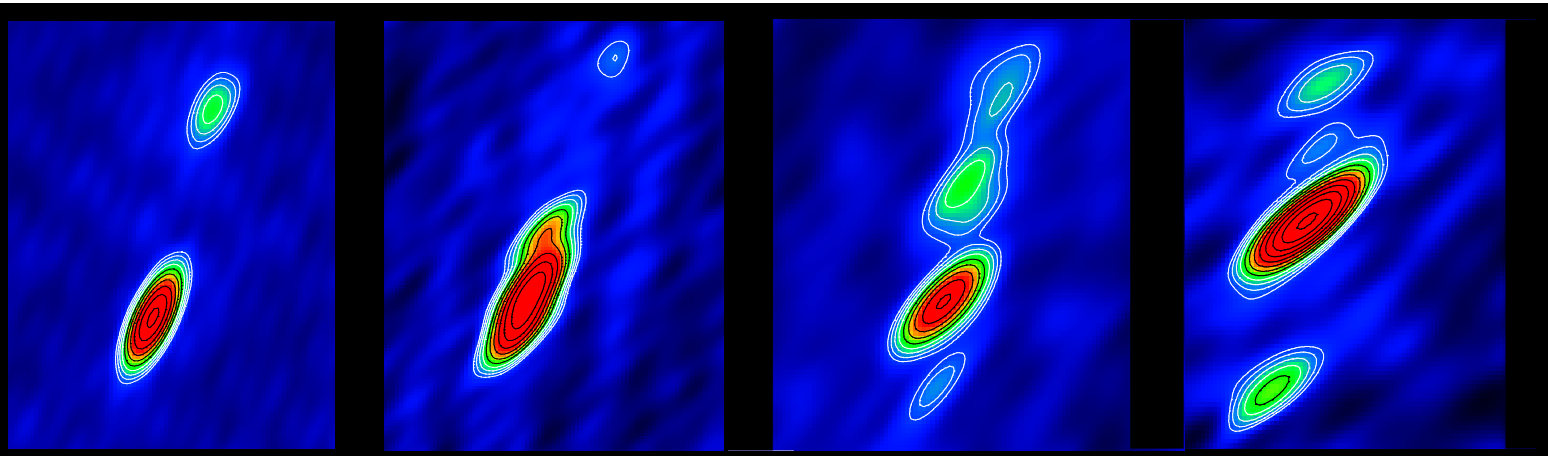

Extreme Jet Ejections from the Black Hole X-ray Binary V404 Cygni: The Unique (Sub-) Millimetre Perspective

Alex Tetarenko
University of Alberta

J.C.A. Miller-Jones (ICRAR), G.R. Sivakoff (UAlberta),
and the JACPOT XRB Team

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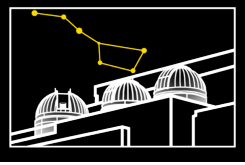

June 2015 Outburst

- On June 15, 2015 X-ray flaring detected by Swift BAT, MAXI and INTEGRAL.
- Extraordinary mutli-wavelength flaring activity followed.
- Brightest BHXB outburst in the past decade.

Rare, bright accretion state + Well-known system parameters + Close Proximity

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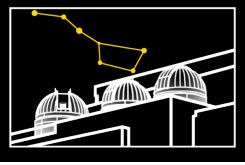

The “Golden Data Set”

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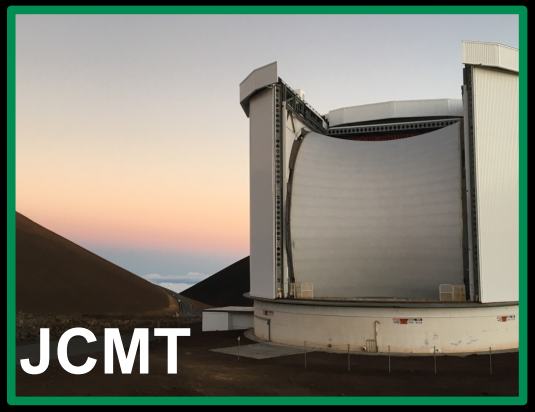

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Unprecedented multi-wavelength view
(9 different frequencies!)

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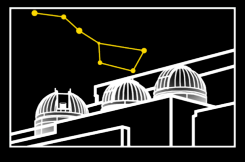
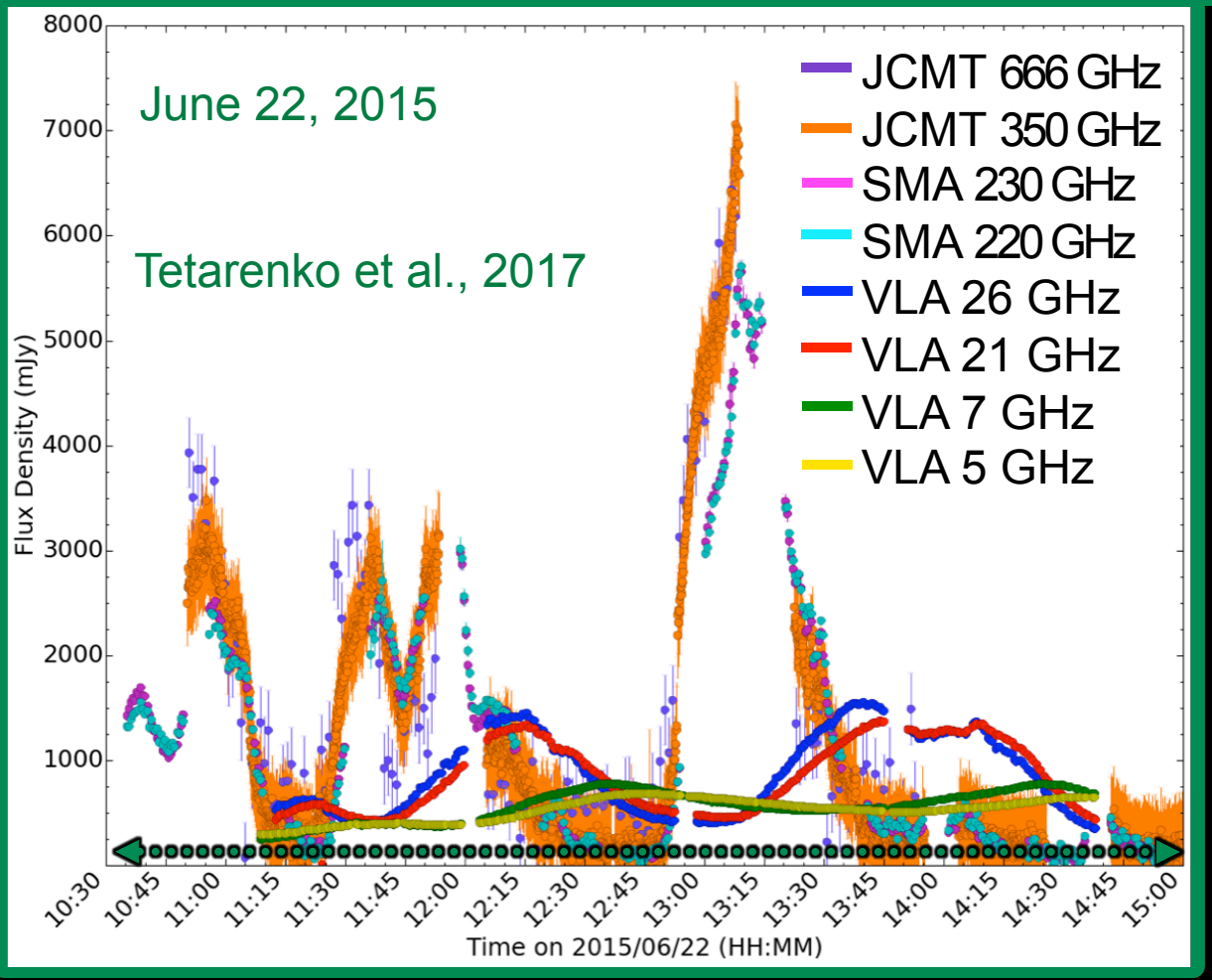


“Golden Data Set”



- Flares reach extremely bright flux levels
- Lower ν are delayed, smoothed version of higher ν
- (Sub-)mm substructure not visible in cm emission

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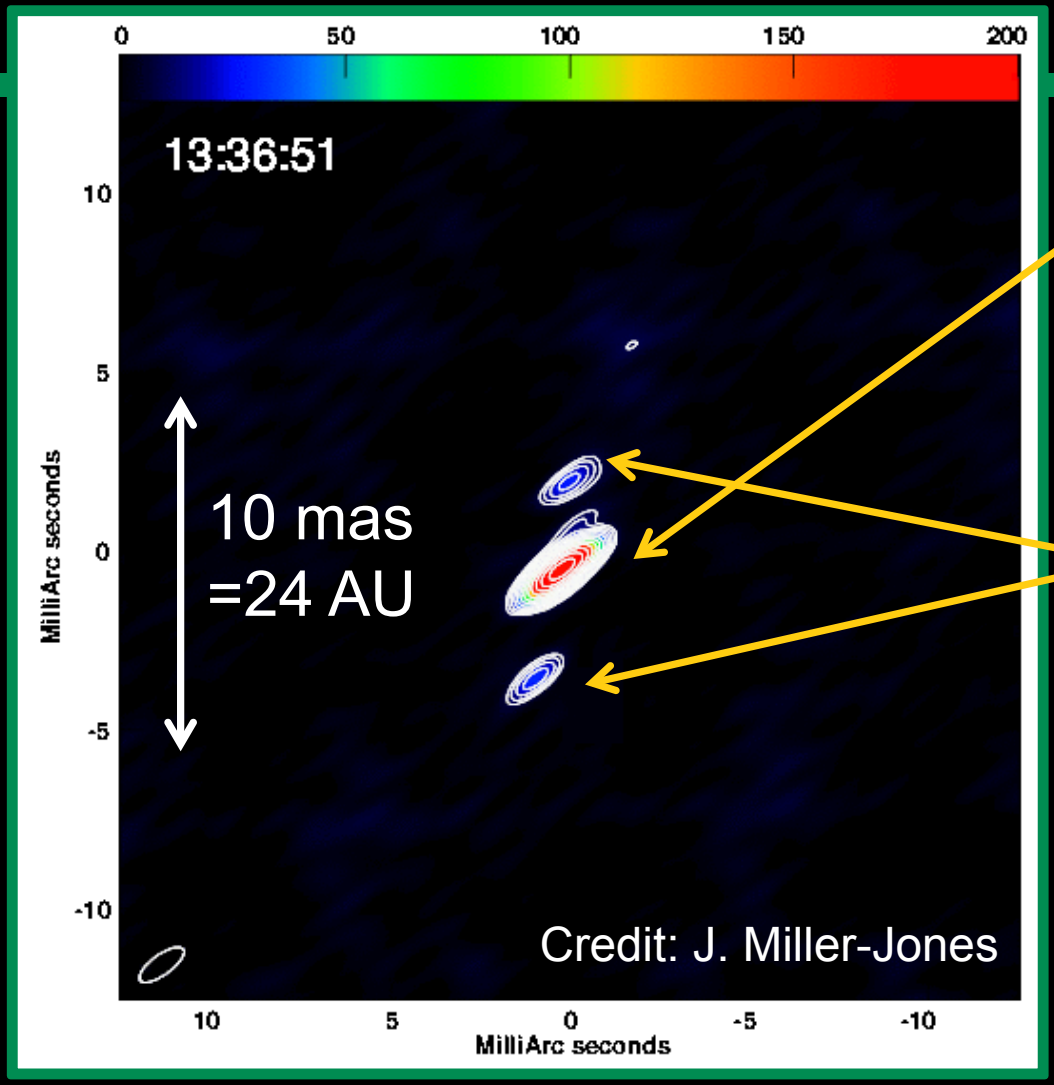
Hints from VLBA



- Compact core component is always bright
- Multiple resolved ejecta
- Rapidly precessing jet axis

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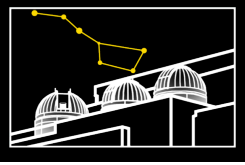
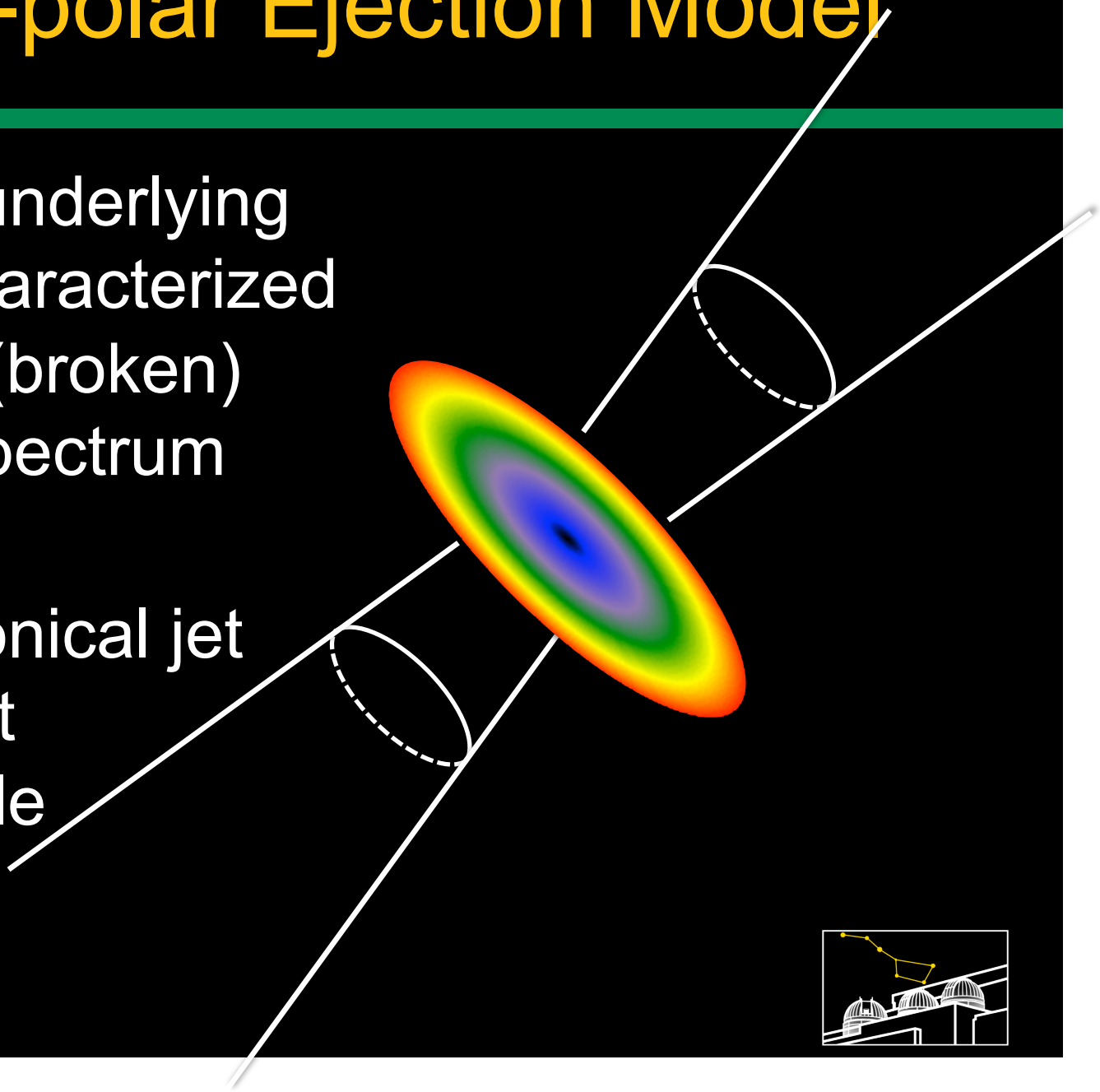


Twin Bi-polar Ejection Model

1. Assume an underlying steady jet characterized by a classic (broken) power-law spectrum

2. Assume a conical jet with constant opening angle



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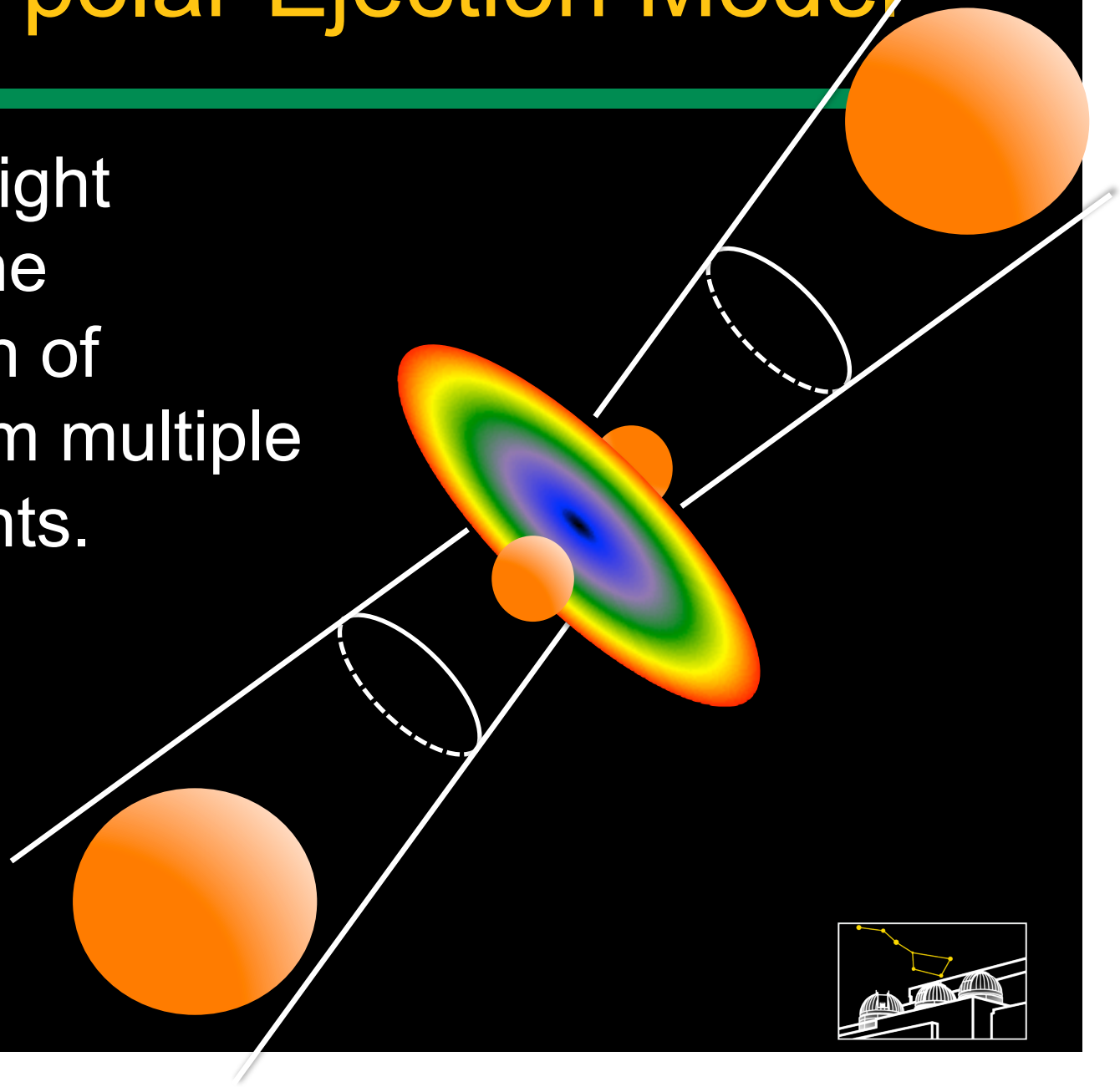
Twin Bi-polar Ejection Model

3. Assume our light curves are the superposition of emission from multiple ejection events.



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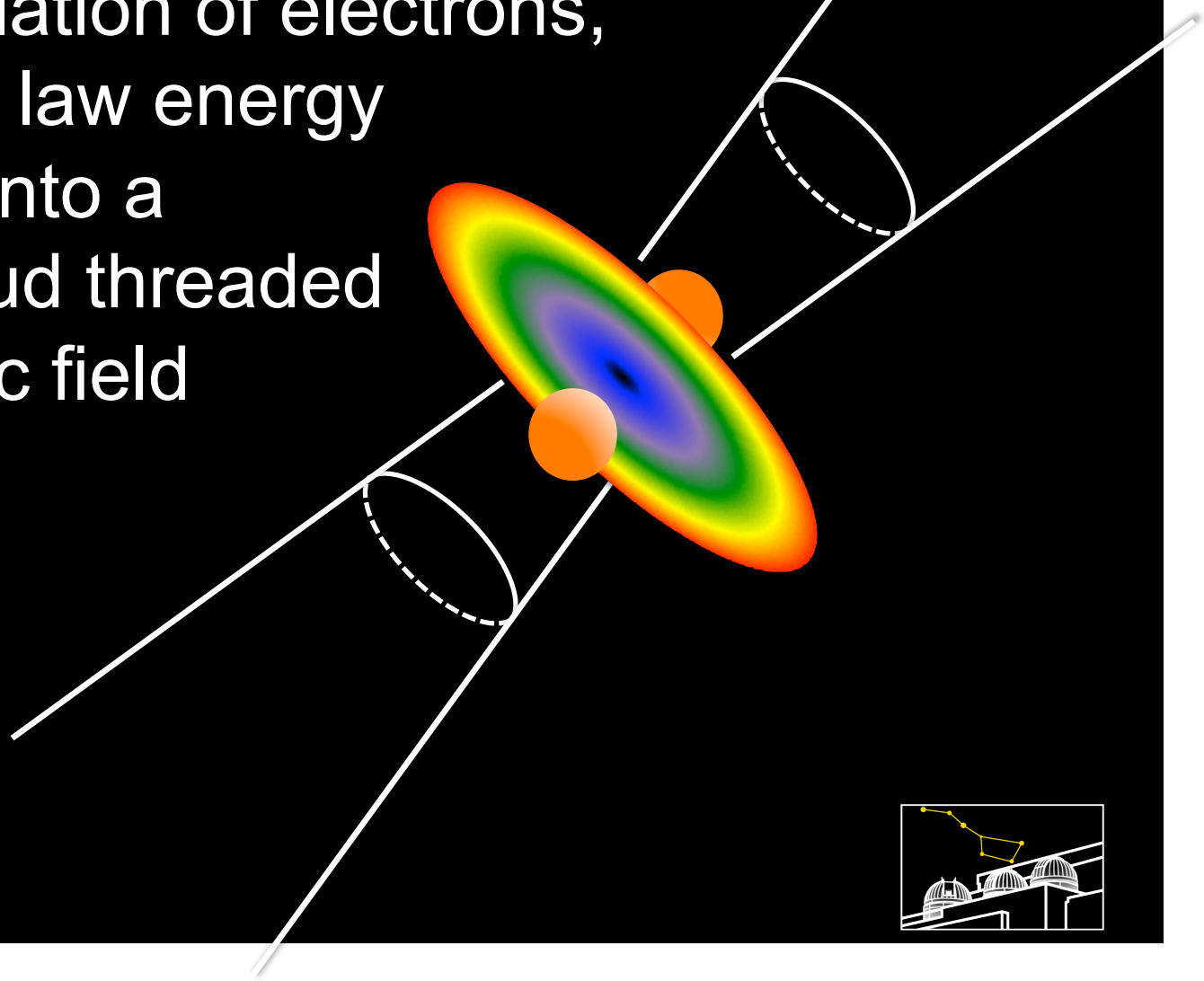
Twin Bi-polar Ejection Model

4. Inject a population of electrons, with a power law energy distribution, into a spherical cloud threaded by a magnetic field



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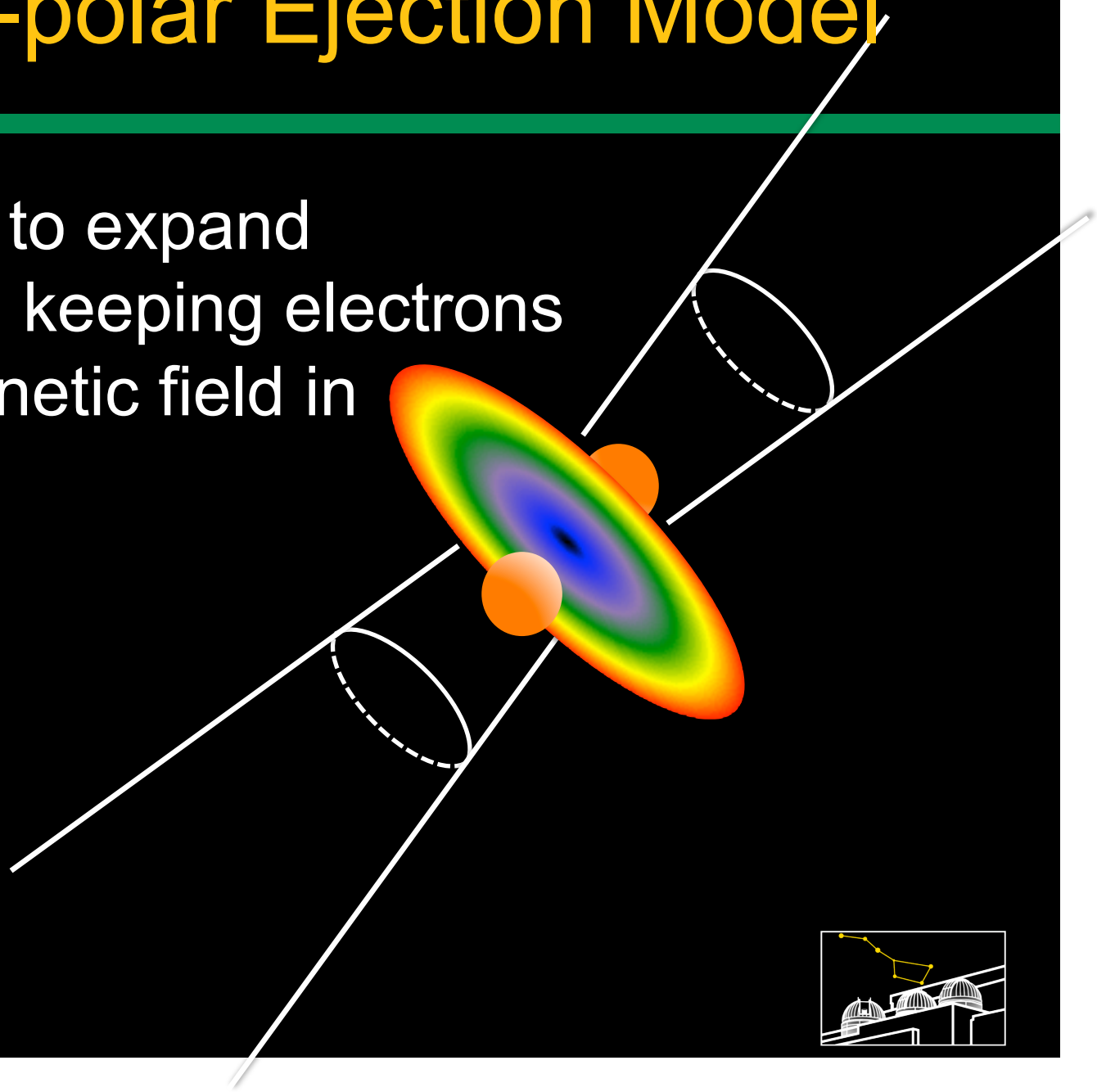
Twin Bi-polar Ejection Model

5. Allow sphere to expand adiabatically, keeping electrons and the magnetic field in equipartition



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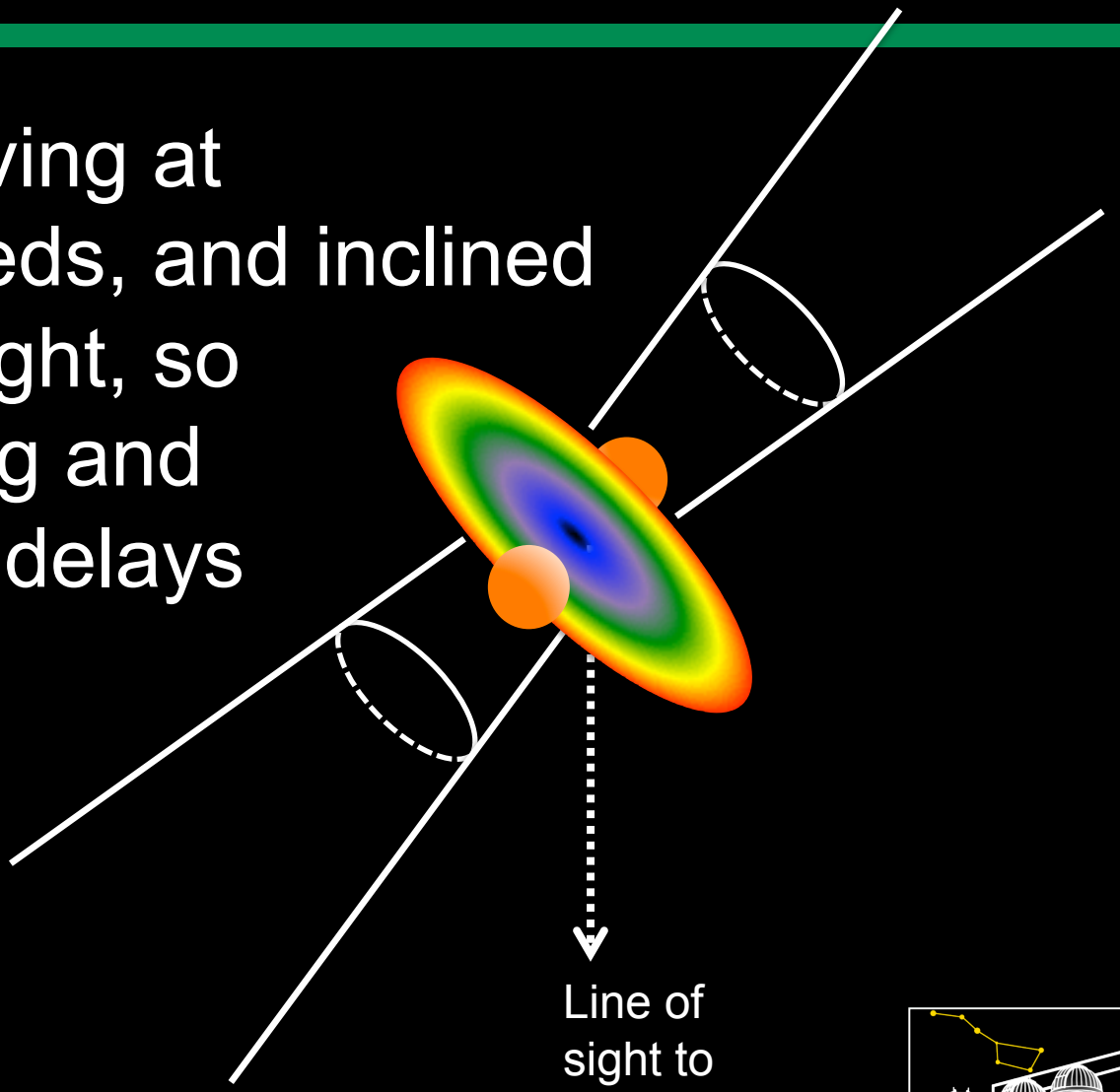
Twin Bi-polar Ejection Model

6. Clouds are moving at relativistic speeds, and inclined to our line of sight, so include beaming and geometric time delays

7. Jet axis is precessing



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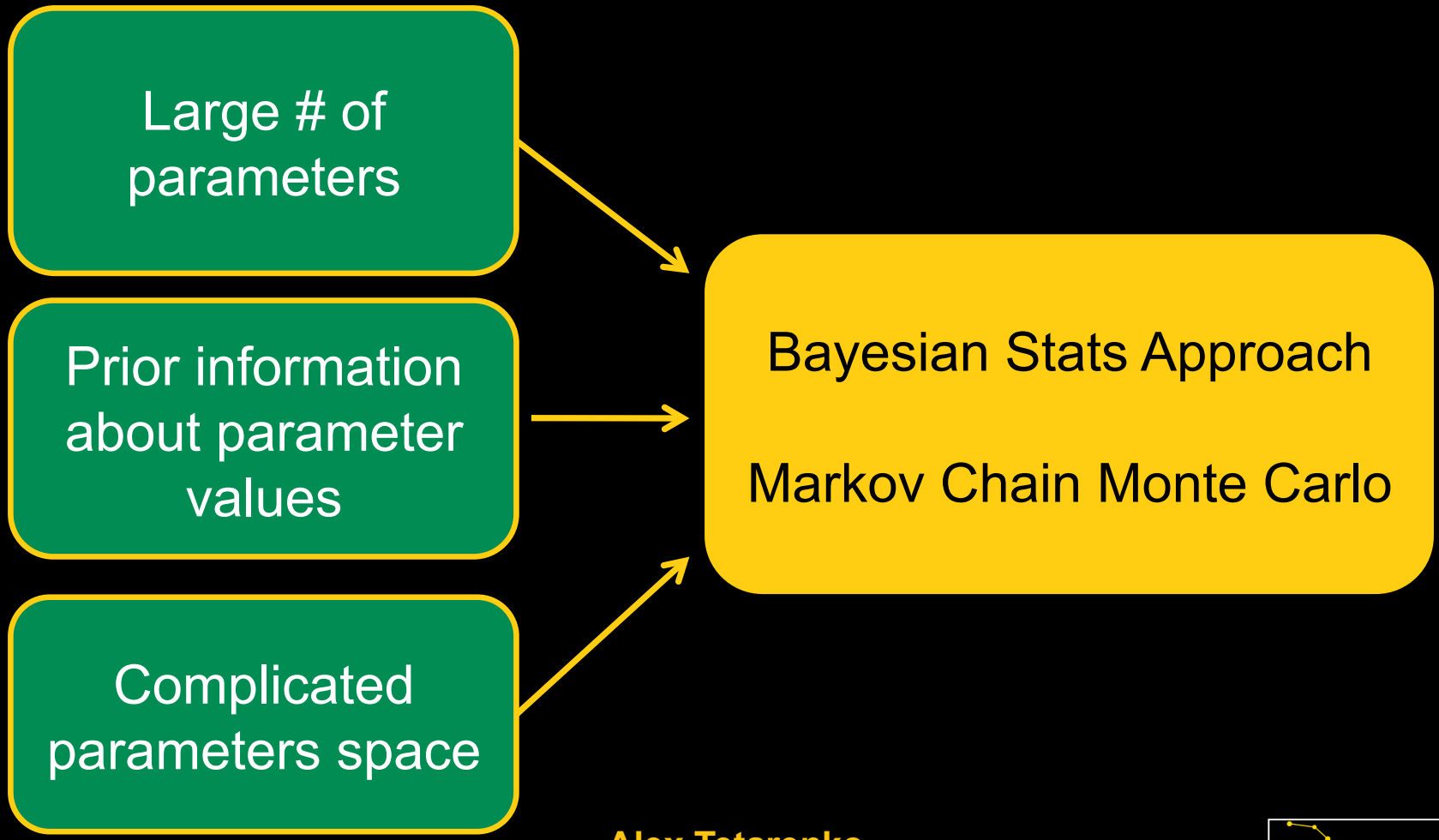
Modeling the Light curves



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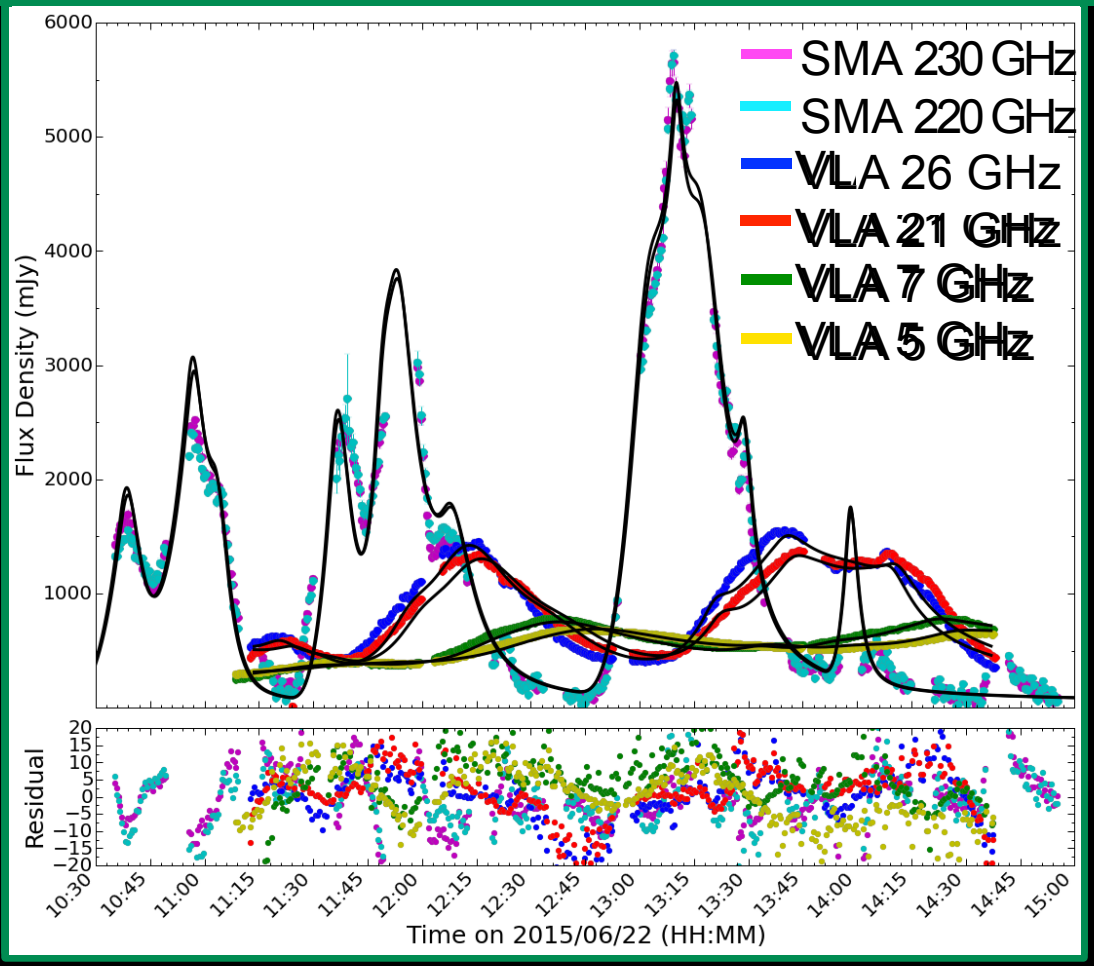
Light Curve Modeling



- Simultaneously fit all frequencies (5 - 350 GHz).
- 8 pairs of ejecta!
- Sub-mm data is crucial in our modeling!

Tetarenko et al., 2017

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Porquerolles 2017

Probing Ejecta Properties

- Intrinsic properties of ejecta vary between events.
- Low bulk speeds, Γ~1.004-1.3, where the fastest ejecta tend to be the brightest.
- Mean power into each ejection event, ~10^{32} – 10^{35} erg/s.
- Ejecta carry very little mass, ~1% $M_{acc,BH}$
- Highly confined jet, ϕ_{obs}~4-9°

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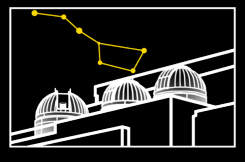
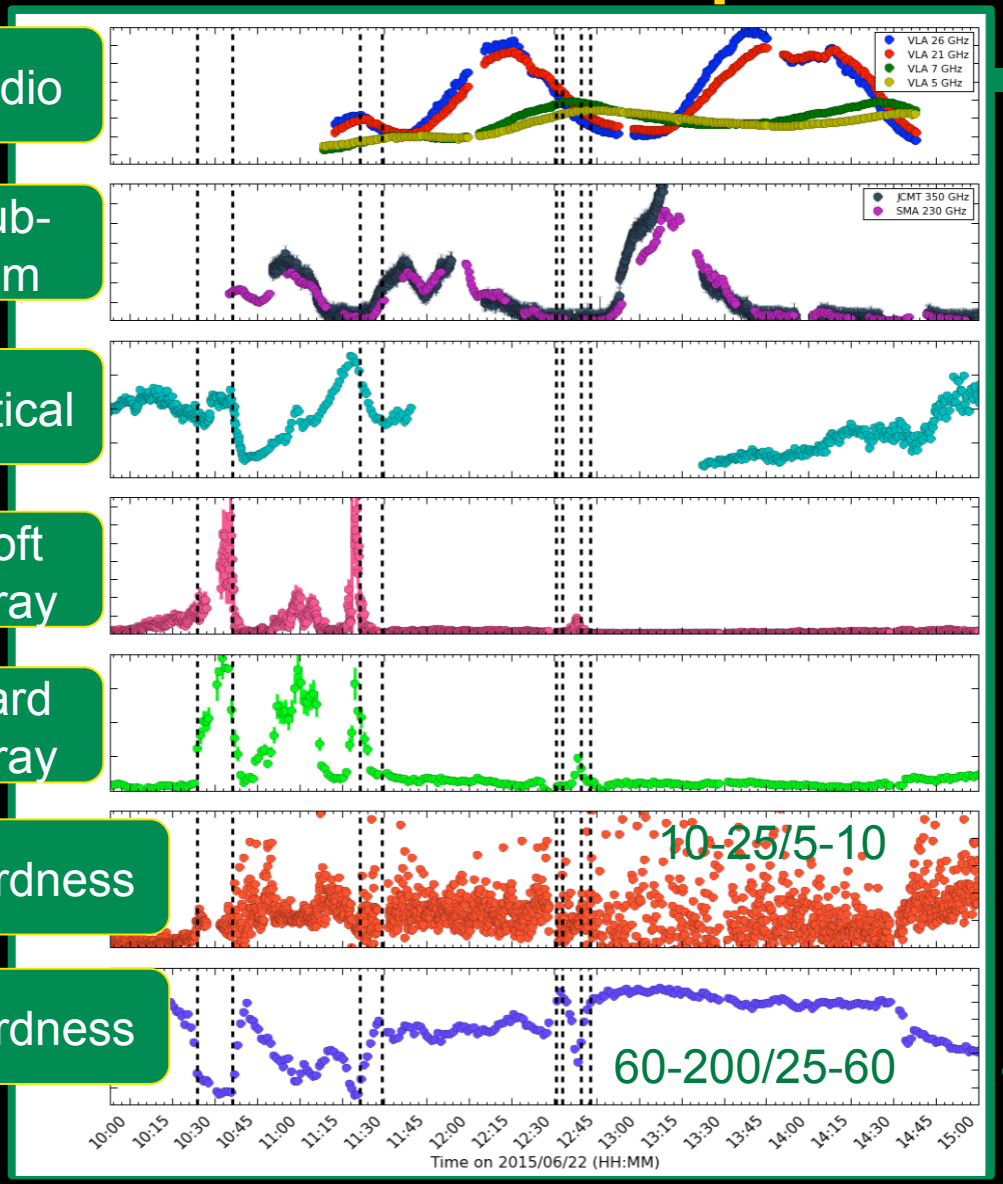


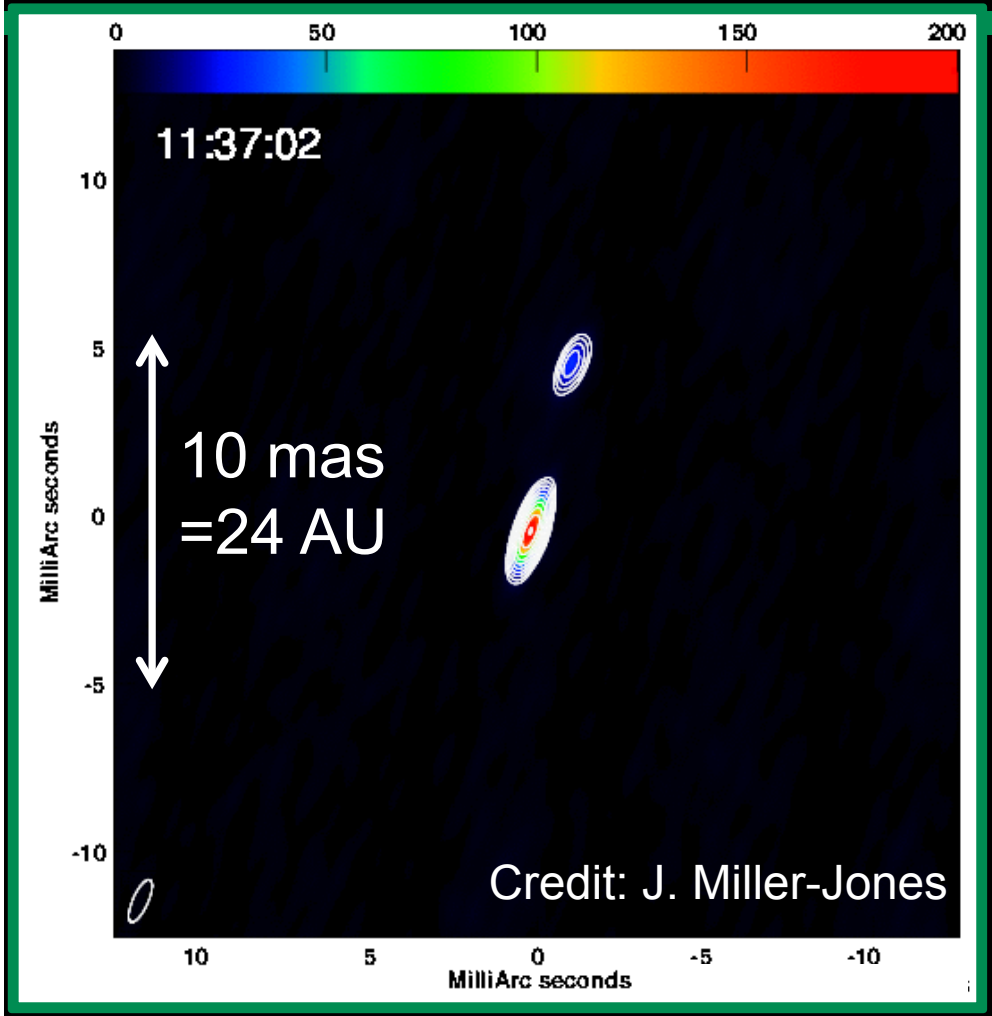
Relationship to OIR/X-ray



- Match groups of ejections with OIR/X-ray peaks?
- X-ray flares coincide with hardness dips
- All ejections occur within a global hardness dip

Tetarenko et al., 2017

What's Next?



- Improvements to model:
  - Equipartion
  - Variable compact jet
  - Ejecta collisions
- VLBA constraints – ejection times, number of ejecta, single sided vs bipolar ejecta

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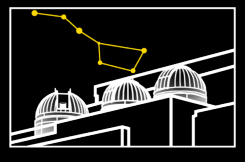
High Time Resolution Measurements

- Our team has developed custom timing scripts for interferometric data that runs in CASA
- Produces light curves on user specified time bin
- Many customizable options:
  - UV or image plane
  - Object detection
  - And many more…
- Will be available soon, stay tuned!

https://github.com/Astroua/AstroCompute_Scripts



Summary

- Simultaneous multi-wavelength coverage essential to unlocking complicated physics.
- Rapid response and specialized observing techniques, like sub-arrays and VLBI, make this possible.
- mm/sub-mm data provides a unique, more detailed view of the jet compared to cm.

Tetarenko et al., 2017, MNRAS, 469, 3141
(arXiv: 1704.08726)

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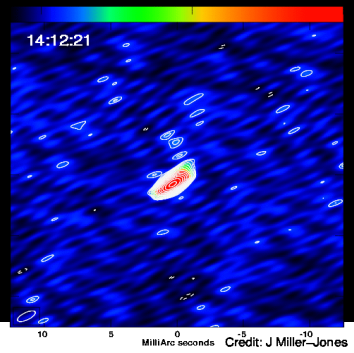

I am currently looking for a Postdoc. If you are interested in giving me a job please let me know!

Thank you!

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