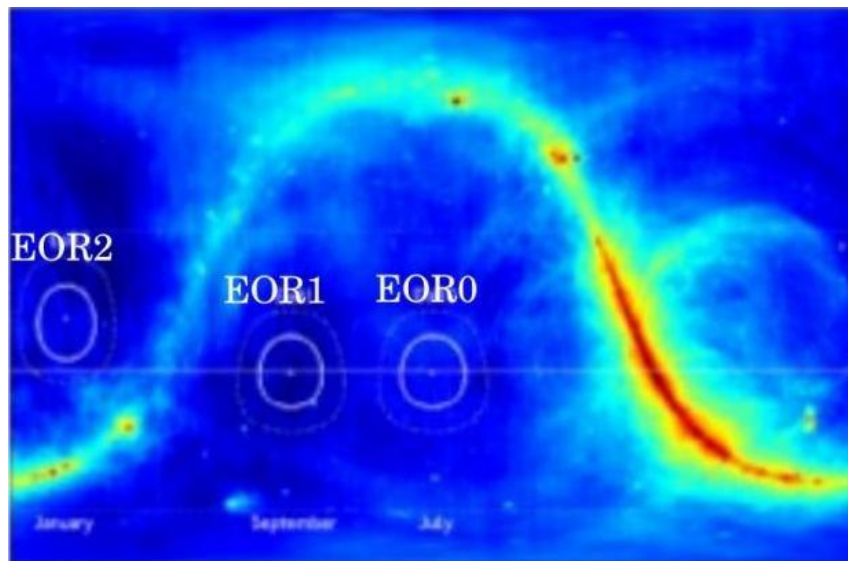
相位中心： $ra0_deg = 0.0$, $dec0_deg = -27.0$

视场大小： 3.5度

天体：

生成的较为暗弱信号 (7667)

GLEAM星表 (366个)



仿真参数

频率：

共完成了6次模拟观测， 带宽为19.2MHz

t1 72.0 - 91.2 MHz

t2 91.2 - 110.4 MHz

t3 110.4 - 129.6 MHz

t5 139.0 - 158.2 MHz

t6 158.2 - 177.4 MHz

t7 177.4 - 196.6 MHz

每次模拟观测有96个通道， 每个通道200kHz

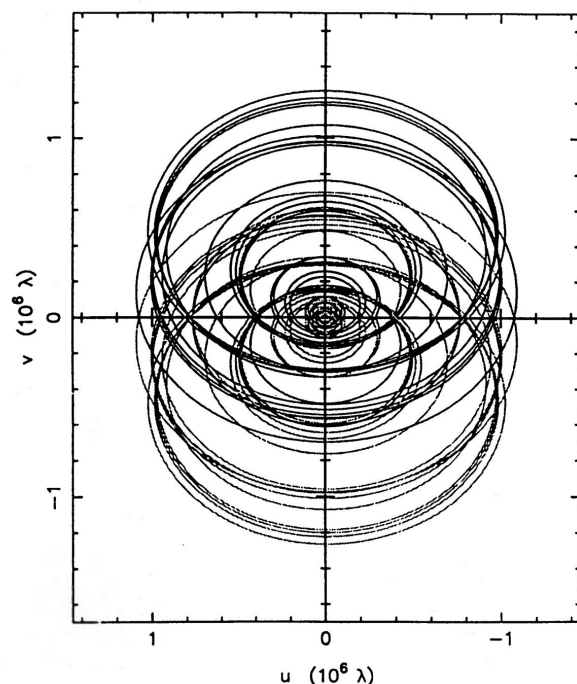
共观测4小时， 每次干涉时间0.9秒， 共240次采样

6个通道进行频率平均

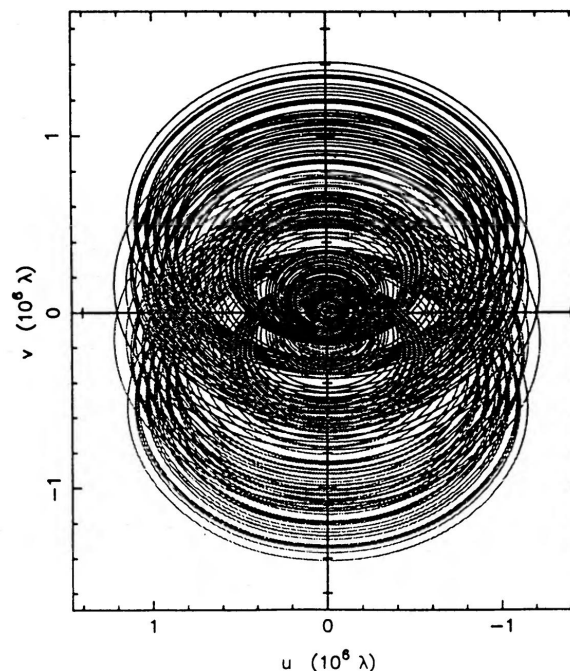
频率:

每6个通道合成一个频率平均覆盖, 共16张图

并将这16张频率平均覆盖, 进行成图操作

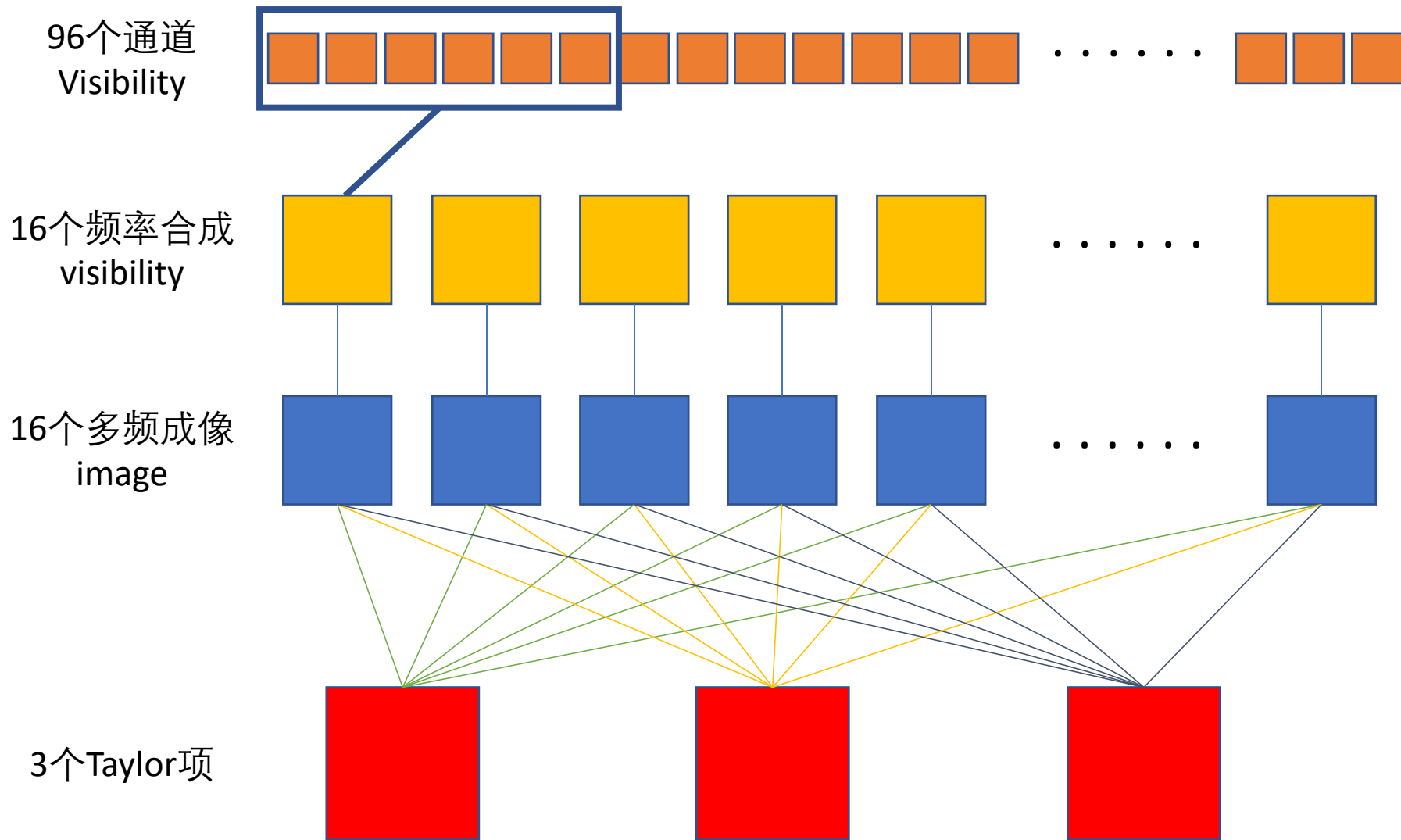


单频的UV覆盖

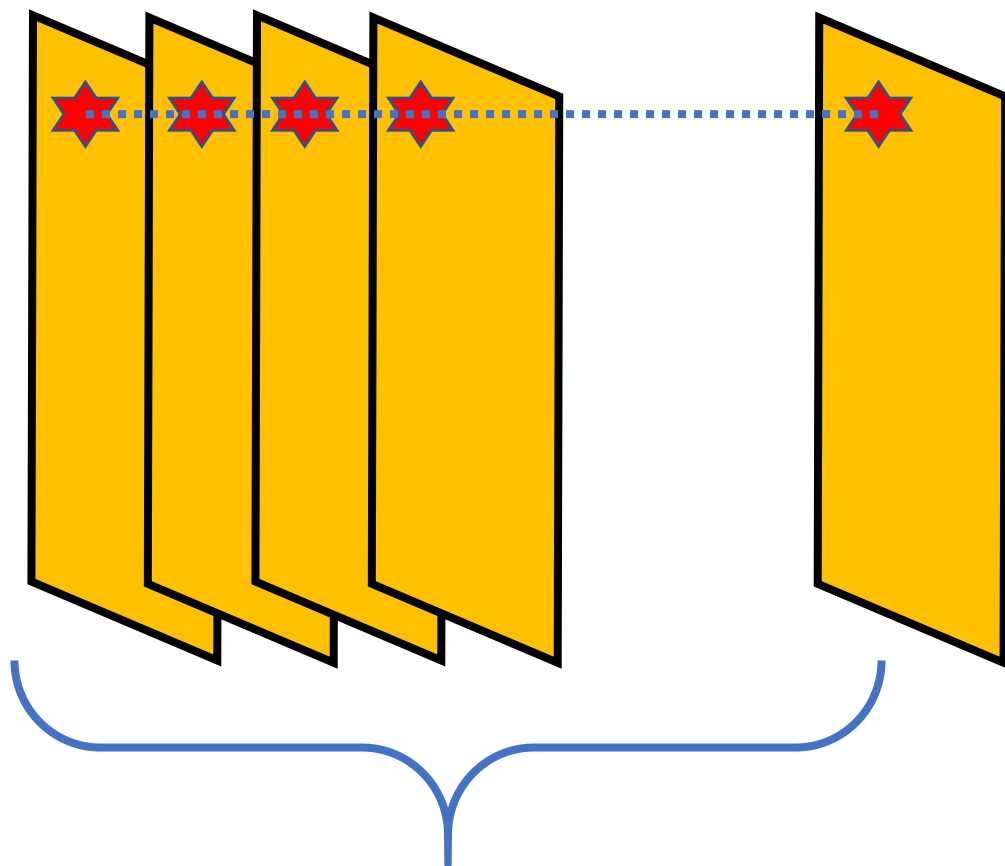


邻近频率组合而成的频率覆盖

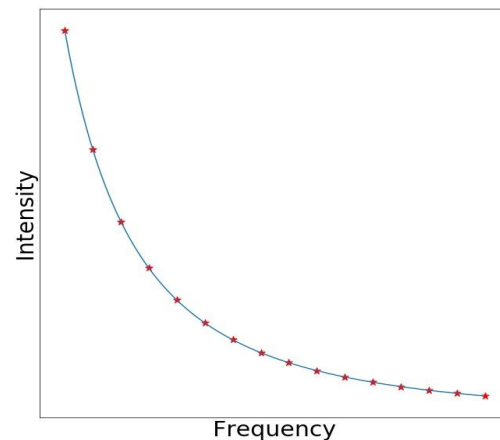
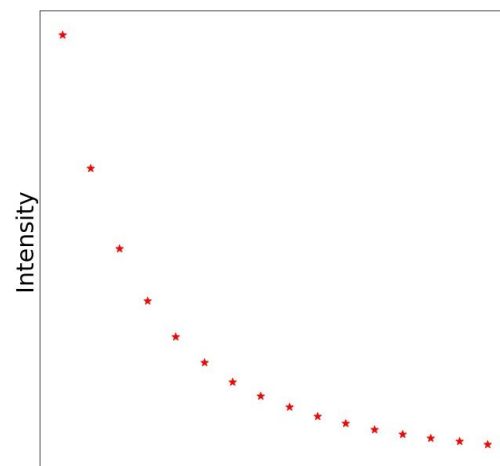
数据仿真流程



用3个Taylor项作为输出结果

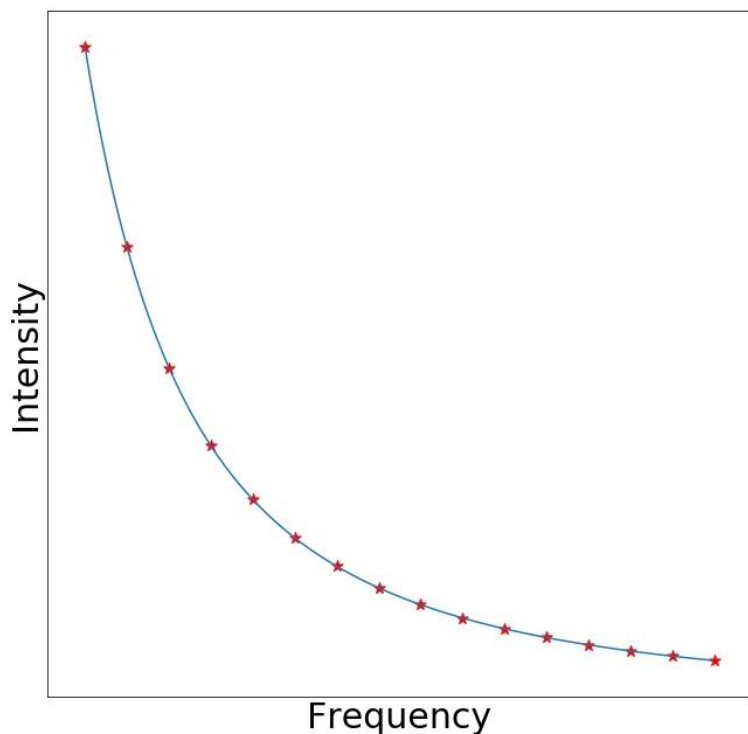


8K * 16张空域图组成的data cube



强度随频率的变化，就是源的SED的一部分

用3个Taylor项作为输出结果



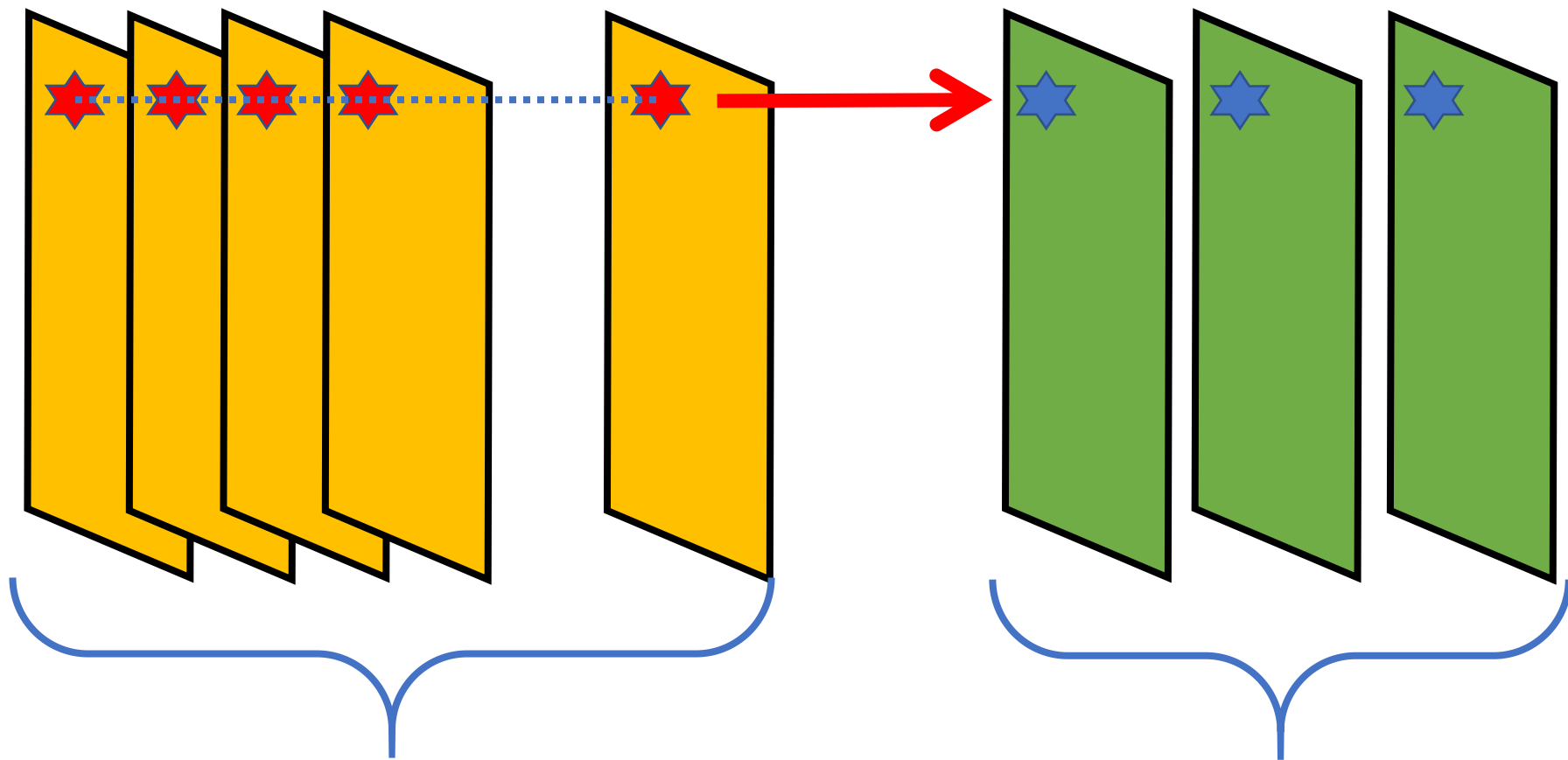
用Taylor级数近似原函数

$$f(x) \approx T_0 + T_1 + T_2 + \dots + T_n + R$$

实际操作中，只要前三项就够了

$$f(x) \approx T_0 + T_1 + T_2$$

用3个Taylor项作为输出结果



8K * 16张空域图组成的data cube

8K * 3张Taylor近似组成的结果



数据仿真结果

实验环境

OSKAR基于显卡并行计算

node	diver	gpus													
		id	name	core	mut	%	mem	total	uM	pow	P	W	C	pcitx	pcirx
lab1	470.86	0	TITAN V	94	33	%	10288	12066	MB	195	250	W	48	0.0	0.0
		1	TITAN V	0	0	%	10263	12066	MB	44	250	W	48	0.0	0.0
		2	TITAN V	94	34	%	10263	12066	MB	74	250	W	47	0.0	0.1
		3	TITAN V	94	34	%	10263	12066	MB	222	250	W	47	0.0	0.1
		4	TITAN V	94	34	%	10263	12066	MB	225	250	W	45	0.0	0.1
		5	TITAN V	0	0	%	10263	12066	MB	40	250	W	44	0.0	0.0
		6	TITAN V	92	34	%	10263	12066	MB	74	250	W	47	2.5	0.0
		7	TITAN V	94	34	%	10263	12066	MB	74	250	W	47	4.4	0.0
		8	TITAN V	94	34	%	10263	12066	MB	129	250	W	44	0.0	0.0
		9	TITAN V	95	36	%	10263	12066	MB	224	250	W	49	1.9	0.0

RASCIL的CIP在多机集群上

id	part	name	user	st	time	ns	nlist
4933	astro-cpu	SKA_CIP	xuyijun	PD	0:00	8	(Resources)
4934	astro-cpu	SKA_CIP	xuyijun	PD	0:00	8	(Nodes)
4935	astro-cpu	SKA_CIP	xuyijun	PD	0:00	8	(Priority)
4936	astro-cpu	SKA_CIP	xuyijun	PD	0:00	8	(Priority)
4937	astro-cpu	SKA_CIP	xuyijun	PD	0:00	8	(Priority)
4938	astro-cpu	SKA_CIP	xuyijun	PD	0:00	8	(Priority)
4939	astro-cpu	SKA_CIP	xuyijun	PD	0:00	8	(Priority)
4940	astro-cpu	SKA_CIP	xuyijun	PD	0:00	8	(Priority)
4941	astro-cpu	DFFT	xieyangf	PD	0:00	9	(Priority)
4931	astro-cpu	SKA_CIP	xuyijun	R	38:50	8	astrolab-hpc-[1-8]

数据量

```
94G ./t1_baseline_realistic_dipole_element_beams_gleam_96_200k_72_0-91_0.ms
94G ./t2_baseline_realistic_dipole_element_beams_gleam_96_200k_91_2-110_2.ms
94G ./t3_baseline_realistic_dipole_element_beams_gleam_96_200k_110_4-129_4.ms
25G ./t4_baseline_realistic_dipole_element_beams_gleam_24_200k_129_6-134_2.ms
94G ./t5_baseline_realistic_dipole_element_beams_gleam_96_200k_139_0-158_0.ms
94G ./t6_baseline_realistic_dipole_element_beams_gleam_96_200k_158_2-177_2.ms
94G ./t7_baseline_realistic_dipole_element_beams_gleam_96_200k_177_4-196_4.ms
94G ./t8_baseline_realistic_dipole_element_beams_gleam_96_200k_196_6-215_6.ms
2.3G ./t1_bug.ms
291G ./t1_bug_bug.ms
77G ./t9_baseline_realistic_dipole_element_beams_gleam_78_200k_215_8-231_2.ms
1.1T .
```

模拟观测的MeasurementSet文件，全阵列每一次观测都是94GB

数据量

8K的fits文件： 0.54 GB

	Type	Size
.taylor.0.deconvolved.fits	FITS	536.9 MB
.taylor.0.residual.fits	FITS	536.9 MB
.taylor.0.restored.fits	FITS	536.9 MB
.taylor.1.deconvolved.fits	FITS	536.9 MB
.taylor.1.residual.fits	FITS	536.9 MB
.taylor.1.restored.fits	FITS	536.9 MB
.taylor.2.deconvolved.fits	FITS	536.9 MB
.taylor.2.residual.fits	FITS	536.9 MB
.taylor.2.restored.fits	FITS	536.9 MB

16K的fits文件： 2.1 GB

	Type	Size
.taylor.0.deconvolved.fits	FITS	2.1 GB
.taylor.0.residual.fits	FITS	2.1 GB
.taylor.0.restored.fits	FITS	2.1 GB
.taylor.1.deconvolved.fits	FITS	2.1 GB
.taylor.1.residual.fits	FITS	2.1 GB
.taylor.1.restored.fits	FITS	2.1 GB
.taylor.2.deconvolved.fits	FITS	2.1 GB
.taylor.2.residual.fits	FITS	2.1 GB
.taylor.2.restored.fits	FITS	2.1 GB

32K的fits文件： 8.6 GB

	Type	Size
.taylor.0.deconvolved.fits	FITS	8.6 GB
.taylor.0.residual.fits	FITS	8.6 GB
.taylor.0.restored.fits	FITS	8.6 GB
.taylor.1.deconvolved.fits	FITS	8.6 GB
.taylor.1.residual.fits	FITS	8.6 GB
.taylor.1.restored.fits	FITS	8.6 GB
.taylor.2.deconvolved.fits	FITS	8.6 GB
.taylor.2.residual.fits	FITS	8.6 GB
.taylor.2.restored.fits	FITS	8.6 GB

洁化图、残图、残差都分别都由Taylor的三项来表示

仿真结果 (只含GLEAM星表)

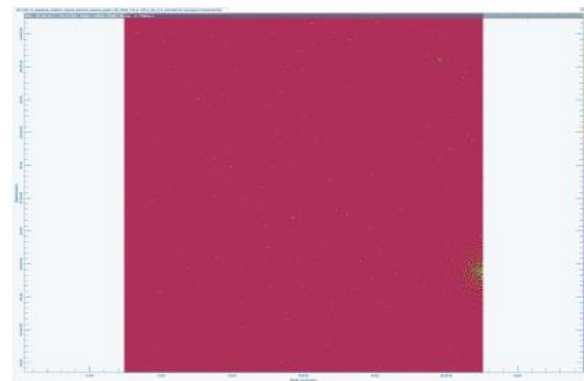
8K成图, Taylor 0



72.0 - 91.2 MHz



91.2 - 110.4MHz



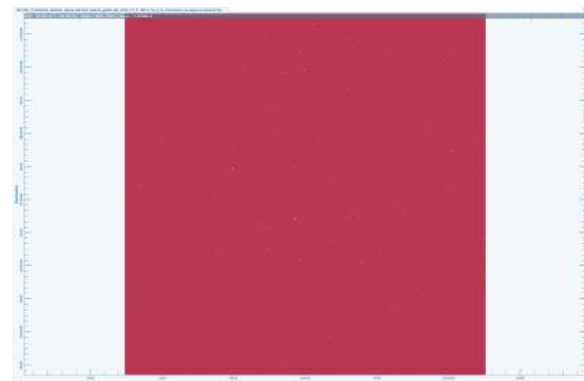
110.4 - 129.6MHz



139.0 - 158.2MHz



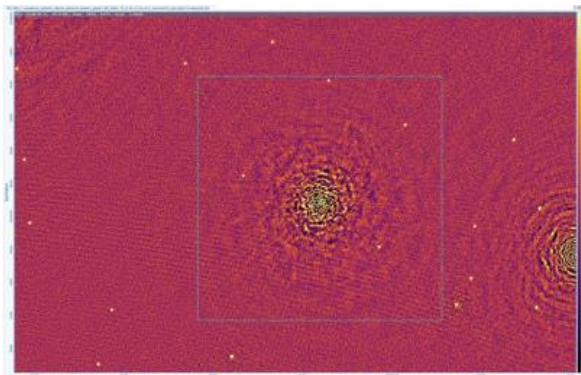
158.2 - 177.4MHz



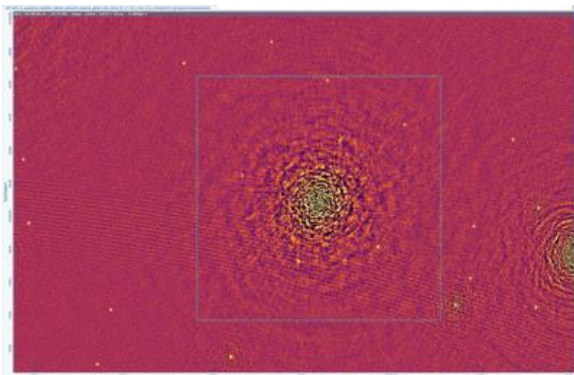
177.4 - 196.6MHz

仿真结果_局部放大强源 (只含GLEAM星表)

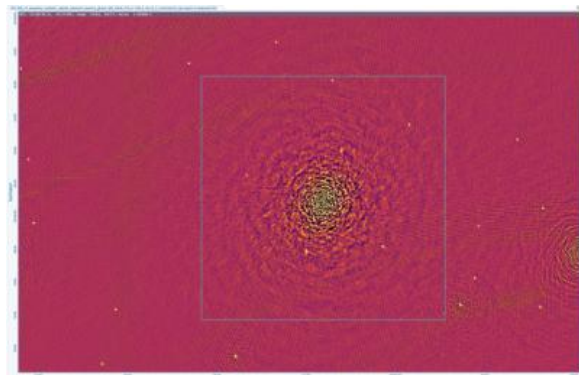
8K成图, Taylor 0



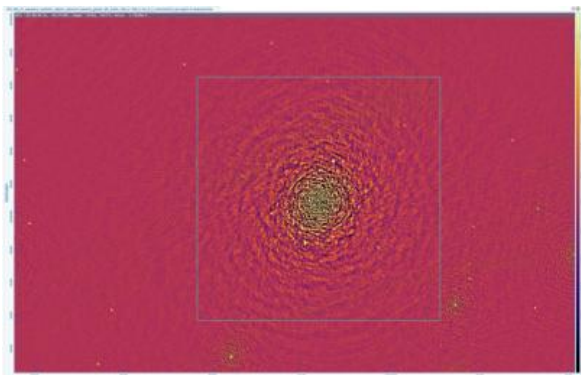
72.0 - 91.2 MHz



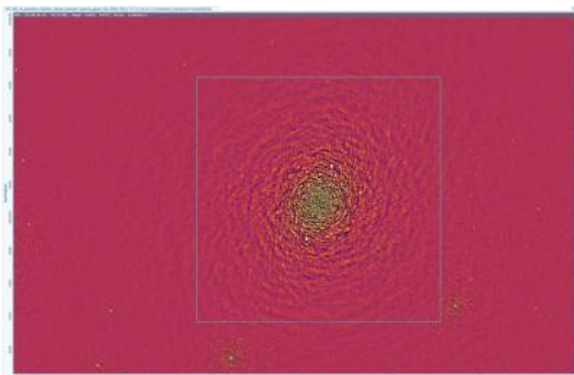
91.2 - 110.4 MHz



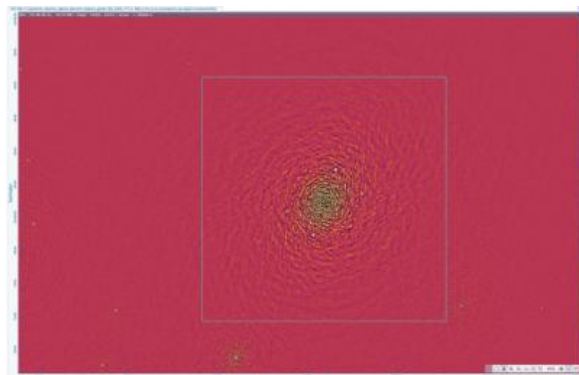
110.4 - 129.6 MHz



139.0 - 158.2 MHz



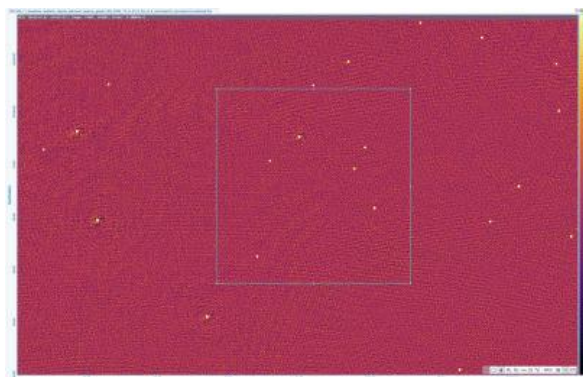
158.2 - 177.4 MHz



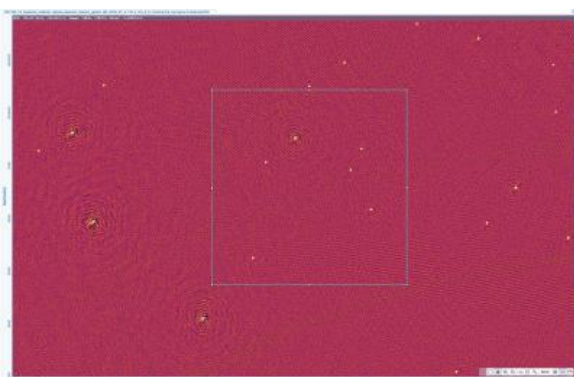
177.4 - 196.6 MHz

仿真结果_局部放大较弱源 (只含GLEAM星表)

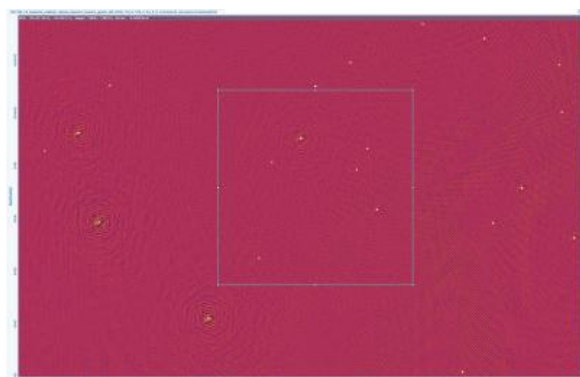
8K成图, Taylor 0



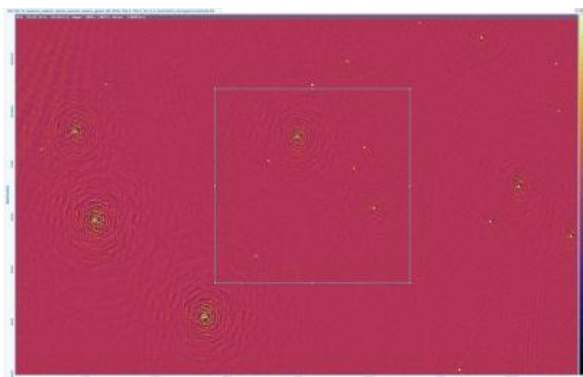
72.0 - 91.2 MHz



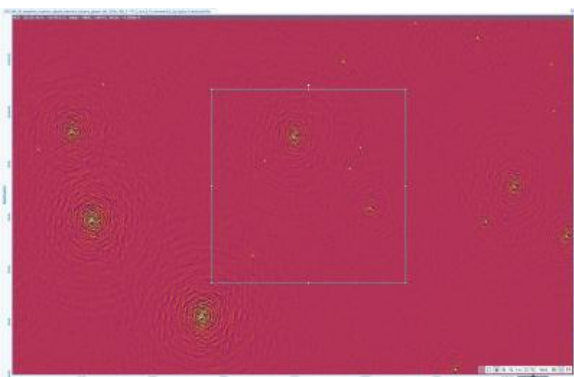
91.2 - 110.4MHz



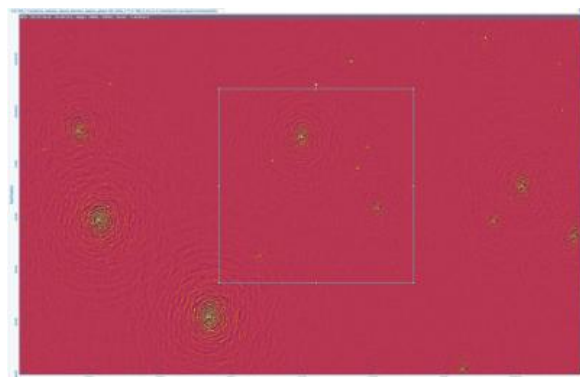
110.4 - 129.6MHz



139.0 - 158.2MHz



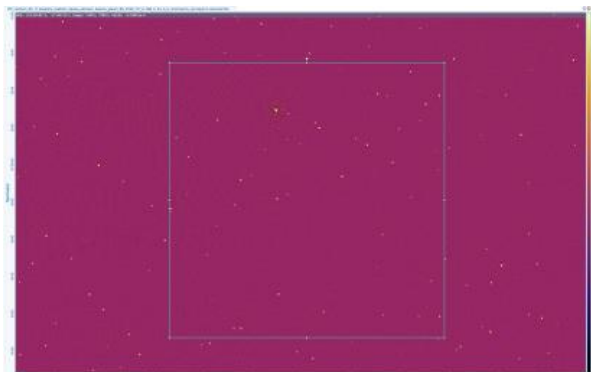
158.2 - 177.4MHz



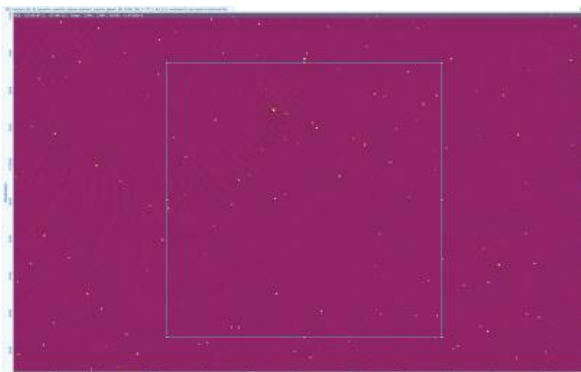
177.4 - 196.6MHz

仿真结果_局部放大 (GLEAM星表和人造弱源)

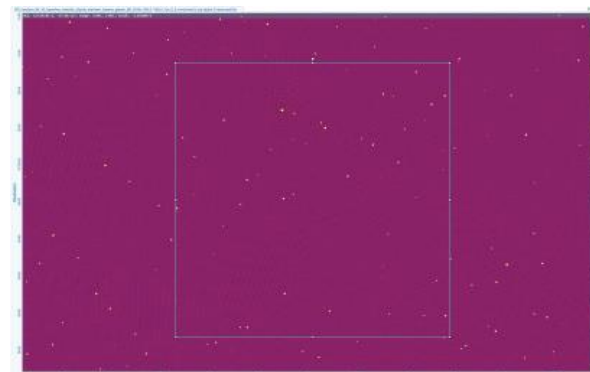
8K成图, Taylor 0



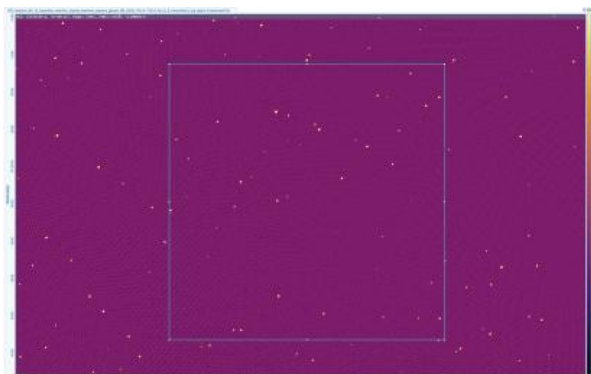
72.0 - 91.2 MHz



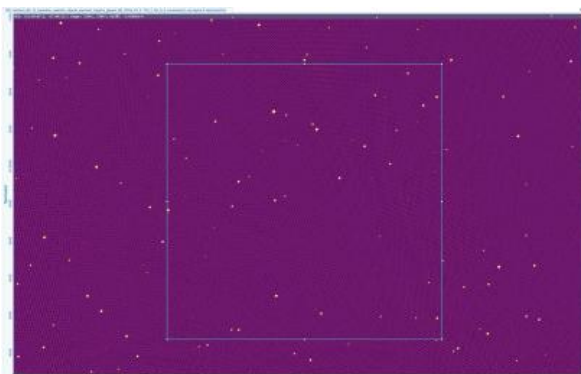
91.2 - 110.4MHz



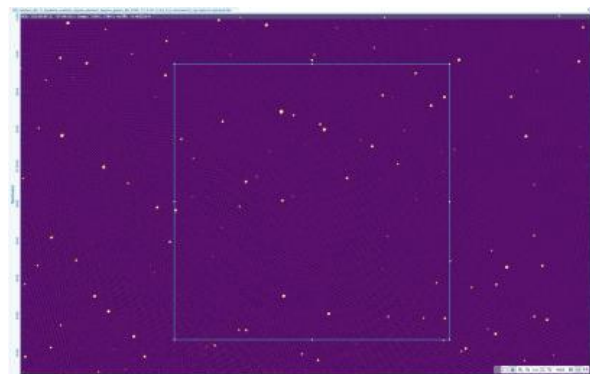
110.4 - 129.6MHz



139.0 - 158.2MHz



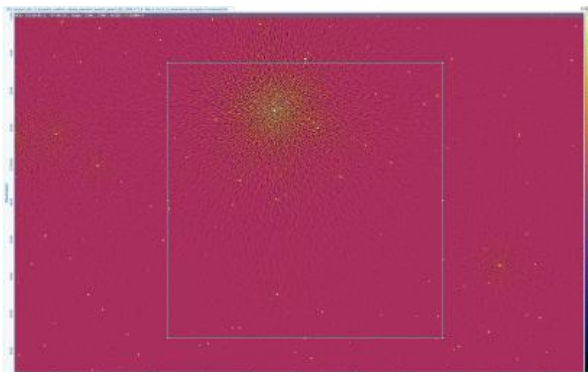
158.2 - 177.4MHz



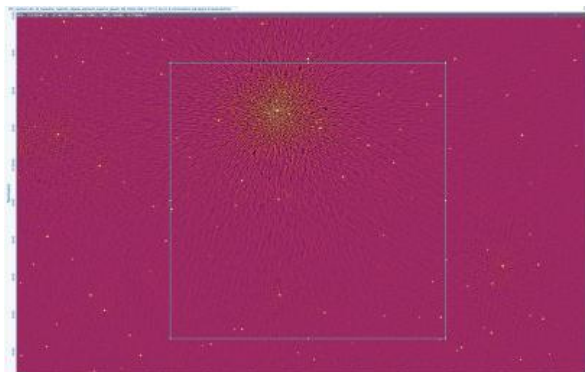
177.4 - 196.6MHz

仿真结果_局部放大 (添加电离层)

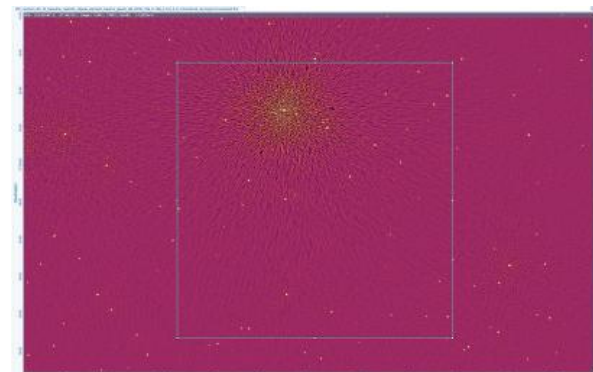
8K成图, Taylor 0



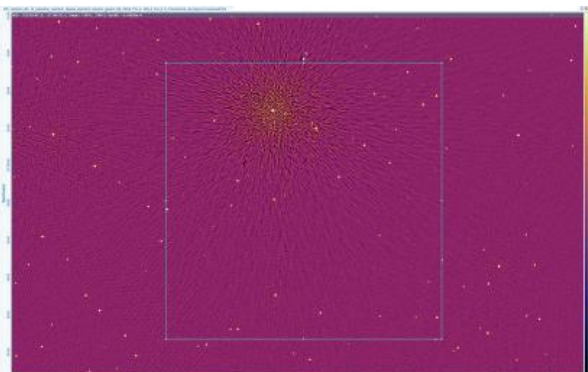
72.0 - 91.2 MHz



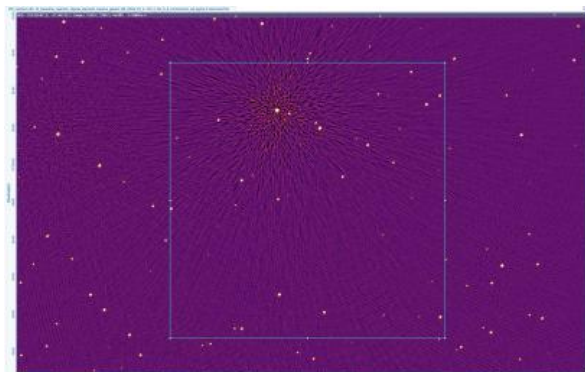
91.2 - 110.4MHz



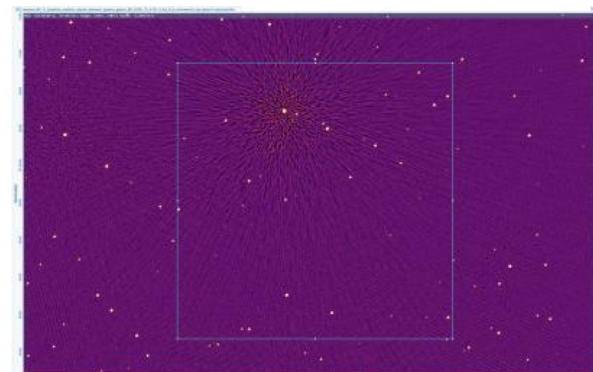
110.4 - 129.6MHz



139.0 - 158.2MHz

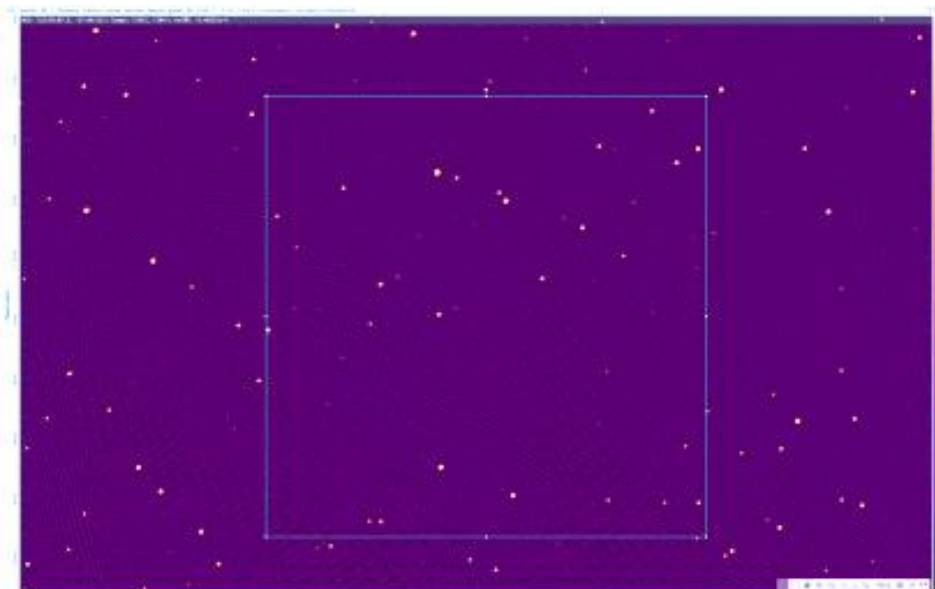


158.2 - 177.4MHz

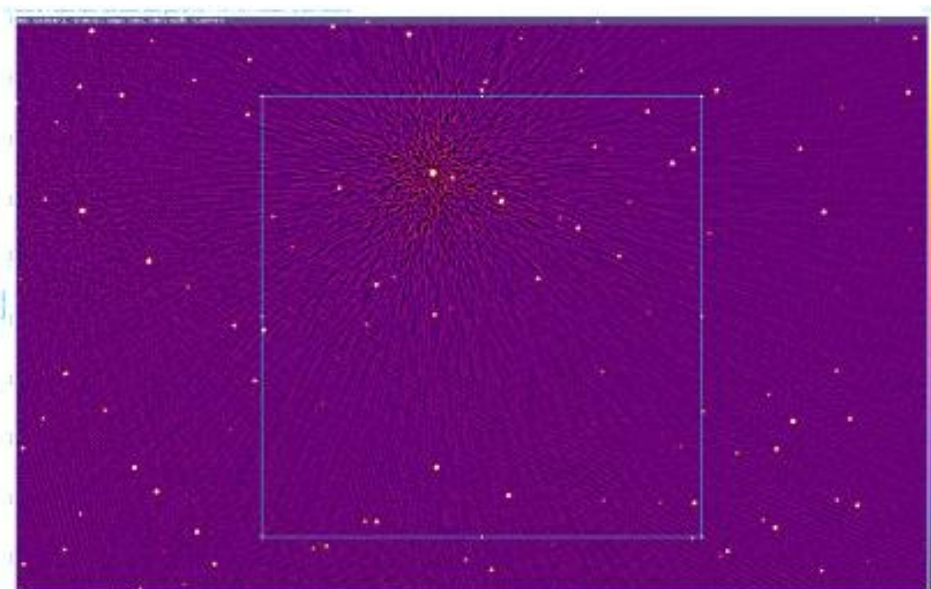


177.4 - 196.6MHz

仿真结果_局部放大 (添加电离层)



无电离层



有电离层



结果初步分析

1. 全阵列成图，符合理论预期
2. 频率越高，分辨率越高，旁瓣也越明显
3. 成图过程中，退卷积所用时间过多
4. 应用了rascil中的CIP管线，洁化效果和速度仍有改进空间