The International VLBI Service for Geodesy and Astrometry (IVS)

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IDS Analysis Workshop, GSFC, 16 Oct 2015

What is the IVS?

The **International VLBI Service for Geodesy and Astrometry (IVS)** is an international collaboration of organizations which operate or support VLBI components:

- IVS inauguration was on **1 March 1999**.
- IVS 10th Anniversary event on 25 March 2009.
- 83 permanent components supported by 41 institutions in 21 countries.
- ~300 Associate Members.

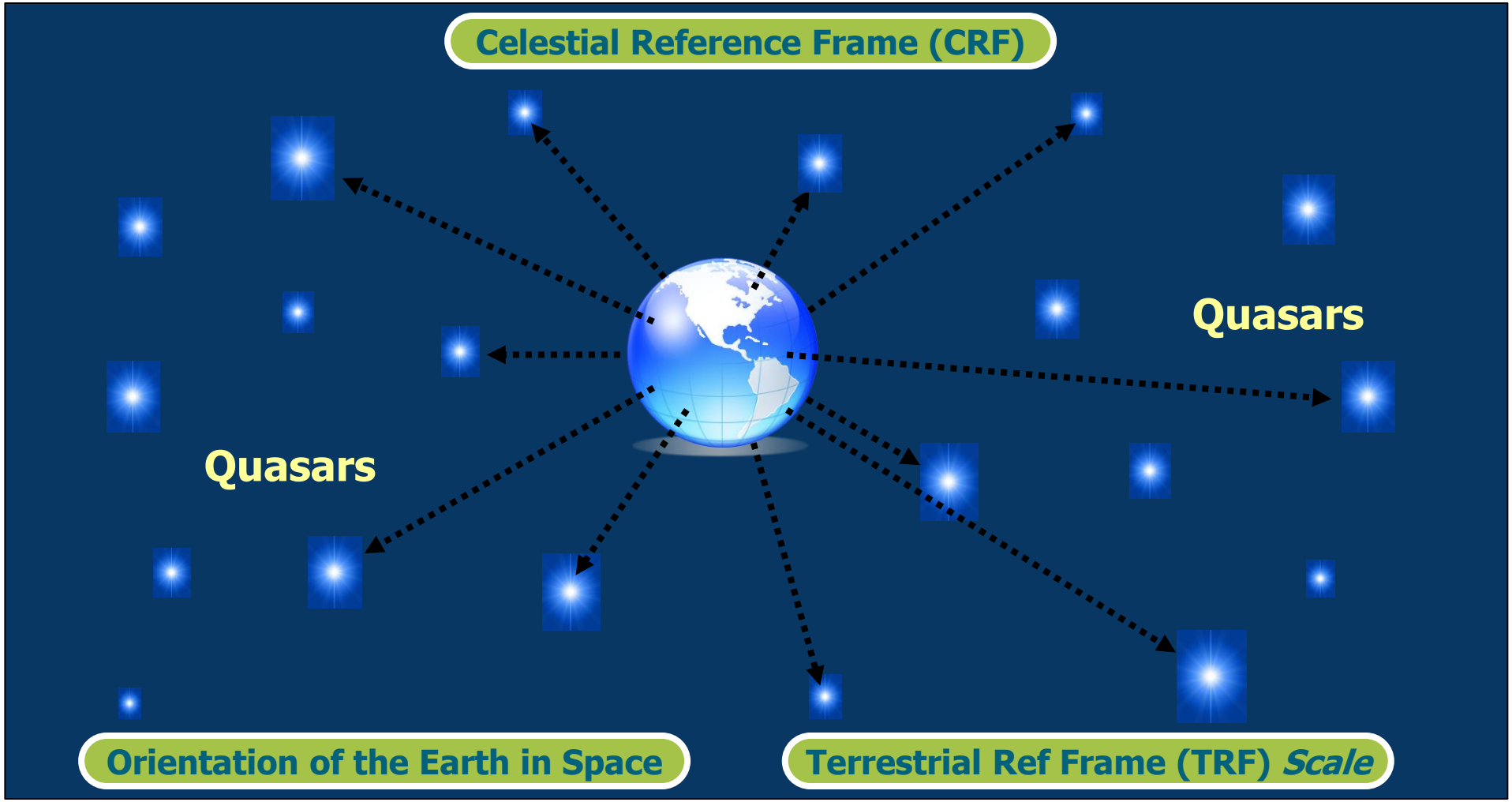
IVS is a recognized service of

- **IAG** – International Association of Geodesy
- **IAU** – International Astronomical Union
- **WDS** – World Data System

IVS Member Organizations

Australia	Geoscience Australia; University of Tasmania; CSIRO
Austria	Vienna University of Technology
Brazil	Centro de Rádio Astronomia e Aplicaçoes Espaciais
Canada	NRCan; Dominion Radio Astrophysical Observatory
China	Chinese Academy of Sciences
Finland	Finnish Geodetic Institute; Aalto University
France	Observatoire de Paris; Observatoire de Bordeaux
Germany	Deutsches Geodät. Forschungsinstitut; Bundesamt für Kartographie und Geodäsie; University of Bonn; Max-Planck-Institute für Radioastronomie; FESG München; GFZ Potsdam
Italy	Istituto di Radioastronomia INAF; Agenzia Spaziale Italiana; Politecnico di Milano DIIAR
Japan	Geospatial Information Authority of Japan; National Institute of Information and Communications Technology; National Astronomical Observatory; National Institute of Polar Research
Korea	Korea Astronomical and Space Institute; National Geographic Information Institute
New Zealand	Auckland University of Technology
Norway	Norwegian Mapping Authority
Russia	Astronomical Institute of St.-Petersburg University; Institute of Applied Astronomy; Sternberg Astronomical Institute of Moscow State University
South Africa	Hartebeesthoek Radio Astronomy Observatory
Spain	Instituto Geográfico Nacional
Sweden	Chalmers University of Technology
Turkey	Karadeniz Technical University
Ukraine	National Academy of Sciences; Crimean Astrophysical Observatory
USA	NASA Goddard Space Flight Center; U.S. Naval Observatory; Jet Propulsion Laboratory

Role of VLBI in Geodesy

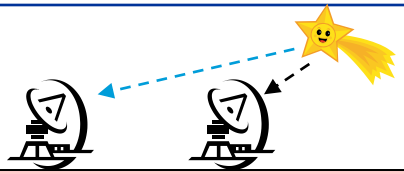


Parkes movie

IVS Products

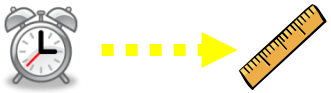
- Earth Orientation Parameters (EOP):
  - 24-hour sessions (all EOP)
  - 1-hour Intensives (UT1–UTC)
- Terrestrial Reference Frame (TRF)
  - VLBI Terrestrial Reference Frame (VTRF)
- Celestial Reference Frame (CRF)
- Daily EOP + station coordinates (SINEX-files)
- Tropospheric Parameters (TROPO)
- Baseline Lengths (BL)

Geodetic VLBI: How does it work?



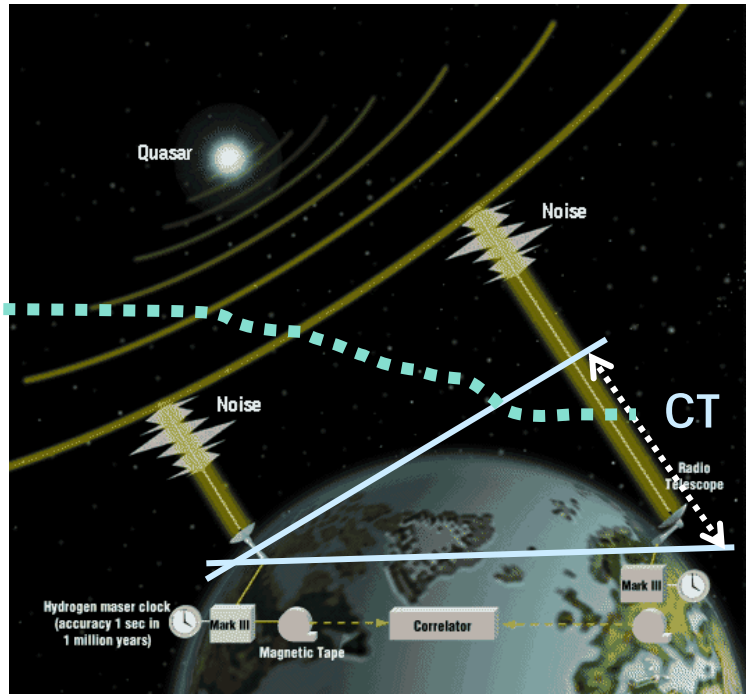
A network of antennas observes a Quasar

The delay between times of arrival of a signal is measured



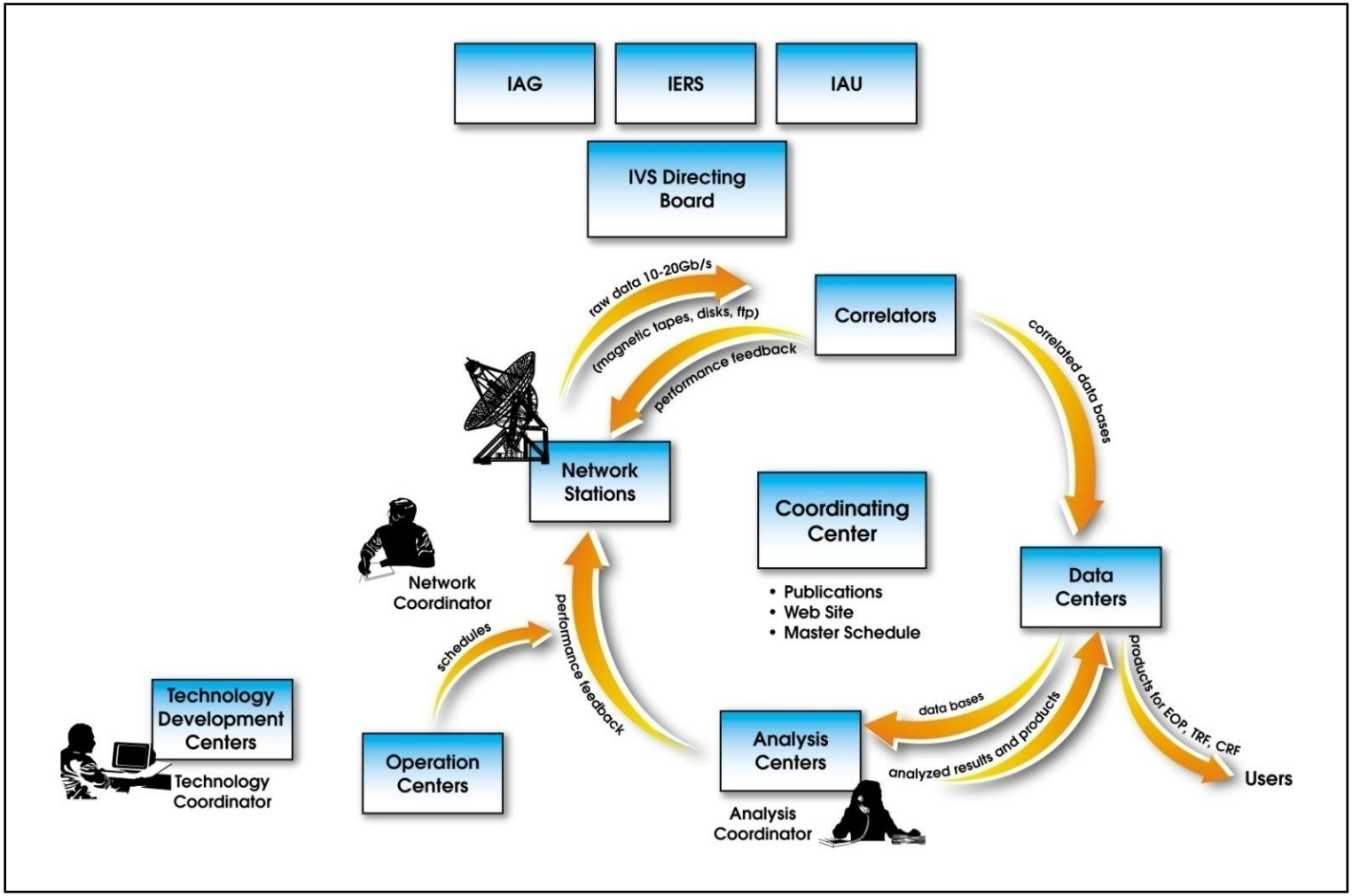
Using the speed of light, the delay is converted to a distance

The distance is the component of the baseline toward the source

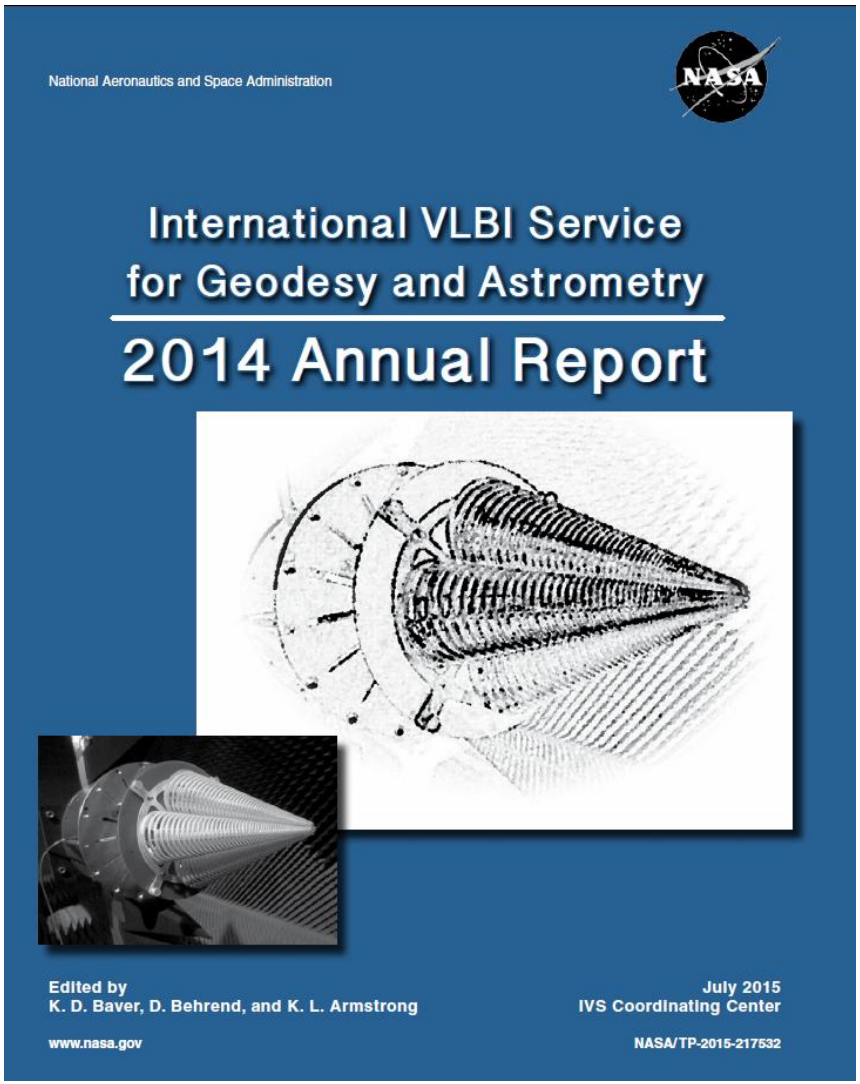


By observing many sources, all components of the baseline can be determined.

Organization of the IVS



IVS 2014 Annual Report



- Editors: Baver, Behrend, Armstrong
- Completed: end July 2015
- 338 pages
- Special reports:
  - VGOS Data Trans. & Corr. Plan
  - Foundation of the AOV
- Publication approval
- Online: end August 2015
- Printed: mid-September 2015

New decision: go to biennial reports, alternating between GM Proceedings and Reports

August 2015 Newsletter

IVS Newsletter

Issue 42, August 2015

VLBI High on the Azores

– Dirk Behrend, NVI, Inc.

It happened in May. It happened a bit later than usual. But it happened with a number of firsts and without doubt made its way into the VLBI history books. The EVGA (European VLBI Group for Geodesy and Astrometry) organized its 22nd meeting in Ponta Delgada on the island of São Miguel, Azores, Portugal. From May 17 through 21 the geodetic VLBI community assembled on the "Green Island" in the North Atlantic Ocean. São Miguel forms, together with Santa Maria, the Eastern group of the Portuguese archipelago of the Azores. The Azores are nine islands in the North Atlantic about two thirds of the way from North America to Europe. They have a prominent location at the triple junction of the tectonic plates of North America, Eurasia, and Africa. They are also known for a weather phenomenon called the Azores High (or Azores Anticyclone).

The President of the Azores, Vasco Alves Cordeiro, during the dedication speech for the radio telescope "Colombo" on Santa Maria.

Before making the trip, I learned that SATA is not only important for mass storage in VLBI data recording modules, but it also plays a major role in mass transportation to/from the Azores. SATA (Sociedade Açoriana de Transportes Aéreos) happens to be the airline headquartered in Ponta Delgada that services flights to North America and Europe. So, it was a SATA airbus that brought many of the 90 registered participants to the island. The participants originated from 18 countries in five continents. The large attendance ensured that for about a week, the Azores had the highest density of VLBI experts in the world. So, in a way Ponta Delgada was the geodetic VLBI capital of the world.

The EVGA meeting proper took place (after an icebreaker reception in the evening of May 17) from May 18 to 19 in the Teatro Micaelense in the center of Ponta Delgada. The scientific program was packed full with 49 oral and 36 poster presentations. The range of topics went from VGOS developments to status reports of the stations and correlators to geodetic analysis and astrometric questions. In the morning of May 19, a live video feed connected the participants to the Caucasus to witness the inauguration of the new VGOS antenna at Zelenchukskaya. Later the same day, our Russian colleagues presented first fringes with the new antenna.

On May 20, the participants experienced a real first for an EVGA meeting or any IVS meeting for that matter: for the inauguration of the RAEGE station on the island of Santa Maria the group had to take a very early charter flight from São Miguel to Santa Maria. Two buses departed from the meeting hotel at 5:30 am to catch the flight for the island hopping (20 min flight). The ceremony for the dedication of the new VGOS antenna was held in the morning at the RAEGE station. After the bishop had blessed the new telescope for its future operations, the Director of the Spanish IGN and the President of the Azores inaugurated the new radio telescope, which is called "Colombo", as the second of the RAEGE project and the first on Portuguese soil. Hence, with the new antenna we can welcome a new country into the fold of the IVS. The day was completed by some sightseeing of the island. At the end of the day, we island-hopped back to Ponta Delgada. The VLBI week was completed by several splinter meetings on the next two days.

We would like to thank the local organizing team led by Luis Santos and Sara Pavão for their excellent work. The days on São Miguel have been very memorable. More information about the meeting can be found online at http://evga2015.raege.net/.

The Azores Archipelago in the North Atlantic Ocean is part of Portugal and will host two VGOS antennas: one on the island of Santa Maria and a second one on the island of Flores.

August 2015
Page 1

- Editors: Behrend, Johnson, Hase
- Feature: Syowa station
- Reports on TOW2015 and EVGA2015 meetings as well as Board meeting report
- Report on retirement of Japanese GARNET network
- Announcement of VLBI Training School
- Printed copy was mailed with flyer for GM2016…

IVS General Meeting 2016

- March 13–17, 2016
- Johannesburg, South Africa
- 1st Announcement: July 21
- 2nd Announcement: October 15
- Abstracts due: December 15
- Registration closes: February 1
- Proceed. opens: January 11
- Proceed. closes: April 30
- Program Committee works on program

- IVS mini-TOW: March 12, 2016
- 2nd VLBI Training School: March 9–12, 2016

2nd IVS VLBI Training School (1/2)

Day-1, Wednesday, 9 March 2016

09:00-09:15	Welcome and practical information (**Rüdiger Haas + Alet de Witt**)
09:15-10:00	**L01:** Introductory lecture, very general overview addressing all aspects (lecturer: IVS chair **Axel Nothnagel**, University of Bonn, Germany)
10:00-10:30	Coffee break
10:30-12:00	**L02:** Technical equipment at stations (e.g. radio telescopes, feeds, receivers) (lecturer: **Bill Petrachenko**, National Resources Canada, Canada)
12:00-13:00	Lunch break
13:00-14:30	**L03:** Digital backends (lecturer: **Gino Tuccari**, Istituto di Radioastronomia, Noto Observatory, Italy)
14:30-15:00	Coffee break
15:00-16:30	**L04:** Data acquisition, data formats, data transfer (lecturer: **Harro Verkouter**, JIVE, The Netherlands)
16:30-17:00	Stretch your legs break
17:00-19:00	**EX1:** Exercises on technical aspects (**Bill, Gino, Harro**)

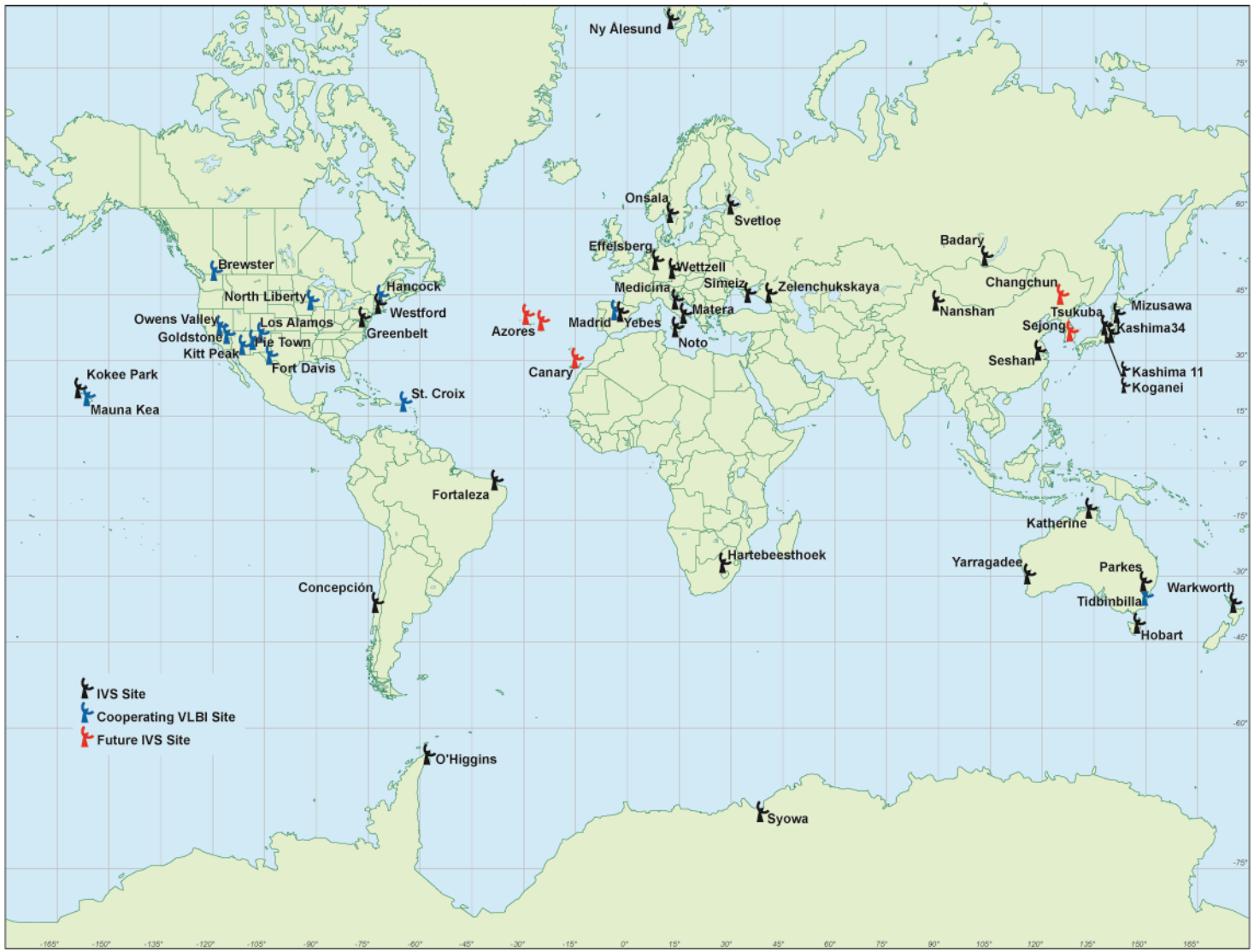
Day-2, Thursday, 10 March 2016

08:30-10:00	**L05:** Experiment scheduling (lecturer: **John Gipson**, NASA, USA)
10:00-10:30	Coffee break
10:30-12:00	**L06:** Observing an experiment incl. remote control (lecturer: **Alexander Neidhardt**, TU Munich, Germany)
12:00-13:00	Lunch break
13:00-14:30	**EX2:** Exercises on scheduling (**John** + tbd)
14:30-15:00	Coffee break
15:00-16:30	**L07:** Correlators for geodesy and astrometry (lecturer: **Walter Brisken**, NRAO, USA)
16:30-17:00	Stretch your legs break
17:00-18:30	**EX3:** Exercises on running an experiment (**Alexander + tbd**)

2nd IVS VLBI Training School (2/2)

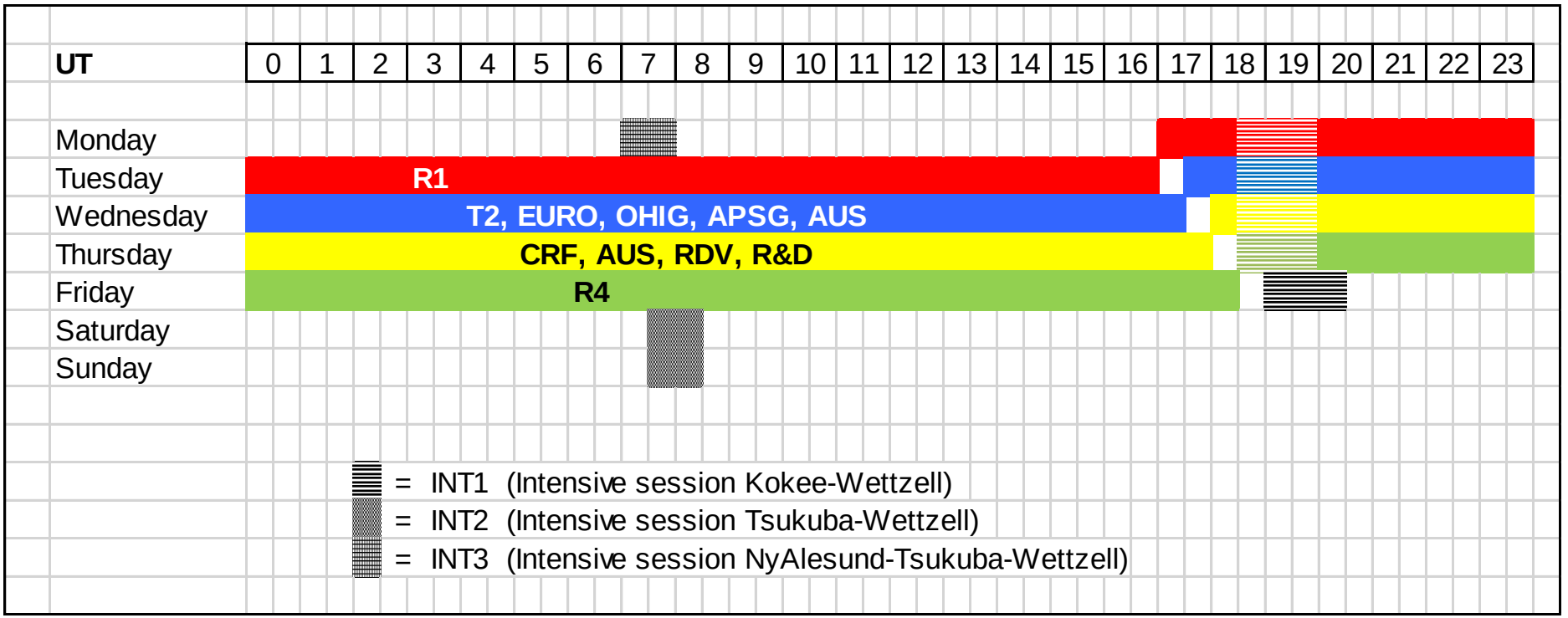
Day-3, Friday, 11 March 2016	
08:30-10:00	**L08:** Post-correlation analysis, fringe-fitting (lecturer: **Alessandra Bertarini**, University of Bonn and MPIfR Bonn, Germany)
10:00-10:30	Coffee break
10:30-12:00	**EX4:** Exercise-4 on correlation (**Walter + Alessandra**)
12:00-13:00	Lunch break
13:00-14:30	**L09:** Geophysical modelling (lecturer: **Thomas Hobiger**, Chalmers University of Technology, Sweden)
14:30-15:00	Coffee break
15:00-16:30	**L10:** Signal propagation (lecturer: **Johannes Böhm**, Technical University of Vienna, Austria)
16:30-17:00	Stretch your legs break
17:00-18:30	**EX5:** Exercises on modelling (**Thomas H. + Johannes** + tbd)
Day-4, Saturday, 12 March 2016	
08:30-10:00	**L11:** Radio sources (lecturer: **Patrick Charlot**, University of Bordeaux, France)
10:00-10:30	Coffee break
10:30-12:00	**L12:** Data analysis for geodesy (lecturer: **Thomas Artz**, University of Bonn, Germany)
12:00-13:00	Lunch break
13:00-14:30	**L13:** Data analysis for astrometry (lecturer: **Chris Jacobs**, JPL, USA)
14:30-15:00	Coffee break
15:00-18:00	**EX6:** Exercises on data analysis, both geodesy and astrometry (**Thomas A. + Chris**)
19:00-22:00	VLBI school dinner

IVS Network Stations



IVS Observing Program

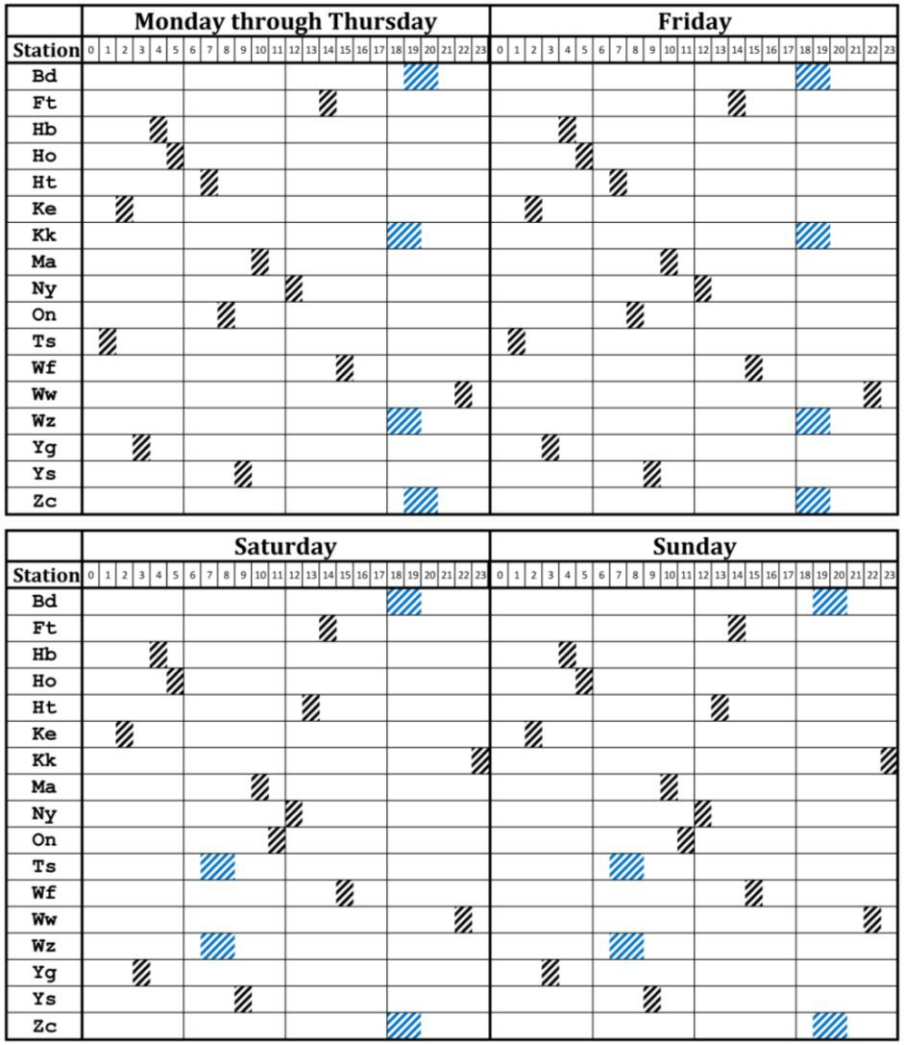
- Typical weekly layout for IVS observing sessions



Continuous VLBI: Example CONT14

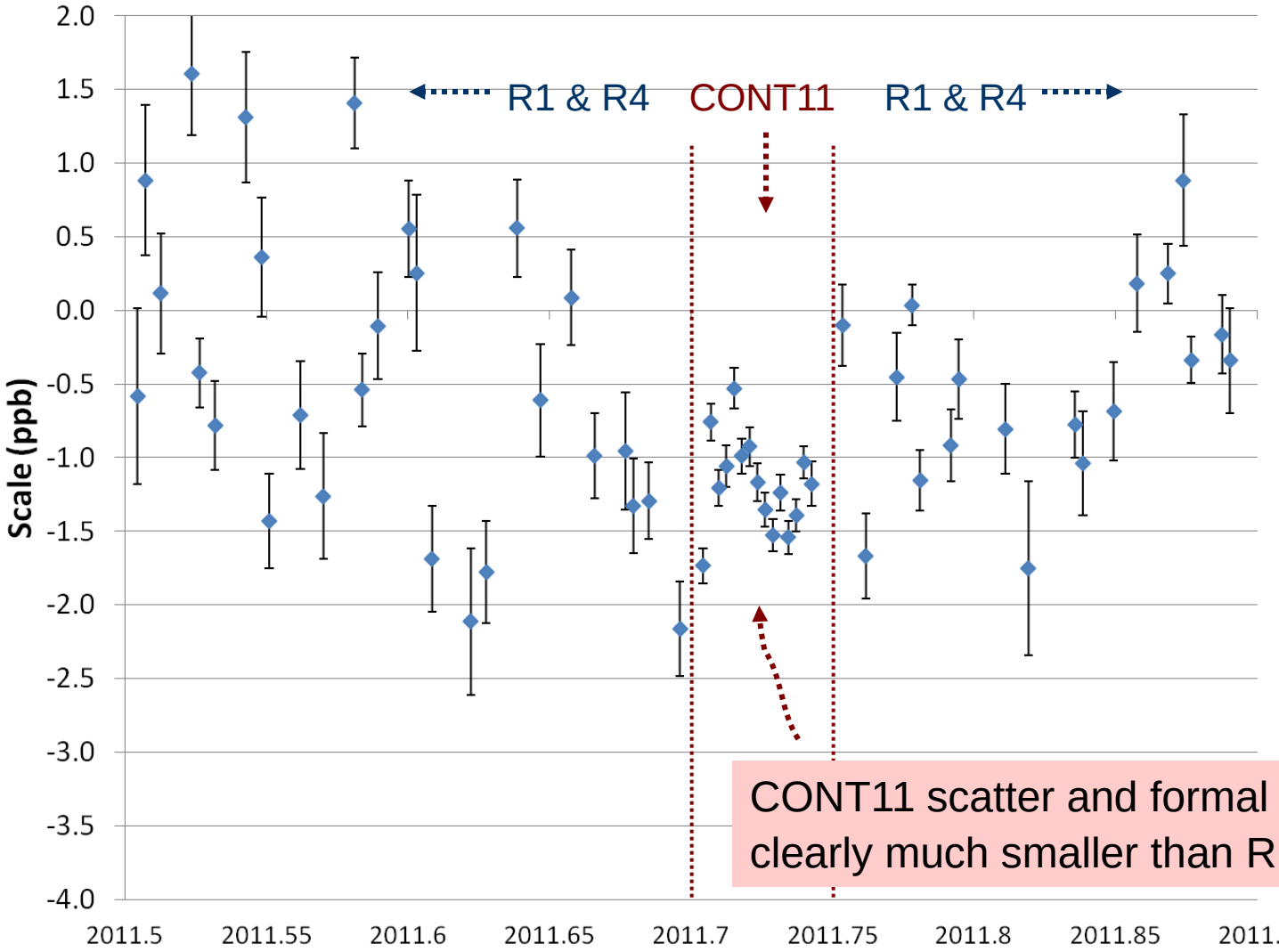
- Continuous VLBI Campaign 2014 (CONT14):
  - 15 consecutive days (May 6–20, 2014)
  - 17 stations (16 sites)

Continuous VLBI: Example CONT14



- VLBI data:
  - Continuous for network
  - Individual stations have maintenance breaks

Scale for R1/R4 and CONT11



CONT11 scatter and formal error clearly much smaller than R1/R4.

Courtesy of Dan MacMillan

VGOS: VLBI Global Observing System

Features:

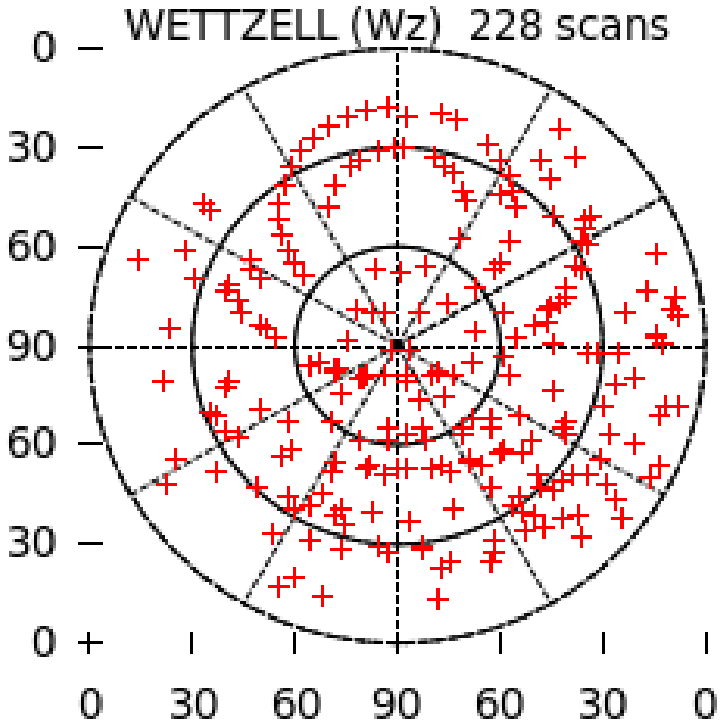
- small and agile telescopes
  - small: 12–13 m dish diameter
  - fast: 12º/s and 6º/s slew speeds
- large bandwidth: 2–14 GHz
- flexible frequency allocation
- dual linear polarization

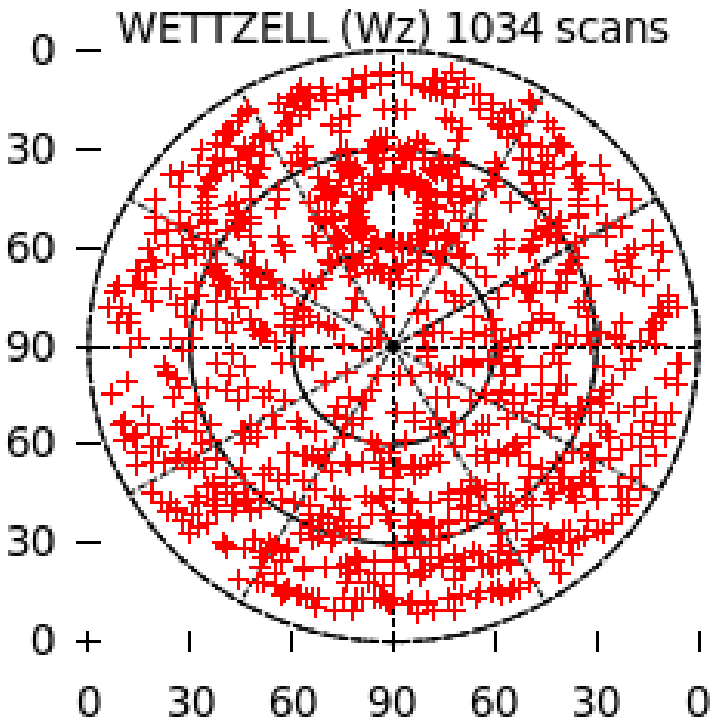
Implies:

- dense sampling of atmosphere
- up to 2 observations per minute (2880/day)

VGOS: VLBI Global Observing System

- dense sampling of local sky for optimal estimation of atmosphere parameters

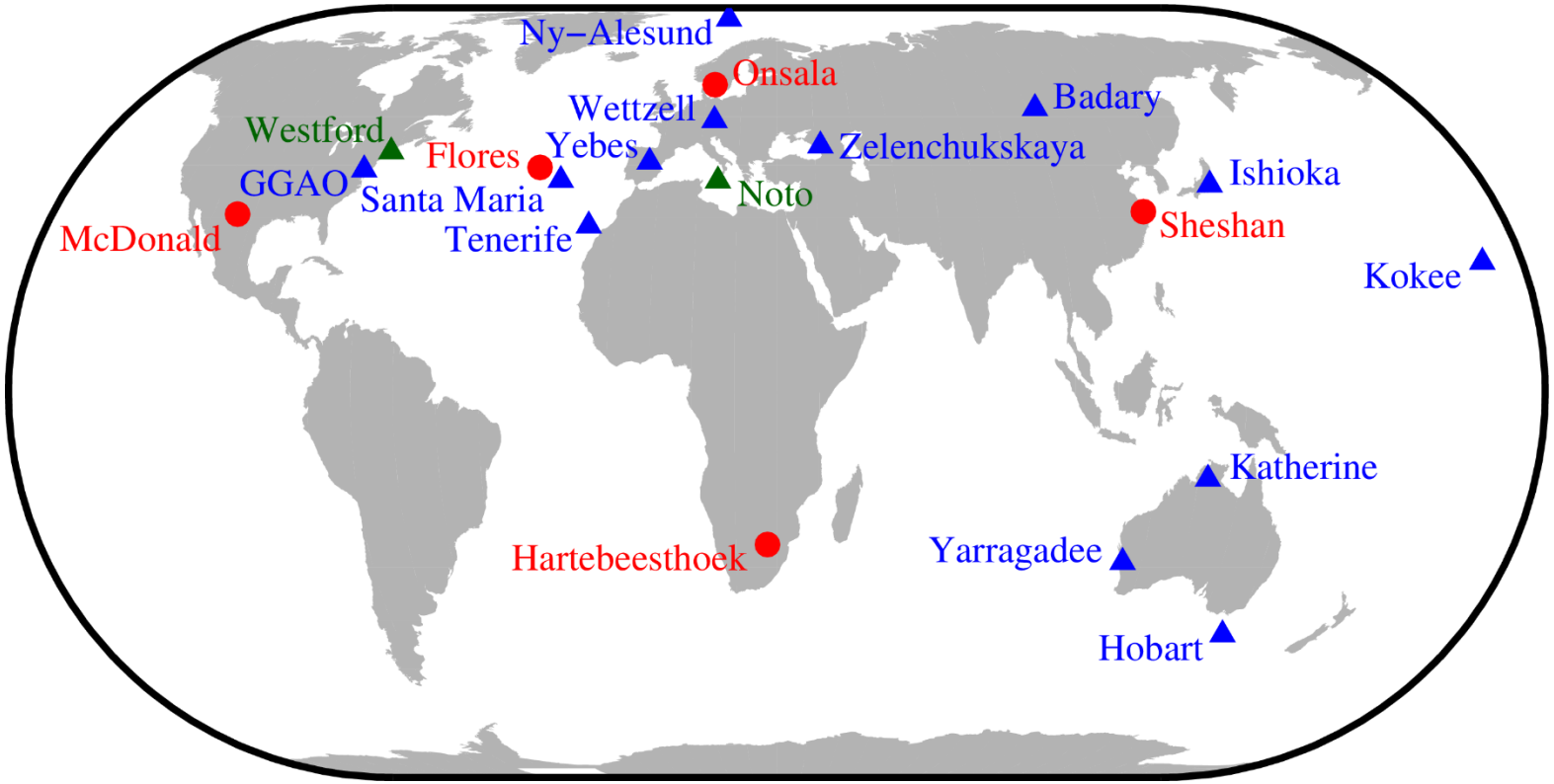




VGOS Roll-out Progress

Station	Recent milestone	Broadband readiness
GGAO	Bi-weekly 1-hour sessions	now on fast RT
Westford	Bi-weekly 1-hour sessions	now on legacy RT
Wettzell	Test observations on S/X/Ka	end 2015
Yebes	First results in S/X legacy mode	late 2015
Noto	Receiver under construction	mid 2016 on legacy RT
Ishioka	First geodetic results	end 2016 (initial S/X/Ka)
Santa Maria	RT constructed at site	2016
Badary	First fringes in S/X	2015 (S/X/Ka)
Zelenchukskaya	First fringes in S/X	2015 (S/X/Ka)
Kokee Park	RT being assembled at site	2016
AuScope	Funding for upgrade secured	2016 on fast RTs
Tenerife	RT assembled at factory	2017
Ny Ålesund	Tower construction underway	2018

VGOS Network Build-out



VGOS progress:

- ▲ hardware work in progress
- ● funding approved
- ▲ legacy upgrade in progress

New VGOS Radio Telescopes

Ny-Alesund (NO)

Courtesy L. Langkaas

Zelenchukskaya (RU)

Courtesy A. Ipatov

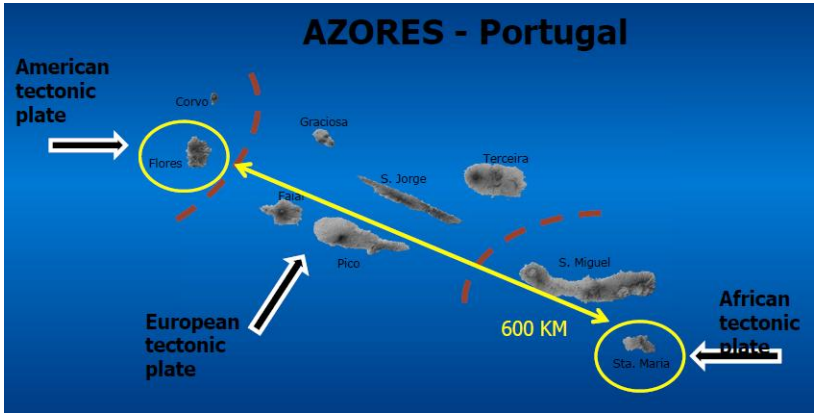
Ishioka (JP) *Courtesy Y. Fukuzaki*

Badary (RU)

Courtesy A. Ipatov

GGAO (US) *Courtesy A. Niell*

Status of RAEGE Project

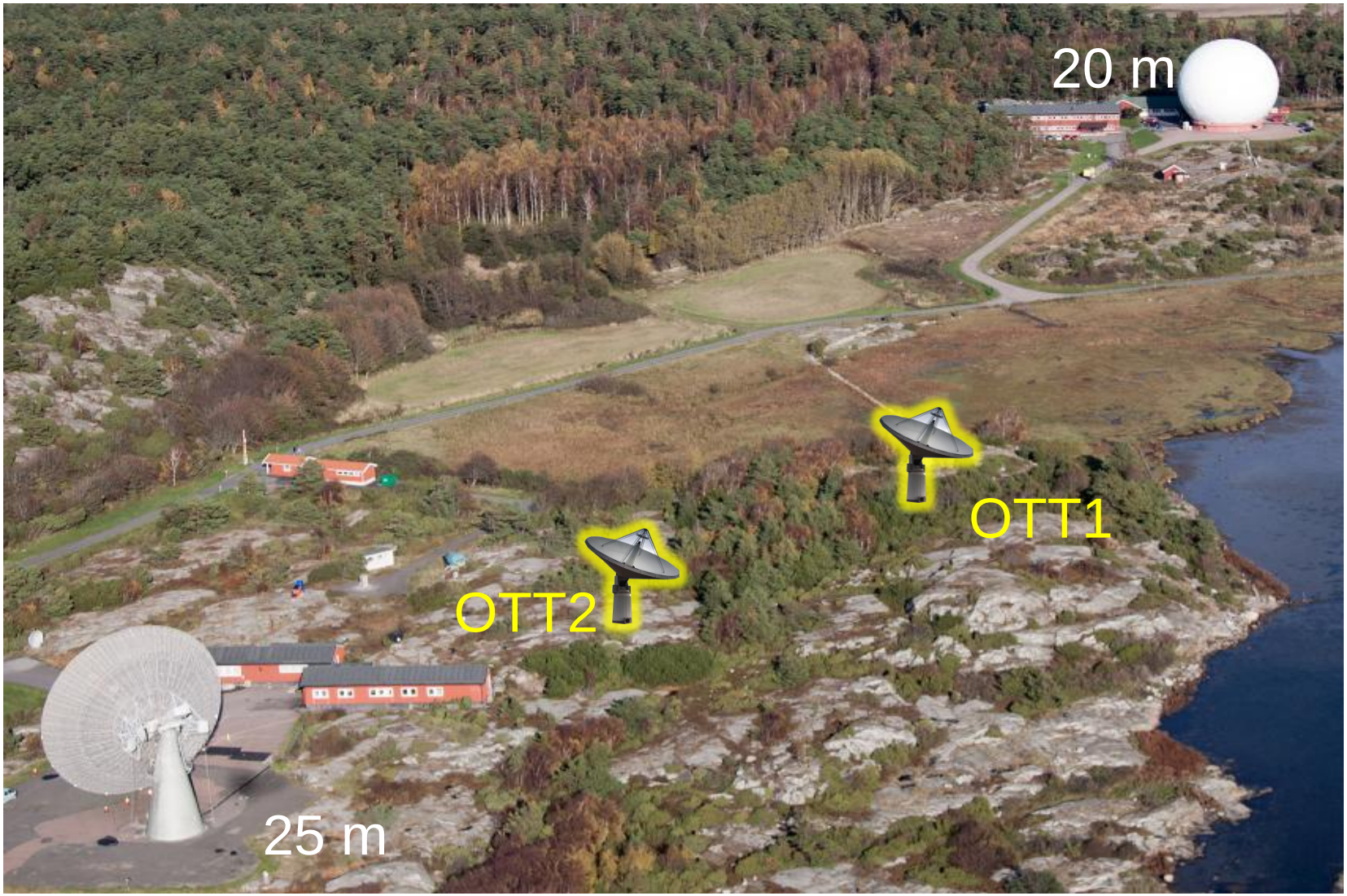


Yebes (Spain) *Courtesy J.A. López Fernández*

Santa Maria (Eastern Azores, Portugal)
Courtesy F. Colomer

Twin Telescope Wettzell

Onsala Twin Telescope

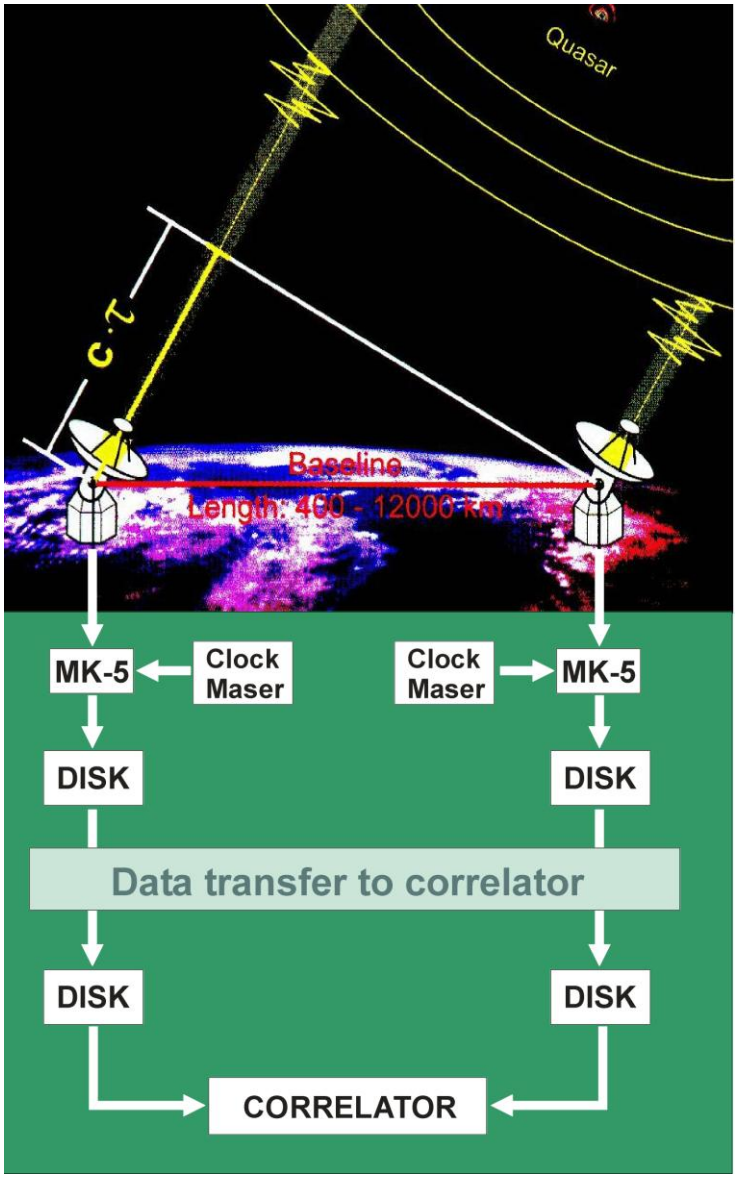


Courtesy R. Haas

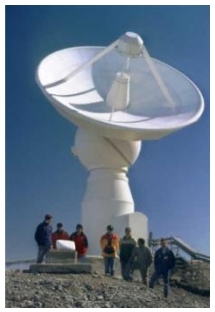
…to be continued…

VLBI Observing System

- Radio signals of quasars or radio galaxies
  - 8 channels X-Band
  - 6 channels S-Band
  - Data stream 1Gbit/s
  - Time & Frequency
    - (DF/F ~ 10^{-15})
  - Data recording
    - Hard drives (MK-5)
    - e-transfer
- Correlation
  - σ_t ~ 10 to 30 ps



Role of VLBI in Science



Science: Astrometry & Astrophysics

Science: Earth mass Exchanges

Celestial Reference Frame (CRF)

Orientation of Earth In Space

UT1

Deep Space Tracking

Science: Solar System Exploration

Precise Orbit Determination

Science: GNSS apps LEOS apps

Quasars

VLBI Antenna: Stable structure Stable phase center No multipath

Terrestrial Reference Frame (TRF) ***Scale***

Science: Sea level change

IVS Goals and Activities

The **goals** of the IVS are to:

- provide a service to support geodetic, geophysical, and astrometric research and operational activities;
- promote research and development in the VLBI technique;
- interact with the community of users of VLBI products and integrate VLBI into a global Earth observing system.

The **main activities** of the IVS are to:

- provide EOP, maintain ICRF, and support maintenance of ITRF;
- coordinate VLBI observing programs;
- set performance standards for the observing stations;
- establish conventions for data formats and products;
- issue recommendations for analysis software;
- set standards for analysis documentation;
- institute appropriate product delivery methods in order to insure suitable product quality and timeliness.