SONOGRAPHY IN CARDIAC ARREST

"TOI 700d" (TESS Object of Interest 700d) - Artist's Impression, NASA, January 2020.

"But who shall dwell in these worlds if they be inhabited?...
Are we or they Lords of the World?...
And how are all things made for man?"

Johannes Kepler

In the deep abyss of space a hundred lights years away, in the Southern Constellation of the Dolphin, Dorado, lurks a seemingly innocuous Red Dwarf Star, going by the unassuming name of TOI 700. In January of 2020 it was discovered to have at least three planets orbiting it. The third, created breathless excitement among the world's Astronomers. The most powerful and sophisticated of the world's orbital and terrestrial telescopes turned their attention toward it.

Just a generation ago it was completely unknown whether planets were unique to our solar system or whether, like life itself in the Universe, this was a one off aberration. We live today in the fourth great age of Astronomy. The Ptolemaic Universe reigned by the First Century AD. By the Seventeenth century it was the Universe of Copernicus, Galileo and Newton and in the Twentieth century it became the vast terrifying, Universe of Einstein and Hubble. The Twenty first century now marks the most tantalizing of all - the fourth great age of the Planet Hunters.

The first extrasolar planet was discovered in 1992 by a Polish astronomer by the name of Aleksander Wolszczan. Two terrestrial sized planets were discovered orbiting around an exotic stellar object known as PSR B1257+12, a deadly type of neutron star known as a pulsar. It was all every well finding a "planet" of sorts, orbiting a city sized remnant of far long ago supernova; but did planets exist around true main sequence stars? Then just three years later, in 1995, the Swiss Astronomers Michel Mayor and Didier Queloz announced the historic discovery of the first planet orbiting a star similar to our own, 51 Pegasi b for which they were awarded the 2019 Nobel Prize in Physics along with Jim Peebles.

But this world was very different to anything in our Solar System, a scorching gas giant dubbed a "hot Jupiter" that orbited so close to its parent star and travelled at such a speed that its year is an astonishing 4 days. 51 Pegasi b was discovered by a technique known as the "radial velocity" method. While a planet orbits a star it induces a very small, but measurable "wobble" in that star, and the planet is inferred from this measurement. Later came an even better method known as the "transit" method that makes use of the light from a star that slightly diminishes when a planet moves across its face while in the line of sight from the Earth. Still later a third technique, known as "microlensing", was discovered, which makes use of Einstein's prediction that light itself can be bent like a lens by very massive objects. These objects can be inferred by their effect on the light from far distant objects behind them.

By these and other miraculous techniques of Twenty first century astrophysics and technology, it is now known that planets are common in our galaxy - more common than stars. But most of these worlds are unlike anything in our own solar system. The real question is not how many planets are out there - but rather how many other potential Earth - like words are out there. There seem very few in proportion to the total number of planets thus far discovered. And yet even so, the Milky Way galaxy is so unimaginably vast that by some estimates it could contain up to 10 billion Earth-like planets.

The unspoken holy grail is to find other worlds that humanity may one day be able to, or indeed need to, colonize when our own planet becomes uninhabitable, be it by natural agencies or by our own ungoverned greed and unfounded and unjustified grand sense of hegemony over and above all other species living on it. But before we have any hope of *even thinking of visiting another world, we must first find them. To this end orbiting telescopes of previously undreamt of sophistication scan the comos looking for "Earth-like" planets. The first generation of these telescopes was the Kepler whose mission was simply to "find planets" and it did in vast numbers - over 4000 extrasolar planets are now known to us, all but handful totally hostile to life, at least as we know it on Earth. Kepler finished its mission and now NASA's, Transiting Exoplanet Survey Satellite (TESS) orbits the Earth on a far more refined mission, scanning the "near" neighborhood of stars within 100 light years that harbor planets within a star's "habitable zone". The habitable zone is one obvious requirement for a planet that may be hospitable to life. It cannot be too close to its star where it would be far too hot and it cannot be too far from its star where it would be too cold. A habitable planet must reside within the so-called "Goldilocks" or "just right" zone from it star so that water, an (assumed) essential element for life, can exist in liquid form.*

However it is not simply enough to say that a planet is habitable just because it resides within this temperate zone. It must also be a great many other things before it can even be considered remotely Earth-like. It must be rocky or terrestrial - as opposed to being a gas or an ice giant. It cannot be so large that its gravity would preclude life, nor can it be too small. Its parent star must be stable and not emit excessive radiation that may strip a planet of its atmosphere over time. It must be old enough to have allowed time for the evolution of life. It probably has to be geologically active. Above all it must have an atmosphere, presumably rich in oxygen just as own own with low or negligible amounts of poisonous gases such as carbon dioxide.

To this end the third generation telescope, the James Webb, will host the astonishing capability of analyzing the spectral light of the atmospheres (if they exist) of exoplanets. As an exoplanet crosses in front of its star, in line of sight with the Earth, its starlight traverses its atmosphere, if it has one. By analyzing the spectrum of this filtered light, Astrophysicists should in principle be able to determine, at least partly, the composition of the exoplanet's atmosphere. The markers that we would expect to see of a possible life-bearing world would include methane, water, or carbon dioxide, but above all molecular oxygen, the strongest indicator of life that we assume. If a sufficiently advanced alien civilization were scrutinizing Earth from a vast distance away, and we happened to be at the right orientation for our world to transit across the face of the Sun from their perspective, they would have extraordinary reasons to be hopeful that life did or could exist on our world.

NASA's Transiting Exoplanet Survey Satellite (TESS) scans the skies in our neighborhood looking for "objects of interest". These will become the targets of intense scrutiny by the atmosphere detecting, James Webb Telescope. In January of 2020, TESS discovered just such an object of interest - TOI 700b. It appears to be a rocky or terrestrial planet, about the size of the Earth. It orbits its star within the "habitable" zone for liquid water. Its parent star is a Red Dwarf. While our Sun is considered an "ordinary" star, it is actually a relatively uncommon type when considering its size. Although there are many stars vastly bigger than our Sun, there are vastly many more stars that are actually much smaller than it. These are the Red Dwarfs, of which the parent star of TOI 700d is one. Red Dwarfs are the most common type of star in our Galaxy. They are much smaller than the Sun and so they give off far less heat. But this doesn't matter if the planet happens to reside much closer to its star than we do to the

Sun. TOI 700d is very much closer to its star than we are to the Sun, however as its star (TOI 700; without the d, which denotes the planet) is roughly only 40% of the Sun's size and its surface temperature is about half that of the Sun. As it gives off much less heat however TOI 700d is still placed within the habitable zone of its system.

Red Dwarfs have characteristics both friendly and hostile to life. Evolution takes eons of time. Our own Sun, is about half way through its life time of around eight to nine billion years, but Red Dwarfs burn their nuclear fuel so slowly it has been estimated that they could live for a trillion years, far longer than the current age of the Universe itself. This virtual immortality means that for any of their planets there is time enough for life to evolve perhaps not just once, but many times over. Red Dwarfs do have some drawbacks however, some have tendencies to produce violent solar flares, emitting so much radiation that they could strip nearby planets of their atmosphere entirely. One of the exciting findings of TOI 700 however is that it does not seem to exhibit violent flare activity.

A second issue with planets in the habitable zone of a Red Dwarf is a phenomenon known as "tidal locking". Planets that are very close to their parent star become tidally locked meaning that their rotation is synchronized with their obit around their star such that the same side of the planet always faces the star. This means that one side would be in perpetual daylight while the other would experience eternal night. This could create enormous temperature variations from one side of the planet to the other, although an atmosphere could distribute the heat. A year on TOI 700d is just 37.4 Earth days. It is an arresting thought experiment to ponder how these alien conditions could shape the evolution of life forms - if they exist - on a planet like TOI 700d. Could there be more than one sentient species on the planet - one adapted to eternal daylight - the other to eternal darkness. Would they live in peace with each other - or would they live in a state of perpetual conflict?

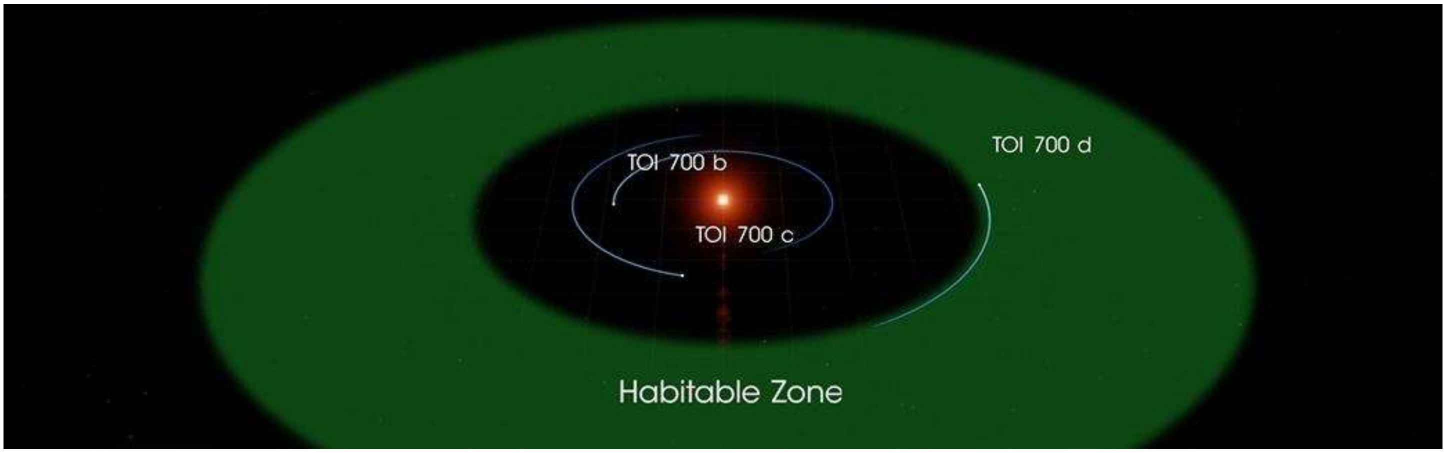
Whether or not a planet resides within its parent star's habitable zone, however, can be a moot point if it contains a poisonous atmosphere or indeed, like Mercury, no atmosphere at all. The next generation James Webb telescope will be the first of the planetary atmosphere hunters. Astrophysicists are working frantically to model just what kinds of light spectrums from exoplanet atmospheres would look like with regard to suggesting the possibility of life. For this they look to the only known example of a life bearing planet that we know of, the Earth. Water vapour and a high percentage of molecular oxygen would be hallmark signatures for life. We currently know of no other natural process, other than life, that could account for a high percentage of oxygen seen within a planet's atmosphere.

There is yet another constraint placed on us in our search for life on other planets. While we may be able to (barely) overcome the barrier of unimaginable distance, we also face the constraint of unimaginable time. Light travels at a finite speed. More distant stars within our galaxy see the Earth as it was centuries or millennia ago, while observers in distant galaxies see us as we were millions or even billions of years ago. The atmospheres of planets are not invariable constants through time. It is only in the Phanerozoic Eon, that commenced around 540 million years ago that oxygen levels began to reach significant levels on Earth. In Earth's early Hadean and Archean eons there was virtually no atmospheric oxygen at all. In the Proterozoic there were only *small amounts. A fantastically advanced alien civilization with the ability to determine the atmospheric composition of planet over 540 million light years away, would conclude that the Earth was lifeless.*

TESS however has its instruments set on planets much closer to home. The light from TOI 700d that we see today left that world just over a century ago. If we find a hospitable atmosphere it is very likely that this will exist for quite some time to come. We live in a new golden age of Astronomy, the age of the Planet Hunters, but perhaps we already stand at the dawn of the next age, where we pursue the most profoundly important endeavour of humanity - if not answering the primal question of "are we alone in the Universe", then possibly something even more profound again, the search for another home. The object known as TOI 700d is indeed an "object of interest".

Our Astronomers scan the skies with miraculous technologies, barely conceivable at the time of discovery of the first extrasolar planet in 1992. Since that time over 4000 planets have been discovered, with thousands more awaiting confirmation. Again our question changes. It is no longer one of "are there planets outside our own Solar System", but rather "are there planets that show any sign of life!" We are only able to conduct these kinds of searches by dint of the wondrous advancements of our ability to see into deep space.

And so too, in the 21st century, our ability to detect the faintest signs of life in patients who suffer apparent cardiac arrest have been made possible by miraculous technologies, barely conceivable in the last decade of the Twentieth century.



Planetary system of the Red Dwarf, TOI 700, in the Southern Constellation of Dorado. The third planet from the star, TOI 700d, is an Earth sized terrestrial planet that resides with the "Goldilocks" or habitable zone of the system. The surface temperature of the planet is not too hot, nor too cold, for water to exist in liquid form, (NASA).

SONOGRAPHY IN CARDIAC ARREST

Introduction

Focused echocardiography - in the hands of an expert/ experienced operator - can be used in **cardio-pulmonary arrest** to:

1. Distinguish VF from asystole from PEA (and pseudo-PEA) - thus also aiding prognostication and in turn decisions regarding cessation of CPR.

2. Help determine the causative pathology in combination with an assessment of the QRS complexes of the ECG rhythm

3. Help to gain vascular access

4. Assisting in procedures

5. Determining response to interventions

Ultrasound is **more reliable** in detecting cardiac activity than clinical assessment (the traditional stethoscope and palpation for a pulse).

It more reliably determine a pulse (e.g. carotid flow) compared with palpation for a pulse.

The use of ultrasound in cardio-pulmonary arrest however can result in some interruption to effective CPR.

This risk needs to be balanced against the need for determining the presence of a reversible cause.

In the future a trans-esophageal placed ultrasound (**TOE**) may help mitigate interruption of effective CPR

See also separate documents on -

- **Sonography in Cardiac Arrest - COACHRED (in Radiography folder).**

- **Pulseless Electrical Activity (in CVS folder).**

Initial Assessment

The **rhythm** is key to ALS.

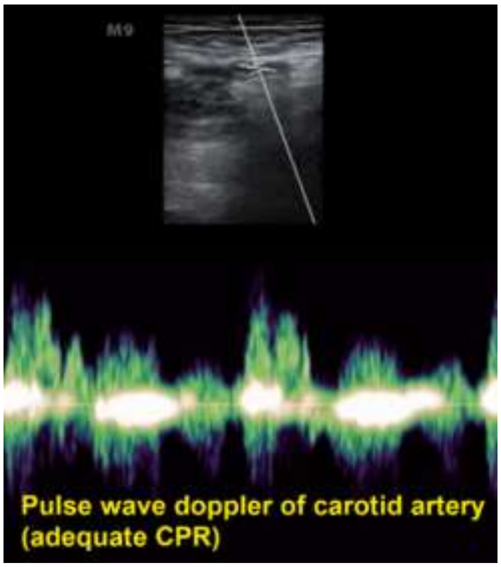
Clear ventricular fibrillation (VF) or pulseless ventricular tachycardia requires **immediate defibrillation**, (not attempts at ultrasound).

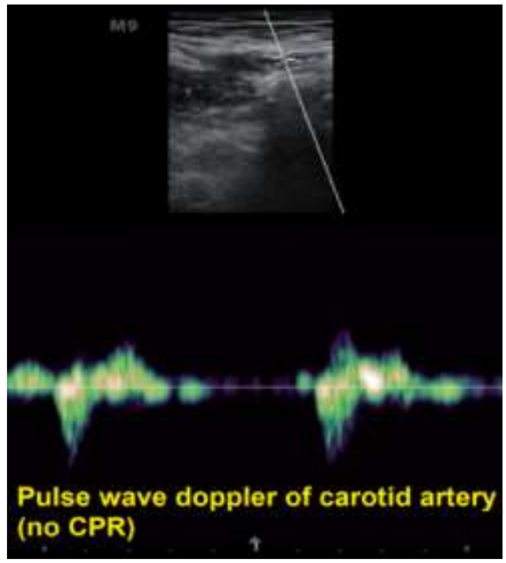
There can on occasions be doubt over “fine” VF versus asystole.

Ultrasound can be used to differentiate a “fine” VF from true asystole when there is this doubt and a shock ca be delivered in the former (when this intervention may be withheld in the mistaken belief that a state of asystole exists).

Fine VF is evident as myocardial fibrillations (a “quivering heart) while true asystole has **no** detectable cardiac activity.

Ultrasound (doppler flow) can be more reliable in determining the presence of a pulse, than clinical assessment.





Cardiac activity is defined as any intrinsic movement of the myocardium but not isolated movement of the cardiac valves.

Note that valvular movements due to positive pressure ventilation or fluid administration may be misinterpreted as cardiac activity.

Absent contractility and end-tidal CO_2 of < 10 mmHg after 2 cycles has a dismal prognosis.

Assessment for Potentially Reversible Causes

The potentially reversible causes of cardiac arrest are traditionally attributed to the so called 4 Hs and 4 Ts

However this is simply a randomly generated mnemonic, that is *variably* defined and can rarely be recalled in the heat of an actual resuscitation.

It is much more useful to consider narrow versus wide QRS complexes on the ECG rhythm strip

Immediately this may suggest likely causes as follows:

Narrow complex (= hypovolemia / hypothermia & mechanical causes):

1. Pseudo-PEA

2. Potentially reversible causes:

   H: **Hypovolemia**

   H: Hypothermia (more likely this will be pseudo-PEA).

   T: Tension pneumothorax

   T: Massive pulmonary embolism.

   T: Cardiac tamponade / myocardial rupture.

   Also: Hyperinflation on mechanical ventilation

   Note that if there is a **pre-existing BBB**, then QRS complexes for the above conditions will be wide.

Wide complex (= metabolic / toxic causes):

1. Irreversible causes

   - Agonal rhythm (< 10) - "dying heart".

2. Potentially reversible causes:

   T: Toxins - **Sodium channel blockade**

   H: **Hyperkalemia**

   T: Myocardial infarction - end stage pump failure

From a consideration of the above stratification, ultrasound can be additionally used to further help determine any potentially reversible pathology.

For example:

1. Hypovolemia

   - Features would include small chambers, normal or hyperdynamic LV and small and collapsing IVC

   - Perform an EFAST and AAA scans to look for free fluid or aneurysm rupture.

2. Cardiogenic shock

- Features include poor LV function or dilated chambers

3. Obstructive causes:

- In cardiac tamponade look for a significant pericardial effusion and tamponade physiology in the form of right-sided collapse and a dilated, non-collapsing IVC.

- With pulmonary embolus look for a severely dilated RV, which is ideally assessed in the apical 4 chamber view.

  Other features would include interventricular septal motion abnormality and a dilated, non-collapsing IVC and the presence of right heart thrombus.

  Peripheral evidence of an **above knee DVT** may also be helpful.

- Lung ultrasound may assist in excluding a tension pneumothorax.

4. Distributive shock

- Features include a hyperdynamic LV and variable IVC.

Assisting Decision to Terminate CPR

The most well supported role for ultrasound in CPR is that it can identify those patients who display **no spontaneous organized cardiac activity** (i.e true asystole) - a very poor prognostic finding – in order to support a decision to cease resuscitative efforts.

Conversely, in patients presenting in an otherwise poor prognostic group of non-shockable rhythms, ultrasound can identify *specific* potentially reversible pathologies, namely pneumothorax, tamponade, hypovolaemia and pulmonary embolus.

Post Resuscitation Care

1. Assessment of LV function:

- A qualitative assessment of LV function in the parasternal long axis or short axis views.

  If the patient is hypotensive and the heart shows poor contractility consider using adrenaline.

  If the patient is hypotensive with good cardiac contractility consider using norepinephrine.

2. Assessing the IVC diameter and collapsibility.

- With normal RA pressures the IVC is seen to collapse by at least 50%. It reverses with positive pressure ventilation.

- If the IVC diameter is <1.0 cm and collapses by > 50% then it is likely that the patient is hypovolemic and fluid responsive.

  However, if the IVC is > 2.0 cm and is collapsing by < 15% then they are unlikely to be fluid responsive.

3. Vascular access

   - Ultrasound assists with vascular access

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