

Periodic masers

IN MASSIVE STAR FORMING REGIONS

IAUS336: ASTROPHYSICAL MASERS

PRESENTER: Sharmila Goedhart

Mike Gaylard (1952 - 2014)







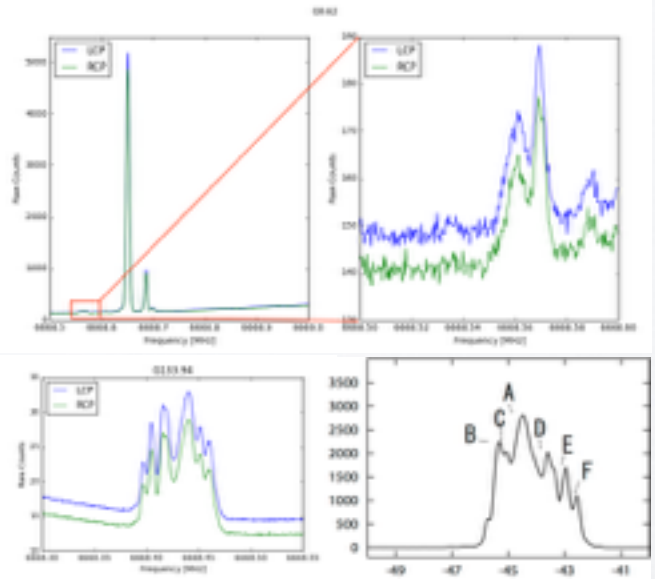


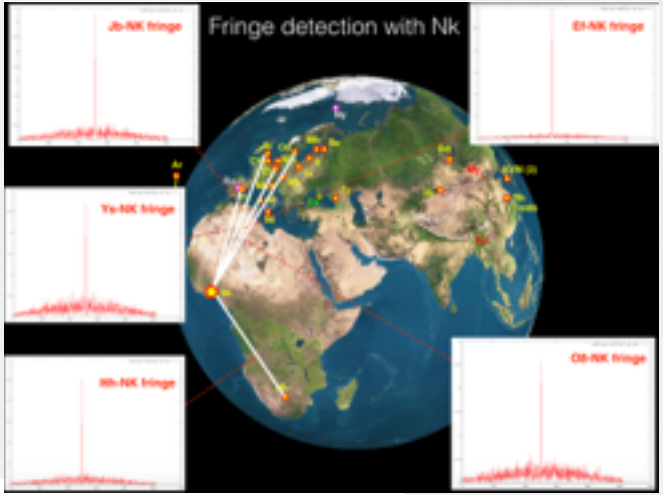
Welcome to Africa's second single dish radio telescope Nkhutunse, Ghana

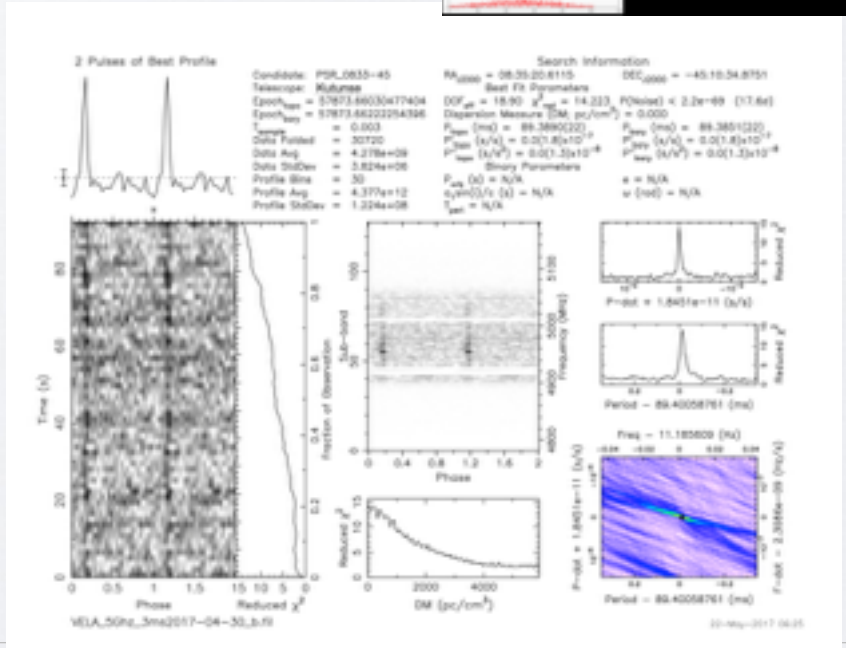
- 32 m, beam waveguide
- C-band (4-8 GHz)
- Continuum and spectral line observations
- Pulsar timing
- VLBI capabilities



First results







Outline

- Introduction
- New results - KAT-7 OH monitoring
- A closer look at G9.62+0.20
- Outlook

Background/history

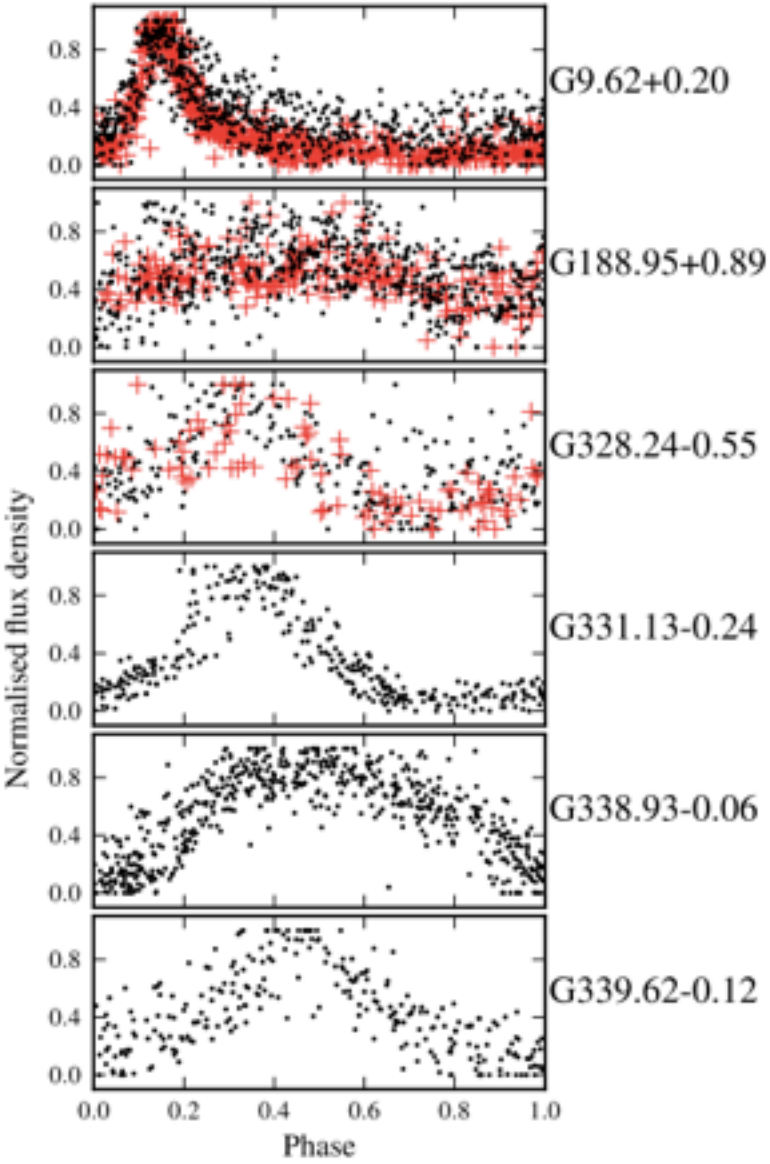
- Caswell, Vaile & Ellingsen (1995) report variability in methanol masers and mention potential quasi-periodicity in G9.62+0.20
- MacCleod & Gaylard (1996) find an extremely variable methanol maser source showing phase lags (G351.78-0.54)
- Goedhart shows up at HartRAO looking for a PhD topic and monitoring of 54 methanol sources at 6.7 GHz starts in 1999
- G9.62+0.20 shows a jump of 400 Jy in one day. The next time round we start monitoring it at a higher cadence when it flares (still looking for phase lags). After three flares we suspect periodicity.
- By 2004 could confirm variability in 7 sources.

Known periodic masers

- 50+ in methanol. 22 d < P < 720 (Goedhart et al, Szymczak et al, Fujisawa et al, Maswanganye et al, Sugiyama et al)
- One in formaldehyde,with correlated methanol (Araya et al 2010)
- A tentative detection of dips in OH (G12.89+0.49) Green & Caswell (2012)
- Anti-correlated water maser vs methanol, periodic variability (Szymczak et al 2016)

Proposed mechanisms

- Colliding wind binary - modulates the radio continuum background (van der Walt et al., 2009)
- Modulation of the infrared radiation field by periodic accretion events (Araya et al., 2010)
- Rotating spiral shocks (Parfenov & Sobolev, 2014)
- Pulsations of a YSO (Inayoshi et al., 2013)
- Eclipsing binary (Maswanganye et al. 2015)



KAT-7

An engineering testbed for MeerKAT



KAT-7 specs

- 7x 12m prime focus dishes
- Min baseline 26 m
- Max baseline 186 m
- Tsys ~26 K
- Ae ~65 %
- 1.2 to 1.95 GHz
- 256 MHz max bandwidth
- Linear pol



OH maser monitoring

- Started 9 Feb 2013
- Weekly observations at 1665 and 1667 MHz, sequentially
- Sometimes KAT-6/5 (receiver issues)
- Typically 40 – 60 mins total integration time per source, tracks over 13 hours, alternating frequencies
- rms noise 0.1 – 0.2 Jy
- Velocity resolution 68 m/s (4K channels, 1.526 MHz bandwidth)
- Convolved beam 3--4 arcmin
- Regular science observations stopped mid 2015 due to multiple unrecoverable failures and lack of tech support

Target list

- G9.62+0.20 *
- G12.89+0.49
- G328.24-0.55
- G331.13-0.24
- G338.93-0.08
- G339.62-0.12 *
- G351.78-0.54

… and others in the primary beam

Some challenges

- Large primary beam, sometimes crowded field, limited dynamic range
- G339.62-0.12, G338.93-0.06 are overlapping fields- sidelobes from G339.62-0.12 dominate the field.
- Need primary beam correction beyond FWHM
- Polarisation calibration - never got it right for KAT-7

Meanwhile, at HartRAO

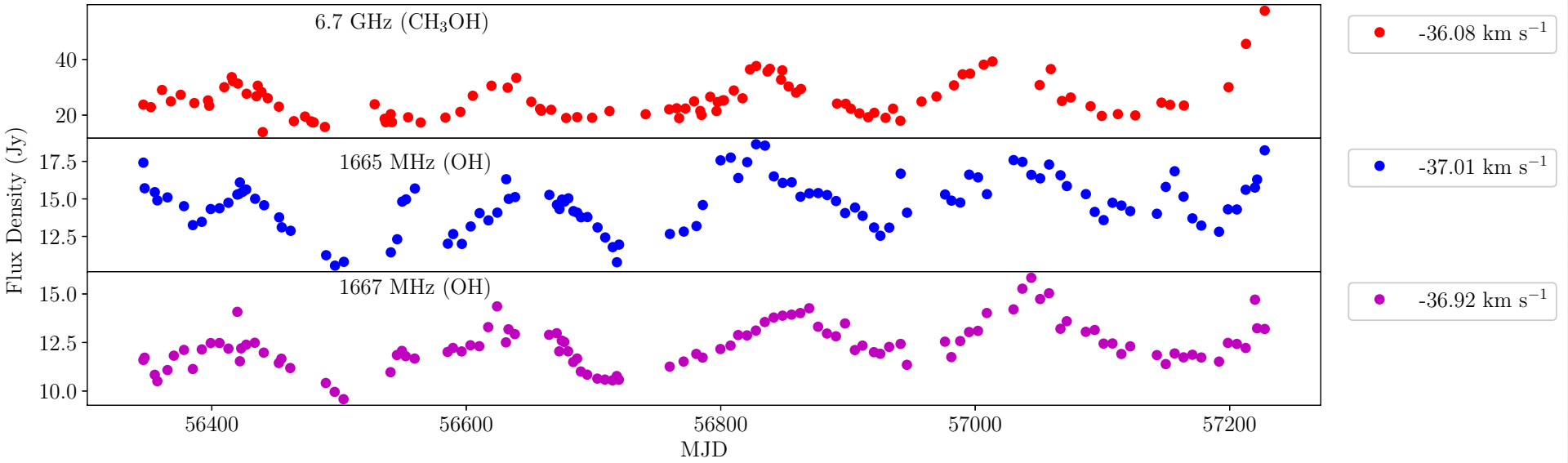
- Ongoing monitoring at
  - 6.7 GHz methanol
  - 12.2 GHz methanol
  - 22 GHz water
  - 1665 + 1667 MHz OH (problems with RFI)



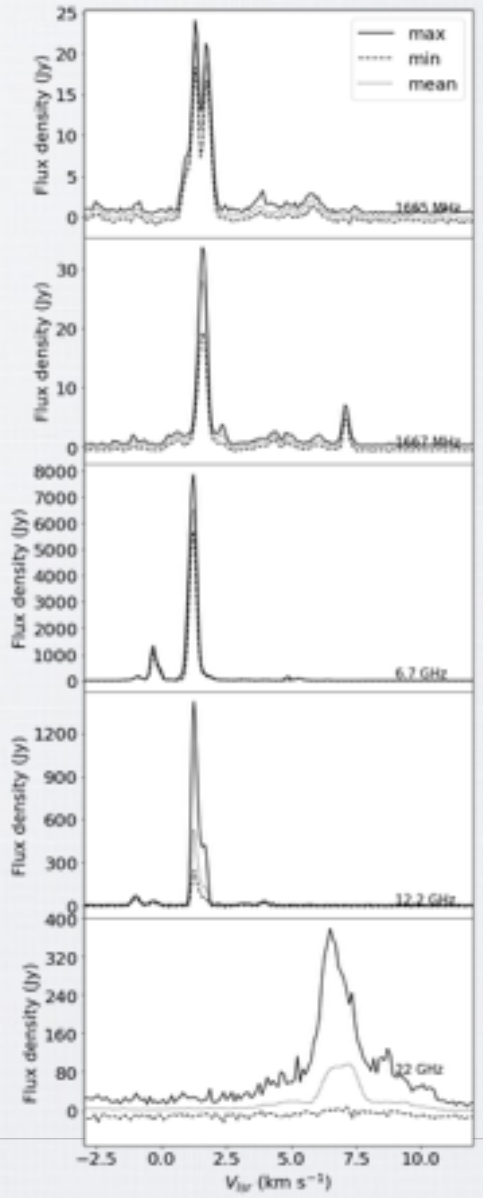
G339.62-0.12

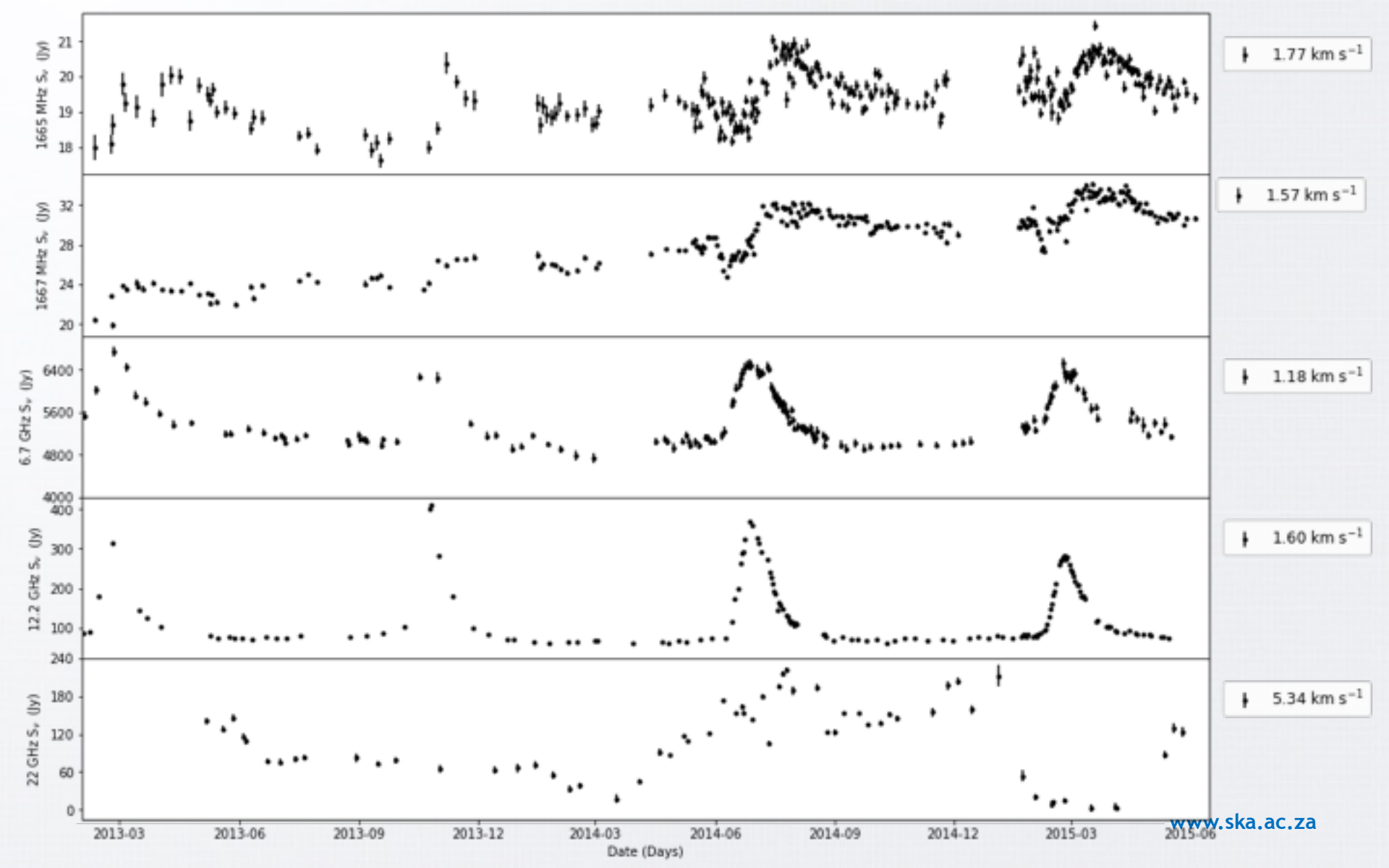
Being worked on by Mavis Seidu (MSc student)

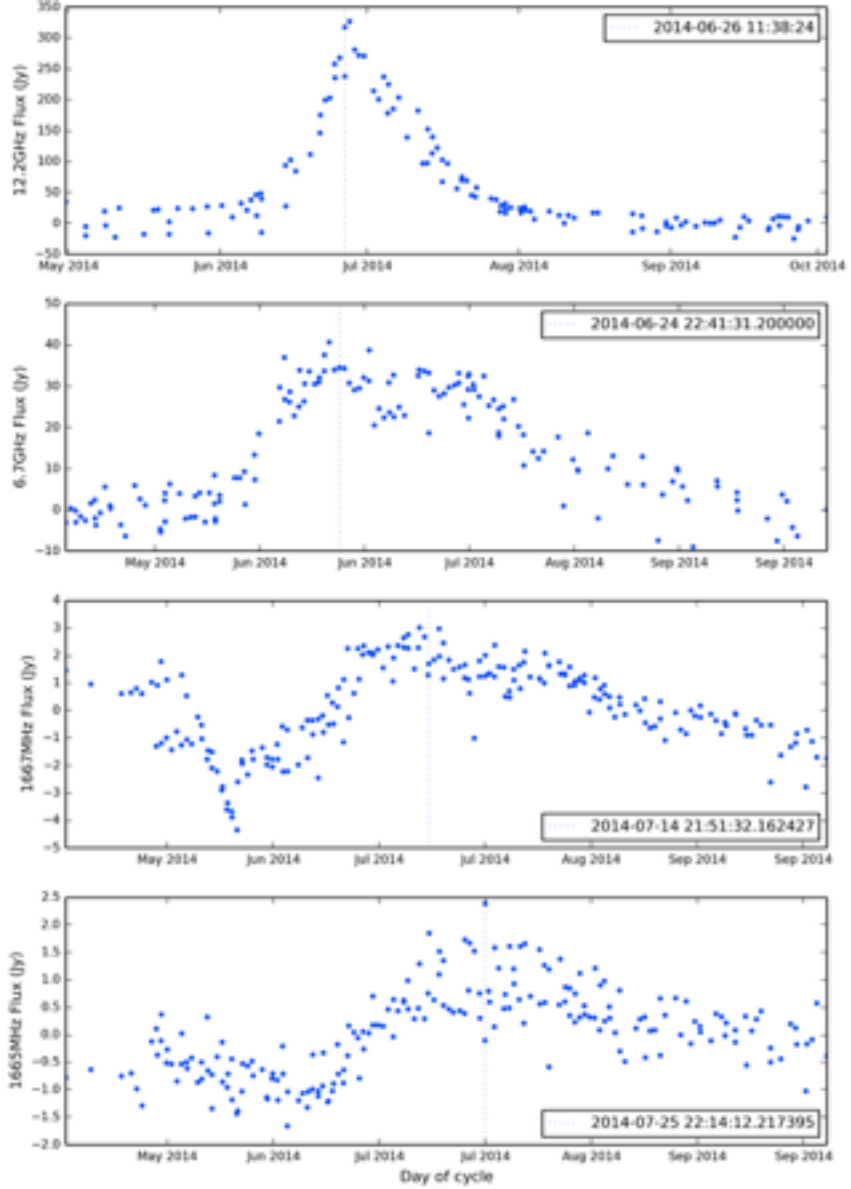




Multi-transition monitoring of G9.62+0.20



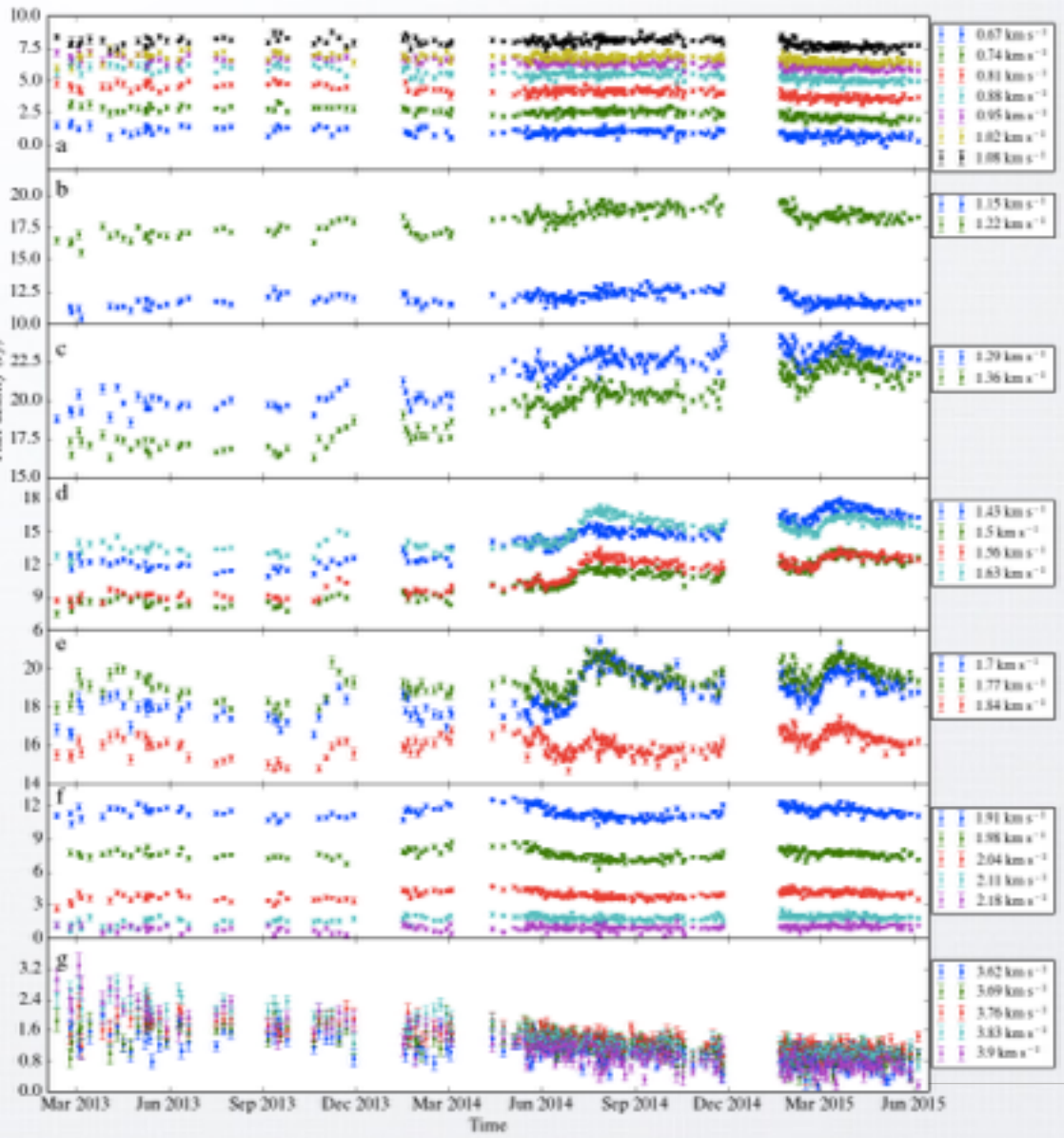

1665 MHz S_ν (Jy)
1667 MHz S_ν (Jy)
6.7 GHz S_ν (Jy)
12.2 GHz S_ν (Jy)
22 GHz S_ν (Jy)
1.77 km s^{-1}
1.57 km s^{-1}
1.18 km s^{-1}
1.60 km s^{-1}
5.34 km s^{-1}
2013-03
2013-06
2013-09
2013-12
2014-03
2014-06
2014-09
2014-12
2015-03
2015-06
Date (Days)
www.ska.ac.za

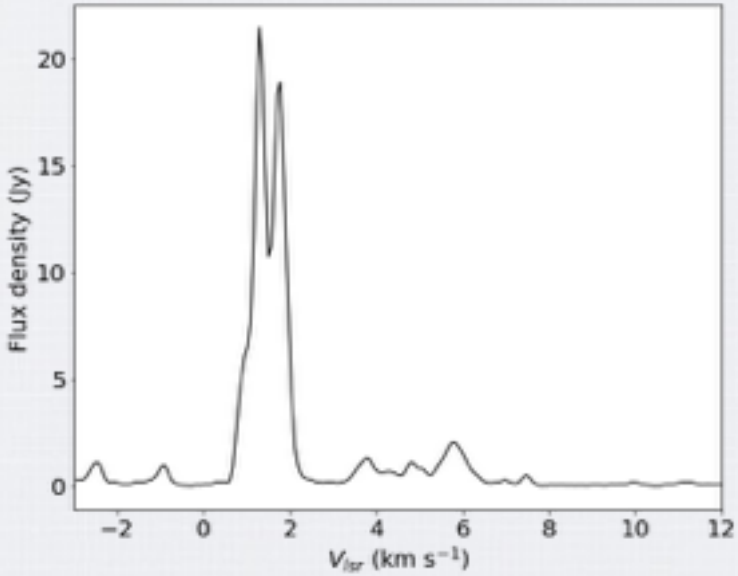


Delays

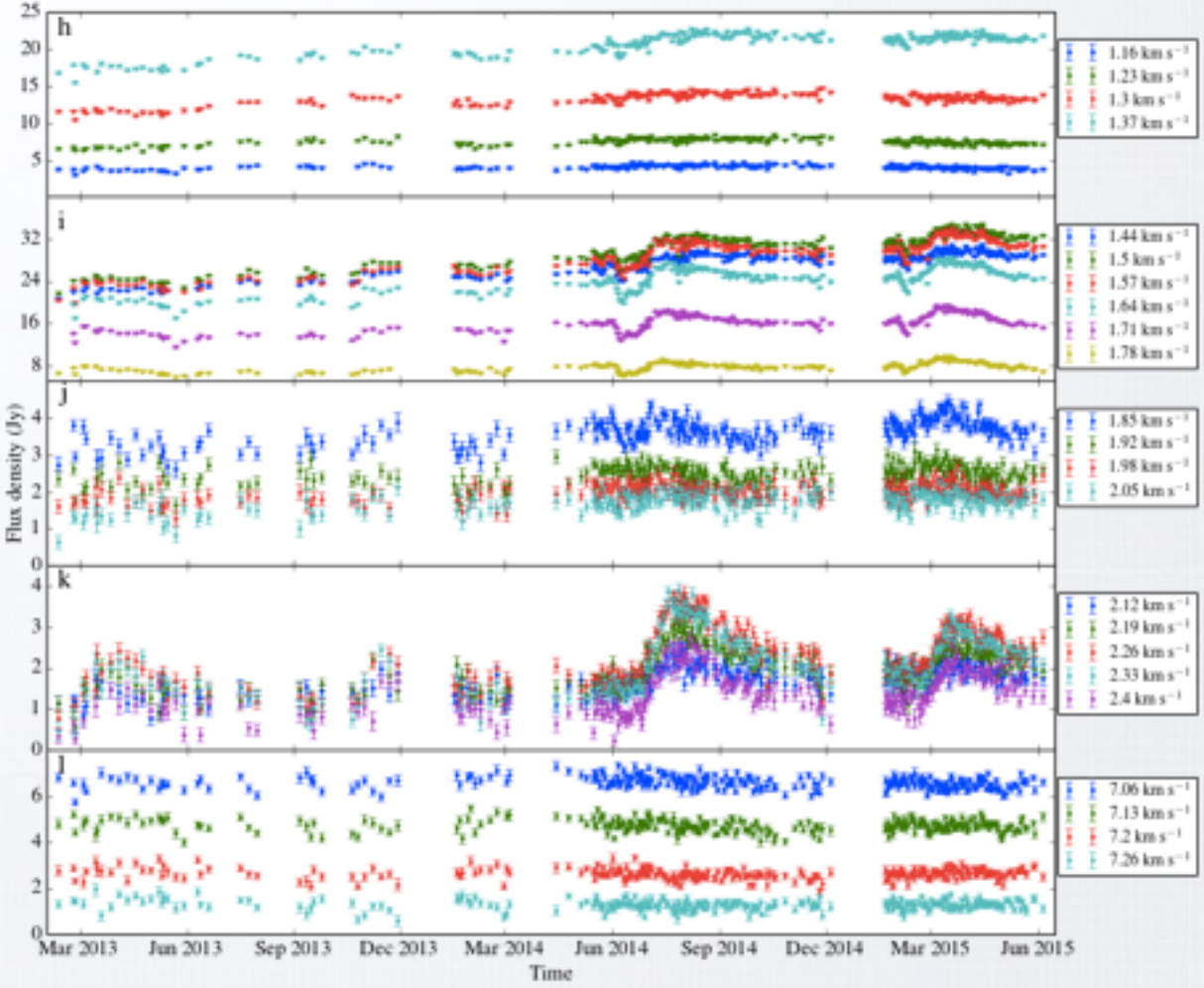
- Difference of 20 hours between 12.2 and 6.7 GHz. Effectively simultaneously?
- 1667 MHz OH peaks ~20 days after the methanol
- 1665 MHz OH peaks 7-10 days after the peak in 1667 MHz

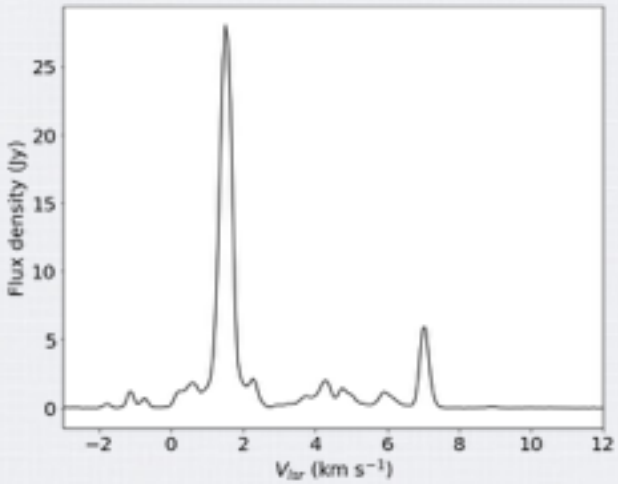
1665 MHz


a
b
c
d
e
f
g
Mar 2013
Jun 2013
Sep 2013
Dec 2013
Mar 2014
Jun 2014
Sep 2014
Dec 2014
Mar 2015
Jun 2015
Time

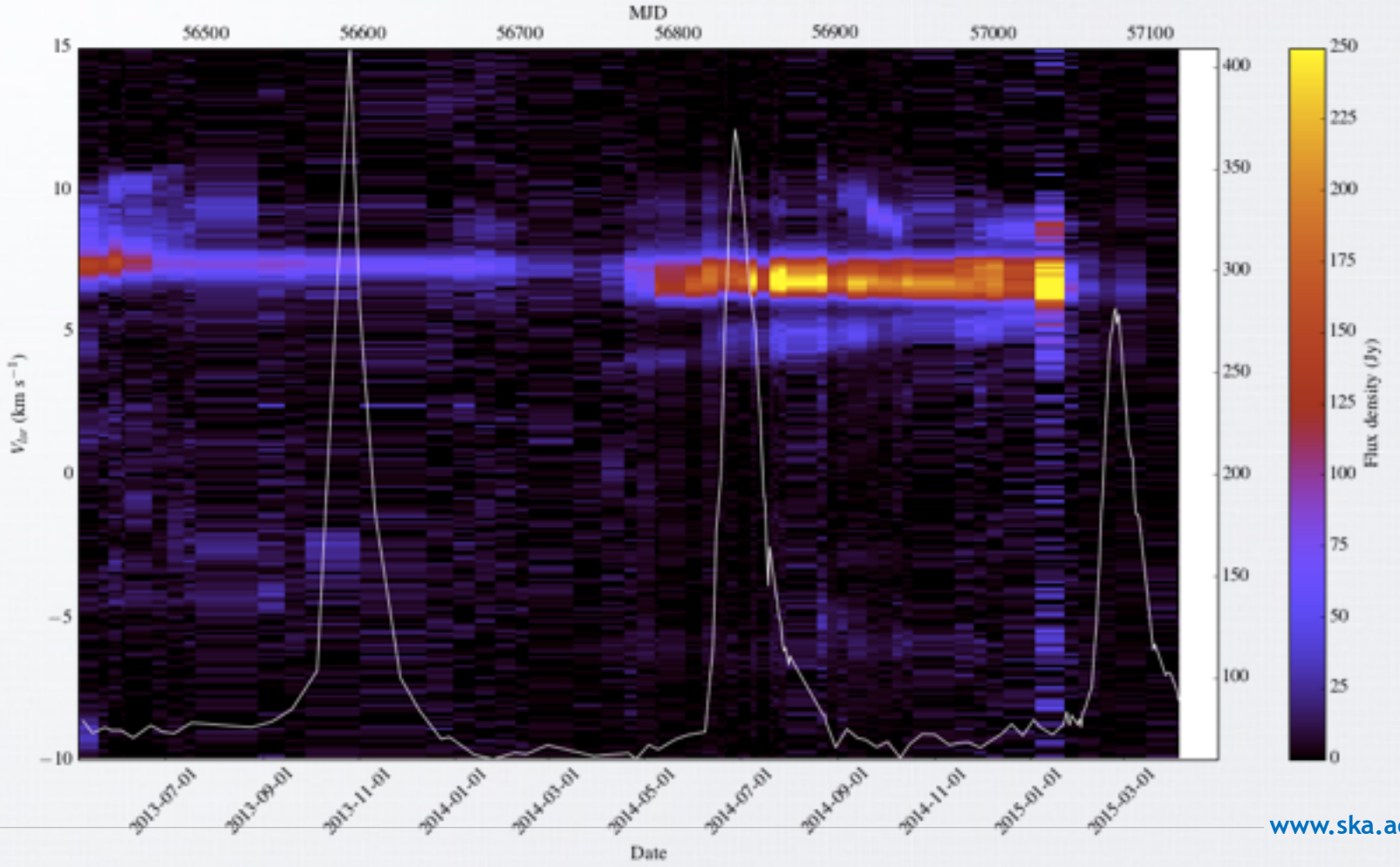

Flux density (Jy)
V_{lsr} (km s^{-1})

1667 MHz

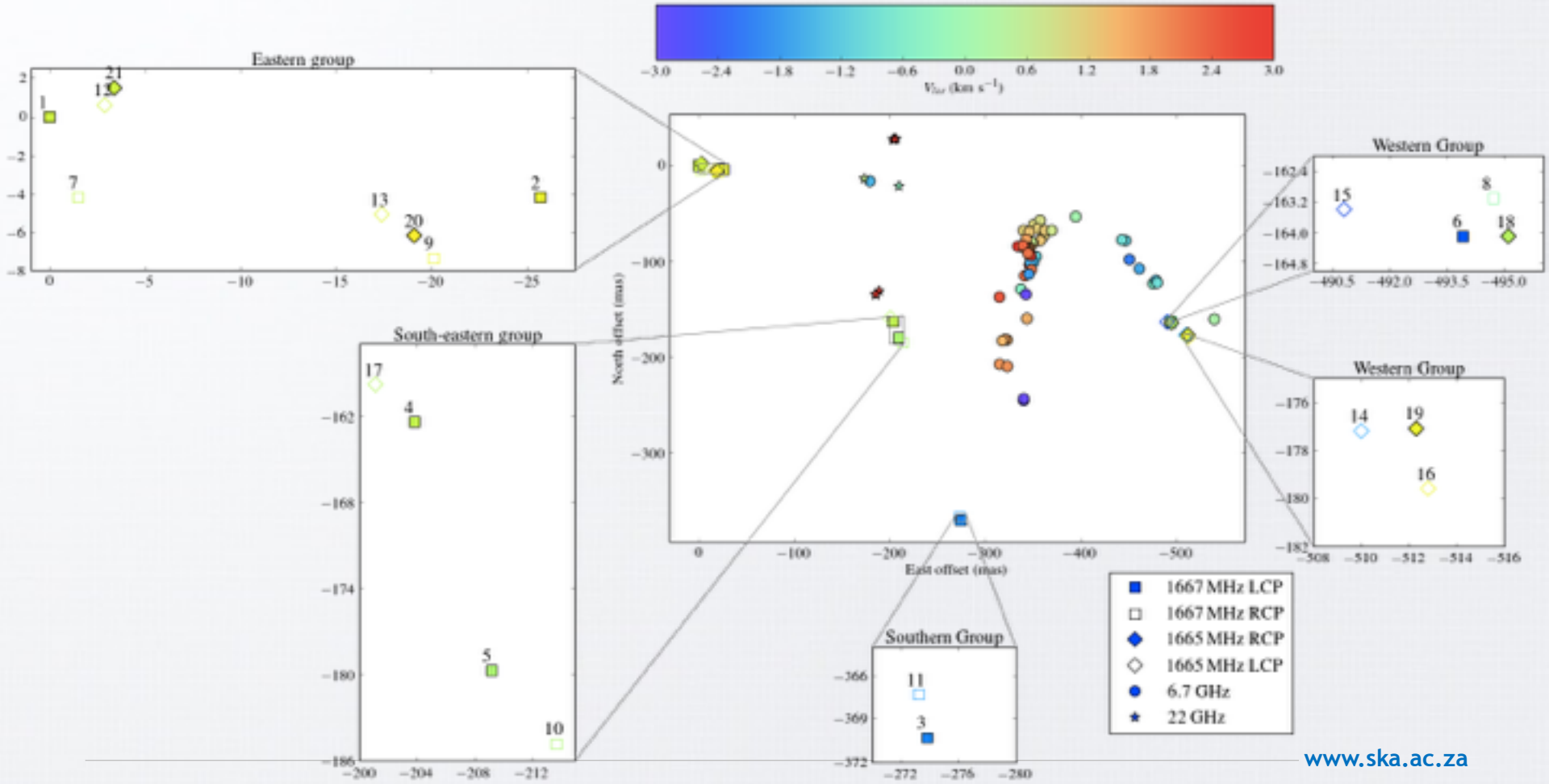

h
i
j
k
l
Flux density (Jy)
1.16 km s⁻¹
1.23 km s⁻¹
1.3 km s⁻¹
1.37 km s⁻¹
1.44 km s⁻¹
1.5 km s⁻¹
1.57 km s⁻¹
1.64 km s⁻¹
1.71 km s⁻¹
1.78 km s⁻¹
1.85 km s⁻¹
1.92 km s⁻¹
1.98 km s⁻¹
2.05 km s⁻¹
2.12 km s⁻¹
2.19 km s⁻¹
2.26 km s⁻¹
2.33 km s⁻¹
2.4 km s⁻¹
7.06 km s⁻¹
7.13 km s⁻¹
7.2 km s⁻¹
7.26 km s⁻¹
Mar 2013
Jun 2013
Sep 2013
Dec 2013
Mar 2014
Jun 2014
Sep 2014
Dec 2014
Mar 2015
Jun 2015
Time


Flux density (Jy)
V_{lsr} (km s^{-1})

Water masers



Sanna et al. 2015 maser map



What on earth is going on?

- The OH masers that show periodicity are offset from the primary HII region and may in fact be superposed on a second, weaker HII region.
- Some features in the OH 1667 MHz transition show a sharp drop in flux density ~ at the onset of the flare in methanol.
- There are significant delays in the peak of the flares in OH.
- The colliding wind binary model predicts the shape of the methanol maser light curve very well (modulation of the radio continuum background). Fanie van den Heever's poster #54
- Could it be that we have a modulation of both the radio continuum and the infrared background as well as pump?

Recommendations

- Should monitor the OH masers at high resolution during a flare event (preferably with polarisation information)
- We should be monitoring periodic masers at **all** possible transitions. This could be the key to understanding the cause of the variability and testing maser models.
- In addition, we need to know the positions of the maser spots of all species relative to each other.
- We need radiative transfer/maser pump models that have time dependence (see Jabulani Maswanganye's poster #27)
- Understand the morphology and dynamics of the dust and gas (ALMA?)
- Continue to increase the sample.