I-Xe AND THE CHRONOLOGY OF THE EARLY SOLAR SYSTEM, J. D. Gilmour[1], O. V. Pravdivtseva[2], A. Busfield[1] and C. M. Hohenberg[2]. [1]University of Manchester, Manchester, M13 9PL, United Kingdom (jamie.gilmour@man.ac.uk). [2]McDonnell Center for Space Sciences, Washington University, St Louis, MO 63130, USA.

Introduction: The I-Xe system is based on the decay of ^{129}I to ^{129}Xe. The 16 Ma half life of ^{129}I is sufficiently long to enable a wide variety of processes from the earliest chondrule formation to processes on sizable planetesimals. Here we examine how best to integrate data from this system into a wider timescale incorporating results from other chronometers.

Calibration of Chronometers: In addition to I-Xe, chronological information with the precision required to study the formation of the solar system can be obtained from systems based on the decay of ^{53}Mn, ^{26}Al and $^{235/238}$U (Pb-Pb). In order to maximize the return on these studies, it is necessary to calibrate the various chronometers against one another. Previous attempts have relied on single analyses of minerals in which more than one system can be accurately measured to determine a calibration[1,2]. However, sufficient data are now available in the case of some chronometer pairs to allow the consistency of the chronometers to be examined more closely. In what follows we adopt the arbitrary zeroes conventional within the I-Xe, Mn-Cr and Pb-Pb systems and examine the data for consistency and to establish a calibration.

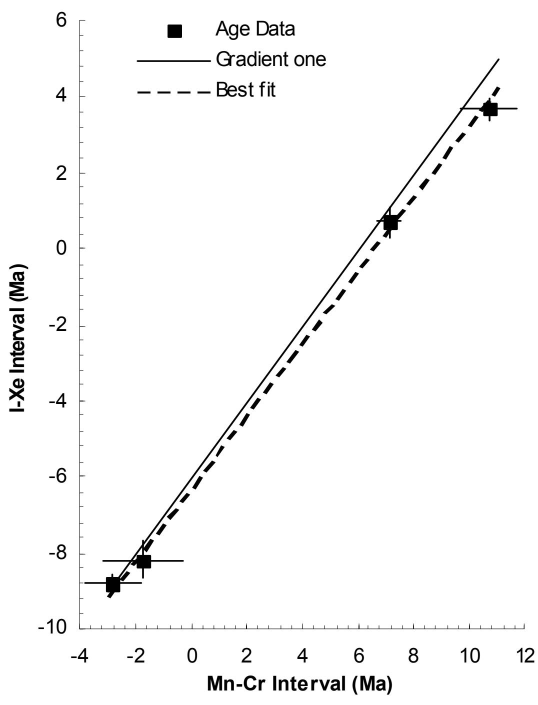

Fig 1. Comparison of relative ages of Acapulco, Richardton, Ste Marguerite and the earliest chondrules in the Mn-Cr and I-Xe systems. Data sources in text and reference [2]

I-Xe vs Mn-Cr. In Fig. 1 we present data from the Mn-Cr and I-Xe system measured in the chondrites Richardton and Ste Marguerite, in Acapulco and from chondrules. I-Xe data are normalized to Shallowater enstatite having a zero age, while the zero of the Mn-Cr system is defined by the angrite LEW86010.

The I-Xe measurement used here for Acapulco dates the closure of phosphate grains to xenon loss, while in the chondrites Ste Marguerite and Richardton it dates the closure of feldspar. I-Xe data for pyroxene from Richardton yield closure ages up to 10 Ma earlier than the feldspar data, testifying to the extended period of processing post-formation that the parent body of this meteorite experienced. The Mn-Cr system in Richardton and Ste Marguerite records the moment at which chromium ceased equilibrating between chromite and silicate phases, suggesting that identification of the Richardton Mn-Cr age with the feldspar I-Xe may be questionable. The final point is obtained from chondrules. In the Mn-Cr system chondrule data are sparse and tightly clustered. I-Xe chondrule data, in contrast, exhibit a wide spread that may be attributed to resetting or setting of the chronometer by parent body processes. However, dynamical considerations suggest that particles of the size of chondrules had to be sequestered on sizable bodies in the solar nebula on timescale short compared to the errors of isotope chronology, suggesting that the earliest parent body processes should approximate formation ages. Thus whether I-Xe ages are formation ages or alteration ages, the earliest chondrule data might be expected to be comparable to Mn-Cr (formation) ages.

There is a reasonable correlation between the two systems and the gradient of the best fit line (0.95) is close to 1. From the best fit line we would deduce that the I-Xe system closed in Shallowater enstatite 6.3 ± 0.3 Ma earlier than the Mn-Cr system closed in LEW86010.

I-Xe (and Mn-Cr) vs Pb-Pb .In Figure 2, we plot Pb-Pb ages vs I-Xe intervals for samples in which we would argue it is plausible that the two chronometers date the same event within the limits of the various techniques. Our first point stems from the identification of the oldest I-Xe chondrule age with the clustered chondrule Pb-Pb ages identified by Amelin et al.[3] We also include two previously unreported Richardton chondrules in which the Pb-Pb and I-Xe systems have

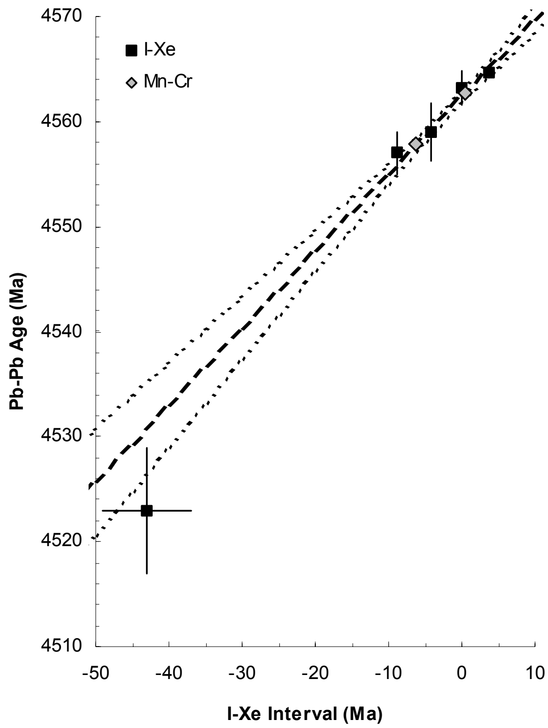

Fig. 2. Comparison of the I-Xe and Mn-Cr systems with the absolute Pb-Pb chronometer for samples from Acapulco, Richardton, Kernouve, LEW86010 and Ste Marguerite. Mn-Cr data have been converted to I-Xe intervals using the calibration of Fig. 1. Data sources in text and reference [2]

both yielded dates (O. V. Pravdivtseva, unpublished data). Data from the Pb-Pb and I-Xe chronometers from samples of Acapulo phosphate were reported by Nichols et al.[1] and are included, as is the data for the two systems from Kernouve reported by Brazzle et al.[4] In addition to these five points, we employ the calibration between Mn-Cr and I-Xe intervals advanced here to add equivalent I-Xe intervals derived from Mn-Cr intervals for the LEW86010 angrite[5] and Ste Marguerite[6]. The correlation line fixes the zero point of the I-Xe dating scheme, closure of Shallowater pyroxene to xenon loss, at 4562.3 +/- .4 Ma before the present. The gradient of the correlation line – 0.73 +/- 0.7 – is significantly different from 1, however, suggesting some error in the half lives of either ^{129}I, ^{235}U or both. Begemann et al.[7] have noted the need for improved determinations of the half lives of longer lived radionuclides and speculated that similar problems may exist among the shorter lived radioactives that form the basis of chronometers. Some indication that this is the case may be seen here, though the details of the calibration are dependent on the choice of samples included[8]

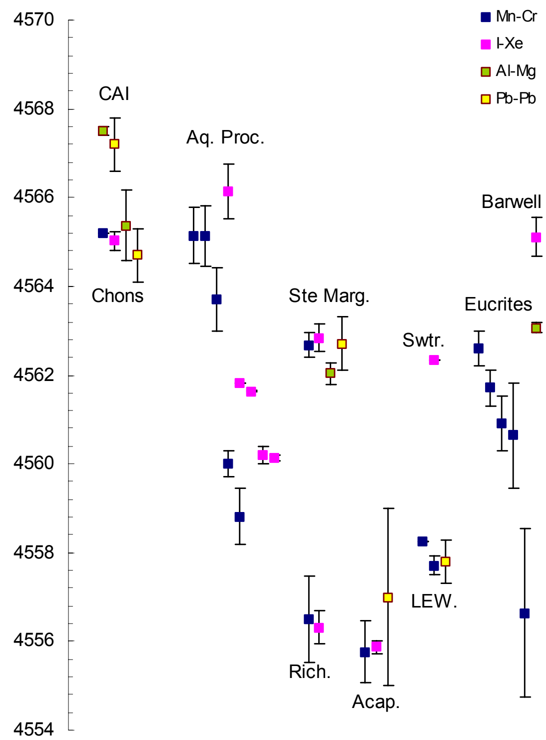

Fig. 3. Chronology derived from adopting the calibrations of Figs 1 and 2 for CAIs, Chondrules, Aqueous Processes Ste Marguerite, Richardton, Acapulco, Shallowater LEW86010, Eucrites and Igneous Clasts from Barwell *data sources in text and ref [2].

Proposed Chronology: the chronology of solar system formation produced by adopting the calibrations derived here is shown in Fig. 3. The sequence of events is perhaps more palatable that that produced in previous attempts at producing a unified chronology[2]; for instance, no parent body processes appear to definitively predate the earliest chondrule ages, though this has been achieved by adopting a calibration between short and long-lived chronometers requiring some revision of accepted half lives.

References:

[1] Nichols et al. (1994) GCA 58 2553. [2] Gilmour and Saxton (2001) Phil. Trans. R. Soc. Lond A 359 2037. [3] Amelin et al. (2002) Science 297 1678. [4] Brazzle et al. (1999) GCA 63 739 [5] Lugmair and Shukolyukov (1998) GCA 62 2863 [6] Polnau and Lugmair (2001) LPSC 32 abs #1527 [7] Begemann et al. (2001) GCA 65 111 [8] Busfield (2002) PhD Thesis, Univ. of Manchester.