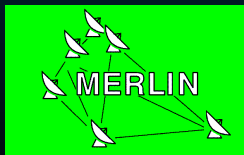


Supernovae and Masers in Arp220: Pushing the limits of VLBI sensitivity

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VLBA 10th Anniversary:
10 June 2003



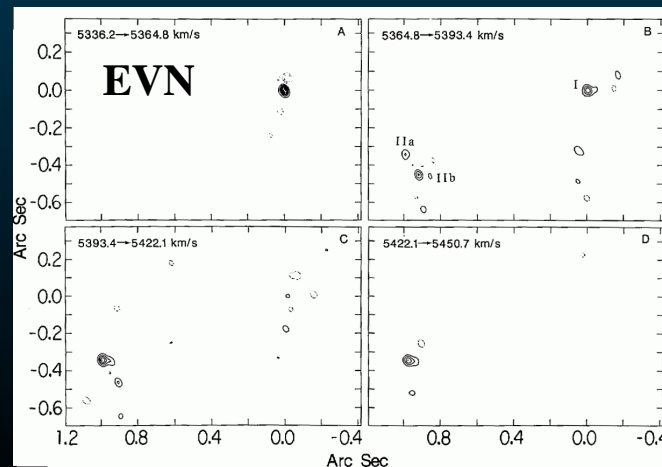
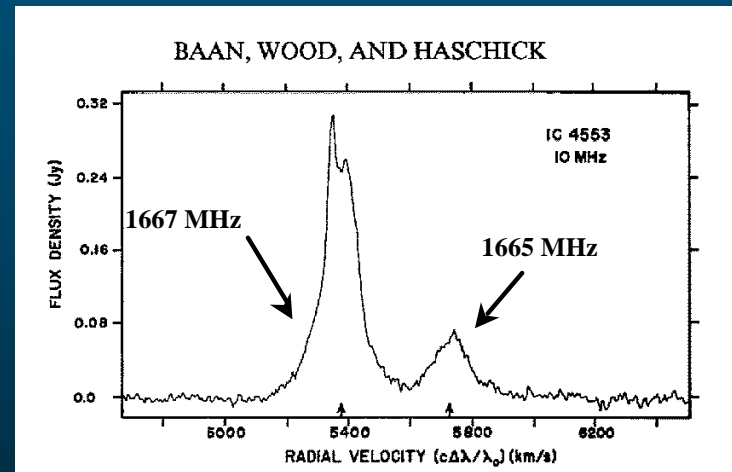
Astronomical Context

- The big questions:
 - How did the universe evolve from ~uniform soup to the stars and galaxies we see today?
 - Structure formation – gravitational collapse generates a world of complexity – what are the details?
 - Early protogalaxies collide and merge to form bigger galaxies – how?
 - Collisions and mergers trigger quasars and radio galaxies – how?
 - AGN activity modifies host galaxies, pumps energy into IGM and affects entire process – how?
 - Supermassive black hole growth catalyzed by mergers – details?
- Ultraluminous IR Galaxies hold the key to some of these questions, sub-mm sky dominated by starbursts:
 - Merger events “caught in the act”, but very heavily obscured
 - VLBI of OH megamasers and continuum offers the sharpest view of activity within ULIRGs.

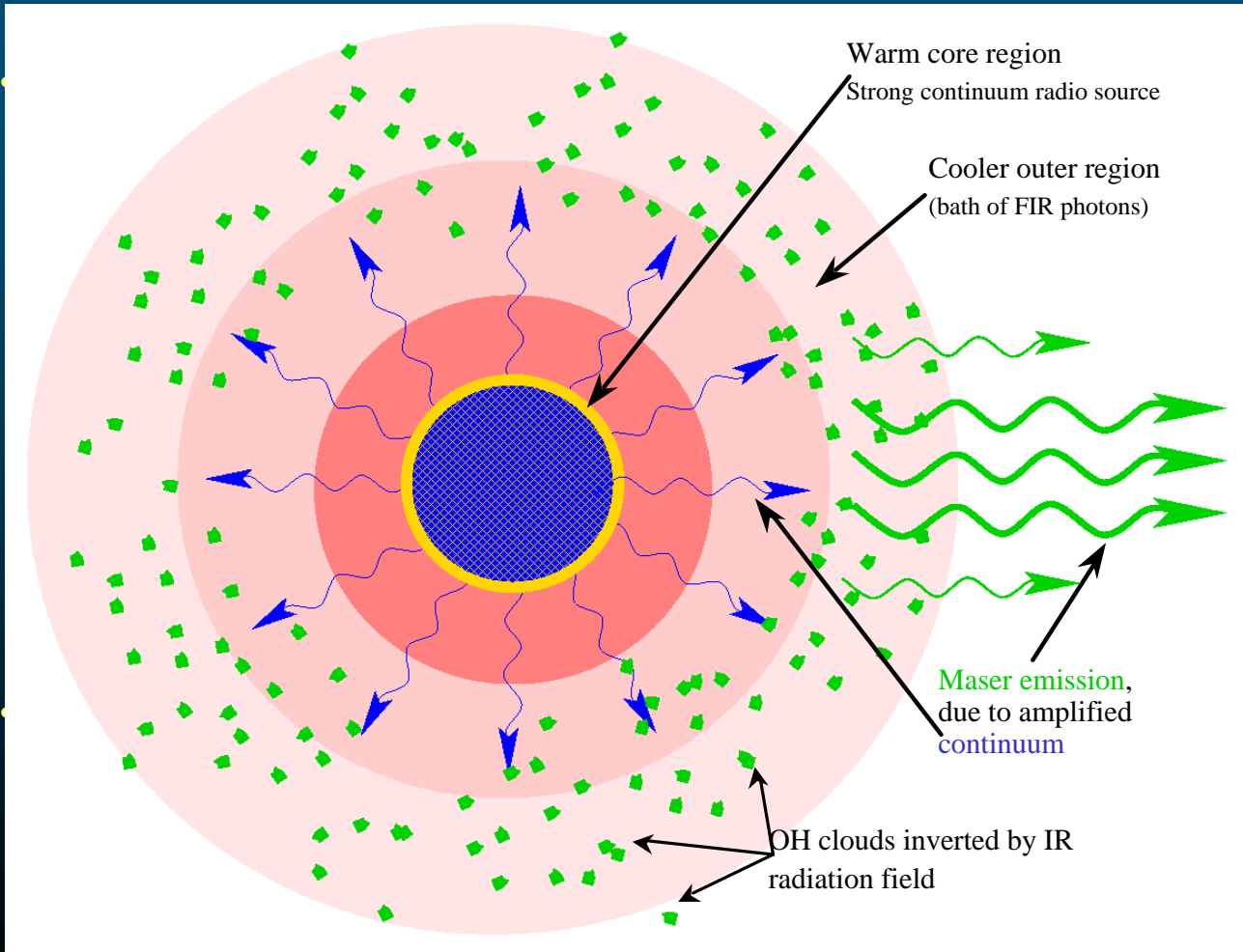
The archetypical OH Megamaser: Arp220

Arecibo spectrum

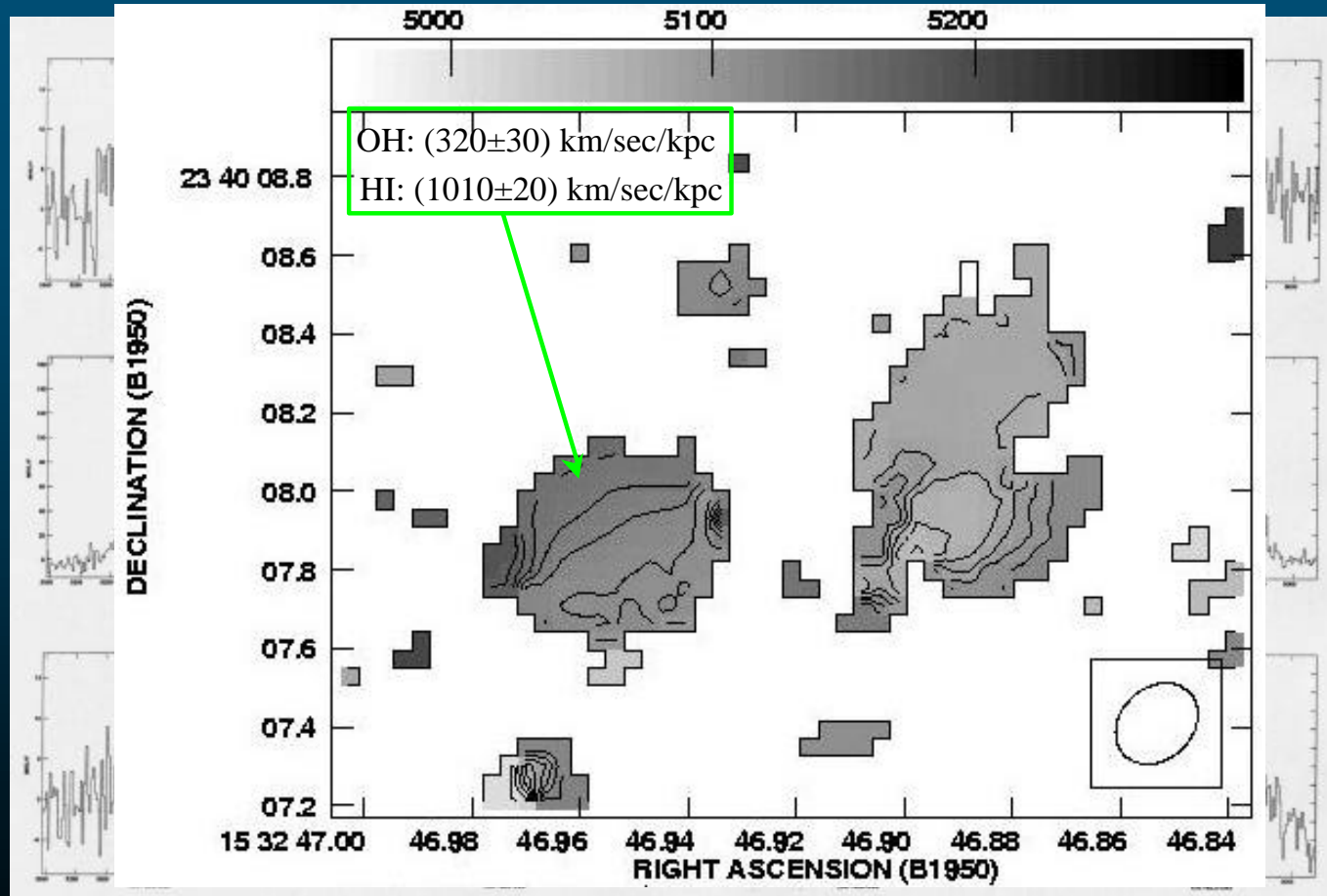
- Arp 220 (= IC4553) was the first – still the best.
 - Baan, Wood and Haschick *Ap.J.* **260**, L49 (1982)
 - Broad velocity width
 - High 1667/1665 ratio
 - Extreme luminosity
 - Total power $> 10^6$ times “typical galactic OH maser - term “OH Megamaser” coined
- First VLBI: Diamond et al. (1989)
 - EVN, 2 MHz bandwidth, MkII
 - Detected compact maser features
 - Interpreted as amplified compact continuum
 - Much of maser emission resolved out



Standard Model



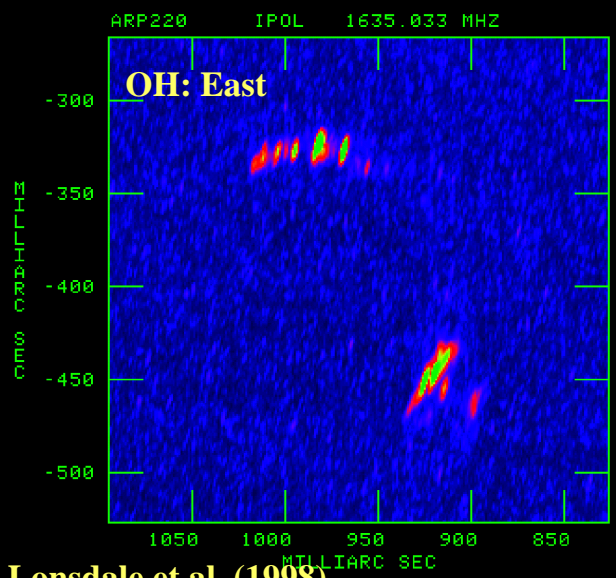
MERLIN 1.6 GHz: Rovilos et al (2003)



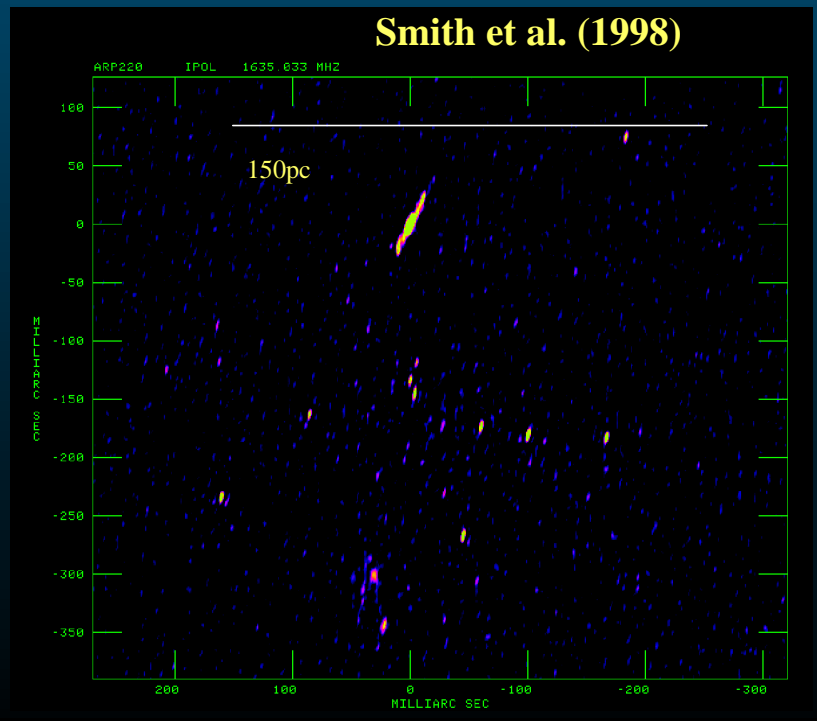
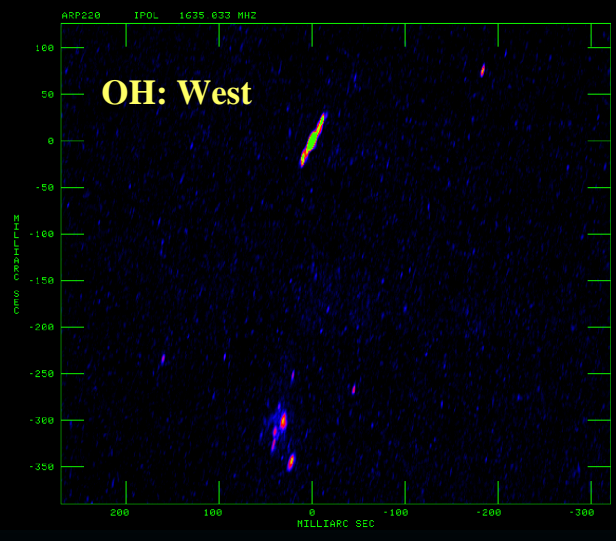
East: maser & continuum coincident: West: maser north and south of continuum

20th Century VLBI

- 1667 MHz OH is compact
- **Revision of standard model** most
- plausibly are radio supernovae; concentrated in W nucleus.



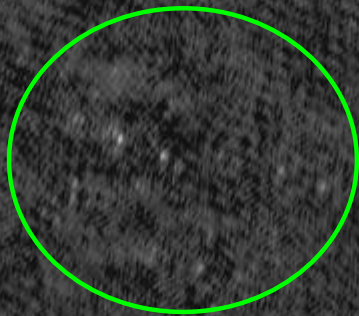
Lonsdale et al. (1998)



21st Century VLBI

- 4 epochs VLBA+Y27 – monitoring continuum + OH, 1997 - 2000
- Nov 2002 : global observation using EVN, Arecibo, GBT, Y27 + VLBA @ 256 Mb/s

Nov 2002: preliminary image, rms ~ 9 mJy/bm

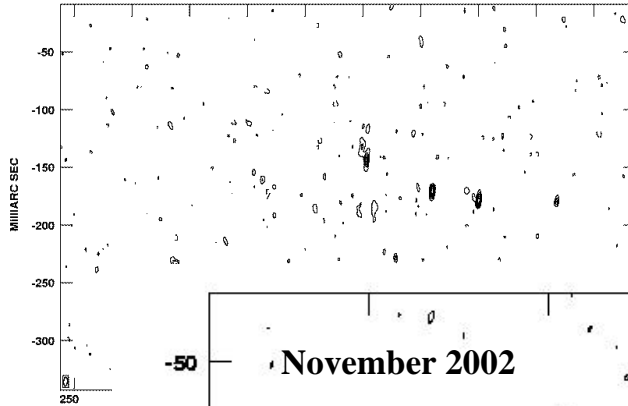


Now have ~30 RSN. Detections in eastern nucleus, new RSN in west.

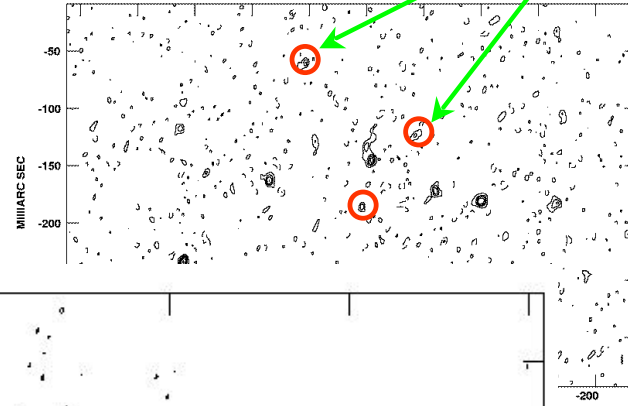
Arp 220 RSN History

transient

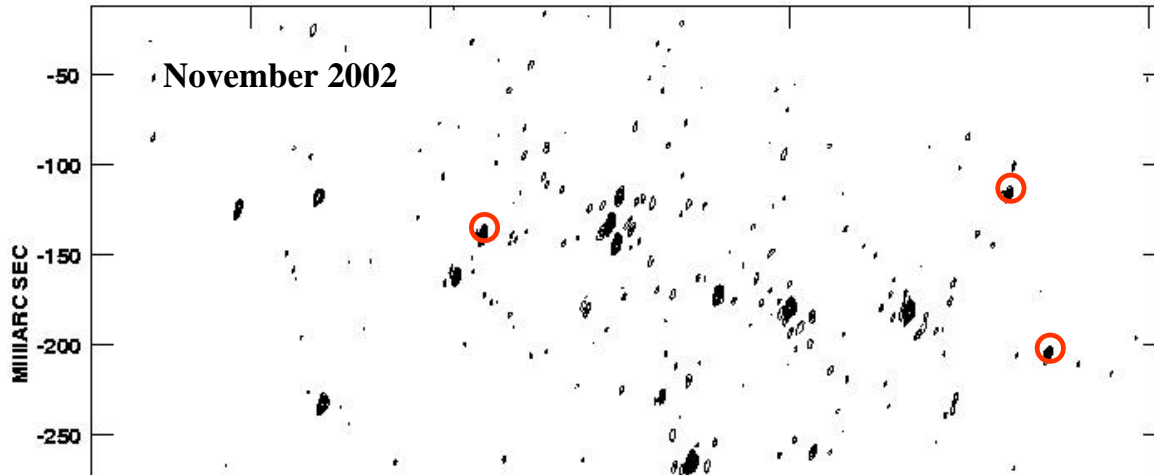
November 1994



June 2000



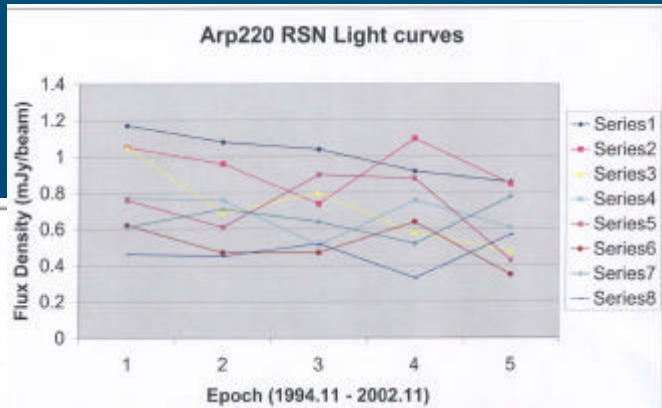
November 2002



SN rate $\sim 2/\text{yr}$;

observe 6 new ones in western nucleus over 8 years, some only in 1 epoch.

We observe the peak of the luminosity function.



• Arp220 RSN appear to be Type II_n

• long decay times

• irregular light curves

• Until now ~25 Type II_n known,

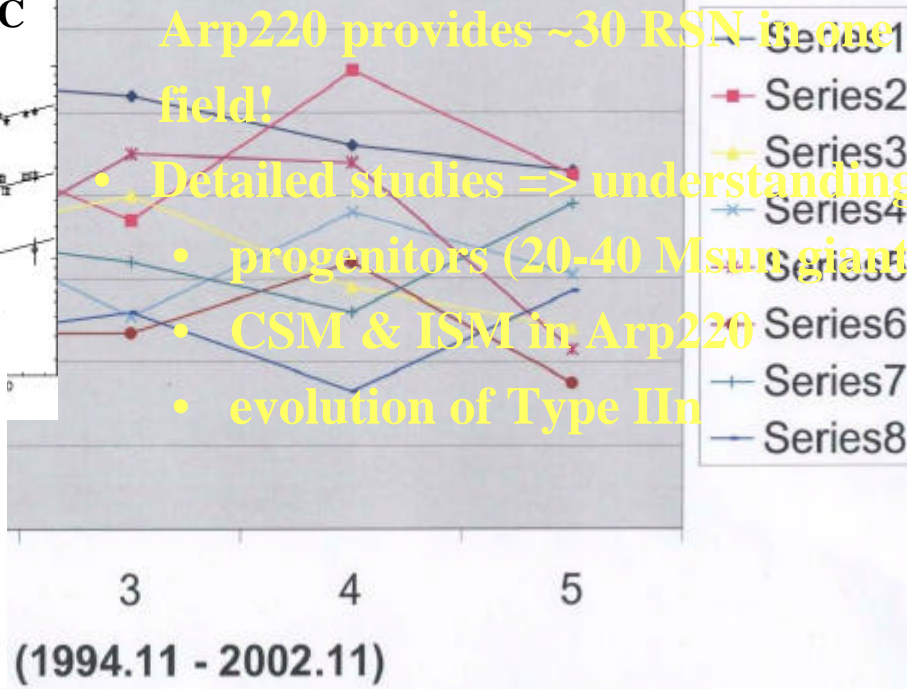
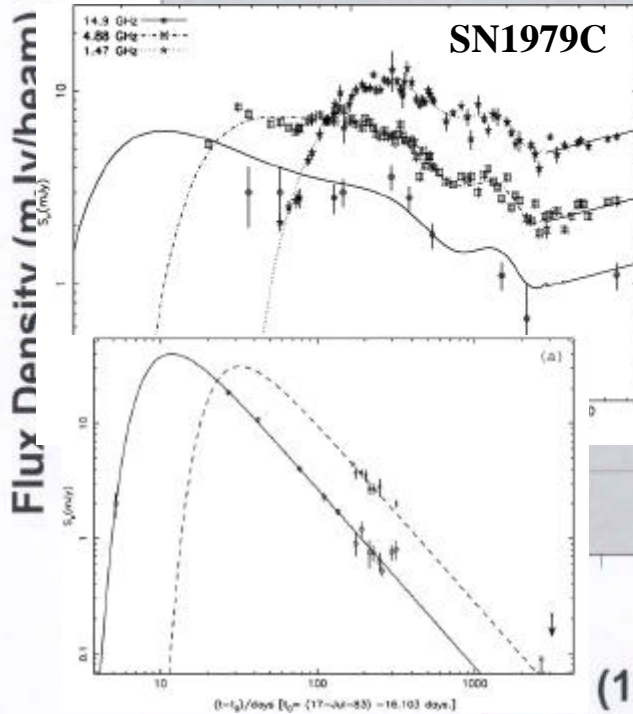
Arp220 provides ~30 RSN in one field!

• Detailed studies => understanding

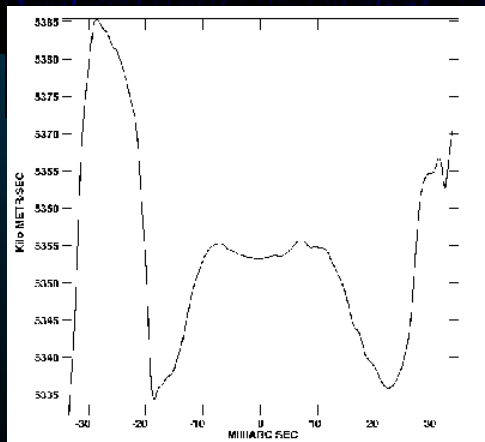
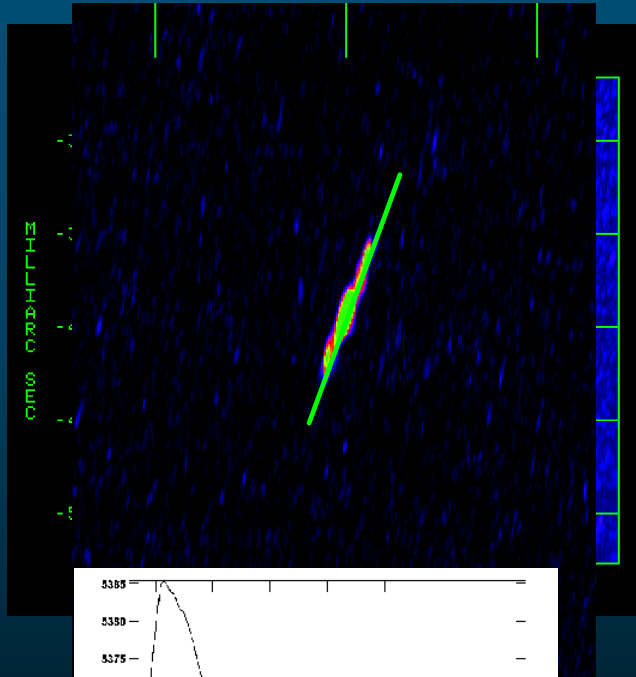
• progenitors (20-40 M_{sun} giants)

• CSM & ISM in Arp220

• evolution of Type II_n

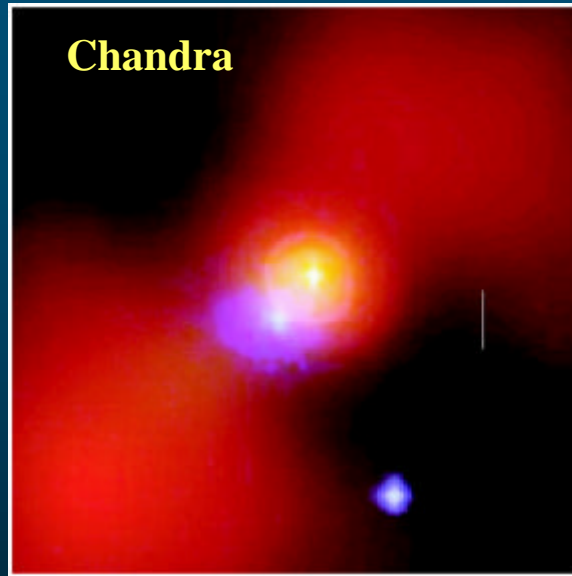


OH line with greater sensitivity



- New images will have ~3 times sensitivity, will:
 - fill in details of OH structures; why do we have huge velocity dispersions/gradients in small areas?
 - Assist in detecting missing flux: ~30% 1667 & 100% 1665 MHz. How are diffuse & compact masers related?
 - Study OH that lies in front of individual RSN
 - Velocity components of intervening gas
 - 3-D location of RSN?

Will Arp220 ever yield up an AGN?



- No strong evidence in radio
 - All compact continuum embodied in RSN
 - But, very peculiar velocity structures within some OH complexes. Still don't understand.
- No strong evidence in X-Ray
 - Shioya et al (2001) & Iwasawa et al (2001) can explain X-ray data with starburst model
 - But, Clements et al (2002) explain Chandra data as low luminosity, heavily obscured AGN or ULXRB.

Speculation – addresses one of the big questions:

- Arp220 currently shows ~30 high luminosity Type II In RSN, probably 2 exploding per year
- Each event may create a significant black hole, ~ several M_{sun}
- Over $10^6 - 10^7$ years will create ~tens of millions M_{sun} worth of black-hole all within 100pc.

Conclusion and the future

- Arp220 is a supernova factory, ~ 2 / year
 - New, high sensitivity observations reveal ~ 30 RSN
 - Monitoring observations demonstrate light curves similar to those of Type II_n supernovae
 - Big antennas will enable best probe yet of OH line structures.
-
- Immediate future: Annual, global VLBI monitoring at L/C-band @ 256/512 Mbps
 - Medium future: monthly, 1 Gbps e-VLBI
 - Long-term: SKA monitoring, if multi-beam machine can dedicate a beam to Arp220!!