3D mapping of the ejecta of SN1987A from ALMA data

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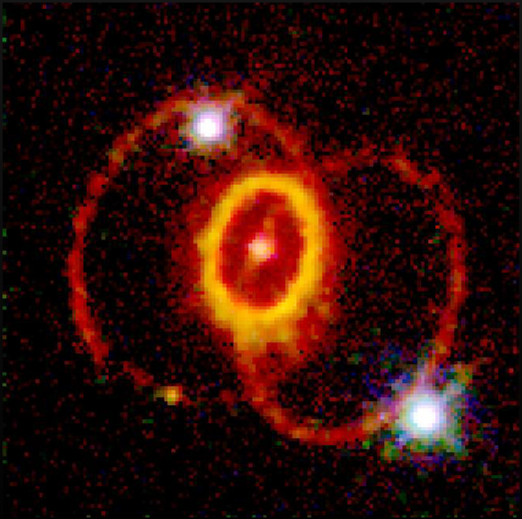
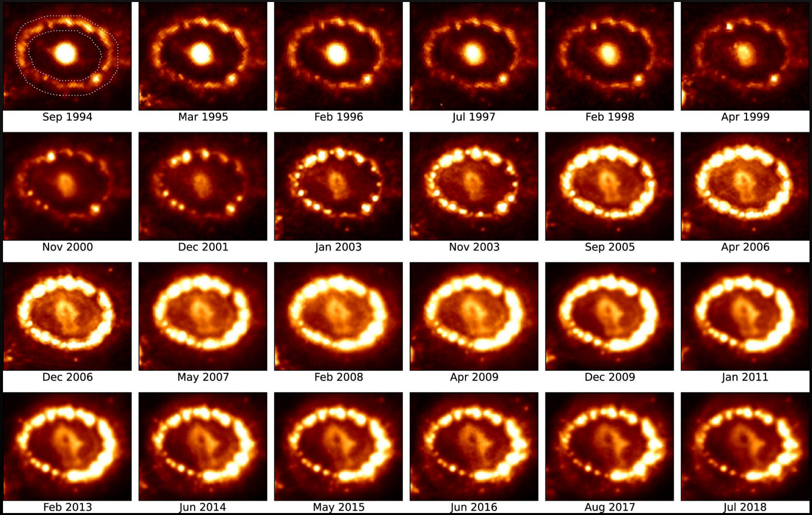
SN1987A exploded on 23 February 1987, at a distance of 51.4 kpc

It was a core-collapse supernova, but with a blue supergiant progenitor

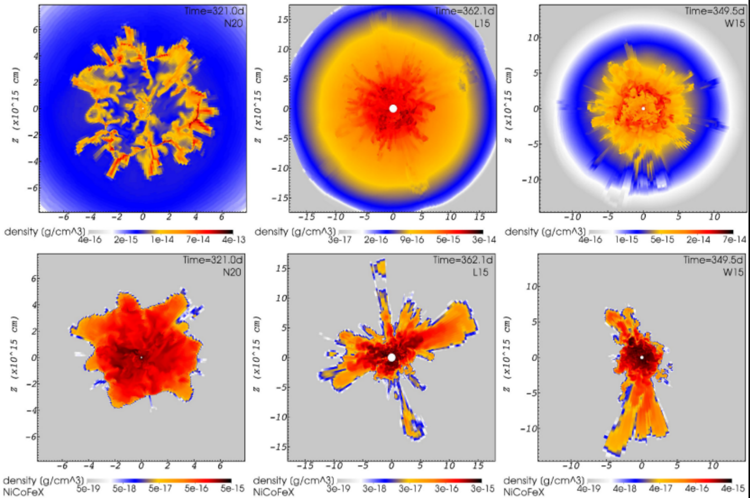
After the explosion, preexisting rings of circumstellar material were discovered



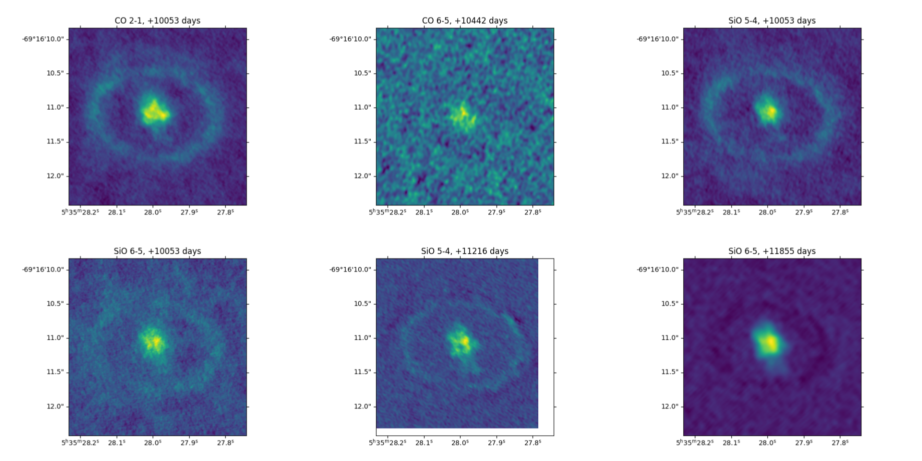
The distance to SN1987A allows its expanding ejecta to be spatially resolved



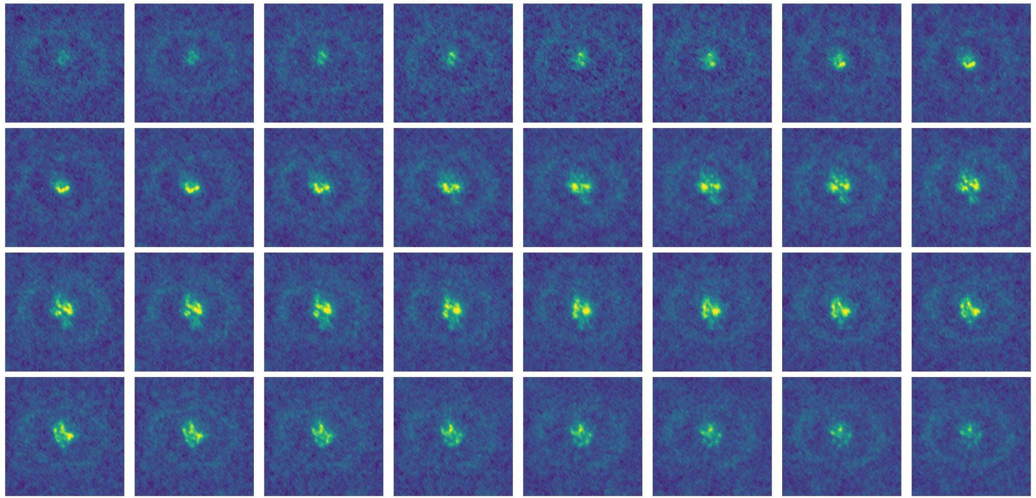
The 3D distribution and velocities of the material within the ejecta are predictions of explosion models



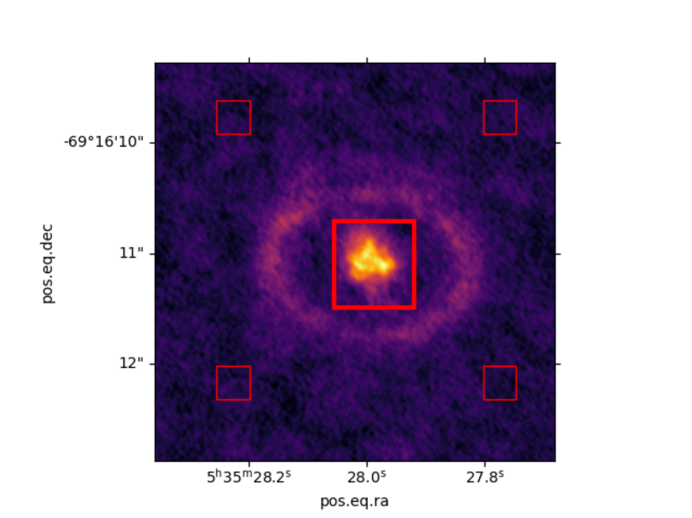
We have analysed ALMA observations of the remnant tracing CO 2-1 (230GHz) and 6-5 (691GHz), and SiO 5-4 (217GHz) and 6-5 (260GHz), ∼10,000 - ∼ 12,000 days after the explosion



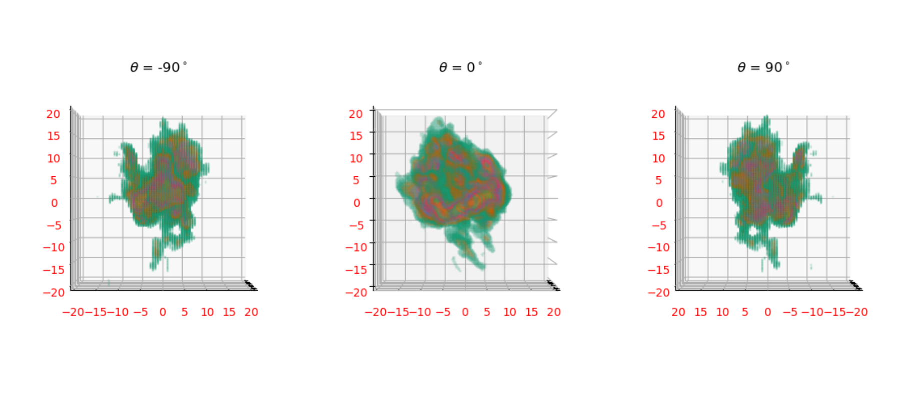
The data cubes have a spatial resolution of 0.06 arcsec (3000 AU), and velocity resolutions of 100 or 300 km/s



To calculate the 3D distribution of these molecules, we first mask out data below a noise threshold estimated from regions beyond the equatorial ring



The 3D position of each point in the data cube is then calculated relative to the explosion position. The mass is assumed to be directly proportional to the observed flux.



CO 2-1

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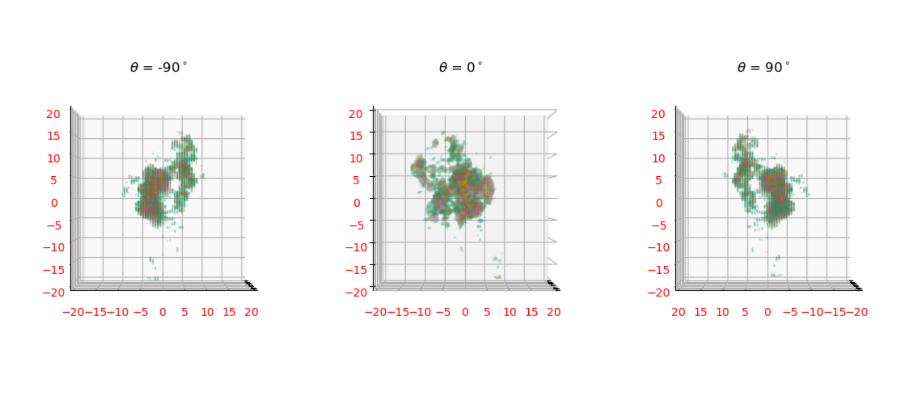
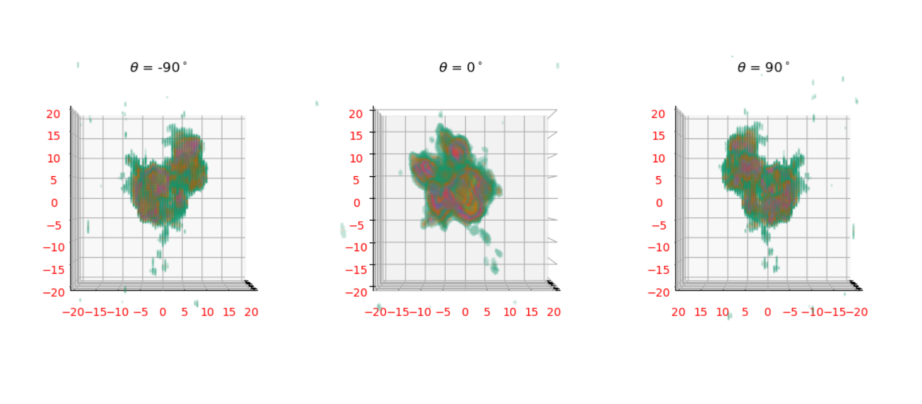


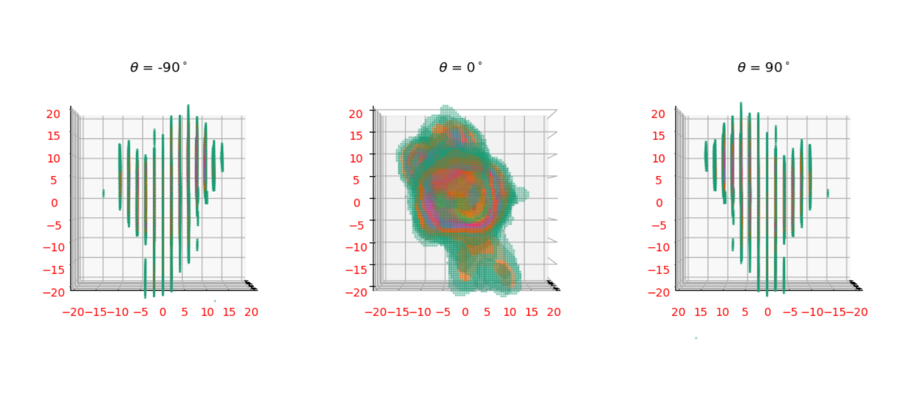
SiO 6-5

The 3D position of each point in the data cube is then calculated relative to the explosion position. The mass is assumed to be directly proportional to the observed flux.



SiO 5-4

The 3D position of each point in the data cube is then calculated relative to the explosion position. The mass is assumed to be directly proportional to the observed flux.



SiO 6-5

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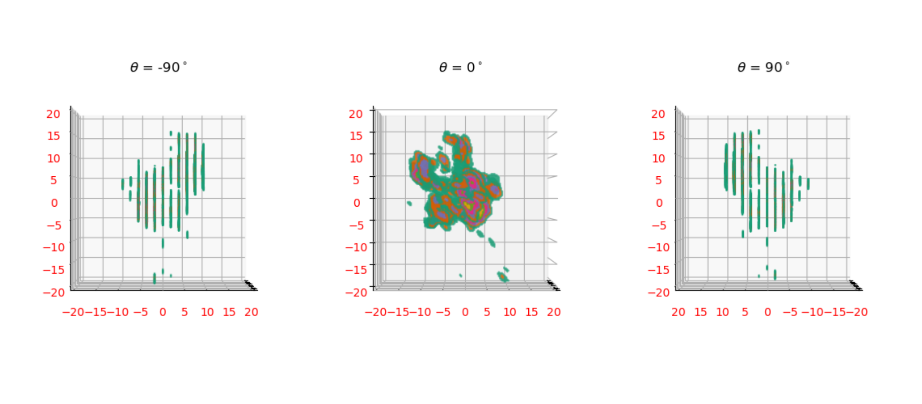
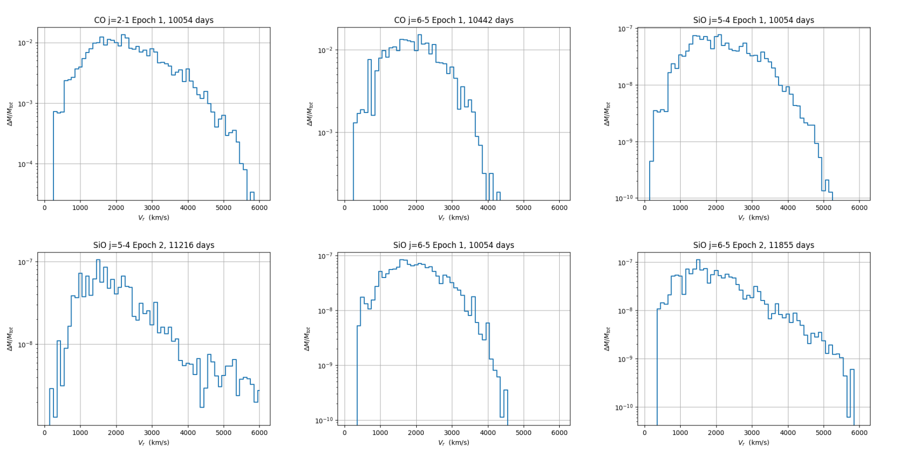


SiO 5-4

We then calculate the radial mass distribution for each molecule



We compare these with some state of the art supernova explosion simulations

Table: Stellar models

Name	Type	mass $[M_\odot]$	E_{expl} $[10^{51}\text{erg}]$	β-decay	sim. time [d]	Ref.
$B15_{\text{without}}$	BSG	15	1.39	no $\beta-$decay	361	Woosley et al. 1998
B15	BSG	15	1.39	without tracer	361	Woosley et al. 1998
$B15_{\text{X}}$	BSG	15	1.39	including tracer X	358	Woosley et al. 1998
N20	BSG	20	1.65	without tracer	362	Shigeyama et al. 1990
L15	RSG	15	1.75	without tracer	321	Limongi et al. 2000
W15	RSG	15	1.47	without tracer	373	Woosley et al. 1995

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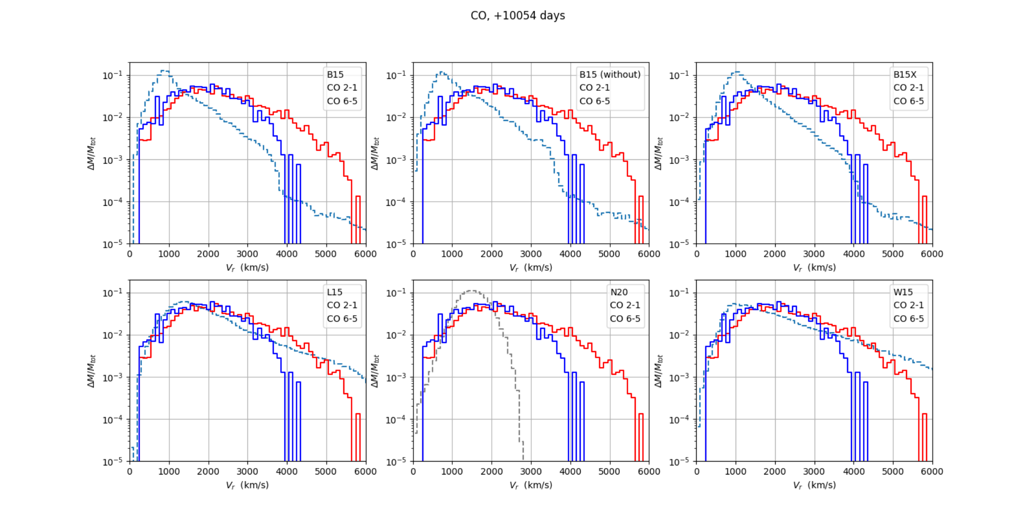

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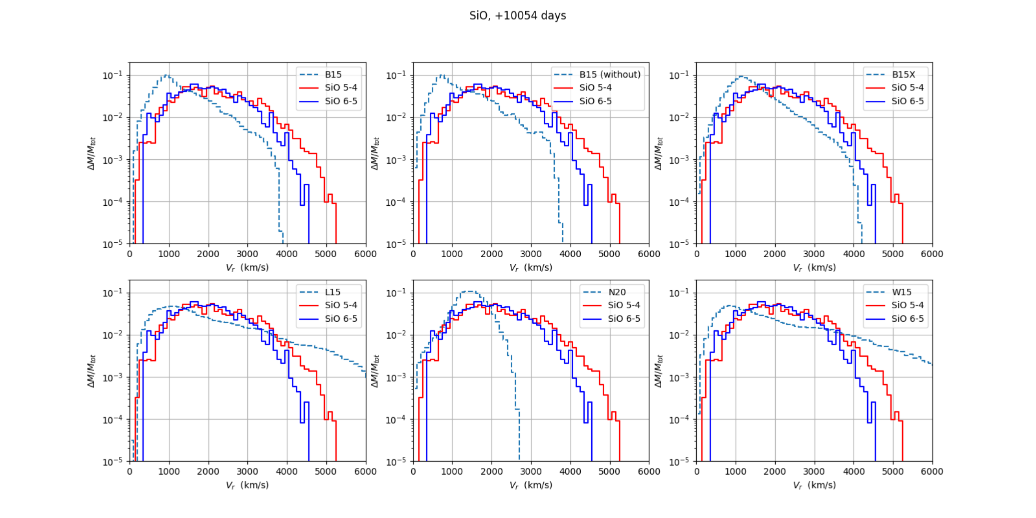

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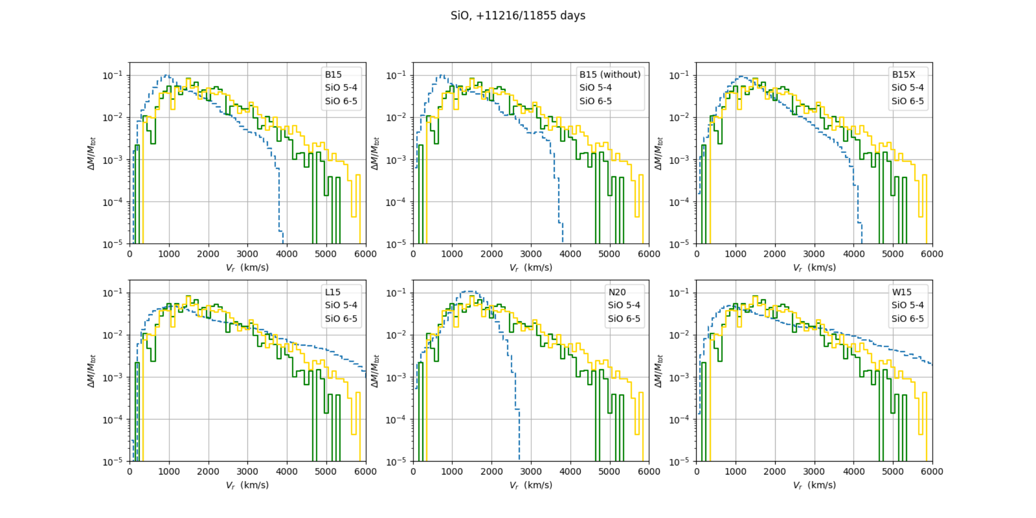
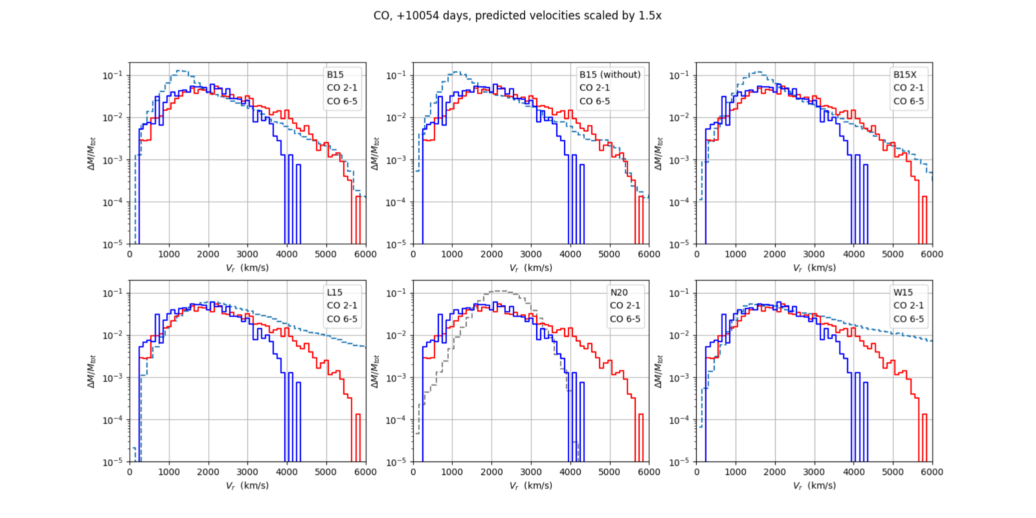


B15 models can be brought into somewhat better agreement with 1.5× higher velocities.



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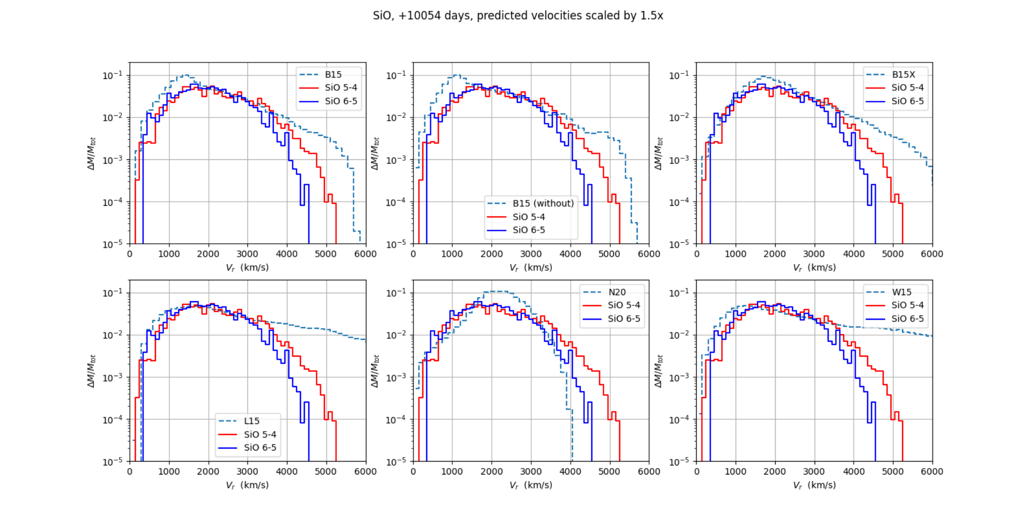

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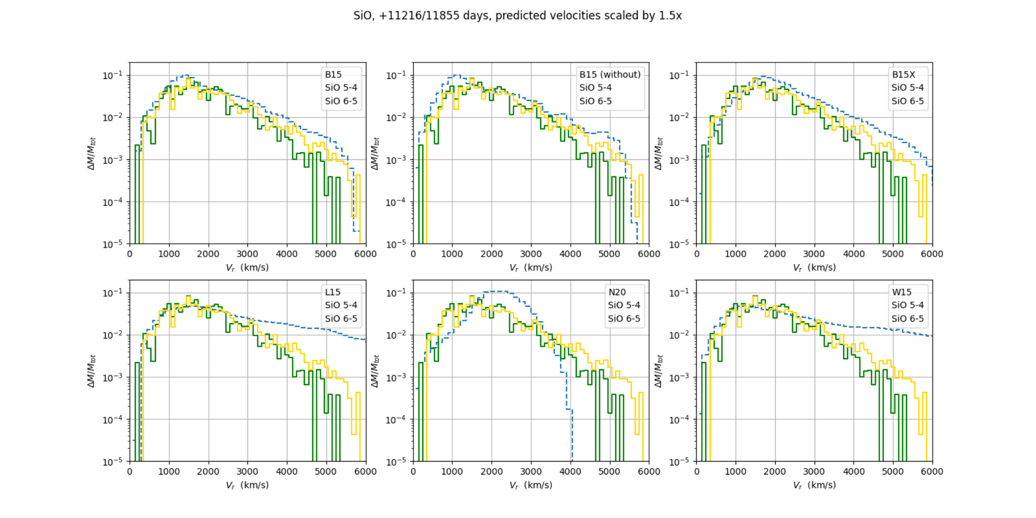

Summary

- From ALMA observations of the remnant of SN1987A, We have determined the 3D distribution of CO 2-1 and 6-5 transitions, and SiO 5-4 and 6-5 transitions
- We calculate the fractional mass distribution against velocity for each transition and compare it to the predictions of state of the art simulations
- None of the models provides a good match to the observations “out of the box”.
- However, B15 models can be brought into somewhat better agreement by scaling velocities by 1.5$\times$, while N20, L15 and W15 models still disagree.
- This would imply a rather implausible increase of the explosion energy by $\times 2$

Postscript: I travelled here overland from the UK

- CO_2 emissions from return flight Cardiff to Chania: 0.96t
- CO_2 emissions from trains, buses and ferries: 96% less, only **42kg**!