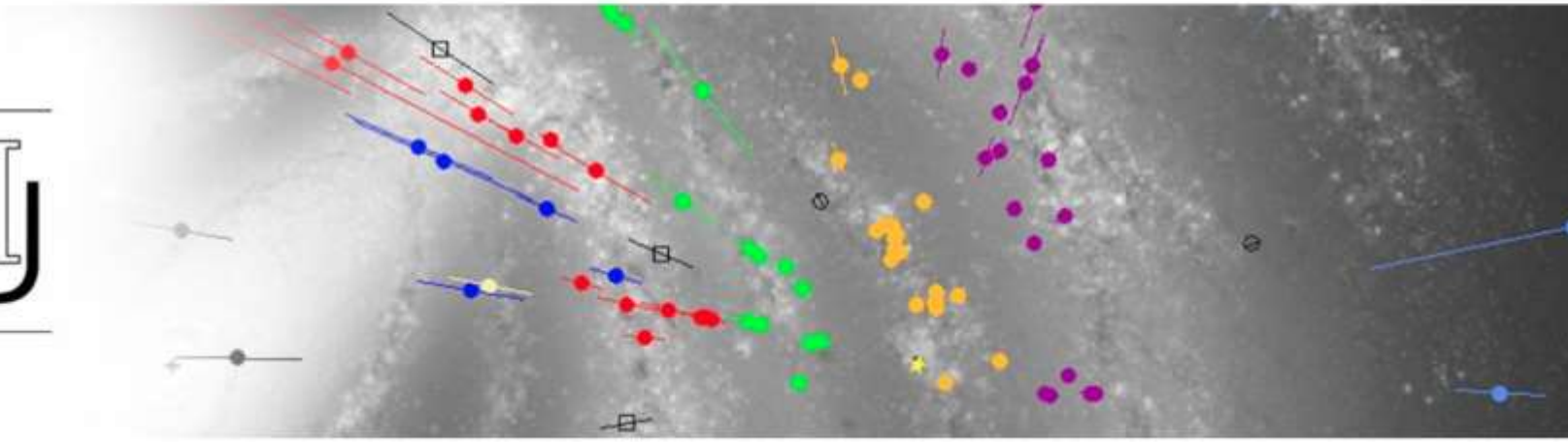
Astrophysical Masers: Unlocking the Mysteries of the Universe

IAU Symposium 336 | Cagliari, 4-8 September 2017



Conference Summary

Philip Diamond

8th September 2017



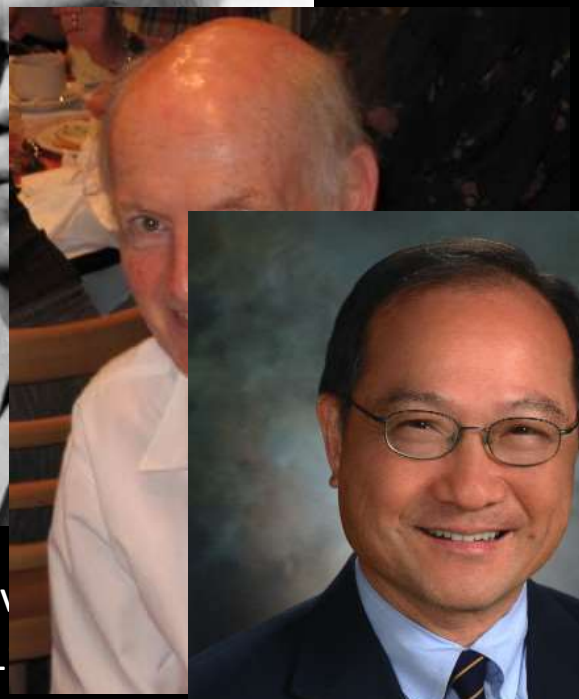
Charles Malcolm Walmsley
1941–2017



Charles Hard
1915–2



Vyacheslav Iv
1



James

Kwok-Yung (Fred) Lo

Huge range of topics and science

- Star-formation → evolved stars → galaxies → SMBH → cosmology

- Topics broadly similar to those discussed in Stellenbosch, but…..
  - Seeing culmination of major monitoring programmes
  - Seeing massive impact from ALMA & JVLA
  - GAIA is a game-changer
  - Panchromatic information enabling much deeper view of physical conditions and overall environments

- Will only get better…

Excellent review talks

50+ Years of Maser Research

Karl M. Menten
MPI für Radioastronomie

IAU 336: Astrophysical Masers: Unlocking the Mysteries – Cagliari, 2017 September 4

Extragalactic Maser Surveys

Detect and locate tiny regions with exceptional activity across the Universe

Great impact also on other fields of research

1. Massive Star Formation (SF)
2. Active Galactic Nuclei (AGN)

C. Henkel

The Local Group mass and its connection to cosmic puzzles

Till Sawala (University of Helsinki)

IAU Symposium 336, Cagliari, 05/09/2017



HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI



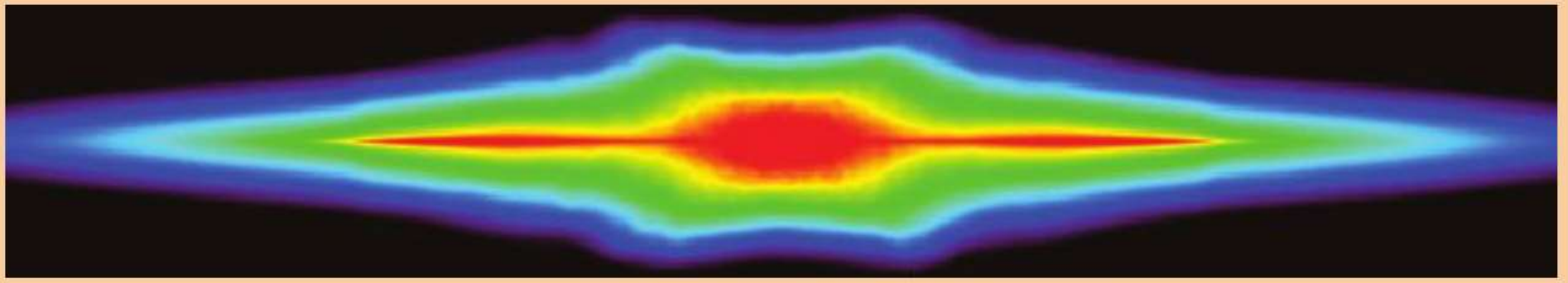
ACADEMY
OF FINLAND

Perspectives on Galactic Structure

Ortwin Gerhard

Max-Planck-Institute for Ex. Physics, Garching

1. Milky Way surveys
2. The Bulge and Bar
3. The Disk
4. The Halo, stellar and dark



MAITE BELTRÁN
INAF-OSSERVATORIO ASTROFISICO DI ARCETRI

PERSPECTIVES ON STAR FORMATION: THE FORMATION OF HIGH-MASS STARS

Perspectives on evolved stars

Astrophysical Masers: Unlocking the Mysteries of the Universe
IAU Symposium 336
Cagliari
4-8 September 2017

Guy Perrin

l'Observatoire de Paris | LESIA
Laboratoire d'Études Spatiales et d'Instrumentation en Astrophysique

7 September 2017

Previous maser meetings

Lecture Notes in Physics



© 1993

Astrophysical Masers

Buy this book

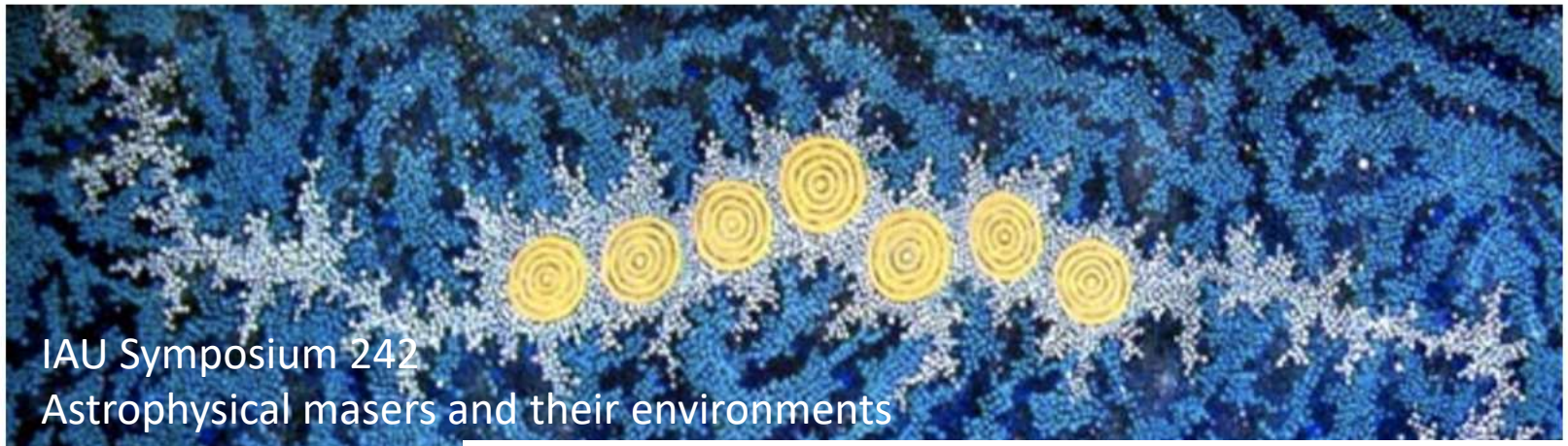
eBook 67,82 €

Softcover 83,19 €

IAU Symposia

IAU

Hol



IAU Symposium 242

Astrophysical masers and their environments

Alice Springs

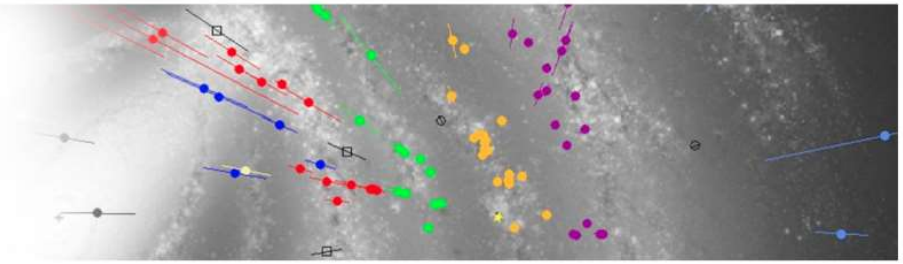
IAU Symposiur

Stellenbosch: J

Astrophysical Masers: Unlocking the Mysteries of the Universe

IAU Symposium 336 | Cagliari, 4-8 September 2017

IAU



Exploring the Universe with the world's largest radio t







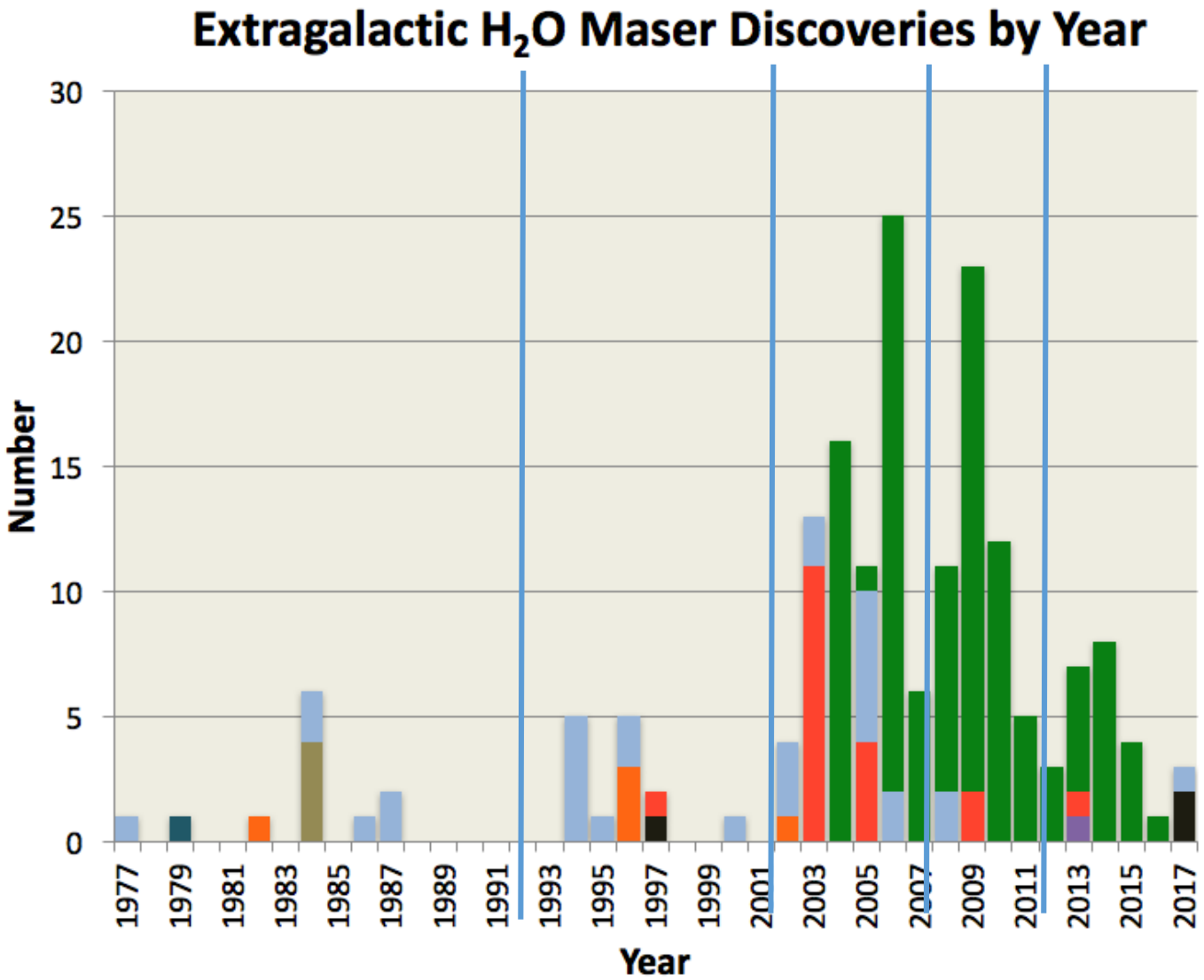
Some 120 people, about half being research students, attended this fourth international maser symposium, held from 29 January to 3 February 2012 in Stellenbosch, South Africa.

Mark Reid's prediction from 2007

Next Meeting?

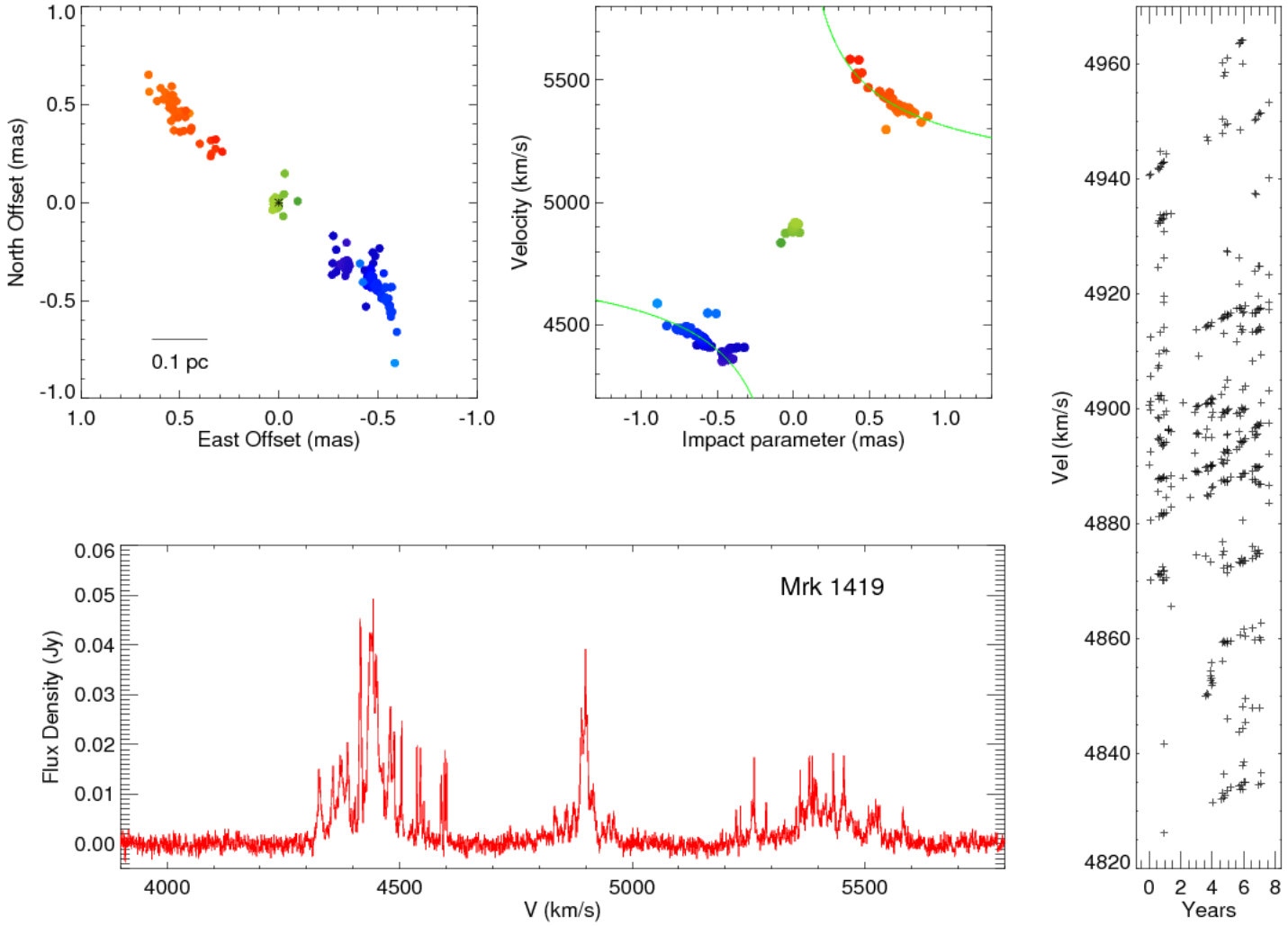
- H_o measured to 3% accuracy…w=1 (and the Universe will end)
- Constancy of Fundamental "Constants" further tested
- mm/submm maser observations will be as common as cm-wave masers
- Blind surveys (of at least the Plane) will be completed for all major classes of molecular masers
- Milky Way mapped with ~200 parallaxes/proper motions
- H-recombination line maser from EOR
- …

Megamaser Cosmology Project (Braatz et al)



- 178 galaxies currently known as maser hosts
- 10 for distance measurements

Mrk 1419


North Offset (mas)
East Offset (mas)
0.1 pc
Velocity (km/s)
Impact parameter (mas)
Mrk 1419
Flux Density (Jy)
V (km/s)
Vel (km/s)
Years

Estimation of H_0 from Geometric Distances

$H_0 = 69.3 \pm 4.2$ km s^{-1} Mpc^{-1}

UGC 3789	45.0 ± 4.7 Mpc	$H_0 = 76 \pm 8$ (Reid et al. 2013, updated)
NGC 6264	137 ± 19 Mpc	$H_0 = 68 \pm 9$ (Kuo et al. 2013)
NGC 6323	107 ± 42 Mpc	$H_0 = 73 \pm 26$ (Kuo et al. 2015)
NGC 5765b	126 ± 11 Mpc	$H_0 = 66 \pm 6$ (Gao et al. 2016)

CGCG 074-064	(8%)
Mrk 1419	(25%)
IC 2560	(20%)
ESO 558-G009	(12% ?)
J0437+2456	(12% ?)

In the next year the MCP will finalize analysis and publish the 5 additional galaxies, and should achieve ~ 4% total uncertainty.

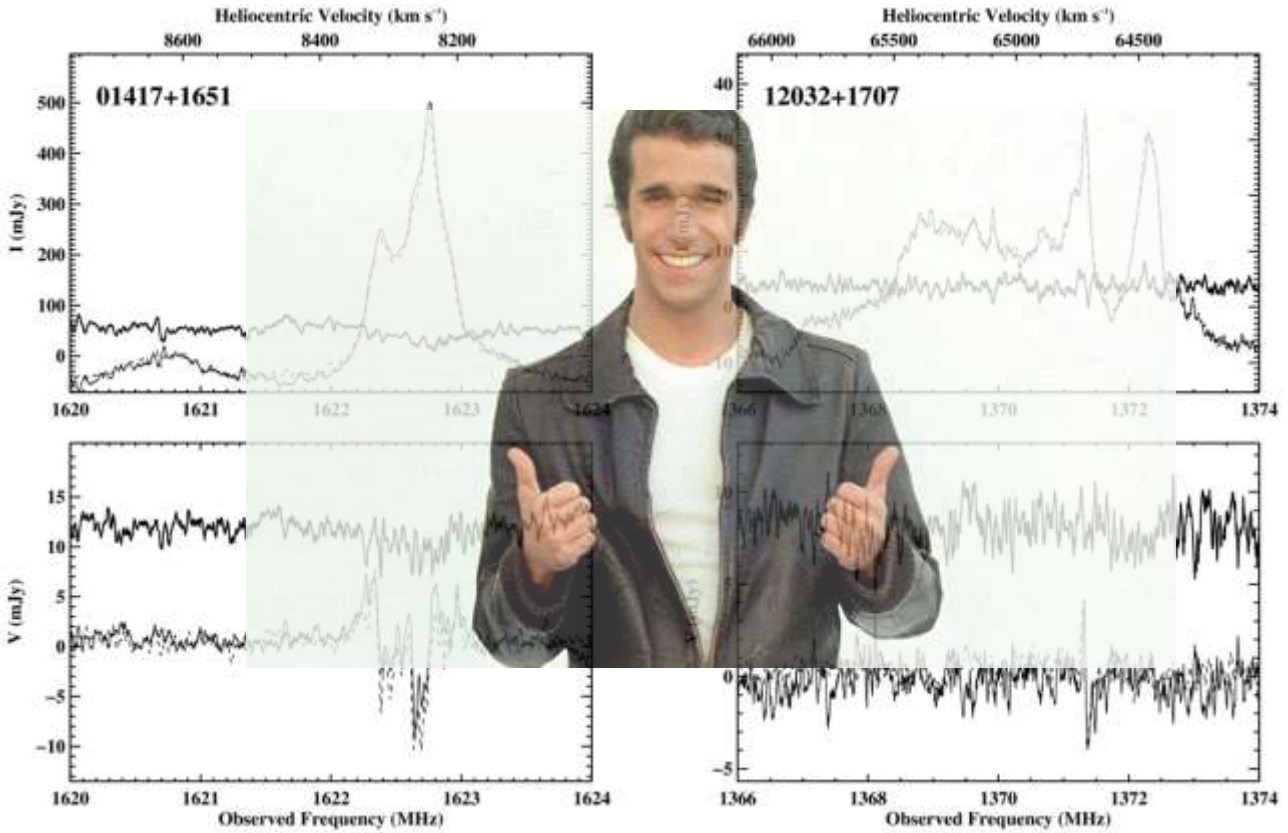
Sherry Shu gave invited talk on H0LiCOW – using time delays from grav lenses to determine H_0

Jiang-Shui Zhang & Francesca Panessa told us of ways to maximise chances of finding more H_2O megamasers: radio-loud Syefert2s & hard X-rays. ~30% possible.

Dominic Pesce investigated Maoz & McKee model for maser excitation – maybe not there yet

Tim Robishaw on OH Megamasers

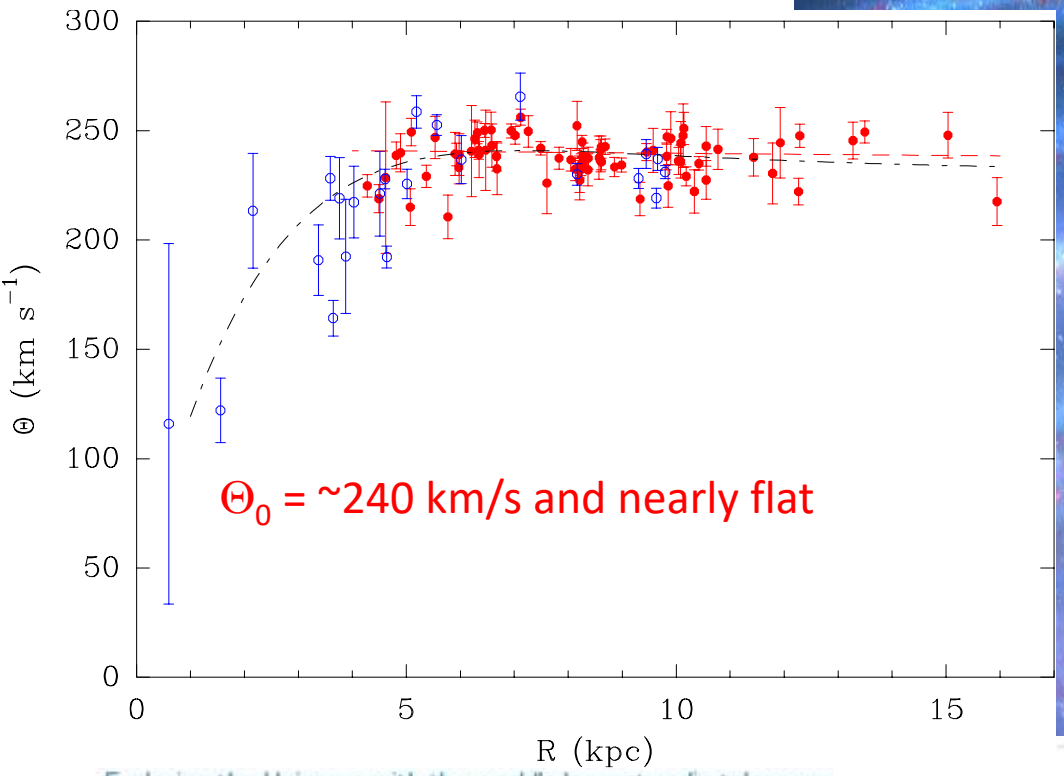
- Pleased his previous work been confirmed!

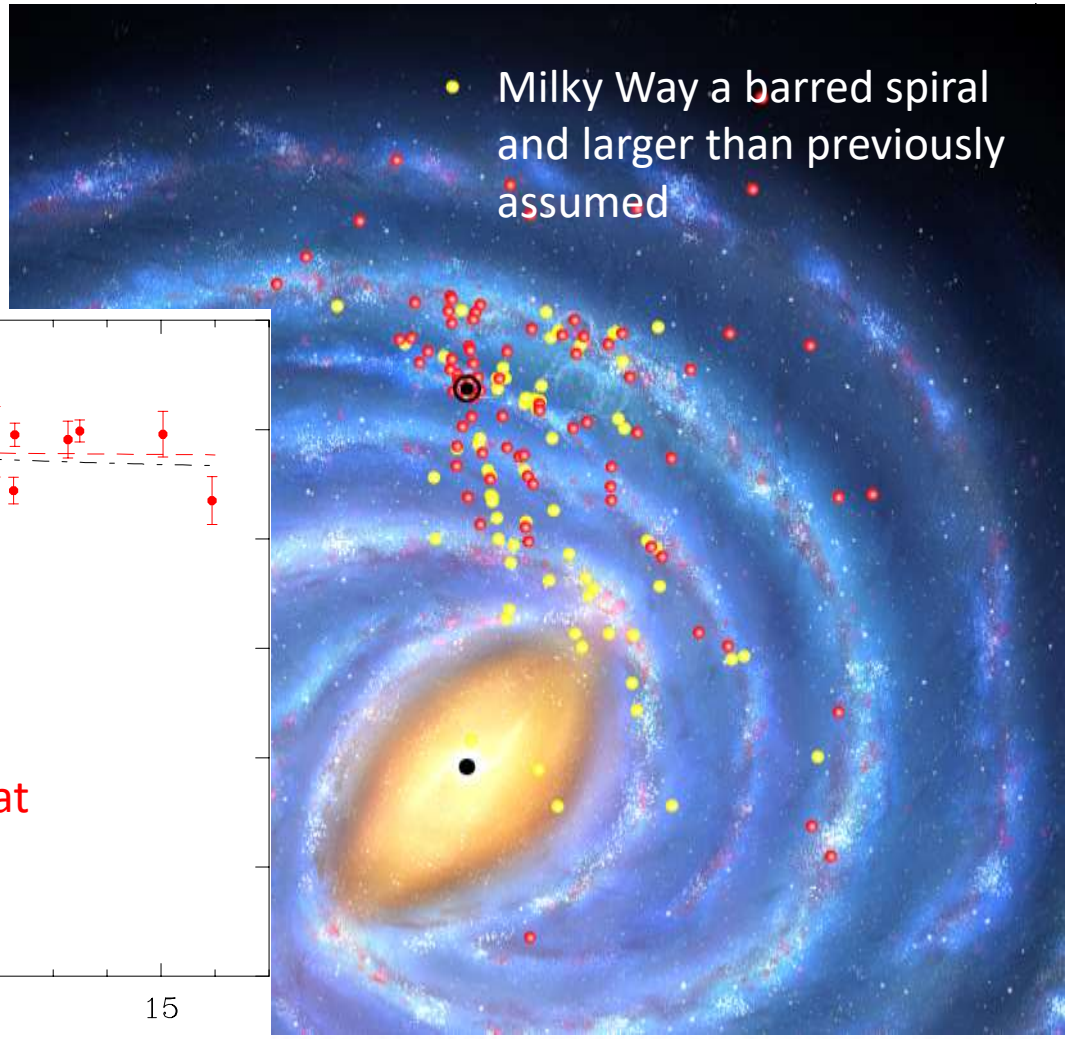


- 8 new Zeeman OHMs detected some years ago – no VLBI as yet

Determining structure of Milky Way

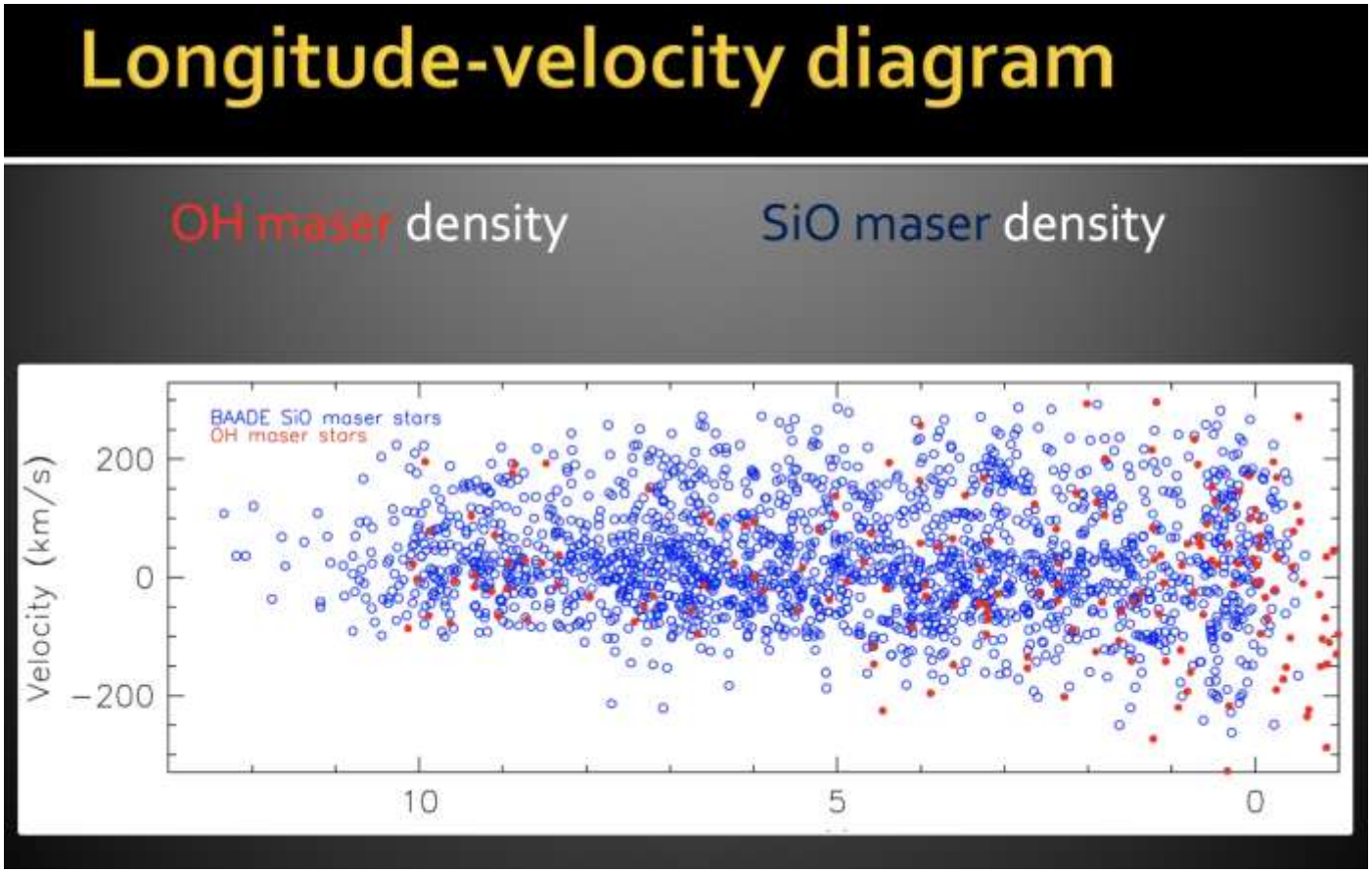
- Mark Reid: BeSSel
- Mareki Honma: VERA





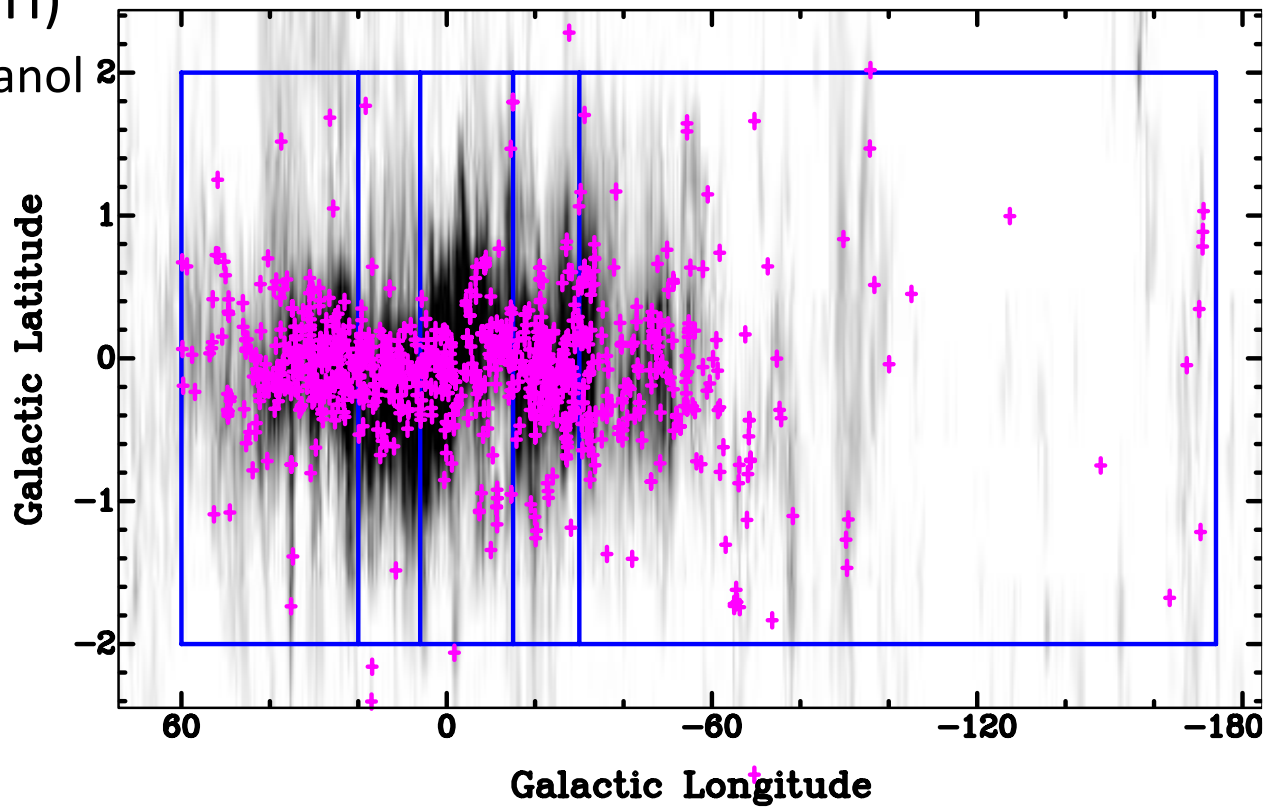
Surveys

- BAaDE: Lorant Sjouwerman et al

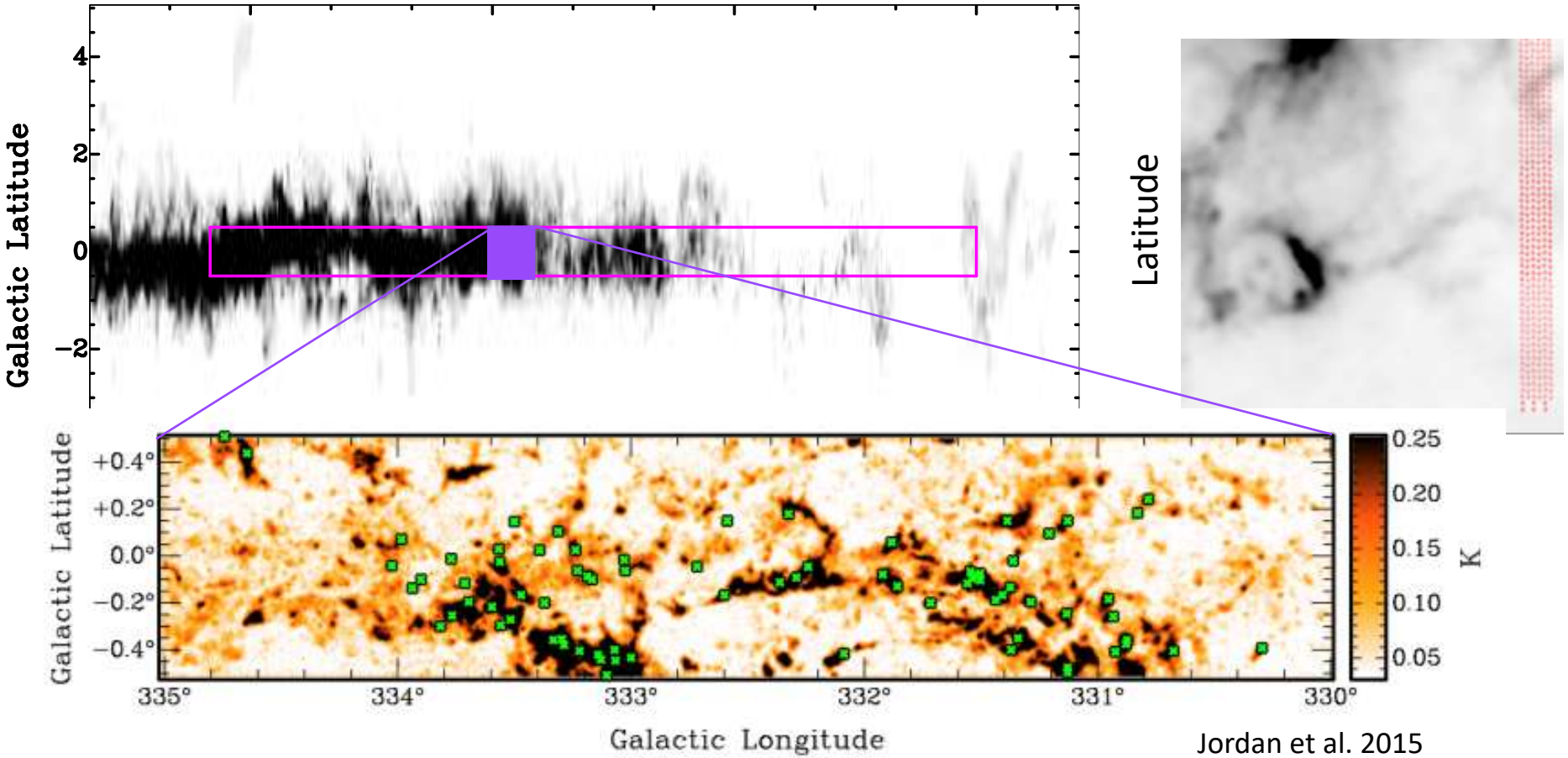


Surveys

- Shari Breen – invited talk
  - The methanol multibeam (both 6.7 GHz methanol and excited-state OH)
    - 12 GHz methanol
    - 22 GHz water
  - HOPS
  - SPLASH
  - MALT45



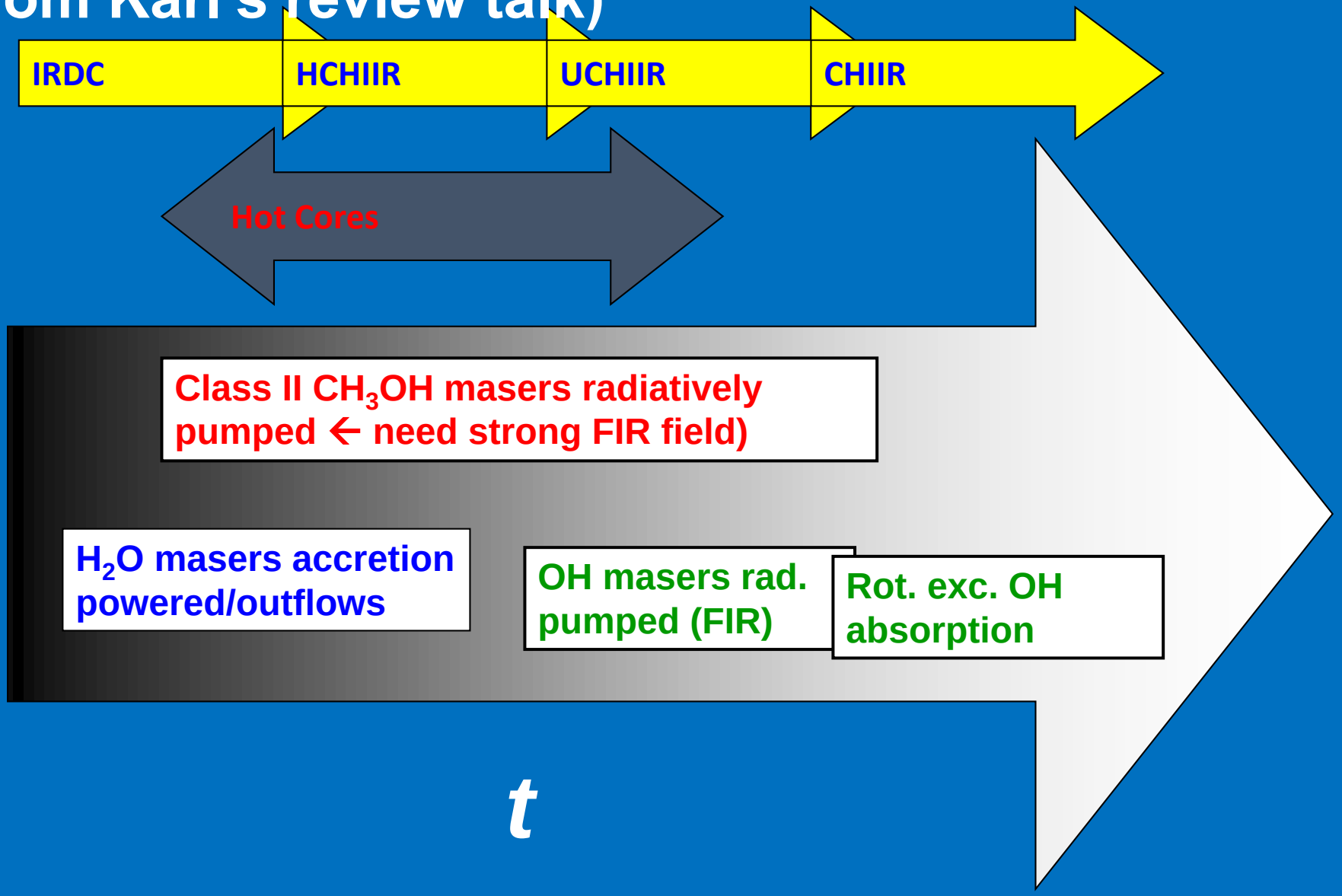
Dense gas across the Milky Way – The ‘full-strength’ MALT45



Jordan et al. 2015

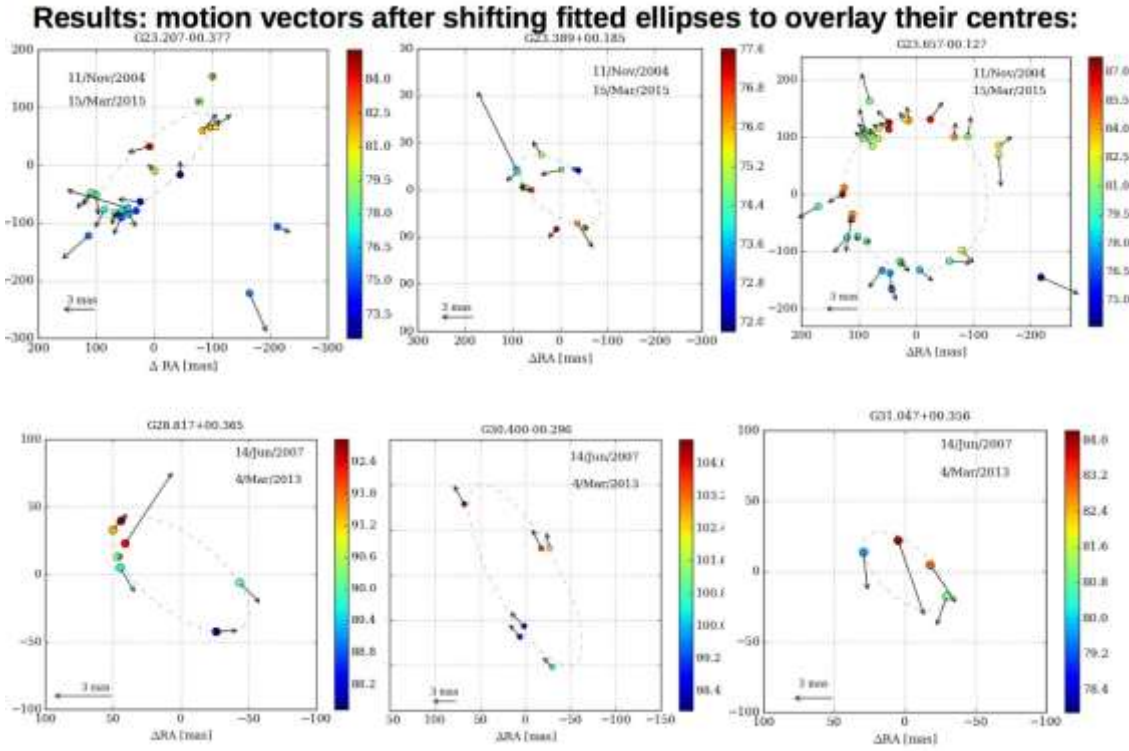
CH_3OH 1_0–0_0 A+	48.37246	Thermal	58	H53α (RRL)	42.95197	Thermal	65
$C^{34}S$ (1–0)	48.20694	Thermal	58	SiO (1–0) $v = 2$	42.82048	Maser	66
H51α (RRL)	48.15360	Thermal	58	SiO (1–0) $v = 3$	42.51934	Maser	66

Masers in Regions of High Mass Star Formation (from Karl's review talk)



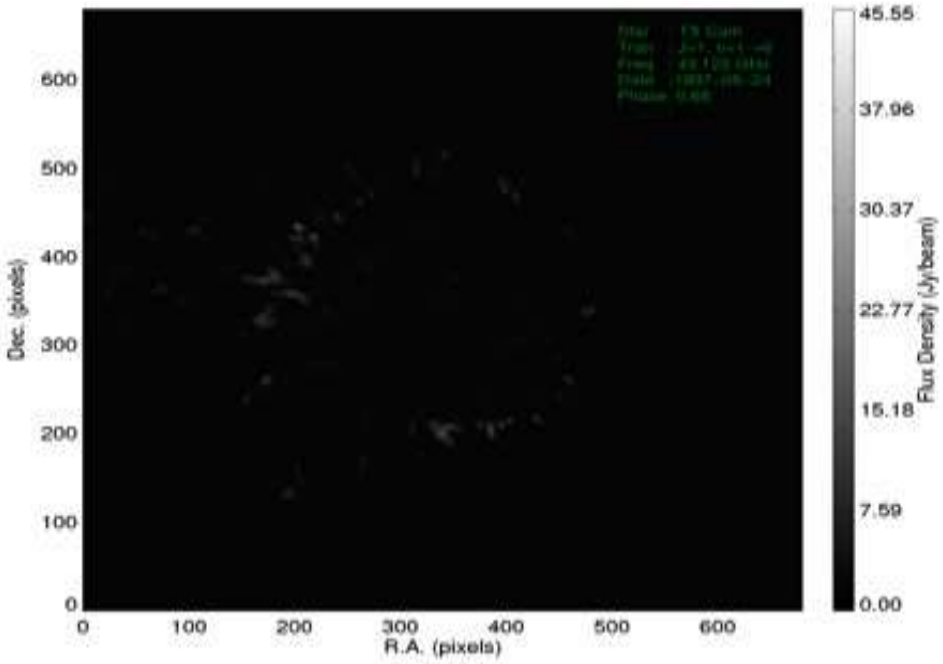
CH_3OH

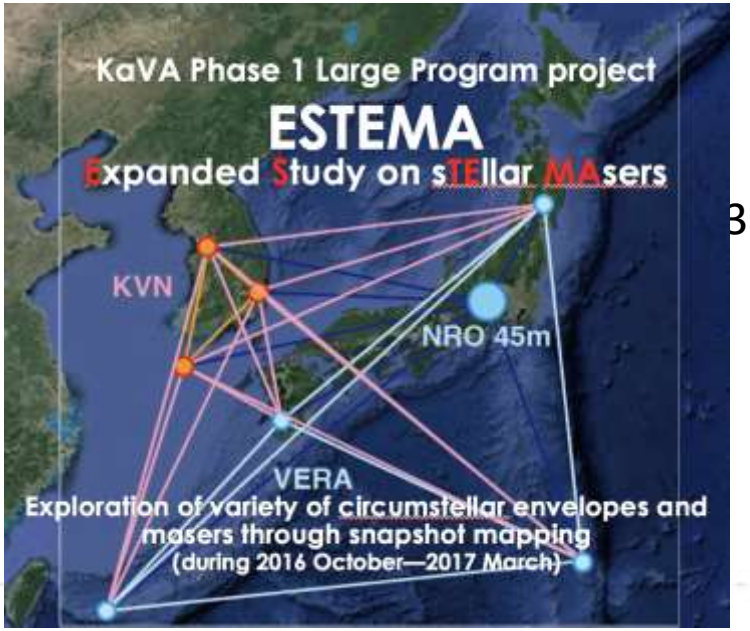
- 21 talks on Class I & II masers
- Significant number of posters
- Class I association with outflows well-established
- Class II associated with HMSF



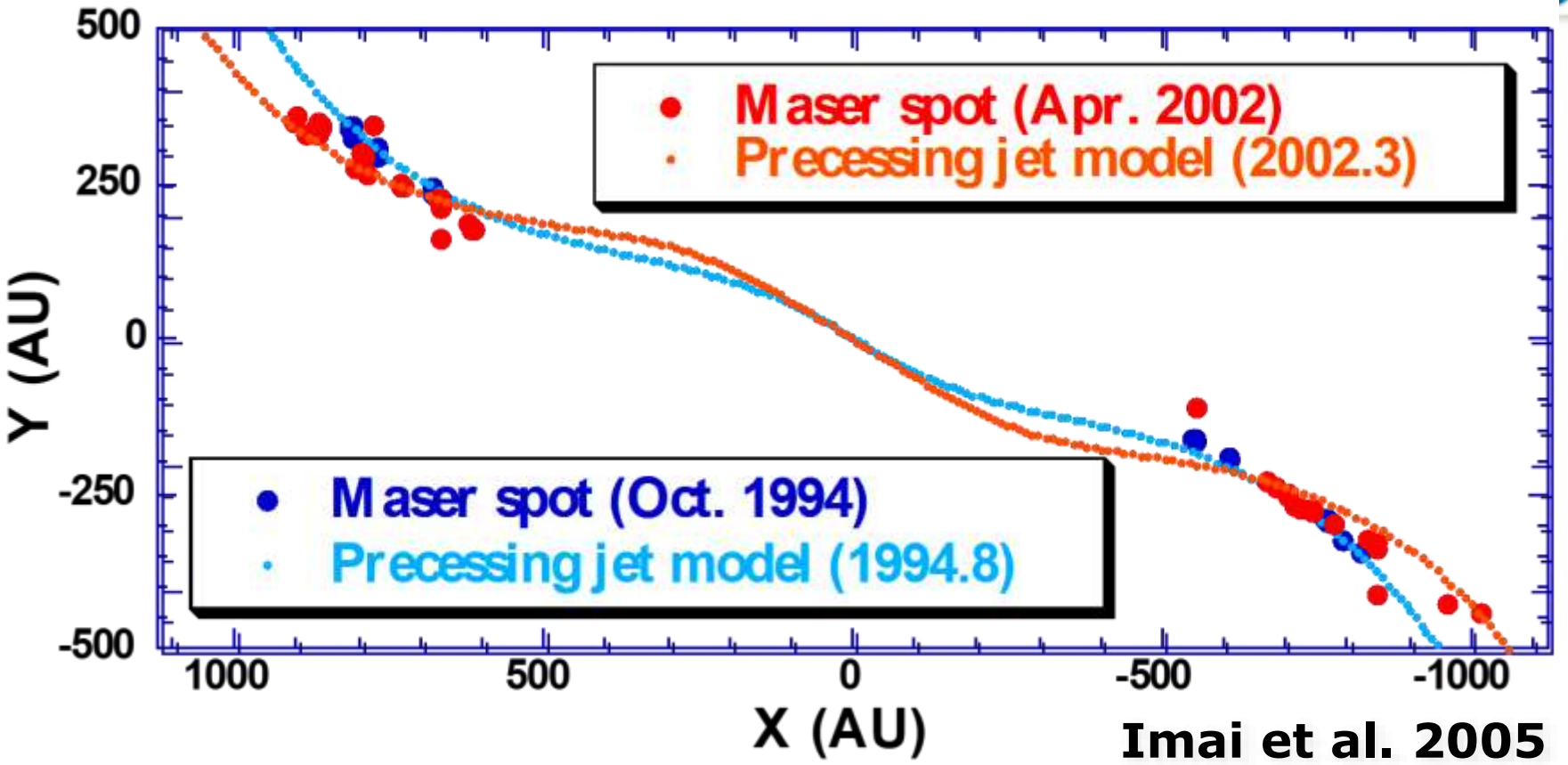
Evolved stars

- Excellent introduction by Hiroshi Imai.
- His summary:
  - Multi-Decadal VLBI monitoring essential for understanding of AGB stellar mass ejection processes and environments
  - (comparable to lifetimes of VLBI observatories and astronomers.)
  - ESTEMA will provide a sufficient number (~20) of target sources for decadal intensive VLBI monitoring observations of circumstellar masers.



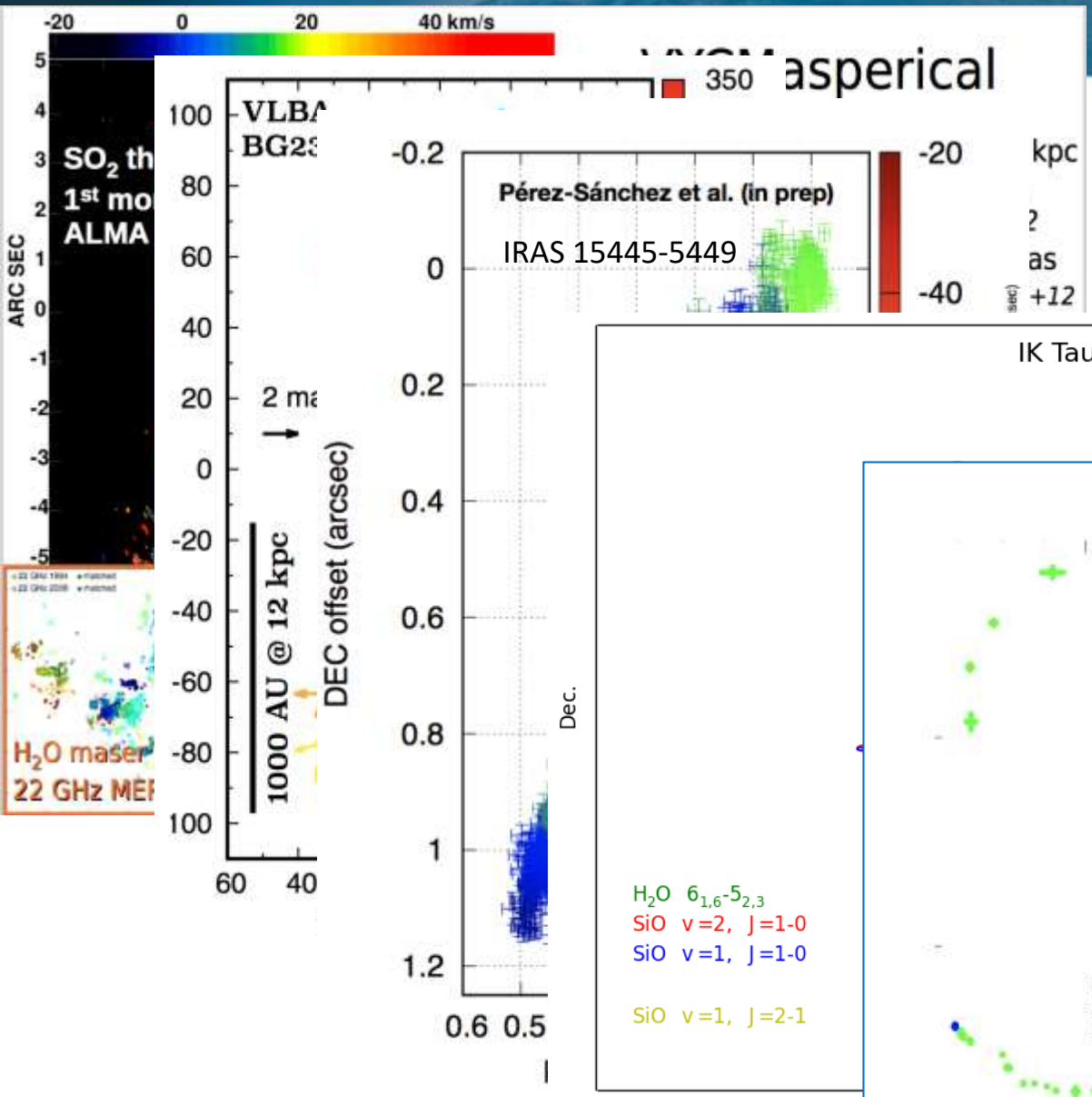


Precessing jet in WS43A?



Imai et al. 2005

Hiroshi states: model is probably wrong. Brave to admit it publically, how science moves forwards



S-Hyung Cho
KVN

Liz Humphreys
Mira

I haven't mentioned…..

- Theory – Malcolm Gray appears to be at the heart of this.
- Polarisation – now relatively routine → magnetic fields
- Variability studies
- Orion –rarely mentioned in this meeting
- Scattering – no mention of scattering….maybe in Radioastron talks?
- …..

Made me smile….

- Simon Ellingsen: ‘No comments, only questions’
- Luca Moscadelli: ‘Seeing Cagliari astronomy as it is now makes me want to cry…’
- Carolina Rodriguez-Garca: ‘Blatant attempt to influence referree ☺ …..
- Kazuhito Motogi: prize for most enthusiastic presentation
- Ross Burns: ‘In 10^4 years I might be a Director’



Mark Reid's prediction from 2007

• H_o measured to 3% accuracy…w=1 (and the Universe will end)	4%
• Constancy of Fundamental "Constants" further tested	X
• mm/submm maser observations will be as common as cm-wave masers	Yes
• Blind surveys (of at least the Plane) will be completed for all major classes of molecular masers	Underway
• Milky Way mapped with ~200 parallaxes/proper motions	Largely
• H-recombination line maser from EOR	X
• …	

What are our future tools?

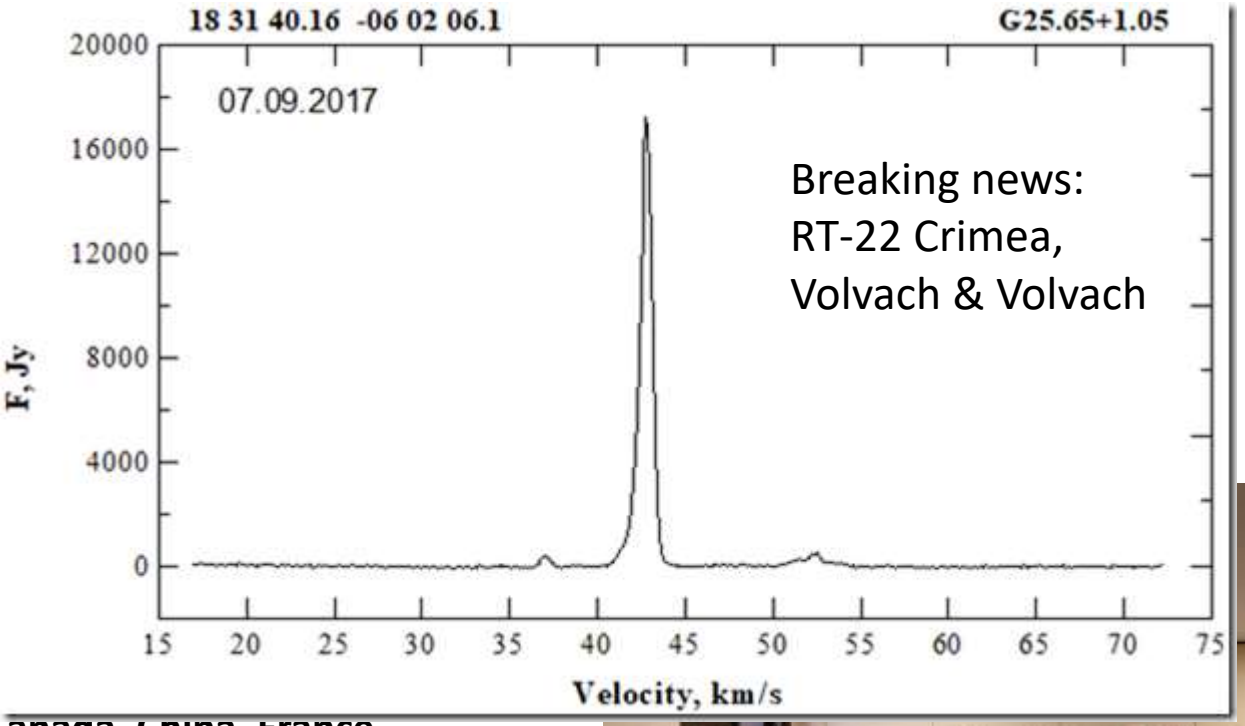
- ALMA is already sho
- MeerKAT: operation
- VLBI: easier to use: V
  antennas in China, A
  - But, danger that
- FAST, will provide
  at L-band
- In 10 years: SKA1
  - hopefully beginning
- 2034: ngVLA



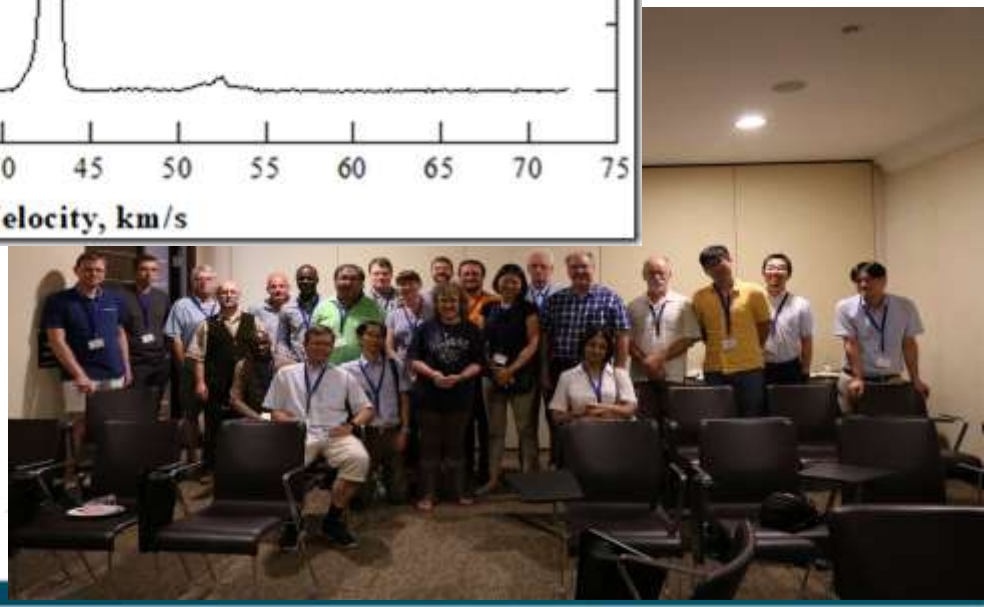
IAUS336: MASER Monitoring Group

- **Formation of a network of MASER monitoring telescopes:**
  - **Independently, groups thought it useful to collaborate.**
  - **Expre**
  - **Creati**
- **Function**
  - **Provi**
  - **Creat**
  - **Devel**
  - **Opera**
  - **Inforr**
  - **Provi**
- **Longer te**
  - **Provi**
    -
- **Countrie**

  Australia, Canada, China, France, Italy, Japan, Korea, Latvia, Poland, Russia, South Africa, Thailand, Ukraine, USA

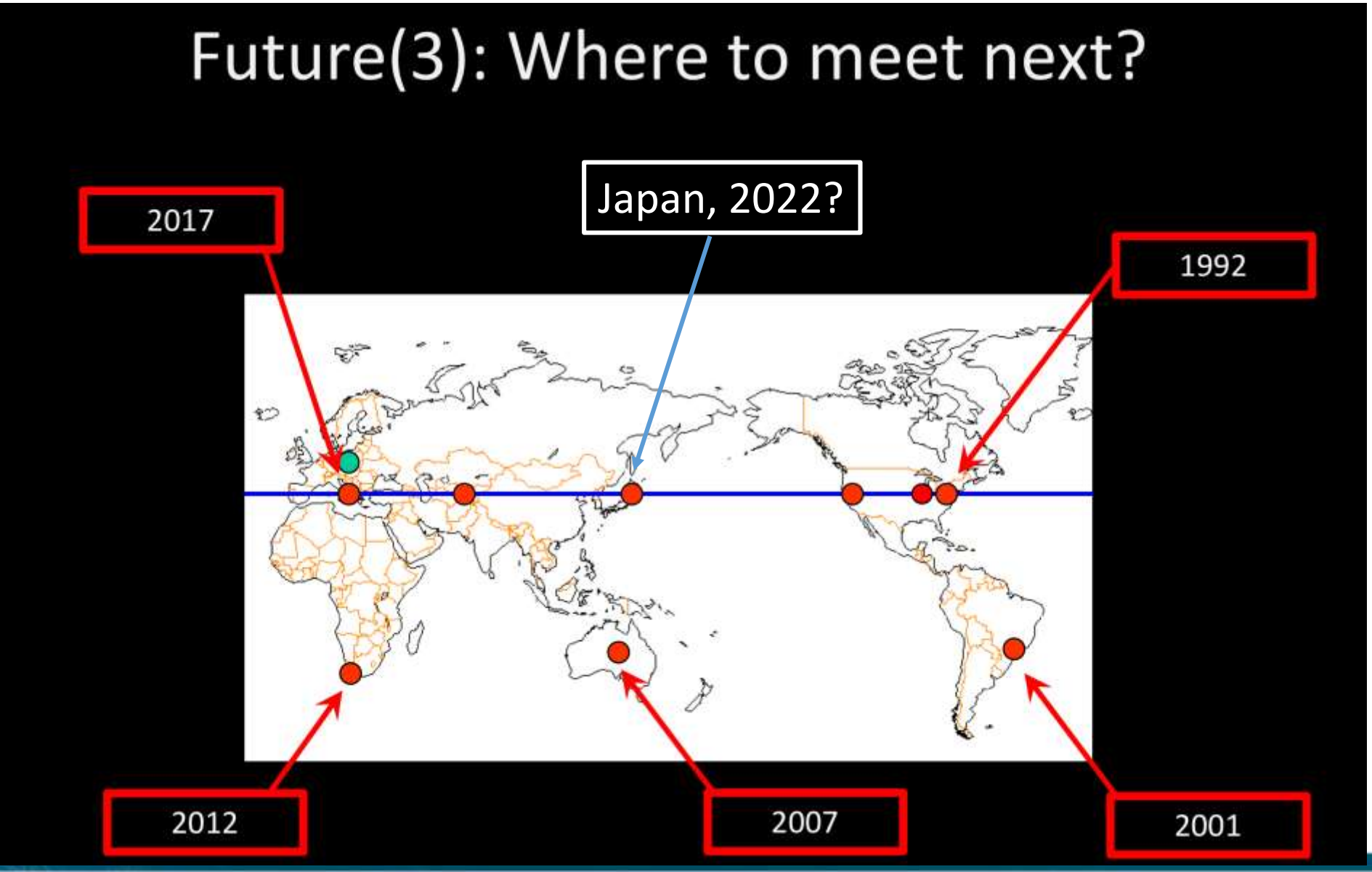


Breaking news:
RT-22 Crimea,
Volvach & Volvach



Contact: gord@hartrao.ac.za

Next meeting?



Many, many thanks

Local Organizing Commitee

Paola Castangia	INAF Cagliari, Italy
Silvia Casu (Chair)	INAF Cagliari, Italy
Davide Coero Borga	INAF, Italy
Tiziana Coiana	INAF Cagliari, Italy
Giuseppe Melis	INAF Cagliari, Italy
Sergio Poppi	INAFÂ Cagliari, Italy
Paolo Soletta	INAF Cagliari, Italy
Gabriele Surcis	INAF Cagliari, Italy
Andrea Tarchi (co-Chair)	INAF Cagliari, Italy

Co-chairs SOC:
Andrea Tarchi
Mark Reid