

# A short history of Space VLBI

Richard Schilizzi

Nikolay's 80<sup>th</sup> birthday symposium, 20 June 2012

## VSOP - HALCA



**Hisashi  
Hirabayashi**



**Masaki  
Morimoto**



**Minoru  
Oda**

# This is a tale of two missions

## VSOP - HALCA



Hisashi  
Hirabayashi



### The three Samurai



Masaki  
Morimoto



Minoru  
Oda

# This is a tale of two missions

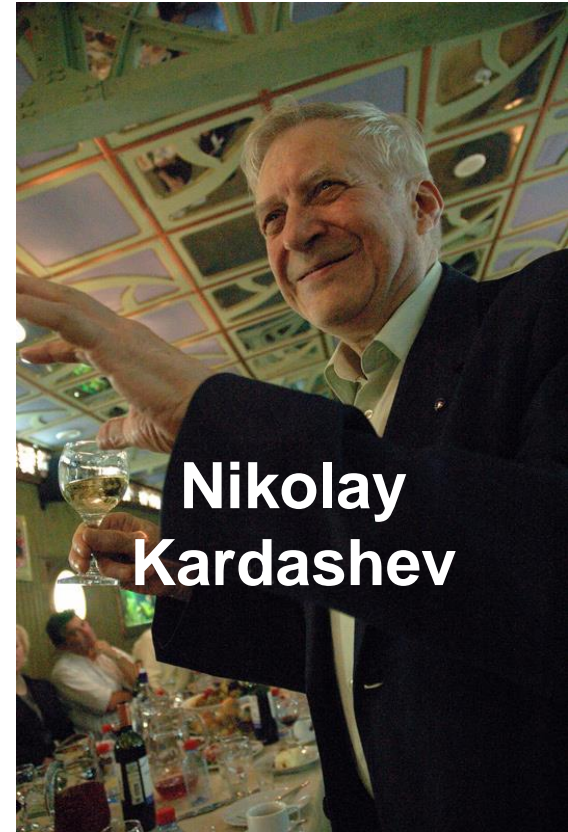
## VSOP - HALCA



**Hisashi  
Hirabayashi**

and

## RadioAstron



**Nikolay  
Kardashev**

## The three Samurai



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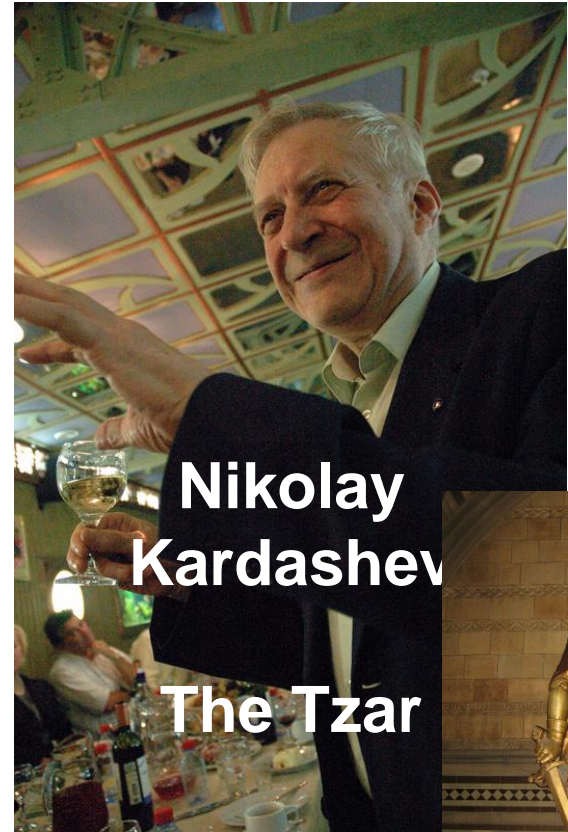
## VSOP - HALCA



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**Nikolay  
Kardashev**

**The Tzar**



**The three Samurai**



**Masaki  
Morimoto**



**Minoru  
Oda**

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This is not only a tale of two  
missions but what went before,  
and in between

It was not a linear process

УДК 621.396.67:523.164

## О РАДИОИНТЕРФЕРОМЕТРЕ С БОЛЬШОЙ БАЗОЙ

*Л. И. Матвеевко, Н. С. Кардашев, Г. Б. Шоломицкий*

Рассмотрена система радиointерферометра без ретрансляции. Регистрация сигналов по промежуточной частоте происходит независимо на каждой антенне (путем записи на магнитную ленту) с последующей совместной обработкой этих записей. Использование двух независимых гетеродинов налагает следующее условие на стабильность их частоты

$$\sqrt{\overline{\Delta f_{\Gamma}^2}}/f_{\Gamma} \leq 1,6 \cdot 10^{-11} D \quad (D — \text{длина базы в км}).$$
 Обсуждаются достоинства такого интерферометра.



# Stage 0: First thoughts...

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Radiophysics 1965

On Radiointerferometry with long baseline

L. I. Matveyenko, N. S. Kardashev, G. B. Sholomitskii

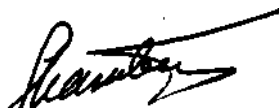


# Stage 0: First thoughts

Таким образом, предлагаемая система позволяет:

1. Избавиться от ретрансляции,
2. автоматизировать регистрацию сигнала и обработку записей,
3. осуществлять полный обзор в пределах диаграммы одиночной антенны,
4. реализовать очень большие базы и, следовательно, увеличить количество разрешаемых источников радиоизлучения.

**Предлагаемую систему удобно также использовать для радиоастрономических наблюдений с ИСЗ. Система из двух антенн, установленных на ИСЗ, работающая по описанному выше принципу, позволит получать при больших базах не только амплитудные, но и пространственно-фазовые характеристики интерференции, а, следовательно, детально исследовать распределение яркости дискретных источников очень малых угловых размеров. В этом случае устраняются ионосферные и тропосферные флуктуации, являющиеся основным препятствием при измерении фазы.**



# Stage 1: The very early days of space

## VLBI: 1977 - 1982

JET PROPULSION LABORATORY

ENGINEERING MEMORANDUM

315-16

11 February 1977

TO: R. A. Preston  
FROM: [REDACTED]  
SUBJECT: VLBI with an Earth-Orbiting Antenna

ABSTRACT:

Satellite-borne VLBI terminals could be used to provide maps of compact celestial radio sources with finer resolution, less ambiguity, and more efficiency than earth-bound VLBI techniques. These maps and their time variability would help unravel the physical processes that govern some of the most enigmatic classes of celestial objects. Hence, VLBI should be one of the principle justifications for placing a large parabolic antenna in earth orbit. This memorandum explores the advantages, technical problems, and scientific goals associated with earth-orbiting VLBI.

RAP:tg



### INVESTIGATION AND TECHNICAL PLAN

#### Volume 1

Of a Proposal to the

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

for a

## VERY LONG BASELINE INTERFEROMETER STATION ON 1981-1983 SPACELAB MISSION

This joint proposal is submitted by the

CENTER FOR SPACE RESEARCH OF THE  
MASSACHUSETTS INSTITUTE OF TECHNOLOGY  
and

GODDARD SPACE FLIGHT CENTER

and the  
JET PROPULSION LABORATORY OF THE  
CALIFORNIA INSTITUTE OF TECHNOLOGY

DR BERNARD F. BURKE

MIT, 26-335  
Cambridge, Mass. 02139  
617-253-2572

15 NOVEMBER 1978

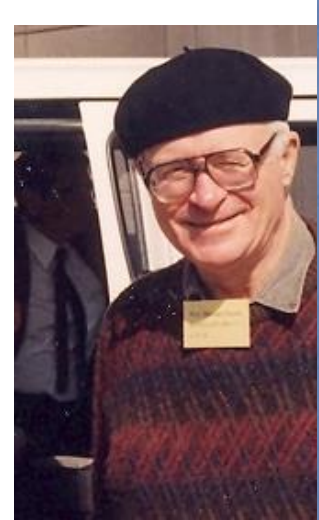
AO-OSS-2-78

15 November 1978



# Stage 1: The very early days of space

## VLBI: 1977 - 1982



Final Report  
Mission Definition Study for a VLBI Station  
Utilizing the Space Shuttle

NAS-5-25543

Center for Space Research  
Massachusetts Institute of Technology  
Cambridge, MA 02139

Professor Bernard F. Burke      October 12, 1982



CENTER FOR SPACE RESEARCH  
MASSACHUSETTS INSTITUTE OF TECHNOLOGY



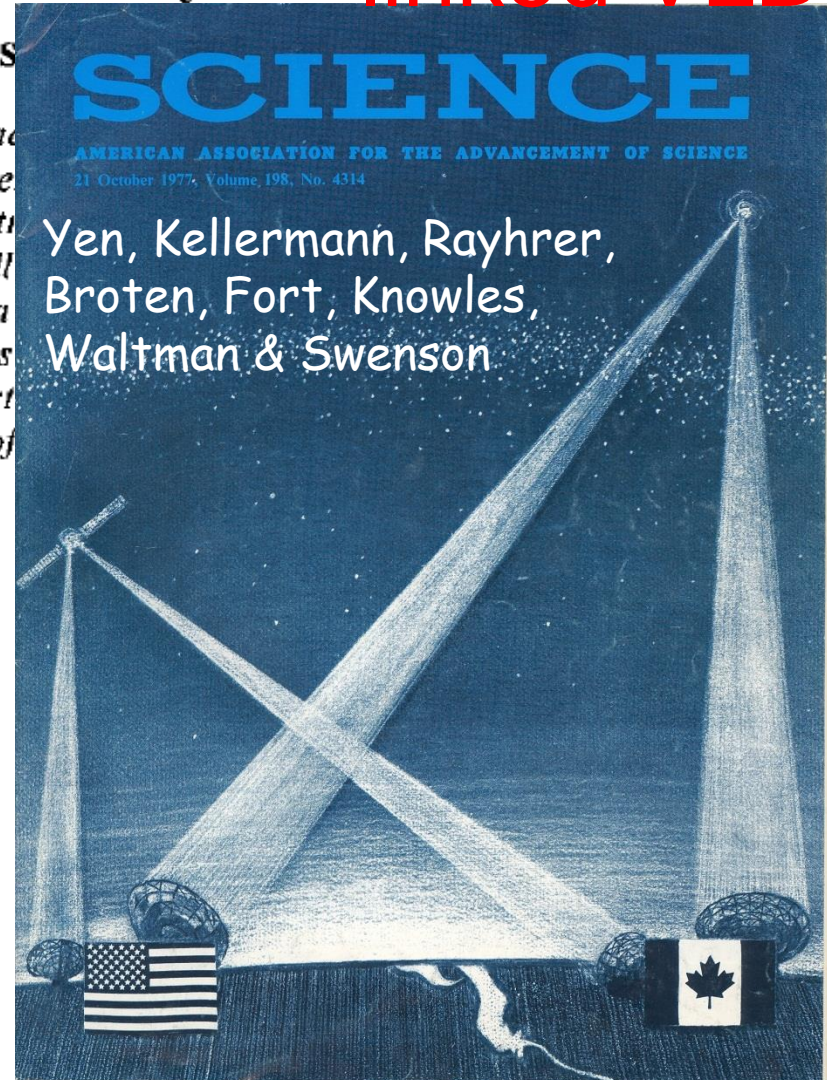
# An important side-show - satellite-linked VLBI

1977

## Real-Time, Very-Long-Baseline Interferometry

### Based on the Use of a Communications

*Abstract. The Hermes satellite, a joint Canadian and Ontario, for very-long-baseline interferometry possible instantaneous correlation of the data as well than that of earlier VLBI systems, by virtue of a With the use of a geostationary communications the tape recorders and the most troublesome part cessing. A further possibility is the development of*



# An important side-show - satellite-linked VLBI

1977

**Real-Time, Very-Long-Baseline Interferometry**

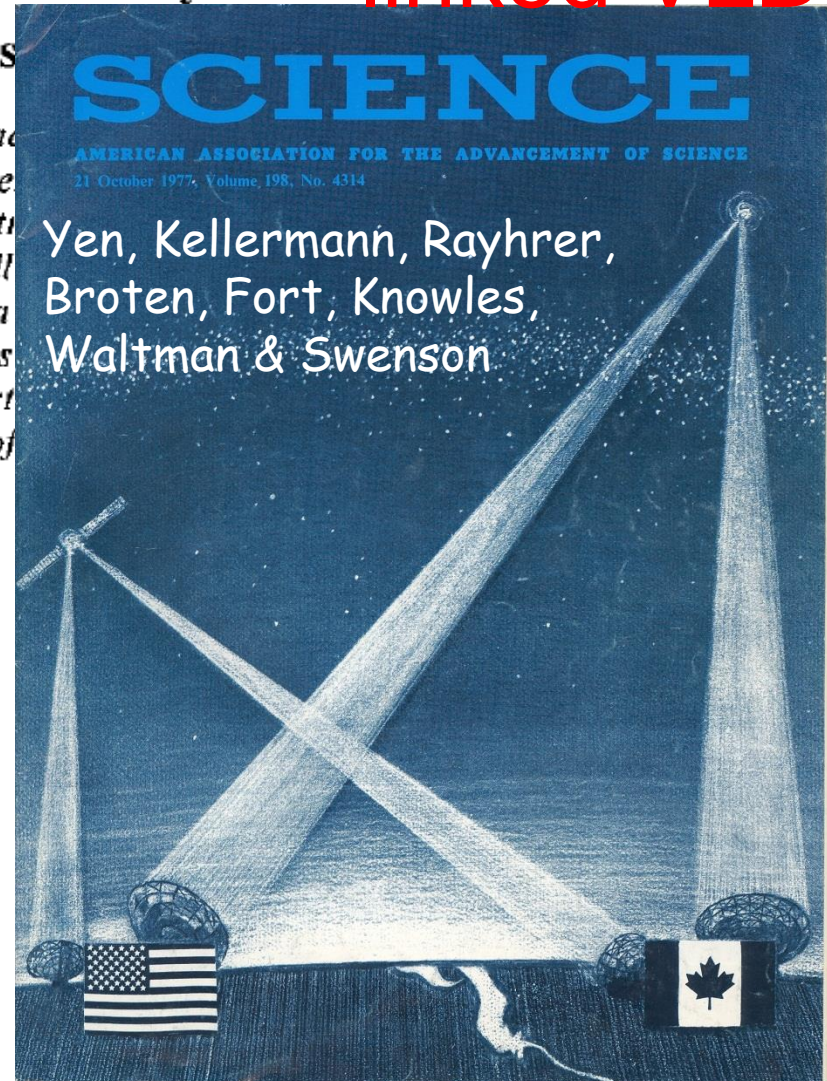
**Based on the Use of a Communications**

*Abstract. The Hermes satellite, a joint Canadian and Ontario, for very-long-baseline interferometry, possible instantaneous correlation of the data as well as that of earlier VLBI systems, by virtue of a geostationary communications satellite. With the use of a geostationary communications satellite, the tape recorders and the most troublesome part of the processing. A further possibility is the development of*

**1978:** ESA Feasibility Study of satellite-linked VLBI (Schilizzi et al)

**1981:** ESA Phase A study of satellite-linked VLBI using L-SAT (Schilizzi et al)

**1982:** Phase transfer via ESA's Orbital Test Satellite by van Ardenne et al



# Stage 1: The very early days of space

## VLBI: 1977 - 1982

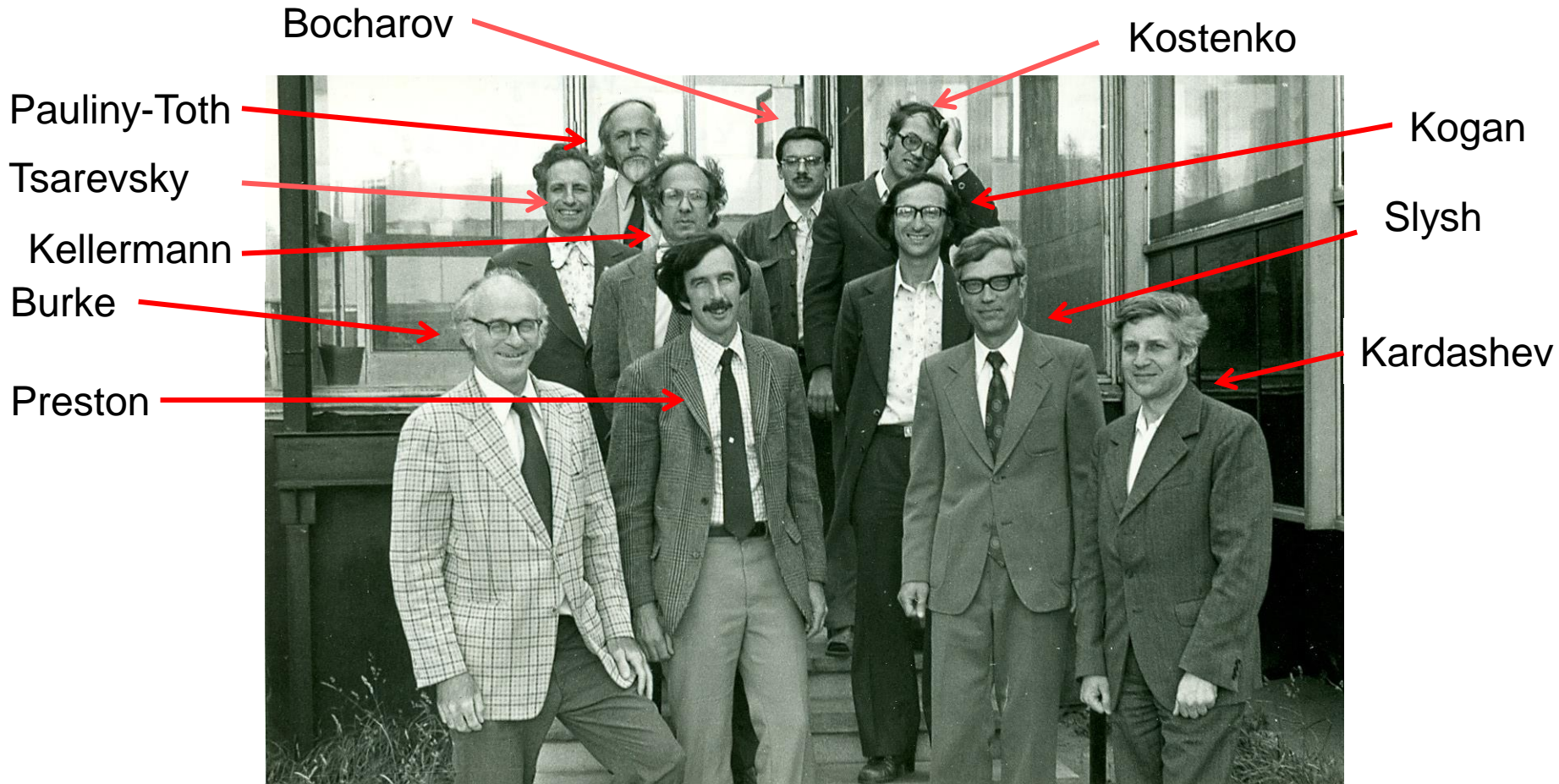
KRT-10 deployed  
on Salyut-6 in 1979



# Stage 1: The very early days of space

## VLBI: 1977 - 1982

### MPIfR-Soviet Academy of Sciences discussions on VLBI in August 1979



But the détente didn't last, at least at the geo-political level....



# Stage 1: The very early days of space

## VLBI: 1977 - 1982

### SPACE VLBI

H. HIRABAYASHI, Y. CHIKADA, M. INOUE, M. MORIMOTO

Nobeyama Radio Observatory\*, Tokyo Astronomical Observatory,

University of Tokyo, Nobeyama, Minamisaku-gun

Nagano - Ken 384-13, Japan

(Submitted to Space Station Symposium Tokyo)

Oct. 1982

Large diameter  
antenna on US  
Space Station



# Stage 2: 1983-1988



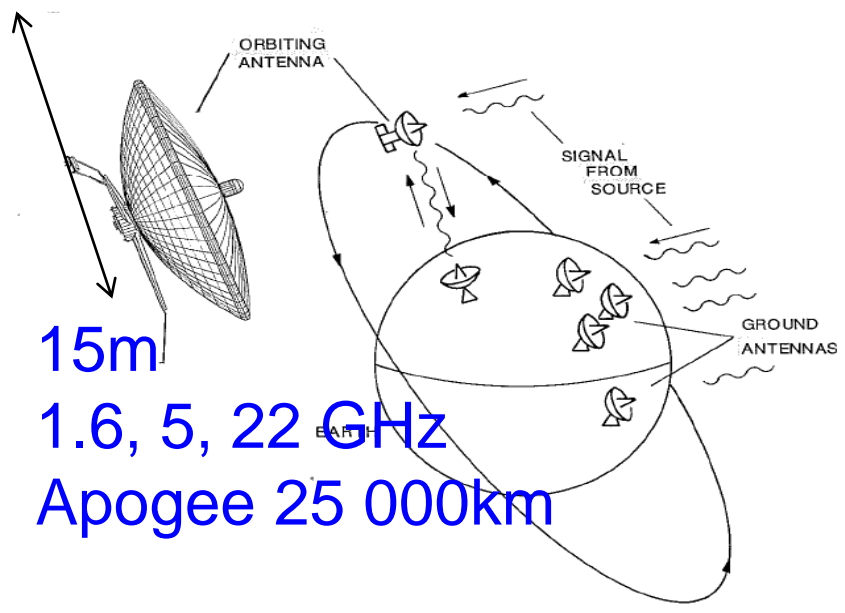
SCI(85)5  
NOVEMBER 1985

## QUASAT

A SPACE VLBI SATELLITE

1983-1985

ASSESSMENT STUDY



15m  
1.6, 5, 22 GHz  
Apogee 25 000km

esa SP-213

1984

## Quasat –

a VLBI observatory  
in space

Proceedings of a Workshop  
held at Gross Enzersdorf, Austria,  
on 18–22 June 1984



# 1984: QUASAT Workshop

## CONTENTS

List of Participants

Members of the Scientific Organising Committee

Introductory Papers

Cosmology

*H. van der Laan*

Some aspects of active galactic nuclei

*A.C. Fabian*

The galaxy scene and Quasat

*C. A. Norman*

The Quasat mission: an overview

*R.T. Schilizzi et al.*

Some prospects of space VLBI

*R.Z. Sagdeev*

Space VLBI studies in Japan

*M. Morimoto*

# 1984: QUASAT Workshop

## Some prospects for space VLBI by R.Z Sagdeev

“Basic concepts of space very longbase radio interferometry are discussed. Two perspective ground-space interferometer projects are considered: with low-orbit space telescope (very complete coverage of uv-plane) and with high orbit space telescope (very good angular resolution).”

# 1984: QUASAT Workshop

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*M. Morimoto*

# 1984: QUASAT Workshop

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## Space VLBI Studies in Japan by M. Morimoto

“The other is a joint study group in Institute for Space and Astronomical Science (ISAS), RRL and NRO, to study a possibility of having a small antenna in space to do VLBI experiments.”

# High-level coordination... began to take place in 1984

- COSPAR Ad-hoc Committee on Space VLBI
  - served as a body to coordinate the three different efforts until the mission-specific International Scientific Committees were formed
  
- Inter-(Space) Agency Consultative Group
  - Panel 1 on Space VLBI

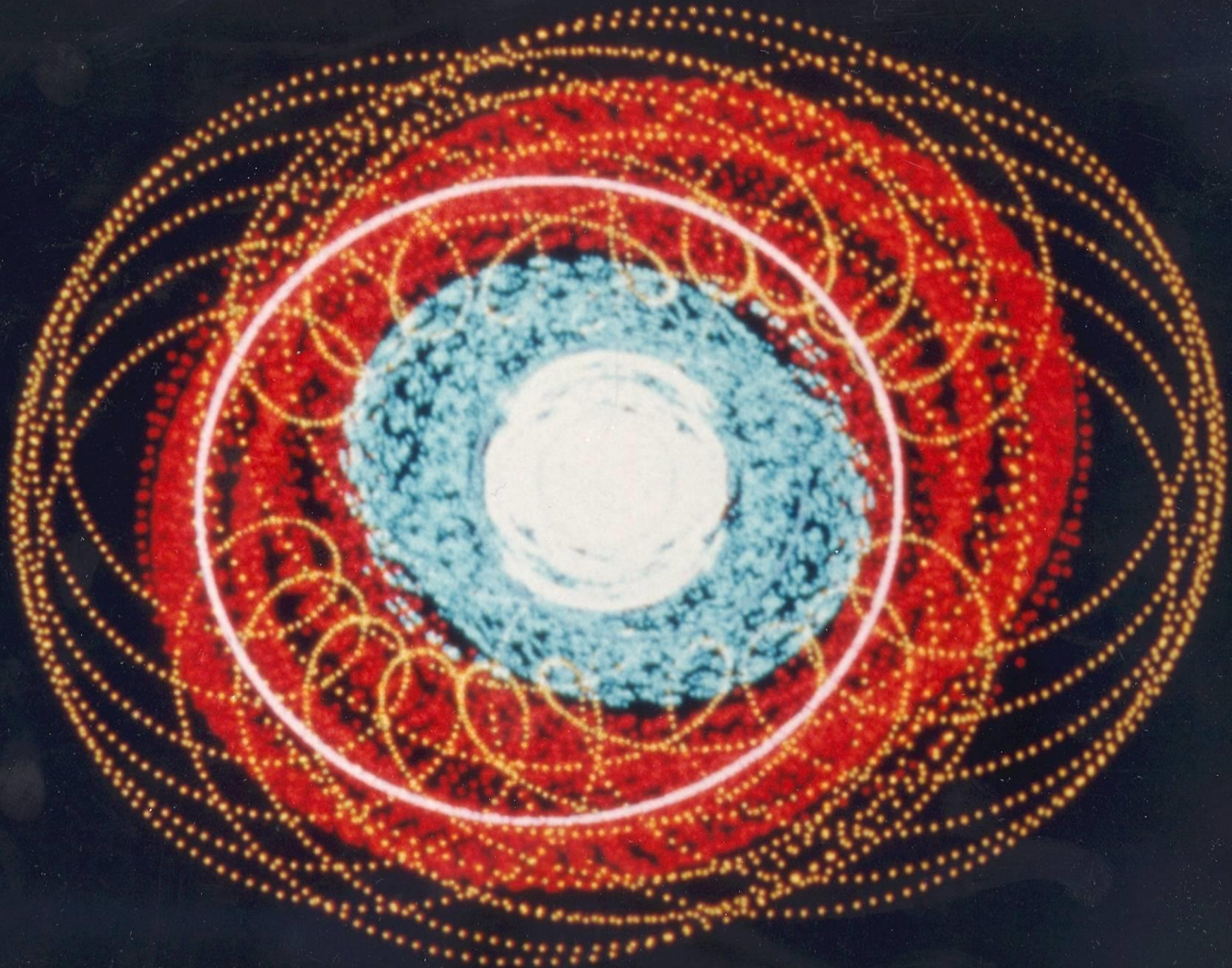
# Dual-satellite space VLBI

In 1984, the QUASAT team realised that it was impossible to combine superb uv-coverage with a substantial jump in angular resolution compared to ground-based VLBI.

So why not combine forces and simultaneously fly two satellites in complementary orbits, and achieve "perfect" uv coverage out to 60 000 km?

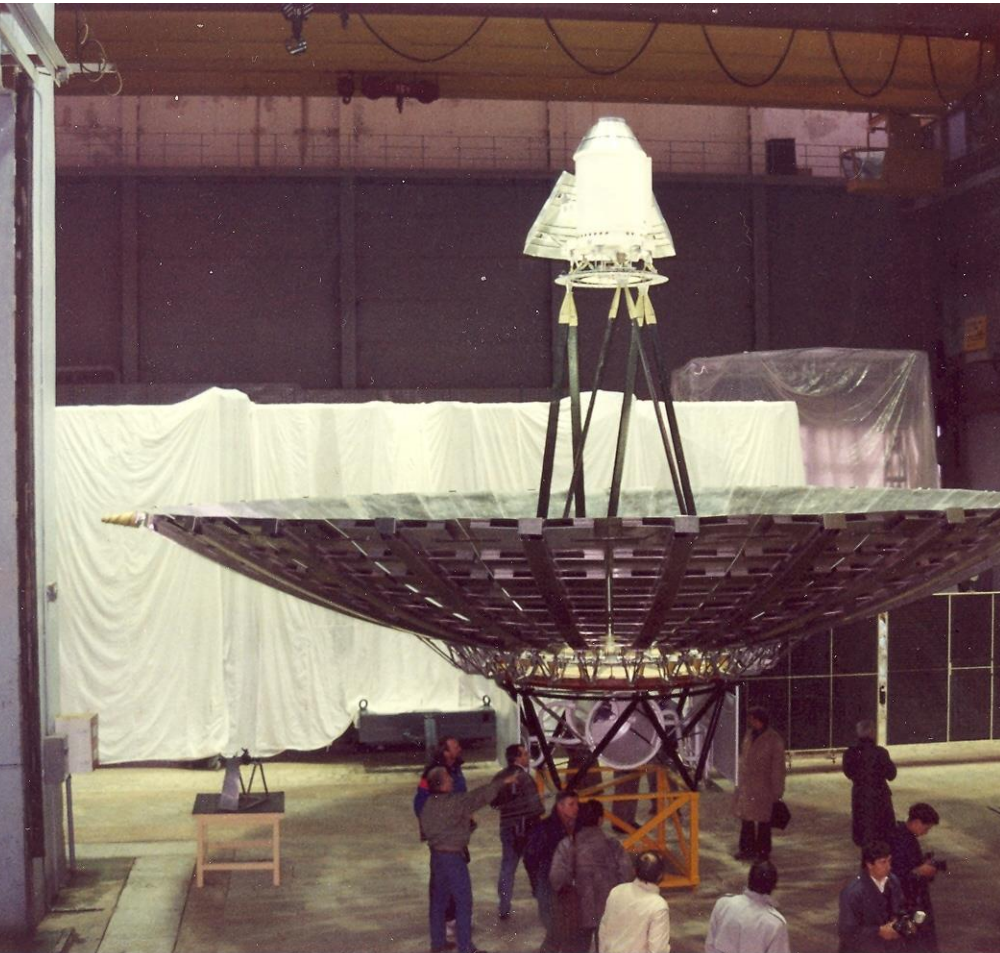
QUASAT + RadioAstron or  
QUASAT + Japanese satellite







# RadioAstron was approved in 1985



10m diameter, 0.3, 1.6, 5, 22  
GHz, apogee 100 000km,  
later changed to 350 000 km

# EVN 6cm receiver for Radioastron

Kardashev and Setti  
signing the agreement  
in 1986



# EVN 6cm receiver for Radioastron



Kardashev and Setti  
signing the agreement  
in 1986

**Although it was built in  
Dwingeloo and Bonn,  
tested at ESTEC, and  
delivered to Moscow, it did  
not fly on RADIOASTRON.**

**But that's another story.....**



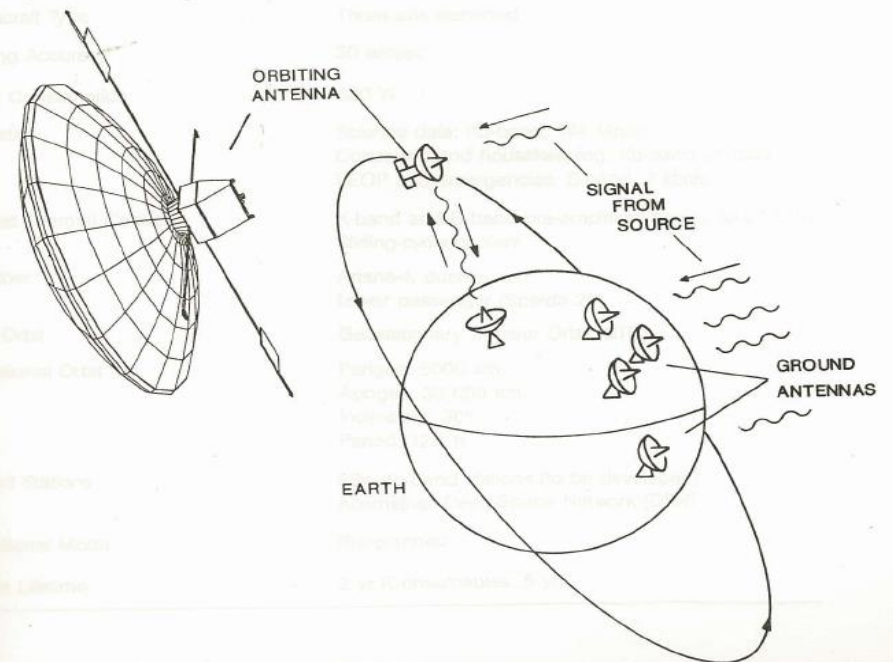
Phase A Study  
1986-1988



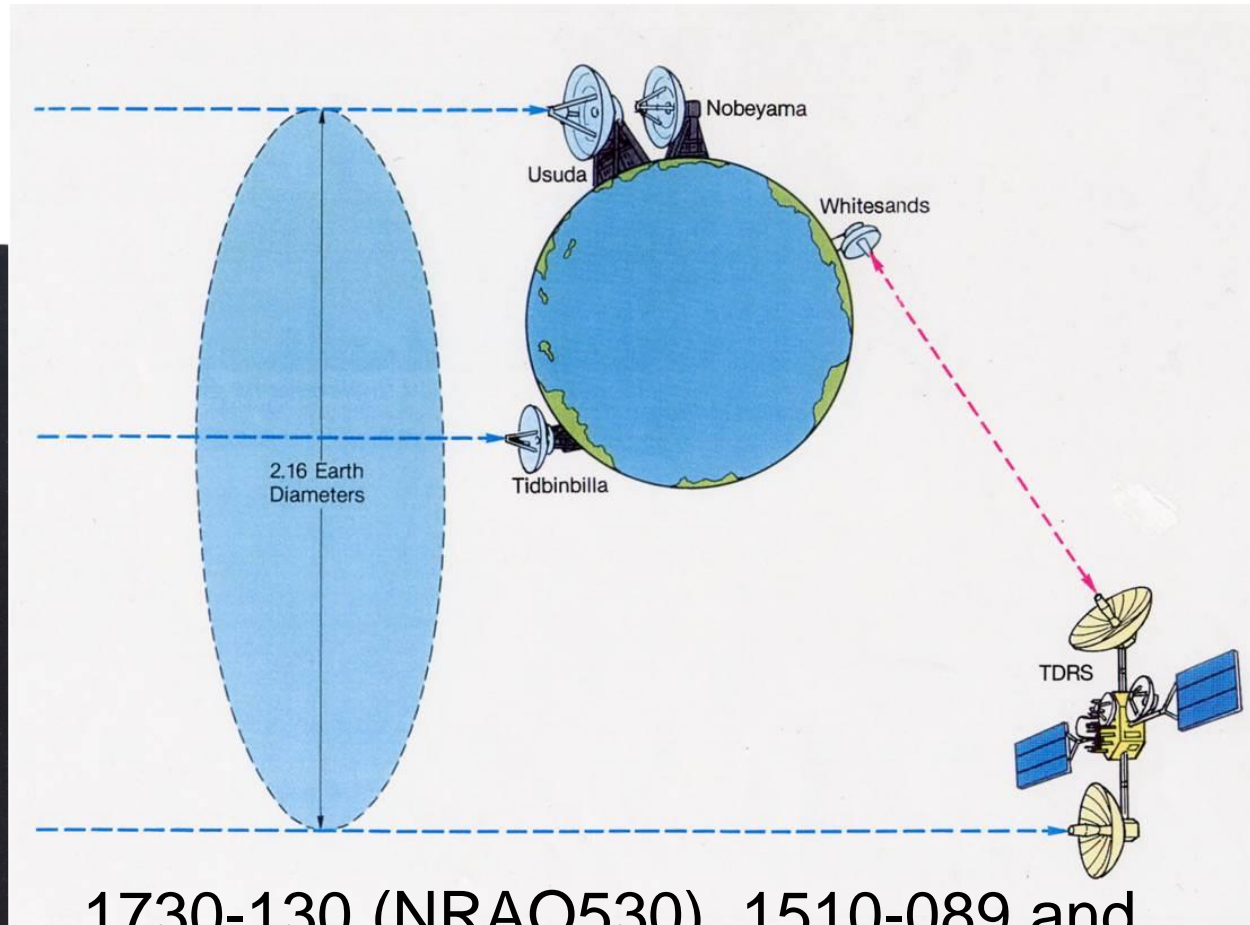
SCI (88) 4  
October 1988

# QUASAT

A SPACE VLBI SATELLITE  
REPORT ON THE PHASE A STUDY



# First space VLBI fringes with TDRSS in 1986



1730-130 (NRAO530), 1510-089 and  
1741-038, detected at 2.3 GHz

# First space VLBI fringes with TDRSS in 1986

12

LINFIELD ET AL.

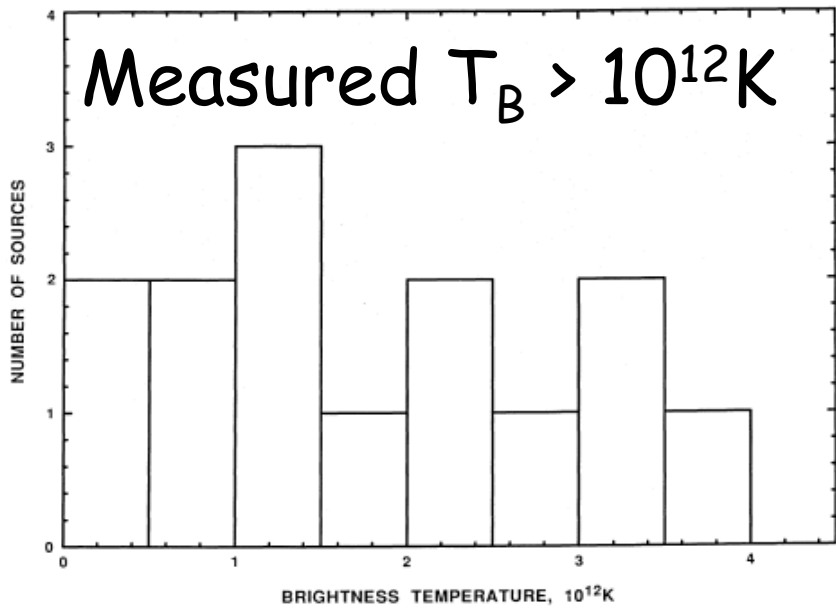
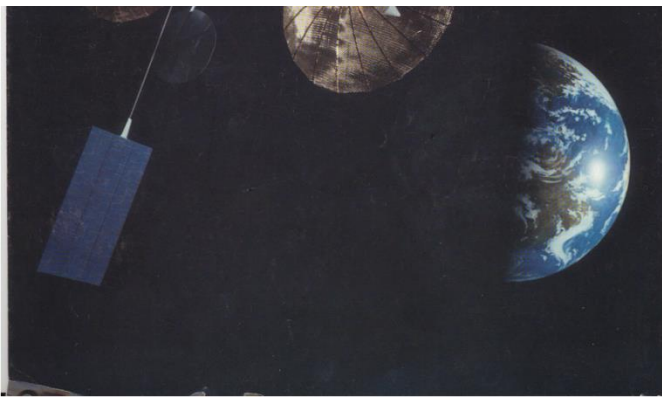
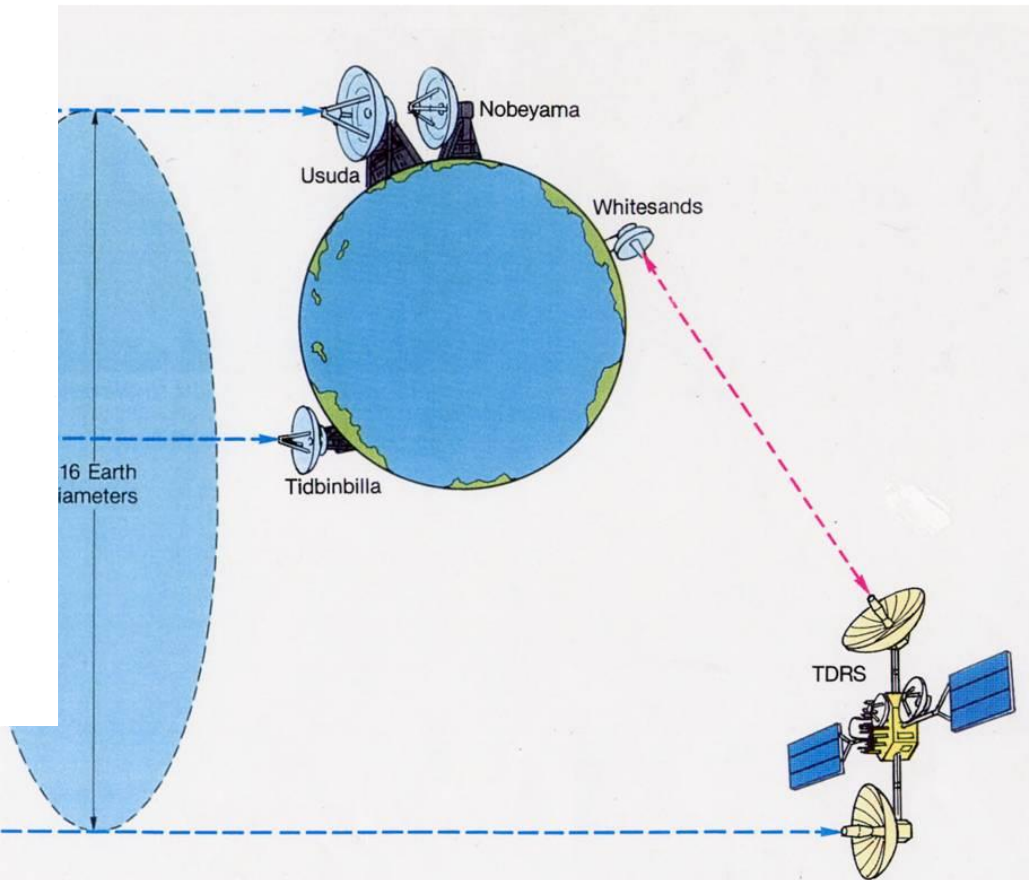


FIG. 4.—Histogram of the measured brightness temperatures for the 14 sources listed in Table 4



1730-130 (NRAO530), 1510-089 and 1741-038, detected at 2.3 GHz



# Cultural exchanges took place



October Revolution Parade in Leningrad,  
November 1988

# So what happened in the end?

QUASAT was shot down by ESA in October 1988 and finally died in 1989 (lost out to Cassini-Huygens)

VSOP was approved by ISAS in December 1988

- 8m diameter 1.6, 5, 22 GHz; apogee 21 600 km

Working closely with the Soviet Union on RadioAstron still didn't have the seal of approval from you know who...

So the QUASAT team all took an oath of allegiance to the Three Samurai.....

while continuing to work with The Tzar, participating in advisory committee meetings and building receivers

# Last gasps from ESA and NASA

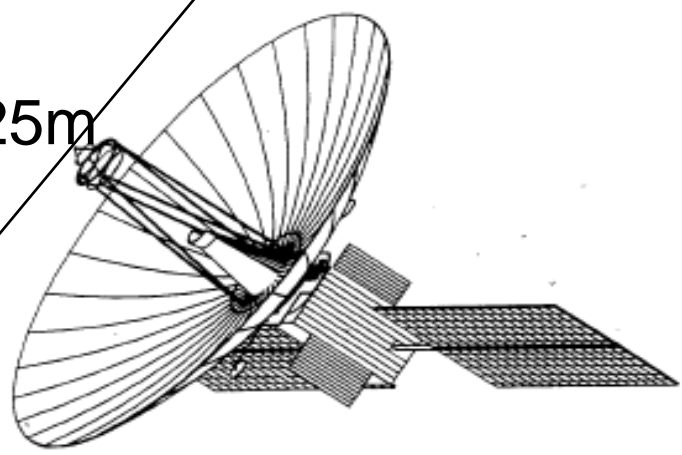


1989-1991

I V S

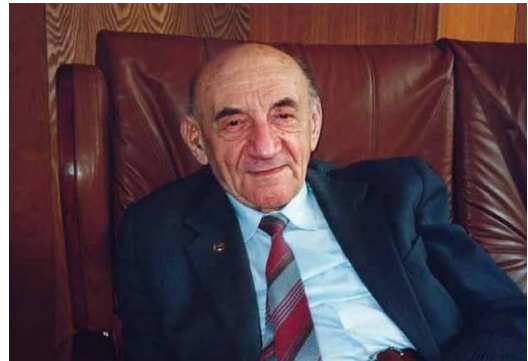
AN ORBITING RADIO TELESCOPE

25m



REPORT ON THE ASSESSMENT STUDY

V. ALTUNEH, B. ANDERSON, J.W.H. BARKS, A. BRADY, R.S. BOOTH, B.E. CHERTOK, J. CORNELISSE,  
Yu.S. DENISOV, L.I. GAVVTA, M.S. KARBANOV, Ya.P. KOLYNO, T. KUJPER, G. PELARATT,  
R.A. PRESTON, R.T. SCHILLERS, V.I. SLYSH, G. TOPKAT, S. VOLANTE, P.N. WILKINSON, T.L. WILSON



Boris Chertok

# Last gasps from ESA and NASA



Ya. Kolyako

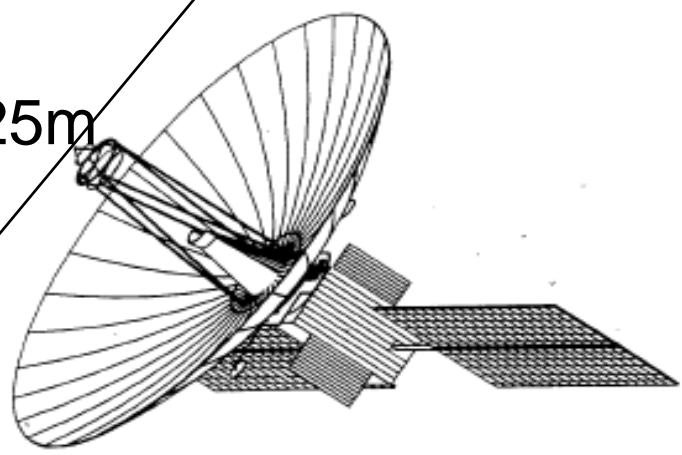
Document 6.2

1989-1991

I V S

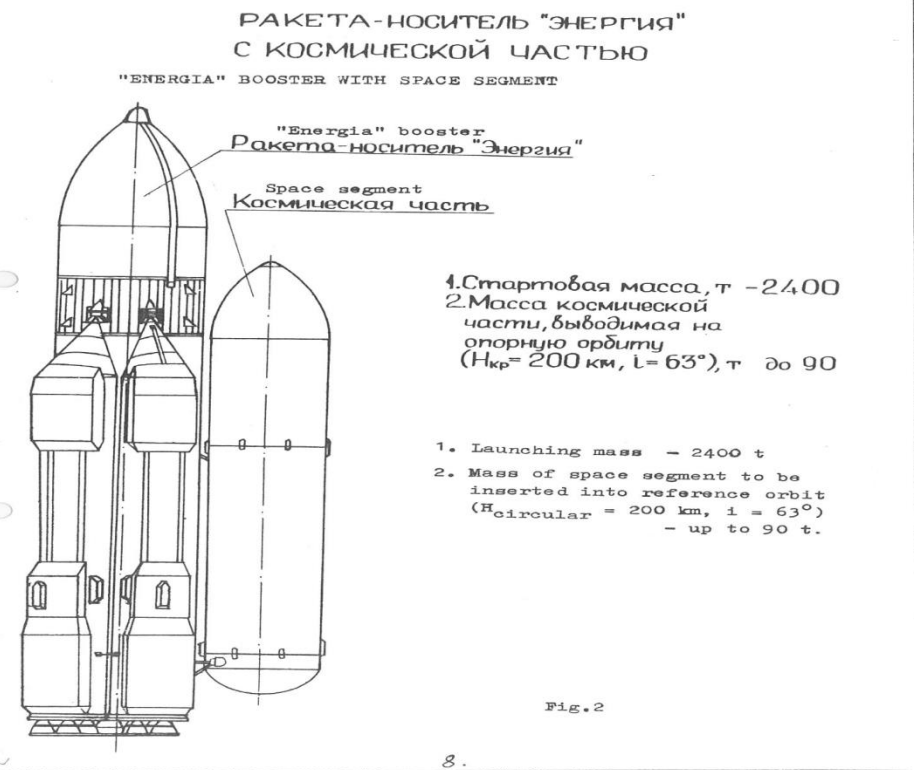
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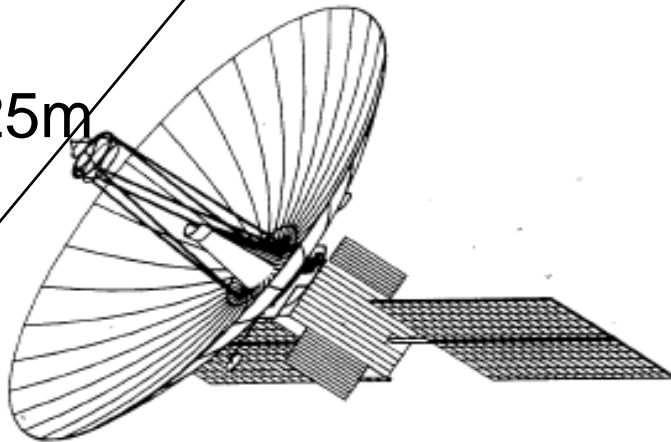


1989-1991

I V S

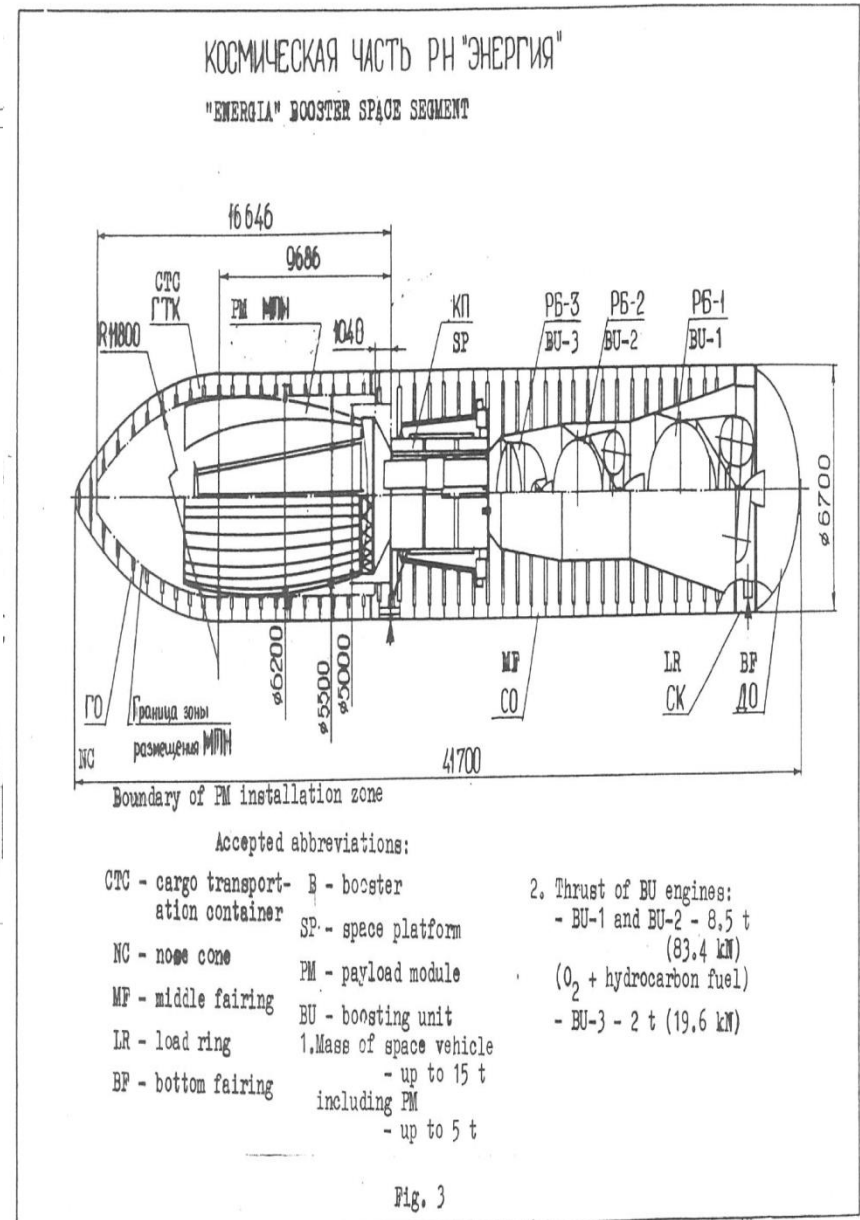
AN ORBITING RADIO TELESCOPE

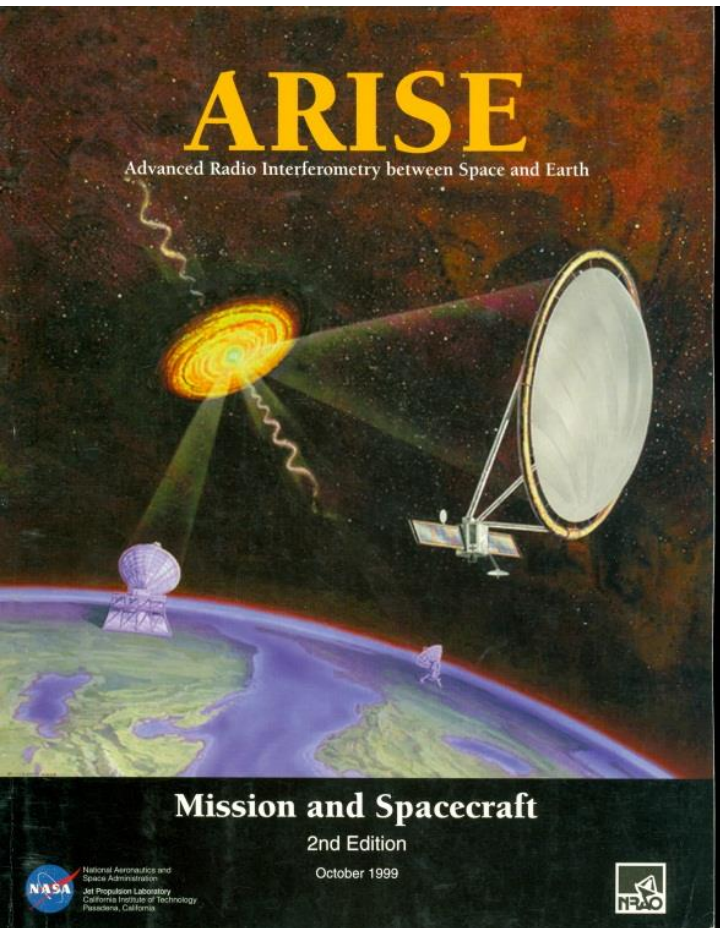
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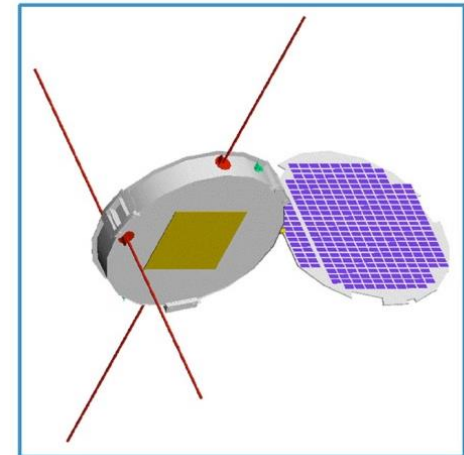




1999

## ALFA (~2002)

<b>Antenna :</b>	<b>100 km array of 16 spacecraft</b>
<b>Frequency Bands (MHz):</b>	<b>0.03 - 30 (tunable)</b>
<b>Resolution (arcseconds):</b>	<b>10,000 - 10</b>
<b>Sensitivity:</b>	<b>several Jy</b>



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Stage 3: 1988 – 2012

VSOP and RadioAstron

# RISC and VISC



RISC - April 1988  
in Dwingeloo

VISC - November 1992  
in Sagamihara





# There were risks in being a RISC member



The bus crash  
Pushchino to Moscow Road,  
November 1991





# The Ground Segment

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## Global VLBI Working Group

Proposed in the Capitol Bar in Socorro in 1990 by Ron Ekers, Roy Booth and Paul Vandembout, **chair: Roy Booth**

## Global VLBI Working Group

Proposed in the Capitol Bar in Socorro in 1990 by Ron Ekers, Roy Booth and Paul Vandembout, **chair: Roy Booth**

The GVWG was established in 1990 as a Working Group of Commission J at the URSI General Assembly in Prague, and recognized in 1991 at the IAU General Assembly in Buenos Aires as a Division X Working Group. The mandate of the GVWG, its membership and chair, are reviewed at Commission J business sessions during URSI General Assemblies.

The current mandate of the GVWG comprises the following tasks:

1. To develop a concept for an International VLBI Network, comprising existing or future national and regional networks.
2. To promote compatibility of technology in VLBI instrumentation.
3. To serve as a liaison between ground-based observatories and national or international space agencies, for coordination of participation by ground radio telescopes in Space VLBI missions.

The GVWG carries out its tasks in conjunction with the organizations concerned, and presents summaries of its activities to URSI Commission J and IAU Division X at their respective General Assemblies.

## Global VLBI Working Group

3. To serve as a liaison between ground-based observatories and national or international space agencies, for coordination of participation by ground radio telescopes in Space VLBI missions.

# The Ground Segment

## Global VLBI Working Group



Onsala, October 1993

# VSOP needed a bit of help from friends with connections.....



# Launch in February 1997



# Launch in February 1997

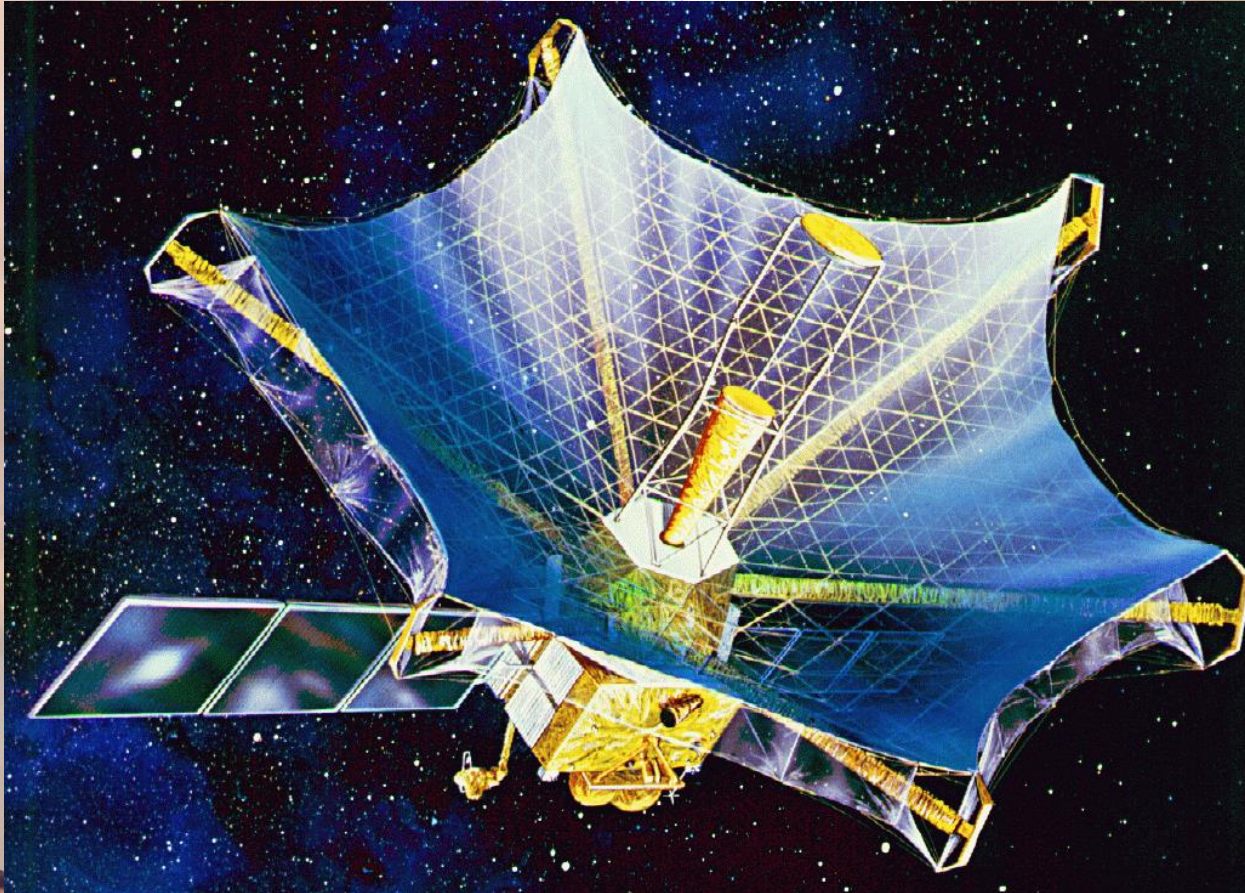




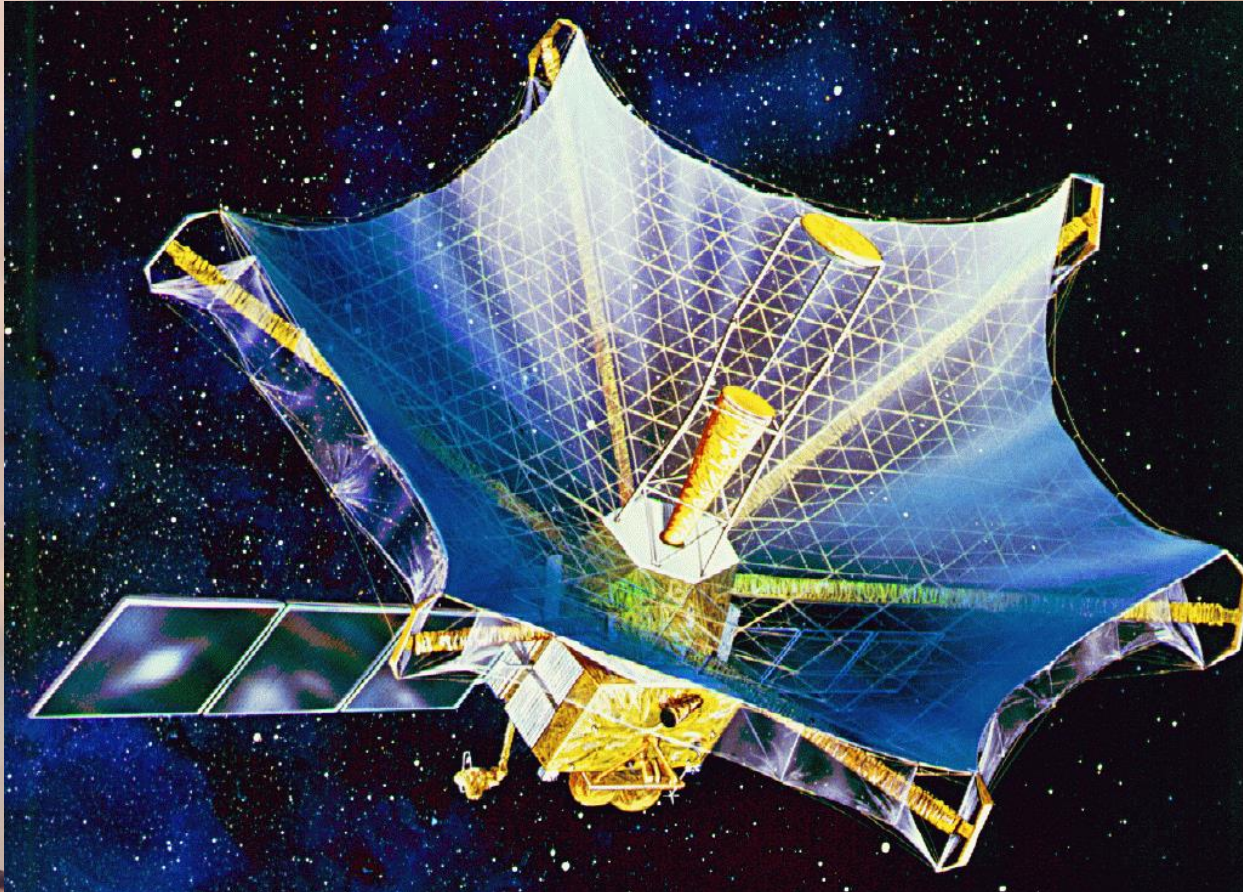
# Launch in February 1997



# Launch in February 1997



# Launch in February 1997



operational  
until Nov  
2005

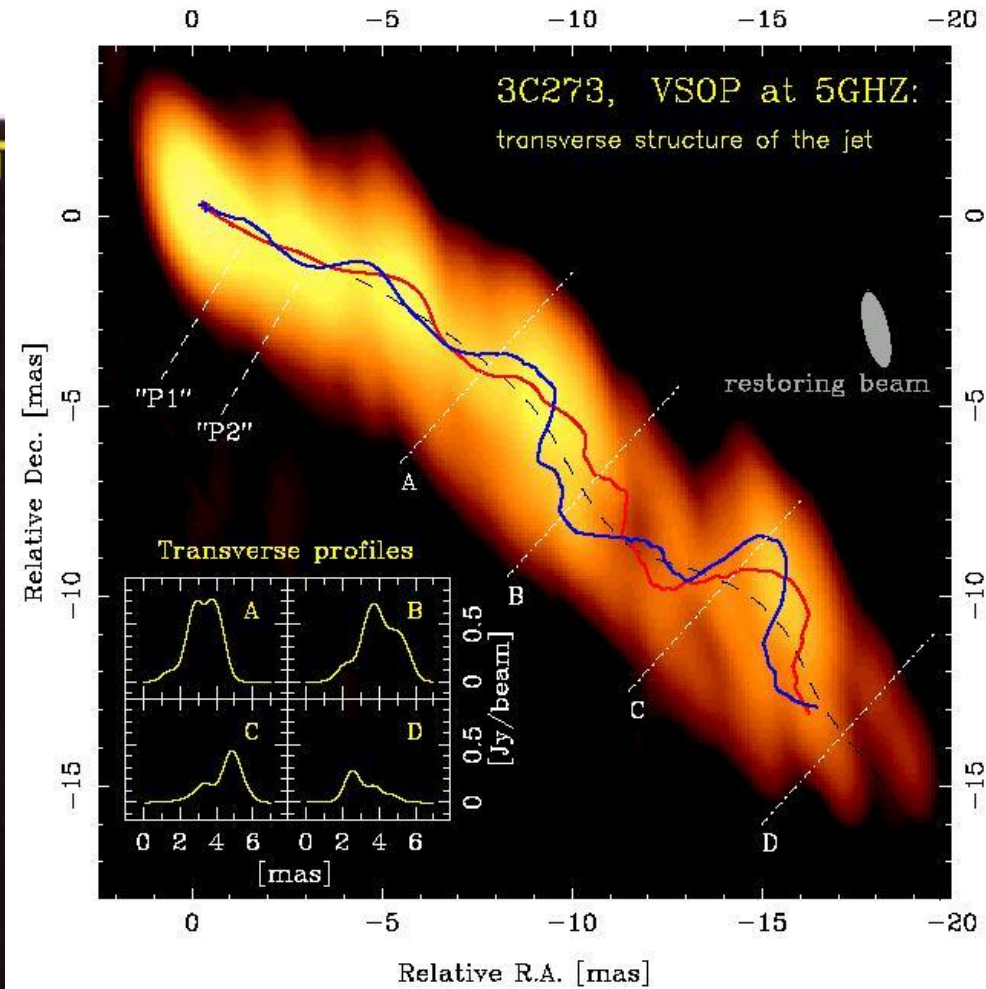
# "V" for Victory or VSOP or ...



Quasar 3C273  
3 billion ly away

Central Core is  
Zoomed by VSOP

Optical: Pseudo-color  
Radio: Contour



VSOP image of 3C273  
by Lobanov et al

Hubble Space telescope (left) and MERLIN (right) images of the Quasar 3C273

# And to follow up...

## The Next-Generation Space VLBI Project

V L B I Space Observatory Programme  
VSOP to **VSOP-2**



9m diameter  
8, 22, 43 GHz  
25000 km apogee

The Space VLBI Project VSOP-2 offers superior spatial resolution to enable imaging of the accretion discs, the regions where jets are produced and collimated in active galactic nuclei, and the magnetospheres around protostars.

# And to follow up...

## The Next-Generation Space VLBI Project

V L B I Space Observatory Programme  
VSOP to **VSOP-2**



The Space VLBI Project VSOP-2 offers superior spatial resolution to enable imaging of the accretion discs, the regions where jets are produced and collimated in active galactic nuclei, and the magnetospheres around protostars.

9m diameter  
8, 22, 43 GHz  
25000 km apogee

Approved in 2007 by JAXA as ASTRO-G, but ran into technical problems and was cancelled in 2011

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In the meantime, Nikolay and his team carried on...



# getting all the help he could...

Prime  
Minister  
Putin





# Ready to go to Baikonur



# And finally the launch in July 2011



# And finally the launch in July 2011



# First fringes!

## RADIOASTRON

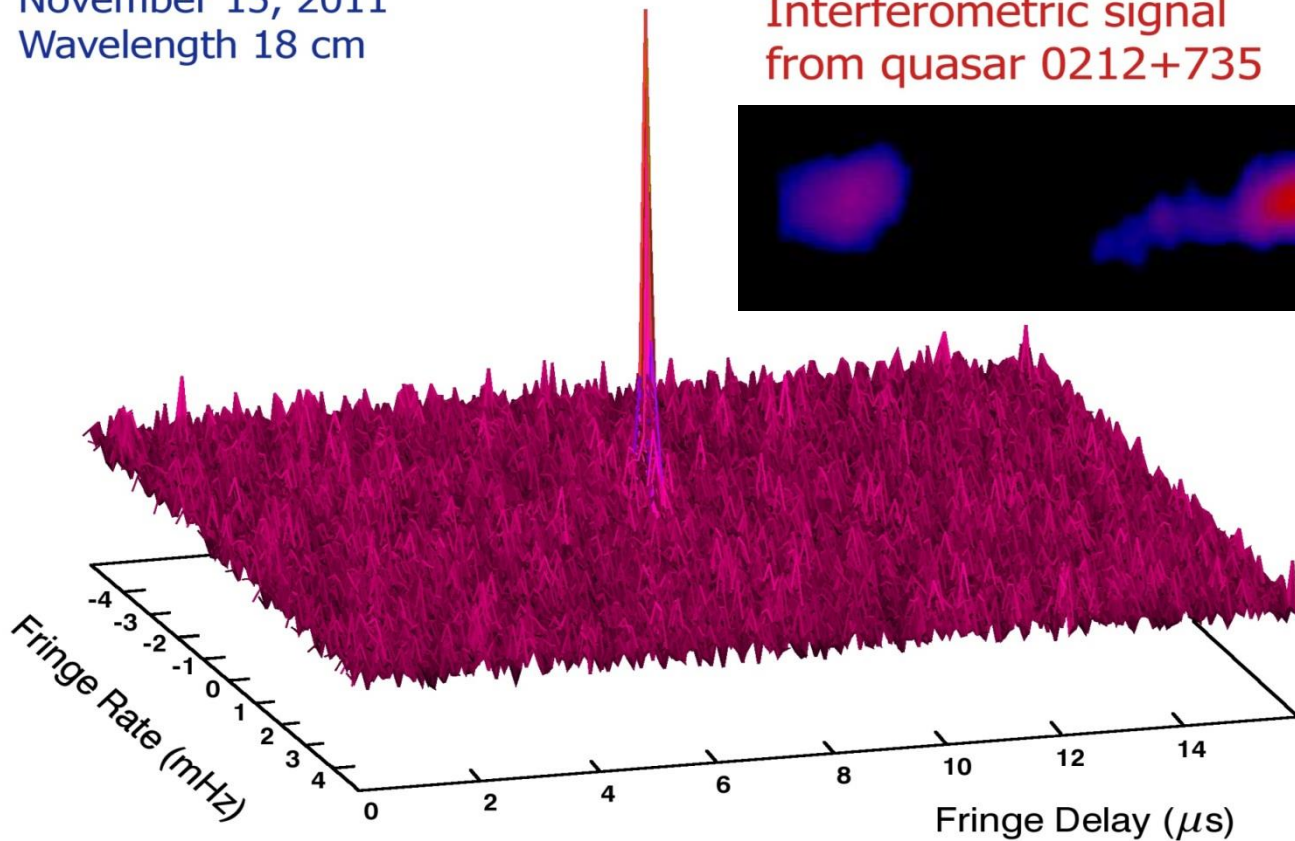
100 000 km from Earth

Baseline projection: 50 M $\lambda$

November 15, 2011

Wavelength 18 cm

Interferometric signal  
from quasar 0212+735



And the rest is history.....