involved want different outcomes.

Both the medical and the sales calls show that, and indicate how, individuals 'want' their conversations to end at different points. We can identify this in real settings in which we understand the authentic purpose of the conversation. It would therefore be interesting to apply Mastroianni and colleagues' methods to the analysis of such transcripts and recordings, to ask individuals later, on reflection, to identify at what point they wanted to continue or end the conversations.

What about conversations between loved ones — such as those recollected in the online survey? In the following conversation[12] (transcript simplified) between Sue (not her real name), a young person with learning disabilities and in residential care, and her dad, Sue asks her dad to bring her extra pocket money when he visits. This is followed by the first turn that moves to close the conversation:

Dad: Right, well, I'm gonna get on now, I'll be there for about half past nine tomorrow morning.

But the conversation continues for a further 45 seconds before another pre-closing event occurs:

Dad: Right, well I'm going to go now, darlin'.
Sue: Yeah I've got to finish my cards off.

Only after three more pre-closings, including those expressing love (Dad: "Okay, lovey?" Sue: "yeah"; Dad: "I love you"; Sue: "love you"), do they bring the call to its end.

How do you show that you care about someone? Mastroianni *et al.* rightly point out that conversation is the "bread and butter" of our psychological and physical health, and this is clear to see in Dad and Sue's conversation. Staying longer in the conversation than external constraints allow (such as in a film scene in which people in a lift miss their floor to keep talking) is one way to do it. Closing rituals are so systematic that the conversational machinery allows us to see how the reopening of closings happen.

Mastroianni and colleagues' findings are compelling. Some media headlines about their study (see go.nature.com/3sgIkup), such as "only 2% of conversations end when we want them to", focused on the disconnect between the desired point for a conversation to end and its actual end. Although the headline news might be the scale of the disconnect, reducing conversations such as this chat between Dad and Sue to 'who wanted what' damages the empirical reality of their conversation and misses its purpose.

There are tremendous real-world benefits to analysing conversation with close scrutiny and rigour. For example, returning to the doctor's surgery, the same research[10] showed that when receptionists proactively confirmed an individual's appointment time and date, rather than doing so only in response to a request for confirmation, the conversation ended collaboratively. Moreover, proactive confirmation was associated with higher patient satisfaction, and the finding was used to train receptionists.

Do conversations end when people want them to? Mastroianni *et al.* conclude that the answer is almost certainly no. Asking people to report on their conversations has shown this clearly. Apart from situations such as in an argument, people generally do not say, "I want this conversation to end." They might tell other individuals, "I was trapped in that conversation for hours", or "I don't want to talk to her", but, in real conversation, people usually convey such things tacitly. This is why examining conversations, including using transcripts, is informative. It is clear, as Mastroianni *et al.* state, that "The more we learn about conversation — about how it begins and ends, runs and stalls, delights and disappoints — the better positioned we will be to maximize its benefits."

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1. Schegloff, E. A. *Social Psychol. Q.* **50**, 101–114 (1987).
2. Mastroianni, A. M., Gilbert, D. T., Cooney, G. & Wilson, T. D. *Proc. Natl Acad. Sci. USA* **118**, e2011809118 (2021).
3. Strivers, T. *Res. Lang. Social Interact.* **41**, 31–57 (2008).
4. Mehl, M. R. *Curr. Direct. Psychol. Sci.* **26**, 184–190 (2017).
5. Baumeister, R. F., Vohs, K. D. & Funder, D. C. *Perspect. Psychol. Sci.* **2**, 396–403 (2007).
6. Schegloff, E. A. *J. Narrative Life Hist.* **7**, 97–106 (1997).
7. Stokoe, E. *Res. Lang. Social Interact.* **46**, 165–185 (2013).
8. Stokoe, E., Sikveland, R. O., Albert, S., Hamann, M. & Housley, W. *Disc. Stud.* **22**, 87–109 (2020).
9. Schegloff, E. A. & Sacks, H. *Semiotica* **8**, 289–327 (1973).
10. Stokoe, E., Sikveland, R. O. & Symonds, J. *Br. J. Gen. Pract.* **66**, e779–e785 (2016).
11. Humă, B. & Stokoe, E. *Res. Lang. Social Interact.* **53**, 271–294 (2020).
12. Patterson, A. & Potter, J. *Br. J. Social Psychol.* **48**, 447–465 (2009).

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Planetary science

Iron and nickel vapours present in most comets

Dennis Bodewits & Steven J. Bromley

The detection of iron and nickel vapours in a broad range of Solar System comets, and of nickel vapour in a comet from outside the Solar System, provides a glimpse into the organic chemistry of young planetary systems. **See p.372 & p.375**

Comets are agglomerates of dust and ice — leftovers from the era of planet formation. For most comets, their distance from the Sun keeps their temperature below a few hundred kelvin, which is still hot enough for water ice and other volatile compounds to sublimate (be converted directly from solid to gas). Comet nuclei are mostly obscured by a surrounding cloud of gas and dust called the coma. Therefore, knowledge of comet surfaces and their composition must be inferred from observations of the coma. Typical telescopic observations of cometary comae do not detect metals, because temperatures at comet surfaces are too low for these elements to sublimate. However, two papers[1,2] in this issue report the discovery of metal atoms in cometary atmospheres, begging the question of where these atoms come from.

There have been several space missions to comets, including Rosetta, Deep Impact and Stardust. These missions have shown that comets are relatively small (typically, just a few kilometres in radius), and might be responsible for moving volatile materials around in the inner Solar System after the planets formed[3]. Such missions provided detailed studies of individual comets, but Earth-based observations have determined the chemical composition of larger numbers of these bodies[4,5].

At optical wavelengths, the spectra of light emitted by comets coincidentally resemble those of flames. They have a broad, continuous part (caused, in flames, by hot soot; in comets, by dust that reflects sunlight), combined with the emission features of molecules and their fragments, such as hydroxyl (OH), cyanide (CN) and dicarbon (C_2) groups. Until now, emission lines of metals — iron, nickel and other heavy elements — were thought to be absent from comet spectra. The detection of lone metal atoms in comets has been limited to specific situations, including sample-return missions (Stardust[6]) and bright, 'sungrazing' comets such as Ikeya–Seki, which plunged into the Sun[7].

Manfroid *et al.*[1] (page 372) used atomic models to predict at which wavelengths, and

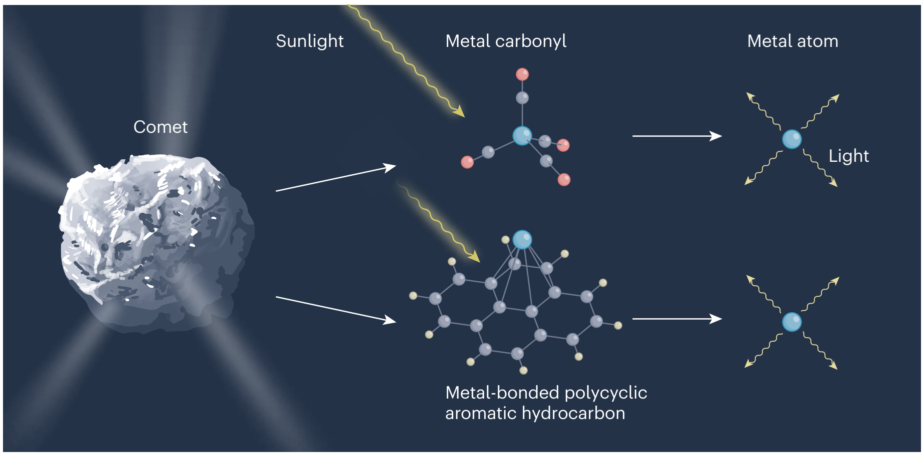

Figure 1 | How comets could release metal atoms. Manfroid *et al.*[1] and Guzik and Drahus[2] have detected the light emitted by metal atoms in the atmospheres of comets. The surfaces of these comets do not reach high enough temperatures to release such atoms directly. Instead, the source of the atoms might be organometallic compounds that are emitted from the comet's surface and then break up in the comet's atmosphere when irradiated by sunlight. These compounds could be metal carbonyl complexes, which consist of carbon monoxide molecules bound to a metal atom, or metal-bonded polycyclic aromatic hydrocarbons, which are sheets of carbon atoms bordered by hydrogen atoms and attached to a metal ion. Carbon, grey; oxygen, red; hydrogen, white.

how strongly, iron and nickel emit light when illuminated by sunlight. They then identified dozens of emission lines of atomic iron and atomic nickel in the spectra of a broad sample of Solar System comets. The authors and their collaborators had observed these comets over the past two decades using the Very Large Telescope in Chile. The emission lines were hiding in plain sight, mingled among the typical (and plentiful) emission features of molecules in the coma.

By looking at the spatial distribution of the light emitted by the iron and nickel atoms, Manfroid *et al.* calculated the rate of metal loss from the comets. The amount of iron and nickel released is surprisingly small – only about 1 gram per second, compared with the roughly 100 kilograms per second of water produced. This finding testifies to the remarkable sensitivity of the Very Large Telescope. Coincidentally, the amount of nickel produced per second is almost exactly the nickel content of a US five-cent coin, or nickel.

As for the source of the iron and nickel atoms, their spatial distribution suggests they are formed in the coma, close to the nucleus. A second clue to their origin lies in the comets sampled by Manfroid and colleagues. Despite large differences in the mass-loss rate, distance to the Sun and chemical composition of individual comets, iron and nickel were found in all comets that were studied in detail. The authors estimated that temperatures reach only about 150 K at the most distant comet examined. This result suggests that the source of the iron and nickel atoms is much more volatile than the sulfides of these metals (which are found in cometary dust grains) or the pure metals.

A third clue to the origin of these atoms is that the amount of nickel relative to iron is much higher in the studied comets than in the Sun, meteoroids and sungrazing comets. Moreover, the observed spectra lack emission lines of other metals, such as chromium and manganese, seen in the spectra of sungrazing comets. These observations rule out direct sublimation of metal particles, and indicate an intermediate chemical or physical process that determines the nickel-to-iron ratio in the coma.

Manfroid and colleagues provide several possible production scenarios. Under certain conditions, tiny dust grains in the coma could reach temperatures above 1,000 K and release the metals into the coma. Alternatively, the metals could initially be locked inside organometallic compounds, such as nickel or iron

"The spatial distribution of the metal atoms suggests they are formed in the coma, close to the nucleus."

carbonyls, which consist of four or five carbon monoxide (CO) molecules bound to a nickel or iron atom (Fig. 1). Modelling by the authors suggests that these carbonyls can sublimate at temperatures as low as 74 K, similar to carbon dioxide. However, the release mechanism is problematic: experiments indicate that the CO molecules would be stripped off the carbonyls sequentially, rather than the metal atoms being released directly[8].

An alternative source of the iron and nickel atoms could be metal-bonded polycyclic aromatic hydrocarbons, which are sheets of carbon atoms bordered by hydrogen atoms and attached to a metal ion (Fig. 1). Such compounds might also sublimate and rapidly break up in the coma when exposed to the Sun's harsh ultraviolet light. Intriguingly, the abundance of these compounds in cometary atmospheres has been reported to be one for every one million water molecules[9] – similar to the relative abundance observed for the iron and nickel atoms.

Independently of Manfroid *et al.*, Guzik and Drahus[2] (page 375) detected light emission from atomic nickel around the comet 2I/Borisov using the Very Large Telescope in January 2020. The orbit of this comet indicated that it came from outside the Solar System, and, surprisingly, both its behaviour and composition of free radicals had much in common with those of regular comets. However, its high content of CO gas suggested that it probably formed under very different circumstances from those for Solar System comets. On the basis of this anomaly, it has been proposed that 2I/Borisov is a fragment of a larger, Pluto-like object[10], or formed around a star smaller and colder than the Sun – such as an M dwarf, the most common type of star in the Galaxy[11].

Guzik and Drahus report a nickel abundance for 2I/Borisov that is similar to that found by Manfroid *et al.* for Solar System comets. Given the unknown chemical origins and physical history of 2I/Borisov, this similarity is striking. If we can unravel the origin of iron and nickel in regular comets and this interstellar object, we might uncover a story of organic chemistry between shared different planetary systems.

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1. Manfroid, J., Hutsemékers, D. & Jehin, E. *Nature* **593**, 372–374 (2021).
2. Guzik, P. & Drahus, M. *Nature* **593**, 375–378 (2021).
3. Rubin, M., Bekaert, D. V., Broadley, M. W., Drozdovskaya, M. N. & Wampfler, S. F. *ACS Earth Space Chem.* **3**, 1792–1811 (2019).
4. A'Hearn, M. F., Millis, R. C., Schleicher, D. G., Osip, D. J. & Birch, P. V. *Icarus* **118**, 223–270 (1995).
5. Dello Russo, N., Kawakita, H., Vervack, R. J. Jr & Weaver, H. A. *Icarus* **278**, 301–332 (2016).
6. Brownlee, D. *Annu. Rev. Earth Planet. Sci.* **42**, 179–205 (2014).
7. Preston, G. W. *Astrophys. J.* **147**, 718–742 (1967).
8. Leadbeater, N. *Coord. Chem. Rev.* **188**, 35–70 (1999).
9. Klotz, A. *et al. Planet. Space Sci.* **44**, 957–965 (1996).
10. Cordiner, M. A. *et al. Nature Astron.* **4**, 861–866 (2020).
11. Bodewits, D. *et al. Nature Astron.* **4**, 867–871 (2020).